Measuring the Liquidity Impact on EMU Government Bond Prices

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Abstract

It is the aim of this paper to measure the impact of liquidity on European Monetary Union (EMU) government bond prices. Although there is a growing theoretical and empirical literature on liquidity effects in fixed income markets there is no clear answer how to measure liquidity and whether liquidity is priced in the market at all. Our empirical analysis is based on an unique data set containing individual bond data from six major EMU government bond markets allowing us to compare yield curves estimated for subportfolios which are formed with respect to different potential liquidity measures. In a second procedure liquidity measures are collected on the single bond level and estimated pricing errors given some reference yield curve are regressed against these liquidity variables. This enables us to conduct formal tests on the pricing impact of liquidity measures. The results indicate that the benchmark property and the number of contributors are the most promising liquidity proxies which have significant results in most countries. The results do not support the hypothesis that other liquidity measures under consideration like the on-the-run property, the issue size, and bid-ask spread related measures have a persistent price impact. A cross-country analysis on the subportfolio level indicates that liquidity effects cannot explain the size of the yield spreads between different issuers. This implies that other effects than liquidity like credit risk are important driving factors of cross-country yield spreads.

JEL: C23, G15

1 Introduction

It is the aim of this paper to measure the impact of liquidity on European Monetary Union (EMU) government bond prices. Although there is a growing theoretical and empirical literature on liquidity effects in fixed income markets there is no clear answer to several important questions. First of all, there is no unequivocal definition of liquidity across different models and empirical studies. As a consequence different authors use different measures or proxies of liquidity. Secondly, there are competing models which yield different implications regarding the price impact of liquidity on fixed income instruments. Moreover, even the elementary question whether liquidity risk is priced in the market at all has no clear-cut answer. There are numerous empirical studies which examine different market segments and use different liquidity measures providing mixed evidence concerning the price impact of liquidity. However, all empirical studies face an obvious joint hypotheses problem which additionally complicates the interpretation of the results.

This is to our knowledge the first study which focuses on the potential liquidity effects on EMU government bond prices. Government securities are seen as nearly default-free and thus form a segment of nearly perfect substitutes enabling to control for all other risk factors than liquidity. In addition to that, the use of EMU market data allows the comparison of liquidity effects on a national submarket level. Since observed yield spreads between different EMU government issuers tend to be remarkably high even after the formation of the EMU in 1999, there is an ongoing discussion among practitioners and academics whether these spreads are due to liquidity or default risk. This paper contributes to this discussion by examining the potential liquidity impact on a submarket level and comparing the results to the observed inter-issuer spreads which helps to disentangle potential default risk and liquidity effects.

Our empirical analysis is based on an unique data set containing individual bond data from six major EMU government bond markets for the period between 01/1999 to 03/2001. To measure the liquidity impact on EMU government bond prices we employ two different procedures. In the first procedure national submarkets are grouped by several liquidity variables comprising nearly all liquidity proxies suggested previously given the availability of the relevant data. For all liquidity based subportfolios discount functions and zero-coupon yield curves are estimated. The comparison of the estimated yield curves gives a first insight into the existence of potential price effects. In the second procedure liquidity measures are collected on the single bond level and estimated pricing errors given some reference yield curve are regressed against these variables. This enables us to conduct formal tests on the pricing impact of liquidity measures.

Besides general theoretical interest on pricing and hedging in incomplete markets and valuation of illiquid securities the results of this study have additional important practical implications. Above all, in the case of a significant and volatile liquidity effect all risk factors driving liquidity could be identified and integrated into a market risk management system. In addition to that, many liquidity measures like original maturity and issue size are under the control of the issuers. If some of these factors turned out to be priced by the market then issuers would seriously have to reconsider their future issue policy.

The remainder of the paper is organized as follows. Section 2 provides a discussion about the definition of liquidity, the most important theoretical implications, the possible measures and proxies of liquidity, and a comprehensive overview over previous empirical studies in this field. Section 3 contains the results of our empirical analysis and section 4 concludes the paper.

2 The Liquidity Impact on Government Bond Prices

2.1 What is liquidity?

Many market participants and academics have a general sense of what liquidity means. However, it is often difficult to define exactly what is meant when a security or a market is referred to as being liquid or illiquid. An additional difficulty arises when an operable definition is needed which is expected to rely on observable quantities rather than on feelings or market sentiments. In a big part of the academic literature liquidity is defined in terms of some kind of transaction costs like the bid-ask spread. This “transaction costs” approach is mainly concerned about inventory risk which will be priced by market participants, e.g. in the form of higher bid-ask spreads. General models which are usually more focused on the equity market like Glosten and Milgrom (1985), Amihud and Mendelson (1986), and Vayanos and Vila (1999) are based on this notion of liquidity as well as models which concentrate on fixed income markets like Amihud and Mendelson (1991) and Kempf and Uhrig-Homburg (2000). A related stream of literature, eg. Grinblatt (1995), Duffie (1996), and Buraschi and Menini (2001) deals with specific features of the repo market which induce an additional interest income on “special” bonds implying higher equilibrium yields on other bonds.

A second part of the academic literature defines liquidity in the spirit of “immediacy”, that is the possibility to execute a trade of any desired size at the desired (market) price in immediate time. This definition goes back to Grossmann and Miller (1988) and several studies in the fixed income markets like Kamara (1994), Ericsson and Renault (2000), Ye (2001), and Janosi, Jarrow and Yildirim (2001) refer to this notion. Along the lines of Hasbrouck (1991) some authors refer to the price impact of a potential trade like Dufour and Engle (2000) or to an agent’s market power like Dimson and Hanke (2001) as definitions of liquidity. In a recent study, Longstaff (2001) defines liquidity in agreement with the transaction costs approach whereas he defines illiquidity in relation to the immediacy approach.

Interestingly, many authors like Warga (1992), Crabbe and Turner (1995), Elton and Green (1998), and more recently Subramanian (2001) do not provide explicit definitions of liquidity but rely implicitly on some definitions by taking specific liquidity measures like size, trading activity, or volume as given. It has to be noted that in many cases the availability of data rather than theoretical considerations is the major driving force behind the choice of the liquidity measures. We will refer to these implicit definitions as empirical notions of liquidity.

Recent work by several authors explicitly recognizes the difficulties in defining liquidity. Some studies, eg. Dimson and Hanke (2001) and Strebulaev (2001), make use of a broader definition which relies on a combination of the transactions cost based and the immediacy based definitions. Jarrow (2001) provides a very general theoretical model which comprises most of the previous notions of liquidity.

2.2 Implications of Liquidity

Although above virtually all of the academic literature stands the paradigm that illiquid securities require a higher yield than liquid ones, a closer look at the implications of liquidity on the prices of government securities seems to be valuable. As shown by Amihud and Mendelson (1991), in the absence of credit risk the expected liquidity premium (under the transaction costs definition) is decreasing with the maturity of the investment. In the presence of credit risk (eg in the swap market) the relation is more complicated as shown eg by Duffie and Singleton (1997) and Ye (2001). In a very general setting Vayanos and Vila (1999) show that agents buy the liquid assets for short-term investments and the illiquid for long-term investments indicating that the required liquidity premium depends on the subjective planning horizon of an agent. In terms of fixed income market practice this means that some investors (eg short-term traders) require a liquidity premium for a specific 10-year government bond which is less liquid compared to an other comparable issue while some other investors (eg pension fund managers) do not require a premium since they do not want to trade the bond until its maturity (note, that this strategy is nearly free of transaction costs and there are no “immediacy costs” of execution). The equilibrium liquidity premium is thus expected to depend on the ratio of short-term over long-term demand in the market and is not determined a priori.

The final answer to the question if liquidity risk in any of its various definitions is priced by the market can only be given empirically. Interestingly, earlier empirical studies, eg Amihud and Mendelson (1991) and Warga (1992), find strong evidence for the existence of a significant liquidity premium. This is probably the reason why the existence of a liquidity premium was taken as given by some of the subsequent studies. Since more recent research, eg Strebulaev (2001), shows that many of the results of earlier studies were due to other effects than liquidity like market segmentation, a conclusive empirical evidence regarding the existence and the size of the liquidity premium is still outstanding.

2.3 Liquidity Measures and Proxies

In previous studies a variety of different liquidity measures and proxies has been used. In many cases the availability of data was the major driving force behind the choice of the variables. This is mainly due to the fact that in most markets the largest portion of trading activity takes place over-the-counter (OTC) and not on exchanges. Naturally, in contrast to exchanges on OTC markets some potential liquidity proxies like volume, turnover-size, number of trades, and effective bid-ask spread are not directly observable. Some authors rely on survey data or on data provided by a single market participant. In general, many studies use proxies which are observable in principle but in many markets there is a lack of academic databases containing the OTC-market structure and usually data vendors do not make these data available on a historical basis.

The most popular liquidity measures used in the academic literature are the quoted bid-ask spread, the issue size, the “on-the-run”, and “specialness” feature, the trading frequency, and the trading volume. Quoted bid-ask spreads are used as a liquidity measure by Amihud and Mendelson (1991), Dimson and Hanke (2001), and Strebulaev (2001). The size of an issue is taken as a liquidity proxy by Warga (1992), Crabbe and Turner (1995), and Kempf and Uhrig-Homburg (2000). The on-the-run feature is used by Warga (1992), Elton and Green (1998), Strebulaev (2001), and Babbel et al. (2001) and the specialness feature of an issue is used by Grinblatt (1994), Duffie (1996), Jordan and Jordan (1997), and Buraschi and Menini (2001). Trading frequency measured by the number of trades or the number of quotes is used by Dufour and Engle (2000), Strebulaev (2001), and Subramanian (2001). Trading volume or turnover is used by Elton and Green (1998), Chakravarty and Sarkar (1999), Ericsson and Renault (2000), Alexander et al. (2000), Subramanian (2001), and Strebulaev (2001).

As pointed out by many authors the age or vintage of an issue is closely related to most of the commonly used liquidity proxies. Warga (1992) Ericsson and Renault (2000) and Chakravarty and Sarkar (1999) use the age of an issue directly whereas Kempf and Uhrig-Homburg (2000) adjust their liquidity measure (which is size) for vintage effects.

More complicated measures which are often combinations of several observable variables are employed by Kamara (1994) who uses a model based immediacy ratio which in fact depends mainly on turnover and by Janosi, Jarrow and Yildirim (2001) who derive a model where corporate bond liquidity is measured by an affine function of spot rate, equity volatility, and market index return.

There are two additional natural candidates for liquidity proxies which are often cited by practitioners but are rarely used by academics most probably due to the lack of data. Firstly, it is often stated that benchmark bonds (bonds where the current market activity is displayed by data vendors on sites which are easily accessible and typically intensively watched by far more market participants like other bonds) are more liquid than other issues. Only the study by Boudoukh and Whitelaw (1991) examines this effect for the Japanese market. However, in the US Treasury market the benchmark property is very closely related to the on-the-run property. Secondly, it might be natural to think about the number of active contributors in an OTC quotation system as a good liquidity proxy. Dimson and Hanke (2001) refer to a small number of contributors as a sign of a dealer’s market power and thus as a measure of liquidity but to our knowledge no academic study used the number of contributors as an explicit liquidity proxy. Furthermore the on-the-run property has been mainly used by US studies but has not been used so far for the European government bond market.

Along the lines of Strebulaev (2001) this paper is aimed to cover a wide variety of potential liquidity proxies. This is justified by the mixed picture of previous research and by the fact that the use of virtually all imaginable liquidity measures might help to overcome the joint hypotheses problem inherent in all empirical studies. If there was no price impact for any of these measures then one would conclude that liquidity is not priced by the market independent of the way how it is measured. The explicit use of the number of contributors and the benchmark feature should additionally contribute to the existing literature in this field.

2.4 Previous Empirical Results

The results of previous empirical studies yield a completely mixed picture. Earlier studies provide results which confirm the existence of a liquidity premium with respect to different measures. Amihud and Mendelson (1991) find a 43 basis points higher annual yield on Treasury notes compared to Treasury bills. Warga (1992) and Duffie (1996) report similar results after having selected on-the-run issues and special issues, respectively. Kempf and Uhrig-Homburg (2000) observe a 40 basis point price difference between small and big issues in their 1992-1994 German government bond market data set whereas Crabbe and Turner (1995) found out that size has no impact on their 1987-1992 US Treasury note and corporate bond sample. Kamara (1994) showed that the liquidity proxy derived by his model which is mainly based on a turnover ratio between bills and notes has a significant price impact. Finally, Boudoukh and Whitelaw (1991) report significant benchmark effects in the Japanese government bond market.

More recent research, however, improved these studies by controlling for market segmentation effects since many studies have simply compared yields of Treasury bills and notes and did not perform intra-market comparisons. Controlling for this effect Elton and Green (1998) could not confirm the previous results using their 1991-1995 US data set. They found nearly no liquidity effect except a weak volume related effect for bonds with longer maturities. In a very comprehensive study Strebulaev (2001) rejected the hypothesis that liquidity risk is priced by the market for all available liquidity proxies (bid-ask spread, turnover, number of quotes, number of trades, trading volume) using a 1995-1997 US data set. Finally, Dimson and Hanke (2001) report that whereas bid-ask spreads do not have any price impact in their UK index-linked bond sample an increasing dealer's market power induces increasing yields.

2.5 Liquidity Hypotheses

Hypothesis 1: Size has a positive price impact.

The issue size has already been used by a number of authors e.g. Warga (1992), Kempf and Uhrig-Homburg (2000), Alexander et al. (2000), as a proxy for liquidity. The motivation for using the issue size as a measure for liquidity is that dealers can more easily manage their inventory in larger issues. Holding a small portion of a large issue could still meet the cash flow needs in absolute terms of the investor and still allowing to get rid off this relatively smaller portion in the market.

This leads to the hypothesis, that larger issues are more liquid than smaller issues and (based on the joint hypothesis that liquidity has a price impact) should have a higher price in order to account for the liquidity premium.

Hypothesis 2: The number of contributors has a positive price impact.

The number of contributors per bond was not used as a measure of liquidity in previous studies. A bond that is quoted by a larger number of contributors allows market participants to have a wider selection of possible counterparties for either buying or selling a bond. This enables the seller or buyer of a bond to split up a large position into smaller portions without influencing the market price.

With respect to this, bonds with a high number of contributors should be more liquid than bonds with a small number of contributors and should have a higher price (based on the joint hypothesis that liquidity has a price impact).

Hypothesis 3: The quoted bid-ask has a negative price impact.

This classical measure for liquidity is used by numerous academics e.g. Amihud and Mendelson (1991), Chakravarty and Sarkar (1999), Strebulaev (2001) measuring the liquidity effect. Illiquid bonds imply a higher bid-ask spread due to higher inventory costs. Market makers are reluctant in bearing these costs and try to pass on these inventory costs by charging a higher bid-ask spread.

Bonds with a smaller bid-ask spread are more liquid and will therefore have a higher price imposing a liquidity premium (based on the joint hypothesis that liquidity has a price impact).

Hypothesis 4: The distance between maximum ask and minimum bid quote has a negative price impact.

The distance between maximum ask and minimum bid quote across all contributors was not used as a liquidity measure in previous studies. This proxy indicates the market depth (and also market width to some extent) and informs market participants about the maximum potential transaction costs to be accepted for either selling or buying a large portion of a bond that can not be satisfied by a single contributor. This variable sets the upper limit for the observed bid-ask spreads.

Bonds with a smaller distance are assumed to be more liquid since they enable the holder of the bond to sell the bond with low transaction costs (based on the joint hypothesis that liquidity has a price impact).

Hypothesis 5: The benchmark property has a positive price impact.

The benchmark property has a binary characteristic which means, that a bond is classified as a benchmark bond or not. Data vendors like Reuters or Bloomberg offer the information whether a bond is classified as a benchmark bond. Usually, when selecting a particular bond to be a benchmark bond data vendors rely on information gathered from major custodians or on a survey among market makers. Benchmark bonds cover particular maturity buckets and allow market participants to use these bonds (where information is easily accessible) for yield curve estimation.

We raise the hypothesis that benchmark bonds are more liquid than non benchmark bonds and should therefore have a higher price (based on the joint hypothesis that liquidity has a price impact).

Hypothesis 6: The on-the-run property has a positive price impact.

The on-the-run property (the most recently issued bond for a given maturity bucket) has already been used by a number of authors e.g. Warga (1992), Duffie (1996), Elton and Green (1998). Strebulaev (2001) and Babbel et al (2001), as a proxy for liquidity. Prices of on-the-run bonds are more closely related to the primary market and might thus show particular liquidity effects. The on-the-run property is closely related to the specialness feature (a bond is said to be "on special" if its repo rate is quoted remarkably lower than the repo rate for comparable bonds). Since we do not have access to individual repo rate data on a historical basis we use the on-the-run feature as a substitute for this effect. In this study a bond is classified as on-the-run bond for the first month since issuance and will be classified as off-the-run bond after the first month.

We raise the hypothesis that on-the-run bonds are more liquid than off-the-run bonds and should therefore have a higher price (based on the joint hypothesis that liquidity has a price impact).

3 Empirical Analysis

3.1 Data

The time series data used in this study include daily prices of EMU government bonds from the period 01/1999 to 03/2001. We restrict our analysis to coupon bonds without any option features with reliable price information and a time to maturity shorter than ten years. The data set includes basic features, e.g. issue date, issue size, maturity, the exact cashflow schedule, history of bid and ask closing prices, and the information on which days a bond was classified as benchmark bond. For a detailed description of this data set refer to Jankowitsch and Pichler (2002). In order to provide meaningful results we make use only of data collected from six national submarkets, i.e. Germany, France, Italy, Spain, The Netherlands, and Austria.

For the purpose of calculating the different liquidity proxies derived from market microstructure information we analyse nine 'snapshots' from the EMU government bond market in August 2001 based on the identification codes of the bonds included in the time-series data set. The inquiry of the data was done on different days-of-the-week in order to avoid possible day-of-the-week-effects. We downloaded the data from Reuters always around 12:00 a.m.

controlling for possible intra-day effects. The data comprises 3,740 records on a contributor level including the quoted bid and ask price, the time stamp of the quotation, the date of the quotation, and the name of the contributor for one ‘snapshot’. All double entries of a contributor for a particular bond with the same timestamp of the quotation and the same bid-ask price were excluded to avoid double counting. Furthermore, all quotations, where the quotation date was older than the query date were deleted. Finally, only double sided quotations, where bid and ask prices per contributor are greater than zero, were included in the data set, which comprehends 33,668 quotations for nine snapshots.

Though this data set is unique with respect to the countries and variables included offering a great opportunity for research it is important to realise possible weaknesses of this data set. First, we do not have access to any volume-related information about the quotations of the contributors since we are using OTC data. Second, the data set only contains quotation prices and not the actual trade price. The quoted price may only hold for a relatively small quantity, whereas traders demanding higher quantities cannot in advance determine the actual price for the entire quantity they wish to trade. Practitioners use these quotations in their daily work and the quotes are regarded by market participants to be good for a certain size, typically EUR 10 million. Dimson and Hanke (2001), however, found in their study that most of the transactions are taking place within the quoted bid-ask spread. Third, the period of the OTC data, August 2001, does not coincide with the time-series data (January 1999 to March 2001). Especially for the number of contributors this seems to have only a small impact since this variable seems to be quite stable over the respective time.

The characteristics of the 237 bond issues in the sample for the six different EMU countries are summarized in table 1. The issue size for the included countries is remarkable, averaging from about EUR 2 bn for Austria to about EUR 14.6 bn for France. Germany has the highest average number of contributors with 16.11 in contrast to Italy, which has only 6.52 contributors on average. The average bid-ask spread for Austria (10.74 basis points) is almost twice as high as for Germany (5.82 basis points).

3.2 Methodology

In the first stage of our analysis we use several potential liquidity proxies as grouping variables to form liquidity based subportfolios. The median value of a certain liquidity proxy is used as a cut-off to divide the bond portfolio of a particular country in two subportfolios one consisting of bonds above and one consisting of bonds below the median of this proxy. Based on this grouping procedure we estimate zero coupon yield curves for all subportfolios which allows us to compare the ‘aggregate price level’ across the subportfolios, and more specifically, to calculate a term structure of liquidity spreads with respect to each grouping variable.

In order to explicitly derive the liquidity proxies used as grouping variables some calculations on a contributor and bond level are performed. In a first step we compute the normalized bid-ask spread on a contributor level which will be the source for further spread related calculations.

The bid-ask spread (measured in basis points) of bond i of contributor j on date t is given by

$$\text{Spread}_{\text{ijt}} = \left(\frac{\left(Ask_{ijt} - Bid_{ijt}\right)}{\left(\text{Bid}_{\text{ijt}} + \text{Ask}_{\text{ijt}}\right) \cdot 0.5} \right) \cdot 10{,}000$$

where i = 1, … , I_t and j = 1, … , N_{it}. I_t denotes the number of bonds observed at time t and N_{it} denotes the number of contributors of bond i at time t.

On a first consolidation level but still on a daily basis we determine the number of contributors, the minimum bid-ask spread which is only used for descriptive purposes, the average bid-ask spread and the distance between maximum ask and minimum bid quote (in the following referred to as distance) on a bond level.

The average bid-ask spread (in bp) per bond i on date t is defined as

$$\text{AverageSpread}_{\text{it}} = \frac{\sum_{j=1}^{N_{it}} \text{Spread}_{\text{ijt}}}{\text{N}_{\text{it}}}$$

The minimum bid-ask spread (in bp) per bond i on date t is given by

$$\text{Minimum spread}_{\text{it}} = \min_j (Spread_{ijt})$$

The distance (in bp) per bond i on date t is defined as

$$\text{Distance}_{\text{it}} = \left[\frac{\max_{\text{j}}(\text{Ask}_{\text{ijt}}) - \min_j(Bid_{ijt})}{(\max_{\text{j}}(\text{Ask}_{\text{ijt}}) + \min_j(Bid_{ijt})) \cdot 0.5} \right] \cdot 10{,}000$$

On a second consolidation level we compute the mean for all spread relevant variables over the nine snapshots per bond. Furthermore we calculated the average number of contributors N_i over the nine snapshots.

The mean average spread_i per bond (in bp) over the nine snapshots is defined as

$$\text{mean average spread}_{\text{i}} = \frac{1}{9} \cdot \sum_{t=1}^{9} \text{average spread}_{\text{it}}$$

The mean minimum spread_i per bond (in bp) over the nine snapshots is given by

$$\text{mean minimum spread}_{\text{i}} = \frac{1}{9} \cdot \sum_{t=1}^{9} \text{minimum spread}_{\text{it}}$$

The mean $distance_i$ per bond i (in bp) over the nine snapshots is defined as

$$\text{mean distance}_{\text{i}} = \frac{1}{9} \cdot \sum_{t=1}^{9} \text{distance}_{\text{it}}$$

Finally, the average number of contributors per bond i over the nine snapshots is given by

$$\text{N}_{\text{i}} = \frac{1}{9} \cdot \sum_{t=1}^{9} \text{N}_{\text{it}}$$

Based on this data set we regress each variable against time to maturity to assess whether a variable is dependent on time to maturity. In order to ensure a meaningful estimation of the zero-coupon yield curves it is important to avoid a maturity-dependent concentration of bonds which fall in the same subportfolio. In our data set several variables are linearly dependent on time to maturity and to account for this dependence we use the residuals of the regression as substitutes for the original variables for further calculations. See table 2 for a list of variables which were transformed by this procedure.

In a next step we compute the median for each variable and each country allowing us to divide a country's bond portfolio in a portfolio of bonds above the median and a portfolio of bonds below the median. In order to estimate the yield curves of the two subportfolios a minimum number of bonds (depending on the choice of the yield curve estimation method) is needed for each maturity bucket above and below the median. Due to specific data constellations we need to reduce the maximum time to maturity of selected bonds for some variables because in these cases too few bonds were available for the yield curve estimation.

After grouping the bonds for a specific separating variable above and below its median value we estimate the zero-coupon yield curve for each subportfolio using the standard cubic spline methodology originally proposed by McCulloch (1975). We use equidistant knots for the yield curve estimation having the first knot always set to zero and the last knot equals the longest maturity of all included bonds of a certain bond portfolio. Most of the time we use three parameters and only exceptionally four parameters are used. The choice of the number of parameters depend on the total number of bonds in the subportfolio and on their distribution across the maturity band.

In order to test for the significance of differences between yields of the above and below median subportfolios, we calculate the yield spreads (ys) for selected maturities (T_m).

$$ys_t(k,c,T_m) = y_t(k,c,T_m)^{illiquid} - y_t(k,c,T_m)^{liquid}$$

k = 1, ... , K	index for liquidity proxy
c = 1, ... , C	index for country
m = 1, ... , M	index for maturity

where $y_t(k,c,T_m)^{\text{illiquid (liquid)}}$ denotes the estimated zero coupon yield for time t of the illiquid (liquid) subportfolio regarding proxy k for country c and maturity T_m. This calculation was performed for all t on a daily basis for the period January 1999 to March 2001.

This enables us to test the hypotheses stated in section 2.5 by performing a sign test on the spread curves (illiquid curve – liquid curve) determining whether yields of illiquid bonds are significantly higher than yields of liquid bonds over the respective period. The advantage of the non-parametric sign test is that no assumption (besides symmetry) about the distribution of the population is necessary. Since our data set contains more than 500 data points for the spread between above and below median yields per country and proxy (illiquid yield curve minus liquid yield curve) we can use a normal approximation for the test statistic.

$$\frac{B^+ - n/2}{\sqrt{n/4}} \sim \text{N}(0,1)$$

B^+	number of observations $ys_t(k,c,T_m) > 0$
n	number of observations

This test does not account for the magnitude of the differences. A criterion for deciding on the economic significance of the yield spread we use the average minimum bid-ask spread per country. The average minimum bid-ask spreads can be seen as the smallest transaction costs which investors need to bear whenever a transaction is done. Yield spreads which are smaller than the average minimum bid-ask spread are thus interpreted as economically insignificant.

In a second stage we extend our analysis to the single bond level where a direct observation of price effects is possible. We use a reference zero-coupon yield curves estimated from the entire sample of bonds in each country to calculate pricing errors for all bonds. We define the pricing error of a bond i (PE_{it}) as the difference between its market value (price plus accrued interest) and its present value (sum of cash flows discounted by the reference yield curve) on date t. Bonds with a positive pricing error are regarded as overvalued with respect to the reference yield curve and vice versa.

Based on the data available the following time-series-cross sectional regression model allows us to conduct parametric tests of the hypotheses stated in section 2.5.

$$\mathrm{PE}_{\mathrm{it}} = \sum_{k=1}^{\mathrm{K}} \mathrm{X}_{\mathrm{itk}} \cdot \mathrm{c}_{\mathrm{k}} + e_{it} \qquad (1)$$

X_{itk} Liquidity proxy k for bond i at time t

The explanatory variables denote three classes of liquidity proxies: (i) Time-varying proxies, eg bid-ask spread for the closing price of bond i on date t, (ii) time-varying binary variables, eg the benchmark indicator (equals one when the bond was a benchmark bond on the observation date), and (iii) proxies which vary over the cross section but are constant over time, eg the issue size of a bond or its average number of contributors. Since some of the explanatory variables are not time varying, we cannot use a constant in the regression model (1). Moreover, the c_k related to these variables can be interpreted as the contribution of variable k to the (implicit) constant of equation i. This allows us to combine time-series and cross-sectional information to infer the empirical results of this stage of our study. Further, to ensure to estimate a model with meaningful economic implications we chose a parameter specification which is fixed over time and bonds.

We do not assume a spherical error process. To address possible serial correlation we add a AR(1)-term to each equation. Following Beck and Katz (1995) we restrict the AR(1)-parameter to be independent of the equation, ie to be independent of the specific bond. Finally, to address spatial correlation we assume contemporaneously correlated errors. This leads to the following specification of our regression model,

$$\mathrm{PE}_{\mathrm{it}} = \mathrm{c}_0 \cdot \mathrm{PE}_{\mathrm{it-1}} + \sum_{k=1}^{\mathrm{K}} \mathrm{X}_{\mathrm{itk}} \cdot \mathrm{c}_{\mathrm{k}} + e_{it} \qquad (2)$$

with $E(\varepsilon_{it}, \varepsilon_{jt}) = \sigma_{ij}$, and with all other covariances equal to zero.

We estimate the model for each country using the seemingly unrelated regression (SUR) method introduced by Zellner (1962).

3.3 Results and Interpretation

3.3.1 Comparison of subportfolios

The results of the first part of the empirical analysis are reported in detail in the appendix showing the average and the volatility of the time series of the yield spreads per maturity bucket between the illiquid and liquid yield curve based on a particular proxy for each country. The following section summarizes the main results.

Issue size

The issue size shows significant results with respect to the sign test for four out of six countries, only for Germany and France the stated hypothesis, that large issues are more liquid than small issues, was not supported. We take the average minimum bid-ask spread per country as a benchmark for deciding whether the results are economically significant. Basically, the results for four countries (Austria, Italy, Spain, and The Netherlands) are economically significant although for a few maturity buckets the economical significance is not given (for details refer to table 6). The results have in common that the volatility of the spread for all maturities is extremely high.

The liquidity yield spread per maturity for a country over the period from January 1999 to March 2001 is summarised by the average yield spread per maturity. In all countries except Spain we observe an almost perfectly linear increasing liquidity spread with time to maturity (see, e.g. for Austria figure 1). This is in line with Kempf and Uhrig-Homburg (2000) who also find a similar increase of the liquidity spread with time to maturity. Note, that the issue size has been corrected for maturity dependence prior to this analysis. In order to find a reasonable explanation for this almost linear increase of the liquidity yield spread by time to maturity we explore the characteristics of the input data on a bond level and we can observe that the difference between the issue size of bonds above and bonds below the median issue size is also increasing with time to maturity. The relative difference in issue size is increasing with maturity (see figure 2). The hump-shaped pattern of the average liquidity yield spread for Spain can also be found in the difference between issue size below and above the median issue size.

We conclude that the shape of the average liquidity yield spread depends on the maturity-dependent differences in issue size between bonds above and below the median issue size. A small difference will be related to a small liquidity yield spread using the issue size as a liquidity measure whereas a large difference will be related to a large liquidity yield spread. This supports a special version of hypothesis 1 when issue size is regarded as relative rather than absolute size.

Number of contributors

The cross-sectional data employed in this study allows us to count the number of market participants who are quoting prices for a particular bond. Only double-sided quotations per bonds and quotations where the quotation date equals the date of inquiry are included in the sample. The results support the hypothesis that bonds with more contributors are liquid whereas bonds with only few contributors are less liquid, for all countries except France and for almost all maturity buckets. Economic significance, referring to the average minimum bid-ask spread, is given for most of the maturity buckets (for details refer to table 5).

The results show a very high volatility of the liquidity spread for all relevant maturity buckets For Austria, Italy, and The Netherlands the average liquidity spread over the period from January 1999 to March 2001 is increasing with time to maturity, whereas for Spain and Germany we can notice a humped shape pattern of the liquidity spread.

The extreme volatility of observed liquidity spreads might be explained by the fact that bonds which have a number of contributors close to the median number of contributors may swap from the liquid portfolio to the illiquid portfolio and vice versa during the respective period of the yield curve estimation. Furthermore specialness could cause a switch from the illiquid to the liquid subportfolio for a particular time assuming that bonds which trade on special or are on-the-run attract more traders to quote. Strebulaev (2001) reports a seven times larger number of quotations for bonds which are on-the-run. This ‘switching’ of bonds between subportfolios might introduce additional volatility.

Bid-ask spread

In line with the results concerning other liquidity proxies it turns out that the volatility of the liquidity spread with respect to the average bid-ask spread is extremely high for all buckets Overall, there is no general pattern of the liquidity spread, which indicates that the bid-ask spread variable used in this study is not a good candidate for a liquidity measure (refer to table 8). This result holds also with respect to different related measures like maximum or minimum bid-ask spread.

The results for all maturity buckets are significant only for The Netherlands whereas only few maturity buckets have significant results for Austria, Germany, France and Spain, and even no single maturity bucket shows a significant result for Italy. The liquidity spread for The Netherlands is economic significant for all maturity buckets, whereas Austria, Germany, Spain represent an economic significant outcome only for one or more maturity buckets. Neither the time series data for Italy nor for France show an economic significance for any liquidity yield spread maturity bucket.

Given the mixed picture resulting from the sign test and the high volatility of observed spreads, we cannot conclude that there is support for the existence of a systematic price impact of bid-ask spread based liquidity proxies.

Distance between maximum ask and minimum bid quote

This proxy for liquidity was not used in previous research so far and should give an indication on the market depth. The distance is defined as the $max_{ask} – min_{bid}$ of all quoted prices per bond and snapshot and can be seen as the upper limit for the maximum price spread an investor needs to accept.

Only in the case of The Netherlands all maturity buckets are persistently significant using the sign-test and also with respect to the economic significance. For all other countries we notice a significant positive difference between the illiquid and the liquid yield curve only for a small part of the maturity spectrum. Assessing the economic significance we realise that for Austria, Spain, and France at least some buckets show a liquidity spread which is above the average minimum bid-ask spread but for Germany and Italy no single maturity bucket offers an economically significant spread (refer to table 9).

The time-series of the spreads using the distance as liquidity measure shows a mixed picture. We observe a very volatile behaviour and no persistent yield difference between the illiquid and liquid yield curve which leads to the conclusion that there exists no systematic price impact when using the distance as a liquidity measure. It is interesting to note that this measure of market depth does not show any systematic price impact at all. This contrasts the immediacy based liquidity hypotheses but we cannot exclude, however, effects caused by the collection of our data which may adversely influence the interpretation of the results.

Benchmark property

None of the countries shows a persistently significant difference between benchmark and non benchmark yield curve for all maturity buckets besides The Netherlands. For all countries one or more buckets have a higher liquidity spread than the average minimum bid-ask spread but even The Netherlands do not show a continuously economically significant liquidity yield spread for all buckets (for details please see table 7). It is remarkable, that for all countries the maturity buckets two, three and four years have yield spreads significant with respect to the sign test, indicating that the distinction between benchmark bonds and non benchmark bonds is more relevant for medium matured bonds.

Note, however, that in contrast to the other cross-sectional snapshots the benchmark property of all bonds was collected on a time-series basis, such that the bonds were grouped on their actual benchmark property on a daily basis in order to estimate the yield curves. This might induce an additional source of uncertainty because the yield curve estimation in the five to ten years maturity spectrum is often based on very few bonds which are not benchmark bonds and spurious results due to the assumed functional form of the discount function are likely to occur. Results obtained from a single bond analysis are expected to be more reliable.

Cross country comparisons

We extend our analysis to a cross-country level in order to explain price differences employing the liquidity measures issue size and number of contributors which turned out to be significant on the country analysis level. As described in the previous section we divided each bond portfolio for a country in bonds above and bonds below a particular median variable, e.g. issue size or number of contributors. Under the hypothesis that liquidity measured by a specific proxy is priced by the market we expect a zero yield spread between subportfolios with coinciding liquidity measures across countries. To test this implication we need to observe the yield curves of subportfolios from different countries with approximately equal or matching liquidity measures. We find almost matching pairs for the size based subportfolios for The Netherlands and Germany and based on the number of contributors we find three matched pairs, i.e. Italy and The Netherlands, Spain and Germany, and Austria and Germany.

Table 3 summarizes the main characteristics for the subportfolios and the average yield spread for a typical maturity is displayed. Results for other maturities support the key results and are not contained in table 3 for convenience. It is interesting to note that despite coinciding liquidity measures of different subportfolios the observed yield spreads do not vanish. A first possible explanation for this result is the quality of the liquidity measures used as grouping variables. These measures, i.e. size and number of contributors, might be influenced by other effects like specialness or they might be poor measures of liquidity at all. The second possible explanation is that liquidity is not the major driving force explaining the yield spreads between different issuers in the EMU government bond market. This is in agreement with Geyer et al. (2001) who explicitly model default risk as a explanatory variable for observed inter-issuer yield spreads.

3.3.2 Panel Data Analysis

In this section we like to employ a formal test on our stated hypotheses on a single bond level using time-series data from January 1999 to March 2001. The procedure of grouping bonds in subportfolios of bonds which are above or below a certain median value of a particular liquidity proxy might lead to results where in some cases no clear interpretation is possible. Furthermore, we are not able to specify the magnitude of the liquidity impact when using a sign test for the verification of our stated hypotheses. We are only concerned about whether a significant number of observations show a positive difference in the used sample. In order to overcome these possible weaknesses and to determine the magnitude of the liquidity spread and the impact of each liquidity proxy we employed a panel data analysis using the country specific yield curve as reference yield curve for pricing each bonds. Based on these yield curves we derive pricing errors as the differences between market prices and present values. The pricing errors are measured in basis points and are used as the dependent variables throughout the subsequent analysis.

We estimated model (2) described in section 3.1 using the seemingly unrelated regression (SUR) method introduced by Zellner (1962). We present results where the following explanatory variables are included to test for possible price effects.

Log issue size	*natural logarithm of issue size measured in EUR*
Bid-ask spread	*relative bid-ask spread of closing quotes*
Benchmark	*1 if a bond is a benchmark bond on that day or 0 otherwise*
On-the-run	*1 if time between observation date and issue date of a bond is less or equal than one month or 0 otherwise*
Number of contributors	*number of contributors for a bond derived from cross-sectional snapshots*

The variables *Log issue size* and *Number of contributors* are constant over time and their regression coefficients indicate the (constant) contribution of the liquidity variable to the observed pricing error. The variables *Benchmark* and *On-the-run* are potentially time-varying but for some bonds the variable is always equal to zero because of the fact that over the test period these bonds have not been classified as being a benchmark bond or on-the-run, respectively. The *Bid-ask spread* variable is the only variable which is time-varying for all bonds.

Table 4 summarizes the results for the six countries. In line with the results of the analysis on subportfolio level it turns out that none of the liquidity proxies used in this study has any price impact on the French bond market. We conclude that either for France a different liquidity measure is needed or – more likely – liquidity is not priced in the French government bond market at all. For the other countries the results partially support the results of the subportfolio analysis. The main difference in the results is that the benchmark property seems to be the most promising liquidity proxy in the panel data analysis. The effect is rather small in Germany and Italy (5-7 basis points) but remarkably strong in Austria, Spain, and the Netherlands (between 11 and 26 basis points). This is in agreement with the observation on the subportfolio level that in some countries, particularly in Italy, the benchmark property has a weaker price impact for longer maturities but a strong price impact for short and medium maturities.

The liquidity measure number of contributors which was not examined in the previous academic literature seems to be a rather good candidate since for Italy, Spain, The Netherlands and Austria we observe significant results. In some countries the price impact per contributor is notably high and up to 3.6 basis points for Austria. This again supports the findings of the subportfolio analysis. The on-the-run property shows a mixed picture. We can observe significant results for Spain and Italy, whereas we have insignificant results for the other countries, and in Austria the estimated coefficient has the wrong sign. We conclude that there might be country specific liquidity effects due to the on-the-run property but on the EMU level this liquidity proxy does not perform sufficiently well. The bid-ask spread seems to be a rather poor liquidity measure. In line with the results of the subportfolio analysis we conclude that bid-ask spread related variables do not have a measurable price impact.

The results concerning the issue size are partially in contrast to the results on the subportfolio level. In most countries we can observe coefficients with a negative sign which implies a negative price impact of issue size. This clearly contradicts hypothesis one that larger issues are more liquid. To ensure that this finding is not an artefact of multi-collinearity effects we repeated the estimation procedure for more parsimonious models where we removed the variables *Benchmark* and *Number of Contributors* from the regression model. This is motivated by the fact that these variables are not objective properties of the bond itself but related to subjective beliefs or forecast of market participants about the future liquidity of a bond. These beliefs are, of course, themselves based on 'objective' facts like the issue size of a bond. This might introduce a multi-collinearity problem in our regression model. After removing these variables from the regression model the main results do not change. Even in a model where both the benchmark property and the number of contributors are removed the issue size has no measurable effect.

Finally, we have to address the quality of the standard errors displayed in table 4. We obtained the standard errors using the Parks estimator technique which – under certain circumstances – underestimates the standard errors of the coefficients in a panel data analysis (for a detailed discussion of this problem refer to Beck and Katz (1995)). The possible effects are rather small for models where serial correlation is sufficiently under control and the number of observation dates is great compared to the number of cross-sectional units which is the case for this study. A detailed analysis of serial correlation in the regression residuals indicates that potential problems might only exist for Austria. Thus, we have to look at the standard errors for Austria with special care. The general results of this analysis, however, should not be affected by this problem.

4 Conclusions

To measure the liquidity impact on EMU government bond prices we employ two different procedures. In the first procedure national submarkets are grouped by several liquidity variables comprising nearly all liquidity proxies suggested previously given the availability of the relevant data. For all liquidity based subportfolios discount functions and zero-coupon yield curves are estimated. The comparison of the estimated yield curves gives a first insight into the existence of potential price effects. The results of the subportfolio analysis indicate that bid-ask spread related measures like the average bid-ask spread or the distance between maximum ask and minimum bid quote do not have any price impact. The number of contributors and the issue size show a significant price impact of the expected sign at least for most countries and most maturity buckets.

In the second procedure liquidity measures are collected on the single bond level and estimated pricing errors given some reference yield curve are regressed against the liquidity variables. This enables us to conduct formal tests on the pricing impact of liquidity measures. It turns out that the benchmark property and the number of contributors are the most promising liquidity proxies which have significant results in most countries. The on-the-run property is only supported by the results of two countries whereas the bid-ask spread again shows no measurable price impact. Finally, the issue size turns out to have no significant price impact in the single bond analysis. Moreover, the estimated coefficients are frequently of the wrong sign. This result holds even after removing the number of contributors and the benchmark property from the regression model.

The intra-issuer analysis shows that liquidity effects are more pronounced in smaller markets like Austria, The Netherlands, and Spain, whereas the effects are less pronounced in larger markets like Germany, Italy, and France, where we observe no significant liquidity effects at all. A cross-country analysis on the subportfolio level indicates that liquidity effects cannot explain the size of the yield spreads between different issuers. The cross-country yield spreads remain even after controlling for liquidity effects. This implies that other effects than liquidity like credit risk are important driving factors of cross-country yield spreads.

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Appendix

	# of Bonds included	avg. Issue Size [EUR]	avg. # Contributors	avg. Bid-Ask Spread [bp]	avg. time to maturity [years]
Austria	45	2,045,234,261	10.08	10.74	2.75
France	33	14,627,687,040	14.89	8.52	3.82
Germany	56	8,514,155,983	16.11	5.82	2.95
Italy	55	9,193,064,521	6.52	6.97	2.76
Netherlands	24	7,647,001,154	13.39	10.44	3.97
Spain	24	8,621,272,177	10.59	8.47	3.69

Table 1: Description of the sample of EMU bonds.

	Austria	Germany	France	Italy	The Netherlands	Spain
Contributor	X	X	X	X		X
Issue Size	X	X		X		
Spread avg.		X				
Spread min.					X	X
Spread max.						
Distance avg.	X	X	X	X	X	

Table 2: Linear dependence of a respective liquidity proxy with the time to maturity. X indicates a linear dependence. For these variables the OLS residuals were used in the subsequent analysis.

Liquidity Proxy: **Issue Size**		avg. issue size	subportfolio	average yield spread in [bp]
Country 1	The Netherlands	EUR 10.6 bn	high	6.19
Country 2	Germany	EUR 11.9 bn	high	

Liquidity Proxy: **Number of Contributors**		avg. # of contributors	subportfolio	average yield spread in [bp]
Country 1	Spain	12.24	high	26.71
Country 2	Germany	11.69	low	

Liquidity Proxy: **Number of Contributors**		avg. # of contributors	subportfolio	average yield spread in [bp]
Country 1	Austria	14.04	high	19.57
Country 2	Germany	11.69	low	

Liquidity Proxy: **Number of Contributors**		avg. # of contributors	subportfolio	average yield spread in [bp]
Country 1	Italy	8.03	high	3.27
Country 2	The Netherlands	8.61	low	

Table 3: Details of the cross-country analysis. In the column subportfolio ‘high’ (‘low’) indicates that the subportfolio with bonds which are above (below) the median value of the liquidity proxy are used. Average yields spreads are calculated as country 1 minus country 2.

Germany	Coefficient	Std. Error	t-Statistic	Prob.
Log issue size	-0.0034	0.0031	-1.0820	0.2792
Bid-ask spread	-53.5452	130.1835	-0.4113	0.6809
Benchmark	0.0663	0.0211	3.1440	0.0017
On-the-run	0.1332	0.0860	1.5485	0.1215
Number of Contributors	0.0037	0.0025	1.4718	0.1411
AR(1)	0.9893	0.0008	1169.5750	0.0000
France	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Log issue size	0.0023	0.0038	0.5924	0.5536
Bid-ask spread	-12.9326	126.1875	-0.1025	0.9184
Benchmark	-0.0198	0.0281	-0.7046	0.4810
On-the-run	0.2699	0.2148	1.2563	0.2090
Number of Contributors	-0.0024	0.0044	-0.5547	0.5791
AR(1)	0.9879	0.0010	1037.1040	0.0000
Italy	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Log issue size	-0.0044	0.0021	-2.1323	0.0330
Bid-ask spread	-80.9788	51.5880	-1.5697	0.1165
Benchmark	0.0497	0.0334	1.4879	0.1368
On-the-run	0.3065	0.1047	2.9289	0.0034
Number of Contributors	0.0150	0.0068	2.2078	0.0273
AR(1)	0.9650	0.0016	612.0899	0.0000
Austria	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Log issue size	-0.0090	0.0047	-1.9164	0.0553
Bid-ask spread	-258.8080	74.0412	-3.4955	0.0005
Benchmark	0.2653	0.0451	5.8768	0.0000
On-the-run	-1.1415	0.3503	-3.2586	0.0011
Number of Contributors	0.0362	0.0052	7.0235	0.0000
AR(1)	0.9190	0.0026	358.9027	0.0000
The Netherlands	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Log issue size	-0.0043	0.0017	-2.5860	0.0097
Bid-ask spread	1.6119	15.5749	0.1035	0.9176
Benchmark	0.1124	0.0306	3.6756	0.0002
On-the-run	0.0153	0.1379	0.1109	0.9117
Number of Contributors	0.0046	0.0025	1.8361	0.0664
AR(1)	0.9847	0.0016	626.0463	0.0000
Spain	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Log issue size	-0.0116	0.0051	-2.2839	0.0224
Bid-ask spread	-54.5879	74.3319	-0.7344	0.4627
Benchmark	0.1109	0.0452	2.4552	0.0141
On-the-run	0.1524	0.0775	1.9671	0.0492
Number of Contributors	0.0228	0.0110	2.0733	0.0382
AR(1)	0.9784	0.0019	511.6515	0.0000

Table 4: Estimation results of model (2). The coefficients were obtained using the seemingly unrelated regression (SUR) method introduced by Zeller (1962). The standard errors are calculated using the GLS-based Parks estimator (see Beck and Katz (1995)).

Country	Austria
Variable	Number of Contributors
Maturity band (in years)	0-6
avg. bid-ask spread (in bp)	5.08
Total number of observations	561

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	516	19.89	3.73	3.65
3	559	23.52	3.98	2.41
4	558	23.43	5.52	2.68
5	561	23.69	8.56	2.93
6	524	20.56	12.40	7.36

Country	Germany
Variable	Number of Contributors
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	2.49
Total number of observations	584

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	211	-6.70	-6.12	11.75
3	429	11.34	3.37	7.56
4	523	19.12	7.29	13.16
5	376	6.95	0.08	26.19
6	366	6.12	-9.62	41.14
7	221	-5.88	-17.77	49.40
8	78	-17.71	-21.85	47.23

Country		France		
Variable		Number of Contributors		
Maturity band (in years)		0-7		
avg. bid-ask spread (in bp)		2.84		
Total number of observations		580		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	217	-6.06	0.30	11.01
3	333	3.57	2.41	6.38
4	468	14.78	2.65	3.29
5	298	0.66	0.67	2.65
6	179	-9.22	-3.30	6.59
7	151	-11.54	-6.77	9.72

Country		Italy		
Variable		Number of Contributors		
Maturity band (in years)		0-7		
avg. bid-ask spread (in bp)		4.66		
Total number of observations		583		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	583	24.15	8.21	4.80
3	479	15.53	2.44	2.86
4	475	15.20	1.23	1.79
5	579	23.81	5.37	3.21
6	581	23.98	15.05	8.90
7	581	23.98	24.14	14.14

Country		The Netherlands		
Variable		Number of Contributors		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.25		
Total number of observations		579		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	304	1.21	-3.70	10.73
3	455	13.76	2.55	3.51
4	579	24.06	5.05	1.83
5	579	24.06	4.59	1.23
6	579	24.06	4.19	1.48
7	579	24.06	5.96	2.23
8	579	24.06	10.27	2.92

Country		Spain		
Variable		Number of Contributors		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.07		
Total number of observations		584		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	285	-0.58	-3.05	8.16
3	523	19.12	2.57	2.06
4	574	23.34	5.84	3.23
5	550	21.35	6.40	4.67
6	437	12.00	3.77	3.97
7	134	-13.08	-2.99	5.16
8	119	-14.32	-12.11	12.71

Table 5: Summary of the subportfolio analysis using the number of contributors as a liquidity proxy. The number of positive observations for each maturity shows the number of dates where the yield of the illiquid subportfolio was greater than the yield of the liquid subportfolio. The column z-value indicates the test statistic of the sign test used to assess the significance of the number of positive observations. The average yield spreads (illiquid yield curve – liquid yield curve) and the standard deviations of the yield spread are presented in basis points.

Country		Austria		
Variable		Issue Size		
Maturity band (in years)		0-6		
avg. bid-ask spread (in bp)		5.08		
Total number of observations		576		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	490	16.83	0.48	4.50
3	547	21.58	2.79	2.45
4	574	23.83	5.22	3.06
5	559	22.58	7.83	3.83
6	509	18.42	10.35	9.84

Country		Germany		
Variable		Issue Size		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		2.49		
Total number of observations		584		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	584	24.17	7.97	2.95
3	570	23.01	4.04	1.85
4	265	-2.23	-0.36	1.77
5	17	-22.76	-2.96	1.99
6	19	-22.59	-2.39	1.45
7	271	-1.74	1.57	5.08
8	412	9.93	7.40	11.03

Country		France		
Variable		Issue Size		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		2.84		
Total number of observations		581		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	265	-2.12	0.06	14.65
3	160	-10.83	0.19	6.69
4	274	-1.37	0.30	1.73
5	296	0.46	0.35	2.90
6	292	0.12	0.32	3.12
7	352	5.10	0.16	2.23
8	333	3.53	-0.41	7.09

Country		Italy		
Variable		Issue Size		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		4.66		
Total number of observations		583		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	451	13.21	0.36	11.16
3	583	24.15	6.42	4.17
4	583	24.15	3.55	1.54
5	573	23.32	9.13	7.62
6	558	22.07	20.54	23.03
7	537	20.34	30.27	37.29
8	482	15.78	39.76	52.38

Country		The Netherlands		
Variable		Issue Size		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.25		
Total number of observations		580		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	536	20.43	3.14	7.07
3	560	22.42	4.10	2.19
4	580	24.08	4.30	1.68
5	580	24.08	3.83	1.53
6	579	24.00	3.95	1.85
7	580	24.08	5.64	2.22
8	579	24.00	9.04	3.00

Country		Spain		
Variable		Issue Size		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.07		
Total number of observations		584		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	398	8.77	0.57	4.75
3	584	24.17	4.67	1.32
4	584	24.17	7.42	2.38
5	584	24.17	8.64	3.75
6	581	23.92	8.06	5.67
7	398	8.77	5.81	9.18
8	232	-4.97	2.90	14.26

Table 6: Summary of the subportfolio analysis using the issue size as a liquidity proxy. The number of positive observations for each maturity shows the number of dates where the yield of the illiquid subportfolio was greater than the yield of the liquid subportfolio. The column z-value indicates the test statistic of the sign test used to assess the significance of the number of positive observations. The average yield spreads (illiquid yield curve – liquid yield curve) and the standard deviations of the yield spread are presented in basis points.

Country	Austria
Variable	Benchmark
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	5.08
Total number of observations	581

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	371	6.68	2.24	6.59
3	580	24.02	7.87	3.60
4	580	24.02	10.36	3.20
5	580	24.02	9.23	2.90
6	580	24.02	5.27	1.80
7	386	7.92	0.93	1.59
8	92	-16.47	-1.98	1.90

Country	Germany
Variable	Benchmark
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	2.49
Total number of observations	585

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	520	18.81	4.26	3.37
3	583	24.02	5.20	2.20
4	584	24.10	4.93	2.45
5	570	22.95	3.34	2.02
6	507	17.74	1.24	1.12
7	181	-9.22	-0.51	0.87
8	22	-22.37	-1.31	0.88

Country	France
Variable	Benchmark
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	2.84
Total number of observations	579

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	393	8.60	1.40	5.92
3	456	13.84	1.62	3.25
4	480	15.83	1.59	2.25
5	465	14.59	1.19	1.77
6	439	12.43	0.42	0.96
7	130	-13.26	-0.34	1.09
8	79	-17.50	-0.84	1.32

Country	Italy
Variable	Benchmark
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	4.66
Total number of observations	585

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	412	9.88	2.80	4.64
3	353	5.00	1.34	2.79
4	334	3.43	0.19	1.72
5	253	-3.27	-0.62	1.61
6	194	-8.14	-1.03	1.77
7	156	-11.29	-0.97	1.56
8	193	-8.23	-0.36	0.96

Country		The Netherlands		
Variable		Benchmark		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.25		
Total number of observations		585		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	578	23.61	3.71	1.75
3	434	11.70	1.78	1.88
4	355	5.17	0.92	2.29
5	388	7.90	1.28	2.02
6	582	23.94	2.54	1.24
7	583	24.02	3.61	0.94
8	583	24.02	3.69	0.99

Country		Spain		
Variable		Benchmark		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.07		
Total number of observations		584		

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	409	9.68	-0.07	8.47
3	465	14.32	1.69	2.07
4	505	17.63	2.23	2.64
5	458	13.74	1.54	2.42
6	410	9.77	0.58	1.18
7	239	-4.39	-0.01	0.87
8	241	-4.22	0.09	0.80

Table 7: Summary of the subportfolio analysis using the benchmark property as a liquidity proxy. The number of positive observations for each maturity shows the number of dates where the yield of the illiquid subportfolio was greater than the yield of the liquid subportfolio. The column z-value indicates the test statistic of the sign test used to assess the significance of the number of positive observations. The average yield spreads (illiquid yield curve – liquid yield curve) and the standard deviations of the yield spread are presented in basis points.

Country	Austria
Variable	avg. bid-ask spread
Maturity band (in years)	0-6
avg. bid-ask spread (in bp)	5.08
Total number of observations	580

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	181	-9.05	-2.95	4.09
3	315	2.08	1.59	3.04
4	579	24.00	5.37	2.71
5	580	24.08	8.27	3.00
6	544	21.09	9.64	7.10

Country	Germany
Variable	avg. bid-ask spread
Maturity band (in years)	0-7
avg. bid-ask spread (in bp)	2.49
Total number of observations	584

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	472	14.90	5.95	5.97
3	582	24.00	7.86	2.95
4	584	24.17	7.51	1.53
5	561	22.26	4.57	2.32
6	299	0.58	-0.86	3.84
7	42	-20.69	-6.15	5.81

Country		France		
Variable		avg. bid-ask spread		
Maturity band (in years)		0-5		
avg. bid-ask spread (in bp)		2.84		
Total number of observations		580		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	390	8.30	-4.36	36.76
3	320	2.49	0.48	2.73
4	237	-4.40	1.02	9.37
5	328	3.16	-2.29	11.83

Country		Italy		
Variable		avg. bid-ask spread		
Maturity band (in years)		0-6		
avg. bid-ask spread (in bp)		4.66		
Total number of observations		583		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	93	-16.44	-4.46	4.56
3	169	-10.15	-4.13	5.72
4	125	-13.79	-2.46	4.06
5	167	-10.31	0.72	5.82
6	217	-6.17	3.28	19.06

Country		The Netherlands		
Variable		avg. bid-ask spread		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.25		
Total number of observations		582		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	470	14.84	1.98	3.06
3	522	19.15	3.37	2.51
4	575	23.54	4.07	2.50
5	580	23.96	4.12	1.54
6	576	23.63	4.16	2.11
7	568	22.96	4.51	2.54
8	443	12.60	4.51	8.01

Country		Spain		
Variable		avg. bid-ask spread		
Maturity band (in years)		0-8		
avg. bid-ask spread (in bp)		3.07		
Total number of observations		584		
maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	320	2.32	-2.39	11.74
3	449	12.99	3.51	4.48
4	562	22.35	7.37	1.91
5	562	22.35	8.92	4.13
6	561	22.26	7.91	5.91
7	344	4.30	5.04	9.23
8	185	-8.86	1.47	13.60

Table 8: Summary of the subportfolio analysis using the average bid-ask spread as a liquidity proxy. The number of positive observations for each maturity shows the number of dates where the yield of the illiquid subportfolio was greater than the yield of the liquid subportfolio. The column z-value indicates the test statistic of the sign test used to assess the significance of the number of positive observations. The average yield spreads (illiquid yield curve – liquid yield curve) and the standard deviations of the yield spread are presented in basis points.

Country	Austria
Variable	avg. distance
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	5.08
Total number of observations	582

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	17	-22.72	-2.59	2.38
3	56	-19.48	-1.26	1.62
4	83	-17.24	-1.23	1.36
5	43	-20.56	-1.96	1.24
6	185	-8.79	-1.49	2.66
7	356	5.39	1.56	3.81
8	525	19.40	7.42	5.61

Country	Germany
Variable	avg. distance
Maturity band (in years)	0-7
avg. bid-ask spread (in bp)	2.49
Total number of observations	585

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	285	-0.62	-1.79	3.99
3	361	5.66	0.85	1.85
4	403	9.14	2.20	3.06
5	393	8.31	2.05	3.29
6	284	-0.70	0.15	2.32
7	160	-10.96	-3.32	4.63

Country	France
Variable	avg. distance
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	2.84
Total number of observations	579

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	486	16.33	15.38	13.24
3	468	14.84	3.23	3.03
4	132	-13.09	-2.76	4.00
5	173	-9.68	-1.68	2.40
6	413	10.26	3.22	5.86
7	433	11.93	8.56	11.84
8	442	12.68	14.83	18.25

Country	Italy
Variable	avg. distance
Maturity band (in years)	0-6
avg. bid-ask spread (in bp)	4.66
Total number of observations	583

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	278	-1.12	-0.65	6.14
3	479	15.53	1.99	3.51
4	353	5.09	0.42	3.03
5	84	-17.19	-4.87	4.26
6	146	-12.05	-12.42	15.01

Country	The Netherlands
Variable	avg. distance
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	3.25
Total number of observations	583

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	538	20.42	2.78	6.99
3	473	15.03	2.99	3.00
4	570	23.07	3.64	2.26
5	582	24.06	4.13	1.62
6	582	24.06	4.29	2.16
7	541	20.67	4.11	2.61
8	427	11.22	3.27	8.64

Country	Spain
Variable	avg. distance
Maturity band (in years)	0-8
avg. bid-ask spread (in bp)	3.07
Total number of observations	584

maturity	number of positive observations	z-value	average yield spread (bp)	standard deviation (bp)
2	310	1.49	-2.57	6.21
3	566	22.68	3.46	1.81
4	584	24.17	7.39	2.11
5	584	24.17	8.91	3.71
6	583	24.08	7.83	5.35
7	379	7.20	4.85	8.81
8	198	-7.78	1.14	14.06

Table 9: Summary of the subportfolio analysis using the average distance as a liquidity proxy. The number of positive observations for each maturity shows the number of dates where the yield of the illiquid subportfolio was greater than the yield of the liquid subportfolio. The column z-value indicates the test statistic of the sign test used to assess the significance of the number of positive observations. The average yield spreads (illiquid yield curve – liquid yield curve) and the standard deviations of the yield spread are presented in basis points.

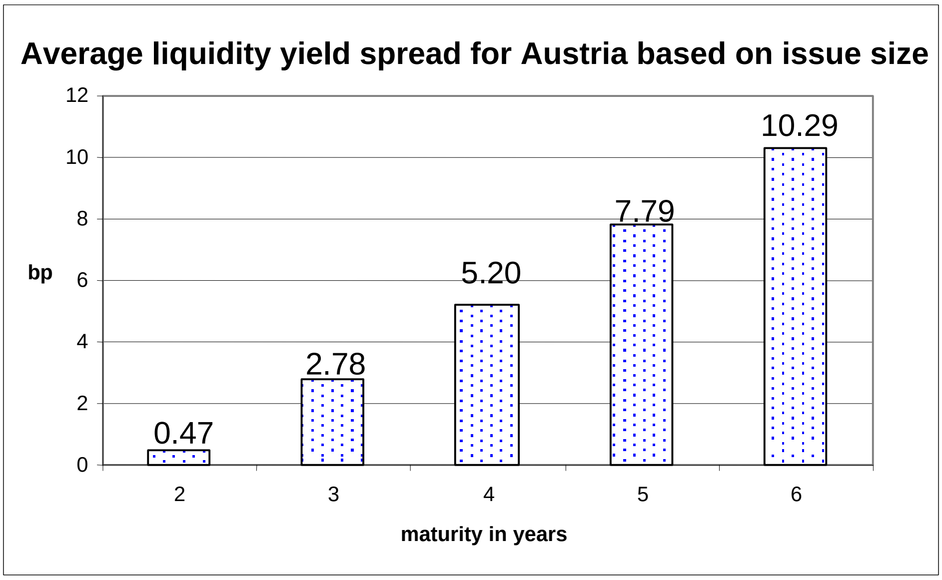

Figure 1: This graph shows the average liquidity spread per maturity for Austria for the period 01/1999 – 03/2001.

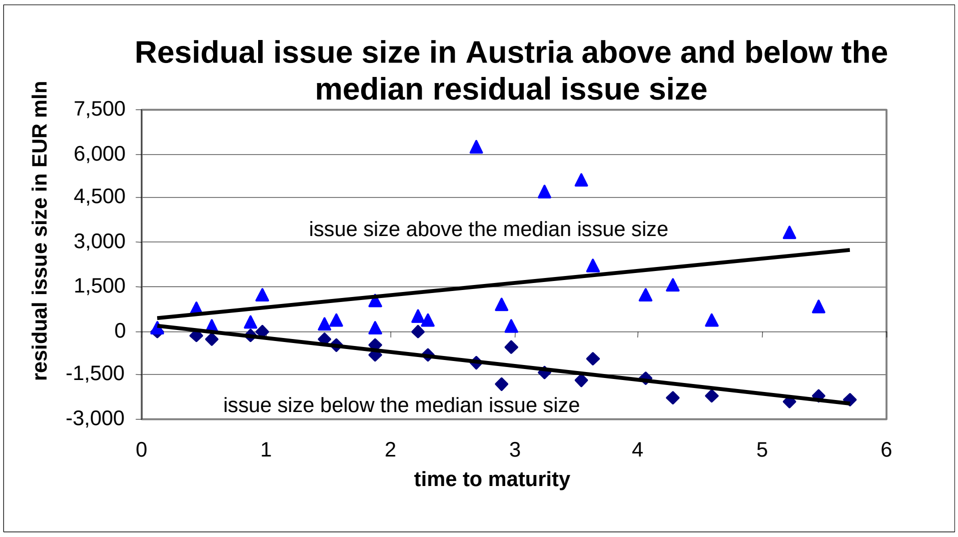

Figure 2: The graph shows the residual issue size of individual bonds for Austria grouped by the median residual issue size.