Liquidity Risk and the Covered Bond Market in Times of Crisis: Empirical Evidence from Germany

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Abstract

Liquidity risk is the risk that an asset cannot always be sold without causing a fall in its price because of a lack of demand for this asset. Many empirical studies examining liquidity premia have focused on government bonds. Therefore, it might be of special interest to examine yield differentials between liquid and illiquid German covered bonds using techniques of time series analysis. We examine the yields of traditional Pfandbriefe and Jumbo Pfandbriefe with different maturities. In terms of credit risk the spread between the yields of these two types of covered bonds should be zero. Moreover, assuming that the liquidity risk premium is a stationary variable the yields of Pfandbriefe and Jumbo Pfandbriefe (which seem to be integrated of order one) should be cointegrated. We examine this by using methodology proposed in the related field of fractional integrated models. Due to the financial crisis, it also seems to be appropriated to consider structural change. Our results indicate fractional cointegrated yields before and after the crisis. However, during the crisis the degree of integration of the spread increases strongly.

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1. Introduction

Liquidity risk is defined as the risk that an asset cannot always be sold without causing a strong fall in its price because of a lack of demand for this asset. The liquidity premium compensates investors for bearing liquidity risk. Many empirical studies examining liquidity premia have focused on government bonds. In fact, there are numerous relevant papers. Boudoukh and Whitelaw (1993), for instance, have examined price differentials among liquid and illiquid Japanese government bonds. More recently, Sibbertsen, Wegener, and Basse (2014) have, for example, suggested that the existence of liquidity premia to compensate investors for the lower liquidity of the Italian and Spanish government bond markets relative to the German government bond market could help to explain their empirical findings that show deviations from the uncovered interest rate parity condition.

In order to gain additional insights with regard to interest rates and liquidity premia it could be of interest to analyze data from the German covered bond market, that incorporates two types of bonds with differences regarding their liquidity. Examining European covered bonds in more detail is also of interest from the perspective of monetary policymakers because the European Central Bank started its Covered Bond Purchasing Programme in 2009 as a kind of spearhead of the measures to engage in the then new practice of quantitative easing. Moreover, the financial crisis seems to have caused a kind of re-pricing of liquidity risk in the European covered bond market.

Practitioners seem to have two very different interpretations of what happened in the European covered bond market. It is generally accepted that the problems of the European covered bond market are closely related to the Subprime Mortgage Crisis but already started before house prices in the U.S. peaked. One more traditional explanation is that the global financial crisis that was caused by the exposure of international banks to the U.S. real estate market (mainly through mortgage backed securities) created some problems and resulted in a liquidity crisis. Taking this perspective the liquidity premium between the yields of the two types of German covered bonds should first have increased; then the Covered Bond Purchasing Programme ought to have lowered spreads in 2009 again. However, some investors seem to believe that with regard to liquidity Jumbo Pfandbriefe are not really a close substitute to German government bonds. According to this point of view Jumbo Pfandbriefe should have been priced more like traditional Pfandbriefe in the crisis and the Covered Bond Purchasing Programme of the European Central Bank should mainly have profited the more liquid bonds bought by the central bank. Thus, according to this hypothesis the spread between Jumbo and the less liquid traditional Pfandbrief bonds might even have increased with the purchases of covered bonds by the European Central Bank. Therefore, it might be of special interest to examine yield differentials between liquid and illiquid German covered bonds using techniques of time series analysis.

The paper is structured as follows: The next section describes the features of covered bonds and their particular importance for the global bond markets. The third part introduces the term of liquidity risk. Section 4 describes the data and provides a first insight about their time series properties. Section 5 introduces a methodology to estimate a fractional cointegrated system. The following section presents the results of an application of covered bond yields. Section 6 concludes.

2. Covered Bonds

Covered bonds are one of the most important segments of the global bond market. These fixed income securities are fully collateralized bonds issued by authorized banks and are backed by a pool of assets that in general consists of mortgage loans or public sector loans. There are some country specific differences with regard to the assets that are eligible to back covered bonds. Meanwhile, German covered bonds (so-called Pfandbriefe), for example, may also be secured by ship and aircraft loans. In marked contrast to asset-backed securities the assets backing covered bonds remain on the balance sheet of the issuer. Only in the case of an insolvency of the issuing bank the assets belonging to the cover pool are separated from the balance sheet of the insolvent bank to meet the claims of the bondholders (e.g., Tolckmitt and Walburg, 2002; Lorenz, 2006).

Covered bonds are usually seen as an important source of funding for the European banking industry. This is especially true for German banks, where covered bonds have a long tradition. In fact, the Pfandbrief can look back upon a history of more than 200 years (e.g., Hagen, 2003; Lorenz, 2006). Therefore, it is hardly surprising that the market for Pfandbriefe is by far the most important segment of the European covered bond market.

There are different types of German covered bonds. Most importantly, there are so-called traditional Pfandbriefe and Jumbo Pfandbriefe. While both types of bonds are governed by the same requirements with regard to credit risk, traditional Pfandbriefe are issued in smaller sizes. Therefore, the market for these securities is regarded to be less liquid than Jumbo Pfandbriefe. The first Jumbo Pfandbrief was issued in 1995 (e.g., Hagen, 2003). This special type of covered bond with a minimum issuing volume of 1 billion EUR was created to provide a more liquid financial instrument for institutional investors. Besides the regulations with regard to issue size, there are additional minimum standards for a Jumbo Pfandbrief in order to increase market liquidity. They must, for example, be placed by a syndicate consisting of at least five banks. These banks act as market makers. Given that both traditional and Jumbo Pfandbriefe are very secure investments, yield spreads between these two types of German covered bonds usually are interpreted as pure liquidity premia by market participants.

3. Liquidity Risk

Liquidity is an important concept in financial economics and measures how easy financial assets can be converted into cash. It is hard to find a generally accepted definition of liquidity. Goldreich, Hanke, and Nath (2005), for example, have noted that the term liquidity is often used to describe the narrowness of the bid-ask spread; however, they have also argued that there are broader definitions (e.g., trading volume, market depth or other measures of market activity). Boudoukh and Whitelaw (1993) have argued convincingly that the value of liquidity results from the uncertainty about future trading needs of current investors. Assuming that all bondholders are buy-and-hold investors, liquidity obviously would not matter when there is no need to engage in additional bond market transactions after the fixed income securities have been purchased. Investors would simply hold the bonds until maturity – in other words for one period (which, of course, is not necessarily one year).

We start with a generalized theory on bond yield spreads. The risk adjusted bond yield of bond A reads ip_t^A ($i_t^A = ip_t^A + RP_t$) and i_t^B is the bond yield of bond B. RP_t is a time dependent risk premium. We assume parity of ip_t^A and i_t^B (see Fratzscher, 2002)

$$ip_t^A = i_t^B \tag{1}$$

and $i_t^A \geq i_t^B$ to imply a positive risk premium RP_t

$$i_t^A - i_t^B = RP_t. \tag{2}$$

In principle, the risk premium might consists out of several kinds of risk like credit risk (CR_t), political risk (PR_t), redenomination risk (RR_t) and even more risk factors.

$$RP_t = LP_t + \underbrace{CR_t + PR_t + RR_t + ...}_{=0} \tag{3}$$

Here, we focus on the liquidity premium LP_t because of the characteristic that both types of bonds are identical with one exception – their liquidity. Investors might be hit by liquidity shocks that force bondholders to sell assets (see Goldreich, Hanke, and Nath, 2005). Lucas (1990) has argued that these liquidity shocks have the capacity to induce sudden large drops in the prices of bonds and other illiquid securities.

Following Goldreich, Hanke, and Nath (2005) the liquidity premium reads

$$i_t^A - i_t^B = \lambda \times (c^A - c^B) \tag{4}$$

while λ is the probability of a liquidity shock that causes flight-to-liquidity effects and c^A and c^B are trading costs for both types of bonds. In addition we assume that c^A and c^B are linear functions of the interest rate level i_t^B and the risk aversion RA_t. Thus, the liquidity premium might have the form

$$i_t^A - i_t^B = \lambda \times \left(c^A\left(i_t^B, RA_t\right) - c^B\left(i_t^B, RA_t\right)\right) \tag{5}$$

which implies a non-constant but stationary spread.

Since we assume that both hand sides of equation 5 contain i_t^B the resulting cointegrating vector would read $(1, -\beta)$ with $\beta \neq 1$. We estimate this cointegrated system and present the results in Section 5.

4. Data and Initial Analysis

We examine the yields of traditional Pfandbriefe and Jumbo Pfandbriefe with the maturities of five, seven and ten years. Our sample starts at 01-01-1999 and ends at 12-30-2011. Therefore we investigate 679 weekly observations taken from Bloomberg Database.

If the spread is not interest rate sensitive, the yields of Pfandbriefe and Jumbo Pfandbriefe should be cointegrated with the vector $\vec{\beta} = (1, -1)$ as discussed in Section 3. Two $I(1)$ variables are said to be cointegrated if they share a common stochastic trend. Thus, first of all, we use the approach suggested by Ng and Perron (2001) to test for $I(1)$ behavior of the yields.

(Insert Table 1 here)

Table 1 shows the test statistics of the unit root test. Comparing the critical values of -1.98 (intercept) and -2.91 (intercept and trend) with the test statistics indicates that the null hypothesis of a unit root for the six time series cannot be rejected.

However, a look at figure 1 causes reasonable doubt that the assumption about the spread is fulfilled.

(Insert figure 1 here)

The autocorrelation functions of the spreads decline very slowly which is an indication of $I(d)$ behavior with $d > 0$. There are a number of possible reasons – the most common sources for this finding are:

1. the spread contains non-linearity or long memory
2. there is a structural break in β
3. there is a structural break in the persistence of the spread
4. a mixture of these points

To start our analysis we employ a modified GPH estimator to investigate the order of integration of the yield differentials in more detail. This modification by Phillips and Magdalinos (2007) has been shown to have better power properties than the original suggested by Geweke and Porter-Hudak (1983).

(Insert Table 2 here)

Also this procedure suggests $I(d)$ behavior with $0 < d < 1$ of the spread as reported in Table 2. For a cointegrating vector of $\vec{\beta} = (1, -1)$ (no interest rate sensitivity), this might be an indication that the yields of the traditional Pfandbrief and the Jumbo Pfandbrief are fractionally cointegrated. Shimotsu (2012) highlights two examples of bivariate fractionally cointegrated systems: The first refers to the case with two time series x_t and y_t which have the same memory parameter $d_x < 1$ and the equilibrium error u_t is integrated of order d_u with $d_u < d_x$ for $t = 1, 2, ...T$. See e.g. Bandi and Perron (2006), Christensen and Nielsen (2006) and Nielsen and Frederiksen (2011) for empirical applications of fractional cointegration matching the foregone case.

The second example refers to the case where x_t and y_t (concerning our application y_t is the yield of bond A i_t^A and x_t is the yield of bond B) are $I(d_x)$ with $d_x = 1$ and u_t is integrated with $0 < d_u < 1$. This one seems to match our case: The yields are individually $I(1)$ and the equilibrium error for $\vec{\beta} = (1, -1)$ is integrated of order $0.45 < d_u < 0.75$. Moreover, using the procedure by Phillips and Magdalinos (2007) to test against $d_x = 0$ and against $d_x = 1$ indicates evidence that x_t and y_t are $I(1)$.[1]

Furthermore, we are particularly interested in whether d_u remains constant over time. Thus, we use the methodology proposed by Sibbertsen and Kruse (2009) to test the hypothesis

$$H_0 : d_u = d_{u,0},\ \forall\ t \text{ vs. } H_1 : \begin{cases} d_u = d_{u,1} \text{ for } t = 1, ..., [\tau T] \\ d_u = d_{u,2} \text{ for } t = [\tau T] + 1, ..., T \end{cases} . \tag{6}$$

[1]Results are not reported in order to conserve space and are available on request from the authors.

Here, $[\tau T]$ denotes the biggest integer smaller than τT with τ as the relative breakpoint estimator and T as the number of observations. The test by Sibbertsen and Kruse (2009) modifies the procedure proposed by Leybourne, Taylor, and Kim (2007) to test against a break in persistence under long-range dependencies of univariate time series. They restricted $0 \leq d_0 < \frac{3}{2}$ under H_0 and $0 \leq d_1 < \frac{1}{2}$ and $\frac{1}{2} \leq d_2 < \frac{3}{2}$ under the alternative. Moreover, d_1 and d_2 can be exchanged, so a break from stationary to non-stationary long-memory and vice versa can be investigated. Thus, we test against a break in the persistence in the spread of traditional and Jumbo Pfandbriefe using the estimated d under the null hypothesis by the modified GPH estimator. In this case there is clear evidence for a break between 2006 and 2007 for all maturities. Table 3 shows the results of this test.

(Insert table 3 here)

However, the European Central Bank established the *Covered Bond Purchase Programme* in order to stabilize the covered bond market in Europe. This intervention might have caused decreasing persistence in 2009. Thus, we test against a break in d_u after the first break. Table 4 shows the results and figure 2 shows the chart of the simple spreads with marked breaks. Thus, it seems that, coincident with the financial crisis, the persistence of the spread increased strongly. This might cause spurious results in order to explain the behavior of the covered bond spreads using regression models (see, for example, Prokopczuk, Siewert, and Vonhoff (2013)).

(Insert figure 2 here)

(Insert table 4 here)

Furthermore, additional breaks or smooth trends might cause spurious long memory before the first breakpoint and after the second break. For this reason we test against a further break in the persistence as proposed above and in addition we use the test by Qu (2011). The procedure by Qu (2011) tests the null hypothesis of stationary long memory against short memory with level shifts or smooth trends. This test evaluates the derivative of the local Whittle likelihood at the first $[\kappa r]$ Fourier frequencies κ with $r \in [\epsilon, 1]$. Here, we consider a bandwidth from $T^{0.55}$ to $T^{0.75}$ and we apply this procedure until the first break in d_u for all maturities with $\epsilon = 0.02$. Regarding the ten years spread we estimate $d_u > 0.5$. Thus, the results in this case might be questionable for a bandwidth between $T^{0.60}$ and $T^{0.75}$.

(Insert table 5 and table 6 here)

Neither the test by Sibbertsen and Kruse (2009) (results are not reported in order to conserve space) nor the results of the procedure by Qu (2011) (results are reported in table 5) indicate doubts that the behavior of the particular spreads until the breaks between 2006 and 2007 might be caused by spurious long memory at a confidence level of $\alpha = 0.1$. Additionally, we apply the test by Qu (2011) to the spreads after the second break. As reported in table 6, we do not find any indications about long range dependencies caused by level shifts or smooth trends on a confidence level of $\alpha = 0.1$ regarding the seven and ten year spread. We do not consider the five year spread because we do not find decreasing persistence in this case. Motivated by these results, we estimate a fractionally cointegrated system for subsamples to control for breaks in d_u and for the full sample in order to investigate the cointegrating vector $\vec{\beta}$ in the following section.

5. Estimating a Fractionally Cointegrated System for Covered Bond Yields

5.1. Methodology

Shimotsu (2012, pg. 266) noted, that if the standard $I(0)/I(1)$ cointegration techniques are applied to fractionally cointegrated time series, "it leads to either (i) a false rejection of the existence of an equilibrium relationship, or (ii) misspecification of the degree of persistence of the stochastic trend and/or the equilibrium error." Thus, considering the results of Section 4, it seems to be appropriate to employ fractional cointegration methods.

A lot of studies examined estimation techniques of fractional cointegrated systems (e.g. Velasco, 2003; Robinson, 2008; Nielsen and Frederiksen, 2011). Robinson (2008) showed that the local Whittle estimator is consistent and has an asymptotic Gaussian distribution if $0 \leq d_u < d_x < 0.5$. Shimotsu (2012) used a tapered version of this estimator on the first stage and the exact local Whittle approach proposed by Shimotsu and Phillips (2005) on the second stage. This two-step estimation procedure accommodates the stationary and the nonstationary case of x_t and u_t, respectively. The estimator of the memory parameters is asymptotic normally distributed in both cases. Moreover, Shimotsu (2012) noted, that the distribution and the convergence rate of β depends on the difference between d_x and d_u. Thus for $d_x - d_u < 0.5$, β is asymptotic normally distributed.

We use the procedure proposed by Shimotsu (2012) to estimate $\vec{\beta} = (1, -\beta)$, d_x and d_u

of the bivariate fractionally cointegrated system

$$\begin{cases} (1-L)^{d_u}(y_t - \beta x_t) = \varepsilon_{1,t}, \\ (1-L)^{d_x} x_t = \varepsilon_{2,t} \end{cases} \tag{7}$$

with $t = 1, 2, ..., T$, $\beta \neq 0$, and $\varepsilon_{1,t}$, $\varepsilon_{2,t}$ are stationary with zero mean. However, we use the estimator by Shimotsu (2010) on the second stage to deal with an unknown mean. Shimotsu (2012) noted that the asymptotic distribution remains the same.

5.2. *Empirical Results*

First of all, we estimate the cointegrated system as proposed in equation 7 for the whole sample $T = 679$ and bonds with the maturity of 5, 7 and 10 years. We consider bandwidths $m = T^{\zeta}$ and $\zeta = 0.55, 0.60, 0.65, 0.70, 0.75$. The results are reported in table 7. Here and in the following, ρ is the correlation between $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$. For $\rho \neq 0$ the most estimation procedures of fractional cointegrated systems fail. However, the procedure by Shimotsu (2012) overcomes this problem.

(Insert table 7 here)

The hypothesis of $d_x = 1$ cannot be rejected on a confidence level of $\alpha = 0.05$ for most m and all maturities. This finding is consistent with the results of the test proposed by Ng and Perron (2001) reported in table 1. Furthermore, $H_0 : \beta = 1$ cannot be rejected in most cases and $\alpha = 0.05$. However, for 5 and 10 years maturity and $m = 0.55$, $d_x - d_u > 0.5$ applies, thus the asymptotic distribution theory for β is not available. For this reason we use a subsampling method with subsamples of size $b = 200$. Also in this case, $H_0 : \beta = 1$ cannot be rejected. Depending on m, d_u is between 0.5 and 0.8 and even the upper bounds of the confidence intervals are smaller than 1. All these findings indicate fractional cointegration with $\{d_u, d_x, \beta\} = \{[0.5, 0.8]), 1, (1, -1)\}$. To investigate the behavior before and after the breaks in d_u, we estimate the cointegrated system as proposed in equation 7 for subsamples based on the results of the test by Sibbertsen and Kruse (2009) as described in Section 4. Considering the time before the particular break date, the results are reported in table 8.

(Insert table 8 here)

The estimation results indicate that the system is fractionally cointegrated with $\{d_u, d_x, \beta\} = \{[0.2, 0.7]), 1, (1, -1)\}$. Most surprisingly, d_u is still significantly different from zero. However, the degree of integration is smaller than for the whole sample. In most cases $d_x - d_u > 0.5$

applies, thus we also use the subsampling method as described above with $b = 100$. Furthermore, we estimate a fractionally cointegrated system after the breakpoints to quantify the change of the parameters. Table 9 shows the results.

(Insert table 9 here)

It is obvious that d_u has increased for all bandwidths and all bonds and d_x and β have remained constant since 2006 and 2007, respectively.

For $\beta = (1, -1)$ and in the case of the seven year spread the test shows decreasing persistence in 2009 for the bandwidth of $T^{0.75}$. This also holds for the ten year spread and all considered bandwidths. Thus, we consider the time from 2006 and 2007, respectively until 2009 and from 2009 to 2011. So we use 166 (87) observations regarding the the seven year spread (ten year spread) before and 106 (144) after the particular break points. Table 10 shows the results of the estimated fractionally cointegrated system.

(Insert table 10 here)

The finding that d_u has increased significantly since 2006 and 2007 is confirmed. This is consistent with the results reported by Sibbertsen et al. (2014) who have examined European government bond yields. Their results can be explained by higher credit risk and possibly even with redenomination risk (a special version of exchange rate risk). Sibbertsen et al. (2014) also have argued that liquidity might matter. With regard to the examined time series, increased risk premia due to changes to credit risk and redenomination risk obviously are of no relevance. However, the reported findings can definitely be explained by higher absolute or relative trading costs $c_B - c_A$ and thus, a higher liquidity premium.

The hypothesis that $\beta = (1, -1)$ and $d_x = 1$ cannot be rejected in most cases – which indicates no interest rate sensitivity of the risk premium. However, confidence intervals have become broader. This might be caused by small sample sizes. Furthermore, we estimate $\{d_u, d_x, \beta\}$ after 2009. The results are reported in table 11.

(Insert table 11 here)

It is obvious that d_u decreased and the hypothesis of $d_x = 1$ cannot be rejected. However, due to broader differences between d_x and d_u the asymptotic distribution theory for β is not available. Nonetheless, we waive the subsampling method due to small sample sizes.

(Insert figure 3 here)

To briefly resume our results, we found fractional cointegration between Pfandbriefe and Jumbo Pfandbriefe with $\{d_u, 1, (1, -1)\}$. We further tested against structural breaks in d_u and found that the relations between the two covered bonds have changed over time. These results might be caused by the financial crisis. Surprisingly, when d_u was low or decreased, which could be a characteristic of moderate economic times, it was still not zero. Figure 3 shows the autocorrelation functions of the spreads in the particular regimes.

6. Conclusion

We examined the relationship between yields of traditional Pfandbriefe and Jumbo Pfandbriefe using techniques of time series analysis. Both seem to be $I(1)$. Accepting that the two types of covered bonds only differ with regard to liquidity risk and assuming that the liquidity risk premium is a stationary variable, the bond yields – as long as the liquidity premium is not interest rate sensitive – should be cointegrated with $\beta = (1, -1)$. The latter cannot be rejected while the simple cointegration framework does not take account for the properties of the considered system. Thus, we used the procedure suggested by Shimotsu (2012) to allow for fractional cointegration. We estimated fractionally cointegrated systems with $([0.5, 0.8], 1, (1, -1))$, therefore the assumption of a stationary liquidity premium could not be confirmed. This result might be spurious due to structural changes in the persistence indicated by the test proposed by Sibbertsen and Kruse (2009). We found increasing persistence for all maturities which coincides with the financial crisis. Regarding seven and ten years bonds, we further examined a second breakpoint with decreasing d_u. Altogether, we considered three regimes: A quite low persistence of the spread before, a high d_u in the crisis and a low d_u after the crisis. In the first and third regime, d_u was not equal to zero but stationary. We used the procedure by Qu (2011) to test against spurious long memory and found true long memory within these regimes. The hypothesis of $\beta = (1, -1)$ cannot be rejected for all three subsamples. These results can be explained by a higher liquidity premium. First of all, the trading costs, represented by $(c_B - c_A)$ respectively, might have increased dramatically, thus the process of convergence of both yields has changed. Furthermore, flight-to-liquidity effects, represented by λ, might have caused a higher d_u. Finally, the investors might have become more risk averse. A mixture of the last two points might be particularly plausible, considering the timing of the breakpoints.

The empirical evidence reported here clearly supports the point of view that the global financial crisis caused a traditional liquidity crisis that also affected the German covered bond market. Consequently, the persistence of the spreads decreased again after the European Central Bank started to buy covered bonds. Our empirical findings might be explained by the yield time series for traditional Pfandbriefe that we do examine. This time series is calculated from bond prices and mainly seems to be based on data from rather liquid traditional Pfandbrief bonds.

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Appendix

Tables

Table 1: Ng Perron Test for unit roots

	Akaike		Schwarz	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
Pfandbrief 5Y	-1.00107	-1.31612	-1.00107	-1.31612
Pfandbrief 7Y	-1.10745	-1.46411	-1.10745	-1.46411
Pfandbrief 10Y	-1.13057	-1.48812	-1.13057	-1.48812
Jumbo Pfandbrief 5Y	-1.01021	-1.29734	-1.01021	-1.29734
Jumbo Pfandbrief 7Y	-1.10774	-1.41607	-1.10774	-1.41607
Jumbo Pfandbrief 10Y	-1.17924	-1.58644	-1.17924	-1.58644

Table 2: Modified GPH

Maturity	Bandwidth	d	StdErr	$t(H_0 : d = 0)$	$P > \|t\|$	$t(H_0 : d = 1)$	$P > \|t\|$
	0.50	0.5124997	0.0981141	5.2235	0.000	-3.8763	0.000
5 Years	0.60	0.6784042	0.0783983	8.6533	0.000	-3.5461	0.000
	0.70	0.6253090	0.0563143	11.1039	0.000	-5.7249	0.000
	0.80	0.6911256	0.0446706	15.4716	0.000	-6.5335	0.000
	0.50	0.4961688	0.1413929	3.5091	0.002	-4.0062	0.000
7 Years	0.60	0.6914198	0.0874687	7.9048	0.000	-3.4026	0.001
	0.70	0.7059399	0.0589845	11.9682	0.000	-4.4929	0.000
	0.80	0.6793011	0.0491622	13.8176	0.000	-6.7836	0.000
	0.50	0.6960751	0.1865023	3.7323	0.001	-2.4166	0.016
10 Years	0.60	0.7190957	0.1107111	6.4952	0.000	-3.0974	0.002
	0.70	0.7117394	0.0713346	9.9775	0.000	-4.4043	0.000
	0.80	0.7303082	0.0568460	12.8471	0.000	-5.7047	0.000

Table 3: Results of the test against changing persistence (1)

Maturity	Bandwidth	Test Statistic	CV low	CV up	Test Decision	Break Date
5 Years	0.5	0.271	0.579	1.704	Increasing Persistence	2006-02-17
	0.8	0.270	0.631	1.588	Increasing Persistence	2006-02-17
7 Years	0.5	0.348	0.508	1.963	Increasing Persistence	2006-10-13
	0.8	0.348	0.620	1.609	Increasing Persistence	2006-10-13
10 Years	0.5	0.513	0.620	1.61	Increasing Persistence	2007-07-27
	0.8	0.513	0.641	1.569	Increasing Persistence	2007-07-27

Table 4: Results of the test against changing persistence (1)

Maturity	Bandwidth	Test Statistic	CV low	CV up	Test Decision	Break Date
5 Years	0.5	0.894	0.579	1.704	Cannot reject H_0	
	0.8	0.894	0.599	1.652	Cannot reject H_0	
7 Years	0.5	1.637	0.459	2.202	Cannot reject H_0	
	0.8	1.637	0.620	1.608	Decreasing Persistence	2009-12-18
10 Years	0.5	2.336	0.825	1.276	Decreasing Persistence	2009-03-20
	0.8	2.336	0.641	1.569	Decreasing Persistence	2009-03-20

Table 5: Results of Qu's Test (1)

Spread	$T^{0.55}$	$T^{0.60}$	$T^{0.70}$	$T^{0.75}$
5 Years	0.51	0.84	0.84	0.77
7 Years	0.63	0.76	0.65	0.61
10 Years	0.82	(1.07)	(1.31)	(1.36)

Table 6: Results of Qu's Test (2)

Spread	$T^{0.55}$	$T^{0.60}$	$T^{0.70}$	$T^{0.75}$
7 Years	0.68	0.45	0.38	0.60
10 Years	0.34	0.37	0.43	0.25

Table 7: Estimated fractional cointegrated system (1)

m	$T^{0.55}$	$T^{0.60}$	$T^{0.65}$	$T^{0.70}$	$T^{0.75}$
5 Years					
d_u	0.6194	0.7154	0.6862	0.7034	0.6725
	[0.461 0.777]	[0.583 0.848]	[0.570 0.802]	[0.605 0.802]	[0.589 0.756]
d_x	1.1290	1.0942	1.1075	1.1030	1.0925
	[0.971 1.287]	[0.962 1.227]	[0.992 1.224]	[1.004 1.202]	[1.009 1.176]
β	1.0190	1.0409	1.0201	1.0193	1.0190
	[0.998 1.074]*	[1.006 1.076]	[0.993 1.047]	[0.989 1.049]	[0.994 1.044]
ρ	-0.3022	-0.3774	-0.2326	-0.2274	-0.2174
7 Years					
d_u	0.6715	0.7943	0.7668	0.7580	0.6832
	[0.514 0.829]	[0.660 0.929]	[0.650 0.884]	[0.660 0.857]	[0.600 0.767]
d_x	1.0697	1.0458	1.0737	1.0872	1.0748
	[0.912 1.227]	[0.911 1.180]	[0.956 1.191]	[0.988 1.187]	[0.991 1.159]
β	1.0173	1.0296	0.9996	1.0051	1.0080
	[0.984 1.051]	[0.965 1.095]	[0.952 1.047]	[0.964 1.046]	[0.979 1.037]
ρ	-0.3453	-0.3301	-0.1641	-0.1705	-0.1985
10 Years					
d_u	0.4930	0.6746	0.6080	0.6227	0.6620
	[0.331 0.654]	[0.539 0.810]	[0.491 0.725]	[0.524 0.721]	[0.579 0.745]
d_x	1.0628	1.0245	1.0512	1.0666	1.0590
	[0.902 1.224]	[0.889 1.160]	[0.934 1.168]	[0.968 1.165]	[0.976 1.142]
β	1.0198	1.0395	1.0253	1.0308	1.0411
	[1.008 1.135]*	[0.991 1.088]	[0.998 1.052]	[1.004 1.057]	[1.005 1.077]
ρ	-0.2051	-0.2757	-0.1873	-0.2206	-0.2580

Table 8: Estimated fractional cointegrated system (2)

m	$T^{0.55}$	$T^{0.60}$	$T^{0.65}$	$T^{0.70}$	$T^{0.75}$
5 Years					
d_u	0.2117	0.2918	0.3119	0.3325	0.3376
	[0.026 0.397]	[0.129 0.455]	[0.172 0.452]	[0.212 0.453]	[0.234 0.442]
d_x	1.1518	1.0689	1.1772	1.1771	1.1102
	[0.967 1.337]	[0.906 1.232]	[1.038 1.317]	[1.057 1.298]	[1.006 1.214]
β	0.9991	1.0003	0.9997	0.9999	1.0007
	[0.997 1.007]*	[0.997 1.009]*	[0.999 1.006]*	[1.000 1.007]*	[1.000 1.009]*
ρ	-0.3483	-0.2832	-0.2796	-0.2443	-0.2626
7 Years					
d_u	0.2529	0.3512	0.4592	0.4142	0.4233
	[0.068 0.438]	[0.190 0.512]	[0.321 0.597]	[0.295 0.534]	[0.321 0.525]
d_x	1.0633	1.0381	0.9978	1.1878	1.0729
	[0.879 1.248]	[0.877 1.199]	[1.013 1.289]	[1.068 1.307]	[0.971 1.175]
β	1.0015	1.0001	0.9978	0.9973	1.0002
	[1.001 1.010]*	[0.997 1.011]*	[0.997 1.006]*	[0.998 1.008]*	[0.997 1.008]*
ρ	-0.2243	-0.2049	-0.1918	-0.1019	-0.1922
10 Years					
d_u	0.3900	0.6939	0.7045	0.6850	0.6686
	[0.207 0.573]	[0.536 0.852]	[0.570 0.839]	[0.571 0.799]	[0.571 0.766]
d_x	1.0410	1.1891	1.0838	1.1669	1.0942
	[0.858 1.224]	[1.032 1.347]	[0.949 1.218]	[1.053 1.281]	[0.997 1.192]
β	0.9938	0.9905	0.9969	0.9966	1.0059
	[0.988 1.022]*	[0.986 0.995]	[0.969 1.025]	[0.987 1.007]	[0.985 1.027]
ρ	-0.1945	-0.1801	-0.1958	-0.2529	-0.2564

Table 9: Estimated fractional cointegrated system (3)

m	$T^{0.55}$	$T^{0.60}$	$T^{0.65}$	$T^{0.70}$	$T^{0.75}$
5 Years					
d_u	0.8294	0.7222	0.7251	0.7377	0.7083
	[0.640 1.019]	[0.549 0.895]	[0.575 0.875]	[0.606 0.869]	[0.595 0.821]
d_x	1.1449	1.1483	1.0723	1.0548	1.0730
	[0.955 1.334]	[0.975 1.321]	[0.922 1.222]	[0.923 1.186]	[0.960 1.186]
β	1.0941	1.0355	1.0439	1.0374	1.0367
	[0.988 1.200]	[0.980 1.092]	[0.960 1.127]	[0.947 1.128]	[0.966 1.108]
ρ	-0.5019	-0.2452	-0.2750	-0.2497	-0.2407
7 Years					
d_u	0.9555	0.8422	0.8038	0.7275	0.6786
	[0.804 1.108]	[0.657 1.028]	[0.646 0.962]	[0.590 0.865]	[0.559 0.798]
d_x	0.9529	1.0875	1.041	1.0321	1.0532
	[0.801 1.105]	[0.902 1.273]	[0.883 1.199]	[0.895 1.169]	[0.933 1.173]
β	-9.3965	0.9723	1.0059	1.0122	1.0064
	[-30.158 11.365]	[0.829 1.116]	[0.868 1.144]	[0.916 1.108]	[0.938 1.075]
ρ	0.9997	-0.0986	-0.1850	-0.2204	-0.1900
10 Years					
d_u	0.5612	0.5105	0.5842	0.6195	0.6551
	[0.348 0.775]	[0.320 0.701]	[0.421 0.748]	[0.478 0.761]	[0.529 0.782]
d_x	1.0322	1.0978	0.9912	1.0035	1.0484
	[0.819 1.246]	[0.907 1.288]	[0.828 1.155]	[0.862 1.145]	[0.922 1.175]
β	1.0997	1.0636	1.0925	1.1055	1.0783
	[1.060 1.139]	[1.030 6.021]*	[1.016 1.169]	[1.022 1.189]	[0.999 1.157]
ρ	-0.4000	-0.1836	-0.3144	-0.3439	-0.2024

Table 10: Estimated fractional cointegrated system (4)

m	$T^{0.55}$	$T^{0.60}$	$T^{0.65}$	$T^{0.70}$	$T^{0.75}$
7 Years					
d_u	0.7549	0.8318	0.7216	0.6791	0.7106
	[0.838 1.105]	[0.620 1.044]	[0.539 0.904]	[0.513 0.845]	[0.566 0.855]
d_x	1.0940	1.0790	1.0615	1.1152	1.1085
	[0.850 1.338]	[0.867 1.291]	[0.879 1.244]	[0.949 1.281]	[0.964 1.253]
β	0.9711	1.0013	1.0328	0.9861	1.0018
	[0.838 0.836]	[0.809 1.194]	[0.914 1.152]	[0.918 1.054]	[0.917 1.087]
ρ	-0.2046	-0.2348	-0.3491	-0.1271	-0.1372
10 Years					
d_u	0.9453	1.0253	0.6709	0.6944	0.8949
	[0.716 1.174]	[0.837 1.213]	[0.451 0.891]	[0.498 0.891]	[0.734 1.056]
d_x	1.0609	1.0350	1.0007	0.9676	1.0393
	[0.832 1.290]	[0.847 1.223]	[0.781 1.221]	[0.771 1.164]	[0.879 1.200]
β	1.9938	16.8853	1.2000	1.2429	1.5414
	[0.990 2.998]	[6.029 27.742]	[0.981 1.419]	[0.978 1.507]	[0.984 2.099]
ρ	-0.9139	-0.9997	-0.4429	-0.4949	-0.7297

Table 11: Estimated fractional cointegrated system (5)

m	$T^{0.55}$	$T^{0.60}$	$T^{0.65}$	$T^{0.70}$	$T^{0.75}$
7 Years					
d_u	-0.1180	0.0256	0.2958	0.3176	0.4991
	[-0.375 0.139]	[-0.212 0.263]	[0.075 0.517]	[0.123 0.512]	[0.327 0.672]
d_x	1.2107	1.1638	1.0320	1.0849	1.1310
	[0.954 1.468]	[0.927 1.401]	[0.811 1.253]	[0.891 1.279]	[0.958 1.304]
β	1.0013	0.9930	0.9913	0.9848	0.9800
	[- -]*	[- -]*	[- -]*	[- -]*	[- -]*
ρ	0.4318	0.2762	-0.0928	0.0264	-0.0118
10 Years					
d_u	0.1254	0.1537	0.3223	0.4691	0.5782
	[-0.127 0.378]	[-0.073 0.381]	[0.127 0.518]	[0.296 0.643]	[0.425 0.732]
d_x	1.1051	1.2546	0.9927	1.0660	1.1138
	[0.853 1.358]	[1.028 1.481]	[0.797 1.188]	[0.893 1.240]	[0.960 1.267]
β	1.0581	1.0552	1.0581	1.0591	1.0550
	[- -]*	[- -]*	[- -]*	[- -]*	[- -]*
ρ	-0.1592	-0.0561	-0.1814	-0.1591	-0.1428

Figures

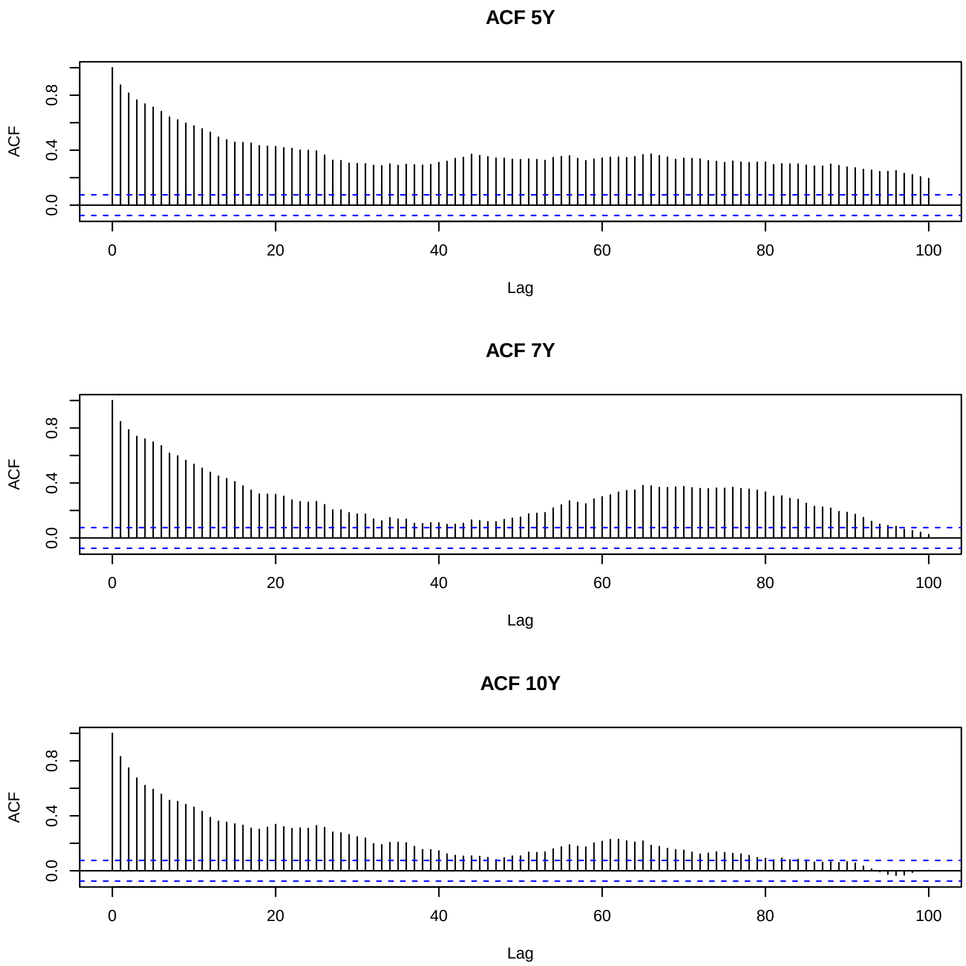

Fig. 1. Autocorrelation functions of the 5, 7, and 10 years spread.

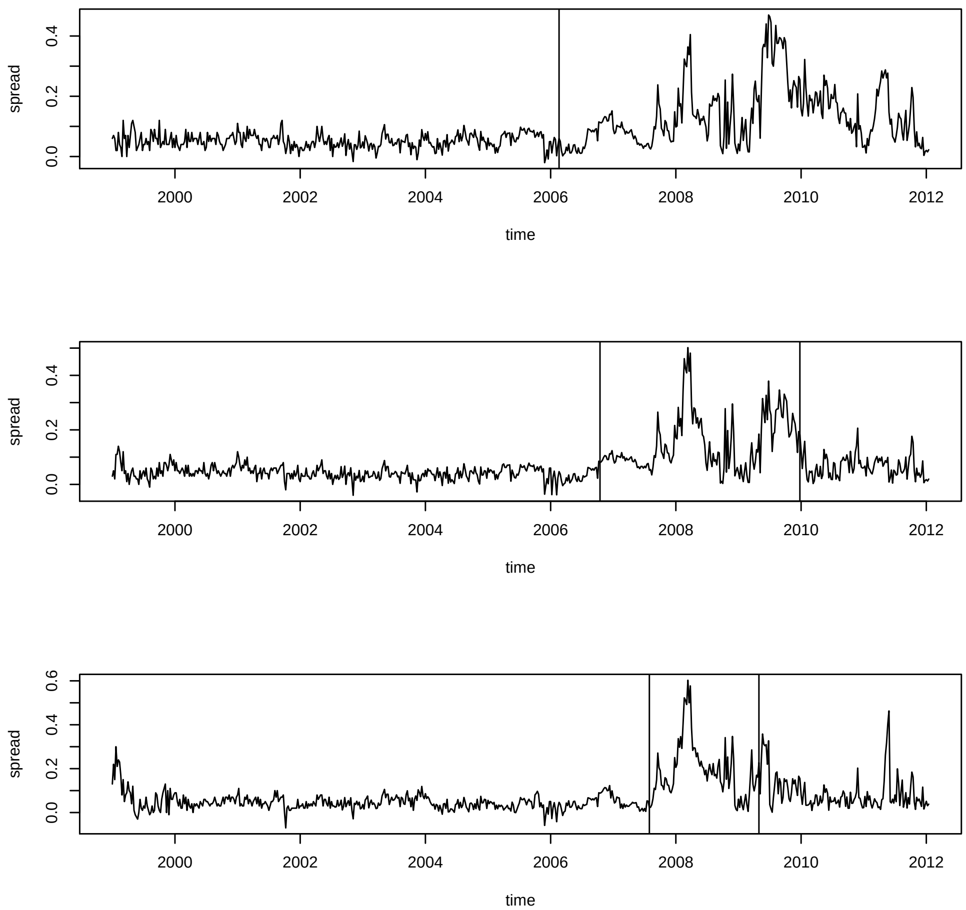

Fig. 2. Spreads of the traditional Pfandbriefe and Jumbo Pfandbriefe. The lines indicate the estimated breakpoints.

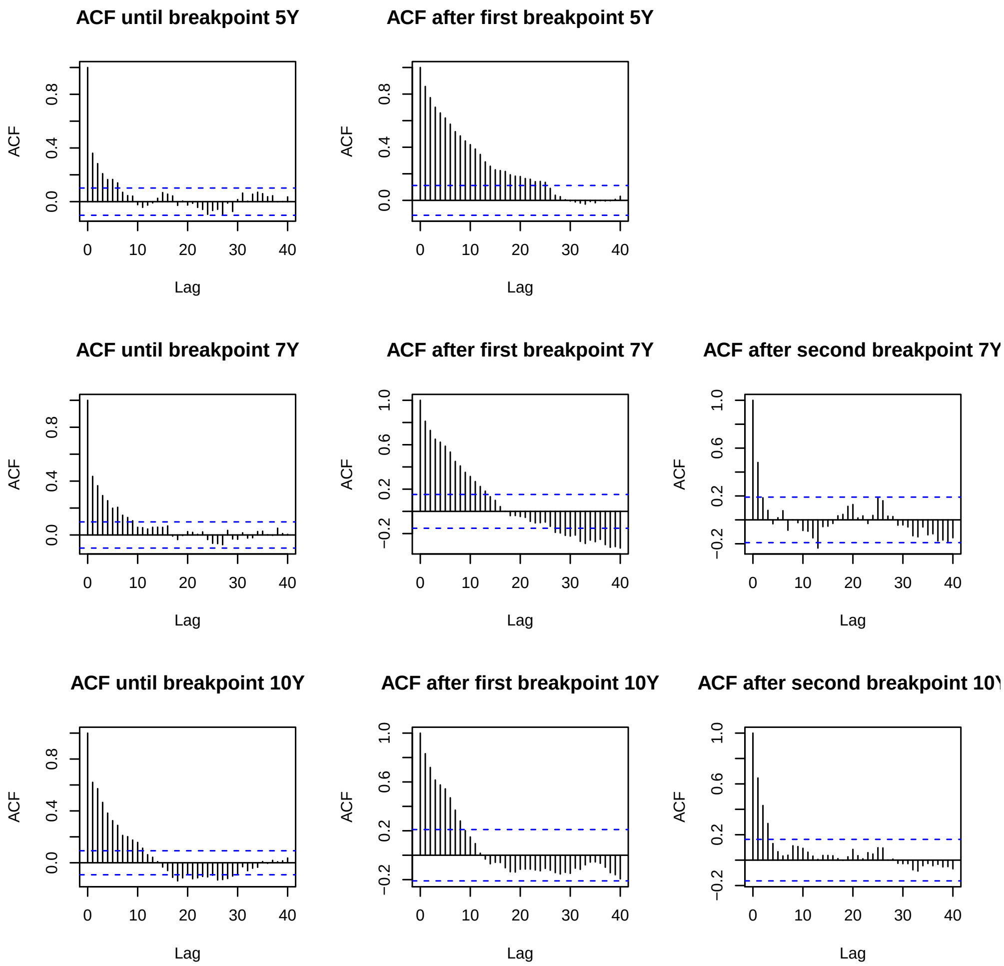

Fig. 3. Autocorrelation functions of the subsamples indicated by the structural break test of the 5, 7, and 10 years spread.