Kempf, Alexander; Korn, Olaf; Uhrig-Homburg, Marliese

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A. Kempf • O. Korn • M. Uhrig-Homburg

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The Term Structure of Illiquidity Premia [†]

Alexander Kempf[‡], Olaf Korn[*], and Marliese Uhrig-Homburg[**]

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[‡]Prof. Dr. Alexander Kempf, Department of Finance and Centre for Financial Research Cologne (CFR), University of Cologne, D-50923 Cologne, Germany, Phone +49 221 470 2741, Fax + 49 221 470 3992, Email kempf@wiso.uni-koeln.de

[*]Prof. Dr. Olaf Korn, Chair of Finance, Georg-August-Universität Göttingen and Centre for Financial Research Cologne (CFR), Platz der Göttinger Sieben 3, D-37073 Göttingen, Germany, Phone +49 551 39 7265, Fax +49 551 39 7665, Email okorn@uni-goettingen.de

[**]Prof. Dr. Marliese Uhrig-Homburg, Chair of Financial Engineering and Derivatives, Universität Karlsruhe (TH) and Karlsruhe Institute of Technology (KIT), D-76128 Karlsruhe, Germany, Phone +49 721 608 8183, Fax +49 721 608 8190, Email uhrig@wiwi.uni-karlsruhe.de

Abstract

This paper investigates the dynamics of the term structure of bond market illiquidity premia using data on German bond market segments which differ only with respect to their liquidity. We analyze the interaction between different parts of the term structure and identify economic factors that drive the illiquidity premia. We obtain three main results: (i) The term structure of illiquidity premia is U-shaped on average but its shape varies over time. (ii) There is a strict separation between the short end and the long end of the term structure of illiquidity premia, i.e. we find no evidence for spill-over effects across different maturities. Different economic factors drive different parts of the term structure. The short end is mainly driven by asset market volatilities which suggests a flight-to-liquidity effect. In contrast, the long end depends on long-term business cycle economic prospects. This suggests that different parts of the term structure are determined by different investor clienteles with different liquidity needs. (iii) There is a smooth transition from short-term to long-term illiquidity premia. The longer the time to maturity of a bond, the less important market volatilities are and the more important long-term economic prospects become.

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1 Introduction

Liquidity is one of the most important attributes of bond markets. Several papers show that both, the level of liquidity and liquidity risk, have a strong impact on bond prices leading to higher yields for less liquid bonds (e.g. Amihud, Mendelson, and Pedersen 2005). Nevertheless, there is still no clear picture on how illiquidity affects bond yields of different maturities. Since a bond's maturity deterministically changes over time, investors are forced to consider maturity-specific illiquidity premia within dynamic trading strategies for single bonds. This is obvious when looking at the well-documented on-the-run/off-the-run cycle, but holds more generally. If illiquidity premia depend on time to maturity, investor's portfolio choice problems are strongly affected.[1] In addition, there are implications for the management of liquidity risk. If illiquidity premia for different maturities are driven by different risk factors, appropriate hedging instruments differ accordingly across maturities.

This paper investigates the dynamics of the term structure of bond market illiquidity premia. We analyze the comovement of short-, medium-, and long-term illiquidity premia and identify economic factors determining them. Our results show that the term structure of illiquidity premia is U-shaped on average but that its shape varies strongly over time. We document a strict separation between the short end and the long end of the term structure of illiquidity premia, i.e. there are no spill-over effects across different maturities. We show that different economic factors drive different parts of the term structure. While the short end is driven by asset market volatilities, the long end depends on longer-term economic prospects. These results suggest that different parts of the term structure are determined by different investor clienteles with different liquidity needs. Our results remain stable during the period of the recent financial crisis.

The illiquidity premium is typically hard to measure because bond yields are jointly driven by three main factors: risk-free rate, default premium, and illiquidity premium. To separate the effects of the risk-free rate, the default premium, and the illiquidity premium on bond yields, we use the zero-coupon

[1] Gârleanu (2009) theoretically studies portfolio choice problems in illiquid markets and shows that the liquidity level has indeed a strong impact on asset holdings.

bond yield difference between two bond market segments: German government bonds (BUNDs) and German Pfandbriefe. These bond market segments only differ with respect to their degree of liquidity but do not differ in terms of default risk. The use of zero-coupon bond yields eliminates coupon-effects. Thus, the yield difference reflects the illiquidity premium of the Pfandbrief market as compared to the BUND market for bonds of different maturities, i.e. the term structure of illiquidity premia.

Related empirical literature provides evidence on illiquidity premia for different bond market segments. First, there is the burgeoning literature on risky bonds such as the recent corporate bond studies of Longstaff, Mithal, and Neis (2005), Lui, Longstaff, and Mandell (2006), Chen, Lesmond, and Wei (2007), De Jong and Driessen (2007), Dieck-Nielsen, Feldhütter, and Lando (2009) and others. They typically have to rely on rather strong assumptions to separate credit risk from liquidity risk. In contrast, our data allows for a much cleaner test of the effects of illiquidity on bond yields. Second, there is a literature concentrating on essentially risk-free bonds using predominantly U.S. Treasury securities. Different studies compare liquid Treasury Bills with more illiquid Treasury Notes (e.g. Amihud and Mendelson 1991, Kamara 1994) and liquid on-the-run Treasuries with more illiquid off-the-run Treasuries (e.g. Warga 1992, Krishnamurthy 2002, Goldreich, Hanke, and Nath 2005). In contrast to our study, they do not focus on the entire term structure of illiquidity premia.

Evidence on the term structure of illiquidity premia is scarce.[2] Koziol and Sauerbier (2007) develop and test an option-theoretical model to quantify illiquidity premia of bonds. Their model predicts a hump-shaped term structure, but the empirical evidence is weak. Longstaff (2004) studies the yield differences between Treasuries and Refcorp bonds and finds a U-shaped term structure, but his results are based solely on six long-term Refcorp bonds. In contrast to these papers we study the dynamic linkage between different parts of the term structure and identify maturity-segment specific determinants of illiquidity premia.

The remaining part of the paper is organized as follows: Section 2 briefly de-

[2] In an interesting study, Goyenko, Subrahmanyam, and Ukhov (2008) discuss term structure effects of bond market liquidity based on bid-ask spreads. However, they do not analyze illiquidity premia.

scribes the structure of the German government bond market and the Pfandbrief market. Section 3 describes our data set and outlines how the term structures for these two market segments are estimated. Results on the shape of the term structure of illiquidity premia are provided in Section 4. Section 5 deals with the determinants of the term structure of illiquidity premia. Subsection 5.1 shows results on the dynamic linkages between different parts of the term structure. In Subsection 5.2 we analyze the impact of additional economic factors and Subsection 5.3 takes a look at the impact of the financial crisis. Section 6 concludes the paper.

2 The German Bond Market

Government bonds (BUNDSs) and Pfandbriefe are the most important segments within the German bond market. In 2007 BUNDs account for about 33% of bonds outstanding and Pfandbriefe have a market share of about 25%.

Similar to the role of US treasuries in the US bond market, BUNDs are the benchmarks for euro-denominated fixed income products with a high level of liquidity in the secondary market. They play an important role as an underlying in derivatives markets, their credit risk is negligible, and they are seen as a "safe haven" in times of financial crises.

The second segment with systemic importance for the German financial system are German Pfandbriefe. Pfandbriefe have a benchmark role in the covered bond market. They are covered by first rank residential and commercial mortgages (Mortgage Pfandbriefe) or claims against the public-sector (Public Pfandbriefe). Pfandbriefe are highly regulated to ensure timely payment as well as bankruptcy-remoteness, i.e. Pfandbrief investors will not suffer any untimely repayments or redemption, even if the issuing bank goes into liquidation.[3] In contrast to US and UK secured mortgages, the underlying loans stay on the balance sheet of the mortgage bank.[4] There is no prepayment risk involved since the prepayment of a loan secured by a mortgage is excluded. Several safeguarding mechanisms protect Pfandbrief investors: (i) Banks must

[3]See Mastroeni (2001), p. 52.

[4]See Mastroeni (2001) for a more detailed description of Pfandbriefe and Peterson (2008) for differences between Pfandbriefe and US and UK asset-backed securities.

fulfill special requirements to obtain a licence to engage in the Pfandbrief business and are subject to cover audits and permanent supervision beyond the general banking supervision. (ii) The determination of the quality and size of the cover assets are subject to conservative guidelines including elements such as mandatory overcollateralization. (iii) Pfandbrief investors have priority access to the cover assets in the event of insolvency. Therefore, the German Pfandbrief is considered to be the safest debt instrument in the private market and until today there has not been a single case of default.

With respect to interest rate, credit risk, and tax treatment, Pfandbriefe are well comparable to BUNDs. The standard format is plain vanilla fixed coupon. The issues cover the whole range of maturities from very short term bonds up to 30 year issues. Currently the prevalent maturity of new issues is about seven years, the average maturity of outstanding bonds around five years. Although some effort has been made to enhance liquidity characteristics in the Pfandbrief market,[5] secondary market trading volume is much lower as compared to BUNDs. Pfandbriefe are perceived to be less liquid than BUNDs by market participants and the Pfandbrief-BUND spread largely compensates for differences in liquidity.

3 Data

Our analysis is based on term structure data provided by Deutsche Bundesbank. Monthly term structure estimates for the BUND market are available from January 1972 onwards. These are based on the cross section of prices of all government bonds (Bundesanleihen, Bundesobligationen and Bundesschatzanweisungen) with remaining times to maturity of at least three months. Analogous term structure estimates for the Pfandbrief market are available from the year 2000 onwards. Therefore, our research period starts in January 2000. As the end of the data period, we choose August 2008. Following the bankruptcy of Lehman Brothers in September 2008, the major Pfandbrief issuer Hypo Real Estate ran into trouble as credit froze on international markets. Most likely, this event created temporarily a very unusual relation between the

[5] For example, Jumbo Pfandbriefe with increased standards concerning minimum issue size, listing, and market making were introduced in 1995.

BUND and the Pfandbrief market.

To condense the term structure information we use the Nelson and Siegel (1987) approach. It allows us to characterize the entire term structure through four parameters only (β_{0t}, β_{1t}, β_{2t}, τ_t). Within the Nelson-Siegel framework, a zero bond yield at time t for time to maturity T is given as

$$y_t(T) = \beta_{0t} + \beta_{1t}\left[\frac{1 - e^{-T/\tau_t}}{T/\tau_t}\right] + \beta_{2t}\left[\frac{1 - e^{-T/\tau_t}}{T/\tau_t} - e^{-T/\tau_t}\right]. \quad (1)$$

The Nelson-Siegel parameters can be interpreted in terms of a factor representation. β_{0t}, β_{1t}, and β_{2t} are the factors and τ_t affects the factor loadings. To estimate the parameters for the BUND and the Pfandbrief market, we select end of month yields with maturities of 3 and 6 months and 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 years for each market from the Bundesbank data. Following standard practice like in Nelson and Siegel (1987) and Diebold and Li (2006), we restrict τ_t to be constant over time and, furthermore, to be identical in the BUND market and the Pfandbrief market. This assumption implies that factor loadings are the same in both markets and that the magnitude of the factors can be directly compared. Estimation is carried out by least squares, i.e. we minimize the sum of squared yield differences over all selected maturities and both markets. This procedure delivers monthly parameter estimates for the BUND market ($\beta_{0t}^{BU}, \beta_{1t}^{BU}$, and β_{2t}^{BU}) and for the Pfandbrief market ($\beta_{0t}^{PF}, \beta_{1t}^{PF}$, and β_{2t}^{PF}) as well as an overall estimate of $\tau = 2.017$. The latter estimate implies a maximum factor loading of the β_{2t} factor at about four years to maturity.

The factors are closely related to different segments of the term structure. β_{0t} determines the level of the long end of the term structure. Therefore, we call β_{0t} the long-term factor. β_{1t} is a slope factor that characterizes the difference between short-term and long-term yields. $\beta_{0t} + \beta_{1t}$ determines the short end of the term structure. Therefore, we call $\beta_{0t} + \beta_{1t}$ the short-term factor. β_{2t} is a shape factor that mainly drives medium-term yields. Due to the hump-shaped form of the corresponding factor loading, a positive value of β_{2t} moves the term structure towards a hump shape and a negative value towards a U-shape. The development of the estimated long-term factor β_0, the short-term factor $\beta_0 + \beta_1$, and the shape factor β_2 for the BUND and the Pfandbrief market is shown in Figure 1.

[Insert Figure 1 about here]

Figure 1 shows that the two markets are clearly linked and the factors move closely together. However, there are differences between the factors of the two markets resulting from illiquidity premia.

4 Shape of the Term Structure

Given the parameter estimates for the two market segments, the term structure of illiquidity premia is easily obtained. The parameters $\beta_{0t}^{SP} \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU}$, $\beta_{0t}^{SP} + \beta_{1t}^{SP} \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU} + \beta_{1t}^{PF} - \beta_{1t}^{BU}$, and $\beta_{2t}^{SP} \equiv \beta_{2t}^{PF} - \beta_{2t}^{BU}$ are the long-term factor, the short-term factor, and the shape factor of the term structure of illiquidity premia, respectively. The long-term (short-term) factor measures the illiquidity premium at the long (short) end of the term structure and the shape factor affects predominantly the medium-term illiquidity premium.

To get a first impression on the form of the term structure of illiquidity premia, we calculate the average over all months in the data period. The resulting average term structure is provided in Figure 2.

[Insert Figure 2 about here]

Figure 2 shows that there is a positive average illiquidity premium for all maturities. However, the premium varies across the different maturities. There is a clear U-shape in the average term structure of illiquidity premia. The premia are fairly high at the short end (45 bp) and at the long end (39 bp) of the term structure, but much lower for medium term bonds (28 bp for bonds with 3.5 years to maturity). Thus, the price of liquidity is higher for short- and long-term bonds than for bonds with a medium time to maturity.

Figure 3 shows the development of the term structure of illiquidity premia over time. It depicts the term structures for each month. The figure shows a strong variation in the level and in the form of the term structure.

[Insert Figure 3 about here]

We frequently observe U-shaped curves of the illiquidity premia, but also increasing term structures, strictly decreasing ones, and occasionally hump-shaped ones. The illiquidity premia are positive at all times for all maturities, but the level varies heavily. For example, the price of liquidity for short term bonds is fairly low at the beginning of 2004, but extremely high from the middle of year 2007 onwards.[6] This pattern suggests a flight-to-liquidity phenomenon during the financial crisis. Investors seek the high liquidity of government bonds and are willing to pay a high price for liquidity. The result complements the empirical findings of Beber, Brandt, and Kavajecz (2009) that fixed-income investors care about liquidity especially in times of heightened market uncertainty. The impact of the subprime crisis on the price of liquidity is much more pronounced at the short end than at the long end. Thus, illiquidity premia at the short and at the long end seem to vary over time in different ways. This phenomenon becomes even more evident in Figure 4 which shows the development of the short-term premium ($\beta_{0t}^{SP} + \beta_{1t}^{SP}$) and the long-term premium (β_{0t}^{SP}) as well the evolution of the shape factor β_{2t}^{SP}.

[Insert Figure 4 about here]

Part A of Figure 4 shows that there are periods where the illiquidity premium at the long end is above the one at the short end (for example, August 2004 until February 2006), i.e. liquidity at the long end is more highly priced. In contrast, from August 2007 to August 2008 investors seem to seek liquidity at the short end. Almost identical spreads at the long end and the short end are observed for example between September 2001 and March 2003. The correlation between short-term and long-term illiquidity premia is slightly negative (-0.13) and not significantly different from zero. This finding suggests that different economic effects might be responsible for illiquidity premia at the long end and the short end of the term structure.

[6] We checked whether the U-shape documented in Figure 2 is driven by the strong increase of the short-term premium during the crisis. This is not the case. Even when concentrating on the pre-crisis period before June 2007, we find an U-shaped average term structure of illiquidity premia. At the short end the premium is 38 bp, at the long end 40 bp, and in the middle segment 24 bp (for bonds with 3.5 years to maturity).

Part B of Figure 4 shows that the shape factor changes heavily over time. It is negative most of the time (which explains the U-shape of the average term structure), but it becomes highly positive at the end of our research period.

5 Dynamics of the Term Structure

5.1 Interactions Within the Term Structure

We now focus on explanations for the estimated illiquidity premia. For this analysis, we restrict our attention to "normal times", i.e., the period prior to the subprime crisis. Specifically, we concentrate on the period before June 2007, the month during which two of Bear Stearns' hedge funds ran into problems.

We first look at the dynamics of the three factors that represent illiquidity premia at different segments of the term structure ($\beta_{0t}^{SP} + \beta_{1t}^{SP}$ (Short), β_{2t}^{SP} (Shape), β_{0t}^{SP} (Long)). We run augmented Dickey-Fuller tests and KPSS tests to analyze the persistence and mean-reversion of the factors.[7] Whereas in the Dickey-Fuller framework one tests a null hypothesis of a unit root, the KPSS test uses stationarity as its null hypothesis. For all three time series, augmented Dickey-Fuller tests do not reject a unit root even at a 10% significance level. Using the KPSS test, stationarity is rejected at a 10% significance level for the short-term factor. For the long-term factor and the shape factor, stationarity is rejected at the 5% level. These result indicate that illiquidity premia show a high persistence and that changes in the premia cannot be predicted based on deviations from the average premium level.

Next we look at the dynamic linkage between different factors. There might be spillover effects as documented by Goyenko, Subrahmanyam, and Ukhov (2008). For US government bonds, they show that liquidity shocks at the

[7]We use the test variants with a constant and without a deterministic time trend. The number of augmentation terms in the Dickey-Fuller regressions was selected by means of the pre-test procedure by Hall (1994). As a result, we obtain one augmentation term for the long-term factor, two for the short-term factor and three for the shape factor. The test statistic of the KPSS test was adjusted for autocorrelation by applying Newey's and West's (1987) variance estimate with twelve lags.

short end of the term structure are transmitted to medium-term and longer maturities in later periods. In a first step, we estimate an unrestricted VAR-model to investigate whether similar lead-lag effects exist for our illiquidity premia:

$$Short_t = \alpha_0^s + \sum_{i=1}^{2} \left(\alpha_{i,s}^s Short_{t-i} + \alpha_{i,sh}^s Shape_{t-i} + \alpha_{i,l}^s Long_{t-i} \right) + \epsilon_t^s, \quad (2)$$

$$Shape_t = \alpha_0^{sh} + \sum_{i=1}^{2} \left(\alpha_{i,s}^{sh} Short_{t-i} + \alpha_{i,m}^{sh} Shape_{t-i} + \alpha_{i,l}^{sh} Long_{t-i} \right) + \epsilon_t^{sh}, \quad (3)$$

$$Long_t = \alpha_0^l + \sum_{i=1}^{2} \left(\alpha_{i,s}^l Short_{t-i} + \alpha_{i,sh}^l Shape_{t-i} + \alpha_{i,l}^l Long_{t-i} \right) + \epsilon_t^l, \quad (4)$$

where ϵ_t^s, ϵ_t^{sh}, and ϵ_t^l denote error terms. The superscripts s, sh, and l stand for short, shape, and long, respectively. The VAR-model is specified in levels to capture possible level relations between the three factors. Information criteria (AIC and SIC) suggest a lag length of one. As we want to allow for a potential influence of past changes in illiquidity premia, a lag length of two is chosen. Estimation results are presented in Table 1.

[Insert Table 1 about here]

Table 1 provides no evidence for a dynamic interaction between the different segments of the term structure of illiquidity premia.[8] The short-term premium is exclusively determined by past short-term premia and the long-term premium exclusively by past long-term premia.[9] The estimated correlation (-0.17) between the error terms ϵ_t^s and ϵ_t^l is low and not statistically significant. These findings suggest a separation between the short end and the long end of the term structure of illiquidity premia. Such a separation is confirmed

[8]A possible reason for this finding is that a monthly data frequency might not be sufficient to identify such a transmission mechanism.

[9]One should judge the significance of the coefficients that refer to lagged explained variables with caution, however, as the distribution of the test statistic has no standard form for time series with a unit root. See Sims, Stock, and Watson (1990).

by the impulse response functions derived from the VAR-model. For example, a one-standard-deviation shock in the short-term premium (about 9 bp) leads to a response in the long-term premium of at most 2 bp only over the following months.

In a second step, we consider a restricted version of the VAR-model that incorporates possible cointegration relations between the three factors. Based on Johansen's trace test, we identify one cointegration vector which includes all three factors. However, the corresponding error correction term only affects the shape factor. Moreover, the existence of one cointegration relation implies that there are two stochastic trends which drive the dynamics of the system. These could be identified as the short end and the long end of the term structure. In summary, there is a clear separation between the short end and the long end of the term structure of illiquidity premia.

5.2 Economic Drivers of the Term Structure

The illiquidity premium gives us a measure of the price of liquidity for different maturities. This price of liquidity should reflect two economic factors: (i) the difference in liquidity between the two markets (which is determined by the institutional setting and the market characteristics) and (ii) the importance which investors attach to liquidity. Therefore, the price of liquidity should depend on investors' expectations about the necessity to trade in the future. We capture these economic factors by different proxy variables.

Our proxy for the liquidity difference between the BUND and the Pfandbrief market is based on the volume of recently issued bonds.[10] Focussing on recently issued bonds is sensible since trading typically concentrates in on-the-run bonds.[11] Our proxy *Volume* is defined as the ratio of the volume issued in the Pfandbrief market and the total volume issued in both markets (Pfandbrief plus BUND) over the previous six months. We construct separate measures for three different maturity ranges (< 2 years, $2 - 9$ years, ≥ 9 years) which roughly capture the short end, the middle range, and the long end of the term structure. The data source is Deutsche Bundesbank.

[10] Volume is used as a measure of liquidity for example in Krishnamurthy (2002).
[11] See, e.g., Goldreich, Hanke, and Nath (2005).

Several papers (e.g. Acharya and Pedersen 2005, Ericsson and Renault 2006, Koziol and Sauerbier 2007) suggest that the value of liquidity increases with volatility. The basic economic idea is that in periods when there is a lot of information flowing into the market and, consequently, volatility is high, portfolio revisions become more likely and the value of liquidity increases. Therefore, we take the volatility in the bond market, *Volatility*, as an explanatory variable in our model. We use the daily yields of a one-year government bond and take its standard deviation within a month as our measure of volatility.

Since there are trading strategies that involve stock and bond markets at the same time, we also include the volatility of the stock market, *VDAX*, in our model. For example, stock market investors might use the bond market as a "safe haven" when stock market volatility is high. Therefore, we expect that liquidity in the bond market becomes more important when stock markets are more volatile. Our proxy for stock market volatility is the VDAX-NEW, the benchmark volatility index of the German stock market. It is based on implied volatilities of options on futures on the German stock market index DAX30, which are traded on EUREX. The VDAX-NEW refers to an option's time to maturity of 30 days and is provided by Deutsche Börse Group. We use end of month values for our study.

Investment decisions are also influenced by longer-term risks. If the long-term outlook on financial markets, personal finances of investors, and the economy in general is positive, it becomes less risky for an investor to commit herself to hold an asset over a longer horizon. Therefore, the liquidity of the asset becomes less important. Conversely, if the long-term outlook is negative, the likelihood increases that even long-term investors are eventually unable to maintain their strategy and might be forced to sell their bonds prior to maturity. Therefore, even these investors value liquid assets higher than illiquid ones. We proxy the general economic outlook and the long-term risk of future trading needs by the Ifo business climate index, *Ifoindex*. The index is the most prominent indicator of the business climate in Germany. It is based on the survey responses of about 7,000 German firms and is published on a monthly basis by the Ifo Institute.[12]

[12] Of course, the economic prospects of Germany, as measured by the Ifo index, might not only influence the magnitude of long-term risks but also investors' risk preferences. If the

In addition to our main explanatory variables, we use several control variables. First, we control for the net investment of foreign investors in the German bond market, *Foreign*, measured in trillions of Euros. Since the Pfandbrief market is not well known outside Germany, foreign investors might buy government bonds not for liquidity reasons, but for awareness reasons. Therefore, foreign net demand might affect the Pfandbrief-BUND spread. We take data on net investments of foreign investors from the monthly financial market statistics of Deutsche Bundesbank. Second, we control for credit risk. Although both, BUNDs and Pfandbriefe, are effectively default free, there might be a perception in the market that Pfandbriefe carry some credit risk. If this is the case, the Pfandbrief-BUND spread would not be entirely liquidity driven. We take the spread between the Bloomberg EUR Eurozone index of industrial AA+/AA bond yields and the Bloomberg EUR Eurozone index of industrial BBB bond yields as our proxy for credit risk.[13] This spread measure, *Credit*, captures the dynamics of credit risk over time. End of month values are used for a maturity of one year. Finally, we leave the lagged values of the illiquidity factors as control variables in our model to capture dynamic interactions. Since our test results from Section 5.1 indicate that the factors have a unit root, we could otherwise obtain spurious regression results.[14] Table 2 provides summary statistics of our explanatory variables.

[Insert Table 2 about here]

To examine the impact of the explanatory variables on the illiquidity premia, we extend our previous VAR-model to a VAR-model with additional exogenous variables (VARX-model). We estimate one equation for each factor of the term structure of illiquidity premia.

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outlook is positive, investors might be willing to take higher risks, including liquidity risk, which leads to a lower price of liquidity. Such an effect on risk preferences, however, works in the same direction as the effect on the magnitude of long-term risks.

[13] We consider the spread between two segments of the corporate bond market and not a spread between either corporate bonds and BUNDs or corporate bonds and Pfandbriefe because in the latter cases the spread would also depend on liquidity differences between corporate bonds, BUNDs, and Pfandbriefe.

[14] See Granger and Newbold (1974). Sims, Stock, and Watson (1990) show that a lagged endogenous variable in the regression ensures that the asymptotic distribution of the regression coefficients of the exogenous variables maintains its standard form.

$$
\begin{aligned}
Short_t &= \gamma_0^s + \gamma_1^s Volume_t^s + \gamma_2^s Volatility_t + \gamma_3^s VDAX_t + \gamma_4^s Ifoindex_t \\
&\quad + \gamma_5^s Foreign_t + \gamma_6^s Credit_t \qquad (5) \\
&\quad + \sum_{i=1}^{2} \left(\alpha_{i,s}^s Short_{t-i} + \alpha_{i,sh}^s Shape_{t-i} + \alpha_{i,l}^s Long_{t-i} \right) + \epsilon_t^s,
\end{aligned}
$$

$$
\begin{aligned}
Shape_t &= \gamma_0^{sh} + \gamma_1^{sh} Volume_t^{sh} + \gamma_2^{sh} Volatility_t + \gamma_3^{sh} VDAX_t + \gamma_4^{sh} Ifoindex_t \\
&\quad + \gamma_5^{sh} Foreign_t + \gamma_6^{sh} Credit_t \qquad (6) \\
&\quad + \sum_{i=1}^{2} \left(\alpha_{i,s}^{sh} Short_{t-i} + \alpha_{i,sh}^{sh} Shape_{t-i} + \alpha_{i,l}^{sh} Long_{t-i} \right) + \epsilon_t^{sh},
\end{aligned}
$$

$$
\begin{aligned}
Long_t &= \gamma_0^l + \gamma_1^l Volume_t^l + \gamma_2^l Volatility_t + \gamma_3^l VDAX_t + \gamma_4^l Ifoindex_t \\
&\quad + \gamma_5^l Foreign_t + \gamma_6^l Credit_t \qquad (7) \\
&\quad + \sum_{i=1}^{2} \left(\alpha_{i,s}^l Short_{t-i} + \alpha_{i,sh}^l Shape_{t-i} + \alpha_{i,l}^l Long_{t-i} \right) + \epsilon_t^l.
\end{aligned}
$$

The time index t runs from August 2001 to May 2007 since credit spreads for the Euro denominated Eurozone corporate bond market are not available before August 2001. Our regression results are provided in Table 3.

[Insert Table 3 about here]

Table 3 shows several results: First, our explanatory variables have a significant impact on the illiquidity premia at the short end and the long end of the term structure, but cannot explain the shape factor. Second, illiquidity premia are mainly driven by the uncertainty the investor faces. The higher the uncertainty, the higher the illiquidity premia. This suggests that investors are attaching more importance to liquidity in uncertain times. However, there are different types of uncertainty which determine the short-term and long-term illiquidity premia. The short-term premium is mainly driven by short-term volatility in the asset markets whereas the long-term illiquidity premium is determined by the uncertainty about the long-term economic outlook as measured by the Ifo index. Thus, distinctly different variables drive different segments of the term structure.

In the regression equation of the short-term premium, we see a significant impact of the bond market volatility and the stock market volatility. The positive values of the coefficients state that higher risks in the bond market and the stock market lead to higher illiquidity premia. This result is in line with the argument that a higher volatility causes a higher probability of trading, which makes the liquidity of an asset more valuable and the BUND market more attractive. The significant effect of the VDAX only at the short end suggests that stock market investors enter bonds markets in volatile periods via short term BUNDs. This is sensible since short term BUNDs provide high liquidity and low interest rate sensitivity. To illustrate the magnitude of the volatility effects, we consider a simultaneous positive shock of one standard deviation in bond market and stock market volatility. In response to such a shock, the illiquidity premium increases by about 6 bp. This is almost one sixth of the average spread at the short end of the spread curve.

The illiquidity premium at the long end of the term structure is mainly driven by the Ifo index. A higher index level (which indicates a positive business climate) leads to a lower illiquidity premium, i.e., the corresponding coefficient is negative. If the Ifo index increases by one standard deviation, the long-term illiquidity premium decreases by more than 4 bp, about ten percent of the average long-term premium.

Our results suggest that different slopes of the term structure of the illiquidity premium reflect different regimes of short- and long-term risk. For example, if short-term volatility is low and the business climate is bad, we would expect an upward sloping liquidity spread curve. Conversely, a downward sloping curve would result from a high volatility and a good business climate.

Surprisingly, the volume of recently issued bonds is insignificant for all three factors. One explanation for this finding could be that market participants do not reevaluate their notion of liquidity differences between BUND and Pfandbrief permanently over time but have a rather static view. In this case, volume effects show up only in the constants. In fact, the positive and highly significant constant at the long end of the term structure is consistent with a much higher volume of long-term BUNDs compared to Pfandbriefe.

When looking at the control variables, we see that the net demand of foreign investors and the credit variable are never significant. Therefore, we have no evidence that spreads between the Pfandbrief and the BUND market are driven by credit risk or by the fact that foreigners are only aware of the Bund market segment. Finally, lagged factors are significant at the short end and the long end of the term structure, which confirms the persistence of premia over time.

So far, we have analyzed illiquidity premia in terms of a three-factor representation of the term structure. For applications such as portfolio choice and dynamic trading strategies it is important to know the implications of our results for illiquidity premia at specific maturities. Our previous findings suggest that the illiquidity premia of short-term bonds and long-term bonds are determined by distinct economic factors. We now analyze whether there is a smooth transition from short-maturity premia to medium- and long-maturity premia. Table 4 provides the corresponding results for maturities between three months and 15 years. It shows the estimated coefficients of regression models like equations (5) to (7) with maturity-specific illiquidity premia as dependent variables.

[Insert Table 4 about here]

The results indeed suggest a smooth transition. The results for the three-months premium and the 15-years premium closely resemble the results for the short-term factor and the long-term factor. For maturities of one and five years, stock market volatility is still significant. For the ten-years premium, stock market volatility looses its explanatory power, but the Ifo index becomes now significant at the 5% level. Thus, short-term volatility becomes the more important for the illiquidity premium the shorter the maturity of a bond. Longer-term economic prospects, however, gain importance for bonds with longer maturities. These findings further support the hypothesis of investor clienteles with different liquidity needs.

5.3 Influence of the Financial Crisis

The financial crisis that began in summer 2007 has been a major disruption for many financial markets and the way investors perceive the risks they face.

Therefore, we test whether our main findings remain stable under such circumstances. As a robustness check, we repeat our analysis using data until August 2008.[15] The results for the VARX-model are given in Table 5.

[Insert Table 5 about here]

Table 5 shows that the separation between short-term and the long-term premia remains qualitatively unchanged. Short-term volatility still determines the short end of the term structure of illiquidity premia, whereas long-term risk determines the long end. Interestingly, the coefficients of the credit spread variable are now positive in all three equations. The p-values of 8.4% for the short-term factor and 9% for the long-term factor suggest that credit risk gained importance during the crisis even in the Pfandbrief market. In this respect, the crisis clearly makes a difference.

6 Conclusions

The German bond market offers a unique testing ground for liquidity studies: essentially default-free bonds with very similar characteristics that only differ with respect to their liquidity are traded along the entire maturity spectrum. In this paper, we take advantage of this situation to examine the term structure of illiquidity premia. In a novel empirical approach, we compare the spread between yields of the liquid BUND market and the relatively less liquid (but otherwise similar) Pfandbrief market for bonds of different maturities. This spread reflects the illiquidity premium of the Pfandbrief market as compared to the BUND market for bonds of different maturities, i.e. the term structure of illiquidity premia.

Our examination of the dynamics of the term structure of illiquidity premia over time delivers several novel findings: The term structure of illiquidity premia is typically not flat but U-shaped and not constant over time, reflecting the impact of a changing economic environment. The short end and the long end of the term structure of illiquidity premia are strictly separated, i.e. there

[15] We cannot analyze the crisis period separately since there are only 19 monthly observations.

are no spill-over effects. The short end of the term structure is mainly driven by the volatility of bond and equity markets. If the volatility rises, so does the short-term illiquidity premium. This is consistent with a flight-to-liquidity argument in turbulent times: if volatility on markets increases, many investors shift their portfolio into the more liquid short-term government bonds. This demand effect leads to an increase in the price of liquidity. The long-term illiquidity premia are driven by the long-term economic outlook. This finding indicates that long-term investors facing an increased risk of early liquidation during an economic downturn are willing to pay a higher price for liquidity of the long-term bonds they typically hold. Given the different risk factors that drive long- and short-term liquidity premia, investors need different instruments for hedging liquidity risk for long- and short-term bonds. The illiquidity premia of medium-term bonds are driven by short-term risk factors and long-term risk factors. If the time to maturity is steadily increased, one observes a decreasing influence of short-term risk factors and an increasing influence of the long-term economic outlook. The results are stable even when including the period of the recent financial crisis.

Overall, these results suggest that illiquidity premia depend mainly on the value that investors are attributing to liquidity. Furthermore, the illiquidity premia of short- and long-term bonds depend on different variables which are important for different investor clienteles: while long-term investors care about the long-term economic outlook, short-term investors are more concerned about the possibility of quick portfolio rebalancing. This finding indicates that different investor clienteles for short- and long-term bonds are responsible for the cross-sectional difference in the determinants of illiquidity premia among these bonds.

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Table 1: Joint dynamics of illiquidity premia: VAR(2)-model.

	Short-term factor	Shape factor	Long-term factor
Constant	0.0597	0.1640	0.0030
	(0.0341)	(0.1493)	(0.0565)
Short-term (t-1)	0.5963**	-0.8460	0.2278
	(0.0991)	(0.4519)	(0.1440)
Short-term (t-2)	0.2314**	0.2115	-0.1191
	(0.0591)	(0.5103)	(0.1166)
Shape (t-1)	-0.0010	0.1259	0.0215
	(0.0329)	(0.1188)	(0.0400)
Shape (t-2)	0.0175	0.0250	0.0092
	(0.0305)	(0.1150)	(0.0290)
Long-term (t-1)	0.0081	-0.0725	0.5647**
	(0.0947)	(0.3185)	(0.1276)
Long-term (t-2)	0.0168	-0.8737**	0.3770**
	(0.0838)	(0.3301)	(0.1017)
R^2	0.62	0.37	0.75

Significant at * 5% level, ** 1% level.

This table shows the results for a VAR(2)-model of the illiquidity factors. The data period is January 2000 to May 2007 (87 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey's and West's (1987) covariance matrix estimator with ten lags.

Table 2: Summary statistics of potential drivers of illiquidity premia.

	Mean	Standard Deviation	Minimum	Median	Maximum
Volume (short)	0.6226	0.2638	0.1695	0.5151	1.0000
Volume (medium)	0.6110	0.0602	0.5033	0.6063	0.7909
Volume (long)	0.2419	0.1152	0.0850	0.2153	0.6151
Volatility	0.0611	0.0320	0.0183	0.0534	0.2354
VDAX	24.50	10.38	12.32	20.96	60.03
Ifo index	96.40	6.10	87.10	95.40	108.80
Foreign	0.0094	0.0104	-0.0152	0.0093	0.0323
Credit	0.2856	0.1673	0.1157	0.2190	0.7834

This table shows some summary statistics of potential drivers of illiquidity premia. The data period is January 2000 to May 2007 (89 observations) for most variables. Due to data limitations credit spreads refer to the period August 2001 to May 2007 (70 observations).

Table 3: Drivers of illiquidity premia: VARX-model.

	Short-term factor	Shape factor	Long-term factor
Constant	0.2384	-0.5919	0.9083**
	(0.3231)	(1.5190)	(0.2548)
Volume	-0.0755	-1.0222	0.2499
	(0.0534)	(1.2048)	(0.2428)
Volatility	0.8635**	-0.1640	-0.6838
	(0.2682)	(1.9157)	(0.3940)
VDAX	0.0029**	0.0135	-0.0023
	(0.0011)	(0.0096)	(0.0025)
Ifo index	-0.0024	0.0129	-0.0071**
	(0.0025)	(0.0095)	(0.0019)
Foreign	-0.0317	-0.2001	0.5493
	(0.9462)	(3.7893)	(1.4758)
Credit	-0.0169	-0.8399	0.1707
	(0.0787)	(0.7250)	(0.1893)
Short-term (t-1)	0.6481**	-0.7844	-0.0343
	(0.0925)	(0.6149)	(0.1440)
Short-term (t-2)	0.1072	0.2025	-0.0547
	(0.0808)	(0.5820)	(0.1994)
Shape (t-1)	0.0512*	0.0355	-0.0100
	(0.0234)	(0.1579)	(0.0474)
Shape (t-2)	0.0478	-0.0171	0.0029
	(0.0334)	(0.1800)	(0.0362)
Long-term (t-1)	0.0803	-0.2862	0.2658
	(0.1072)	(0.5504)	(0.1531)
Long-term (t-2)	0.0791	-0.8355	0.2338*
	(0.1497)	(0.4547)	(0.1181)
R^2	0.77	0.33	0.45

Significant at * 5% level, ** 1% level.

This table shows the results for the VARX-model, which includes different explanatory variables for the illiquidity factors. The data period is August 2001 to May 2007 (70 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey's and West's (1987) covariance matrix estimator with ten lags.

Table 4: Drivers of illiquidity premia for different maturities.

	3-months premium	1-year premium	5-years premium	10-years premium	15-years premium
Constant	0.2185	0.1944	0.4180	0.5342**	0.6522**
	(0.2658)	(0.1659)	(0.3642)	(0.1468)	(0.1579)
Volume	-0.0208	0.1012	-0.1482	0.0627	0.1208
	(0.0479)	(0.0562)	(0.3665)	(0.1332)	(0.1593)
Volatility	0.6665*	0.2024	-0.1843	-0.4126	-0.5019
	(0.2952)	(0.4428)	(0.5570)	(0.4474)	(0.3883)
VDAX	0.0035**	0.0049**	0.0041*	0.0020	0.0007
	(0.0010)	(0.0012)	(0.0019)	(0.0012)	(0.0013)
Ifo index	-0.0019	-0.0010	-0.0015	-0.0033*	-0.0045**
	(0.0020)	(0.0013)	(0.0023)	(0.0015)	(0.0015)
Foreign	-0.1047	-0.2417	0.1923	0.2827	0.3678
	(0.8070)	(0.6431)	(0.7333)	(0.7921)	(0.9668)
Credit	-0.0773	-0.2042*	-0.1841	-0.0685	0.0059
	(0.0726)	(0.0987)	(0.1394)	(0.0991)	(0.1060)
R^2	0.77	0.65	0.11	0.21	0.34

Significant at * 5% level, ** 1% level.

This table shows the effects of different explanatory variables on the illiquidity premia for maturities between three months and fifteen years. The results are obtained from a model with two lagged values of each illiquidity factor and different explanatory variables. Coefficients of the lagged illiquidity factors are not reported. The short-term volume ($<$ 2 years) is used as an explanatory variable for the 1-month and 3-years premia, the medium-term volume ($2 - 9$ years) for the 5-years premia, and the long-term volume ($\geq$ 9 years) for the 10-years and 15-years premia. The data period is August 2001 to May 2007 (70 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey's and West's (1987) covariance matrix estimator with ten lags.

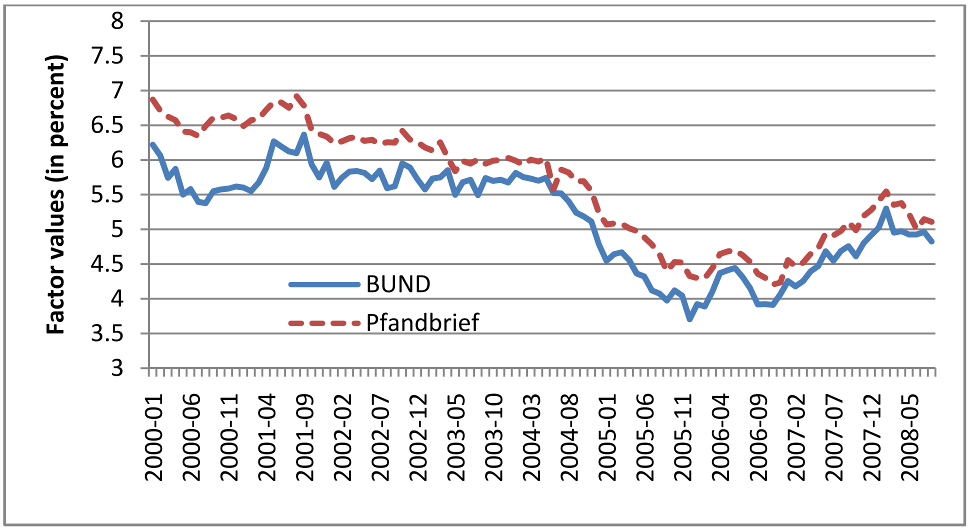
Table 5: Influence of the financial crisis: Drivers of illiquidity premia: VARX model

	Short-term factor	Shape factor	Long-term factor
Constant	0.0220	-0.9331	0.7593**
	(0.3502)	(1.3692)	(0.1988)
Volume	-0.1565*	-1.2005	0.1924
	(0.0707)	(0.9078)	(0.2176)
Volatility	1.2385*	-1.0140	-0.5508
	(0.5822)	(1.4557)	(0.3350)
VDAX	0.0022*	0.0029	-0.0020
	(0.0010)	(0.0058)	(0.0016)
Ifo index	-0.0004	0.0156	-0.0058**
	(0.0029)	(0.0086)	(0.0017)
Foreign	0.3561	-0.5521	0.9394
	(1.0581)	(3.7632)	(1.0573)
Credit	0.1290	0.0752	0.1703
	(0.0746)	(0.3150)	(0.1003)
Short-term (t-1)	0.9500**	-1.2335**	0.0559
	(0.1039)	(0.3084)	(0.0606)
Short-term (t-2)	-0.1450	1.4088**	-0.1348
	(0.1390)	(0.4261)	(0.1033)
Shape (t-1)	0.1315**	0.097	0.0013
	(0.0441)	(0.0851)	(0.0310)
Shape (t-2)	0.0686	0.1193	0.0085
	(0.0358)	(0.1120)	(0.0259)
Long-term (t-1)	0.2748*	-0.3674	0.3247**
	(0.1398)	(0.4188)	(0.1223)
Long-term (t-2)	0.0426	-0.5783	0.2213*
	(0.1512)	(0.5002)	(0.1030)
R^2	0.81	0.40	0.46

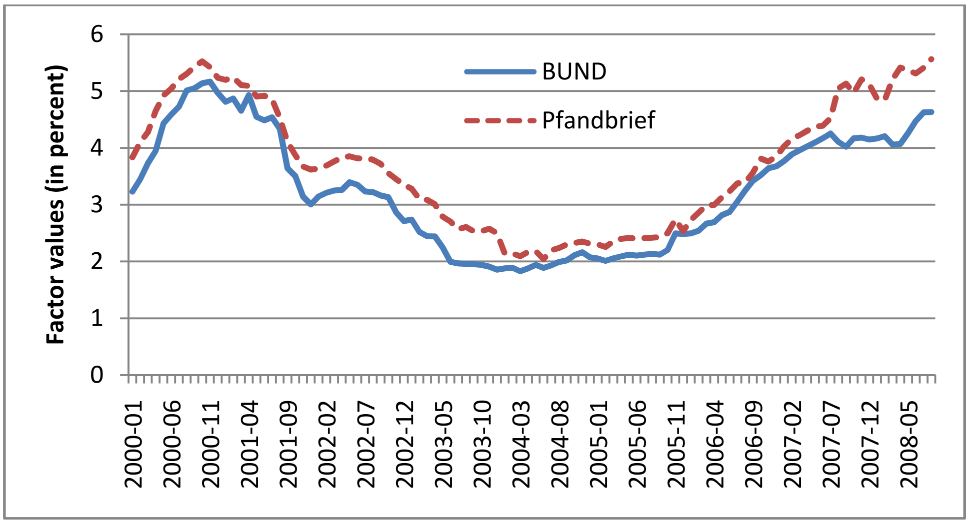
Significant at * 5% level, ** 1% level.

This table shows the results for the VARX-model, which includes different explanatory variables of the illiquidity factors. The data period is August 2001 to August 2008 (85 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey's and West's (1987) covariance matrix estimator with ten lags.

Part A: Long-term factors



Part B: Short-term factors



Part C: Shape factors

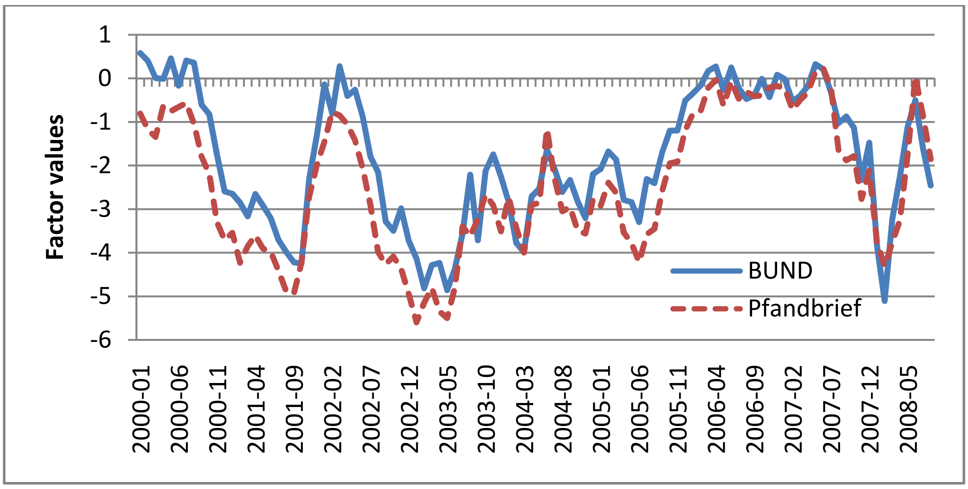


Figure 1: Development of the term structure factors over time.

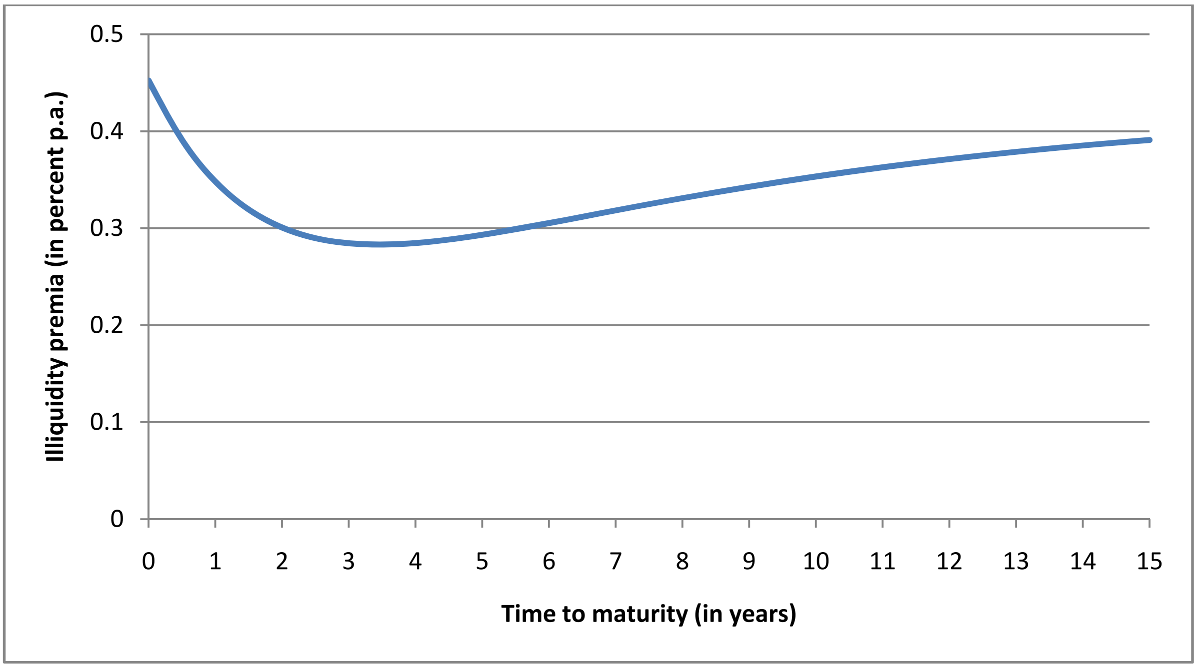


Figure 2: Average term structure of illiquidity premia. Data period from January 2000 to August 2008.

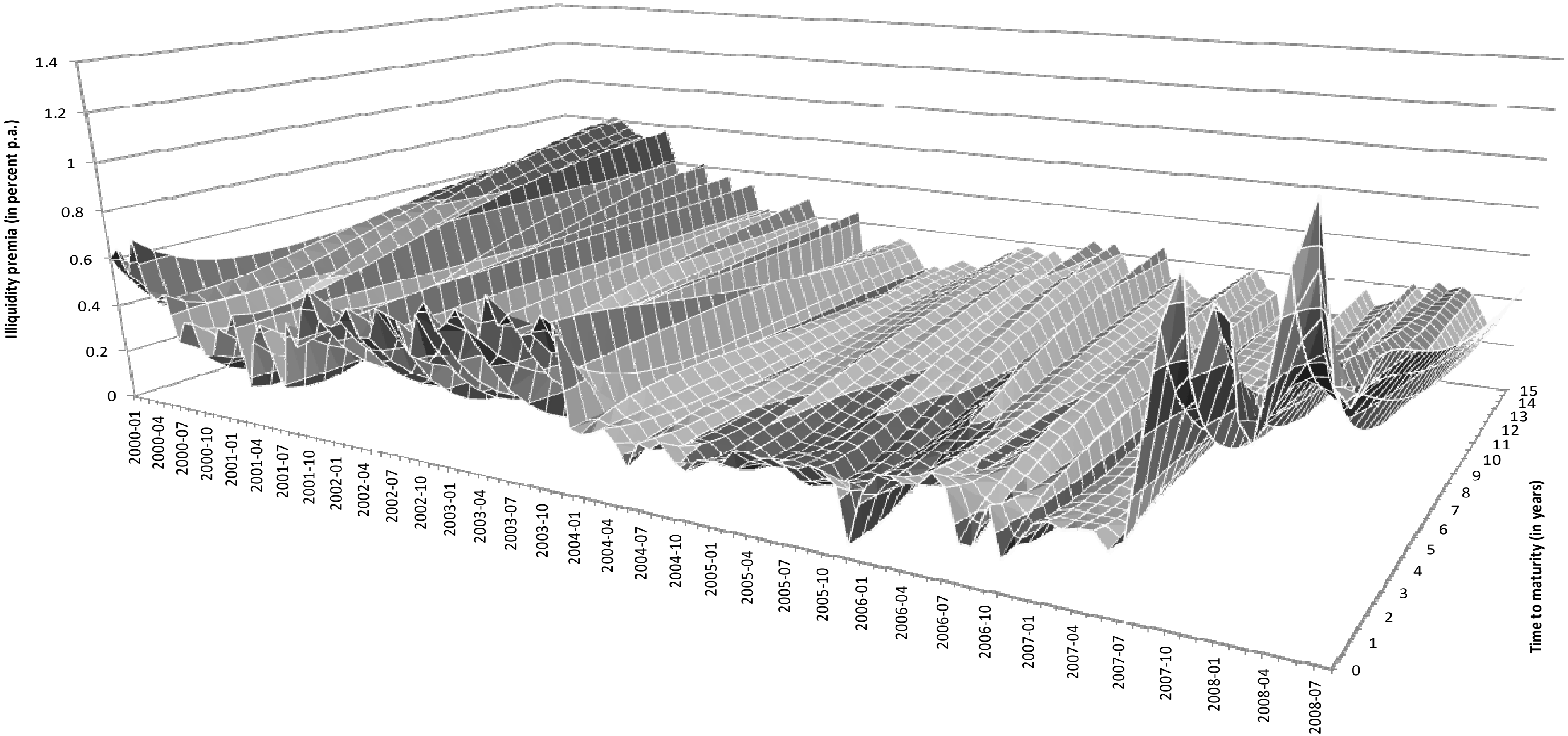
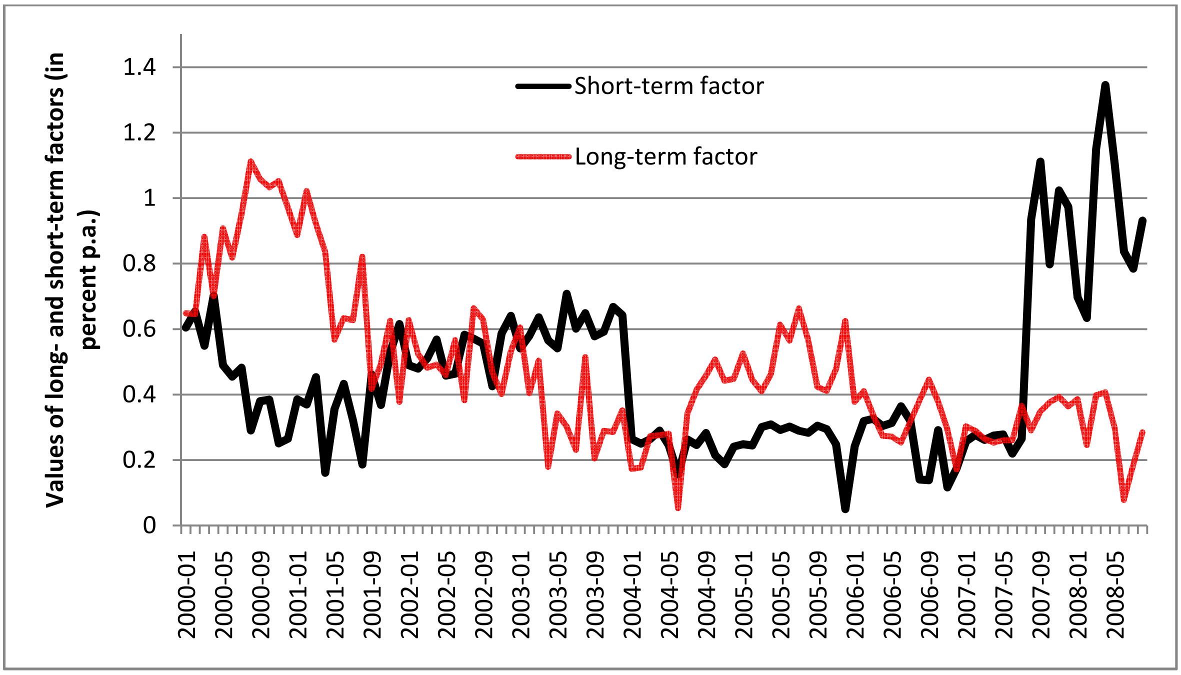


Figure 3: The term structure of illiquidity premia over time.

Part A: Short-term factor and long-term factor



Part B: Shape factor

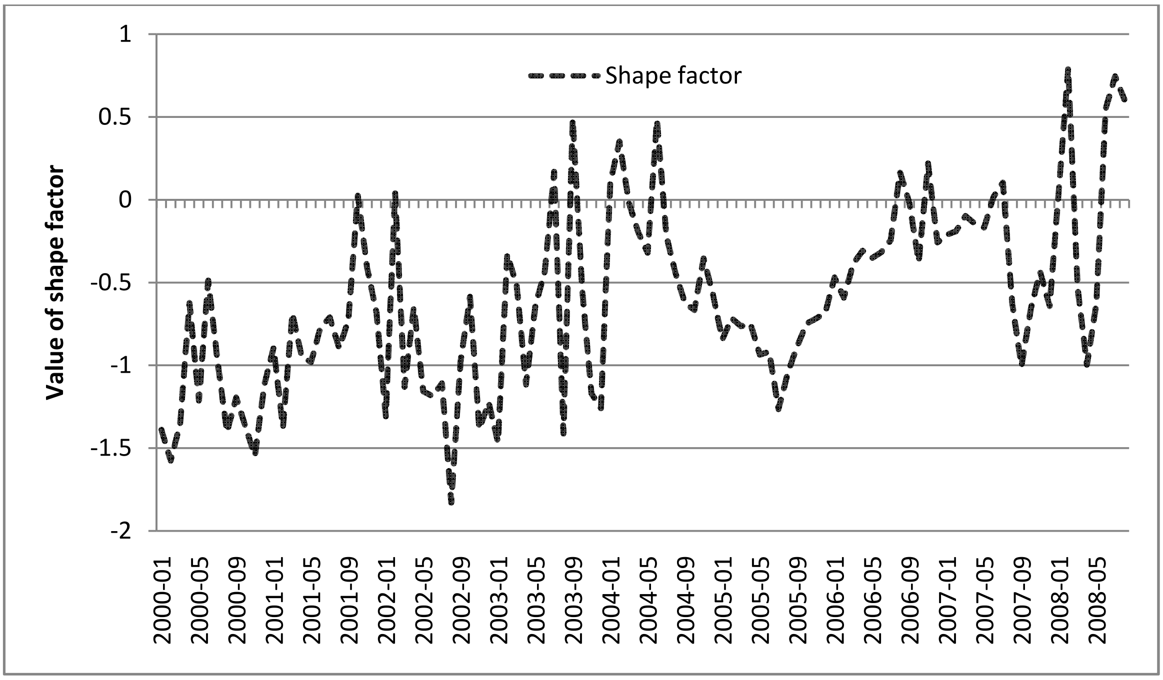


Figure 4: Development of the term structure of illiquidity premia factors over time.

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centre for financial research
cfr/university of cologne
Albertus-Magnus-Platz
D-50923 cologne
fon +49(0)221-470-6995
fax +49(0)221-470-3992
kempf@cfr-cologne.de
www.cfr-cologne.de