A Global Liquidity Factor for Fixed Income Pricing

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Abstract

Liquidity premiums have been widely documented in equity markets. However, empirical evidence for fixed income instruments, which are typically far less liquid, is limited. We show that a liquidity factor - based on the difference between corporate bond spreads and credit default swaps - is significantly associated with the returns of a wide range of fixed income markets. The associated liquidity premium is time-varying and drives a fair amount of the serial and cross-sectional variation of fixed income prices. Moreover, liquidity exposure varies predictably with maturity and credit rating.

Keywords: Liquidity, Bond Market, Asset pricing, Factor Models

JEL Classification: G12, G15, G21

1 Introduction

The recent turmoil in financial markets has documented the importance of liquidity. For weeks interbank lending markets and swap markets, the backbones of modern banks' liquidity and interest rate risk management, have been completely frozen. Only unprecedented, massive provision of liquidity by central banks and government guarantees have started to ease the gridlock.

There is also a growing literature modeling liquidity and predicting its effects. Generally, illiquid assets earn a return premium over relatively liquid assets. Whilst liquidity premiums have been widely documented for equity markets, the empirical evidence for bond markets remains limited.

In this paper, we proxy the liquidity component of fixed income prices by employing a simple, observable measure for the price of liquidity. We start by decomposing the yield spread of corporate bonds over government bonds into two components: a default component and a liquidity component. For certain bonds, the default component is immediately observable in the form of the spreads quoted for credit default swaps (CDS). Thus, we are able to identify the liquidity component. We then postulate that liquidity is a global pricing factor in the sense that a change in the price of liquidity affects all assets albeit at varying degrees; i.e. the liquidity factor backed out from selected series contains systematic information about the bond market's liquidity and, thus, significantly relates to other bond returns. The main contribution of the paper is providing empirical evidence for this: Changes in the observable liquidity component of certain bonds have statistically and economically significant effects on the prices of other fixed income instruments. This systematic liquidity factor is fairly stable, but time-varying. We show further that the liquidity component of prices increases with maturity and decreases in credit quality.

Our findings offer interesting time-series evidence for some recent theoretical liquidity-based pricing models and provide additional empirical facts on the cross-section of liquidity risk exposure of assets. The results are also important for the financial industry as they provide a sound empirical basis for incorporating liquidity risk and liquidity premiums into pricing tools, risk management methods and investment strategy.

As the recent financial crisis has brought to the fore the significance of the liquidity premium for pricing and valuation, accounting standard setters and financial markets' regulators have made very explicit the need to adjust market value for liquidity effects.[1] The guideline is that prices or quotes from thin or inactive markets may not reflect fair value, and, thus, fair value estimates should be based on non-market inputs ("level 3 inputs") in a DCF calculation. Our results show that there is a simple and reliable way of calculating the liquidity discount for a particular asset. Thus, an alternative estimate of fair value may be calculated by adding back the liquidity discount to a "fire-sale" market price. This may be a more reliable and transparent approach than discounting expected cash flows at risk-adjusted discount rates, both of which are notoriously difficult to estimate. At least, the alternative estimate may serve as robustness check to the DCF method.

Similarly, decomposing the spread of a fixed income asset is helpful in estimating the expected return for the asset, which is crucial for asset allocation decisions of market participants. A natural decomposition of the spread comprises three parts: a component reflecting the expected credit losses (= default probability times expected loss in default), a component reflecting the risk premium associated with default risk, and a component reflecting the compensation for illiquidity of the asset. Obviously, the first two components reflect very different risks from the third. In particular, an investor willing and able to hold the asset to maturity can be certain of capturing the liquidity premium at no additional risk (in addition to default risk!).

Finally, our analysis can be used as the basis for new liquidity risk measurement

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[1] See `http://www.sec.gov/news/press/2008/2008-234.htm` and `http://www.iasb.org/News/Press+Releases/IASB+publishes+educational+guidance+on+the+application+of+fair+value+measurement+when+markets+become.htm`

methods. For lack of alternatives, current liquidity risk measures are based on cash flow maturities and qualitative assessment of assets' eligibility for secured funding (e.g., Principle 5 of the BIS' Principles for Sound Liquidity Risk Management and Supervision[2], Sept. 2008). Clearly, using market-implied measures of liquidity would probably increase the precision of and provide sound theoretical underpinnings to the liquidity risk estimates. Such market measures of liquidity could be built along the factor model approach familiar from market risk models.

The remainder of the paper is organized as follows. First, we review some of the literature on liquidity in section 2.1, before we elaborate on the difference between spreads and CDS levels of a particular portfolio as a proxy for the liquidity premium in section 2.2. Section 2.3 develops the model. We then test whether the proxy has reasonable and significant loadings in a time-series model of returns for a variety of assets. Put simply, we want to show that the proxy is indeed a valid factor that can price fixed income assets. The results of this analysis and the description of the data are contained in section 3. To corroborate the findings, we perform numerous robustness checks using different liquidity proxies which are reported in 4. Section 5 analyzes the effect of bond maturity and rating on the liquidity exposure. Concluding remarks are offered in section 6.

2 Liquidity & The Asset Pricing Model

2.1 Relation to the Existing Literature

There is a substantial body of literature dealing with liquidity in conjunction with asset pricing. For an extensive survey of the literature see Amihud et al. (2005).

However, most of this work focuses on equity markets. As one of the first papers

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[2] Further, Principle 4 states that "A bank should incorporate liquidity costs [...] in the internal pricing [...] for all significant business activities [...]". Clearly, a suitable estimate of these costs would be based on the same insights. In fact, we find it difficult to think of any alternative estimation technique other than plain guessing.

in this area, Amihud and Mendelson (1986) present a theoretical model which is often cited to motivate empirical work on the issue. Along these lines Amihud (2002), Pastor and Stambaugh (2003), or Sadka (2006) document a significant effect of liquidity on expected returns for US equities. Martínez et al. (2005) take the analysis to an international level by investigating liquidity effects on equity returns using Spanish data. Korajczyk and Sadka (2008) combine information from various measures using a principal component analysis to back out a latent liquidity factor. The merits of the approach are that, according to the authors, it is impossible to distinguish whether different priced factors are evidence of multiple risk premiums or whether all proxies measure the same latent liquidity risk.

Apart from liquidity effects of on/off the run US treasuries (see e.g. Amihud and Mendelson (1991)), evidence for fixed income markets is relatively limited, by comparison. Combining stock and bond market data, Chordia et al. (2005) document linkages of the two markets due to liquidity.

Using a calibration approach Huang and Huang (2003) find that corporate spreads are too high to be solely explained by credit risk. Elton et al. (2001), and also Longstaff et al. (2005) - albeit in a different manner, corroborate these results by comparing model and empirical spreads. Analyzing CDS spreads, the latter work is able to relate a large part of the non-default component to typical market microstructure measures of liquidity and, hence, identifies a return premium due to liquidity risk. As already hinted at above, and explained in more detail below, this non-default component of corporate spreads, backed out using CDS spreads, is the basis for our analysis.

De Jong and Driessen (2005) attempt to explain the credit spread puzzle[3] by applying the analysis of Pastor and Stambaugh (2003) to the bond market. The former find liquidity risk being priced in the market when employing the illiquidity

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[3] The finding of spreads being too high is typically referred to as the credit spread puzzle.

factor of Amihud (2002).[4]

Chen et al. (2007) extend Lesmond et al. (1999) to obtain a two factor model of returns. Their contribution to the credit spread and liquidity literature lies in that they find a significantly positive effect of illiquidity on yield spreads by estimating transaction costs in the corporate bond market.

Taking up the idea of latent liquidity, Mahanti et al. (2008) and Mahanti et al. (2007) propose and employ an alternative to typical transaction based measures of liquidity in the bond market. Their latent factor approximates asset accessibility by investor holdings.

2.2 Measuring the Liquidity Premium

Defining a liquidity premium requires a benchmark of a perfectly or most liquid asset. It appears that assets are liquid to varying degrees, and some are almost as liquid as cash in terms of being able to acquire and sell them quickly. For example, the enormous depth and institutional set-up of stock exchanges render many equity securities very liquid. Another, almost perfectly liquid asset is a government bond, since central banks typically accept government bonds as collateral at their repo-windows or as a substitute for minimum deposits. Thus, while a particular government bond might not be particularly liquid - easy to buy or sell - by itself, the central bank's acceptance as first-rate collateral for cheap cash lending renders it near-cash equivalent from a liquidity perspective.[5] This also implies a neat separation of maturity and liquidity, similar to that of maturity and duration. Despite being of long maturity, an asset may still be very liquid - either because of secondary markets or an exogenous liquidity provider (the central bank as the "liquidity provider of last resort").

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[4] Some authors, e.g. Collin-Dufresne et al. (2002), also try to explain the corporate spread puzzle by means of jump risk premiums.

[5] In addition, interbank repo-markets typically work on the same counterparty rules as the central banks.

Table 1 shows the haircuts[6] which the ECB applies to the different types of collateral and confirms the superiority of government bonds in terms of liquidity. Sovereign bonds have relatively low haircuts (for example, 2.5% for a 5 year bond). Corporate bonds, on the other hand, carry approximately double the haircut of government bonds (e.g. 4.5% on a 5 year corporate). Also note that haircuts are increasing in maturity.

Table 1: *ECB haircuts for marketable assets in % of market value*

	Cat. I **(sov. bonds)**		**Cat. II** **(sub-sov. bonds)**		**Cat. III** **(bank & corp.)**		**Cat. IV** **(bank loans)**		**Cat. V** **ABS**
Res. Mat.	Fixed C	Zero	Fixed C	Zero	Fixed C	Zero	Fixed C	Zero	all Coupons
0-1	0.5	0.5	1	1	1.5	1.5	6.5	6.5	12
1-3	1.5	1.5	2.5	2.5	3	3	8	8	12
3-5	2.5	3	3.5	4	4.5	5	9.5	10	12
5-7	3	3.5	4.5	5	5.5	6	10.5	11	12
7-10	4	4.5	5.5	6.5	6.5	8	11.5	13	12
>10	5.5	8.5	7.5	12	9	15	14	20	12

Source: ECB (2008)

Because of the just described property of government bonds, we use these as our reference for measuring liquidity, i.e. we assume that government bonds are almost perfectly liquid. Holding a government bond, such as a US Treasury security, Gilts, Bunds, etc, carries hardly any liquidity premium and no default premium. Thus, the yield on the bond is purely a compensation for the nominal time-value of money. On the other hand, the yield on a corporate bond represents at least three compensation payments: for the time value of money[7], for default risk (including expected default), and for illiquidity. We, thus, investigate illiquidity as the potential price discount that is *not* due to changing riskless interest rates or default risk when selling the asset. We do not, however, analyze the potential sources of illiquidity such as asymmetric information, capacity constraints induced by regulation or capital constraints, etc. An example of research along these lines can be found in Brunnermeier and Pedersen (2007).

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[6] A haircut is the percentage by which an asset's value is reduced for the purpose of calculating collateral levels.

[7] Compensation for time value of money includes compensation for inflation as well as a return for foregoing consumption today.

The basic variable for measuring the liquidity premium is the corporate bond spread, i.e. the difference between the par yield on a particular fixed-rate corporate bond and the par yield of a corresponding fixed-rate government bond that matches the currency and the maturity of the bond. We use par yields as they are more widely available than zero yields. Since perfectly matching maturities are rarely available, the spreads are usually calculated based on interpolated yields.

With the two bonds being matched on maturity, the spread is independent of the time value of money. Thus, the spread reflects only two components: a default component and a residual component that we interpret as reflecting mostly a liquidity premium, following along the previously cited research of Longstaff et al. (2005).

For a range of issuers, there are active markets for credit default swaps (CDS), which essentially are insurance ("protection") against the default of a particular reference bond of that issuer. In a credit default swap, the buyer of protection pays a fixed premium (the CDS spread) and receives a compensation payment in case of a "credit event", typically a (potentially only technical) default of the reference bond. The compensation payment is usually the difference between the par value and the market value of the reference bond (which is likely to be positive due to positive recovery values). Thus, the CDS insures the holder against the loss due to default of a particular reference bond. Consequently, the fair price of the CDS must reflect the expected loss due to a default and a risk premium for the default risk. With losses of other debt of an issuer being comparable - unless there are differences in the seniority of the debt - a particular CDS can be used as protection against default in any debt issue as long as the maturity of the CDS and the bond are similar.

A portfolio consisting of a CDS and the corresponding reference bond with matching notional is essentially a position with no default risk - assuming no counterparty risk on the CDS[8] - for the remaining maturity of the position. In other words, the

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[8] Standard CDS contracts along ISDA guidelines are collateralized and, thus, counterparty risk is minimized.

portfolio is equivalent to a government bond in terms of default risk, and, therefore, in some sense a "synthetic" government bond position. Similarly, we could construct a "synthetic" corporate bond by incurring a long position in the government bond and "selling protection" in the CDS market.

However, the liquidity of the synthetic positions is different from the liquidity of the cash bonds. At the repo windows, central banks acknowledge a difference between the synthetic and actual government bonds and simply do not accept the former as collateral.[9] Hence, the actual government bond is, independent of its maturity, near-cash from a liquidity perspective, while its synthetic version is not. Similarly, the synthetic corporate bond does not earn a liquidity premium because the CDS is usually not affected by liquidity concerns.[10]

In addition to CDS on individual issuers, there are also CDS on a group of reference entities. These so-called Index CDS then offer protection against the default of any individual issuer in the reference portfolio. In the empirical analysis, we use broad indices and index CDS to estimate the liquidity premium. While this reduces the power of our tests, its simplicity serves well for a first pass. And, as the robustness checks in section 4 will show, this simplification does not materially alter the results.

2.3 Modeling Setup

To motivate the empirical model for analyzing the impact of liquidity on bond returns, we consider the well known relationship between the bond price B and its yield y. Denoting cash flows of the bond by C_t, the bond price is given by

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[9] Central banks apply different haircuts to government and corporate bonds. Table 1 shows these for the ECB.

[10] In the recent past, however, even the CDS market has suffered form evaporating liquidity. Since mid-2007 CDS desks periodically have been quoting excessively high prices on credit protection to deter potential buyers because the banks had no capacity left for these trades. Thus, during certain periods CDS levels contain a liquidity component as well, implying that CDS do no longer provide a clean separation of liquidity and default risk. Despite the quoting of unrealistic spreads during the outbreak of the credit crisis, evidence of liquidity effects in CDS markets has also been reported by Bühler and Trapp (2005), Nashikkar et al. (2007) and Bongaerts et al. (2008).

$B(y) = \sum_{t=1}^{T} \frac{C_t}{(1+y)^t}$, and the effect of a yield change can be expressed as

$$\begin{aligned} \frac{\partial B}{\partial y} &= -\frac{1}{1+y} \sum_{t=1}^{T} \left(t \frac{C_t}{(1+y)^t} \right) \\ &= -\frac{D}{1+y} B = -D^* B \end{aligned} \tag{1}$$

where D^* is the modified duration of the bond. Rearranging (1), we obtain that the bond return is approximately equal to the change in yield scaled by the duration

$$\begin{aligned} \frac{dB}{B} &= -D^* dy \\ \Rightarrow \frac{\Delta B}{B} &\approx -D^* \Delta y. \end{aligned} \tag{2}$$

Given the relationship in (2), we now decompose the yield into the compensation for time value of money, credit risk, and liquidity risk. Further, we postulate that the three factors are the same for all bonds in the sample, i.e. there exists a notion of liquidity in the bond universe that is captured by our liquidity proxy.

Controlling for equity performance, as motivated by Chen et al. (2007), the empirical model considered is

$$\begin{aligned} R_{i,t} &= \alpha_i + \beta_i^{(1)} \Delta \mathrm{Rates}_t + \beta_i^{(2)} \Delta \mathrm{Default}_t + \beta_i^{(3)} \Delta \mathrm{Liqui}_t \\ &\quad + \beta_i^{(4)} R_t^{\mathrm{MSCIw}} + \epsilon_{i,t} \end{aligned} \tag{3}$$

where $R_{i,t}$ is bond i^{th}'s return in period t, $\Delta\mathrm{Rates}_t$ is the change in the ten year government mid-yield corresponding to the currency of denomination of bond i, R_t^{MSCIw} is the return on the MSCI World, and $\Delta\mathrm{Default}_t$ and $\Delta\mathrm{Liqui}_t$ are the changes in the default and liquidity factors, respectively.

For the purpose of this study, we are primarily interested in the liquidity loading $\beta_i^{(3)}$; i.e. does our proxy for inherent liquidity risk help pricing assets? If so, and since Liqui, as backed out from certain CDS and corporate bond indices, constitutes a price in basis points, we can interpret a significant loading as evidence for the economic significance of the factor (see e.g. Elton et al. (2001) who draw a similar conclusion).

3 Data & Estimation Results

3.1 Base Case Liquidity Proxy

As the base proxy for the liquidity premium, we use the difference between the average spread of the JPMorgan EUR Investment Grade Corporate - Financials Index 5-7years (the "Index") and the CDS spread of the iTraxx Europe Senior Financials for the rolling series (the "CDS"). Figure 1 shows the two series. The corporate spread (blue, solid line) is calculated as the difference between par yields of corporate and government bonds with matching maturity. The spread for the index is the average of individual spreads weighted by the market capitalization of the bonds. The CDS spread (grey, dashed line) is from the running series, which is rolled over with the introduction of a new series. All data are month-end observations.

While we presented some theoretical arguments in the last section, Figure 1 provides further empirical motivation for our approach. It comprises an entire economic cycle of credit spreads as it begins with the high levels during the banking crisis in 2002 - mainly a German phenomenon - with slow decline to rock-bottom levels during the recovery and boom during the mid 2000s, and finally the dramatic rise in the wake of the subprime crisis and liquidity crunch. Apart from the historical development, two striking features emerge. Firstly, the two series move roughly in lock-step, reflected in a correlation of 86%. Secondly, the corporate spread with an average of 50 basis points (bps) is consistently above the CDS level with an average of 26 bps. Thus, Figure 1 strongly supports the idea of modelling the corporate spread as the sum of two premiums and using CDS to back out the components.

Figure 2 shows the difference between the spread for JPMorgan EUR Investment

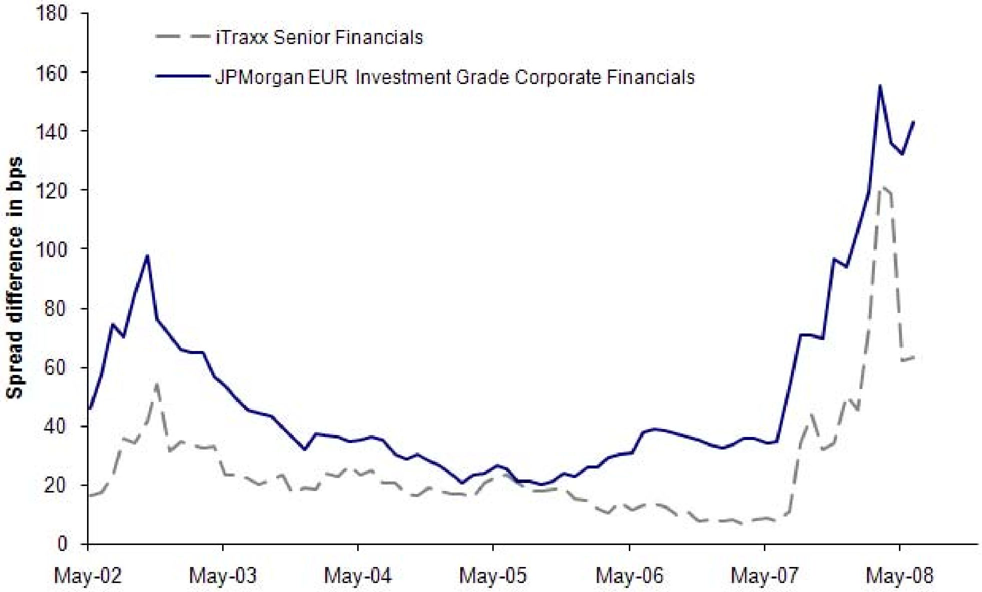

Figure 1: *CDS and Corporate Spreads of Senior Financials*

Grade Corporate Financials Index and the CDS spread of the iTraxx Senior Financials Index (the blue, solid line). This difference between the spreads constitutes our candidate proxy for the the bond market liquidity premium and is denoted by $\text{Liqui}_{\text{Fin}}$. It is positive at all times and on average 24 bps. In general, the spread difference starts at levels of 30 to 40 bps, then slowly but steadily drops to almost zero by 2005 and starts to rise again reaching a plateau for most of 2006 and the first half of 2007, and then increases to a range of 50 to 70 bps. It is interesting to point to the increase in the spread difference in 2005 while CDS levels continued to decline. This suggests that the price of liquidity increased long before default premiums rose again.

Looking at some of the statistical properties of the series, there appears to be a somewhat larger variability at the beginning of the sample period, which might be due to limited liquidity during the infancy of CDS markets. There is markedly higher variability in the spread difference for the last 12 months of the sample period. While

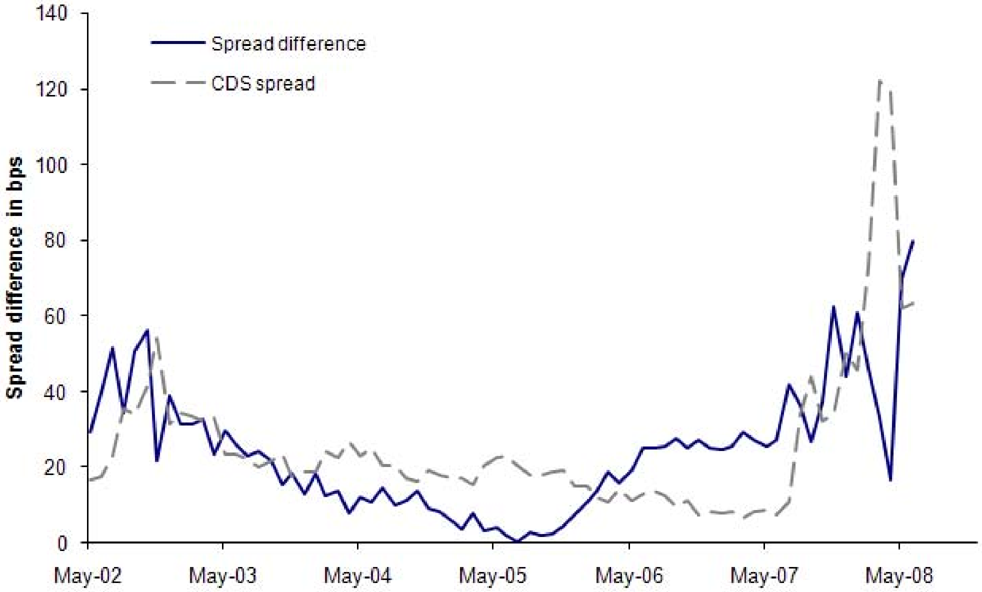

Figure 2: *Spread Difference of Senior Financials*

the spread difference exhibits some time-series variation, reflected in a monthly time-series volatility of 17 bps, the series is also quite stable. Despite high persistence, as documented by a first order auto-correlation of about 71% and a large AR(1) coefficient, the series is clearly stationary as economic intuition suggests.[11] For comparison, the default premium denoted by Def_{Fin} and measured by the CDS spread has a monthly volatility of 21 bps and an autocorrelation of 85%.[12] Thus, the spread difference satisfies two important requirements for a return premium, namely being positive and relatively stable (in the sense of slow mean reversion) through time. Moreover, time-series variation and serial correlation are very much in line with that of the default premium. Cosequently, the preliminary analysis of time-series properties of the series itself is generally supportive of the idea that the

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[11] The time series model that seems to best capture the behavior is the parsimonious ARMA(1,1) specification with AR and MA coefficients of 0.97 and -0.61, respectively.

[12] Also here, the parsimonious ARMA(1,1) specification best captures the behavior with AR and MA coefficients of 0.71 and 0.64, respectively.

difference captures a return premium.

Just as some of the previously cited literature has highlighted, Figure 2 also points toward a weakness of the approach, in particular, the assumption of CDS not being affected by liquidity. The development of the spread difference since mid-2007 is very volatile compared to the earlier period, and the spread difference narrows dramatically for a short time in spring 2008. This is due to an extreme spike in CDS spreads, which is not mirrored in the cash bond market. Thus, the sharp drop in the spread difference is driven exclusively by the increase in CDS levels. This very much suggests that CDS levels were not too indicative of default premiums, because they reflected the extremely tight risk positions of CDS desks, which prevented them from showing executable quotes and virtually shut down the CDS market. To take into account potential biases arising in the sample for that unusual period, we perform subsequent analyses excluding the period after June 2007. A preliminary Chow breakpoint test for a structural break in the coefficient estimates after July 2007 confirms this choice.

3.2 Estimation Methodology

We use the following JPMorgan indices obtained from JPMorgan DataQuery to estimate equation (3):

- Corporate Bond Index (All Industries) USD, High Yield US, Corporate Bond Index (All Industries) EUR, Pfandbriefe EUR, Subordinated Financial EUR, Corporate Bond Index (All Industries) GBP, Senior Financials GBP, Corporate Bond Index (All Industries) JPY, Emerging Markets Global Diversified, Corporates Emerging Markets, MBS Index, ABS Index USD, CMBS Index, Munis, Hedge Funds, Loans[13]

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[13] Based on CLO data.

The sample period considered is June 2002 till July 2007. This period is deemed sufficiently long to obtain meaningful results whilst avoiding potentially substantial liquidity problems in the CDS market, either due to its infancy or the subprime crisis. For the computation of the bond index returns, note that the construction of the indices accounts for coupon payments so that these do not have to be considered separately when estimating the model.

Since we only use the change in government yield that corresponds to the bond index's currency of denomination, equation (3) really has the other government yields' coefficients restricted to zero. As such, estimating a time series regression for each i individually would not be efficient, and the cross-correlation of residuals can be exploited to obtain more efficient estimates. We, therefore, resort to a Seemingly Unrelated Regression setup using the first step covariance matrix as estimate for the correlation structure.

3.3 Results

Table 2 shows the estimation results when using the base proxy $\text{Liqui}_{\text{Fin}}$. As expected, the liquidity factor is mostly significantly negative. A Wald test for the joint equality of the liquidity and default coefficients can be rejected. Thus, using the liquidity component contains incremental information when compared to just regressing returns on the corporate spread of the base index. Focusing on the liquidity coefficient, its sign is intuitively meaningful. A negative coefficient implies that, as to be expected, the return goes down as the liquidity premium increases (i.e. liquidity becomes more expansive). Also the relative magnitude of the coefficients can mostly be explained by attributes of the underlying asset. For example, the High Yield index is much more sensitive to changes in liquidity than an investment grade corporate index. Strikingly, the coefficients on liquidity and default risk are typically very similar. Most of the other coefficients have easily interpretable signs and magnitudes, too. Looking, for instance, at Collaterlized EUR which are essentially Pfandbriefe, we have a rate coefficient, representing modified duration, of about -4.5 which is clearly different from zero, as must be the case for a fixed rate bond. The negative, albeit insignificant, default coefficient reflects the comparably secure nature of Pfandbriefe. It is also interesting to observe that GNMAMortgages are not significantly affected by our liquidity measure. This should not come as a surprise, though. After all, these mortgage securities are as good as US treasuries from a collateral point of view. For ABS, the non-existing negative return impact of the liquidity factor is counter intuitive and suggests that market participants did not see the inherent liquidity risk prior to July 2007. Repeating the estimation for the sample extending till June 2008, reveals that the ABS coefficient is no longer significantly positive, but decreasing liquidity is associated with lower returns, as one would expect (the estimation results are reported in table A1 in the appendix).

Table 2: *Estimation Results using* $Liqui_{Fin}$

	Coefficients of					
	1	R_{MSCIw}	ΔRate	$\Delta\mathrm{Liqui}_{\mathrm{Fin}}$	$\Delta\mathrm{Def}_{\mathrm{Fin}}$	R^2
CorpIG USD	0.0040 *	0.0636 *	-5.4712 *	**-8.4055** *	-7.5330 *	94.67%
HY US	0.0069 *	0.1592 *	-1.7145 *	**-17.8235** *	-16.0749 *	65.71%
CorpIG EUR	0.0039 *	0.0037	-4.1176 *	**-4.8266** *	-4.0157 *	90.48%
Collateralized EUR	0.0031 *	-0.0151	-4.4629 *	**-1.2829** *	-0.5213	94.83%
FinSub EUR	0.0044 *	-0.0115	-5.5412 *	**-7.1393** *	-6.6085 *	91.71%
CorpIG GBP	0.0044 *	0.0454 *	-6.5186 *	**-4.6568** *	-5.8772 *	91.92%
FinSen GBP	0.0043 *	0.0103	-5.5198 *	**-4.7719** *	-6.1825 *	95.17%
CorpIG JPY	0.0007 *	0.0013	-1.9189 *	**-2.1348** *	-1.7226 *	63.14%
EMBIGlobDiv USD	0.0070 *	0.3717 *	-6.1014 *	**-10.8285** *	-8.5150 *	70.14%
CorpEM USD	0.0064 *	0.1002 *	-6.5743 *	**-7.9745** *	-9.2069 *	88.56%
GNMAMortgages USD	0.0033 *	0.0246	-2.2911 *	**-0.3356**	1.5272	73.84%
ABS USD	0.0033 *	-0.0041	-1.6394 *	**1.0604** *	1.1193 *	89.21%
CMBS USD	0.0039 *	0.0246	-4.9613 *	**-1.0670**	-1.4887	93.95%
Munis USD	0.0043 *	0.0094	-4.8031 *	**-3.7824** *	-5.8674 *	88.29%
HedgeFunds USD	0.0063 *	0.3228 *	-0.60219	**-1.9831**	-7.1210 *	68.13%
Loans USD	0.0045 *	0.0107	0.06897	**-9.3315** *	-14.0000 *	66.25%

NOTE: * indicates significance at the 95% level; inference is based on robust standard errors

To better understand the properties of the liquidity factor, the variance of returns can be decomposed according to

$$Var(R_i) = \sum_{j=1}^{4} \left(\beta_i^{(j)}\sigma_j\right)^2 + 2\sum_{j=1}^{3}\sum_{k=j+1}^{4} \beta_i^{(j)}\beta_i^{(k)}\sigma_j\sigma_k\rho_{jk} + \sigma_i^2 \tag{4}$$

where σ_j^2 is the variance of factor $j = 1, ..., 4$, ρ_{jk} is the correlation between factors j and k, and $\sigma_i^2 = E\left[\epsilon_i^2\right]$. The equation shows that, were regressors uncorrelated, identifying the relative importance of the liquidity factor would be a straightforward task based on the sum of squares.

Table 3: *Explanatory power associated with* $\Delta Liqui_{Fin}$ *based on* R^2

	CorpIG USD	CorpIG GBP	EMBIGlobDiv USD	HY US	FinSub EUR	CorpEM USD
ΔR^2	8.89%	4.56%	6.87%	32.31%	12.42%	5.53%
		CorpIG EUR	GNMAMortgages USD	HedgeFunds USD	FinSen GBP	CMBS USD
ΔR^2		10.43%	0.06%	0.61%	6.72%	0.19%
		CorpIG JPY	Collateralized EUR	Munis USD	ABS USD	Loans USD
ΔR^2		11.15%	0.67%	2.01%	1.16%	39.59%
Mean			8.95%			

NOTE: Table displays the increase in R^2 when adding the liquidity factor to the model that contains all other regressors.

From equation (4) it is obvious that relative importance based on sum of squares is at best indicative when uncorrelatedness of regressors cannot be assumed. Nonetheless, the increase in R^2, when the liquidity component is added, reveals the usefulness of the variable to some degree. Following convention, the effect of adding the liquidity factor to the model containing all other regressors is given in table 3. Looking, for example, at USD corporate investment grade bonds, inclusion of the liquidity factor enhances the explanatory power of the model by 8.9%. The average effect of 9% indicates a substantially improved model performance. As we do not want to dwell on the particular size of a coefficient of determination in a regression, we do not pursue more sophisticated estimators of relative importance at this point.[14]

Altogether, these results suggest that we have discovered a priced liquidity component that significantly relates to various bond returns and, hence, is of economic importance. It allows, for example, long term investors who are not driven by short term liquidity concerns to identify assets for which they can reap a liquidity premium given the amount of credit risk they are willing to take.

4 Robustness & Latent Liquidity

4.1 Alternative Proxies

So far, we have used the liquidity component of senior financials as proxy to capture the salient factors of bond market liquidity. It is very much possible, though, that other proxies behave similarly. To explore this option, we have repeated the previously described analysis with the liquidity premium $\text{Liqui}_{\text{Corp}}$ obtained from the difference of the government spread of the JPMorgan EUR Investment Grade Corporates Index and the CDS spread of the iTraxx Europe Main. The results of the estimation are very similar to the ones of the previous section; they are reported in table A2 of the appendix. This hints at both liquidity proxies capturing one and the same underlying liquidity factor of the bond market. We will examine this possibility later.

Another measure sometimes considered as a proxy for the liquidity premium is the swap spread, which measures the difference in yields between rates for interest rate swaps and corresponding government bonds (Figure 3). An interest rate swap is a contract that stipulates the counterparties to exchange a floating rate, typically 3 or 6 month LIBOR, versus a specific fixed rate, for the duration of the contract, say 10 years. There are basically two alternatives for a funded position, i.e. a synthetic

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[14] Lindeman et al. (1980), for instance, discuss an estimator of relative importance that takes account of the correlation terms and the implicit impact of other regressors due to non-zero correlations.

fixed rate bond, corresponding to the government bond with the same maturity. The first is a revolving bank deposit at a LIBOR bank plus the swap. The other alternative is a combination of a 10 year LIBOR floating rate note plus the swap. Since the latter alternative matches the cash flow profile of the government bond more closely, we believe it to be the better alternative.

The swap itself carries hardly any credit risk because counterparty risk is virtually eliminated by requiring collateral to the extent of the mark-to-market of the swap (reference). Thus, the only credit risk of the position is that of the LIBOR floating rate note. However, the credit risk of that note is different from a LIBOR deposit with a bank, to which the floating rate references. In general, a bank deposit is of very short maturity, and, thus, implicitly of higher seniority and better credit quality than a longer maturity note by the same issuer. The term funding of such a bank exceeds LIBOR, reflecting a rising credit spread curve. Therefore, the credit risk of the 10 year note paying LIBOR flat is better than that of a 10 year note issued by a LIBOR pool bank, which is typically AA rated. Issuers persistently paying approximately LIBOR flat for term funding include German Länder and Pfandbriefe.

In summary then, the 10 year swap rate reflects 10 years credit risk of an issuer substantially better than AA and a liquidity premium for 10 years on the underlying note. Given the quality of the issuers, compensation for credit risk should in general be a relatively minor component of the swap spread. However, during the recent credit crisis LIBOR rates probably have been reflecting substantially larger credit risk components. Accordingly, swap spreads should be more strongly related to default risk in the recent past, and, therefore, a less reliable measure of the liquidity premium than our proxy.

As expected, Figure 3 shows that the EUR swap spread and the CDS based liquidity proxy are significantly correlated. For the full sample, the correlation coefficient (between levels) is 0.79, whereas, surprisingly, the correlation is considerably lower at 0.54 for the period up to June 2007. On the other hand, a multiple regression of swap spreads on CDS levels and the liquidity proxy shows that swap spreads are associated with changes in default risk as well. The coefficient on the CDS levels is statistically significant, and the R^2 of the regression is 70%. However, decomposing the variance shows that 62% of the swap spread variation is due to variation in the liquidity proxy and only 8% of the swap spread variation is explained by the default component. Thus, the swap spread is, at least, also a reasonable proxy for the liquidity premium. As such, it is not surprising that the estimation results for equation (3) are qualitatively similar to the previous two proxies; results are shown in table A3 of the appendix.

Throughout the paper we have advocated an index based approach to back out the liquidity component. Despite its simplicity, this type of analysis may suffer from a mismatch between Index and CDS. This is due to the composition of the underlying portfolios differing slightly. While the Index contains issues denominated in EUR by global financials (basically the largest European and US banks), the reference portfolio comprises only European financials; the Index is market-weighted, while the CDS reference is equally-weighted; the Index contains issues with a range of maturities from 5 to 7 years; while the maturity of the CDS is at most 5 years and then rolling down to nearest reset of the contract in six months. While the measurement error due to this mismatch could be large, we show that a repetition of the analysis with exactly matching indices corroborates the previous results. However, we only have at our disposal CDS and corporate spread information of US investment grade corporate senior unsecured fixed coupon non-callable bonds for the period January 2005 till June 2007, which is why we do not use these series for the original analysis. The results in table A4 of the appendix, indeed, confirm the previous coefficient estimates. Again the liquidity sensitivities are negative and relative magnitudes are intuitive (e.g. high yield bond returns respond much more to changes in liquidity than investment grade corporates).

4.2 Latent Liquidity

The robustness checks of the previous section have shown that different candidate measures produce qualitatively similar results. This suggests that they all proxy the same underlying latent liquidity factor of the bond market. We formally take up this idea of latent liquidity, following Korajczyk and Sadka (2008), and perform a principal component analysis (PCA) using the introduced factors $\text{Liqui}_{\text{Fin}}$, $\text{Liqui}_{\text{Corp}}$, and $\text{Liqui}_{\text{Swap}}$ which are available for the entire sample. Since the unit of measurement is equivalent for all three series, we can decompose the variation based on the covariance matrix to give the resulting principal components (PCs) a meaningful interpretation in terms of basis points. It turns out that the first principle component, $\text{Liqui}_{\text{PCA}}$, explains almost 80% of the variation. Figure 3 compares the three previously introduced proxies as well as the just described first PC. Besides the principal component having an intuitive interpretation in terms of latent liquidity, the approach also serves to alleviate the potential bias arising from the classical errors in variables problem.

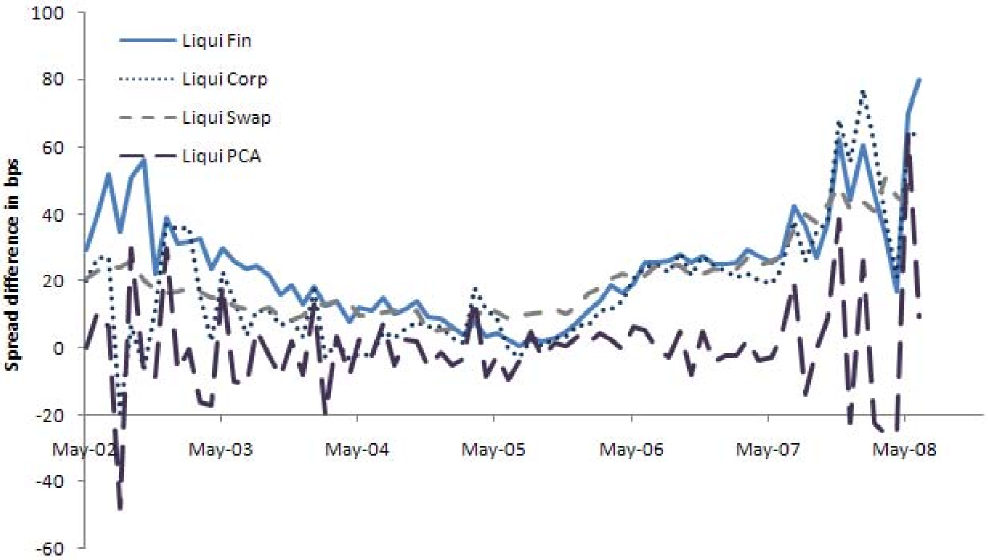

Figure 3: *Considered liquidity proxies*

Using the principal component of our liquidity measures to capture latent liquidity and the default PC obtained from Def_{Fin} and Def_{Corp}, we again estimate the model (equation (3)). Table 4 shows the estimation output.

Table 4: *Estimation Results using* $Liqui_{PCA}$

	Coefficients of					
	1	R_{MSCIw}	ΔRate	$\Delta\text{Liqui}_{\text{PCA}}$	$\Delta\text{Def}_{\text{PCA}}$	R^2
CorpIG USD	0.0039 *	0.0600 *	-5.4626 *	**-4.9412** *	-5.5128 *	94.79%
HY US	0.0067 *	0.1511 *	-1.6287 *	**-10.3327** *	-11.4927 *	65.13%
CorpIG EUR	0.0038 *	-0.0051	-4.1462 *	**-3.4293** *	-3.2425 *	92.80%
Collateralized EUR	0.0031 *	-0.0185 *	-4.4698 *	**-1.0962** *	-0.7619 *	95.10%
FinSub EUR	0.0043 *	-0.0190	-5.5734 *	**-4.5373** *	-4.7153 *	92.60%
CorpIG GBP	0.0045 *	0.0282 *	-6.5814 *	**-3.5733** *	-3.3816 *	93.11%
FinSen GBP	0.0043 *	0.0038	-5.5431 *	**-2.7852** *	-3.2358 *	94.34%
CorpIG JPY	0.0007 *	0.0014	-1.9229 *	**-1.2323** *	-1.1182 *	60.73%
EMBIGlobDiv USD	0.0070 *	0.3396 *	-6.1486 *	**-8.6978** *	-6.7831 *	72.73%
CorpEM USD	0.0064 *	0.0911 *	-6.5353 *	**-4.5989** *	-5.1796 *	88.04%
GNMAMortgages USD	0.0033 *	0.0256	-2.2643 *	**-0.4314**	0.3454	73.57%
ABS USD	0.0034 *	-0.0081	-1.6545 *	**0.2374**	0.7604 *	89.75%
CMBS USD	0.0040 *	0.0132	-5.0051 *	**-1.4035** *	-0.8469	94.32%
Munis USD	0.0043 *	0.0104	-4.7758 *	**-1.4868**	-2.3553 *	87.17%
HedgeFunds USD	0.0064 *	0.3217 *	-0.5959	**-0.0769**	-2.9332 *	69.31%
Loans USD	0.0044 *	0.0160	0.0653	**-3.7289** *	-6.2092 *	51.88%

NOTE: * indicates significance at the 95% level; inference is based on robust standard errors

Accounting for the fact that liquidity is a latent factor, the PCA allows to capture the salient features of the variation in liquidity. The resulting liquidity coefficients mirror the previously discussed estimation results, while R^2s are slightly higher, hinting at a superior liquidity proxy. Negativity of the coefficients again implies that bond returns decrease as illiquidity increases. Also again, the impact of the liquidity measure varies in accordance with expectation. We interpret these findings as evidence for the existence of a latent liquidity factor in the bond market. That is, bond returns are affected, albeit to differing degrees, by the same, easily obtained, liquidity premium.

5 Maturity & Rating

To analyze the impact of maturity and rating category on the sensitivity to liquidity, we obtain data for sub-classes of the previously considered indices with 1-3 years, 3-5 years, 5-7 years, 7-10 years, 10+ years maturities and available rating categories. We then estimate a restricted version of the empirical model, where the $\Delta\text{Liqui}_{\text{PCA}}$ coefficients are set to be the same for each maturity (rating class).

5.1 Maturity

For an asset with T years to maturity equations of the following type comprise the SUR system

$$\begin{aligned} R_{i,t} &= \alpha_i + \beta_i^{(1)} \Delta\text{Rates}_t + \beta_i^{(2)} \Delta\text{Default}_t + \beta_{\mathbf{T}}^{(\mathbf{3})} \Delta\text{Liqui}_t \\ &\quad + \beta_i^{(4)} R_t^{\text{MSCIw}} + \epsilon_{i,t}. \end{aligned} \tag{5}$$

Recalling the, with maturity increasing, ECB haircuts (table 1), we expect longer maturities to be associated with a bigger liquidity effect as they are less liquid from a collateral point of view. This is exactly what can be observed from table 5. Apart from two exceptions, the liquidity loading monotonically increases (in absolute terms) with maturity.[15] Taking a closer look at the maturity impact for EUR denominated assets, we can compare the price effects with the change in ECB haircuts for different maturities. As the here considered assets are all issued by corporates or financial institutions, the EUR numbers of table 5 should be matched up to the haircuts applied to Category III assets in table 1. When doing this, we find that market prices for different maturities react to changes in liquidity much in line with the ECB implied ranking in terms of collateral acceptance. For example, the difference in haircuts between 3-5 and 5-7 year maturity, fixed coupon, Category III assets is

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[15] For completeness, the unrestricted coefficient estimates of the remaining parameters in the EUR case are given in table A5 of the appendix.

1.5%. Table 5 shows that the incremental effect of 1.6 of moving from the 3-5 year to the 5-7 year maturity range is almost identical for market implied data.

Table 5: *Effect of varying maturity for different currencies*

Maturity		$\beta_{\mathbf{T}}^{(\mathbf{3})}$	
	EUR	GBP	USD
1-3	-2.5860	-0.4085	-0.5581^{+}
3-5	-3.4812	-0.6537	-1.0466
5-7	-5.1421	-1.6851	-2.1539
7-10	-4.1691	-2.7080	-3.3929
10+	-7.7848	-4.3314	-3.2713

NOTE: Unless indicated otherwise, coefficients are significant at the 95% level; $^{+}$ indicates significance at the 90% level

A comparison of EUR and USD maturities further shows that the USD assets are much less sensitive to changes in liquidity than the EUR issues. This reflects the much bigger size of USD denominated asset markets and should not be surprising. For GBP issues the coefficient estimates do not neatly fit into the picture, though. As the market for GBP bonds is much smaller than for EUR or USD counterparts, we would expect coefficients to be larger in absolute value than the USD or EUR ones. One possible explanation for the absence of this is the different decomposition of the assets used for estimation. As such it is possible that the GBP assets are inherently more liquid which then does not imply that the GBP market is in general more liquid than the other two. A second explanation refers to the classical error-in-variables (CEV) problem. Considering the CEV setup

$$\text{Liqui Proxy} = \text{Global Factor} + \text{measurement error}, \tag{6}$$

a correlation between the proxy and the measurement error (i.e. local liquidity factor) leads to a downward bias of the coefficient estimate. The liquidity proxy that has been employed is based on indices and iTraxx series (as well as swaps) comprising EUR and USD issuers. For these two currencies we can expect the measurement error impact to be negligible. This need not be true for GBP bonds, though, and the small coefficient estimates can be reconciled with the correlation of proxy and error introducing an attenuation bias in the estimates.

5.2 Rating

Looking at the impact of liquidity on assets of different rating classes, a similar picture emerges. The better the rating, the smaller the effect of changes in liquidity. Restricting the liquidity coefficients to be the same for each rating class (similar in spirit to equation (5)), table 6 shows the estimates for the sample in- and excluding July 2007 till June 2008.

Table 6: *Effect of rating class for different currencies*

Rating	$\Delta \text{Liqui}_{\text{PCA}}$ Coefficient					
	EUR		GBP		USD	
	02 - ’07	02 - ’08	02 - ’07	02 - ’08	02 - ’07	02 - ’08
AAA	-	-	-1.3900 **	-1.5429 **	-0.5288 *	-0.7240
AA	-2.8053 **	-3.8979 **	-1.8680 **	-2.8971 **	-0.9067 **	-1.2340 **
A	-2.6965 **	-4.3233 **	-2.1652 **	-3.2325 **	-1.1326 **	-2.3844 **
BBB	-6.8641 **	-6.5974 **	-3.3608 **	-3.1099 **	-3.6986 **	-4.1414 **

NOTE: * indicated significance at the 90% level; ** at the 95% level

The findings support the notion of flight to quality; i.e. high quality assets are less affected by liquidity. Almost without exception, the impact of liquidity decreases with credit quality for both sample periods. Investors’ demand, and subsequently the market size, for high quality issues rises during turbulent times. A comparison of coefficient estimates for the different samples further confirms the flight to quality idea. The AAA coefficient for USD issues becomes indistinguishable from zero and lower credit qualities are punished by an even bigger liquidity discount compared to the smaller sample.

6 Concluding Remarks

The paper has investigated the relation of bond returns and changes in the non-default component of corporate spreads which is interpreted as liquidity premium. Time series properties of the spread difference support this interpretation as well as the results do. With the considered liquidity measures proxying the same underlying latent bond market liquidity, a principal component analysis allows us to obtain a liquidity factor that represents a priced component and significantly relates to the cross-section of bond returns considered. Liquidity coefficients indicate that returns are negatively affected by declining liquidity and magnitudes allow the identification of assets particularly influenced by liquidity. Looking at the effect of credit quality, the estimates reflect the flight to quality. For different maturities, the maturity-dependent size of the ECB haircuts is well reflected in market data. These results imply that there exists a statistically and economically significant liquidity factor in bond markets that can be backed out using CDS.

Especially for long-term investors, these findings can be very important. Given the amount of credit risk they are willing to bear, they should focus on bonds that are more sensitive to liquidity, as this will allow them to reap a liquidity premium. For them this constitutes an extra return and not a compensation for risk, as they are unlikely to be involved in fire-sales and can divest when most lucrative from a liquidity perspective. For valuation purposes, the approach allows to obtain a liquidity discount for a particular asset. This promises to be an easily implementable way to meet account standard setters' demand of adjusting market prices for liquidity. Also for risk managers, the presented approach offers a feasible opportunity to identify the portfolio's sensitivity to liquidity.

Lastly, the robustness checks have shown that the implications of slightly mismatched indices are not material as results are similar when using the exactly matching data. Additionally, it may be interesting to repeat the empirical investigation with bond returns replaced by excess returns; we do not expect results to materially change, though. In terms of illiquidity in the CDS market, the period following the wake of the subprime crisis is likely to remain special. If CDS become exchange traded, they will be more liquid than ever and the proposed model can be easily implemented in the future.

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Appendix

Table A1: *Entire Sample Estimation Results using* $Liqui_{Fin}$

Sample			Coefficients of			
2002 M06 - 2008 M06	1	R_{MSCIw}	ΔRate	$\Delta\text{Liqui}_{\text{Fin}}$	$\Delta\text{Def}_{\text{Fin}}$	R^2
CorpIG USD	0.0042 *	0.0688 *	-5.4973 *	**-7.0613** *	-6.3691 *	93.95%
HY US	0.0072 *	0.1965 *	-1.8786 *	**-12.0816** *	-9.1759 *	63.32%
CorpIG EUR	0.0039 *	0.0130	-4.2356 *	**-4.3893** *	-4.2963 *	91.09%
Collateralized EUR	0.0030 *	-0.0092	-4.4316 *	**-1.5969** *	-1.4661 *	93.88%
FinSub EUR	0.0045 *	-0.0040	-5.3566 *	**-9.8872** *	-10.1923 *	88.41%
CorpIG GBP	0.0045 *	0.0434 *	-6.5460 *	**-5.2086** *	-6.1856 *	89.47%
FinSen GBP	0.0045 *	0.0049	-5.4241 *	**-5.8269** *	-6.4276 *	93.40%
CorpIG JPY	0.0007 *	-0.0079	-2.0244 *	**-2.5815** *	-1.9805 *	55.71%
EMBIGlobDiv USD	0.0076 *	0.3565 *	-6.0822 *	**-6.7731** *	-5.9880 *	65.73%
CorpEM USD	0.0064 *	0.1201 *	-6.3810 *	**-7.5260** *	-7.8312 *	83.72%
GNMAMortgages USD	0.0035 *	0.0311 *	-2.3487 *	**0.2042**	0.4301	73.99%
ABS USD	0.0027 *	-0.0102	-1.6576 *	**-0.6954**	-1.6617 *	69.33%
CMBS USD	0.0033 *	0.0757 *	-4.7330 *	**-2.2993**	-2.7720 *	66.18%
Munis USD	0.0039 *	0.0497	-4.7168 *	**-3.0445**	-4.4144 *	58.66%
HedgeFunds USD	-0.0113	1.3966 *	-4.4399	**2.1276**	-3.4633	16.72%
Loans USD	0.0046 *	0.0444	-0.0722	**-7.2084** *	-7.1370 *	51.60%

NOTE: * indicates significance at the 95% level; inference is based on robust standard errors

Table A2: *Estimation Results using* $Liqui_{Corp}$

			Coefficients of			
	1	R_{MSCIw}	ΔRate	$\Delta\text{Liqui}_{\text{Corp}}$	$\Delta\text{Def}_{\text{Corp}}$	R^2
CorpIG USD	0.0036 *	0.0668 *	-5.4340 *	**-5.4338** *	-6.4819 *	94.02%
HY US	0.0060 *	0.1661 *	-1.5849 *	**-11.3322** *	-13.4837 *	62.25%
CorpIG EUR	0.0037 *	-0.0015	-4.1514 *	**-3.9850** *	-4.0411 *	92.31%
Collateralized EUR	0.0031 *	-0.0168 *	-4.4720 *	**-1.2449** *	-0.9967 *	95.00%
FinSub EUR	0.0040 *	-0.0134	-5.5758 *	**-5.1564** *	-5.6903 *	91.74%
CorpIG GBP	0.0043 *	0.0275 *	-6.5461 *	**-4.4789** *	-4.3642 *	93.54%
FinSen GBP	0.0041 *	0.0053	-5.5231 *	**-3.2744** *	-3.8594 *	94.06%
CorpIG JPY	0.0006 *	0.0040	-1.9374 *	**-1.3207** *	-1.3200 *	59.26%
EMBIGlobDiv USD	0.0067 *	0.3450 *	-6.0891 *	**-10.3230** *	-8.8685 *	72.62%
CorpEM USD	0.0061 *	0.0960 *	-6.5122 *	**-5.2015** *	-6.0909 *	87.62%
GNMAMortgages USD	0.0033 *	0.0276	-2.2342 *	**-0.3168**	0.3654	73.31%
ABS USD	0.0034 *	-0.0091	-1.6688 *	**0.1200**	0.7352 *	89.78%
CMBS USD	0.0039 *	0.0125	-5.0217 *	**-1.9057** *	-1.3094 *	94.48%
Munis USD	0.0042 *	0.0124	-4.7676 *	**-1.5953**	-2.5523 *	86.96%
HedgeFunds USD	0.0062 *	0.3177 *	-0.6582	**-0.4505**	-3.2179 *	69.07%
Loans USD	0.0040 *	0.0221	0.0596	**-3.9624** *	-6.7332 *	47.83%

NOTE: * indicates significance at the 95% level; inference is based on robust standard errors

Table A3: *Estimation Results using* $\mathit{Liqui}_{\mathit{Swap}}$

	Coefficients of					
	1	R_{MSCIw}	ΔRate	$\Delta\text{Liqui}_{\text{Swap}}$	$\Delta\text{Def}_{\text{Fin}}$	R^2
CorpIG USD	0.0038 *	0.1132 *	-5.4828 *	**-8.0122** *	-0.7249	87.10%
HY US	0.0063 *	0.2712 *	-1.7586 *	**-14.5849**	-1.6358	36.93%
CorpIG EUR	0.0038 *	0.0286 *	-4.2209 *	**-6.8017** *	-0.0849	83.55%
Collateralized EUR	0.0032 *	-0.0164 *	-4.5299 *	**-5.2344** *	0.5440	96.00%
FinSub EUR	0.0042 *	0.0301	-5.6668 *	**-7.9878** *	-0.8071	81.90%
CorpIG GBP	0.0043 *	0.0727 *	-6.5725 *	**-4.8828** *	-2.1016 *	88.21%
FinSen GBP	0.0041 *	0.0440 *	-5.5469 *	**-2.5256**	-2.3270 *	88.76%
CorpIG JPY	0.0005	0.0233 *	-1.9834 *	**1.5135**	-0.0181	52.94%
EMBIGlobDiv USD	0.0068 *	0.4277 *	-6.1187 *	**-13.4559**	0.2700	65.02%
CorpEM USD	0.0063 *	0.1415 *	-6.6163 *	**-10.2447** *	-2.7170	84.50%
GNMAMortgages USD	0.0033 *	0.0252	-2.2574 *	**-0.4460**	1.7773	73.80%
ABS USD	0.0033 *	-0.0088	-1.6433 *	**1.5509**	0.2617	88.47%
CMBS USD	0.0040 *	0.0244	-5.0168 *	**-4.2089** *	-0.5762	94.18%
Munis USD	0.0041 *	0.0400	-4.7615 *	**0.2392**	-2.8500 *	86.30%
HedgeFunds USD	0.0059 *	0.3555 *	-0.6151	**6.1686**	-5.5412 *	68.48%
Loans USD	0.0041 *	0.0702 *	0.0579	**-7.1272**	-6.4503 *	30.36%

Note: * indicates significance at the 95% level; inference is based on robust standard errors.

Table A4: *Estimation Results using* $\mathit{Liqui}_{\mathit{Exact}}$

	Coefficients of					
	1	R_{MSCIw}	ΔRate	$\Delta\text{Liqui}_{\text{Exact}}$	$\Delta\text{Def}_{\text{Exact}}$	R^2
CorpIG USD	0.0213 *	0.0744 *	-5.7275 *	**-0.8327** *	-4.4193 *	94.79%
HY US	0.0551 *	0.3227 *	-2.8209 *	**-2.6728** *	-12.1879 *	65.34%
CorpIG EUR	0.0176 *	0.0259	-4.4180 *	**-0.9496** *	-3.2667 *	89.03%
Collateralized EUR	0.0121 *	-0.0092	-4.7682 *	**-0.4956** *	-2.2331 *	97.28%
FinSub EUR	0.0279 *	0.0429 *	-5.5666 *	**-1.8103** *	-5.2305 *	92.45%
CorpIG GBP	0.0205 *	0.0853 *	-7.0732 *	**-1.2812** *	-3.4347 *	91.64%
FinSen GBP	0.0172 *	0.0432 *	-4.9288 *	**-1.1722** *	-2.5851 *	92.85%
CorpIG JPY	0.0008	0.0209	-2.5821 *	**0.0078**	-0.1401	70.49%
EMBIGlobDiv USD	0.0285 *	0.4151 *	-5.7872 *	**-2.6075**	-4.0704	68.36%
CorpEM USD	0.0397 *	0.2078 *	-6.2189 *	**-2.8268** *	-7.0152 *	80.55%
GNMAMortgages USD	0.0063	0.0634 *	-3.2759 *	**0.1276**	-1.1092	85.71%
ABS USD	0.0037 *	0.0009	-1.5217 *	**0.5658** *	-0.7967 *	91.84%
CMBS USD	0.0176 *	0.0280	-4.4675 *	**-0.4787**	-3.6744 *	92.63%
Munis USD	0.0142 *	0.0191	-3.4920 *	**-0.8309**	-2.0600 *	86.01%
HedgeFunds USD	-0.0031	0.4462 *	0.3609	**1.3103**	0.6481	68.68%
Loans USD	0.0511 *	0.0568	0.1376	**-3.2930** *	-9.7385 *	75.78%

Note: * indicates significance at the 95% level; inference is based on robust standard errors.

Table A5: *Unrestricted coefficient estimates when analyzing impact of maturity*

			Coefficients of			
	1	R_{MSCIw}	ΔRate	$\Delta\text{Liqui}_{\text{PCA}}$	$\Delta\text{Def}_{\text{PCA}}$	R^2
Collaterlized 1-3 EUR	0.00297 *	-0.05603 *	-1.66037 *	-	-1.64706 *	59.08%
Collaterlized 3-5 EUR	0.00336 *	-0.06201 *	-3.79735 *	-	-2.35014 *	82.85%
Collaterlized 5-7 EUR	0.00380 *	-0.07630 *	-5.52925 *	-	-3.65759 *	87.67%
Collaterlized 7-10 EUR	0.00392 *	-0.04384 *	-7.04159 *	-	-3.14362 *	94.88%
Collaterlized 10+ EUR	0.00428 *	-0.06327 *	-9.21909 *	-	-5.69419 *	87.93%
FinSub A 1-3 EUR	0.00357 *	-0.05926 *	-1.80502 *	-	-1.87099 *	67.66%
FinSub AA 3-5 EUR	0.00359 *	-0.05356 *	-4.06300 *	-	-2.81903 *	85.20%
FinSub A 3-5 EUR	0.00379 *	-0.02836 *	-3.67663 *	-	-2.98730 *	85.26%
FinSub AA 5-7 EUR	0.00400 *	-0.06675 *	-5.20576 *	-	-3.80740 *	86.61%
FinSub A 5-7 EUR	0.00420 *	-0.03662 *	-6.66889 *	-	-4.23004 *	91.78%
FinSub BBB 5-7 EUR	0.00425 *	-0.05629 *	-5.29255 *	-	-4.38039 *	89.89%
FinSub AA 7-10 EUR	0.00387 *	0.01810	-6.66914 *	-	-4.76560 *	91.46%
FinSub A 7-10 EUR	0.00499 *	-0.00422	-4.68094 *	-	-5.91689 *	77.03%
FinSub BBB 7-10 EUR	0.00521 *	0.06408 *	-6.22146 *	-	-6.45621 *	73.22%
FinSub AA 10+EUR	0.00519 *	-0.08614 *	-7.96529 *	-	-5.25956 *	69.41%
FinSub A 10+ EUR	0.00420 *	-0.02449	-8.33776 *	-	-8.16946 *	86.84%
Corp AA 1-3 EUR	0.00306 *	-0.05202 *	-1.67476 *	-	-1.70360 *	59.74%
Corp A 1-3 EUR	0.00332 *	-0.04579 *	-1.66150 *	-	-1.80948 *	63.92%
Corp BBB 1-3 EUR	0.00320 *	-0.01569	-1.48943 *	-	-2.85984 *	65.70%
Corp HY 1-3 EUR	0.00747 *	0.25897 *	-0.71251	-	-5.88840 *	32.86%
Corp AA 3-5 EUR	0.00370 *	-0.06278 *	-3.68829 *	-	-2.24749 *	82.21%
Corp A 3-5 EUR	0.00378 *	-0.04747 *	-3.49900 *	-	-2.83948 *	84.38%
Corp BBB 3-5 EUR	0.00328 *	0.00786	-3.22082 *	-	-3.67851 *	74.76%
Corp HY 3-5 EUR	0.00924 *	0.34871 *	-1.26397	-	-3.71927	31.72%
Corp AA 5-7 EUR	0.00409 *	-0.06743 *	-5.35961 *	-	-3.59311 *	88.81%
Corp A 5-7 EUR	0.00429 *	-0.04154 *	-5.17248 *	-	-4.25199 *	89.58%
Corp BBB 5-7 EUR	0.00381 *	0.01194	-4.75219 *	-	-5.09573 *	87.06%
Corp HY 5-7 EUR	0.00196	0.77399 *	-2.57898	-	-12.63393 *	41.96%
Corp AA 7-10 EUR	0.00424 *	-0.03011 *	-6.70830 *	-	-2.87239 *	94.82%
Corp A 7-10 EUR	0.00456 *	0.00695	-9.45509 *	-	-3.47227 *	95.41%
Corp BBB 7-10 EUR	0.00430 *	0.00402	-6.30401 *	-	-4.10425 *	94.13%
Corp HY 7-10 EUR	0.00532 *	0.06520 *	-9.02943 *	-	-3.36937 *	84.11%
Corp AA 10+ EUR	0.00498 *	0.00015	-6.09835 *	-	-5.56044 *	81.34%
Corp BBB 10+ EUR	0.00534	0.46189 *	-3.01324	-	-14.92849 *	36.91%

NOTE: * indicates significance at the 95% level; inference is based on robust standard errors.