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The Term Structure of Illiquidity Premia

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Abstract

This paper investigates the term structure of bond market illiquidity premia. We empirically show that the term structure varies greatly over time. Moreover, short and long end are strictly separated suggesting that different economic factors drive different parts of the term structure. We propose a stylized theoretical model which implies that the short end is driven by current trading needs of investors and the long end by the long-term risk of being forced to liquidate bond positions. Empirical evidence supports these predictions. While short-term liquidation risk captured by asset market volatilities drives the short end, the long end depends on the long-term economic outlook.

JEL classification: G12, G13

I Introduction

Liquidity is one of the most important attributes of bond markets. Several papers show that both, level of liquidity and liquidity risk, have a strong impact on bond prices leading to higher yields for less liquid bonds (for a survey, see Amihud, Mendelson, and Pedersen 2005). Although the existence of the illiquidity premium is beyond doubt, it is still unclear how this premium depends on the maturity of the bond.

Understanding the term structure of illiquidity premia is an important task for several reasons. (i) 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. (ii) If illiquidity premia depend on time to maturity, investors' portfolio choice problems are strongly affected.[1] (iii) There are also 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.

Our paper contributes in two ways to a better understanding of the term structure of illiquidity premia. Our first contribution is to provide insights into the dynamics of the term structure of bond market illiquidity premia using an ideally suited data set. 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 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. Thus, the

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

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. Using this data set, we show that the shape of the term structure varies heavily over time. There are periods of increasing term structures, but also periods in which the term structure is flat or even decreasing. We also document a strict separation between the short end and the long end of the term structure of illiquidity premia. The correlation is almost zero and we find no spill-over effects across different maturities. This result suggests that different economic factors drive different parts of the term structure.

Our second main contribution is to identify economic factors which determine level and form of the term structure of illiquidity premia. We propose a stylized theoretical model which is, nevertheless, flexible enough to capture the observed dynamics of the term structure of illiquidity premia. The economic rationale of the model is straightforward. The term structure of illiquidity premia is determined by the investors' demand for liquidity. This demand is driven by the risk of being forced to sell bonds. If the current risk is unusually high in comparison with the expected risk in the long run, the expected per period trading costs of short-term bonds are higher than those of long-term bonds and the term structure of illiquidity premia is downward sloping. The opposite is true if the current liquidation risk is below its long-run mean. The model has two main implications: (i) The long end of the term structure is determined by the long-term liquidation risk of the investor whereas the short end is driven by her current trading needs. (ii) The influence of long-term risk increases with the time to maturity of the bond whereas the influence of the short-term risk decreases. In the empirical part of the paper we provide support for both hypotheses: While the short end of the term structure of illiquidity premia is driven by short-term liquidation risk captured by asset market volatilities, the long end depends on the long-term economic outlook. The short-term liquidation risk becomes more important for the illiquidity premium the shorter the maturity of a bond is. Economic prospects, however, gain importance for bonds with longer maturities.

Our paper is related to several strands of the literature. The theoretical part of our paper contributes to the scarce literature on how illiquidity premia should behave across maturities. Ericsson and Renault (2006) propose a stylized version of a search market model that predicts a decreasing term structure of illiquidity premia. Bond holders suffer from random liquidity shocks forcing them to sell the bond prior to maturity at a discount. However, the shape is mainly driven by the possibility of selling voluntarily under favorable conditions. This option renders future liquidity shocks less important and leads to illiquidity premia that decrease with time to maturity. Koziol and Sauerbier (2007) apply Longstaff's (1995) idea that the liquidity advantage equals the payoff of a lookback option to bond markets. Their model predicts a humped-shaped term structure of illiquidity premia. For very short maturities the disadvantage from a temporary trading restriction is virtually irrelevant but it increases with time to maturity. The subsequent decrease occurs because the temporary trading restrictions become relatively less important when maturity goes to infinity. Whereas these models allow only for one specific form of the term structure, our model is flexible enough to capture the variation of the term structure over time. It traces the form of the term structure back to the liquidation risk faced by the investor. Our model complements the recent search-based model by Feldhütter (2011) which also allows for different shapes of the term structure, but traces them back to search costs and occasional selling pressure.

Related empirical literature provides evidence on illiquidity premia for different bond market segments. First, there is the burgeoning literature on default-risky bonds such as the recent corporate bond studies of Longstaff, Mithal, and Neis (2005), Houweling, Mentink, and Vorst (2005), Lui, Longstaff, and Mandell (2006), Chen, Lesmond, and Wei (2007), De Jong and Driessen (2007), Van Landschoot (2008), Dieck-Nielsen, Feldhütter, and Lando (2009) and others. They typically have to rely on rather strong assumptions to separate credit risk from liquidity risk.[2] 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.[3] 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.[4] Koziol and Sauerbier (2007) test their theoretical model, but the empirical evidence is weak. Longstaff (2004) looks at yield differences between Treasuries and Refcorp bonds. He finds a U-shaped term structure, but his results are based on only six long-term Refcorp bonds. In contrast to these papers we study the dynamic linkage between different parts of the term structure using a large sample of bonds varying only with respect to liquidity and identify maturity-specific determinants of illiquidity premia.

The remaining part of the paper is organized as follows: Section II provides information on our data set. First results on the shape and dynamics of the term structure of illiquidity premia are provided in Section III. Section IV deals with the economic determinants of the term structure. Here, we present a stylized model of the term structure of illiquidity premia, test its main implications, and check the robustness of our findings. Section V concludes the

[2] This separation is also a crucial step in the empirical studies on the Euro-Area bond market by Beber, Brand, and Kavajecz (2009) or the study on municipal bonds by Wang, Wu, and Zhang (2008).

[3] See also the studies on the Japanese market by Boudouck and Whitelaw (1993) or the more recent study on the Spanish Treasury bond market by Díaz, Merrick, and Navarro (2006).

[4] 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.

paper.

II Data

Our study is based on German bond data. We focus on government bonds (BUNDSs) and Pfandbriefe which 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.[5] In contrast to US and UK secured mortgages, the underlying loans stay on the balance sheet of the mortgage bank.[6] There is no prepayment risk involved since the prepayment of a loan secured by a mortgage is excluded.

[5]There are several safeguarding mechanisms in place: (i) Banks must fulfill special requirements to obtain a licence for doing Pfandbrief business and they 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 is 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. See Mastroeni (2001).

[6]See Peterson (2008) for a description of the differences between Pfandbriefe and US and UK asset-backed securities.

Altogether, 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 identical 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, the Pfandbrief market is still much less liquid than the BUND market. The average issue size in the BUND market is more than forty times as large as in the Pfandbrief market and even for the Jumbo Pfandbrief segment which consists of the largest Pfandbriefe, the average issue size is only one quarter and the turnover ratio in the secondary market is less than half as high as in the BUND market.[7] Thus, Pfandbriefe are much less liquid than BUNDs and the Pfandbrief-BUND spread largely compensates for differences in liquidity.

We get term structure data from Deutsche Bundesbank. Monthly term structure estimates for the BUND market are available from January 1972 on. 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 May 2007, which excludes the period of the subprime crisis.[8]

To condense the term structure information we use the Nelson and Siegel (1987) approach. It allows us to characterize the entire term structure through

[7]See Mastroeni (2001) for estimates of the turnover ratio.

[8]We use a non-crisis sample since we believe that this period allows a better understanding of the general factors driving the term structure of illiquidity premia. We check for the robustness of our results during the crisis in Section IV.C.

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

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

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 as 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 minimizing the sum of squared yield differences over all selected maturities and both markets. This procedure leads to a mean absolute fitting error of 1.9 bp for the BUND market and 3.5 bp for the Pfandbrief market across the selected maturities. Fitting errors are higher at the very short end and the very long end of the term structure and somehow lower in the medium range. For the BUND market, we obtain mean absolute fitting errors of 4.2 bp, 1.8 bp and 2.6 bp for maturities of three months, five years and 15 years, respectively. For the Pfandbrief market, the corresponding fitting errors are 7.9 bp, 2.5 bp and 4.6 bp.

The estimation procedure delivers monthly parameter estimates for the BUND market (β_{0t}^{BU}, β_{1t}^{BU}, and β_{2t}^{BU}) and for the Pfandbrief market (β_{0t}^{PF}, β_{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. The short-term factor and the long-term factor of the Pfandbrief segment are always above the respective factors of the Government segment, indicating a positive illiquidity premium at the short end and the long end of the term structure of illiquidity premia. The shape factor of the Pfandbrief segment is below that of the BUND segment most of the time, leading to a reduction of the illiquidity premium for medium-term maturities.

III Dynamics of the Term Structure

Given the parameter estimates for the two market segments, the term structure of illiquidity premia is easily obtained. The parameters $Long_t \equiv \beta_{0t}^{PF}-\beta_{0t}^{BU}$, $Short_t \equiv \beta_{0t}^{PF}-\beta_{0t}^{BU}+\beta_{1t}^{PF}-\beta_{1t}^{BU}$, and $Shape_t \equiv \beta_{2t}^{PF}-\beta_{2t}^{BU}$ 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.

As a first indication of the level and slope of the term structure of illiquidity premia, we calculate the average premia of 1-year bonds and 15-years bonds over all months in the data period. The resulting premia are 29 bp and 40 bp respectively, which implies an average slope of 11 bp.

To get a more detailed view on the evolution of the term structure, we present the term structures for each month in Figure 2. The figure clearly indicates a strong variation in the level and in the form of the term structure.

[Insert Figure 2 about here]

We observe increasing term structures of illiquidity premia, decreasing ones, U-shaped curves, and occasionally hump-shaped ones. The illiquidity premia are positive at all times for all maturities, but the level varies greatly.

Illiquidity premia at the short and at the long end seem to vary over time in different ways. This phenomenon becomes more evident in Figure 3 which shows the development of the short-term premium ($Short_t$) and the long-term premium ($Long_t$).

[Insert Figure 3 about here]

Figure 3 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 to February 2006). In contrast, from February to December 2003 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 October 2002. The correlation between short-term and long-term illiquidity premia is very low (0.08) and not significantly different from zero.

In the following, we focus on the dynamic linkage between the short-term, long-term, and shape factor. There might be spillover effects, as documented by Goyenko, Subrahmanyam, and Ukhov (2008). For US government bonds, they show that liquidity shocks at the short end of the term structure are transmitted to medium-term and longer maturities in later periods. To investigate whether similar lead-lag effects exist for our illiquidity premia, we estimate an unrestricted VAR-model.

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

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

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

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.[9] The short-term premium is exclusively determined by past short-term premia and the long-term premium exclusively by past long-term premia. 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

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

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 only 2 bp over the following months.

IV Economic Drivers of the Term Structure

The descriptive empirical results derived thus far pose a challenge to existing theories. The term structures are hardly ever humped-shaped as predicted from the models of Longstaff (1995) and Koziol and Sauerbier (2007) nor are they always decreasing as implied by Ericsson's and Renault's (2006) stylized search market model. Therefore, we suggest a new stylized model which is flexible enough to capture the dynamics observed. It helps to understand why the term structures of illiquidity premia vary over time and why the short end and the long end behave so differently.

A Stylized Model

Consider a default-free pure discount bond paying one unit at maturity T. This bond is illiquid in the sense that trading the bond causes trading costs. The bond is held by risk-neutral investors who face random liquidity shocks, as in Ericsson and Renault (2006) or He and Xiong (2010). If a liquidity shock occurs at time t, the bond owner has to sell the bond and to pay the trading costs c_t. We assume that the trading costs are a constant fraction c of an otherwise identical but perfectly liquid bond $b^{liq}(t,T)$:

$$c_t = c\ b^{liq}(t,T) = c\ e^{-r(T-t)}, \tag{5}$$

where r denotes the risk-free interest rate. We take this assumption since we do not want to induce a specific term structure directly through bond-specific trading costs. Below, we will show that our assumption makes c a pure scaling parameter within our term structure of illiquidity premia.

After the trade, the new holder of the bond might also face a random liquidity shock which would force her to sell to yet another investor. Therefore, the current price $b^{ill}(0,T)$ reflects the expected total trading costs that current and future bondholders have to pay until maturity:

$$b^{ill}(0,T) = e^{-rT}(1 - E_0(C)). \tag{6}$$

$E_0(C)$ is the time T value of the total trading costs expected at time zero. To calculate $E_0(C)$, we assume that liquidity shocks can occur at discrete points in time $t = 1, 2, \ldots, T$. The probability for a shock at time t is denoted by q_t. The probabilities $q_t, t = 1, \ldots, T$, are random variables from the perspective of time zero, and the current probability q_0 is known. The time T value of the expected total trading costs is given as

$$E_0(C) = \sum_{t=1}^{T} e^{r(T-t)} c_t E_0(q_t) = c \sum_{t=1}^{T} E_0(q_t). \tag{7}$$

We assume that q_t follows a discrete-time first-order autoregressive process

$$(q_t - \bar{q}) = \alpha(q_{t-1} - \bar{q}) + \epsilon_t, \tag{8}$$

where $\bar{q}$ is the long-term mean and $1 > \alpha \geq 0$ denotes the corresponding mean-reversion parameter. ϵ_t is a zero-mean random variable. Given the process (8), the expected value of q_t is

$$E_0(q_t) = (1 - \alpha^t)\bar{q} + \alpha^t q_0, \tag{9}$$

and the time T value of the expected total trading costs results in

$$E_0(C) = c\left[\left(\sum_{t=1}^{T}(1 - \alpha^t)\right)\bar{q} + \left(\sum_{t=1}^{T}\alpha^t\right)q_0\right]. \tag{10}$$

Obviously, compared to an otherwise identical, but perfectly liquid bond, the price discount of the illiquid bond is $e^{-rT}E_0(C)$. The resulting return premium due to illiquidity, $premium(0,T)$, is the difference between the yield to maturities of the illiquid and the liquid bond:

$$\begin{aligned} premium(0,T) &= \frac{-ln(b^{ill}(0,T))}{T} - \frac{-ln(b^{liq}(0,T))}{T} \\ &= \frac{-ln(1-E_0(C))}{T} \\ &\approx \frac{E_0(C)}{T} \\ &= c\left[\left(\frac{1}{T}\sum_{t=1}^{T}(1-\alpha^t)\right)\bar{q} + \left(\frac{1}{T}\sum_{t=1}^{T}\alpha^t\right)q_0\right]. \end{aligned} \tag{11}$$

For different maturity dates T, equation (11) describes the term structure of illiquidity premia.

The trading costs parameter c is a pure scaling factor of the term structure reflecting the liquidity difference between liquid and illiquid bonds with identical maturity. Since c does not depend on time to maturity, the functional form of the term structure is not driven by maturity dependent liquidity differences between the markets. The functional form is solely determined by the maturity dependent liquidity demand of investors which is reflected in the bracket term in equation (11). For all maturities, the illiquidity premium is a weighted sum of the current probability q_0 of facing a liquidity shock and the long-term probability $\bar{q}$. The higher the probabilities of a shock, the more valuable liquidity and the higher the illiquidity premium is. The weights of the current (q_0) and the long-term probability ($\bar{q}$) depend on the bond maturity T.

At the long end of the term structure of illiquidity premia ($T \to \infty$), the premium converges to $c\,\bar{q}$, i.e., the long-term risk of facing a liquidity shock drives the long end of the term structure. In contrast, the short end ($T \to 0$) is solely determined by the current risk of facing a liquidity shock. The premium converges to $c\,q_0$ at the short end.

For the middle part of the term structure, the relation between time to maturity of a bond and the weight of the long-term risk depends on the mean reversion parameter α. The smaller α, the more quickly the probability that a shock occurs, q_t, reverts to the long-term probability $\bar{q}$ and, therefore, the more important the long-term probability is. If there is an immediate mean reversion ($\alpha = 0$), only the long-term probability matters and the illiquidity spread is $c\,\bar{q}$. In contrast, only the current probability matters if there is no mean reversion at all ($\alpha \rightarrow 1$). For $0 < \alpha < 1$ the long-term probability is more important the longer the maturity of a bond is. This property follows immediately from the fact that $\frac{1}{T}\sum_{t=1}^{T}\alpha^t$ is strictly decreasing in T. Thus, the term structure of illiquidity premia can be flat ($q_0 = \bar{q}$), strictly increasing ($q_0 < \bar{q}$), or strictly decreasing ($q_0 > \bar{q}$).

Summing up, our stylized demand based model offers a simple mechanism that explains why the term structure of liquidity premia varies over time and why the short and long end behave so differently. The short end is driven by the short-term risk of facing a liquidity shock, whereas a long-term risk of future trading needs determines the long end of the term structure. For the middle part of the term structure, the short- and the long-term risk matter, with the respective weights depending on the maturity of the bond. The longer (shorter) the maturity, the more important the long-(short-)term risk is.

B Empirical Results

In this section we empirically analyze economic factors driving the term structure of illiquidity premia. Our model provides assistance in selecting appropriate variables. The model makes two main predictions: (i) The long end of the term structure is determined by the long-term liquidation risk of the investor whereas the short end is driven by her current trading needs. (ii) The influence of long-term risk increases with the time to maturity of the bond whereas the influence of the short-term risk decreases.

We proxy the long-term liquidation risk of investors by their expectations about the future economic situation. The rationale is as follows: If the economic outlook deteriorates, it becomes more likely that the investor will get into financial difficulty in the future which might force her to sell her assets. We capture the economic outlook by the Ifo Business Climate index. This 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. The index consists of two parts, the first one concerning the firms' assessments of the current business situation and the second one concerning their expectations about the future situation. To stress the forward-looking aspect, we concentrate on the second component, the expectations index *Ifo Exp*, measuring how confident firms are regarding their future business situation. The index is widely accepted as a reliable leading indicator.

We use financial market volatility as our proxy for short-term trading needs. The basic economic idea is that in periods when there is a lot of information flowing into the market and, consequently, volatility is high, forced portfolio revisions become more likely. We take two measures of volatility as explanatory variables in our empirical model. The first one, *BondVola*, captures the volatility of the bond market. We use the daily yields of a 1-year government bond and take its standard deviation within a month as our measure *BondVola*. In addition, we include a measure of stock market volatility since there are trading strategies that involve stock and bond markets at the same time. Our proxy for stock market volatility, *StockVola*, 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.

In addition, we use a set of control variables which might have an impact on the illiquidity premia. A first variable controls for a changing liquidity difference between the BUND and the Pfandbrief market over time. We measure market liquidity by the volume of recently issued bonds.[10] Focussing on recently issued bonds is sensible since trading typically concentrates in on-the-run bonds as shown by Goldreich, Hanke, and Nath (2005) among others. To capture the liquidity difference between the two markets, we calculate 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. We call them $Ratio^{short}$, $Ratio^{medium}$, and $Ratio^{long}$, respectively. The data source is Deutsche Bundesbank.

Selling or buying pressure from abroad might influence the Pfandbrief-BUND spread since it might hit the two markets in different ways. To control for this possible effect, we use the net investment of foreign investors in the German bond market, *Foreign*, as an additional control variable. It is measured in trillions of Euros. We take data on net investments of foreign investors from the monthly financial market statistics of Deutsche Bundesbank.

Furthermore, we control for a possible convenience yield in the BUNDs.[11] At the short end, collateral borrowing rates are used. We proxy the short-term convenience yield ($CYield^{short}$) as the yield difference between the three-months overnight index swap rate (IOS) and the corresponding BUND yield. To measure medium- and long-term convenience yields we focus on bonds with cheapest-to-deliver status (CTD bonds) in the 5-Years Euro Bobl and 10-Years Euro Bunds Futures. We proxy the respective convenience yield ($CYield^{medium}, CYield^{long}$) as the average yield of the two bonds with maturities closest to the CTD maturity (one below, one above) minus the yield of

[10]For example, Krishnamurthy and Vissing-Jorgensen (2010) highlight the impact of the Treasury supply on yield spreads.

[11]Reasons for a convenience yield from holding government bonds are discussed e.g. in Feldhütter and Lando (2008).

the CTD bond.

We also control for credit risk. Although both, BUNDs and Pfandbriefe, are effectively free of default risk, 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 financial AA+/AA bond yields and the Bloomberg EUR Eurozone index of financial BBB bond yields as our proxy for credit risk.[12] This spread measure captures the dynamics of credit risk over time. At the short end we take a maturity of one year ($Credit^{short}$). In the middle part of the term structure we take values for five years ($Credit^{medium}$). Since there are no values available for ten years, we also take values for five years at the long end ($Credit^{long} = Credit^{medium}$). End of month values are used throughout.

Finally, we leave the lagged values of the illiquidity factors as control variables in our model to capture dynamic interactions. Since unreported results from unit roots tests provide no clear evidence about the stationarity of the factors, we could otherwise obtain spurious regression results.[13]

Table 2 provides summary statistics of our explanatory variables. Since the Bloomberg Eurozone financial indexes are not available before October 2001, our data period runs from October 2001 to May 2007.

[Insert Table 2 about here]

The daily yield volatility in the bond market is about 5.5 bp for a typical month, and the average annualized stock market volatility about 25 percent.

[12] 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.

[13] 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.

The economic outlook (*Ifo Exp*) is on average slightly below the neutral value of 100. The ratio of issue size shows that the issuer in the Pfandbrief market typically chooses short- to medium-term maturities whereas the Bund clearly dominates in the long-term maturities. The net investment of foreigners fluctuates around zero with a mean of 106 billion Euros net inflows. On average, our convenience yield proxies are close to zero for medium- and long-term bonds, but positive (4 bp) at the short end. The credit spreads vary remarkably during the research period. The average values are about 60 and 80 basis points, respectively.

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.

$$\begin{aligned} Short_t &= \gamma_0^s + \gamma_1^s BondVola_t + \gamma_2^s StockVola_t + \gamma_3^s IfoExp_t + \gamma_4^s Ratio_t^{short} \\ &\quad + \gamma_5^s Foreign_t + \gamma_6^s CYield_t^{short} + \gamma_7^s Credit_t^{short} \\ &\quad + \sum_{i=1}^{2} \left(\alpha_{i,s}^s Short_{t-i} + \alpha_{i,sh}^s Shape_{t-i} + \alpha_{i,l}^s Long_{t-i} \right) + \epsilon_t^s, \end{aligned} \tag{12}$$

$$\begin{aligned} Shape_t &= \gamma_0^{sh} + \gamma_1^{sh} BondVola_t + \gamma_2^{sh} StockVola_t + \gamma_3^{sh} IfoExp_t + \gamma_4^{sh} Ratio_t^{medium} \\ &\quad + \gamma_5^{sh} Foreign_t + \gamma_6^{sh} CYield_t^{medium} + \gamma_7^{sh} Credit_t^{medium} \\ &\quad + \sum_{i=1}^{2} \left(\alpha_{i,s}^{sh} Short_{t-i} + \alpha_{i,sh}^{sh} Shape_{t-i} + \alpha_{i,l}^{sh} Long_{t-i} \right) + \epsilon_t^{sh}, \end{aligned} \tag{13}$$

$$\begin{aligned} Long_t &= \gamma_0^l + \gamma_1^l BondVola_t + \gamma_2^l StockVola_t + \gamma_3^l IfoExp_t + \gamma_4^l Ratio_t^{long} \\ &\quad + \gamma_5^l Foreign_t + \gamma_6^l CYield_t^{long} + \gamma_7^l Credit_t^{long} \\ &\quad + \sum_{i=1}^{2} \left(\alpha_{i,s}^l Short_{t-i} + \alpha_{i,sh}^l Shape_{t-i} + \alpha_{i,l}^l Long_{t-i} \right) + \epsilon_t^l. \end{aligned} \tag{14}$$

Our regression results for the period from October 2001 to May 2007 are provided in Table 3.

[Insert Table 3 about here]

Table 3 shows that the illiquidity premia are mainly driven by the uncertainty the investor faces. The higher the uncertainty, the higher the illiquidity premia. However, different types of risk drive the different segments of the term structure. The short-term premium is driven by short-term trading needs as proxied by the volatility in the financial markets. In contrast, the long-term illiquidity premium is determined by the expectations about the future economic situation.

In the regression equation of the short-term premium, we see a positive and significant impact of the bond market volatility and the stock market volatility. Higher risks in the bond market and the stock market lead to higher illiquidity premia at the short end. 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 5 bp. This is about 15 percent 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 outlook) 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 almost 5 bp, about twelve percent of the average long-term premium.

When looking at the control variables, we see that the ratio of recently issued bonds is insignificant for all three factors. Possibly, market participants do not re-evaluate their notion of liquidity differences between BUND and Pfandbrief regularly over time but have a rather static view. In this case, differences in issue size show up only in the constants. In fact, the positive and significant constant at the long end of the term structure is consistent with a much higher issue size of long-term BUNDs compared to Pfandbriefe.

The net demand of foreign investors, the convenience yield variable and the credit variable are never significant. Therefore, we have no evidence that spreads between the Pfandbrief and the BUND market are driven by a convenience yield of the BUNDs, credit risk or buying or selling pressure of foreigners. Finally, lagged factors are significant at the short end of the term structure, which indicates the persistence of illiquidity premia over time.

Overall, our results suggest that different slopes of the term structure of the illiquidity premia reflect different regimes of short- and long-term liquidation risk. For example, if financial market volatility is low (leading to low short-term trading needs) and the economic outlook is bad (leading to high long-term trading risk), we would expect an upward sloping liquidity spread curve. Conversely, a downward sloping curve would result from high current volatility and a good economic outlook. Therefore, the findings thus far support the first main implication of our model.

We now turn to the second prediction of the model and analyze whether the impact of the short-term (long-term) liquidation risk on the illiquidity premium is the larger, the shorter (longer) the maturity of the bond is. We run regression models like equations (12) to (14) with maturity-specific illiquidity premia as dependent variables. Table 4 provides the corresponding results for maturities between one month and 15 years.

[Insert Table 4 about here]

The results suggest a smooth transition from short-term to medium- and long-term premia. Financial market 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. The results for the 1-month's premium and the 15-years' premium closely resemble the results for the short-term factor and the long-term factor. Thus, our empirical results also support the second main implication of the our stylized model.

C Robustness

In this section, we conduct robustness checks in which we use different input data and an extended research period including the financial crisis.

One objection could be that the Nelson-Siegel framework affects the empirical results through its smoothing effect. We check this issue by re-doing the analysis based on the yield spreads from the original Bundesbank data. More specifically, we pick three points on the BUND and the Pfandbrief yield curves, calculate 3-months, 5-years, and 15-years yield spreads, and run the VARX-model based on these yield spreads. The results are reported in Table 5.

[Insert Table 5 about here]

The results documented in Table 5 are very similar to those shown in Table 3: The short-term premium is driven by the volatility in the financial markets while the economic outlook as measured by the Ifo expectations index is significant when it comes to explaining the long-term illiquidity premium. Again, none of the control variables is significant. Lagged yield spreads are significant at the short end and at the long end of the term structure and, again, we find no spill-over effects from the short end to the long end. Thus, our main results are not affected by using the Nelson-Siegel framework.

As a second robustness check, we consider an extended data sample including 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. We re-estimate the VARX-model using data up to December 2010. The results are given in Table 6.

[Insert Table 6 about here]

Table 6 shows that the separation between short-term and long-term premia remains unchanged. Furthermore we find that the short end of the term structure is still driven by financial market volatility. However, only the bond market volatility remains significant. Two control variables are now significant at the short end: the net demand of foreign investors and the proxy for the convenience yield. Both effects are highly sensible. In crisis-periods, a flight-to-liquidity phenomenon is well documented which should lead to a strong buying pressure in BUNDs.[14] This is reflected in the positive impact of the convenience yield proxy and the net foreign investment.

Short-term volatility negatively affects the shape factor. Although not very intuitive at first sight, a reason might be that the term structure of illiquidity premia is strongly downward-sloping and convex during the crisis. Thus, times of high market uncertainty coincide with illiquidity premia for medium-term bonds that are below average (of short- and long-term premia) leading to the negative effect observed.

At the long end, only the lagged factor is highly significant, which indicates the persistence of premia over time. The Ifo expectations index has the same sign as before, but it is no longer significant at conventional levels.

Note that the results are strongly affected by extreme events during the crisis. If we take, for example, the extreme market situation of September 2008 out of the sample, all control variables become insignificant and the significant negative impact of volatility on the shape also vanishes. This highlights the impact of extreme events on the results and suggests that the pre-crisis period allows for a better understanding of the general factors driving the term structure of illiquidity premia.

V Conclusions

The German bond market offers a unique testing ground for liquidity studies: Essentially default-free bonds that only differ with respect to their liquidity are traded along the entire maturity spectrum. In this paper, we take advantage

[14]See e. g. Beber, Brand, and Kavajecz (2009).

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 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 empirical analysis of the dynamics of the term structure of illiquidity premia over time delivers several novel findings: The term structure of illiquidity premia is not constant over time - neither with respect to its level nor to its shape. We observe increasing term structures, but also flat or decreasing term structures resulting from a changing economic environment.The short end and the long end of the term structure of illiquidity premia are strictly separated, i.e., we find no significant correlation or spill-over effects. This result suggests that different economic factors drive different parts of the term structure. We propose a stylized theoretical model which is able to capture the dynamics of the term structure. In this model, the illiquidity premia are determined by trading needs of investors. The model predicts that the long end of the term structure is determined by the long-term liquidation risk of the investor whereas the short end is driven by her current trading needs. The influence of long-term risk increases with the time to maturity of the bond whereas the influence of the short-term risk decreases. The data provide strong support for both hypotheses: While the short end of the term structure of illiquidity premia is driven by short-term liquidation risk captured by asset market volatilities, the long end depends on the long-term economic outlook. The short-term liquidation risk becomes more important for the illiquidity premium the shorter the maturity of a bond is. Economic prospects, however, gain importance for bonds with longer maturities.

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

	$Short(t)$	$Shape(t)$	$Long(t)$
$Constant$	0.0597*	0.1640	0.0030
	(0.0341)	(0.1493)	(0.0565)
$Short(t-1)$	0.5963**	-0.8460*	0.2278
	(0.0991)	(0.4519)	(0.1440)
$Short(t-2)$	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)
$Long(t-1)$	0.0081	-0.0725	0.5647**
	(0.0947)	(0.3185)	(0.1276)
$Long(t-2)$	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 the VAR(2)-model as shown in equations (2) - (4) of the main text. $Long(t) \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU}$, $Short(t) \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU} + \beta_{1t}^{PF} - \beta_{1t}^{BU}$, and $Shape(t) \equiv \beta_{2t}^{PF} - \beta_{2t}^{BU}$ are the long-term factor, the short-term factor, and the shape factor of the term structure of illiquidity premia, respectively. The data period is January 2000 to May 2007 (87 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey 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
$BondVola$	0.0554	0.0229	0.0182	0.0508	0.1247
$StockVola$	24.50	11.51	12.32	19.85	60.03
$IfoExp$	97.40	4.63	87.90	97.25	105.40
$Ratio^{short}$	0.4995	0.2055	0.1695	0.4610	1.0000
$Ratio^{medium}$	0.5980	0.0473	0.5033	0.5673	0.7103
$Ratio^{long}$	0.1946	0.0596	0.0850	0.1874	0.3182
$Foreign$	0.0106	0.0112	-0.0152	0.0107	0.0323
$CYield^{short}$	0.0424	0.0552	-0.0935	0.0358	0.1570
$CYield^{medium}$	-0.0018	0.0195	-0.0415	-0.0045	0.0310
$CYield^{long}$	-0.0011	0.0205	-0.0475	-0.0035	0.1000
$Credit^{short}$	0.5943	0.4344	0.0760	0.5703	2.5663
$Credit^{medium}$	0.7904	0.5681	0.2308	0.5989	3.8584

This table shows summary statistics of potential drivers of illiquidity premia. *BondVola* captures the volatility of the bond market. It is calculated as the standard deviation of the daily yields (in percentage points) of a 1-year government bond within a month. *StockVola* is the end of month value of the VDAX-NEW, the benchmark volatility index of the German stock market. *Ifo Exp* is the value of the Ifo business expectations index. *Ratio* 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 short-term bonds (<2 years), medium-term bonds ($2-9$ years), and long-term bonds (≥ 9 years). *Foreign* is the net investment of foreign investors in the German bond market and measured in trillions of Euros. *CYield* refers to the convenience yield of government bonds. At the short end, it is captured by the yield difference between the three-months overnight index swap rate (IOS) and the corresponding BUND yield. In the medium- and long-term maturity range, we focus on bonds with cheapest-to-deliver status in the 5-Years Euro Bobl and 10-Years Euro Bunds Futures. We proxy the respective convenience yields as the average yield of the two bonds with nearest maturities (one below, one above the CTD) minus the yield of the cheapest-to-deliver bond. *Credit* is the spread between the Bloomberg EUR Eurozone index of financial AA+/AA bond yields and the Bloomberg EUR Eurozone index of financial BBB bond yields, measured in percentage points. The short-term spread refers to bonds with a time to maturity of one year. The medium-term spread refers to 5-years bonds. The data period is October 2001 to May 2007 (68 observations).

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

	$Short(t)$	$Shape(t)$	$Long(t)$
$Constant$	-0.3034	0.0271	1.2432*
	(0.4092)	(1.6550)	(0.5033)
$BondVola$	0.7693*	-1.5919	0.5662
	(0.3047)	(2.8184)	(0.6457)
$StockVola$	0.0025*	0.0057	-0.0015
	(0.0010)	(0.0066)	(0.0017)
$IfoExp$	0.0022	0.0049	-0.0101*
	(0.0035)	(0.0152)	(0.0043)
$Ratio$	-0.0571	-0.2667	0.0285
	(0.0563)	(1.2901)	(0.2502)
$Foreign$	-0.1163	-0.7714	0.1834
	(1.0475)	(3.9941)	(1.4540)
$CYield$	0.5587	-3.2519	-0.3054
	(0.3592)	(2.8735)	(0.6324)
$Credit$	0.0110	-0.0565	0.0035
	(0.0116)	(0.0928)	(0.0336)
$Short(t-1)$	0.5340**	-0.8936	-0.0134
	(0.1130)	(0.5804)	(0.1321)
$Short(t-2)$	0.1900	0.0675	-0.1301
	(0.0984)	(0.6399)	(0.1655)
$Shape(t-1)$	0.0502	0.0827	-0.0459
	(0.0276)	(0.1404)	(0.0463)
$Shape(t-2)$	0.0624	0.0219	-0.0338
	(0.0323)	(0.1551)	(0.0374)
$Long(t-1)$	0.1693	-0.3911	0.2202
	(0.1143)	(0.3785)	(0.1175)
$Long(t-2)$	0.1880	-0.9236	0.1257
	(0.1325)	(0.5321)	(0.1256)
R^2	0.79	0.30	0.45

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

This table shows the results for the VARX-model as shown in equations (12) - (14) of the main text. $Long(t) \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU}$, $Short(t) \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU} + \beta_{1t}^{PF} - \beta_{1t}^{BU}$, and $Shape(t) \equiv \beta_{2t}^{PF} - \beta_{2t}^{BU}$ are the long-term factor, the short-term factor, and the shape factor of the term structure of illiquidity premia, respectively. The exogenous variables are defined as in Table 2. The data period is October 2001 to May 2007 (68 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey and West's (1987) covariance matrix estimator with ten lags.

Table 4: Drivers of illiquidity premia for different maturities.

	1-month premium	3-months premium	6-months premium	1-year premium	5-years premium	10-years premium	15-years premium
Constant	-0.2867	-0.2526	-0.2000	-0.0920	0.8132	0.9804**	1.0678**
	(0.3827)	(0.3343)	(0.2727)	(0.1882)	(0.4390)	(0.2687)	(0.2786)
BondVola	0.6753*	0.5021	0.2760	-0.0733	0.1523	0.2743	0.3642
	(0.3036)	(0.3335)	(0.4180)	(0.5955)	(0.7276)	(0.6353)	(0.5767)
StockVola	0.0024*	0.0023*	0.0021*	0.0018	0.0015	0.0002	-0.0003
	(0.0010)	(0.0009)	(0.0009)	(0.0009)	(0.0012)	(0.0008)	(0.0008)
IfoExp	0.0022	0.0021	0.0019	0.0014	-0.0050	-0.0073**	-0.0082**
	(0.0033)	(0.0029)	(0.0023)	(0.0016)	(0.0035)	0.0028	(0.0027)
Ratio	-0.0328	0.0020	0.0475	0.1186	-0.1400	-0.0576	-0.0319
	(0.0551)	(0.0549)	(0.0585)	(0.0709)	(0.2843)	(0.1441)	(0.1654)
Foreign	0.1289	0.1520	0.1813	0.2243	0.0289	0.1323	0.1492
	(0.9758)	(0.8481)	(0.6942)	(0.5131)	(0.6268)	(0.6929)	(0.8924)
ConvYield	0.5608	0.5625	0.5596	0.5386*	-0.6758	-0.2158	-0.2434
	(0.3395)	(0.3046)	(0.2627)	(0.2112)	0.5707	(0.3989)	(0.4461)
Credit	0.0109	0.0107	0.0101	0.0087	-0.0092	-0.0133	-0.0082
	(0.0105)	(0.0095)	(0.0104)	(0.0152)	(0.0082)	(0.0090)	(0.0157)
R^2	0.80	0.81	0.79	0.68	0.12	0.24	0.38

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

This table shows the results of a regression model similar to equations (12) - (14). In contrast to equations (12) - (14), the endogenous variable is now the illiquidity premium for bonds of a fixed maturity. We look at illiquidity premia for maturities between one month and fifteen years. The exogenous variables are defined as in Table 2. We use the ratio based on short-term bonds ($<$ 2 years) as an explanatory variable for the 1-month, 3-months, 6-months, and 1-year premia, the ratio based on medium-term bonds ($2-9$ years) for the 5-year premia, and the ratio based on long-term bonds ($\geq$ 9 years) for the 10-years and 15-years premia. Similarly, we use the short-term convenience yield and credit variables for the 1-month, 3-months, 6-months and 1-year premia. The medium-term convenience yield and credit variables are used for the maturity of five years and the long-term convenience yield variable for the 10-years and 15-years maturity. Because of the lack of a long-term credit variable, the medium-term variable is also used for the 10-years and 15-years premia. In addition, we include two lagged values of each illiquidity factor. Coefficients of the lagged illiquidity factors are not reported. The data period is October 2001 to May 2007 (68 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey and West's (1987) covariance matrix estimator with ten lags.

Table 5: Robustness check: VARX-model estimated with yield spreads from the original data.

	$Short(t)$	$Medium(t)$	$Long(t)$
$Constant$	0.3810	1.1139*	1.1368*
	(0.5559)	(0.5315)	(0.5129)
$BondVola$	1.2163*	0.2315	0.3117
	(0.4869)	(0.7075)	(0.5969)
$StockVola$	0.0015	0.0003	-0.0017
	(0.0011)	(0.0010)	(0.0010)
$IfoExp$	-0.0035	-0.0077	-0.0090*
	(0.0049)	(0.0040)	(0.0044)
$Ratio$	0.0131	-0.0712	-0.1151
	(0.0728)	(0.3544)	(0.2244)
$Foreign$	-0.7795	0.0124	0.8951
	(1.3459)	(0.7037)	(1.1951)
$ConvYield$	0.1898	-0.7879	-0.1709
	(0.3887)	(0.5351)	(0.4145)
$Credit$	0.0132	-0.0065	0.0117
	(0.0145)	(0.0072)	(0.0118)
$Short(t-1)$	0.5073**	0.0675	0.1252
	(0.0969)	(0.1053)	(0.1012)
$Short(t-2)$	0.1174	-0.0679	-0.0946
	(0.1109)	(0.1539)	(0.0992)
$Medium(t-1)$	0.0525	0.0224	-0.3846**
	(0.1013)	(0.1058)	(0.1405)
$Medium(t-2)$	0.1404	0.1053	-0.1028
	(0.1101)	(0.1606)	(0.1264)
$Long(t-1)$	-0.0181	-0.0152	0.5810**
	(0.1519)	(0.1241)	(0.0848)
$Long(t-2)$	-0.1664	-0.3489**	0.0811
	(0.1282)	(0.1206)	(0.1164)
R^2	0.84	0.22	0.52

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

This table shows the results for a VARX-model similar to the one shown in equations (12) - (14) of the main text. $Short(t)$ refers to the 3-months yield spread, $Medium(t)$ to the 5-years yield spread and $Long(t)$ to the 15-years yield spread. The exogenous variables are defined as in Table 2. The data period is October 2001 to May 2007. However, the data points which refer to June 2004 and December 2005 are excluded because of data errors. Therefore, the results are obtained from 62 usable observations. Standard errors of the coefficients are given in parentheses. They are based on Newey and West's (1987) covariance matrix estimator with ten lags.

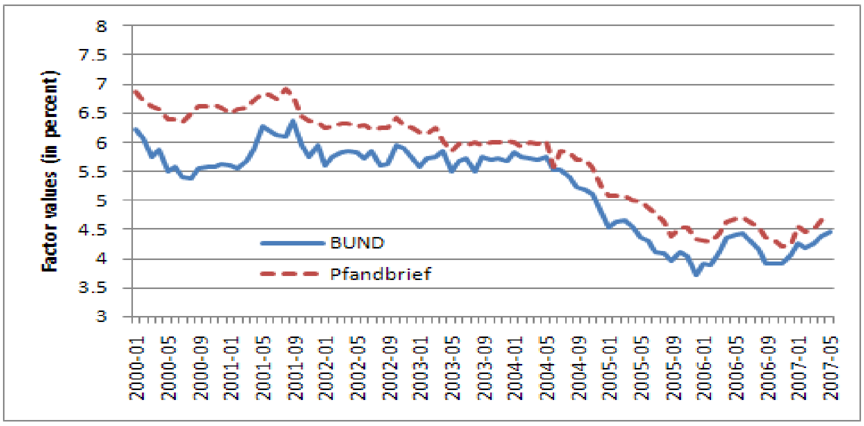
Table 6: Robustness check: VARX-model for an extended data sample including the financial crisis.

	$Short(t)$	$Shape(t)$	$Long(t)$
$Constant$	0.5210	-0.1787	-0.2976
	(0.3162)	(1.7917)	(0.7473)
$BondVola$	1.5691*	-8.8819*	0.3376
	(0.6448)	(4.2307)	(0.4183)
$StockVola$	-0.0013	0.0061	0.0002
	(0.0021)	(0.0061)	(0.0017)
$IfoExp$	-0.0047	0.0046	0.0036
	(0.0030)	(0.0162)	(0.0068)
$Ratio$	0.0796	-0.6136	0.1402
	(0.0868)	(0.7256)	(0.2741)
$Foreign$	1.8218**	1.3414	0.0711
	(0.6394)	(3.3660)	(0.9862)
$ConvYield$	1.2963**	0.1907	-1.1660
	(0.0765)	(1.9173)	(0.6924)
$Credit$	-0.1036	-0.0742	0.0357
	(0.0615)	(0.1092)	(0.0490)
$Short(t-1)$	0.6362**	0.1472	-0.0959
	(0.0659)	(0.3932)	(0.0693)
$Short(t-2)$	0.0261*	0.4281	0.1198
	(0.0579)	(0.2255)	(0.0613)
$Shape(t-1)$	0.0999**	0.2837**	-0.0023
	(0.0332)	(0.0915)	(0.0308)
$Shape(t-2)$	0.0152	0.1198	0.0247
	(0.0341)	(0.0931)	(0.0281)
$Long(t-1)$	0.0188	-0.4354	0.5178**
	(0.1111)	(0.4231)	(0.1114)
$Long(t-2)$	0.0853	0.2870	0.1556
	(0.1313)	(0.4488)	(0.1246)
R^2	0.95	0.43	0.43

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

This table shows the results for the VARX-model as shown in equations (12) - (14) of the main text. $Long(t) \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU}$, $Short(t) \equiv \beta_{0t}^{PF} - \beta_{0t}^{BU} + \beta_{1t}^{PF} - \beta_{1t}^{BU}$, and $Shape(t) \equiv \beta_{2t}^{PF} - \beta_{2t}^{BU}$ are the long-term factor, the short-term factor, and the shape factor of the term structure of illiquidity premia, respectively. The exogenous variables are defined as in Table 2. The data period is an extended one that reaches from October 2001 to December 2010 (111 observations). Standard errors of the coefficients are given in parentheses. They are based on Newey and West's (1987) covariance matrix estimator with ten lags.

Part A: Long-term factors



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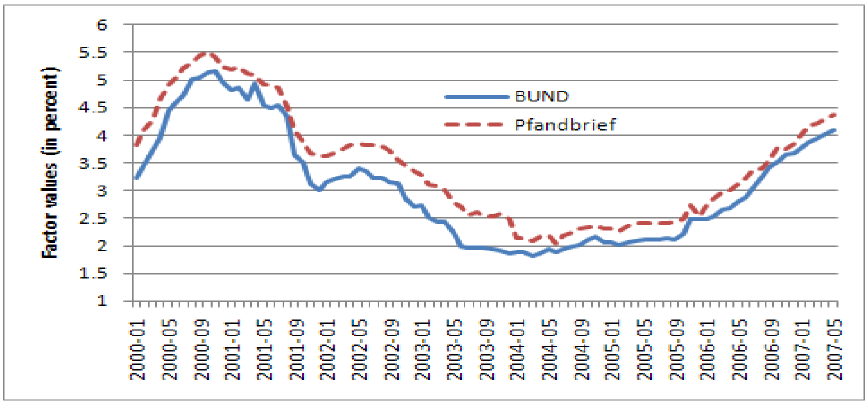

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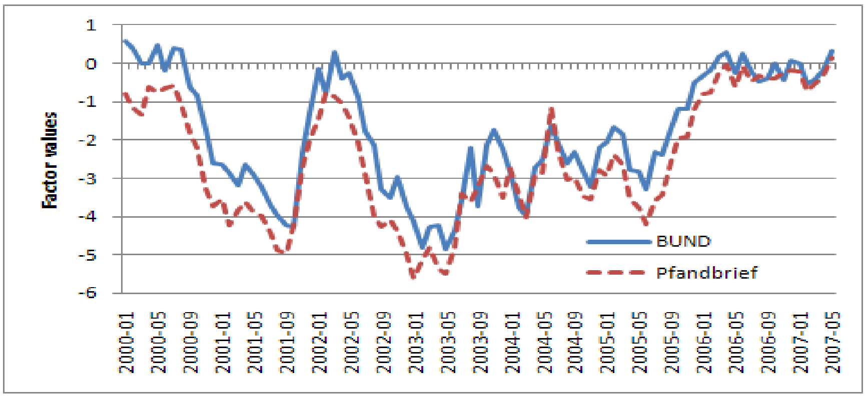

Figure 1: Term structure factors.

This figure shows the development of the term structure factors over time. The solid lines depict the factors for the BUND market and the dashed lines the factors for the Pfandbrief market. Part A provides the estimates of the long-term factors (β_{0t}), Part B the ones for the short-term factors ($\beta_{0t} + \beta_{1t}$) and Part C the ones for the shape factors (β_{2t}). Estimation was carried out by minimizing the sum of squared yield differences according to equation (1) for 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. The data period is January 2000 to May 2007.

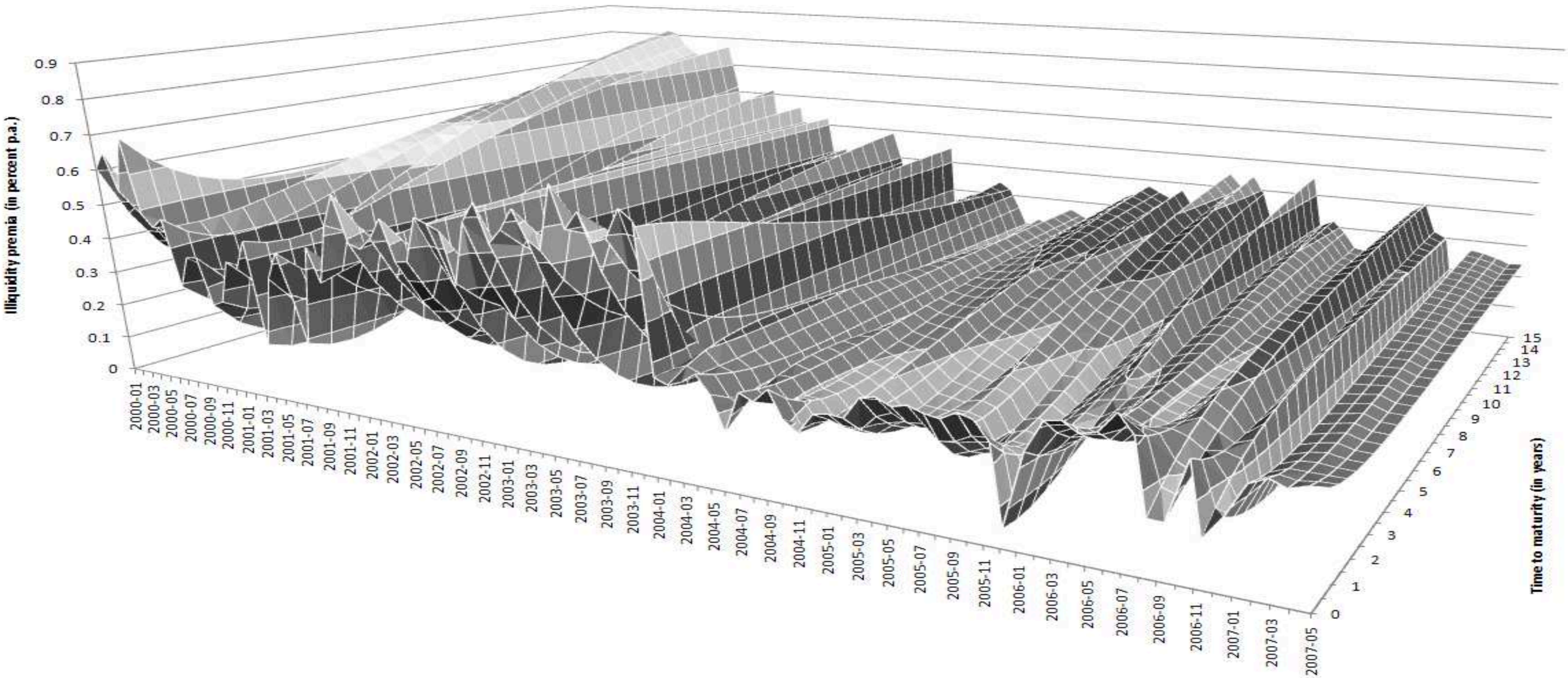

Figure 2: Term structures of illiquidity premia.

This figure shows the development of the term structure of illiquidity premia over time. The illiquidity premium for a particular maturity is calculated as the difference between the corresponding yields of Pfandbriefe and BUNDs, as obtained from the Nelson-Siegel curves. These curves use a common parameter value of $\tau = 2.017$, which is the least squares estimate. Maturities of up to 15 years are considered. The data period is January 2000 to May 2007.

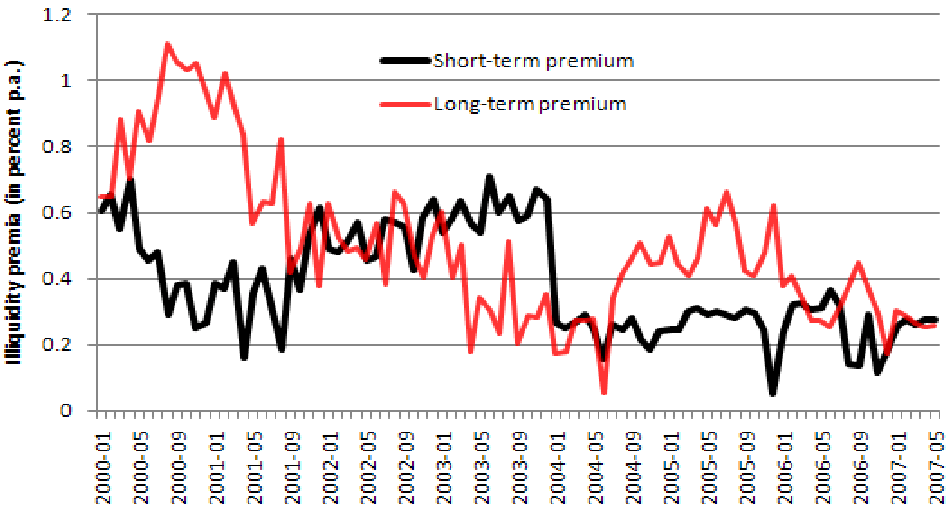

Figure 3: Short-term and long-term illiquidity premia.

This figure shows the development of the short-term and the long-term illiquidity premia over time. The dark line depicts the short-term illiquidity premium, which equals the difference between the short-term factors for the Pfandbrief market and the BUND market ($\beta_{0t}^{PF} - \beta_{0t}^{BU} + \beta_{1t}^{PF} - \beta_{1t}^{BU}$). The light line provides the long-term illiquidity premium, which equals the difference between the long-term factors for the two markets ($\beta_{0t}^{PF} - \beta_{0t}^{BU}$). The data period is January 2000 to May 2007.

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