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by Jens Dick-Nielsen, Jacob Gyntelberg, Thomas Sangill

Monetary and Economic Department

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Liquidity in Government versus Covered Bond Markets *

Jens Dick-Nielsen,† Jacob Gyntelberg,‡ Thomas Sangill,§

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Abstract

We present findings on the secondary market liquidity of government and covered bonds in Denmark before, during and after the 2008 financial crisis. The analysis focuses on wholesale trading in the two markets and is based on a complete transaction level dataset covering November 2007 until end 2011. Overall, our findings suggest that Danish benchmark covered bonds by and large are as liquid as Danish government bonds – including in periods of market stress. Before the financial crisis of 2008, government bonds were slightly more liquid than covered bonds. During the crisis, trading continued in both markets but the government bond market experienced a brief but pronounced decline in market liquidity while liquidity in the covered bond market was more robust – partly reflective of a number of events as well as policy measures introduced in the autumn of 2008. After the crisis, liquidity in the government bond market quickly rebounded and government bonds again became slightly more liquid than covered bonds.

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† Corresponding author. Copenhagen Business School. Email: jdn.fi@cbs.dk.

‡ Bank for International Settlements, Basel. Email: jacob.gyntelberg@bis.org.

§ Danish Central Bank. Email: thsa@nationalbanken.dk.

Executive summary

In this paper we present findings on the liquidity of the government and covered bond markets in Denmark before, during and after the 2008 financial crisis. The analysis focuses on wholesale trading in the two markets and is based on a complete transaction level dataset covering November 2007 until end 2011. Overall, our findings suggest that Danish benchmark covered bonds by and large are as liquid as Danish government bonds – including in periods of market stress. Before the financial crisis of 2008, government bonds were slightly more liquid than covered bonds. During the crisis, trading continued in both markets but the government bond market experienced a brief but pronounced decline in market liquidity while liquidity in the covered bond market was more robust – partly reflective of a number of events as well as policy measures introduced in the autumn of 2008. After the crisis, liquidity in the government bond market quickly rebounded and government bonds again became slightly more liquid than covered bonds. These results confirm and extend those of the earlier, preliminary study of Buchholst et al. (2010).

Our second main finding is that the price impact of a trade overall is lower in inter-dealer markets than dealer-client markets. The price impact of trades was visibly higher for dealer-client trades during the crisis whereas it remained stable in the inter-dealer market. However, average daily turnover in the inter-dealer market declined dramatically during the crisis compared to the dealer-client market. The combination of notable increases in the price impact of trade in the dealer-client market combined with a dramatic decline in inter-dealer market turnover is suggestive of a situation where dealers found it difficult to sell bonds in the inter-dealer market and instead sold bonds to clients.

Finally, we also find that the variability of liquidity across individual bonds – liquidity risk – increased notably during the crisis, most pronounced for short-term government and long-term fixed-rate callable covered bonds. The substantial increase in liquidity risk measures during the crisis could reflect that the funding constraints of capital constrained traders became binding during the crisis.

1 Introduction

We analyse secondary market liquidity of Danish government and covered bonds before, during and after the 2008 financial crisis. The analysis focuses on wholesale trading in benchmark bonds in the two markets and is based on an up to now virtually unused, complete transaction level dataset for the period from November 2007 until end 2011. Specifically, we rely on MiFID transaction reports[1] to calculate and analyze high-frequency bond market liquidity measures.

Our findings suggest that Danish benchmark covered bonds by and large are as liquid as Danish government bonds – also in periods of market stress. Before the financial crisis of 2008, government bonds were slightly more liquid than covered bonds. During the crisis, the government bonds experienced pronounced declines in market liquidity while liquidity of the market for covered bonds was more robust. However, liquidity in the government bonds quickly rebounded after the crisis and has remained robust and stable in recent years.

These results confirm and extend those of the earlier, preliminary study of Buchholst et al. (2010). Overall, secondary market liquidity has returned to the same levels as seen before the crisis, and have even improved slightly for government bonds during the euro area sovereign debt crisis – a finding which is consistent with the substantial capital inflows into Denmark as a result of the credit risk concerns that have affected a number of euro area government bond markets in the last few years.

We also find that the variability of liquidity across individual bonds increased notably during the crisis, most pronounced for short-term government and long-term fixed-rate callable covered bonds. This is consistent with theories of liquidity risk which suggest that both the level of liquidity and idiosyncratic liquidity risk contribute to expected returns of securities (Acharya and Pedersen (2005)). The substantial increase in liquidity risk measures during the crisis could reflect that the funding constraints of capital constrained traders became binding during the crisis (Brunnermeier and Pedersen (2009)).

Different events as well as policy measures introduced in the autumn of 2008 contributed to stabilizing the banking sector as well as restoring confidence among market participants. First, government guarantees (in return for a fee) on banks liabilities were introduced. Second, on 31 October an agreement between the Danish Insurance Association and the Ministry of Economic and Business Affairs allowing pension funds to use a discount curve partly linked to the rates on coverd bonds for their liabilities was concluded. The aim was to ensure that the widening spread between covered and government bonds would not endanger the solvency of pension funds. Potentially this could have forced pension funds who have historically been among the largest investors in covered bonds to divest covered bonds from their portfolios. Third, in the beginning of November it was announced that the Social Pension Fund, which is managed by the Danish central bank on behalf of the government, would invest around EURbn 3 in short-term covered bonds with the aim of covering the central-government's interest-rate risk related to the financing of subsidised housing. Although this relatively small measure was attributed to the government's interest-rate risk management, it was widely interpreted by market players as a signal that the government was ready to support the market in case of further turmoil related

[1] We have obtained MiFID transaction reports from the Danish Financial Supervisory Authority.

to the crisis – thereby shoring up investor confidence at the peak of the crisis. Finally, the Danish central bank, in line with other central banks, established temporary lending facilities. The significant size of the covered bond market, however, meant that most banks had sufficient amounts of eligible collateral for central bank repo funding during the crisis.

The remainder of the paper is structured as follows. Section 2 provides an overview of the financial markets of interest and introduces the dataset. Section 3 describes the metric used to capture bond market liquidity and explains the regression setup. The following sections 4 to 7 present our main empirical findings. The final section concludes.

2 The markets and the data

This section provides a brief overview of the government and covered bond markets in Denmark. We focus on aspects of the markets and data that are important for the analysis of market liquidity conducted in section 4 to 7. Our sample period is defined by the availability of MiFID data and therefore starts in November 2007. We have obtained the MiFID data up until end 2011. The raw MiFID data was cleaned before usage as described in appendix A.

As the aim of our analysis is to determine the liquidity characteristics of covered and government bonds from the perspective of banks' ability to liquidate these assets in times of market wide stress we focus on transactions with a nominal value of at least DKKm 10 (approximately EURm 1.34). By excluding transactions with a nominal value of less than DKKm 10 we exclude only a small fraction of the total turnover.

In both markets we find that a large part of the transactions takes place in standard trade sizes e.g. DKKm 20, 50, 100, and 200. Thus, some of our tables relate specifically to these numbers.[2]

2.1 The covered bond market

The Danish mortgage bond market is one of the most sophisticated housing finance markets in the world.[3] By end 2011 the outstanding amount of covered bonds reached DKKbn 2,500, corresponding to around 140 percent of GDP.

A decade ago, the Danish mortgage market was dominated by one standard contract; long-term (up to 30 years) loans at a fixed rate with an option to make penalty-free prepayments. This 30-year fixed rate callable mortgage loan is funded by a cash-flow matching 30-year fixed rate callable bond. By end 2011 30 year fixed rate mortgages with a coupon of 4 % were funded by each mortgage banks' issue of the 4 % fixed rate callable covered bond maturing October 2041. See Frankel et al. (2004) for an in-depth description of the Danish market for callable fixed rate mortgage bonds.

The Danish mortgage bond market has undergone a significant transformation over the last ten years. The result has been that the by far most popular new loan type is a 30-year loan

[2]Because transactions are conducted in standard trade sizes (round figures) by Danish kroner we keep DKK as currency throughout the paper. Denmark conducts a fixed-exchange-rate policy vis-a-vis the euro at a central rate of 7.46038 kroner per euro. Since 1997 Danmarks Nationalbank has kept the krone very close to its central rate.

[3]For recent descriptions of the Danish mortgage market – including during the financial crisis – see also Gundersen et al. (2011) and Gyntelberg et al. (2012).

where the interest rate changes once a year based on the funding conditions at the time of refinancing of the underlying bonds. The loan is funded by a sale of fixed rate bullet bonds – the majority of which have a 1-year maturity. By end 2011 nearly two-thirds of all outstanding residential mortgages and almost 90 % of all new mortgages were of this type.

The dramatic change in composition of the outstanding bonds has been facilitated by low stable short-term interest rates. Despite the change towards 1-year adjustable rate mortgages (ARMs) as the dominant loan type the funding strategy used by the mortgage banks has not changed. The mortgage banks have continued to operate according to a model with very close cash flow based matching between the loans and the bonds used to fund the loans. Historically, this has been a defining characteristic of the Danish mortgage system. This practice no doubt reflects that regulation for many years only allowed mortgage banks to hold very limited market or prepayment risk and therefore they only held credit risk.

This regulatory restriction, the so-called *balance-principle*, essentially required mortgage banks to fund their lending activities by issuing mortgage bonds with cash flows that fully match those of the underlying mortgage loans until maturity on a loan-by-loan basis. In line with the balance-principle, the 1-year ARMs are funded by issuance of 1 year non-callable bullet bonds. The interest period on these bonds exactly matches the interest period of 1 year for the home owner thereby creating a natural interest rate hedge for the mortgage bank. For each interest period of 1 year, the cash flow of the loans and the bonds issued to fund them match, and the mortgage bank is therefore fully hedged regarding interest rate, currency and prepayment risk. In addition, as the borrower pays the mortgage banks' cost-of-funds plus a margin, the mortgage bank is also hedged against rising funding spreads. However, the mortgage bank is exposed to the risk of a complete freeze in the funding markets when the issuance of new bonds to roll over the funding of maturing bonds is impossible at any price.[4]

Throughout the paper we restrict our sample for covered bond to bonds issued by the 3 largest issuers which cover around 65-85 % of the market. The market does not discriminate between these issuers in terms of credit quality.[5] Thus, bonds with the same cash flow from different issuers trade in the market on a cheapest to deliver basis. This is referred to as the unity market for Danish covered bonds. Therefore, the so-called unity market allows us to effectively treat bonds with the same cash flow as one bond when calculating our liquidity measure (see section 3). This greatly increases the number of observations and thereby the accuracy of our analysis.

2.1.1 Short-term covered bonds

The short-term covered bonds in our sample are fixed-rate bullet bonds with a time to maturity of less than 1.2 years. The 1-year bonds underlying the 1-year ARMs are usually auctioned off 14 month prior to maturing. At the auction the bonds are settled with a delivery 2 month

[4]While the funding model used by the mortgage banks has not changed fundamentally, the Danish covered bond legislation was amended with effect from January 2008 to incorporate recent changes in the EU Capital Requirement Directive (CRD). The amendments introduced a new covered bond definition. A key change was a requirement for covered bond issuers to perform regular validation of LTV-ratios, which are limited to 80 % for residential mortgages and 60 % for commercial mortgages.

[5]The issuers are Realkredit Danmark, Nordea Realkredit and Nykredit Realkredit. Furthermore, we include older issues from Totalkredit Realkredit, now part of Nykredit Realkredit.

later and right after the auction the bonds start to trade in the secondary market (with a late delivery in the first two months). In table 1 we can see that for short-term covered bonds, our sample captures around 65 % of the amount outstanding and around 45 % of the turnover. The relatively low turnover for our sample can be explained by the fact that apart from conditioning on the issuer we also remove auction days from our sample (see appendix A). The auctions are removed as we are interested in secondary market liquidity.

Table 1: **Summary statistics - Short-term covered bond market and sample**

Variable (Monthly average)	Market Short-term	Sample Short-term
Amount outst. (DKKbn)	750	497
Number of Bonds	35.7	17.5
Bond Size (DKKbn)	22.1	29.7
Turnover (DKKbn)	332	155
Number of trades	1763	928
Mean tradesize (DKKm)	158	156
Median tradesize (DKKm)	69	70.1
Time to Maturity (Years)	0.64	0.63

2.1.2 Long-term covered bonds

The long-term covered bonds in our sample are the standard 30-year fixed rate callable bonds. In table 2 we present summary statistics for the entire market (all issuers) as well as our sample (the 3 largest issuers). Our sample captures around 85 % of the amount outstanding and 90 % of the turnover. The summary statistics are based on actively traded issues so where the market consists of 115 actively traded issues there are actually around 1,250 different callable fixed-rate bonds outstanding in the Danish covered bond market.[6] This reflects a large number of very small callable fixed-rate bonds mirroring that the mortgage banks issue bonds with cash flows that match those of their lending portfolio (as explained in section 2.1). Hence, a given covered bond issue exists until all borrowers who have their mortgages funded by this specific bond have paid off their mortgages completely (or defaulted).

2.2 The government bond market

The outstanding volume of Danish government bonds by end 2011 was just over DKKbn 750, corresponding to around 40 % of GDP (see Danmarks Nationalbank (2012)). The Danish government debt and hence the issuance of bonds is managed by the Danish central bank. The outstanding bonds consist of short-term T-bills and plain vanilla bullet bonds with standard maturities between 2 and 30 years. The sale of bonds takes place via auctions and tap sales, with auctions being the dominant issuance form since 2009. T-bills and a new 30-year bond were only issued in part of our sample period. Therefore, we do not include these instruments as to keep our sample as homogeneous as possible over time.

[6] A bond is included in the monthly statistic if it had at least one wholesale transaction in that given month.

Table 2: **Summary statistics - Long-term covered bond market and sample**

Variable (Monthly average)	Market Long-term	Sample Long-term
Amount outst. (DKKbn)	494	424
Number of Bonds	115.1	78.7
Bond Size (DKKbn)	4.3	5.4
Turnover (DKKbn)	115	104.7
Number of trades	2109	1891
Mean tradesize (DKKm)	54.2	55.1
Median tradesize (DKKm)	26.9	28
Time to Maturity (Years)	26.0	26.3

Table 3: **Summary statistics - Government bond market**

Variable (Monthly average)	Short-term bonds	Long-term bonds
Amount outst. (DKKbn)	257	174
Number of Bonds	4.2	2.8
Bond Size (DKKbn)	62.3	63.6
Turnover (DKKbn)	65	76
Number of trades	405	591
Mean tradesize (DKKm)	169.4	136.6
Median tradesize (DKKm)	66.1	47.8
Time to Maturity (Years)	2.53	8.03

In table 3 short-term bonds are those with time to maturity of no more than five years while long-term bonds are those with time to maturity of between five and ten years. The summary statistics reflect that the government bond market is dominated by a few very large benchmark issues (average bond size of DKKbn 62.3 for short-term government bonds, see table 3) compared to the covered bond market (average bond size of DKKbn 22.3 for short-term covered bonds, see table 1).

3 Empirical methodology

This section explains the empirical methodology. In order to measure the level of secondary market liquidity we define a liquidity measure based on price impact. This measure is later used to form a liquidity risk measure. Finally, we set up simple regressions designed to investigate changes over time in market liquidity and liquidity risk.

3.1 Measuring bond market liquidity

We measure liquidity by using price impact, where the price impact[7] for a given transaction is defined as the absolute return between adjacent transactions:

$$\mathrm{PI}_{t,i,k} = \frac{|p_{t,i,k} - p_{t,i-1,k}|}{p_{t,i-1,k}} \tag{1}$$

where i refers to the ith transaction on day t in bond k. Price impact measures how much a single transaction moves the price. In a liquid market we would not expect the price to move much when we trade hence we would expect a low price impact. Contrary, in a illiquid market we would expect a high price impact when trading. We require that both transactions in the calculation are executed within the same day in order to minimize the possibility of new information arriving in the market. Since we seek to eliminate new information from the price impact measure, the median price impact over a given period, for example one week, resembles an effective bid-ask spread over that period. This happens because the most common reason for a price impact is a bounce between a buy and a sell price.

Our price impact measure is closely related to the Amihud (2002) Illiq-measure which is based on the model in Kyle (1985). Dick-Nielsen et al. (2012) show that a modified version of the Amihud measure is a good liquidity proxy for US corporate bonds. We improve on this methodology by not necessarily assuming a positive linear relationship between price impact (PI) and trading volume (Q) i.e. we do not ex-ante assume that $\mathrm{PI} = \lambda \times Q$ for some $\lambda > 0$ as in the Amihud measure. In fact, we use the raw price impact measure and do not scale with volume at all. This choice is based on the empirical observation we make later on in the paper that price impact is a nearly flat function of volume (or even slightly downward sloping).

On a more technical note, in our data sample we observe a high number of zero price impacts i.e. transactions where the price does not change between consecutive trades. This is an artefact of the reporting system and of the market maker arrangement. First, it reflects that in a large number of transactions bonds are simply handed from one dealer to another and then passed on to a customer. These types of transactions are usually reported with the same price for both trades (same clean price). However, the introducing dealer charges a commission not visible in the data sample which wrongly results in a zero price impact. Second, in the Danish bond market a group of market makers (large banks) post binding quotes for certain quantities. These quotes are not always adjusted after a transaction, hence it may be possible to execute several transactions at the same price. To avoid an artificially high number of zero price impacts we adopt an order book view of the market. Thus, when consecutive transactions have the same price, we sum the quantities and record the total volume executed at this given price as a single transaction. Finally, we calculate the price impact of each transaction. This methodology results in a strictly positive price impact measure.

When we calculate the price impact measure in the covered bond market, we pool all bond issues with matching cash flows into the same bond family and regard them as a single issue, hence we do not distinguish between the issuers (see section 2.1).

[7]Throughout the paper we measure price impact in basis points.

3.2 Liquidity risk

Investors care not only about the level of liquidity, i.e. the ease with which they can trade a security, but also about liquidity risk (Acharya and Pedersen (2005)). Liquidity risk is the risk that the security can become illiquid at a later date when perhaps liquidity is needed. We define a liquidity risk measure as the quantile range in the distribution of price impact observations over a given period:

$$\text{Liquidity risk} = \text{PI}^{75\%} - \text{PI}^{25\%} \tag{2}$$

where $\text{PI}^{X\%}$ is the X percentile in the price impact distribution over some pre-specified period.

When our liquidity risk measure is high it means that the price impact measure vary a great deal over the period. Hence, the expected level of liquidity is uncertain from the investor's point of view.

3.3 Regression setup

In section 4 to 7 we present regressions of our liquidity measure on time series dummies. For each market segment we perform the regression:

$$\text{PI}_{t,i,k} = \alpha + \beta_1 \times \text{Crisis}_t + \beta_2 \times \text{Post-Crisis}_t + \beta_3 \times \text{Sovereign Crisis}_t + \epsilon_{t,i,k} \tag{3}$$

where i refers to the ith observation on date t in bond k. We assume that the error term follows a normal distribution with possible correlation across time and within bond issues.[8] The crisis dummy is 1 between August 15th, 2008 and December 15th, 2008 and 0 elsewhere. The post-crisis dummy is one between December 16th, 2008 and April 30st, 2010 and 0 elsewhere. The sovereign crisis dummy is 1 between May 1st, 2010 and end 2011. The chosen starting point of the sovereign crisis is arbitrary. The first signs of this crisis started in the second half of 2009 but it took some time before it affected the financial market. The results are robust to choosing an earlier starting date for the sovereign crisis. With these definitions the intercept has the interpretation of being the pre-crisis period level and the estimated coefficients for the dummy variables are deviations from the pre-crisis period level.

4 Liquidity in normal versus stress periods

This section compares the liquidity in covered versus government bonds during normal and stress periods. We do both a graphical inspection and a statistical analysis of our liquidity measure. Outside the 2008 financial crisis, government bonds are slightly more liquid than covered bonds. However, during the crisis the covered bond market performed better.

[8] In all regressions through out the paper, T-statistics are calculated using two-dimensional cluster robust standard errors (Petersen (2009)). The standard errors are robust to correlation caused by a time dimension correlation, i.e. transactions executed within the same time span (a week) across different bonds might be correlated, and to a family dimension correlation, i.e. transactions in the same bond or family at different time points might be correlated.

Table 4: Market liquidity in normal versus stress periods

Market	Intercept	Crisis	Post-Crisis	Sovereign Crisis
Short covered	**5.669**	2.872	**1.194**	**1.830**
$N = 11,183$	(0.158)	(1.855)	(0.491)	(0.639)
Short Gov.	**3.857**	**11.260**	**3.720**	1.355
$N = 6,383$	(0.679)	(1.270)	(1.655)	(0.860)
Long covered	**11.711**	0.916	-0.263	**2.646**
$N = 29,992$	(0.700)	(0.791)	(0.925)	(1.213)
Long Gov.	**10.095**	**5.584**	0.730	-0.052
$N = 11,675$	(0.611)	(2.401)	(0.891)	(1.127)

Note: Estimates in bold typeface are significant on a 5% level. More detailed regression tables can be seen in appendix B and C.

4.1 Markets for short-term bonds

Our liquidity measure suggests (see figure 1) that liquidity was broadly the same for short-term covered bonds and government bonds before the 2008 crisis.[9] This is also evident from the regressions in table 4. The estimated liquidity levels for the pre-crisis period (the intercepts) statistically point to higher average liquidity in the government bond market. However, the actual difference in liquidity in terms of price impact implied by the regression is only in the 1-2 basis point range, corresponding to a difference in price movement of around 0.01-0.02 percent.

During the peak of the 2008 crisis there was a notable decline in liquidity in both markets. The decline in liquidity was however significantly higher for the government bond market, where the average price impact of trade increased to nearly 15 basis points compared to roughly 4 basis points before the crisis. This constitutes a significant drop in liquidity. In contrast, the increase was only around 3 basis points from 6 to 9 basis points for short-term covered bonds. Furthermore, this increase was not statistically significant.

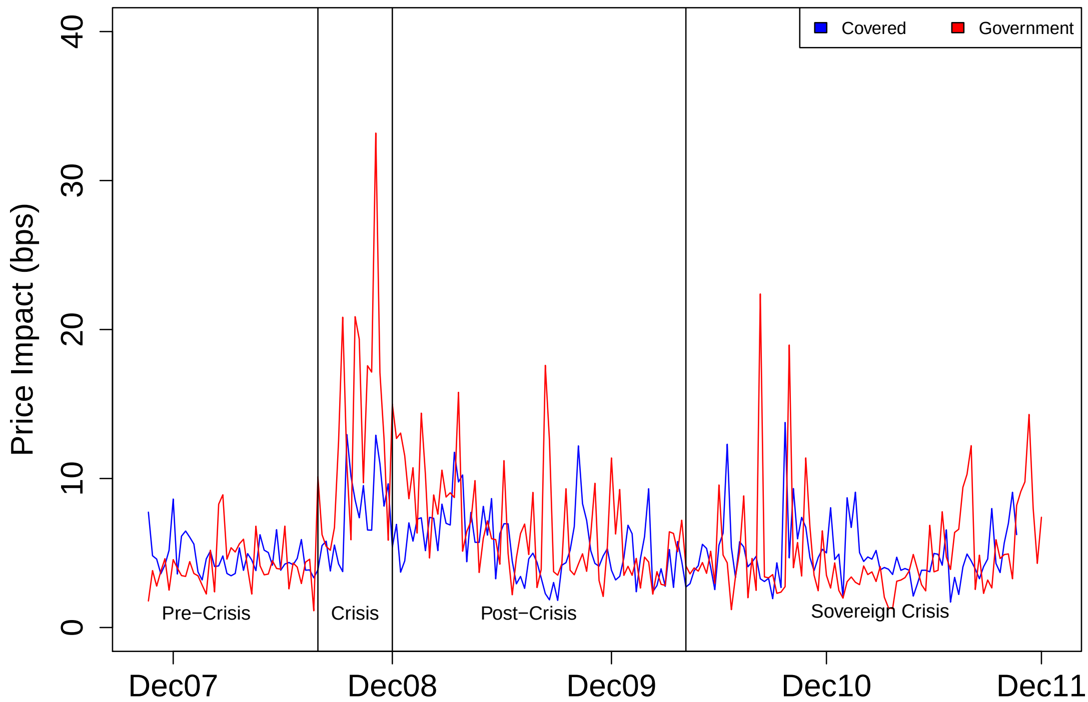
In the post-crisis period we see that although liquidity has been lower than before the crises both markets have remained fairly liquid with an average price impact of trade around 7 basis points – not far away from the pre-crisis level for the covered bond market. More recently, during the first years of the euro area sovereign debt crisis, liquidity in the short-term government bond market has returned to its pre-crisis level. In contrast, liquidity in the short-term covered bond market has remained below the level (i.e. higher price impact) seen before the 2008 crisis. Despite the decline in liquidity, both markets are, however, still quite liquid, with an average price impact of trade in the 4-7 basis point range.

4.2 Markets for long-term bonds

Similar to the markets for short-term bonds, the average price impact was broadly the same for long-term covered and government bonds over the entire sample period as can be seen in figure

[9] Using different data, Buchholst et al. (2010) show that the pre-crisis liquidity level (from January 2005 to August 2008) was very stable.

Figure 1: Liquidity in markets for short-term bonds.



Note: Weekly medians of liquidity measure.

2. Looking at the regressions in table 4 we can see that the pre-crisis levels for the liquidity measure are not statistically different. But they do show a lower level of liquidity for long-term bonds than short-term bonds. The difference in price movement compared to the short-term bonds as implied by the regression is around 6 basis points, corresponding to a difference in price movement of around 0.06 percent.

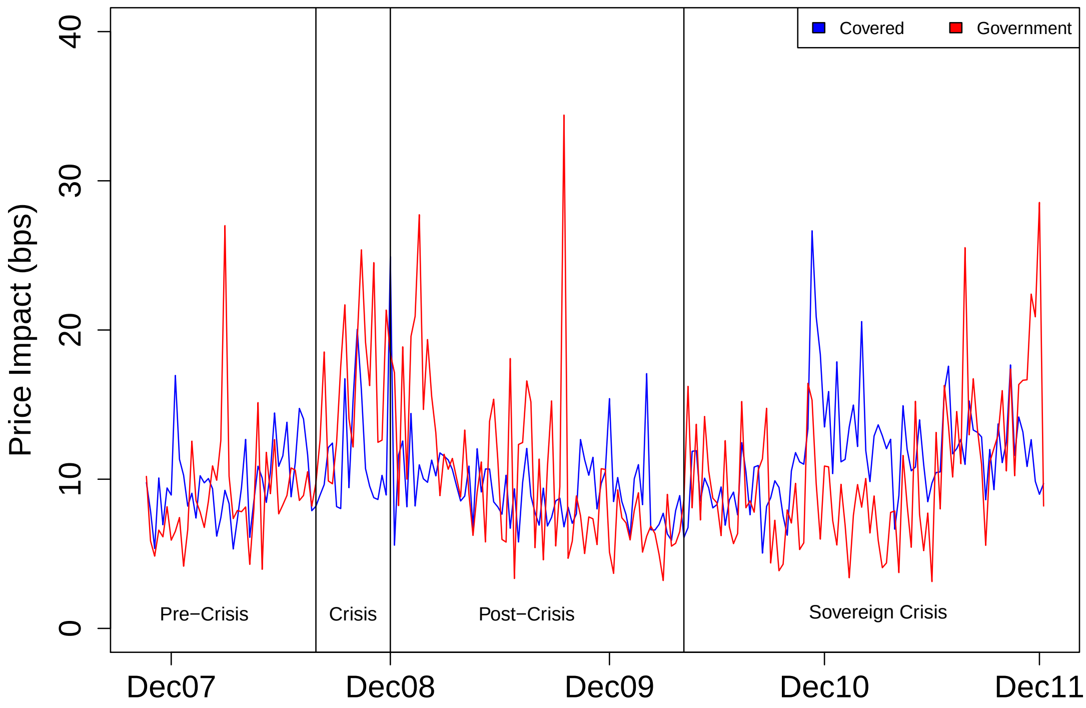
During the peak of the crisis in October 2008 and the period leading up to the crisis there was a notable decline in the long-term government bond market liquidity as we also saw it for the short-term government bonds. In contrast, liquidity remained more or less the same in the covered bond market.

The average price impact decreased rapidly in the period after the crisis in the government both market. While market liquidity has returned to its pre-crisis level for government bonds, it has decreased somewhat for covered bonds during the later period of the euro area sovereign crisis. In general the crisis affected the long-term market far less than the short-term market. The price impact measure for short-term government bonds increased with a factor 3, whereas the long-term government bonds increased with a factor 0.5.

5 Liquidity and trade size

A somewhat surprising observation is that the price impact of a given trade is independent of the trade size. This can be seen from table 5 to 8, which show the price impact measure for four of the most frequently used trade sizes. In fact, in most periods the price impact of a DKKm

Figure 2: Liquidity in markets for long-term bonds.



Note: Weekly medians of liquidity measure.

200 trade is smaller than one of DKKm 20. This observation strongly supports our choice not to scale the raw price impact measure with volume.[10]

We find that during the crisis period large trades had much price impact in both the short-term covered bond and the short-term government bond market (see table 5 and 6). For small trades however the liquidity was more robust in the short-term covered bond market.

Table 5: Liquidity by trade size - Short-term covered bonds

Period	Percentile	20 mill.	50 mill.	100 mill.	200 mill.
Pre-Crisis	5	0.30	0.50	0.40	0.50
	50	5.03	4.57	3.42	3.00
	95	26.06	21.68	13.12	35.53
Crisis	5	0.62	0.50	0.30	1.00
	50	3.45	3.23	8.24	6.05
	95	23.55	14.72	35.44	32.49
Post-Crisis	5	0.21	0.49	0.50	0.20
	50	3.28	3.26	3.42	2.98
	95	16.15	14.64	15.48	18.10
Sovereign Crisis	5	0.49	0.38	0.36	0.20
	50	2.95	2.97	2.14	2.50
	95	10.76	27.69	21.39	21.33

[10] Note that the Amihud measure predicts that the price impact for a DKKm 200 should be 10 times that of a DKKm 20. Such a relationship cannot be found anywhere in the data.

Table 6: Liquidity by trade size - Short-term government bonds

Period	Percentile	20 mill.	50 mill.	100 mill.	200 mill.
	5	0.50	0.20	0.47	0.29
Pre-Crisis	50	3.53	3.03	2.86	2.44
	95	26.17	16.62	19.00	16.50
	5	0.30	0.57	0.28	0.29
Crisis	50	9.32	8.32	8.63	8.26
	95	27.29	56.39	44.05	44.88
	5	0.68	0.57	0.45	0.29
Post-Crisis	50	2.93	6.28	4.58	3.93
	95	15.30	26.37	34.53	19.51
	5	0.46	0.09	0.29	0.27
Sovereign Crisis	50	3.63	2.25	2.76	1.82
	95	28.28	14.40	18.15	11.30

Similar to the markets for short-term bonds, the relationship between trade size and the price impact measure for long-term bonds is more or less flat. This can be seen in table 7 and 8. Again we notice that even though the regressions showed no significant increase in price impact for the covered bonds during the 2008 crisis, we can in fact see an increase for the larger trade sizes. The large trade sizes for covered bonds experience very similar movements over time as those for the government bonds.

Table 7: Liquidity and trade size - Long-term covered bonds

Period	Percentile	20 mill.	50 mill.	100 mill.	200 mill.
	5	0.28	0.56	0.41	0.67
Pre-Crisis	50	7.90	8.18	7.52	7.33
	95	43.16	45.30	39.10	28.80
	5	0.20	0.28	0.45	1.35
Crisis	50	5.79	10.28	11.42	9.25
	95	48.46	45.75	51.87	57.35
	5	0.75	0.95	0.73	1.06
Post-Crisis	50	6.61	7.49	7.72	6.18
	95	40.57	36.93	35.12	32.39
	5	0.98	1.04	1.51	1.60
Sovereign Crisis	50	8.74	9.64	9.65	8.61
	95	40.18	52.97	59.60	43.20

Table 8: Liquidity and trade size - Long-term government bonds

Period	Percentile	20 mill.	50 mill.	100 mill.	200 mill.
Pre-Crisis	5	1.01	1.00	1.00	0.31
	50	9.62	8.73	7.50	5.87
	95	54.02	39.11	36.94	36.25
Crisis	5	0.96	1.03	0.31	0.30
	50	10.65	11.27	13.55	7.72
	95	48.08	57.27	60.89	64.38
Post-Crisis	5	0.99	0.96	0.50	0.29
	50	7.90	8.47	7.13	5.76
	95	31.85	55.68	36.81	29.05
Sovereign Crisis	5	0.73	0.86	0.89	0.27
	50	7.32	8.36	9.30	7.33
	95	44.58	49.16	54.04	37.08

6 Liquidity in inter-dealer versus dealer-client markets

As the MiFID data contains counterparty identifiers, we are able to split our sample of bond market transactions into those between dealers (inter-dealer) and those between dealers and their clients. This makes it possible to perform a more granulary evaluation of bond market liquidity. In particular we are able to compare the liquidity of the inter-dealer market with the dealer-client market during both normal and stress periods. From a policy perspective, the value-added is that this sheds light on the ability of dealers to raise cash in inter-dealer markets versus dealer-client market under different market conditions.

Table 9: Dealer-client market liquidity.

Market	Intercept	Crisis	Post-Crisis	Sovereign Crisis
Short covered	**4.599**	2.866	**1.564**	**2.706**
$N = 4,327$	(0.285)	(2.470)	(0.391)	(0.755)
Short Gov.	**5.237**	**10.067**	1.680	2.077
$N = 6,383$	(1.055)	(0.978)	(1.721)	(1.943)
Long covered	**11.403**	**2.446**	**3.475**	**5.128**
$N = 10,946$	(0.837)	(0.412)	(1.415)	(1.477)
Long Gov.	**11.503**	**6.505**	0.407	**2.863**
$N = 5,294$	(0.680)	(1.463)	(0.656)	(1.401)

Note: Estimates in bold typeface are significant on a 5% level. More detailed regression tables an be seen in appendix B and C.

The regression results in tables 9 and 10 show that price impact overall is lower in inter-dealer markets than in dealer-client markets. They also show that in most market segments the price impact significantly increased for dealer-client transactions during the crisis whereas price impact remained stable in most segments of the inter-dealer market.

Table 10: Inter-dealer market liquidity.

Market	Intercept	Crisis	Post-Crisis	Sovereign Crisis
Short covered	**2.471**	-0.127	**2.150**	0.947
$N = 1,123$	(0.193)	(1.076)	(0.647)	(0.658)
Short Gov.	**3.224**	**4.046**	**1.783**	-0.299
$N = 722$	(0.310)	(2.377)	(0.559)	(0.467)
Long covered	**7.705**	-0.463	**-1.787**	0.335
$N = 8,174$	(0.605)	(0.823)	(0.688)	(0.767)
Long Gov.	**7.255**	2.434	1.403	**3.029**
$N = 1,040$	(0.789)	(1.509)	(0.986)	(0.644)

Note: Estimates in bold typeface are significant on a 5% level. More detailed regression tables can be seen in appendix B and C.

However, as can be seen from table 12 and 11, turnover in the inter-dealer market declined dramatically during the crisis compared to the dealer-client market. Hence the unchanged price impact measures do not capture all aspects of the changes in market liquidity during the crisis. The combination of notable increases in the price impact of trade in the dealer-client market combined with a dramatic decline in inter-dealer market turnover is suggestive of a situation where dealers found it difficult to sell bonds in the inter-dealer market and instead sold bonds to clients. This suggest that the inter-dealer community as a whole was cash-constrained during the crisis.

Table 11: Dealer-Client market turnover

Market	Pre-Crisis	Crisis	Post-Crisis	Sovereign Crisis
Short covered	1,240	2,670	3,860	3,530
Short Gov.	410	700	360	740
Long covered	1,800	2,170	1,330	1,330
Long Gov.	910	720	630	700

Note: Average daily turnover in DKKm.

Table 12: Inter-dealer market turnover

Market	Pre-Crisis	Crisis	Post-Crisis	Sovereign Crisis
Short covered	210	110	230	230
Short Gov.	170	50	50	130
Long covered	790	850	610	560
Long Gov.	180	110	90	80

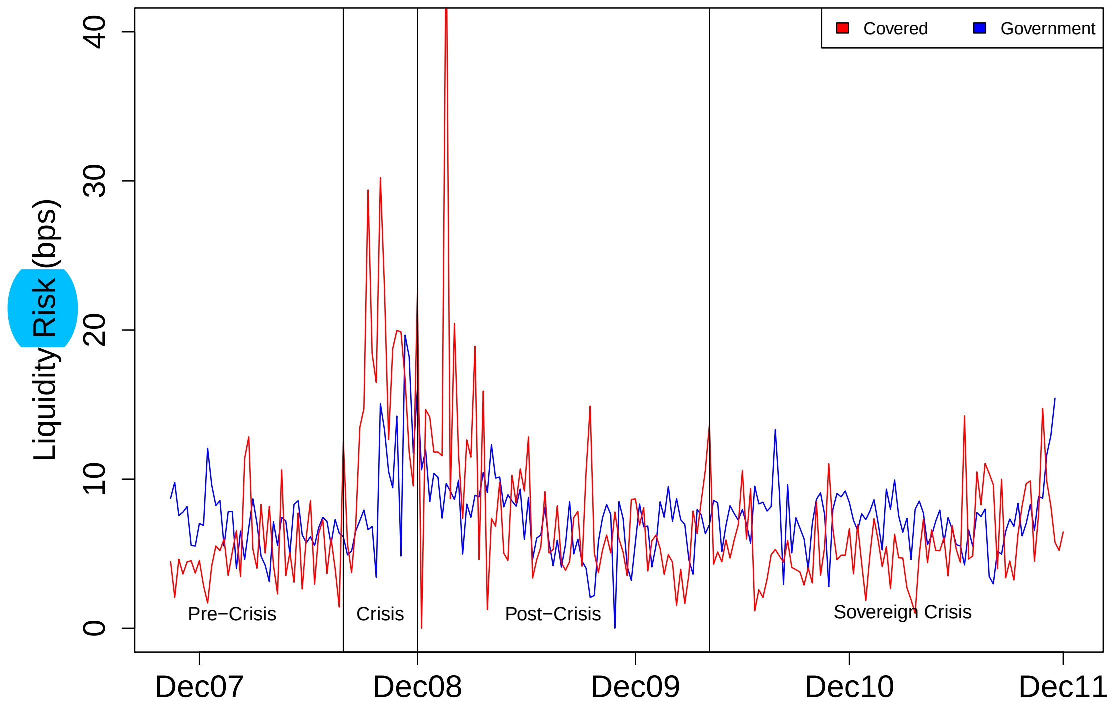
Note: Average daily turnover in DKKm.

7 Liquidity risk

As suggested by Acharya and Pedersen (2005), both the level of liquidity and liquidity risk contributes to the expected return of an asset. Hence a decrease in liquidity is likely to further lower the market price of the bond making it more costly for banks to increase there cash-holdings during periods of severe market stress.

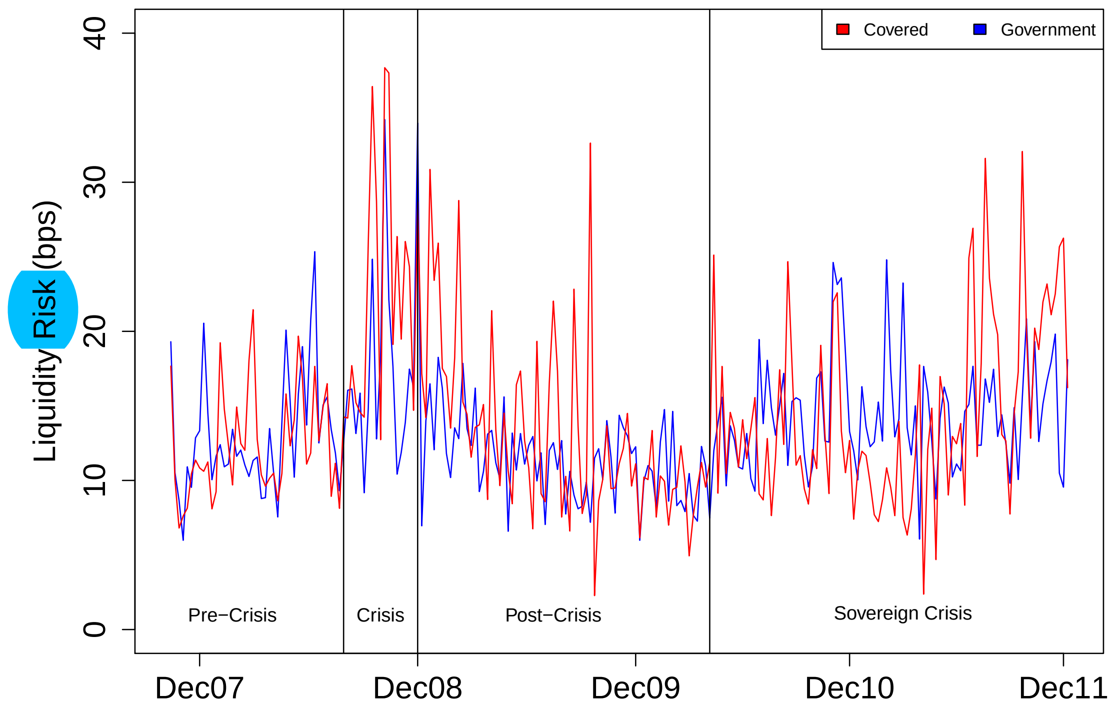
During the 2008 crisis, we do not only find a decrease in the level of liquidity (i.e. higher price impact), we also find an increase in liquidity risk. Figure 3 and 4 show that the variability of our liquidity measure, the liquidity risk, increased during the crisis for all bond types. Hence, it became more uncertain what the price impact would be if an investor wanted to trade. Liquidity risk in the markets for short-term bonds has returned to its pre-crisis levels, while it has increased in the market for long-term bonds. The increase is most significant (see regression tables in appendix D) for the long-term covered bonds.

Figure 3: Liquidity risk - short-term bonds



Note: Weekly liquidity risk measure.

Figure 4: Liquidity risk - long-term bonds



Note: Weekly liquidity risk measure.

8 Concluding Remarks

We find that Danish benchmark covered bonds by and large are as liquid as Danish government bonds during periods of market stress. These results, which are based on a different sample period and on more carefully cleaned data, confirm and extend those of the earlier, preliminary study of Buchholst et al. (2010).

Our findings suggest that before and after the crisis government bonds were slightly more liquid than covered bonds in both the short- and long-term market segments. During the 2008 crisis liquidity decreased in both markets but the covered bond market was more liquid than the government bond market, especially for smaller trade sizes. However, the differences between liquidity in the two markets are economically small and both markets were fairly liquid even during the crisis.

Our second main finding is that the price impact of a trade overall is lower in inter-dealer markets than dealer-client markets. The price impact of trades was visibly higher for dealer-client trades during the crisis whereas it remained stable in the inter-dealer market. However, average daily turnover in the inter-dealer market declined dramatically during the crisis compared to the dealer-client market. Hence, the unchanged price impact measures clearly do not capture all aspects of the changes in market liquidity during the crisis. The combination of notable increases in the price impact of a trade in the dealer-client market combined with a dramatic decline in inter-dealer market turnover is suggestive of a situation where dealers found it difficult to sell bonds in the inter-dealer market and instead sold bonds to clients.

Our third main finding is that liquidity risk in both bond markets increased during the 2008 crisis. This indicates that it became more uncertain what the price impact of a trade would be. After the crisis liquidity risk decreased to the pre-crisis level, except in the market for long-term covered bonds, where liquidity risk remained somewhat higher than before the crisis. As suggested in Brunnermeier and Pedersen (2009), the large increase in liquidity risk during the 2008 crisis could be a result of an increase in the frequency of non-linear price moves in response to trades, which could reflect that the funding constraints of capital constrained traders became binding during the crisis.

From a practical perspective our use of MiFID data, which should also be available in other European countries, suggests a possible way forward for competent authorities seeking to provide robust empirical evidence on the liquidity of various bond markets. Data on actual transactions do provide the opportunity to look at what actually happened. It should however be pointed out that the use of the highly granular transaction level data requires additional effort and investments in data structuring and quality control to be used for analysis of the kind presented here.

A benefit of our price impact measure is that it resembles an effective bid-ask spread over a given period. Hence, even though we do not have observed bid-ask spreads on executable or indicative quotes by trade size, price impact embeds information on actual market depth at given points in time. Nevertheless, it could be interesting to compare our study with studies based directly on pre-trade bid-ask spreads from executable or indicative quotes posted on bond trading-platforms.

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A MiFID data

A.1 Data fields

According to article 25(3) and (4) of Directive 2004/39/EC investment firms and credit institutions are required to report transactions when trading a financial instrument admitted to trading on a regulated market. Furthermore, the transaction reports are to be passed on to the competent authority of the most relevant market in terms of liquidity. This directive is implemented by the Commission Regulation (EC) 1287/2006 clarifying the required content of these so-called MiFID transaction reports. The requirement has applied since November 1st, 2007. Therefore, our dataset should include all transactions in Danish government and covered bonds carried out by an investment firm or credit institution in the EU as one of the counterparties since these transactions should have been reported and the reports passed on to the Danish FSA. The fields in the transaction report used in our analysis are shown in table 13.

Table 13: Transaction report variables

Variable	Description
Instrument identification	The International Securities Identification Number (ISIN) that uniquely identifies the transacted bond
Trading date time	The date, time and time zone when the trade was executed.
Unit Price	Price per bond excluding commission and accrued interest (clean price).
Quantity	The total nominal value of bonds included in the transaction
Currency	Currency in which the price is expressed.
Buy/sell indicator	Identification whether the transaction was a buy or a sell from the perspective of the reporting investment firm if acting as a principal, or of the client if acting as an agent.
Trading capacity	Identification whether the reporting firm executed the transaction "on its own account, either on its own behalf or on behalf of a client" (principal) or "for the account, and on behalf, of a client" (agent).
Reporter identification	A unique code to identify the firm which executed the transaction. An 11 characters ISO 9362 SWIFT/Bank Identifier Code (BIC).
Counterparty ID	The BIC code if the counterparty is a MiFID investment firm. The MIC code of the trading venue if the counterparty is a regulated market or a multilateral trading facility (MTF). Otherwise an internal code for the customer/client is used.
Client name	The name of the client/customer. This field is optional.

A.2 Bond metadata

The MiFID transaction reports naturally include variables related to transactions only. However, as the MiFID transaction reports identify uniquely all instruments by the international securities identification number (ISIN) it is straightforward to add information from other data sources. Thus, bond specific data, i.e. outstanding volume, maturity, issuer, etc. can easily be added from another data source. We have obtained this information form the Danish central bank, Nationalbanken, which receives this information from the central securities registration agent in Denmark, VP-securities, on a monthly basis.

A.3 Data cleaning

We have adjusted and cleaned the data in several steps:

1. The aim of the analysis is to determine the liquidity characteristics of government and covered bonds from the perspective of banks ability to liquidate these assets in times of stress. Therefore, retail size trades should be removed as they will otherwise distort the analysis. In the case of Danish government bonds and covered bonds we remove all transactions with a nominal value of less than DKK 10,000,000 (approximately EUR 1,340,000).

2. The variable 'Trading capacity' is used to adjust the buy/sell indicator so that for all reports the buy/sell indicator reflects the perspective of the reporting firm. If the 'Trading capacity' variable indicates that the reporting firm is acting as an agent and therefore reports the transaction as seen from the perspective of the counterparty we change the buy/sell indicator from buy (sell) to sell (buy). This ensures that the indicator reflects the perspective of the reporting firm.

3. A large number of errors were identified in the counterparty identifiers. Reporting firms often use an internal code for MiFID investment firms instead of the BIC-code. By manually inspecting the most frequent internal codes in the field; 'Counterparty ID' and using the optional variable 'Client name' we were in most cases able to correct this.

4. Although repo transactions should not be reported, some firms nevertheless report repo transactions. We were able to detect and remove repo transactions cases where we found two transactions in opposite direction (buy/sell) and different prices, with the same counterparty in the same bond and of the same amount at exactly the same point in time.

5. Transactions between two investment firms are to be reported by both parties. Therefore, these transactions will be reported twice. This is also the case for transactions on a regulated market or a MTF as both parties trading on a regulated market or a MTF will be required to report the transaction. All transactions that are reported twice need to be detected and only one of the transactions should be kept in the dataset. Fortunately this is straightforward as one can easily identify all transactions between two investment firms or between and investment firm and a regulated market or a MTF.[11] For all these transactions either only the sell side or the buy side transaction report should be kept. Specifically, we choose to keep only the sell side transactions. We have observed that some counterparties that are investment firms never report any transactions themselves.

[11] A complete list of MIC codes can be found at the ESMA webpage http://mifiddatabase.esma.europa.eu/

To adjust for this error in the data we also require that counterparties that are investment firms should have reported at least one transaction themselves before we delete the buy-side transactions.

6. Although primary market activity is not required to be reported under the MiFID directive, we find that transactions at the primary market are nevertheless reported in some cases. Furthermore, at days of auctions in short-term covered bonds the activity is often much higher than in normal days. This heighten activity do not reflect the normal situation faced by a bank that need to liquidate (parts of) its bond portfolio. Therefore we have decided to remove these observations from our dataset. As compared to the preliminary findings in Buchholst et. al. (2010) this is an improvement in our data cleaning process. For the covered bond market, auction dates are identified from announcement on auction schedules made by the mortgage banks. On a date where a mortgage bank conduct auctions we remove all trades in short term bonds issued by this particular bank. This method will inevitably result in too many trades being removed as the auctions do not necessarily involve all short-term bond issued by the bank. However, it would have been highly time-consuming to identify exactly the bonds involved in the auctions. Apart from the auction dates themselves we have also identified some circumstances of unusual heightened activity in the days close to the auctions involving bonds with very short time-to-maturity. Apparently this reflects that sometimes the mortgage banks for operational reasons buy back some of the bonds that are anyway maturing very soon. We define such unusual high trading activity as days within a month of refinancing where we observe at least 5 trades of more than DKK 5 billion in the same bond. We then remove that trading day for the bond in which we observed the very large trades. Government bond market information on auctions and tap sales are obtained from the Danish Debt Management Office. We do not observe an elevated turnover at days with auctions or tap sales in the Government bond market. Thus, we decided not to remove these days. Instead we have removed all transactions that involve the Danish central bank as the Debt Management Office carries out all its transactions through the central bank.

7. We have removed outliers by deleting all trades at prices below DKK 50 or above DKK 150 as any breach of these limits would result in implausible yields for our sample of bonds. We also delete trades involving a higher volume than the outstanding amount of the bond. Finally, we manually inspected all trades with a price impact (see section 3) of more than 100 basis points. In most cases we found that the high price impact is due to a single transaction reported at a very odd price compared to other transactions at that time. Thus, we end up deleting (almost) all transactions giving rise to price impacts of more than 100 basis points.

B Market liquidity - short-term bonds

Table 14: Short-term covered - liquidity in subperiods

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	5.669	0.158	35.794	0.000
Crisis	2.872	1.855	1.548	0.122
Post-Crisis	1.194	0.491	2.430	0.015
Sovereign Crisis	1.830	0.639	2.863	0.004
R^2	0.004			
N	11,183			

Table 15: Short-term government bonds - liquidity in subperiods

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	3.857	0.679	5.681	0.000
Crisis	11.260	1.270	8.868	0.000
Post-Crisis	3.720	1.655	2.247	0.025
Sovereign Crisis	1.355	0.860	1.574	0.115
R^2	0.079			
N	6,383			

Table 16: Short-term covered bonds - price impact on period dummies - interdealer

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	2.471	0.193	12.820	0.000
Crisis	-0.127	1.076	-0.118	0.906
Post-Crisis	2.150	0.647	3.323	0.001
Sovereign Crisis	0.947	0.658	1.438	0.151
R^2	0.011			
N	1,123			

Table 17: Short-term covered bonds - price impact on period dummies - client

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	4.599	0.285	16.117	0.000
Crisis	2.866	2.470	1.160	0.246
Post-Crisis	1.564	0.391	4.000	0.000
Sovereign Crisis	2.706	0.755	3.582	0.000
R^2	0.016			
N	4,327			

Table 18: Short-term government bonds - price impact on period dummies - interdealer

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	3.224	0.310	10.410	0.000
Crisis	4.046	2.377	1.702	0.089
Post-Crisis	1.783	0.559	3.190	0.001
Sovereign Crisis	-0.299	0.467	-0.640	0.522
R^2	0.051			
N	722			

Table 19: Short-term government bonds - price impact on period dummies - client

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	5.237	1.055	4.963	0.000
Crisis	10.067	0.978	10.290	0.000
Post-Crisis	1.680	1.721	0.976	0.329
Sovereign Crisis	2.077	1.943	1.069	0.285
R^2	0.055			
N	2,152			

C Market liquidity - long-term bonds

Table 20: Long-term covered bonds - liquidity in subperiods.

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	11.711	0.700	16.726	0.000
Crisis	0.916	0.791	1.158	0.247
Post-Crisis	-0.263	0.925	-0.284	0.776
Sovereign Crisis	2.646	1.213	2.181	0.029
R^2	0.007			
N	29,992			

Table 21: Long-term government bonds - liquidity in subperiods.

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	10.095	0.611	16.523	0.000
Crisis	5.584	2.401	2.326	0.020
Post-Crisis	0.730	0.891	0.820	0.412
Sovereign Crisis	-0.052	1.127	-0.046	0.963
R^2	0.012			
N	11,675			

Table 22: Long-term covered bonds - price impact on period dummies - interdealer

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	7.705	0.605	12.742	0.000
Crisis	-0.463	0.823	-0.563	0.574
Post-Crisis	-1.787	0.688	-2.597	0.009
Sovereign Crisis	0.335	0.767	0.436	0.663
R^2	0.010			
N	8,174			

Table 23: Long-term covered bonds - price impact on period dummies - client

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	11.403	0.837	13.627	0.000
Crisis	2.446	0.412	5.935	0.000
Post-Crisis	3.475	1.415	2.455	0.014
Sovereign Crisis	5.128	1.477	3.472	0.001
R^2	0.015			
N	10,946			

Table 24: Long-term government bonds - price impact on period dummies - interdealer

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	7.255	0.789	9.200	0.000
Crisis	2.434	1.509	1.613	0.107
Post-Crisis	1.403	0.986	1.420	0.155
Sovereign Crisis	3.029	0.644	4.700	0.000
R^2	0.010			
N	1,040			

Table 25: Long-term government bonds - price impact on period dummies - client

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	11.503	0.680	16.918	0.000
Crisis	6.505	1.463	4.446	0.000
Post-Crisis	0.407	0.656	0.621	0.535
Sovereign Crisis	2.863	1.401	2.043	0.041
R^2	0.015			
N	5,294			

D Liquidity risk

Table 26: Short-term covered bonds - liquidity risk on period dummies.

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	6.820	0.282	24.212	0.000
Crisis	2.446	1.058	2.312	0.022
Post-Crisis	0.505	0.422	1.195	0.233
Sovereign Crisis	0.056	0.386	0.144	0.885
R^2	0.057			
N	217			

Table 27: Short-term government bonds - liquidity risk on period dummies.

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	5.268	0.378	13.954	0.000
Crisis	10.113	1.754	5.767	0.000
Post-Crisis	2.825	0.840	3.364	0.001
Sovereign Crisis	-2.199	0.809	-2.717	0.007
R^2	0.261			
N	219			

Table 28: Long-term covered bonds - liquidity risk on period dummies.

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	12.954	0.596	21.717	0.000
Crisis	3.971	1.686	2.356	0.019
Post-Crisis	-1.590	0.681	-2.335	0.020
Sovereign Crisis	3.084	0.516	5.971	0.000
R^2	0.162			
N	220			

Table 29: Long-term government bonds - liquidity risk on period dummies.

Variable	Parameter	Standard Dev.	t-statistic	p-value
Intercept	12.120	0.615	19.710	0.000
Crisis	10.124	1.928	5.250	0.000
Post-Crisis	0.866	0.938	0.923	0.357
Sovereign Crisis	1.479	0.969	1.527	0.128
R^2	0.172			
N	220			