Liquidity premia in German government bonds*

Jacob W. Ejsing † Jukka Sihvonen ‡

July 2009

Abstract

There is strong evidence that on-the-run U.S. Treasury securities trade much more liquidly and at significantly higher prices than their off-the-run counterparts. We examine if the same phenomenon is present in the German government bond market whose market structure differ markedly from that of the U.S. Treasury market. In sharp contrast to the U.S. evidence, we find that on-the-run status has only a negligible effect on the liquidity and pricing once other factors have been controlled for. Instead, the highly liquid German bond futures market, whose turnover is many times larger than in the cash market, leads to significant liquidity spillovers. Specifically, we find that bonds which are deliverable into futures contracts are both trading more liquidly and commanding a significant price premium, and that this effect became more pronounced during the recent financial crisis.

Keywords: *Government bond, liquidity, liquidity premium, futures market*

JEL Classification: *E43, G12, H63*

---

*The views expressed in this paper are those of the authors and do not necessarily reflect the views of the European Central Bank or Danmarks Nationalbank. We thank the anonymous referee and seminar participants at the ECB and at the GSF Summer Research Workshop in Finance, May 2009, for helpful comments.

†European Central Bank and Danmarks Nationalbank

‡European Central Bank and Department of Accounting and Finance, University of Vaasa.

1 Introduction

Previous studies of liquidity and liquidity premia in government bond markets, based predominantly on data from the U.S. Treasury market, have identified pronounced liquidity differences across government securities. In particular, the most recently issued securities in a given maturity bracket, the so-called on-the-run issues, have been found to trade much more actively and liquidly than their more seasoned counterparts. This pattern is usually referred to as the 'on-the-run liquidity phenomenon'. It has also been found that these differences in liquidity between on-the-run and off-the-run securities have important implications for bond pricing, and that - particularly in times of market stress - the on-the-run securities command a significant price premium. For example, the yield discount on the on-the-run ten-year U.S. Treasury note relative to older issues with similar remaining maturity reached over 50 basis points in the autumn of 2008.

With a view to better understand the underlying causes of liquidity and liquidity premia, an examination of the German government bond market can potentially provide new insights. Specifically, the market structures of the U.S. and German government bond markets differ considerably; most notably with regard to the relative sizes of cash and futures markets. Table 1 compares U.S. and German trading volumes in government securities (excluding bills) and corresponding futures contracts. Whereas trading volumes in the German cash bond market is dwarfed by the activity in US Treasury market, the trading volumes in the two futures markets are of the same order of magnitude. This has important implications: whereas benchmark status and on-the-run status are synonymous in the U.S. Treasury market, in the German market, the benchmark status is de facto shared between a number of bonds, namely those bonds which are deliverable into the nearest-to-expiry futures contracts. Figures 1a and 1b show an example of how these differences affect trading volumes throughout the lives of selected ten-year bonds maturing around 2010. The U.S. 'on-the-run liquidity phenomenon' is clearly reflected in the sharp drop-off in traded volumes after the on-the-run period (top panel). For the German bonds (middle panel), however, the initial decline is much less pronounced, and there is a strong resurgence of trading as the bonds become deliverable again for the five-year futures and (albeit to a lesser extent) for the two-year futures.

Table 1: German and US markets for government securities and related futures (2008)

	Amount outstanding (EUR[a] billion)	Total volume 2008 (EUR billion)		Relative size of futures market in %
		Cash market	Futures	
Germany	879	5961	58715	985%
United States	2302	81426	45748	56%

Sources: Eurex, Bundesrepublik Deutschland Finanzagentur,
Federal Reserve Bank of New York, Chicago Board of Trade and the US Treasury Department.
[a]US dollar amounts were converted using the average exchange rate of 2008, 1.4711 USD per EUR.

In this paper, we ask whether the extremely large German futures market (relatively to the cash market) gives rise to significant liquidity spillovers to the cash bond market. In particular, we examine whether deliverable bonds systematically enjoy enhanced liquidity (as measured by higher trading volumes, higher quoted depths and/or tighter bid-ask spreads). Moreover, we investigate whether such liquidity effects are reflected in the prices of German government bonds. There are two main reasons for expecting spillover effects. First, deliverable bonds are easier to hedge using futures contracts, and thus more attractive for dealers (and other market participants with short horizons) to hold. Second, trading of deliverable bonds is directly supported by the strategies of arbitrageurs and speculative investors targeting the bond-future basis.

Our empirical results demonstrate that deliverability into futures contracts - rather than on-the-run status - is the key driver of liquidity and liquidity premia in the German market once other relevant factors have been controlled for. The sizes of the liquidity premia in the German market are found to be much smaller than those previously reported for U.S. on-the-run securities. This is consistent with the more ambiguous

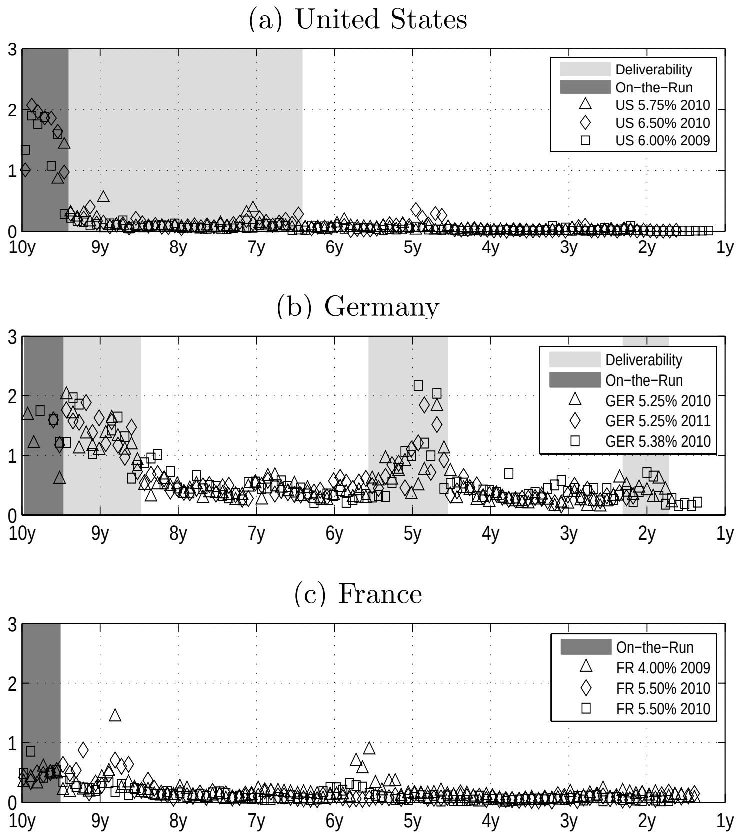

Figure 1: Monthly averages of daily trading volumes (EUR billion, on y-axes) as a function of time-to-maturity (years, on x-axis) for nine 10-year governments bonds. On-the-run and deliverability periods are shaded in darker and lighter colors, respectively. Source: ICMA.

notion of benchmark status in the German market, which diffuses short-horizon trading over a larger set of bonds. We find that the positive effect of deliverability has intensified during the recent financial crisis, probably reflecting that the ability to hedge positions has become even more important amid unusually high volatility.

Our contributions relative to the existing literature on liquidity premia in government bond markets are fourfold. First, we pay closer attention to a key feature of German government bonds, namely their deliverability into extremely liquid futures contracts such as the Euro-Bund future. We find that this feature, which has been largely neglected in most previous studies on euro area bond market liquidity, is key to explaining relative pricing along and vis-à-vis the German yield curve. Our emphasis on market structure also helps explaining the remarkable differences in liquidity premia found between the U.S. Treasury market and other government bond markets.

Second, in contrast to most previous studies conducted on euro area data, which typically have aimed at explaining levels of and variations in sovereign spreads, we take a single-issuer perspective and focus on Germany, the bellwether market for euro-area bond yields. This approach permits a richer cross-sectional analysis, simultaneously considering liquidity and liquidity premia for all outstanding bonds, and allows us to separately identify the effects of deliverability, on-the-run status and other liquidity determinants. Such identification could not have been achieved with the typical approach of comparing, say, ten-year benchmark yields across countries. As a control, we replicate our results with French bonds, which are issued in amounts similar to those of German bonds, but cannot be delivered into futures contracts.

Third, our empirical analysis is based on a very rich data set obtained from a European electronic limit-order market, MTS, containing high quality intra-day measures of liquidity (such as quoted depth and bid-ask spreads) for virtually all outstanding German and French bonds (among other issuers). Our data set covers both the periods before and after the onset of the financial crisis in mid-2007, which allows us to assess whether the determinants of liquidity and liquidity premia changed across these very different market regimes. We use the high-frequency quote data to form robust measures of market liquidity, which are superior to the 'snapshot measures' from a specific time of the day often used in the existing literature on euro area bond market liquidity.

Fourth, since premia related to deliverability contort the German yield curve in subtle ways, which cannot be captured with standard methods (such as the extended Nelson-Siegel specification), we use a flexible approach to yield curve estimation. By allowing for multiple (inverse) humps, our spline-based approach can accommodate the peculiar features of the German yield curve arising from the identified liquidity spillovers from the futures market. Figure 2 preempts the results of our curve estimation analysis. The stars and the circles represent observed spot yields on French and German bonds on a single day in 2008, plotted against their remaining maturity. The figure clearly reveals pronounced inverse humps along the German term structure, which in time-to-maturity terms coincide with the baskets of deliverable bonds for the futures contracts.[1]

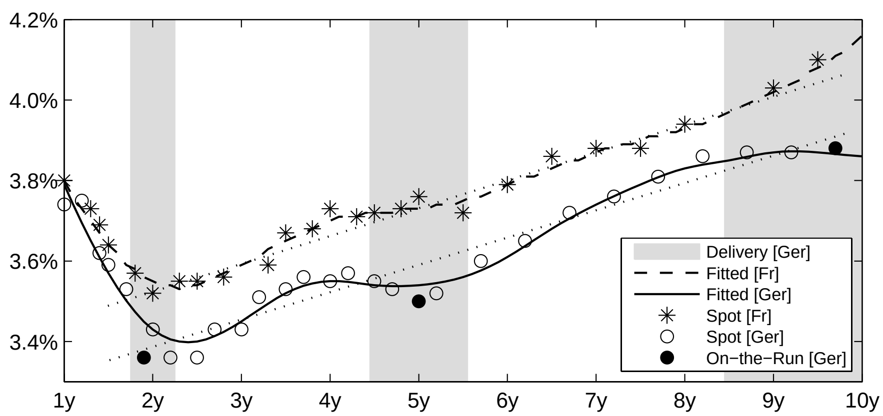

Figure 2: Actual and fitted spot rates for French and German bonds on 11 April 2008 (although plotted, the on-the-run securities are not included in the curve estimation).

The remainder of the paper is organized as follows. The next section discusses the economics of the on-the-run phenomenon, including a brief literature review. The third section presents our data set, and the fourth section examines the determinants of liquidity in the German government bond market. Section 5 examines to what extent liquidity and deliverability is priced. A final section concludes.

[1] The spot rates are bootstrapped from actual market yields according to the no-arbitrage principle. The dashed and the solid line represent the estimated curves for France and Germany, respectively, and as can be seen from the figure, the flexibility of the spline becomes important in capturing the relatively complex shapes of the two term structures. For comparison, we estimated the zero-coupon curves with another popular method, the extended Nelson-Siegel model. Its functional form however turned out to be too restrictive for the yiled curves experienced after August 2007.

2 The economics of the on-the-run liquidity phenomenon

The empirical observation that bond trading and liquidity concentrate on few issues is not necessarily surprising. First of all, it is unnecessary to hold (or short) the entire market portfolio, since a suitable combination of short-, medium-, and long-term bonds captures almost all the variation in the level and shape of the yield curve [Litterman and Scheinkman (1991); Bliss (1997)].[2,3] Once trading in certain maturities becomes customary, positive externalities will tend to reinforce it [Pagano (1989)].

The short-, medium-, and long-term bonds that are the most sensitive to yield curve risk within their maturity segment tend to become *benchmark* bonds [Yuan (2005); Dunne, Moore, and Portes (2007)]. Since benchmark bonds tend to be more liquid [Boudoukh and Whitelaw (1991); Higo (1999)] and therefore trade at lower yields [Boudoukh and Whitelaw (1993)], issuers make efforts to ensure that their bond issues will obtain benchmark status. For example, major sovereign issuers now auction bonds in accordance with an issuance calendar published in advance. This (shorter-term) predictability and transparency of issuance schedules contribute to reduced idiosyncratic price variation in the secondary market by alleviating supply uncertainty. Moreover, concentration of issuance on a few key maturities allows for larger issue sizes, which reduce the price impact of large trades. Related, Brandt and Kavajecz (2004) find that idiosyncratic price variation tends to increase with bond age (often referred to as 'seasonedness'). According to a commonly held view, the relative scarcity of seasoned bonds increases the price impact of trading. For this reason, the most recently issued bond usually becomes the benchmark, and the 'benchmark liquidity phenomenon' becomes indistinguishable from the 'on-the-run liquidity phenomenon'. In the literature, researchers commonly use the latter term to describe the positive liquidity effects (partially) caused by the former. From a theoretical point of view this is mislead-

[2] This is also supported by the sovereign issuance strategies. For example, most new debt issued by the G-10 countries has 2-, 5-, or 10-year maturities.

[3] Hedging or replication of the market return based on three key maturities is common in passive bond portfolio management, see Dynkin, Gould, Hyman, and Konstantinovsky (2006)].

ing because the two phenomena have different origins: benchmark bonds are traded by those who wish to gain or hedge yield curve risk with minimal exposure to idiosyncratic risk, and on-the-run bonds by those who rebalance their portfolios after government auctions [Pasquariello and Vega (2009)] or prefer securities trading near par [Eom, Subrahmanyam, and Uno (1998); Elton and Green (1998)].

Although conceptually distinct, the benchmark and on-the-run liquidity effects are mutually reinforcing because increased liquidity arising from scale is beneficial to all traders. Uninformed trading in the market for on-the-run bonds, like hedging or portfolio rebalancing, attracts informed traders who minimize the price impact of their trades by pooling with the uninformed [Kyle (1985); Chowdhry and Nanda (1991)]. Informed trading fosters price discovery and improves the hedging effectiveness of the on-the-run bonds, which, as a consequence, become benchmarks of their maturity segments.

Intermediaries such as market makers are able to offset their exposure to yield curve risk by short-selling benchmark bonds. Subsequently, however, hedgers have to borrow benchmark bonds from those who own them to cover the short positions in the cash market.[4] To achieve this, hedgers use the repurchase market where they search for bond lenders and bargain over the terms of bond loans. In the repurchase market, hedgers' uninformed demand for benchmark bonds induces bond lenders to increase their supply which, in turn, makes benchmark bonds easier to locate and reduces search costs [Duffie, Garleanu, and Pedersen (2007)]. Vayanos and Weill (2008) show that this virtuous circle arises because short-sellers are contractually bound to a particular bond, which is the one that they initially sold short and eventually will have to buy back and deliver in the repurchase contract. Because of this delivery constraint, market participants typically find it optimal to short the same security as everyone else, i.e. the benchmark bond. As shown by Duffie (1996), superior repurchase-market availability of benchmark bonds increases their value as collateral, leading to an counterintuitive outcome that active short-selling may in fact *inflate* cash prices. Yet the very same phenomenon

[4]Fisher (2002) provides a description of the use of repo markets for bond inventory management.

that causes distortions in benchmark prices, namely their repo-market availability, also facilitates price discovery. This is because informed investors' ability to implement their pessimistic beliefs via shorting benchmarks is key to efficient price discovery process [Diamond and Verrecchia (1987); Cohen, Diether, and Malloy (2007); Boehmer, Jones, and Zhang (2008)] that, ultimately, warrants the retention of the benchmark status itself. Figure 3 illustrates this market coordination process that ultimately leads to the superior liquidity of benchmark on-the-run Treasuries.

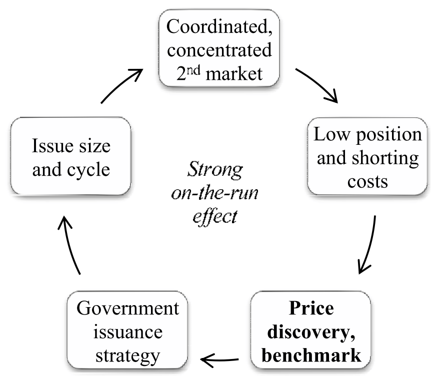

Figure 3: On-the-run effect in the cash market for U.S. Treasury securities.

As discussed above, a well-functioning repurchase market is key to cash market liquidity. On the supply side, market makers are able to lend out bonds and thereby leverage their capital, hold larger inventories, and provide more depth to the market. On the demand side, a large and dispersed investor base that ensures active trading and high liquidity is sustainable only if investors, who want to hedge or speculate with bonds that they do not already own, can take part in the market. For example, hedgers who sell and buy back benchmark bonds on a continuous basis increase the trading volume in the cash market, but are only able to do so using reverse repurchase contracts.

However, due to the multiplicity of markets and market participants involved in creating and maintaining liquidity, it is conceivable that multiple equilibria may occur, some of which may be characterized by low liquidity. Persistent pricing anomalies or market frictions reduce the usefulness of a benchmark for hedging or speculative purposes. For example, frictions in the repurchase market may force market makers to deleverage and cut back their liquidity provision in the cash market for including benchmark bonds. Also, cash market frictions may cause an inflationary spiral of shorting costs whereby investors gradually refrain from short-selling due to its trading intensive nature, and migrate to futures or swap market to create short positions.[5] Consequently, the decline in short selling in response to high shorting costs reduces cash market liquidity and shifts the locus of price discovery towards alternative markets. Brandt, Kavajecz, and Underwood (2007) as well as Mizrach and Neely (2008) provide recent empirical evidence from the U.S. Treasury market.

2.1 The German government bond market

Mainly as a consequence of its relative novelty, the euro-denominated sovereign bond market is still considerably more fragmented than the U.S. Treasury market. This fragmentation remains an impediment for the liquidity and informational efficiency of the European market, as order flow is dispersed over a large number of heterogeneous securities and markets. Consequently, positive externalities that arise when traders come together in space and time, namely better liquidity and/or price discovery, are not realized to the same extent as in the homogeneous U.S. Treasury market. The absence of 'spontaneous' liquidity described above leads to need for more 'artificial' liquidity providers in the form of market makers.

Notwithstanding the considerable widening of sovereign spreads in the course of the financial crisis, euro-area yields have converged dramatically relative to the pre-EMU period. This has created the conditions and the demand for common benchmark securities that accurately reflect the term structure of risk-free euro interest rates. Given that the benchmark status is gained through competition rather than being conferred,

[5] Establishing and maintaining a short position requires more trading than a long position because repurchase contracts are usually very short-term.

the multiplicity of sovereign issuers and the growth of euro-denominated swap market ensure that this implicit definition of benchmark bonds is ongoing in the euro area. In practice, 10-year German government bonds have retained their benchmark status within the euro area, owing to their relative liquidity and credit quality.[6] However, decentralized trading infrastructure in addition to a less well-established repurchase market increase the costs of taking and reversing short-term positions in the German cash market, which is why the bulk of trading and a major share of price discovery take place in the futures market [Bundesbank (2007); Upper and Werner (2007)] .[7] As a consequence, the benchmark status of German government securities may be attributed to both cash and futures markets: the futures contracts are the main instruments for hedging and speculating on euro area interest rates, while the cash instruments are primarily used for asset allocation purposes. This market organization contrasts with that of the U.S. Treasury market, where cash instruments, i.e. the benchmark on-the-run bonds, are used uniformly for pricing, positioning, and hedging.

In a futures-driven cash market, bonds that are deliverable for futures contracts may challenge the benchmark status of the on-the-run securities. This has been shown to be the case in the Japanese government bond (JGB) market, where the market's view of long-term yields is first reflected in the prices of JGB futures [Singleton (1996); Miyanoya, Inoue, and Higo (1999)], and then through arbitrage in the price of key deliverable bond and the rest of the JGBs [Shigemi, Kato, Soejima, and Shimizu (2001)]. Consistent with the arbitrage argument, Shigemi et al. report that the on-the-run and the key deliverable bond are the most actively traded JGBs in the cash market. In addition, Singleton (2004) finds that the key deliverable JGB has the highest sensitivity to changes in the term structure of all off-the-run JGBs, which corresponds to the

[6] Yields on French government BTANs and OATs are occasionally used as reference rates in the intermediate maturities.

[7] Bid-ask spreads in the EUREX futures market are approximately five to ten times smaller than in the MTS cash market. For comparison, the spreads in the cash and futures market for U.S. Treasuries are approximately equal.

argument by Yuan (2005) that benchmark status depends on securities' sensitivity to systematic risk. On the other hand, Singleton's results from the futures-driven JGB market contradicts those from the cash-driven U.S. Treasury market, where Brandt and Kavajecz (2004) find that the sensitivity to market risk declines monotonically in bond seasonedness.

Given the extremely large and liquid futures market for German government securities, one would expect that the relation between the cash and the futures market resembles that of the Japanese market rather than the U.S. Treasury market. As an initial assessment of this conjecture, we estimate the market sensitivities of German on- and off-the-run bonds as a crude measure of benchmark characteristics, and compare these sensitivities to those reported by Brandt and Kavajecz (2004). The bond-specific sensitivity is measured by the amount of yield variation explained by the three first principal components estimated from the term structure of German bonds. The results shown in Table 2 indicate that the German off-the-run bonds, which typically are the key deliverable bonds, reflect to changes in the term structure more precisely than on-the-run bonds. The exact opposite holds for the U.S. Treasury market, where the on-the-run bonds are most sensitive to yield curve risk. Overall, the results in Table 2 and the previous studies on the JGB market suggest that the on-the-run bonds would share the benchmark status with deliverable bonds in the German cash market.

What does the predominance of futures trading in the German market imply for the emergence of liquidity differences between bonds? The more diffuse benchmark status (shared among the bonds in the deliverable basket) contrasts with the unambiguous benchmark status of the on-the-run treasuries, and would suggest that liquidity differentials in the futures-driven German bond market ceteris paribus should be smaller than in U.S. market. Results of Witherspoon (1993) point to a certain threshold level in the informativeness of cash markets relative to futures markets, above which the benchmark status of on-the-run securities (and the liquidity effects thereof) is supported. If the futures market is too dominant with respect to price discovery, it tends

Table 2: The explanatory power of the first three principal components.

This table presents the percentages of yield variation explained by the three first principal components extracted from the correlation matrix of daily changes in German term structure. The sample includes observations on on- and off-the-run bonds in 2-, 5-, and 10-year maturities for the period January 2006-September 2008. The results for U.S. Treasury securities are from Brandt and Kavajecz (2004).

	Adjusted R^2	
Maturity	Germany	United States
2-year		
On-the-run	96.91%	99.57%
Off-the-run	97.27%	99.14%
5-year		
On-the-run	96.65%	99.44%
Off-the-run	97.77%	99.15%
10-year		
On-the-run	98.08%	99.28%
Off-the-run	98.36%	98.72%

to hamper the cash market liquidity due to substitution, but may otherwise enhance the liquidity and price discovery of deliverable bonds through cross-market arbitrage [Holden (1995)].[8]

Indirect evidence of cross-market arbitrage can be seen in the Figure 1 in the Introduction. This figure plots average daily trading volumes for 10-year bonds issued by the United States, Germany and France. The periods during which the bonds are on-the-run and deliverable for futures contracts are shaded with darker color. Maturities where bonds are deliverable, but no longer on-the-run are shaded in a lighter color. As opposed to 10-year U.S. Treasuries in Figure 1a and French OATs in Figure 1c, German Bunds in Figure 1b continue to be actively traded well after the six month on-the-run period and the volume of trading remains high for another year until the bonds are no longer deliverable for the 10-year futures contract. Indeed, the trading activity of

[8]Cross-market arbitrage had grown so popular that in 2003 Eurex launched "basis instruments" for German government bond market, which involve opposite positions in futures and cash markets.

off-the-run Bunds in Figure 1b appears to be governed by deliverability; trading seems to be less active through the periods of non-deliverability, only to become more intense again as seasoned Bunds again become deliverable.

A similar volume pattern does not obtain for U.S. Treasury securities, despite the fact that they are deliverable for the 10-year futures contract traded at the Chicago Board of Trade. A possible explanation is that the simultaneous price discovery in cash and futures markets weakens the cross-market lead-lag effect and thereby makes arbitrage less profitable and trading less worthwhile. Also, the delivery basket for the U.S. 10-year futures contains considerable more securities than in the German case, making arbitrage-based trading less observable in individual securities.

To sum up, costly frictions in the cash market for German government bonds would suggest a diversion of order flow away from the cash instruments and towards futures contracts. Low transaction costs and the ease of taking short positions in the futures market attracts both uninformed as well as informed traders. For this reason, German futures contracts dominate price discovery in euro interest rates over cash bonds.

This is a key difference from the U.S. Treasury market, where trading in the on-the-run bonds and futures contracts are complementary with regard to price discovery. As much an outcome as a cause, the on-the-run U.S. Treasuries are liquid relative to off-the-run securities and actively traded for hedging and speculative purposes. In the absence of such trading, such as for German on-the-run bonds, one would expect the liquidity differentials between on- and off-the-run bonds to be much less pronounced. Indeed, turnover and the related positive liquidity effects may be even greater for German *off-the-run* bonds, since they are typically the cheapest-to-deliver into the two-, five-, and ten-year futures contracts and therefore subject to cross-market arbitrage trading. Figure 4 illustrates this particular relationship between the German cash and futures markets.

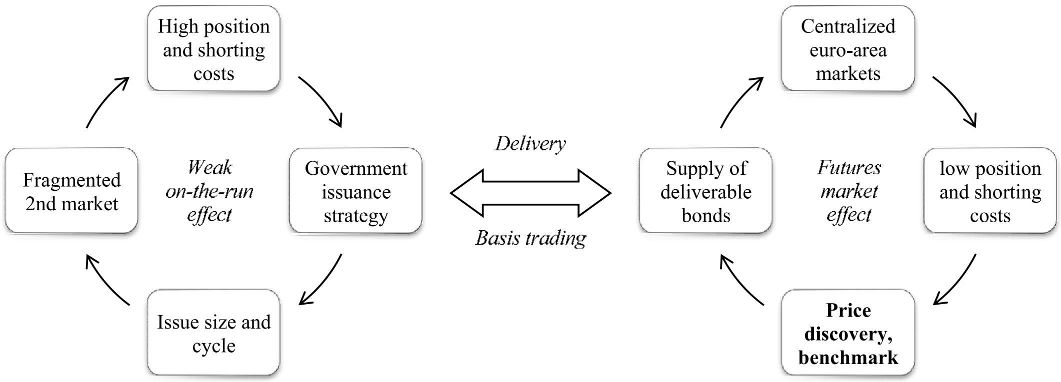

Figure 4: The combined cash and futures market effect in the German market.

3 Data

As is the case with most government bond markets, the secondary market for German government bonds is predominantly an over-the-counter market. Trading takes place mostly between dealers, either using traditional voice brokers and bilateral negotiation, or increasingly through electronic platforms. The source of our data on bond prices, quoted depth and quoted bid-ask spreads is MTS, the largest electronic trading venue for German government bonds, see Bundesbank (2007). MTS is a system of quote-driven platforms with designated market makers who compete for other market participants' order flow. Market makers supply liquidity for the bonds assigned to them by providing two-way proposals of a minimum size for at least five hours a day.

Our sample extends from January 2006 through September 2008. This period is particularly suitable for analysing government bond market liquidity as it covers both the tranquil period before mid-2007 as well as the turbulent period following the onset of the financial crisis.

Overall, our data include approximately ten million quotes and sixty thousand trades on bonds issued by the Federal Republic of Germany. The quote records include three best bid and offer quotes with the associated quote sizes at tick-by-tick frequency. Since quotes on MTS are binding unless withdrawn, the quote records allow us to obtain reliable estimates of the transaction costs that the market participants face as well as the size of the inventory that is available for immediate trade.[9] The transaction records include prices and quantities with an indicator variable of the direction of the trade (buy or sell). Every quote and trade entry in our records is identified by an individual security identification number (ISIN) and a time stamp recorded to the nearest millisecond. Bond issue sizes are provided by the German Finance Agency.

Despite its significant role in electronic trading, the MTS transactions constitute only a small fraction of the overall trading volume in German government bonds. For that reason, we supplement our MTS data with trading volume information provided by International Capital Market Association (ICMA) through Datastream. Analogous to GovPX in United States, ICMA collects and disseminates data on transactions made by its members in the over-the-counter markets. Approximately 400 financial institutions, including the largest dealers in German government bond market, report their trades to ICMA. The sample for traded volumes covers the period January 2002 through February 2009.

Following the findings of previous research, and reflecting the firm-quote nature of our data, we use traded volumes, quoted depths and quoted bid-ask spreads as our measures of liquidity. The quoted spread is defined as the difference between best ask and bid price and is measured in percent of the midpoint price. The bid-ask spread alone, however, does not provide any information about the amounts available for trading at a given time. We therefore also include market depth as a complementary measure of liquidity. Market depth is proxied by the average volume available for trading at the best three bid and offer prices.[10] Both quoted depths and spreads, which are observed at the intra-day frequency, are collapsed into representative daily

[9] To mitigate concerns that quotes are actually not firm, we compare transaction prices to standing quotes. We find that two thirds of the transactions in our sample are made exactly at the quoted prices. For the remaining third of the trades, the differences between quoted prices and transaction prices were small.

[10] Since MTS allows large transactions to be executed as iceberg orders, i.e. partially outside the order book, the market may be actually deeper than the cumulative depth indicates. We do not have data on the iceberg orders, but MTS reports that their share of all orders is less than two percent.

values by taking the median. This is an effective way of removing outliers, which is a serious problem when using end-of-day (or 'snapshot') quotes.

4 Determinants of liquidity in the German bond market

The aim of this section is to empirically assess whether liquidity differences across German government bonds are explicable in terms of deliverability into futures contracts. For this purpose, we consider four different liquidity measures: traded volumes, quoted depths, quoted bid-ask spreads and the 'liquidity index' proposed by Bollen and Whaley (1998). By constructing an (unbalanced) panel consisting of time-series observations (on liquidity measures and potential liquidity determinants) for a large cross-section of bonds, we can separately identify the impact on liquidity of deliverability and 'on-the-run' status. With respect to the impact of deliverability, we distinguish between 'cheapest-to-deliver' (CTD) bonds, and bonds which are merely deliverable.[11] We control for multiple other factors which have previously been found to determine liquidity. The set of control variables includes time to maturity, seasonedness (i.e. bond age) and issue size. Since our main interest is in the cross-sectional variation in liquidity between bonds with different characteristics, we also include time dummies. Time dummies help us overcome the potentially important short-coming that the MTS data reflect activity on electronic trading platforms and not the entire market. Anecdotal evidence suggests that in addition to the general decline in liquidity after July 2007, the market share of electronic platforms have declined.[12] By including time dummies, we minimize the impact of any trend in market share on our results.

To be more confident that any deliverability-related liquidity effects we may de-

[11] Owing to the construction of the so-called conversion factors, during our entire sample, the CTD bonds are consistently the outstanding bond with shortest remaining time to maturity of the bonds in the delivery basket.

[12] As volatility rose precipitously after mid-2007, market participants apparently became increasingly reluctant to supply liquidity to each other in the form of tradeable buy or sell quotes in limit-order markets.

tect are genuine, we conduct identical analyzes for a control country lacking a futures market. For this purpose we use France, as the French government bond market is comparable to the German market in terms of credit rating, currency and amounts outstanding in the individual bonds. In the following, we analyze the determinants of traded volumes, quoted depths, quoted bid-ask spreads and the liquidity index.

4.1 Determinants of traded volumes

To assess the determinants of traded volumes, we regress log average daily volume on time dummies (for each month), deliverability dummies, cheapest-to-deliver dummies, on-the-run dummies, time to maturity (measured in years), seasonedness (also measured in years) and log issue size.

The deliverability dummies reflect the EUREX criteria determining whether a particular bond is eligible for delivery into the 2, 5 and 10-year German bond futures. Eligible bonds for these three contracts have remaining maturity in the ranges 1.75-2.25 years, 4.5-5.5 years and 8.5-10.5 years, respectively. This gives rise to three deliverability dummies.[13] Note that (the compounded value of) the coefficients on these dummies can be interpreted as the percentage increase in trading volume for bonds belonging to the particular maturity bracket (relative to bonds in any of the undeliverable maturity brackets). We also include specific cheapest-to-deliver (CTD) dummies (one for each of the 2, 5 and 10-year futures contracts) taking the value one when a given bond is CTD into the next-to-expire futures contract, and zero otherwise.[14]

The remaining estimated coefficients also have interesting interpretations. The coefficient on the on-the-run dummies gauge the impact on trading volumes related to

[13] A newly issued 10-year bond will first be deliverable into the 10-year futures and then experience a time period where it is not deliverable (from 8.5 to 5.5 years remaining maturity) before it again becomes deliverable into the 5-year futures, and so on. For maturities below 1.75 years, the bond will never again become deliverable.

[14] We use the implied repo rate method to identify the cheapest-to-deliver bonds for each date and futures contract.

a bond being the most recently issued bond of a given original maturity. As mentioned above, studies on U.S. Treasuries typically find very large on-the-run effects on liquidity. The coefficient on the seasonedness variable can be interpreted as the annual percentage decay in trading volume as the bond ages. One would expect that trading volume (and other liquidity measures) decline as a bond ages, because an increasingly large fraction of the issued amount ends up in buy-and-hold portfolios. By controlling for other liquidity determinants in a panel setting (in particular deliverability and on-the-run effects, and developments in overall market liquidity as captured by the time dummies), we can identify the pace of such decay. Finally, the coefficient on the (log) issue size provides the elasticity of trading volumes with respect to issued amounts.[15]

Table 3 displays the results for the determinants of trading volumes for German bonds, and as a control, for French bonds. We first consider the results for Germany. Lines 2-4 of the table show that the impact of deliverability in all cases have the expected positive sign, and the coefficients are all highly statistically significant. The estimated effects of deliverability are economically important, as the estimated coefficients between 0.54 and 1.05 correspond to increases in trading volumes between 72% and 186%.[16] The next three lines in the table reveal that a bond tends to experience an *additional* boost in trading volumes when it is the cheapest-to-deliver bond. The (compounded) increases in trading volume for CTD bonds (relative to comparable non-deliverable bonds) are 148%, 253% and 229% for the 2, 5 and 10-year maturities.[17] On the other hand, on-the-run status *per se* has a somewhat smaller effect, increase trading by around 100%. Although the on-the-run effect on volumes is positive and highly statistically significant, it is smaller than the effects related to being cheapest-to-

[15] Lacking a time series of real-time outstanding amounts, we use outstanding amounts at the end of our sample. This of course ignores changes over time due to tap issues. Therefore we may overstate somewhat the outstanding amounts in some cases, and thus underestimate the true coefficient.

[16] The compounded effects are obtained as the exponential of the relevant estimated coefficients minus one.

[17] In this case, the compounded effects are obtained as the exponential of the sum of the relevant estimated coefficients (e.g. 2-year deliverability and 2-year CTD) minus one.

Table 3: Determinants of trading volumes for German and French bonds

The dependent variable is log trading volume. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively. Monthly observations from Jan. 2002 through Feb. 2009 (T=86).

	Germany		France	
	Slope	t-value	Slope	t-value
Intercept	-13.12	(-2.62)***	-13.64	(-2.40)**
$1.75 \leq$ maturity < 2.25	0.54	(8.27)***	0.38	(5.08)***
$4.50 \leq$ maturity < 5.50	0.67	(8.75)***	0.33	(3.67)***
$8.50 \leq$ maturity < 10.50	1.05	(7.99)***	0.51	(5.73)***
Cheapest-to-deliver for 2-year future	0.37	(2.78)***		
Cheapest-to-deliver for 5-year future	0.59	(7.45)***		
Cheapest-to-deliver for 10-year future	0.14	(1.19)		
On-the-run status	0.69	(4.88)***	0.59	(5.96)***
Seasonedness (in years)	-0.08	(-4.54)***	-0.12	(-7.19)***
Time to maturity (in years)	-0.02	(-1.79)*	0.01	(1.22)
Log issue size	1.42	(6.64)***	1.38	(5.79)***
Month-fixed effects	Yes		Yes	
Sample	Jan 02-Feb 09		Jan 02-Feb 09	
Number of months	86		86	
Number of bonds	109		66	
Number of month-bond obs.	4427		3024	
Adjusted-R^2	0.73		0.64	

deliver. This comparatively modest on-the-run effect contrasts with the overwhelming effect seen in studies using U.S. Treasury data. The decay related to bond aging (seasonedness) is estimated to be around 8% per year. This implies, for example, that an old 30-year with eight years remaining maturity would attract less than a fifth of the trading volume of a two-year-old 10-year bond with same remaining maturity and issue size. Finally, we find the elasticity of trading volumes with respect to the amount issued to be higher than one. This may reflect that not only are large issues traded more, the resulting enhanced liquidity (in terms of depth and expected transaction costs) may also feed back positively on trading in the bond.

The two rightmost columns of Table 3 display the comparable results for French government bonds. A first thing to note is that all significant coefficients have the same sign as in the German case. Also, all the coefficients of the control variables have very similar magnitudes. There are, however, notable differences in the relative size of the coefficients on the deliverability and on-the-run dummies. In particular, the dummies for the three maturity brackets considered (corresponding to 'deliverability' in the German case) have coefficients which are below that of the on-the-run dummy. This considerably smaller 'deliverability' effect for French bonds probably reflects the absence of a liquid futures market for French government bonds. It should be noted, though, that even these hypothetically 'deliverable' French bonds tend to trade significantly more than their 'non-deliverable' counterparts. A possible explanation is that French bonds which match the maturity requirements for the German futures also can be quite accurately hedged with positions in these futures. Moreover, higher cash-market liquidity for German bonds would make cross-country spread trades cheaper to execute. Therefore, both direct and indirect liquidity spillovers from the German futures market into the French cash bond market are conceivable.

Tables 13-14 in Appendix A show the results when the data set is split in pre-crisis and crisis samples. While the main results remain unchanged, it is notable that the 'deliverability' effect French bonds declined in the crisis sample. This may reflect that the ability to hedge French bonds with German futures was hampered by the dramatic increase in the level and variability of the French-German yield spread. Thus liquidity spillovers to 'deliverable' French bonds may well have declined.

As a robustness check, Table 12 (also in Appendix A) displays the corresponding results for the full-sample panel regressions, but without time dummies. The estimated coefficients remain virtually unchanged and the 85 dummies add relative little to the overall explanatory power of the model. This clearly suggests that the inclusion of time dummies does not drive the results.

4.2 Determinants of quoted depths

Table 4 shows the results of similar panel regressions, but now using quoted debts as the dependent variable. For the pre-crisis sample (the two leftmost columns), quoted depths can be broadly explained by time-to-maturity, seasonedness and log issue size. However, even in this tranquil period, there is evidence that deliverability increases quoted depths. The effects are however smaller than for traded volumes.

In the crisis sample (from July 2007 to September 2008), the importance of deliverability become more pronounced.[18] The amount available for immediate trading at firm quotes was thus significantly higher for deliverable bonds. This holds for all three futures contracts considered (2, 5 and 10 years). Interestingly, the status as 'cheapest-to-deliver' does not appear to add extra depth in this period. This suggests that it is the ability to hedge a given bond with a futures contract which matters for liquidity, rather than the prospects of actual delivery. It is also noteworthy that during the crisis, on-the-run status became insignificant for German bonds. Overall, the coefficients for the remaining controls are quite comparable over the sub-samples: seasonedness and time-to-maturity have the expected signs and are always highly significant. This is in line with the inventory view, where bonds with a long time to maturity (and thus the

[18]This is formally confirmed by a joint exclusion test (F-test) for sub-period dummies interacted with deliverability variables, carried out in regression for the entire sample.

high interest rate risk) are less liquid, as are bond which are 'old' (because the have increasingly ended up in 'buy-and-hold' portfolios). As expected, issue size is important for depth, although much less so than it was for volumes.

For the control country, France (see Table 15 in Appendix A), in the pre-crisis sample, 'deliverability' had a positive effect on depth, but again less than for Germany. The 'on-the-run' status was again found to be quantitatively more important than 'deliverability' for French bonds (in both sub-samples).

4.3 Determinants of quoted bid-ask spreads

Table 5 shows the results for quoted bid-ask spreads. The results for the pre-crisis period are somewhat puzzling: three of deliverability dummies are significant, but have the wrong sign. On-the-run status, on the other hand, has the right negative sign (i.e. spreads are tighter for on-the-run issues), although not strongly significant. One possible explanation is that in the pre-crisis sample, market makers had quoting obligations (i.e. they had to post bid and ask prices which complied with a certain maximum spread). Our results suggests that these spreads were to a very large extent determined by bond characteristics such as time to maturity, seasonedness and issue sizes. Note also that R^2 is as high as 0.93 in this case.[19]

During the crisis sample, where market-maker obligations were suspended most of the time, the picture changed somewhat. Two of the deliverability dummies become significant, and they also have the expected negative sign. Quantitatively, the estimated effects on spreads remain rather small, though. This may indicate that for smaller trade sizes, the distinction between deliverable and non-deliverable bonds may not be particularly important. Market-makers may be willing to provide liquidity in the form of relatively tight bid-ask spreads for small amounts also in non-deliverable bonds. It seems plausible, on the other hand, that if market makers are to provide substantially liquidity in the form of tight bid-ask spreads for large amounts, the ability to hedge

[19]Table 16 in Appendix A shows the comparable results for France, which are broadly similar.

Table 4: Determinants of quoted depth for German government bonds

The dependent variable is monthly averages of daily cumulated (log) depth. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively.

	pre-crisis		crisis	
	Slope	t-value	Slope	t-value
Intercept	4.00	(1.97)**	9.20	(4.60)***
$1.75 \leq$ maturity < 2.25	0.32	(6.51)***	0.34	(7.89)***
$4.50 \leq$ maturity < 5.50	0.04	(0.68)	0.38	(7.90)***
$8.50 \leq$ maturity < 10.50	0.16	(2.18)**	0.47	(10.10)***
Cheapest-to-deliver for 2-year future	-0.06	(-0.97)	-0.06	(-0.94)
Cheapest-to-deliver for 5-year future	0.09	(2.67)***	0.05	(0.67)
Cheapest-to-deliver for 10-year future	0.07	(0.94)	-0.05	(-1.18)
On-the-run status	0.20	(3.26)***	0.09	(1.25)
Seasonedness (in years)	-0.04	(-4.51)***	-0.05	(-5.24)***
Time to maturity (in years)	-0.05	(-13.88)***	-0.03	(-10.46)***
Log issue size	0.58	(6.75)***	0.35	(4.18)***
Month-fixed effects	Yes		Yes	
Sample	Jan 06-Jun 07		Jul 07-Sep 08	
Number of months	18		15	
Number of bonds	75		75	
Number of month-bond obs.	902		748	
Adjusted-R^2	0.78		0.71	

with futures likely becomes more important. To better capture both the depth and spread dimensions of liquidity simultaneously, we finally consider a ‘liquidity index’ defined as the quoted depth divided by the bid-ask spread.

4.4 Determinants of the liquidity index

The liquidity index is intended to capture the possibility that despite tightly quoted bid-ask spreads, a market may not necessarily be liquid with respect to execution of larger trades. Similarly, although quoted depth is a quite informative measure, it does not take into account the tightness of the market: there may large depth, but if bid and ask prices are far apart, such a situation would not necessarily correspond to a liquid market. To ensure the robustness of our findings against such short-comings of the one-dimensional liquidity measures, we present in Table 6 the results of the same regressions as above, but now using the liquidity index as the dependent variable. On this alternative measure of liquidity, the importance of deliverability clearly rose in the crisis sample for the 5 and 10-year maturities. In the pre-crisis samples, the liquidity index could be explained almost most exclusively by time to maturity, seasonedness and issue size.

Overall, this section has provided three main results. First, the liquidity of German bonds which were deliverable into the nearest-to-expiry futures contracts were found to be superior to non-deliverable bonds, when controlling for relevant bond characteristics such as time to maturity, seasonedness and issue size. Second, the positive impact on liquidity of belonging to the deliverable maturity intervals was consistently found to be higher for German bonds than for the control (French bonds), and - consistent with the more diffuse benchmark notion in the German market - the importance of ’on-the-run’ status was found to be correspondingly lower for German bonds. Third, with respect to the comparison across market regimes, i.e. the pre-crisis versus crisis samples, we found that the importance of deliverability generally increased in the crisis sample. We now turn to the question, whether deliverability is also priced into German bond yields,

Table 5: Determinants of quoted bid-ask spreads for German government bonds

The dependent variable is monthly averages of daily (log) bid-ask spreads. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively.

	pre-crisis		crisis	
	Slope	t-value	Slope	t-value
Intercept	10.25	(4.42)***	12.42	(7.41)***
$1.75 \leq$ maturity < 2.25	0.03	(0.55)	-0.10	(-2.11)**
$4.50 \leq$ maturity < 5.50	0.36	(4.89)***	0.03	(0.37)
$8.50 \leq$ maturity < 10.50	0.25	(3.38)***	-0.12	(-1.66)*
Cheapest-to-deliver for 2-year future	0.26	(2.62)***	0.41	(2.57)**
Cheapest-to-deliver for 5-year future	-0.02	(-0.55)	0.05	(0.43)
Cheapest-to-deliver for 10-year future	-0.09	(-1.40)	-0.12	(-0.66)
On-the-run status	-0.25	(-2.36)**	-0.25	(-2.31)**
Seasonedness (in years)	0.03	(3.33)***	0.04	(5.95)***
Time to maturity (in years)	0.09	(16.13)***	0.09	(18.61)***
Log issue size	-0.43	(-4.37)***	-0.52	(-7.32)***
Month-fixed effects	Yes		Yes	
Sample	Jan 06-Jun 07		Jul 07-Sep 08	
Number of months	18		15	
Number of bonds	75		75	
Number of month-bond obs.	846		736	
Adjusted-R^2	0.93		0.91	

Table 6: Determinants of liquidity index for German government bonds
The dependent variable is monthly averages of daily (log) depth divided by bid-ask spread. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively.

	pre-crisis		crisis	
	Slope	t-value	Slope	t-value
Intercept	5.83	(2.83)***	13.11	(5.71)***
$1.75 \leq$ maturity < 2.25	0.15	(2.79)***	0.20	(2.87)***
$4.50 \leq$ maturity < 5.50	0.08	(1.06)	0.46	(5.97)***
$8.50 \leq$ maturity < 10.50	0.10	(1.05)	0.57	(6.31)***
Cheapest-to-deliver for 2-year future	-0.33	(-2.94)***	-0.42	(-2.20)**
Cheapest-to-deliver for 5-year future	0.01	(0.34)	-0.06	(-0.59)
Cheapest-to-deliver for 10-year future	0.09	(1.06)	0.12	(0.83)
On-the-run status	0.30	(2.88)***	0.25	(1.58)
Seasonedness (in years)	-0.05	(-5.43)***	-0.07	(-6.54)***
Time to maturity (in years)	-0.13	(-21.83)***	-0.13	(-18.33)***
Log issue size	0.84	(9.53)***	0.52	(5.33)***
Month-fixed effects	Yes		Yes	
Sample	Jan 06-Jun 07		Jul 07-Sep 08	
Number of months	18		15	
Number of bonds	75		75	
Number of month-bond obs.	902		748	
Adjusted-R^2	0.94		0.91	

either directly or indirectly through enhanced liquidity.

5 Price effects of liquidity and deliverability

Having established the positive relation between deliverability and a range of liquidity measures for German government securities, we now examine whether liquidity in general and deliverability in particular are priced. We refrain from using German non-deliverable bonds as pricing benchmarks since their *future* deliverability may affect current prices in the form of liquidity or convenience premium. Instead, we compare the yields on deliverable and non-deliverable German securities to those of France. Besides having monetary policy in common, France is, as mentioned above, a natural choice as a benchmark since the amount of outstanding French debt corresponds to that of Germany in both absolute and relative (% of GDP) terms. Partly as a consequence, the difference in the credit quality are small, which allows us to pin down more precisely the marginal valuation of liquidity. In addition, France does not have a bond futures market, and this allows us to identify the impact of deliverability on German bond yields.

5.1 Variable construction

In order to obtain and easily compare French and German bond yields at different maturities, we estimate continuous zero-coupon yield curves for both countries using smoothed cubic spline interpolation. Cubic splines have been widely used in the literature, and this functional form provides enough flexibility to capture local yield effects that may arise from market segmentation. Once the two curves are estimated from the cross-section of French and German bond prices, we compute the yield spread between the two curves at maturities $m = \{1.0, 1.5, ..., 10.0\}$, with additional observations at 1.75 and 2.25 year maturities.[20] These maturities cover the most relevant part of the

[20]To ensure that the set of securities used in the estimation procedure is homogenous, the following types of securities are excluded: securities with floating rate coupons, securities with remaining maturity

yield curve, and the following maturity subsets 1.75−2.25, 4.5−5.5, and 8.5−10.0 that correspond to the baskets of EUREX German government securities deliverable for 2-, 5-, and 10-year futures contracts, respectively. We calculate these yield differentials for each trading day from January 2006 through September 2008.[21]

We attempt to explain the yield spread across maturities and over time with the difference between French and German bond market liquidity and the deliverability of German securities. To accomplish this, we use the MTS data on French bonds to compute daily liquidity measures similar to those described in Section 3. Once we have the necessary liquidity measures for both French and German bonds, we average them across non-overlapping maturity brackets centered on each maturity m. That is, we use group averages instead of individual values in order to mitigate individual bond effects and non-synchronous maturities. The valuation effects of deliverability are captured by a set of dummy variables that correspond to the ranges of deliverable maturities specified in EUREX futures contracts.

In addition to liquidity and deliverability, several recent studies find that perceived differences in the credit quality of euro-area sovereign issuers have effects on the relative pricing of their bonds.[22] Although we minimize this effect by comparing two sovereign issuers with similar fiscal fundamentals, a market-based measure that is available on daily basis is nevertheless desirable to capture additional aspects of governments' perceived credit quality. For this reason, we augment our empirical model of the interest rate spread with data on sovereign credit default swaps (CDS). [23]

---

less than one year, securities with issue size less than EUR 5 billion, securities issued in non-euro currencies, securities originating from a coupon-stripping program, securities issued by government special fund, and inflation- or index-linked securities. Moreover, to disentangle the hypothesized price effect of on-the-run status, the most recently issued securities are excluded as well.

[21] The fit of the spline function is good for both countries, with the mean absolute fitting error being less than one basis point.

[22] See, for instance, Codogno, Favero, and Missale (2003); Bernoth, von Hagen, and Schuknecht (2004); Beber, Brandt, and Kavajecz (2009); Schuknecht, von Hagen, and Wolswijk (2008)

[23] A sovereign CDS is contract that allows the investor to hedge against the event that a particular government defaults on its debt. In exchange for this 'credit protection', the investor agrees to make

A convenient property of CDS premiums is that they provide more direct reflections of the market's assessment of sovereign credit risk. This allows us to compute the credit risk premium on a five-year German government bond simply by subtracting the premium paid on a five-year CDS contract from bond's par yield. In the case of non-integer maturities for which the CDS contracts are not traded, we use observed premiums on nearby contracts to linearly interpolate the missing intermediate ones. Once the credit risk premium is netted out, we can decompose the residual par yield into elements associated with risk-free rate, liquidity, and deliverability. Consequently, French and German spot rates obtained from the spline estimation are transformed into par yields.

Finally, motivated by the results of Krishnamurthy and Vissing-Jorgensen (2007), we control for a potential negative relationship between aggregate supply and pricing of government debt. In particular, we calculate the average sizes of outstanding French and German bond issues on a daily basis and use their logarithmic difference to gauge changes in the relative supply of national debt. We also include year dummies and time-to-maturity as additional control variables to capture any unobserved factors that might affect the relative valuation.

Table 7 presents the summary statistics for yield, liquidity, quality, and issue size differentials between France and Germany. To facilitate comparison across maturities, the statistics are categorized by maturity segments that correspond to permanently non-deliverable maturities as well as 2-, 5-, and 10-year delivery baskets. As shown in Table 7, the differentials of par yields, bid-ask spreads, and credit risk are consistently positive across maturities, whereas log issue size differentials are negative. Taken together, this imply that investors perceive liquidity and credit quality of French bonds to be slightly inferior to their German counterparts, and this may explain that the French securities

periodic payments, known as premiums, to the seller of the contract over its life or until the government defaults. Compiled by Credit Market Analysis Ltd. and provided by Thomson Datastream, our CDS data is based on daily indicative bid premiums quoted by thirty key market participants for contracts on French and German government bonds with average residual maturities from one to ten years.

command higher yields across the yield curve. Several other results should be noted from Table 7. In our sample, the average size of French issues is approximately six per cent smaller than that of German bonds, and the size differential varies from -12% to zero. Yet despite the larger stock of debt, German bonds seem to trade at yield levels that are economically and statistically lower than those required on French securities, which suggests that the positive liquidity effects associated with larger float outweigh the direct supply effects. In addition, the variables in Table 7 exhibit substantial variation both in the cross-sectional and time-series dimensions, which motivates the use of panel estimation techniques.

5.2 Empirical results

To empirically test the conjectured relation between the French-German yield spread and the factors associated with relative liquidity, quality, and deliverability, we pool our data in a panel that includes a time series of daily observations from 2 January 2006 to 30 September 2008 for each maturity m. We split the panel into two sub-samples, using 1 July 2007 as the break to investigate whether the economic importance of our valuation factors change after the onset of the financial crisis. To this end, we estimate the following econometric model both for the pre-crisis period and the crisis period using panel least squares regression:

$$\begin{aligned} R^F_{t,m} - R^G_{t,m} = \alpha + \beta_1(LIQ^F_{t,m} - LIQ^G_{t,m}) + \beta_2(CDS^F_{t,m} - CDS^G_{t,m}) \\ + \ \beta_3[\log(AIS^F_t / AIS^G_t)] + \boldsymbol{\delta}(\mathbf{DEL_m}) + \boldsymbol{\lambda}(\mathbf{X_{t,m}}) + \varepsilon_{t,m} \quad (1) \end{aligned}$$

where

$$\mathbf{DEL_m} = \{NONDEL_{<1.75}, DEL_{1.75-2.25}, DEL_{4.5-5.5}, DEL_{8.5-10.5}\}$$
$$\mathbf{X_{t,m}} = \{m,\ \textit{year dummies}\}$$

and $R^i_{t,m}$ denotes the estimated par yield for country i and maturity m at day t. $CDS^i_{t,m}$

Table 7: Summary statistics on variables used in multivariate analysis

This table presents the summary statistics on the variables used in multivariate analysis for various maturities m. Asterisks *** after robust t-values (in parentheses) denote values significantly different from zero at the 1% level. Daily observations from January 2nd 2006 to September 30th 2008.

	Mean	t-value	Min	Max	SD		Mean	t-value	Min	Max	SD
Par yield differential (*bps*)						Log depth differential					
$m<1.75$	2.17	(4.19)***	-2.00	9.00	1.71	$m<1.75$	-0.19	(-2.01)***	-1.09	0.89	0.33
$1.75\leq m<2.25$	3.61	(17.73)***	-1.00	18.00	3.77	$1.75\leq m<2.25$	0.06	(0.97)	-1.10	0.81	0.38
$4.50\leq m<5.50$	4.28	(15.59)***	-4.00	27.00	5.94	$4.50\leq m<5.50$	-0.42	(-2.96)***	-2.30	0.86	0.48
$8.50\leq m<10.0$	10.79	(10.97)***	2.00	34.00	6.76	$8.50\leq m<10.0$	-0.29	(-3.61)***	-1.94	1.79	0.48
All	5.21	(6.16)***	-4.00	34.00	5.96	All	-0.23	(-4.14)***	-2.30	1.95	0.42
Percentage bid-ask spread differential (*bps*)						Credit risk differential (*bps*)					
$m<1.75$	0.79	(4.62)***	-3.00	67.00	3.47	$m<1.75$	0.60	(17.3)***	-3.95	6.65	1.48
$1.75\leq m<2.25$	1.26	(13.34)***	-3.00	45.00	2.48	$1.75\leq m<2.25$	0.64	(10.24)***	-5.60	7.00	1.77
$4.50\leq m<5.50$	3.48	(11.88)***	-3.00	62.00	6.78	$4.50\leq m<5.50$	0.95	(14.07)***	-3.10	7.10	1.79
$8.50\leq m<10.0$	2.49	(7.64)***	-2.00	65.00	5.25	$8.50\leq m<10.0$	1.43	(27.19)***	-2.20	6.50	1.95
All	2.60	(6.35)***	-3.00	67.00	5.60	All	1.05	(8.74)***	-5.60	7.10	1.83
Log average issue size differential											
All	-0.06	(-50.71)***	-0.12	0.00	0.04						

and $LIQ^{i}_{t,m}$, and AIS^{i}_{t} are the credit default swap premium, liquidity measure, and average issue size, respectively. The liquidity measures are percentage bid-ask spread, log depth, or the log ratio of depth and spread. We adopt log specifications in order to be able to interpret the corresponding regression coefficients as semi-elasticities of the yield spread. $\mathbf{DEL_m}$ is a vector of dummy variables that represent different deliverability conditions and $\boldsymbol{\delta}$ is the corresponding vector of coefficients. In particular, DEL_m takes the value of one if maturity m is deliverable for a German futures contract, that is, it satisfies the maturity condition shown in the subscript. $NONDEL_{<1.75}$ is one for maturities less than 1.75 years that are permanently non-deliverable. $\mathbf{X_{t,m}}$ includes other control variables, namely time-to-maturity and year dummies. In all the regressions, we adjust for both cross-sectional and time effects in residuals $\varepsilon_{t,m}$ using the variance estimators suggested by Thompson (2005).[24]

The estimation results for Equation 1 appear in Tables 8 and 9. Table 8 reports the determinants of the yield spread before the onset the financial crisis. The coefficients for different liquidity measures are not statistically different from zero, suggesting that liquidity was not a key concern for the marginal investors in the pre-crisis period. This result, however, holds only for measures of "artificial liquidity" (i.e. liquidity provided by market makers as opposed to endogenously emerging liquidity): the log ratio of average issue sizes, a measure of relative float, loads negatively on the yield spread and is statistically significant. This means that the indirect liquidity benefits arising from larger issues more than offset the direct supply effects.[25]

[24]Thompson (2005) suggests the following variance estimator $\widehat{Var}(\widehat{\beta})$ for an OLS estimator $\widehat{\beta}$ that is robust to heteroscedasticity and correlation across both distinct maturities m and time t:

$$\widehat{Var}(\widehat{\beta}) = \widehat{\mathbf{V}}_{\mathbf{m}} + \widehat{\mathbf{V}}_{\mathbf{t}} - \widehat{\mathbf{V}}_{\mathbf{White}}$$

where $\widehat{\mathbf{V}}_{\mathbf{m}}$ and $\widehat{\mathbf{V}}_{\mathbf{t}}$ are the estimate variances that cluster by maturity and time [Huber (1967); Rogers (1983)], respectively, and $\widehat{\mathbf{V}}_{\mathbf{White}}$ is the usual heteroskedasticity robust OLS variance matrix [White (1984)].

[25]Although it has to be emphasized that the economic importance of increased float is marginal: coefficient -0.22 implies that a one standard deviation decrease (-0.04) in the issue size ratio increases the yield spread by approximately one basis point.

TABLE 8: THE DETERMINANTS OF SOVEREIGN YIELD SPREAD: PRE-CRISIS PERIOD

This table contains the results contains the results of least squares regression of Equation 1. The dependent variable is $R^F_{t,m} - R^G_{t,m}$, the difference between French(F) and German(G) par yield for maturity m at day t, measured in basis points. $CDS^i_{t,m}$, $LIQ^i_{t,m}$, and AIS^i_t are the credit default swap premium, liquidity measure (bid-ask spread, log depth, or the log ratio of depth and spread), and average issue size, respectively. $NONDEL_m$ and DEL_m are dummy variables that take the value of one if maturity m satisfies the limits shown in the subscripts. Asterisks *, ** and *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively. Daily observations from January 2nd 2006 to June 29th 2007.

	Spread		log Depth		$\log \frac{\text{Depth}}{\text{Spread}}$	
	Slope	t-value	Slope	t-value	Slope	t-value
Intercept	-0.86	(-1.53)	-0.87	(-1.55)	-0.87	(-1.59)
$LIQ^F_{t,m} - LIQ^G_{t,m}$	-0.11	(-0.99)	0.42	(1.33)	0.33	(1.51)
$CDS^F_{t,m} - CDS^G_{t,m}$	0.16	(2.24)**	0.15	(2.20)**	0.15	(2.22)**
$\log(AIS^F_t / AIS^G_t)^\dagger$	-0.22	(-6.34)***	-0.22	(-6.44)***	-0.22	(-6.35)***
$NONDEL_{<1.75}$	0.80	(2.30)**	0.97	(2.34)**	0.91	(2.45)**
$DEL_{1.75-2.25}$	0.83	(5.00)***	0.74	(4.72)***	0.77	(5.21)***
$DEL_{4.5-5.5}$	-0.60	(-1.45)	-0.51	(-1.25)	-0.55	(-1.41)
$DEL_{8.5-10.5}$	3.56	(4.24)***	3.57	(4.22)***	3.51	(4.20)***
m	0.24	(1.71)*	0.25	(1.74)*	0.25	(1.81)*
Year-fixed effects	Yes		Yes		Yes	
Number of obs.	6133		6133		6133	
Adjusted-R^2	0.69		0.68		0.69	

†The regression coefficient is multiplied by 100.

In addition, the deliverability of German bonds appear to be priced, with the convenience yield for holding deliverable bonds being the highest in the 10-year segment at 3.5 *bps*, and less significant for 2- and 5-year segments. Positive, albeit small, coefficient for non-deliverable bonds indicates that deliverable bonds do not lose value once they drop permanently out of delivery basket, which mutes the importance of deliverability especially in the 2-year segment. The coefficients for time-to-maturity, all around 0.25, indicate that the yield spread increases by one basis point for every four-year increment in residual maturity.

Consistent with economic intuition, we also find that the difference in perceived credit quality is positively related to the sovereign yield spread.

Table 9 the results based on the crisis period. All statistically significant coefficients have the expected sign and are larger in magnitude than for the pre-crisis sample. This points to an increased importance of liquidity, quality, and deliverability associated in times of market stress. For example, positive and negative coefficients for bid-ask and liquidity index differentials, respectively, indicate that increased demand for the relatively more liquid German securities depresses the entire yield curve compared to the French one. In particular, a positive coefficient of 0.19 for the bid-ask spread differential implies that a two standard deviation (7.2 in the crisis sample) increase in the relative bid-ask spread is associated with 1.4 *bps* increase in the yield spread across maturities. Also, the liquidity index, which incorporates both spread and depth information, is higher for German securities and thereby loads negatively on the yield spread.

In addition to relative liquidity, the economic importance of relative credit quality increases in the times of market disturbance. Specifically, we find that the coefficients for credit risk differential triple in the crisis sample, ranging from 0.35 to 0.42. Therefore, a ten basis point increase in the CDS spread is associated with approximately four basis point increase in the yield spread.

Consistent with the results in Table 8, the relative issue size is negatively related

Table 9: The determinants of French-German yield spread: Post-crisis period

This table contains the results of the Panel OLS regression of Equation 1. The dependent variable is $R^F_{t,m} - R^G_{t,m}$, the difference between French(F) and German(G) par yield for maturity m at day t, measured in basis points. $CDS^i_{t,m}$, $LIQ^i_{t,m}$, and AIS^i_t are the credit default swap premium, liquidity measure (bid-ask spread, log depth, or the log ratio of depth and spread), and average issue size, respectively. $NONDEL_m$ and DEL_m are dummy variables that take the value of one if maturity m lies in the maturity range shown in the subscripts. Asterisks *, ** and *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively. Daily observations from 1 July 2007 to 30 September 2008.

	Spread		log Depth		$\log \frac{\text{Depth}}{\text{Spread}}$	
	Slope	t-value	Slope	t-value	Slope	t-value
Intercept	-1.58	(-1.14)	-0.30	(-0.23)	-1.34	(-0.91)
$LIQ^F_{t,m} - LIQ^G_{t,m}$	0.19	(6.33)***	0.37	(0.82)	-0.52	(-1.77)*
$CDS^F_{t,m} - CDS^G_{t,m}$	0.42	(3.82)***	0.35	(2.92)***	0.36	(2.98)***
$\log(AIS^F_t / AIS^G_t)^\dagger$	-0.65	(-7.22)***	-0.61	(-6.1)***	-0.69	(-6.88)***
$NONDEL_{<1.75}$	-2.15	(-3.36)***	-2.19	(-3.91)***	-2.29	(-3.49)***
$DEL_{1.75-2.25}$	1.67	(3.88)***	1.56	(3.39)***	1.75	(3.88)***
$DEL_{4.5-5.5}$	1.37	(2.91)***	1.87	(4.45)***	1.41	(3.43)***
$DEL_{8.5-10.5}$	6.03	(4.25)***	5.36	(4.79)***	5.39	(4.36)***
m	0.39	(1.95)**	0.58	(4.14)***	0.52	(2.88)***
Year-fixed effects	Yes		Yes		Yes	
Number of obs.	5511		5511		5511	
Adjusted-R^2	0.75		0.71		0.71	

†The regression coefficient is multiplied by 100.

to the yield spread in the crisis time as well. However, coefficients from -0.61 to -0.69 are three times larger and suggest that in times of stress, a large float (which makes bonds easier to locate in an OTC market) becomes especially important.

Finally, the deliverability indicators have explanatory power for the yield spread even after controlling for the liquidity differential, which suggests that the value of holding deliverable bonds cannot be completely explained with their superior liquidity as measured by our liquidity indicators. Again, the convenience yield is largest for the 10-year segment, 5.4 to 6.0 *bps* depending on the model specification. Furthermore, it should be emphasized that these figures are over and above the future deliverability premium, which varies from 2.2 to 2.3 *bps*, so that the total convenience yield for 10-year deliverables could well be as high as 8.2 *bps*. For short- and medium-term deliverable bonds the convenience yields are smaller, but still economically significant at around four basis points. We conjecture that wider and deeper delivery baskets in the 2- and 5-year segments reduce the convenience yield attached to individual bonds. The coefficient for time-to-maturity implies that the yield spread in the 10-year segment is ranges from 4 to 6 *bps*, ceteris paribus, depending on the liquidity measure used.

In a recent article, Kuipers (2008) finds similar albeit much smaller deliverability effects for U.S. Treasury bonds deliverable for 30-year futures contract. Kuipers (2008) reports a price premium of less than one basis point on a yield basis, which is in gross terms since the effect of liquidity is not controlled for.

We perform two robustness checks. First, we re-estimate both samples using quantile regression which is less sensitive to distributional assumptions and outliers. In particular, maximum yield and bid-ask spreads presented in Table 7 are quite high compared to their sample averages, which raises concerns that the above results are driven by a few influential outliers. To address this concern, we model the conditional *median* of the independent variables instead of the conditional *mean* reported in Tables 8 and 9. For brevity, we do not report these results in detail but note that they are qualitative similar to those presented in the above tables. Therefore, we conclude that extreme observations do not drive our findings. Second, we address the potential simultaneity bias arising from the joint determination of sovereign yield and CDS spreads by excluding the latter from the regressions. Leaving the CDS differential out of the regressions does not change the subsequent results in any significant way, suggesting that out conclusions from Tables 8 and 9 are robust also in that respect.

5.3 Value of on-the-run status

Having established the negative relation between German bond yields and deliverability, we turn our attention to the most recently issued securities and ask whether the on-the-run status has pricing relevance beyond deliverability. Our approach is straightforward and familiar from the work of Elton and Green (1998) and others. We use the spot curve estimated from the daily prices of German off-the-run bonds to value a synthetic bond with a cash flow schedule similar to that of the on-the-run bond. The reference price is then converted to a yield and subtracted from the actual market yield of the on-the-run bond. If the resulting yield spread is negative, it means that investors are willing to accept lower yields for on-the-run securities relative to similar, off-the-run securities. Table 10 provides summary statistics on yield spreads for German 2-, 5-, and 10-year on-the-run securities.

The yield discount attached to the on-the-run status is surprisingly small for German government bonds. The mean yield concessions that investors are willing to pay in order to own on-the-run securities varies from 1.8 *bps* in the 2-year segment to -1.7 *bps* in the 10-year segment, where the latter value is not statistically different for zero. Since the reference yields in the 10-year segment are based on the prices of deliverable bonds, it can be concluded that investors do not attach additional value to newly issued 10-year bonds over seasoned 10-year bonds which remain deliverable for the 10-year futures contracts. In the 2- and 5-year segments, the on-the-run bonds trade at yields that are 1-2 *bps* below the off-the-run curve, but it should be emphasized that the economic significance of on-the-run status appears trivial compared to Japanese or

Table 10: Summary statistics on yield discounts associated with German on-the-run issues

This table reports summary statistics on yield spreads between actual German on-the-run bonds of various types and reference securities with similar maturity and coupon rate. Reference yields are estimated from the term structure using cubic splines. All values are in basis points. Asterisks *** after robust t-values (in parentheses) denote values significantly different from zero at the 1% level. Daily observations from 2 January 2006 to 30 September 2008.

	Mean	t-value	Min	Max	SD
2-year	-1.75	(-2.72)***	-15.77	3.84	2.81
5-year	-0.67	(-3.25)***	-4.90	4.48	1.36
10-year	1.74	-1.48	-9.54	13.98	3.96

U.S. government bond markets, where yield discounts often are found to be at least an order of magnitude larger.

6 Conclusion

We find no evidence of a significant 'on-the-run liquidity phenomenon' in the German government bond market. Once deliverability into futures contracts and other liquidity determinants are properly controlled for, German on-the-run bonds neither enjoy substantially better liquidity nor trade at an economically significant price premium. In the light of the evidence from the U.S. Treasury market, which documents large liquidity and pricing effects associated with on-the-run status, this is surprising.

Instead, we find clear evidence that the cross-sectional variation in liquidity measures as well as yields across German government bonds is closely related to their eligibility for the two, five and ten-year futures contracts. The yield discounts on deliverable bonds cannot, however, be fully explained by standard liquidity measures and may thus be partly related to a premium for liquidity *risk*.

Our findings suggests that on-the-run securities play very different roles in the German and U.S. Treasury market, in particular with respect to hedging and speculation. In the U.S. market, the benchmark status of the on-the-run securities is indisputable, whereas this status - and the related superior liquidity - appear to be shared among multiple bonds in the Germany market. More generally, our empirical findings highlights the role of a liquid futures markets in supporting the liquidity of the underlying cash market.

Exploiting that our sample covers part of the recent turbulent period in financial markets, we find that the economic importance of liquidity and deliverability increased considerably under severe market stress. Furthermore, our results suggest that the large price premium observed on German bonds during the crisis (relative to other large euro area issuers) may partly be explained by significant liquidity spillovers from the very liquid German futures market. The presence of these effects have implications for studies of euro-area sovereign spreads, which typically are computed relative to German yields.

References

Beber, A., M. W. Brandt, and K. A. Kavajecz (2009): "Flight-to-Quality or Flight-to-Liquidity? Evidence from the Euro-Area Bond Market," *Review of Financial Studies*, 22, 925–57.

Bernoth, K., J. von Hagen, and L. Schuknecht (2004): "Sovereign Risk Premia in the European Government Bond Market," ECB Working Paper Series No. 369.

Bliss, R. (1997): "Movements in the term structure of interest rates," *Federal Reserve Bank of Atlanta Economic Review*, Fourth Quarter.

Boehmer, E., C. Jones, and X. Zhang (2008): "Which Shorts Are Informed?," *Journal of Finance*, 63, 491–527.

Bollen, N., and R. Whaley (1998): "Are Teenies Better?," *Journal of Portfolio Management*, 25, 10–24.

Boudoukh, J., and R. Whitelaw (1991): "The Benchmark Effect in the Japanese Government Bond Market," *Journal of Fixed Income*, 1-2, 52–59.

——— (1993): "Liquidity as a Choice Variable: A Lesson from the Japanese Government Bond Market," *Review of Financial Studies*, 6(2), 265–292.

Brandt, M., and K. Kavajecz (2004): "Price Discovery in the U.S. Treasury Market: The Impact of Orderflow and Liquidity on the Yield Curve," *Journal of Finance*, 59(6), 2623–2654.

Brandt, M., K. Kavajecz, and S. Underwood (2007): "Price Discovery in the Treasury Futures Market," *Journal of Futures Markets*, 27, 1021–1051.

Bundesbank (2007): "Primary and secondary markets for German public sector debt instruments," Deutsche Bundesbank Monthly Report, July 2007.

Chowdhry, B., and V. Nanda (1991): "Multimarket trading and market liquidity," *Review of Financial Studies*, 2, 483–511.

Codogno, L., C. Favero, and A. Missale (2003): "Yield spreads on EMU government bonds," *Economic Policy*, 18(37), 503–532.

Cohen, L., K. Diether, and C. Malloy (2007): "Supply and Demand Shifts in the Shorting Market," *Journal of Finance*, 62, 2061–2096.

Diamond, D., and R. Verrecchia (1987): "Constraints on short-selling and asset price adjustment to private information," *Journal of Financial Economics*, 18, 277–311.

Duffie, D. (1996): "Special Repo Rates," *Journal of Finance*, 51, 493–526.

Duffie, D., N. Garleanu, and L. Pedersen (2007): "Valuation in over-the-counter markets," *Review of Financial Studies*, 20, 1865–1900.

Dunne, P., M. Moore, and R. Portes (2007): "Benchmark Status in Fixed-Income Asset Markets," *Journal of Business Finance & Accounting*, 34, 1615–1634.

Dynkin, L., A. Gould, J. Hyman, and V. Konstantinovsky (2006): *Quantitative Management of Bond Portfolios*. Princeton University Press.

Elton, E., and T. Green (1998): "Tax and Liquidity Effects in Pricing Government Bonds," *Journal of Finance*, 53(5), 1533–1562.

Eom, Y., M. Subrahmanyam, and J. Uno (1998): "Coupon Effects and the Pricing of Japanese Government Bonds: An Empirical Analysis," *Journal of Fixed Income*, 8, 69–86.

Fisher, M. (2002): "Special Repo Rates: An Introduction," *Federal Reserve Bank of Atlanta Economic Review*, Second Quarter.

Fleming, M. (2002): "Are Larger Treasury Issues More Liquid? Evidence from Bill Reopenings," *Journal of Money, Credit, and Banking*, 34(3), 707–735.

Higo, H. (1999): "The Change of Liquidity in the Life Cycle of Japanese Government Securities," in *Market Liquidity: Research Findings and Selected Policy Implications*. Bank of International Settlements CGFS Publications No. 11.

Holden, C. (1995): "Index Arbitrage as Cross-Sectional Market Making," *Journal of Futures Markets*, 15, 423–455.

Huber, P. (1967): "The Behavior of the Maximum Likelihood Estimates Under Nonstandard Conditions," *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*, 1, 221–233.

Krishnamurthy, A., and A. Vissing-Jorgensen (2007): "The Demand for Treasury Debt," National Bureau of Economic Research Working Paper No. 12881.

Kuipers, D. (2008): "Does deliverability enhance the value of U.S. Treasury bonds?," *Journal of Futures Markets*, 28(3), 264–274.

Kyle, A. (1985): "Continuous Auctions and Insider Trading," *Econometrica*, 53(6), 1315–1335.

Litterman, R., and J. Scheinkman (1991): "Common Factors Affecting Bond Returns," *Journal of Fixed Income*, 1, 54–61.

Miyanoya, A., H. Inoue, and H. Higo (1999): "Microstructure and liquidity in the Japanese government securities market," Bank of Japan Working Paper No. 99-1.

Mizrach, B., and C. Neely (2008): "Information shares in the US Treasury market," *Journal of Banking & Finance*, 32, 1221–1233.

Pagano, M. (1989): "Trading Volume and Asset Liquidity," *The Quarterly Journal of Economics*, 104, 255–274.

PASQUARIELLO, P., AND C. VEGA (2009): "The On-the-Run Liquidity Phenomenon," *Journal of Financial Economics*, 92, 1–24.

ROGERS, W. (1983): "Analyzing Complex Survey Data," Rand Corporation Memorandum, Santa Monica, CA.

SCHUKNECHT, L., J. VON HAGEN, AND G. WOLSWIJK (2008): "Government risk premiums in the bond market: EMU and Canada," ECB Working Paper Series No. 879.

SHIGEMI, Y., S. KATO, Y. SOEJIMA, AND T. SHIMIZU (2001): "Pricing of Japanese Government Bonds: Influence of Futures Prices, Repo Rates, and Supply-Demand Conditions of Specific Issues," Bank of Japan Working Paper No. 01-E-1.

SINGLETON, K. (1996): "Institutional and Regulatory Influences on Price Discovery in Cash and Futures Bond Markets," in *The Industrial Organization and Regulation of the Securities Industry*, ed. by A. Lo, pp. 243–274. National Bureau of Economic Research.

——— (2004): "Yield Curve Risk in Japanese Government Bond Markets," *International Review of Finance*, 1, 97–121.

THOMPSON, S. (2005): "A simple formula for standard errors that cluster by both firm and time," Harvard University working paper.

UPPER, C., AND T. WERNER (2007): "The tail wags the dog: time-varying information shares in the Bund market," Bank for International Settlements Working Paper No. 224.

VAYANOS, D., AND P. WEILL (2008): "A Search-Based Theory of the On-the-Run Phenomenon," *Journal of Finance*, 63(3), 1361–1398.

WHITE, H. (1984): "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test of Heteroskedasticity," *Econometrica*, 48, 817–838.

WITHERSPOON, J. (1993): "How Price Discovery by Futures Impacts the Cash Market," *Journal of Futures Markets*, 11, 685–696.

YUAN, K. (2005): "The Liquidity Service of Benchmark Securities," *The Journal of the European Economic Association*, 3, 1156–1180.

Appendix

A Summary statistics and additional tables

Table 11 provides summary statistics for the number bonds, their outstanding amounts, trading volume, and liquidity measures. As for the number of bonds, our sample includes more on-the-run and off-the-run bonds in the two-year segment than in other segments. This reflects the tighter issuance cycle in the short end of the yield curve, as German Finance Agency issues two-year bonds four times a year while five- and ten-year bonds are issued semiannually. Nonetheless, the coverage across maturity and seasonedness ranges is overall quite good, as there are at least five bonds in each category.

Yield spreads between off-the-run and on-the-run bonds appear quite modest, even at the long end of the yield curve. Indeed, the yields for the most recently issued bonds and their immediate predecessors deviate on average less than two basis points. Bid-ask spreads generally get wider with remaining time-to-maturity. For instance, the mean percentage bid-ask spread for the most recently issued 2-year bond is little over two basis points, compared to 3.4 basis points for the 10-year on-the-run bond. This is consistent with market-making models based on inventory management, in which competitive dealers charge wider spreads for securities that have higher price volatility. For bonds with different original but similar residual time-to-maturity, however, the spreads are roughly the same. For example, the bid-ask spreads for original five- and ten-year bonds with approximately three and half years to maturity are virtually identical. The bid-ask spreads between on-the-run and off-the-run bonds do not seem to differ in an economically important way either. This contrasts with the U.S. Treasury market evidence, where Fleming (2002) reports five times wider bid-ask spread for off-the-run bills and Pasquariello and Vega (2009) two times wider spread for off-the-run Treasury bonds. Market depth, while being similar between on-the-run and off-the-run bonds, appears to decline with seasonedness.

Table 11: Sample summary statistics.

This table presents means and standard deviations [in brackets] of yields, trading volumes, percentage price bid-ask spreads and quoted depth for German government bonds over the period January 2006 through September 2008. Bonds are categorized by the original maturity and seasonedness. The on-the-run (off-the-run) bond is the most (next-to-most) recently issued bond in the maturity segment. Sources: MTS Deutschland, ICMA, and German Finance Agency.

	Seasonedness					
Original maturity	On-the-run	Off-the-run	1-2 yrs.	2-5 yrs.	5-7 yrs.	7-10 yrs.
Number of bonds						
2-year	10	10	13			
5-year	6	5	7	11		
10-year	5	5	6	10	10	13
Yield (%)						
2-year	3.660 [0.405]	3.683 [0.415]	3.528 [0.520]			
5-year	3.790 [0.338]	3.781 [0.351]	3.767 [0.360]	3.686 [0.410]		
10-year	3.959 [0.279]	3.941 [0.281]	3.928 [0.286]	3.880 [0.311]	3.784 [0.361]	3.719 [0.411]
Volume (EUR billions)						
2-year	0.907 [0.571]	0.574 [0.456]	0.280 [0.143]			
5-year	1.140 [0.288]	0.446 [0.291]	0.244 [0.082]	0.284 [0.109]		
10-year	2.450 [1.111]	1.630 [0.809]	1.201 [0.571]	0.501 [0.206]	0.502 [0.201]	0.230 [0.118]
Spread (basis points)						
2-year	2.193 [1.335]	2.170 [1.194]	1.785 [1.232]			
5-year	3.103 [0.800]	3.106 [0.712]	2.927 [3.007]	2.318 [1.887]		
10-year	3.444 [0.861]	3.584 [0.802]	3.817 [0.983]	3.430 [1.497]	2.900 [0.885]	2.280 [2.263]
Depth (EUR millions)						
2-year	93.666 [35.638]	101.643 [35.447]	31.369 [7.526]			
5-year	94.740 [29.714]	93.224 [29.524]	79.831 [32.108]	56.806 [28.491]		
10-year	114.709 [45.647]	119.394 [46.698]	82.609 [36.887]	59.664 [22.957]	66.946 [25.229]	55.616 [29.646]

Table 12: Determinants of trading volumes for German and French bonds: Panel regression without time dummies

The dependent variable is log trading volume. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively. Monthly observations from Jan. 2002 through Feb. 2009 (T=86).

	Germany		France	
	Slope	t-value	Slope	t-value
Intercept	-11.26	(-2.54)**	-13.85	(-2.38)**
$1.75 \leq$ maturity < 2.25	0.57	(8.42)***	0.38	(5.16)***
$4.50 \leq$ maturity < 5.50	0.70	(8.86)***	0.32	(3.60)***
$8.50 \leq$ maturity < 10.50	1.06	(7.91)***	0.51	(5.19)***
Cheapest-to-deliver for 2-year future	0.34	(2.77)***		
Cheapest-to-deliver for 5-year future	0.58	(7.05)***		
Cheapest-to-deliver for 10-year future	0.15	(1.14)		
On-the-run status	0.65	(5.15)***	0.58	(5.70)***
Seasonedness (in years)	-0.09	(-5.58)***	-0.13	(-7.35)***
Time to maturity (in years)	-0.02	(-1.72)*	0.01	(1.21)
Log issue size	1.31	(7.00)***	1.39	(5.66)***
Month-fixed effects	No		No	
Sample	Jan 02-Feb 09		Jan 02-Feb 09	
Number of months	86		86	
Number of bonds	109		66	
Number of month-bond obs.	4427		3024	
Adjusted-R^2	0.70		0.60	

Table 13: Determinants of trading volumes for German and French bonds (pre-Crisis sample)

The dependent variable is log trading volume. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively. Monthly observations from Jan. 2002 through Jun. 2007 (T=66).

	Germany		France	
	Slope	t-value	Slope	t-value
Intercept	-16.16	(-2.88)***	-11.40	(-1.55)
$1.75 \leq$ maturity < 2.25	0.55	(7.50)***	0.43	(4.33)***
$4.50 \leq$ maturity < 5.50	0.64	(7.02)***	0.34	(3.29)***
$8.50 \leq$ maturity < 10.50	1.01	(6.70)***	0.51	(4.98)***
Cheapest-to-deliver for 2-year future	0.37	(2.60)***		
Cheapest-to-deliver for 5-year future	0.66	(7.85)***		
Cheapest-to-deliver for 10-year future	0.17	(1.32)		
On-the-run status	0.67	(4.34)***	0.54	(5.00)***
Seasonedness (in years)	-0.06	(-2.88)***	-0.14	(-6.30)***
Time to maturity (in years)	-0.02	(-1.95)*	0.01	(1.31)
Log issue size	1.55	(6.47)***	1.29	(4.17)***
Month-fixed effects	Yes		Yes	
Sample	Jan 02-Jun 07		Jan 02-Jun 07	
Number of months	66		66	
Number of bonds	109		66	
Number of month-bond obs.	3426		2294	
Adjusted-R^2	0.74		0.61	

Table 14: Determinants of trading volumes for German and French bonds (Crisis sample)

The dependent variable is log trading volume. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively. Monthly observations from Jul. 2007 through Feb. 2009 (T=20).

	Germany		France	
	Slope	t-value	Slope	t-value
Intercept	-5.81	(-1.29)	-20.27	(-3.45)***
$1.75 \leq$ maturity < 2.25	0.60	(5.61)***	0.22	(2.28)**
$4.50 \leq$ maturity < 5.50	0.74	(8.43)***	0.28	(1.94)*
$8.50 \leq$ maturity < 10.50	1.07	(8.27)***	0.45	(3.37)***
Cheapest-to-deliver for 2-year future	0.36	(1.69)*		
Cheapest-to-deliver for 5-year future	0.27	(1.74)*		
Cheapest-to-deliver for 10-year future	0.05	(0.43)		
On-the-run status	0.69	(3.49)***	0.73	(5.20)***
Seasonedness (in years)	-0.11	(-7.40)***	-0.10	(-5.69)***
Time to maturity (in years)	-0.01	(-0.94)	0.00	(0.25)
Log issue size	1.08	(5.68)***	1.66	(6.69)***
Month-fixed effects	Yes		Yes	
Sample	Jul 07-Feb 09		Jul 07-Feb 09	
Number of months	20		20	
Number of bonds	109		66	
Number of month-bond obs.	1001		730	
Adjusted-R^2	0.73		0.74	

Table 15: Determinants of quoted depth for French government bonds

The dependent variable is monthly averages of daily cumulated (log) depth. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively.

	pre-crisis		crisis	
	Slope	t-value	Slope	t-value
Intercept	9.86	(3.85)***	17.00	(2.98)***
$1.75 \leq$ maturity < 2.25	0.17	(2.73)***	0.27	(3.35)***
$4.50 \leq$ maturity < 5.50	-0.09	(-1.50)	-0.07	(-0.63)
$8.50 \leq$ maturity < 10.50	0.16	(3.86)***	0.27	(3.05)***
On-the-run status	0.49	(6.71)***	0.50	(3.95)***
Seasonedness (in years)	-0.05	(-7.71)***	-0.05	(-4.38)***
Time to maturity (in years)	-0.04	(-13.57)***	-0.02	(-4.04)***
Log issue size	0.33	(3.05)***	0.01	(0.06)
Month-fixed effects	Yes		Yes	
Sample	Jan 06-Jun 07		Jul 07-Sep 08	
Number of months	18		15	
Number of bonds	51		51	
Number of month-bond obs.	668		555	
Adjusted-R^2	0.81		0.65	

Table 16: Determinants of quoted bid-ask spreads for French government bonds

The dependent variable is monthly averages of daily (log) bid-ask spreads. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively.

	pre-crisis		crisis	
	Slope	t-value	Slope	t-value
Intercept	7.50	(2.25)**	6.52	(2.47)**
$1.75 \leq$ maturity < 2.25	0.09	(1.70)*	-0.08	(-1.22)
$4.50 \leq$ maturity < 5.50	0.12	(2.47)**	0.22	(3.93)***
$8.50 \leq$ maturity < 10.50	0.06	(0.98)	-0.04	(-0.75)
On-the-run status	-0.23	(-3.35)***	-0.44	(-5.72)***
Seasonedness (in years)	0.01	(1.54)	0.01	(1.39)
Time to maturity (in years)	0.08	(14.84)***	0.08	(15.77)***
Log issue size	-0.30	(-2.16)**	-0.25	(-2.22)**
Month-fixed effects	Yes		Yes	
Sample	Jan 06-Jun 07		Jul 07-Sep 08	
Number of months	18		15	
Number of bonds	51		51	
Number of month-bond obs.	634		553	
Adjusted-R^2	0.91		0.89	

Table 17: Determinants of liquidity index for French government bonds
The dependent variable is monthly averages of daily (log) depth divided by bid-ask spread. Asterisks *, **, *** after robust t-values (in parentheses) denote values significantly different from zero at the 10%, 5%, and 1% levels, respectively.

	pre-crisis		crisis	
	Slope	t-value	Slope	t-value
Intercept	10.53	(4.10)***	17.57	(3.79)***
$1.75 \leq$ maturity < 2.25	0.13	(2.54)**	0.21	(2.23)**
$4.50 \leq$ maturity < 5.50	-0.09	(-1.37)	-0.31	(-2.54)**
$8.50 \leq$ maturity < 10.50	0.01	(0.29)	0.20	(2.25)**
On-the-run status	0.48	(8.09)***	0.74	(5.74)***
Seasonedness (in years)	-0.07	(-7.67)***	-0.06	(-4.30)***
Time to maturity (in years)	-0.12	(-29.79)***	-0.11	(-15.25)***
Log issue size	0.63	(5.77)***	0.31	(1.59)
Month-fixed effects	Yes		Yes	
Sample	Jan 06-Jun 07		Jul 07-Sep 08	
Number of months	18		15	
Number of bonds	51		51	
Number of month-bond obs.	668		555	
Adjusted-R^2	0.96		0.88	