Integration and Disintegration of EMU Government Bond Markets

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Abstract

This paper analyzes market integration among long-term government bonds in the Eurozone since the inception of the Euro in 1999. While it is commonly assumed that markets for EMU government bonds were closely integrated prior to the EMU debt crisis, we find that there is significant time variation in their relationship. There are periods of integration and disintegration, and differences between core and periphery countries can be observed long before the EMU debt crisis.

To obtain insights into the sources of the observed time variation, we analyze the dependence on variables related to market sentiment, risk and risk aversion. The drivers of market integration are found to be similar to those for the well documented flight-to-quality effects from stocks to bonds, suggesting that in times of crisis investors do not only shift their portfolios from stocks to bonds, but there is also a stronger differentiation between more and less risky bonds. The persistence of these differentials leads to the conclusion that (at least in times of crisis) the pricing of EMU government bonds implied the possibility of macroeconomic and fiscal divergence between the EMU countries.

JEL-Numbers: G01, C32, C14, C58, E43

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1 Introduction

It is well documented that there are flight-to-quality effects in the dependence structure of price changes in bonds and stocks. While Shiller and Beltratti (1992) and Campbell and Ammer (1993) show that the long-run correlation between stock-market and bond-price returns is slightly positive as implied by present value relations and rational expectations, they also find that there is considerable time variation that cannot be accounted for. Further studies such as those of Gulko (2002) and Hartmann et al. (2004) show that there are subperiods during which the relationship turns negative. These are related to stock market crashes during which investors shift their portfolios from stocks to bonds, which leads to a negative correlation between stock returns and bond (price) returns. More complex econometric models for this effect include those of Guidolin and Timmermann (2006) and Cappiello et al. (2006). The relative pricing of risky stocks and comparably secure government bonds therefore exhibits considerable time variation between bull and bear markets.

Apart from this inter-asset class variation, the contagion literature has also documented considerable intra-asset class variation in the markets for sovereign bonds. In the context of the EMU debt crisis, it is found that there is an intensification of transmission mechanisms of shocks from the yield spreads of one country to the other. Examples of this literature include Metiu (2012), Ludwig (2014), De Santis (2014), Reboredo and Ugolini (2015) and Ehrmann and Fratzscher (2017), among many others.

Furthermore, there are a number of contributions that show that changes in risk pricing and shock transmission already occurred during the subprime mortgage crisis and thus in a bear-market period prior to the EMU debt crisis. For example, Ehrmann and Fratzscher (2017) and Benzoni et al. (2015) find contagion effects originating from Greece during this period. Similarly, Leschinski and Bertram (2017) argue that contagion was more prevalent during the subprime crisis than during the EMU crisis and Sibbertsen et al. (2014) report an increase in the persistence of spreads during the subprime crisis.

These findings on the relationship between bull and bear markets and flight-to-quality effects on the one hand, and the presence of contagion effects in a bear market before the EMU debt crisis on the other hand, raise the question to what extent changes in the pricing of sovereign default risk are typical for bear-market periods. Even though it is commonly assumed that EMU government bond markets were economically highly integrated prior to the EMU debt crisis (cf. for example Ehrmann and Fratzscher (2017)) the findings discussed above clearly suggest that market phases are associated with changes in the pricing of risk that also take effect within the bond market.

To address this issue and to draw economic conclusions, we take a very different perspective from previous contributions to the literature. Instead of focusing on the shock transmission among the spreads, we test for the existence of an equilibrium among the interest rates themselves. The analysis is based on the concept of market integration that is widely used in other areas such as the analysis of commodity markets. This concept is closely connected to the existence of a (fractional) cointegrating relationship, which enables us to draw conclusions about market equilibria, by using a wide set of modern methods for the analysis of fractionally cointegrated systems.

This allows us to make three major contributions. First, we establish that the EMU bond markets were integrated during bull markets but disintegrated in bear markets. This is achieved by testing pairwise for fractional cointegration among the yields directly and by considering the persistence of the yield spreads. The yield spreads between the countries are the cointegrating residuals obtained by imposing the cointegrating vector $(1, -1)'$ on the yields. The persistence of the spreads is therefore directly related to the existence of an equilibrium relationship among the yields. Further insights into the dynamics of integration and disintegration in the EMU bond markets are therefore obtained from a rolling window analysis of the memory of the spreads.

The second contribution is to provide insights into the sources of the time-varying persistence in the spreads. To this end, the estimated degree of persistence is regressed on a set of variables that proxy for market sentiment, risk, and risk aversion. The analysis not only confirms the relationship between integration and bull and bear markets, but also shows that the degree of market integration is driven by market risk.

Finally, the third contribution is to provide insights into the possible economic origins of the observed time variation in market integration. Here, we make use of the fact that the yields are the sum of the risk-free rate, the default risk premium, and the liquidity risk premium of the respective country. Due to the special situation in the EMU where (due to the common currency area) the risk-free rate is the same for all countries and Germany is typically assumed to be risk free, the spreads relative to Germany are solely determined by the default risk premium and the liquidity risk premium.

We present some statistical arguments on the possible mechanisms that can generate the observed time variation in the persistence of the spreads. These lead to two possible conclusions. The first one is that markets expect economic and fiscal divergence within the EMU area in bear markets, whereas they are optimistic about convergence within the Eurozone in bull markets. The second possible explanation is that markets always assume that divergence is a possibility, but the default risk premium exhibits so little variation in good times that the persistence of the spreads is dominated by the liquidity premium. In contrast to that, in bad times when risk and risk aversion are high the persistence of the spreads is dominated by the default risk premium, due to its increased variability.

Both of these arguments lead to the conclusion that (at least in crisis times) the pricing of EMU government bonds implied the possibility of macroeconomic and fiscal divergence between the EMU countries, long prior to the EMU debt crisis. Also, differences between the core and periphery countries are already visible during previous bear-market periods.

The rest of the paper is structured as follows: Section 2 provides a discussion of market integration and a brief review of fractional integration and cointegration. Subsequently, Section 3 describes the data set and discusses the definition of bull and bear markets. Section 4 provides formal tests for market integration separately for bull and bear markets, whereas Section 5 contains rolling window estimates of the persistence of the spreads. The drivers of the degree of market integration are analyzed in Section 6, before possible explanations are discussed in Section 7, and Section 8 concludes.

2 Market Integration, Fractional Integration, and Fractional Cointegration

Markets for different goods that are close substitutes, or markets for the same good that are spatially separated are considered to be (economically) integrated with each other if the law of one price (LOP) applies. In the strict sense, the LOP requires that there is a correction mechanism (such as arbitrage) in place that enforces the stability of an equilibrium relationship, and that the form of this equilibrium is such that prices in both markets are exactly the same. The weaker definition of partial market integration only requires the existence of a stable equilibrium relationship but not exact equality between the prices.

Tests for market integration are routinely carried out to determine whether spatially separated markets for agricultural products or markets for commodities that are close substitutes are integrated in the sense that they form a single market.

For non-stationary prices, this definition is often tied to the concept of cointegration (cf. Ravallion (1986), Ardeni (1989)), since cointegration implies the existence of an equilibrium relationship between unit root processes. In the classical $I(0)/I(1)$ framework, deviations from this equilibrium have to be weakly persistent in the sense that they are stationary and have short memory. This, however, is an unnecessary restriction, since an equilibrium relationship only requires deviations from the mean to be transitory in the sense that they are mean reverting.

We therefore allow for fractional cointegration when testing for (partial) market integration. That means, we conclude that markets are integrated if the persistence of deviations from the equilibrium is reduced compared to the persistence of the prices. A similar approach that uses fractional cointegration to test for market integration was recently adopted by García-Enríquez et al. (2014).

There are several applications in the literature showing that fractional cointegration can be better suited to model economic equilibrium relationships than the classical $I(0)/I(1)$ framework. Examples include the purchasing power parity (cf. Cheung and Lai (1993) and Baillie and Bollerslev (1994)) or the parity between implied and realized volatility (cf. Christensen and Nielsen (2006)).

Since the analysis in this paper relies heavily on methods developed for long-memory time series and fractionally cointegrated systems, a brief discussion of some key concepts is provided below. Usually, long memory is defined by the behavior of the spectral density $f(\lambda)$ at frequency λ, where $f(\lambda) \sim G\lambda^{-2d}$, as $\lambda \to 0^+$. Here, G is a positive and finite constant, and $a \sim b$ denotes that the ratio of the left and right hand side converges to unity. Thus, the spectral density of the process has a pole at the origin. The definition is equivalent to the autocorrelation function $\gamma(\tau)$ decaying with a hyperbolic rate as the lag τ approaches infinity so that $\gamma(\tau) \sim \tau^{2d-1}$, for $\tau \to \infty$. In this context, the parameter $0 \leq d \leq 1$ determines the memory of the process. The most popular parametric model for long memory time series is the fractionally integrated process

$$(1-B)^d X_t = v_t, \tag{1}$$

where B with $BX_t = X_{t-1}$ is the usual lag operator, v_t is a short memory process with continuous and bounded spectral density (such as an ARMA process), and $-1/2 < d \leq 1$. The fractional differences $(1-B)^d$ are defined in terms of generalized binomial coefficients such that

$$(1-B)^d = \sum_{k=0}^{\infty} \binom{d}{k} (-1)^k B^k = \sum_{k=0}^{\infty} \pi_k B^k,$$
$$\text{with} \quad \binom{d}{k} = \frac{d(d-1)(d-2)\ldots(d-(k-1))}{k!}.$$

The process in (1) is said to be $I(d)$ and the properties of X_t depend on the value of d. For $0 < d < 1/2$ the process has stationary long memory and is mean reverting with finite variance. If $d > 1/2$, the process is still mean reverting, but with infinite variance. For $d < 0$, the process is antipersistent, and unit root processes are obtained for the special case of $d = 1$.

For a linear process X_t with Wold representation $X_t = \sum_{\tau=0}^{\infty} \psi_\tau u_{t-\tau}$, where u_t is a martingale difference sequence, there is another way to define long memory. The essential feature of long memory is that it generates persistence in the data. Therefore, we can also interpret it as the rate at which the impact of shocks in the distant past decays.

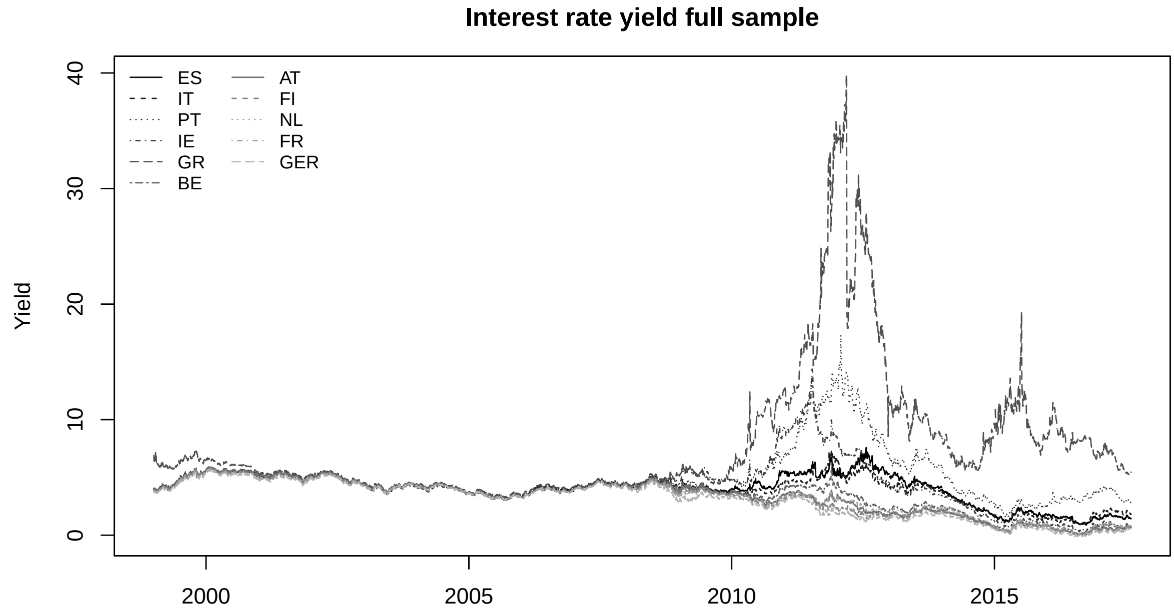

Figure 1: Interest rate yield on 10-year maturity benchmark bonds for a selection of EMU countries.

Accordingly, a process has long memory if

$$\psi_\tau \sim \Gamma(d)^{-1}\tau^{d-1}, \text{ for } \tau \to \infty, \tag{2}$$

where Γ denotes the Gamma function. Consequently, if we are willing to assume that the process is linear, we can think of long memory in terms of slowly decaying impulse-response functions. This implies that the impact of shocks fades out very slowly compared to a short memory process.

In multivariate time series, long memory allows for a very natural extension of the concept of cointegration. Two variables that are fractionally integrated of the same order $0 \leq d \leq 1$ are said to be fractionally cointegrated if there is a linear combination of them that is of order $I(d-b)$ for some $0 < b \leq d$.

As stated above, this corresponds to the existence of an equilibrium relationship with possibly persistent deviations from the equilibrium, and we will conclude that markets for EMU government bonds that could be considered as close substitutes are (partially) integrated if they are fractionally cointegrated with each other.

Figure 2: Development of the Eurostoxx stock market index and timing of bull and bear markets.

3 Data and Definition of Bull and Bear Markets

Our analysis is based on the daily interest rates on 10-year maturity benchmark government bonds of eleven EMU countries. As is customary in the literature, we refer to Spain, Italy, Portugal, Ireland, and Greece as the periphery countries. Belgium, Austria, Finland, the Netherlands, and France are called the core countries. The data set contains daily (bid) yields on benchmark bonds for these ten countries and for Germany as well as a range of explanatory variables. All series are obtained from Thomson Reuters Eikon and observed between January 1, 1999 and August 8, 2017.

The yields are shown in Figure 1. It is clear to see that the yields of the different countries were very similar up to the collapse of Lehman Brothers in September 2008, where the levels began to separate before they fully decoupled during the EMU debt crisis. From these observations, it seems obvious to conclude that EMU bond markets were economically integrated at least up to the subprime mortgage crisis. However, as we discuss in detail below, market integration requires that deviations from the equilibrium level are of a transitory nature. Whether this is the case cannot be determined from the level of the yields in Figure 1.

As discussed in the introduction, one of the main objectives of this paper is to analyze whether EMU bond market integration differs between bull and bear markets. To do so, we need to define which periods are regarded as bull markets and which ones are regarded as bear markets. Since there is no universally accepted definition of bull and

	Begin	Index	End
Bull 1	01/01/1999	313.92	03/05/2000
Bear 1	03/06/2000	466.24	03/11/2003
Bull 2	03/12/2003	165.43	05/31/2007
Bear 2	06/01/2007	442.87	03/08/2009
Crisis	03/09/2009	169.38	08/08/2017

Table 1: Definition of bull- and bear-market periods.

	ES	IT	PT	IE	GR	BE	AT	FI	NL	FR	GER	(s.e.)
Bull 1	1.02	1.02	1.07	1.03	0.95	1.03	1.02	0.98	1.04	0.98	1.05	(0.07)
Bear 1	0.94	0.94	0.93	0.94	0.95	0.93	0.93	0.94	0.93	0.92	0.95	(0.05)
Bull 2	1.05	1.06	1.04	1.06	1.05	1.05	1.04	1.06	1.06	1.05	1.06	(0.04)
Bear 2	1.00	0.91	0.93	1.00	0.91	0.94	0.89	0.98	0.99	0.99	1.04	(0.06)
Crisis	0.89	0.92	0.97	1.02	0.95	0.96	0.99	1.00	0.99	0.99	0.98	(0.03)
Full sample	1.04	1.01	0.96	0.99	0.93	0.95	1.03	1.10	0.98	0.97	1.00	(0.02)

Table 2: Memory estimates of the yields for different subperiods. In the Bull 2 period the standard error of the estimate for Ireland is 0.05.[1]

bear markets, we simply rely on a visual inspection of the trajectory of the Eurostoxx index shown in Figure 2. Every bull-market period begins with a local minimum and every bear-market period begins with a local maximum. The timing of these local extrema is indicated by vertical dashed lines in Figure 2, and the exact definitions along with the index values at the starting date of the respective series are given in Table 1. The first two periods are determined by the Dot-com bubble and the subsequent crash starting on March 6, 2000. The recovery and boom thereafter lasted from March 12, 2003, until May 31, 2007, when the subprime mortgage crisis began. This bear market lasted until March 8, 2009. In the recovery after that, it could be argued that there were several shorter bull- and bear-market periods. However, it can be expected that the mechanisms driving the pricing of EMU government bonds changed permanently with the onset of the EMU debt crisis in October 2009, when the Greek government revised its deficit figures. We therefore focus on the previous bull and bear markets and refer to the post-2009 period as the crisis period.

Estimates of the memory parameters in each subsample are given in Table 2. Here and hereafter, all memory parameters are estimated using the exact local Whittle estimator of Shimotsu and Philips (2005) and a bandwidth of $m = \lfloor T^{0.7} \rfloor$. As can be seen, the estimated memory parameters are statistically indistinguishable from one, so that

[1]The standard error of IE differs from the others due to a number of missing observations that reduce the sample size.

it is reasonable to assume that the interest rates follow a stochastic trend. This is also supported by formal tests.

4 Testing for Market Integration Among the Yields

As discussed in Section 2, integration in the market for EMU government bonds requires the yields to be pairwise fractionally cointegrated. Since the German government bonds are considered to be the most liquid and essentially risk free, it is customary to use Germany as the base country and to analyze the pairwise relationship of each country with Germany. We therefore adopt this approach and start our analysis by applying tests for the null hypothesis of no fractional cointegration on these pairs in each of the subsamples.

The methods used are semiparametric and do not impose any assumptions on the short run behavior of the series, apart from mild regularity conditions. This approach has the advantage that we can avoid spurious findings that might arise due to misspecifications. Research on semiparametric tests for fractional cointegration has been an active field in recent years and there is a variety of competing approaches.

The first group of tests is based on the fact that the rank of the rescaled spectral matrix at the zero frequency is reduced for fractionally cointegrated systems. This property is used by the rank estimation criterion of Nielsen and Shimotsu (2007) that extends the approach of Robinson and Yajima (2002) to nonstationary processes, the spectral regression approach of Souza et al. (2016), and the Hausman-type test of Robinson (2008). A second group of tests is residual based, since the cointegrating residuals have reduced memory if a fractional cointegrating relationship exists. Chen and Hurvich (2006) and Wang et al. (2015) provide tests that rely on this property. A third group of tests proposed by Marmol and Velasco (2004) and Hualde and Velasco (2008) relies on the behavior of pairs of estimators for the cointegrating vectors. These pairs include one estimator that is only consistent under the null hypothesis of no fractional cointegration and one estimator that is only consistent under fractional cointegration. Finally, Nielsen (2010) suggests a variance ratio trace test.

All of these tests follow different testing principles and they require different assumptions. To ensure that our findings are robust, we therefore employ all of them. The results of this analysis are shown in Table 3. Each line represents the results for one of the available methods in one of the subperiods. Empty fields indicate that the test is not able to reject the null hypothesis of no fractional cointegration or that the estimated cointegrating rank is zero. If a cointegrating relationship is found, the numbers in the non-empty fields give estimates of b - the strength of the relationship. In the cases of Nielsen and Shimotsu (2007) and Robinson (2008), where the methods themselves do

		ES	IT	PT	IE	GR	BE	AT	FI	NL	FR
Bull 1	NS07	0.62	0.38	0.48	0.49		0.60	0.55	0.77	0.69	0.64
	SRF16	0.55	0.33	0.54	0.54		0.49	0.63	0.86	0.67	0.79
	MV04	0.62	0.38	0.53	0.56		0.62	0.71	0.77	0.71	0.71
	WWC15	0.62	0.38	0.53	0.57	0.07	0.62	0.71	0.77	0.71	0.71
	R08	0.62	0.38	0.48	0.49		0.60	0.55	0.77	0.69	0.64
	CH06	0.60	0.38	0.53	0.54		0.62	0.69	0.76	0.71	0.71
	HV08	0.62	0.38	0.53	0.57		0.62	0.71	0.77	0.71	0.71
	N10			0.53	0.56		0.57	0.71	0.63	0.70	0.71
Bear 1	NS07	0.14	0.05	0.10	0.12	0.08	0.14	0.13	0.32	0.20	0.33
	SRF16	0.29		0.25	0.24			0.27	0.39	0.27	0.36
	MV04				0.12				0.33	0.16	0.30
	WWC15	0.10			0.12		0.08		0.33	0.16	0.30
	R08								0.32		0.33
	CH06								0.33		0.33
	HV08								0.33		0.30
	N10										
Bull 2	NS07	0.49	0.13	0.36	0.44	0.39	0.22	0.45	0.43	0.46	0.32
	SRF16	0.44		0.28	0.39	0.34	0.18	0.36		0.29	0.27
	MV04	0.49		0.36	0.45	0.38	0.21	0.44	0.48	0.47	0.32
	WWC15	0.49		0.36	0.45	0.38	0.21	0.44	0.48	0.47	0.32
	R08	0.49		0.36	0.44	0.39		0.45	0.43	0.46	0.32
	CH06	0.48		0.36	0.45	0.39		0.43	0.46	0.46	0.32
	HV08	0.49				0.38		0.44	0.48	0.47	
	N10	0.49			0.44			0.45	0.44	0.46	0.32
Bear 2	NS07	0.07	0.08	-0.00			-0.02	0.01	0.18	0.11	0.15
	SRF16		0.28					0.35	0.41	0.30	0.36
	MV04		0.15				0.10	0.15	0.23	0.18	0.25
	WWC15		0.15					0.15	0.23	0.18	0.25
	R08										0.15
	CH06										0.26
	HV08										
	N10										
Crisis	NS07							0.11	0.13	0.19	0.11
	SRF16								0.18	0.16	
	MV04										
	WWC15										
	R08	0.06					0.10		0.13	0.19	
	CH06								0.14	0.21	
	HV08										
	N10										

Table 3: Strength of the fractional cointegration relationship between the yields of bonds of the respective country and Germany. Empty fields indicate the absence of a significant fractional cointegrating relationship at the 5%-level.

not produce an estimate of the cointegrating strength, we estimate it by the difference between the memory of the yields and the memory of the spread. This is because the spreads are the cointegrating residuals obtained by imposing the cointegrating vector $(1,-1)'$, as discussed in detail in Section 5.

For the interpretation of the results, note that a rejection of the null of no cointegration indicates the presence of an equilibrium relationship, as is required for market integration. The strength of this relationship b determines the speed of adjustments towards the equilibrium. Since the yields are $I(1)$, the memory of the cointegrating residuals (and thus of deviations from the equilibrium) between the yield of country i and Germany is $1-b_i$.

Since the methods employed are based on very different properties of fractionally cointegrated systems, it is not surprising that there is some variation in the findings. However, overall the results show that the majority of interest rates were indeed cointegrated with the German rate during the bull-market periods but not during the bear-market periods. A notable exception is Greece in the first bull market, since it only joined the EMU in 2001, which is during our first bear-market period.

When comparing the bull-market periods and bear-market periods, it is immediately noticeable that the tests reject the null hypothesis less often during the bear markets than during the bull markets. Evidence for the existence of an equilibrium relationship during the bear-market periods is mainly found for the core countries. Furthermore, when comparing the strength of the cointegrating relationships that persist during bull and bear markets, we can observe that the strength declines in bear-market periods.

If we consider Finland, for example, deviations from the equilibrium have a memory of approximately $1-b_i = 0.25$ in the first bull market. This increases to nearly 0.7 in the first bear market, before dropping to 0.5 in the second bull market, and rising again to about 0.8 in the second bear market.

When we consider the results for the EMU crisis period, we find that there is no evidence for the existence of an equilibrium relationship for the periphery countries anymore. Among the core countries some weak evidence is found, but mostly for the Netherlands and Finland. The overwhelming majority of the tests are unable to detect any evidence for market integration during this period.

To gain further insights into the dynamics of market integration between all possible country pairs, we repeat the same analysis using the method of Chen and Hurvich (2006). The results are presented in a heatmap in Figure 3. Here, a darker color indicates a strong equilibrium relationship. Clearly, there is much more evidence for pairwise market integration between the countries during the bull-market periods, which are shown on the left-hand side, than during the bear-market periods depicted on the right-hand side.

We observe that, during the bull markets, there is a larger number of equilibrium

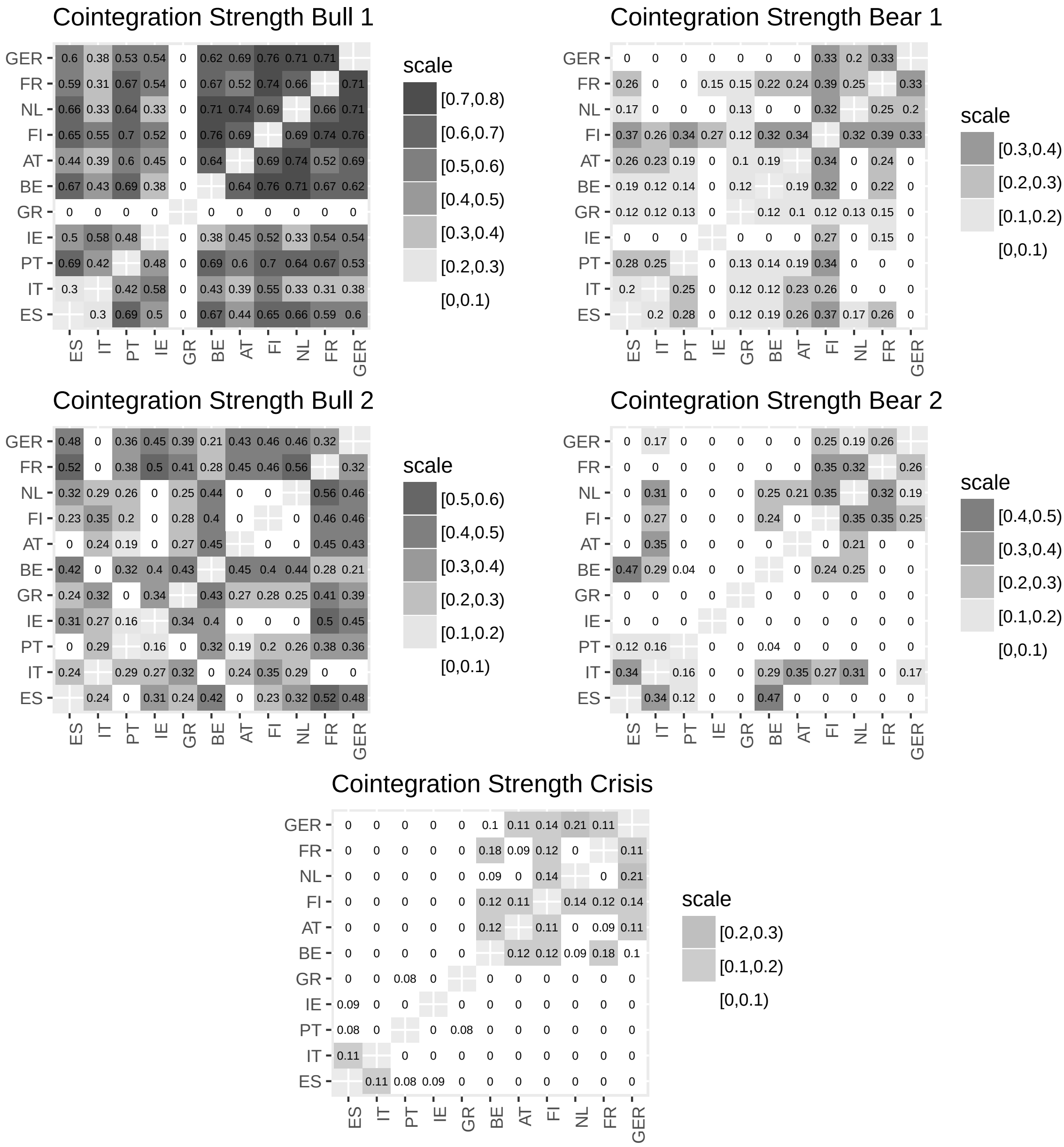

Figure 3: Heatmaps for the strength of pairwise cointegration relationships between EMU government bonds for different subperiods obtained using the method of Chen and Hurvich (2006).

relationships among the core countries than there is among the periphery countries. During the first bear market, Finland is a notable exception, since it appears to be fractionally cointegrated with all of the core countries and with all of the periphery countries. In the second bear market Italy is an exception, since it is in equilibrium with the majority of core countries. We can also observe that there is a tendency of Portugal, Italy, and Spain to remain in equilibrium with each other during the bear markets. Finally, we observe a clear distinction between periphery countries and core countries during the crisis period. Here, the core countries tend to remain (weakly) integrated with each other in an economic sense, whereas the periphery countries disintegrate completely.

Taken together, we find that there are periods of integration and periods of disintegration associated with bull and bear markets. Already during these early periods we can observe that there is stronger market integration between the core countries than between the core and the periphery during bear markets. Finally, we observe a disintegration of the yields for all countries during the crisis. Considering the behavior of the Eurostoxx in Figure 2, the EMU crisis could be regarded as a bull-market period, which usually is a period of integration. The cyclical relationship with periods of integration and disintegration therefore breaks down with the advent of the EMU debt crisis.

As a robustness check, we repeat the analysis in Table 3 using France instead of Germany as the base country and we repeat the analysis in Figure 3 using the method of Nielsen and Shimotsu (2007) instead of that of Chen and Hurvich (2006). The results of these exercises are shown in Table 9 and Figure 8 in the appendix. As can be seen, the results remain very stable.

5 Testing for Market Integration among the Yield Spreads

We denote the interest rate yield on bonds of country i in period t by y_{it} for $i = 1,...,N$ and $t = 1,...,T$. The spreads s_{it} are usually formed relative to the yield of the German bonds

$$s_{it} = y_{it} - y_t^{GER}. \tag{3}$$

It is commonly assumed that the interest rates of country i can be decomposed into

$$y_{it} = r_t^f + \delta_{it} + l_{it}, \tag{4}$$

where r_t^f is the risk-free interest rate, and δ_{it} and l_{it} are the risk premiums for the default risk and liquidity risk of country i. The risk-free rate is the same across countries due to the common currency area. If Germany — the benchmark country — is assumed to have no default risk and no liquidity risk, so that $y_t^{GER} = r_t^f$, it follows that

$$s_{it} = \delta_{it} + l_{it}. \tag{5}$$

Therefore, the spreads are the risk premiums associated with the liquidity and default risk of the respective country. If Germany is not assumed to be risk-free, δ_{it} and l_{it} are

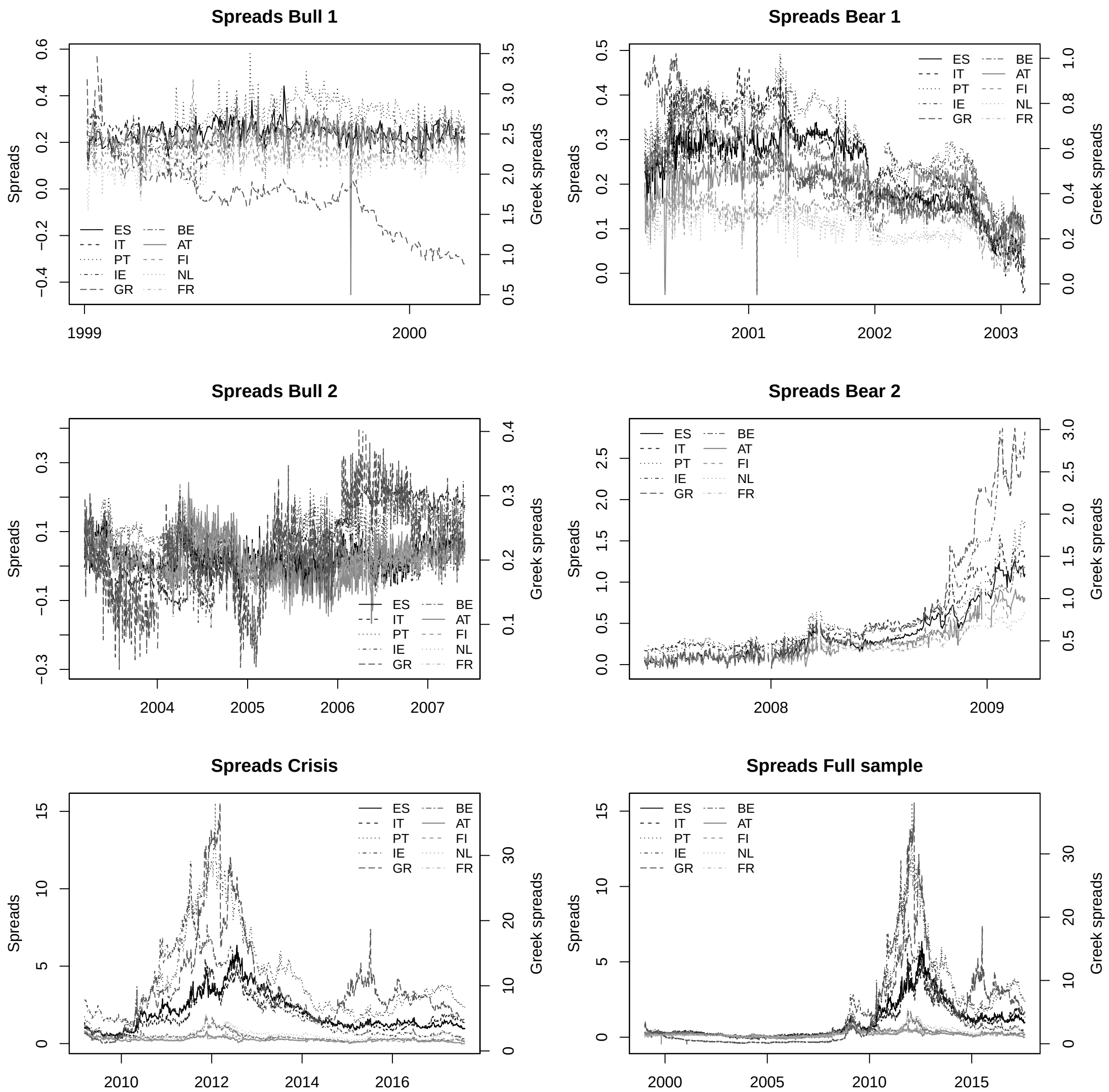

Figure 4: Interest rate yield spreads s_{it} relative to Germany.

interpreted as risk premium differentials between the respective country and Germany. However, if the risk of Germany and its variation are low compared to that of the respective country, the behavior of the differentials will still be dominated by the risk premiums of the country. We therefore maintain the assumption that Germany is risk-free to simplify the verbal description of the results.

The risk-free interest rate r_t^f in (4) is driven by expected macroeconomic factors such as GDP-growth, inflation rates, and interest rates, and it is widely found to be $I(1)$ (cf. for example Mishkin (1992), Stock and Watson (1988), Chen and Hurvich (2003) and Nielsen (2010)). That means y_{it} and y_t^{GER} can only be cointegrated if r_t^f is removed from the linear combination $\beta'(y_{it}, y_t^{GER})'$, as it is the case in the spreads in (5).

	ES	IT	PT	IE	GR	BE	AT	FI	NL	FR	(s.e.)
Bull 1	0.41	0.64	0.58	0.55	0.93	0.44	0.47	0.24	0.35	0.37	(0.07)
Bear 1	0.81	0.89	0.84	0.83	0.88	0.81	0.82	0.62	0.74	0.61	(0.05)
Bull 2	0.56	0.92	0.68	0.62	0.67	0.84	0.59	0.62	0.60	0.73	(0.04)
Bear 2	0.95	0.90	0.99	1.06	1.01	1.01	0.95	0.82	0.90	0.87	(0.06)
Crisis	0.88	0.91	0.96	0.96	0.96	0.87	0.88	0.86	0.80	0.88	(0.03)
Full sample	0.93	0.99	0.94	0.95	0.93	0.81	0.86	1.07	0.80	0.96	(0.02)

Table 4: Memory estimates of the spreads s_{it} relative to Germany for different subperiods. In the Bull 2 period the standard error of the estimate for Ireland is 0.05 and in the full sample the standard error of the estimate for Greece is 0.03.

Forming the spreads according to (3) therefore means to impose the cointegrating vector $\beta = (1, -1)'$ on the yields, which is the only possible cointegrating direction according to the theoretical arguments outlined above. The spreads are therefore the cointegrating residuals.

This observation gives way to another approach to test for the existence of a fractional cointegrating relationship between y_{it} and y_t^{GER}. Since in this case the cointegrating residuals are not affected by estimation error, we can apply a simple test for the null hypothesis that the memory $d(s_{it})$ of the spread s_{it} of country i at time t is equal to one. If this hypothesis can be rejected, this is statistical evidence for market integration.

Figure 4 shows the spreads for the bull- and bear-market subperiods. Visually, the spreads appear to be less persistent during bull markets than during bear markets. This is also confirmed by the memory estimates in Table 4. These findings clearly support those from the previous section. Furthermore, it can be seen that there is little evidence for market integration if the whole sample period is considered.

However, in this context we no longer need to impose specific time periods that are defined to be bull or bear markets. We can therefore gain further insights into the dynamics of economic integration and disintegration among the interest rates in the Eurozone, by adopting a semiparametric approach and testing for $d(s_{it}) = 1$ in a rolling window. The window size is set to 250 observations, which corresponds to one year, and provides a good tradeoff between bias and sampling variation of the estimate.

The results of this exercise are shown in Figure 5 for the core countries and in Figure 6 for the periphery countries. Each point represents the estimated memory parameter $\hat{d}(s_{it})$ from the window that ends on this date. The horizontal dashed lines represent a 95-percent confidence band centered around $d(s_{it}) = 1$, based on $1.96/\left(2\sqrt{\sum_{j=1}^{m} \nu_j^2}\right)$, where $\nu_j = \log\lambda_j - m^{-1}\sum_{j=1}^{m}\log\lambda_j$ and $\lambda_j = 2\pi j/250$. This is the typical finite sample correction for the variance of the estimator that is based on its Hessian. For a detailed study

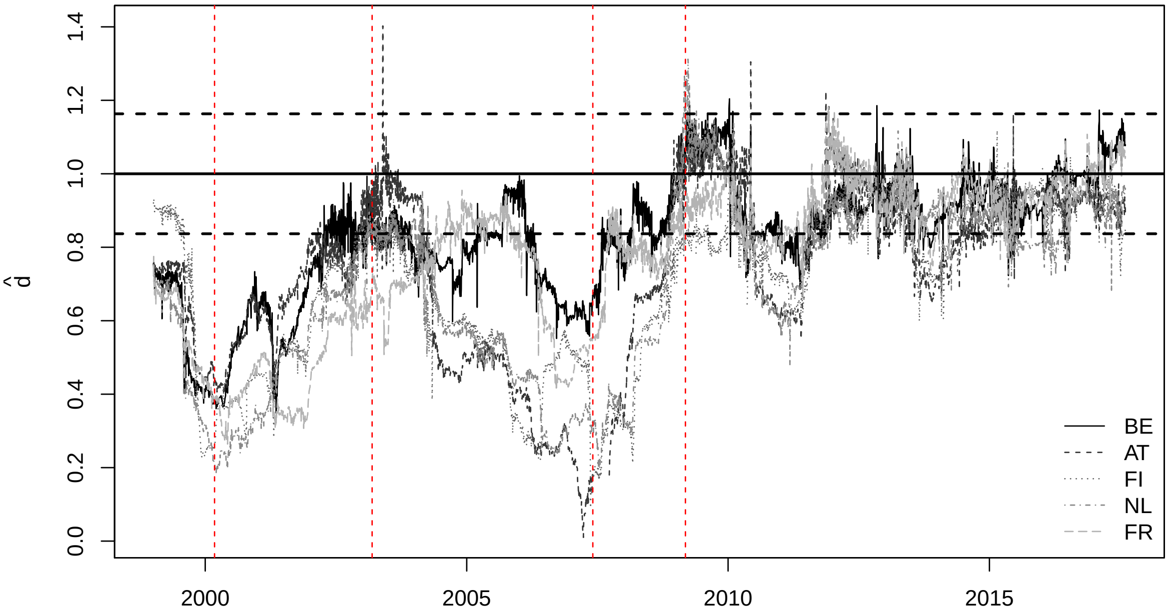

Figure 5: Rolling window estimates of the memory $d(s_{it})$ in the spreads of the core countries.

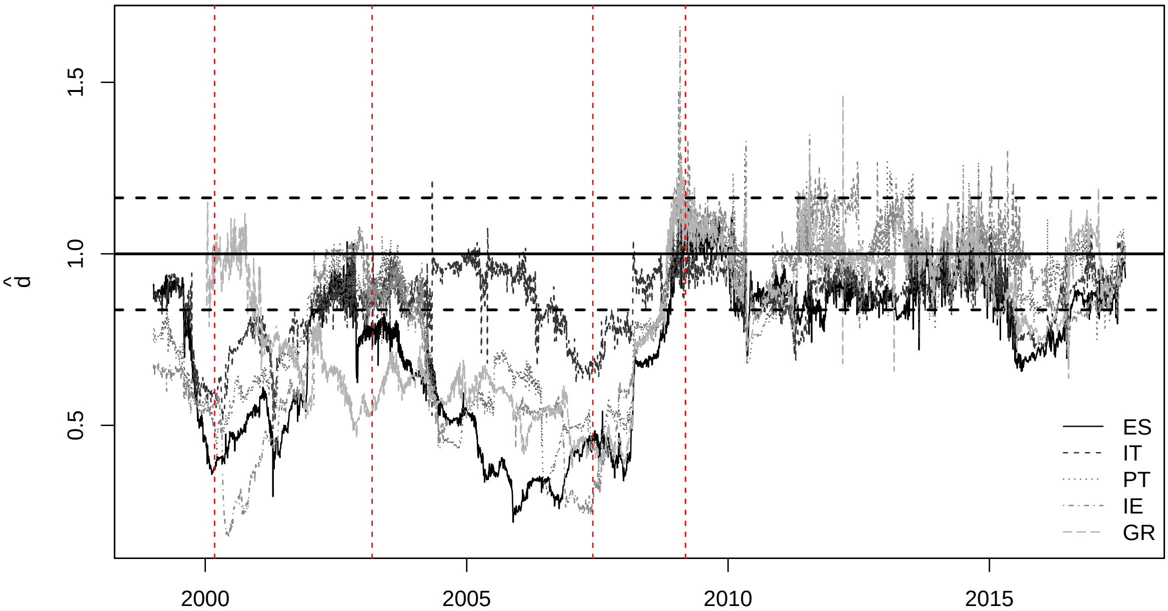

Figure 6: Rolling window estimates of the memory $d(s_{it})$ in the spreads of the periphery countries.

of hypothesis tests based on semiparametric estimates, refer to Hassler and Olivares (2013). It is well known that these tests remain liberal even despite the correction. We therefore might reject the hypothesis of no fractional cointegration too often. As before, the vertical dashed lines mark the start and endpoints of the bull- and bear-market periods defined as before.

Considering the results for the core countries in Figure 5, we can make several observations. When we move from a bull-market period to a bear-market period, the estimated memory parameter increases as new observations enter the estimation window. Conversely, when we enter a bull market after a bear market, the new observations entering the estimation window tend to decrease the estimated memory parameter. A similar pattern can be observed for the periphery countries in Figure 6, although they are a bit less homogenous.

Around the end of the first bear market in 2003, there is an extended period during which the estimated memory parameters indicate the absence of a fractional cointegrating relationship and thus no evidence for market integration.

In both groups there are some deviations from the general pattern. Among the core countries the persistence of the Belgian and French spreads keeps increasing in the initial phase of the second bull market. Similarly, the persistence of the Greek and Italian spreads remains high in the same period. Finally, Ireland shows a somewhat different behavior during the first bull and bear market.

After the second bear market — with the advent of the EMU debt crisis — the relationship breaks down. The estimates of the $d(s_{it})$ are close to 1, and well within the confidence bands, indicating that there is no equilibrium relationship. A notable exception is a short dip in the level of the persistence after April, 2010 when the European Financial Stability Facility (EFSF) was first established. Here, the estimated memory parameters are close to the lower confidence band. However, this period ended quickly thereafter, which implies that the EFSF as a policy measure was not sufficient to effectively calm the market and re-establish an equilibrium.

Overall, the results are clearly in line with those in the previous section that show that there are periods of integration and periods of disintegration that are related to bull markets and bear markets.

6 Drivers of Market Integration and Disintegration

To gain further insights into the determinants of EMU bond market integration, we conduct a regression analysis of the sources of variation in the estimated memory parameters from Section 5. The main objective of this analysis is to determine whether the observed time variation in the persistence of the spreads can be explained by factors such as market risk or risk aversion that might also drive bull and bear markets. Our focus is therefore on the effect of market risk and risk aversion in conjunction with the effect of market phases or sentiment.

Typical measures for market risk or "uncertainty" include realized and implied volatility. Let there be N intraday returns r_{it} observed at trading day t, then the realized variance is given by

$$RV_t = \sum_{i=1}^{N} r_{it}^2,$$

which provides a consistent estimate of the quadratic variation of the respective asset as $N \to \infty$. We therefore consider the realized volatility of the Eurostoxx index as a measure of current market risk. The implied volatility measured by the VIX and its European equivalent, the VSTOXX, is a forward-looking measure that extracts the expected average volatility over the next 22 trading days from a panel of option prices, assuming that market participants are risk-neutral. As discussed in detail in Chernov (2007), the VSTOXX can therefore be decomposed into the expected average volatility over the next month and a risk premium according to

$$VSTOXX_t = E_t[RV_{t+22}^{(22)}] + VP_t,$$

where $RV_t^{(H)} = H^{-1} \sum_{h=0}^{H-1} RV_{t-h}$. Under the assumption of rational expectations, we can obtain an ex post estimate of VP_t via

$$VP_t = VSTOXX_t - RV_{t+22}^{(22)}.$$

It is typically found that the VSTOXX has explanatory power for the flight-to-quality effect (cf. for example Connolly et al. (2005)). Due to the persistence of RV_t and the relationships discussed above, it is unclear whether this explanatory power is due to the current level of market risk RV_t, the expected change in the average market risk over the next month

$$\Delta RV_t = RV_{t+22}^{(22)} - RV_t,$$

or the variance premium VP_t. The variance premium VP_t has received a lot of attention in the recent literature, since it is related to the degree of risk aversion. Bollerslev et al. (2009) and Bollerslev et al. (2013), for example, show theoretically and empirically that it has some explanatory power for future stock returns, and Bekaert and Hoerova (2014) show that it improves forecasts of future realized volatility.

Instead of including the VSTOXX itself, we therefore consider RV_t, ΔRV_t, and VP_t separately so that it is possible to distinguish the effect of current market risk from that of (expected) future risk and that of changes in risk pricing.

To formally test the hypothesis that the existence and strength of equilibrium relationships between the bonds of the respective country and Germany are driven by bull-and bear-market periods, we include the bull-market indicator ($\mathbb{1}_{bull,t}$) that corresponds to the market phases defined in Section 3. Due to the special interest in this variable, we include interaction terms between the bull-market indicator and all market-uncertainty measures.

As additional control variables, the daily return of the Eurostoxx (r_t), the spread between BBB-rated US corporate bonds and AAA-rated US government bonds (BBB_t), and the 3-month Euribor rate ($Euribor_t$) are included.

For a better approximation by the normal distribution, we consider the log of RV_t and VP_t. Furthermore, due to the different levels of persistence among these variables, the regressors RV_t, ΔRV_t, VP_t, BBB_t and $Euribor_t$ are fractionally differenced to achieve balanced regressions. Finally, the regressors are standardized to have zero mean and unit variance to facilitate the interpretation of the regression coefficients. This leads to the regression equation

$$\begin{aligned}\hat{d}_{t+125}(s_{it}) = {} & \beta_0 + \beta_1\ \mathbb{1}_{bull,t} + \beta_2\ RV_t + \beta_3\ \Delta RV_t + \beta_4\ VP_t + \beta_5\ r_t + \beta_6 BBB_t \\ & + \beta_7\ Euribor_t + \beta_8\ \mathbb{1}_{bull,t} \times RV_t + \beta_9\ \mathbb{1}_{bull,t} \times \Delta RV_t + \beta_{10}\ \mathbb{1}_{bull,t} \times VP_t + u_t,\end{aligned}$$

where u_t is the innovation term. To achieve the best possible estimation of the respective memory parameters, the dependent variable at time t is the rolling window estimate from period $t+125$ so that the day of interest is in the middle of the estimation window. We observed in the previous sections that the relationship between market sentiment and persistence of the spreads breaks down in the EMU crisis period. Here, the spreads remain persistent despite the bullish environment due to investors' concerns about sovereign default risks. Our estimation period is therefore restricted to the period up to March 8, 2009 — the end of the second bear market.

An econometric complication lies in the fact that our dependent variable itself is estimated in a rolling window of 250 observations, which induces a long autocorrelation structure. This issue is similar to the problems incurred in long-horizon regressions that test stock return predictability for overlapping time periods. However, in our case the plausible dependence structure is more general than that of asset returns. The dependent variable is not directly observable, and the overlap concerns also past variables. Typical approaches to address this problem, such as those of Hansen and Hodrick (1980) and its extensions by Richardson and Smith (1991) and Hodrick (1992), can therefore not be applied in our setup.

Another common approach is to use HAC estimators with a long lag structure, as for example in Bekaert and Hoerova (2014). This is also the approach we follow here. To account for the autocorrelation caused by the rolling window estimation of the dependent variable, we use a Newey-West estimator with 500 lags. Since this number

	ES	IT	PT	IE	GR	BE	AT	FI	NL	FR
const	0.73 **	0.85 **	0.82 **	0.79 **	0.75 **	0.80 **	0.78 **	0.63 **	0.64 **	0.62 **
$\mathbb{1}_{bull,t}$	−0.27 **	−0.02	−0.24 **	−0.29 **	−0.14	−0.08	−0.32 **	−0.15 **	−0.18 *	0.05
RV_t	0.15	0.09	0.11	0.28	0.11	0.19 *	0.20 **	0.15	0.28 *	0.25 **
ΔRV_t	0.15	0.08	0.10	0.27	0.11	0.19 *	0.20 **	0.15	0.28 *	0.24 **
VP_t	−0.00	−0.00	−0.00	−0.00	−0.01 *	−0.00	−0.00	−0.00	−0.00	−0.00
r_t	−0.01	−0.01	−0.01	−0.01	−0.00	−0.01	−0.01	−0.01	−0.01 *	−0.01
BBB_t	−0.00	−0.00	−0.00	−0.00	0.00	−0.00	−0.00	−0.00	−0.00	−0.00
$Euribor_t$	−0.01	−0.00	−0.01	−0.00	−0.00	−0.01	−0.01 *	−0.01 **	−0.01	−0.00
$\mathbb{1}_{bull,t} \times RV_t$	−0.41 *	−0.05	−0.17	−0.45 *	−0.27	−0.00	−0.38 **	−0.31 **	−0.34 *	−0.19
$\mathbb{1}_{bull,t} \times \Delta RV_t$	−0.41 *	−0.05	−0.17	−0.45 *	−0.27	0.00	−0.38 **	−0.30 **	−0.34 *	−0.19
$\mathbb{1}_{bull,t} \times VP_t$	−0.02	−0.00	−0.01 **	−0.01	0.00	−0.00	−0.02 **	−0.01	−0.02 **	−0.00
$R^2_{adj.}$	0.42	0.02	0.41	0.33	0.14	0.13	0.45	0.18	0.20	0.03
b_{HAC}	0.20	0.20	0.20	0.23	0.21	0.20	0.20	0.20	0.20	0.20
$crit_{0.975}$	2.55	2.55	2.55	2.66	2.59	2.55	2.58	2.55	2.55	2.55
$crit_{0.95}$	2.08	2.08	2.08	2.16	2.11	2.08	2.10	2.08	2.08	2.08

Table 5: Regression of the rolling window estimate $\hat{d}(s_{it})$ on the bull-market dummy $\mathbb{1}_{bull,t}$ and controls for the period 01/01/1999–03/08/2009. $*$ and $**$ indicate significance at the 10% level and 5% level, respectively.

of lags is relatively large in proportion to the sample size, we cannot resort to standard asymptotics. Instead we use so-called fixed-b asymptotics introduced by Kiefer and Vogelsang (2005) that explicitly account for this effect and provide better size control.

The results of this exercise are shown in Table 5. It can be seen that the estimated memory parameters are indeed significantly lower in bull markets. The estimated coefficients are negative for all countries but France and significant in 6 out of 10 cases. The reduction in memory in these cases ranges from -0.15 for Finland to -0.32 for Austria. We also find a significant impact of current risk and future risk changes for the core countries, as well as a number of significant interaction terms between the bull market dummies and the risk variables. In bear markets a one standard deviation increase in the fractionally differenced realized volatility leads to an increase of the memory parameter of about 0.2, whereas the effect is offset or even reversed in bull markets where the interaction terms come into effect. The variance risk premium does not generally have a significant effect, and where it does, the size of the effect is not economically meaningful. With regard to the quality of the models, the $R^2_{adj.}$ is around 0.4 for Spain, Portugal, and Austria and it is between 0.18 and 0.33 for Ireland, the Netherlands, and Finland. For Belgium and Greece the explanatory power is lower and the model fails to explain the time variation in the persistence of the spreads of France and Italy.

The bull- and bear-market periods defined in Section 3 are *ex post*, since they require the knowledge of subsequent highs and lows of the index. This information is not available to market participants in real time. Instead, they can consider a *nowcast* of the probability of being in a bull market that is based on past returns. Furthermore, even though the results in Table 5 clearly indicate that the market periods specified in Section 3 are meaningful for the degree of integration, the regression analysis conducted here does not require long uninterrupted bull- and bear-market periods.

We therefore consider an alternative specification of the bull- and bear-market model, where the state of the Eurostoxx index is determined endogenously, and the bull- and bear-market periods are allowed to be short-lived. This is achieved by using a Markov-switching mean and variance model, where

$$r_t = \mu_{s_t} + \sigma_{s_t}\eta_t, \tag{6}$$

with $\eta_t \overset{iid}{\sim} (0,1)$. Here $s_t \in \{1,2\}$ is a Markov chain with transition probabilities p_{12} and p_{21}. For identification purposes, we assume $\mu_1 > \mu_2$ and call regime one the "bull-market regime". Let $s_{t|t} = P(s_t = 1|r_t, r_{t-1}, ...)$ denote the probability of a bull market at time t conditional on the observations up to time t estimated on the basis of the Markov-switching model. We will refer to $s_{t|t}$ as the market sentiment.

When the model is applied to the Eurostoxx returns, we can observe that the bull-market regime is associated with a positive mean $\hat{\mu}_1 = 0.0008$ and a low standard deviation $\hat{\sigma}_1 = 0.0089$, whereas the bear market regime has a negative mean of $\hat{\mu}_2 = -0.0014$ and a larger standard deviation. The probability to stay in the bull-market regime is estimated to be 0.9884, whereas the probability of staying in the bear-market regime is 0.9746. Therefore both regimes are persistent, but the average bear market is shorter than the average bull market.

The filtered state probabilities $s_{t|t}$ for a bull market are shown in Figure 7, with the previous dating of bull and bear markets indicated by vertical dashed lines. It can clearly be seen that the bull-market probability seems to be higher during those periods that were previously classified as bull markets. However, in the nowcast there is much more uncertainty about the market environment.

The regression results for $\mathbb{1}_{bull,t}$ replaced with $s_{t|t}$ are shown in Table 6. When comparing the results with those in Table 5, we find that RV_t and ΔRV_t are no longer significant. This indicates that the bull-market state probability carries all necessary information about the volatility. The reduction of the memory in bull markets compared to bear markets appears to be even higher, but the overall fit of the model is reduced when compared to the specification with the bull-market dummy $\mathbb{1}_{bull,t}$ in Table 6.

Since the Markov-switching model gives a non-constant bull-market probability for the EMU-crisis period as well, we can analyze the change of the relationship in the bull market during the EMU crisis. As can be seen in Table 7, the relationship between the bull-market probability and the persistence of the spreads breaks down completely and the model loses its explanatory power.

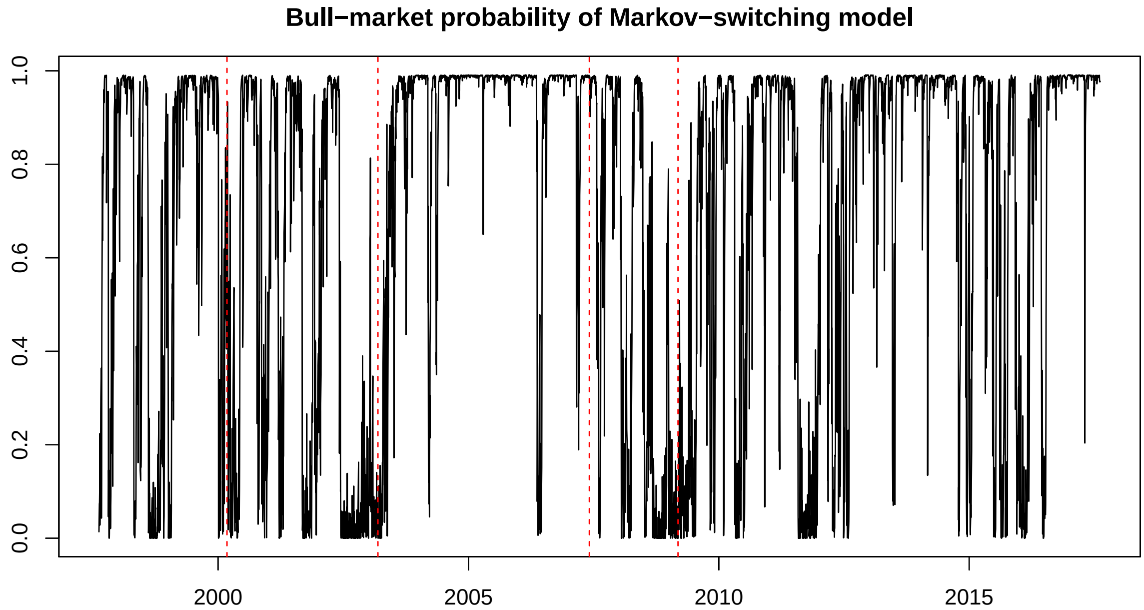

Figure 7: Filtered probabilities $s_{t|t}$ for a bull-market regime in the Markov-switching mean-variance model (6) estimated for the Eurostoxx index.

	ES	IT	PT	IE	GR	BE	AT	FI	NL	FR
$const.$	0.78 $**$	0.86 $**$	0.87 $**$	0.83 $**$	0.79 $**$	0.81 $**$	0.87 $**$	0.72 $**$	0.74 $**$	0.63 $**$
$s_{t\|t}$	−0.28 $**$	−0.03	−0.25 $**$	−0.26 $**$	−0.17	−0.08	−0.37 $**$	−0.25 $**$	−0.28 $**$	0.03
RV_t	0.07	0.02	0.09	0.19	0.08	0.14	0.03	−0.01	0.13	0.09
ΔRV_t	0.07	0.02	0.10	0.19	0.07	0.14	0.04	−0.00	0.14	0.09
VP_t	−0.01	−0.00	−0.01	−0.00	−0.01 $**$	0.00	−0.01	−0.00	0.00	0.00
r_t	−0.02 $**$	−0.01	−0.01 $**$	−0.02 $**$	−0.01	−0.01	−0.01 $*$	−0.01 $*$	−0.01 $*$	−0.01
BBB_t	−0.00	−0.00	−0.00	−0.01	0.00	−0.00	−0.00	−0.00 $**$	−0.00	−0.00
$Euribor_t$	−0.01 $*$	−0.00	−0.00	−0.01	−0.01	−0.00	−0.00	−0.01	−0.01	−0.01
$s_{t\|t} \times RV_t$	−0.25 $**$	0.07	−0.16 $*$	−0.18	−0.26	0.10	−0.18	−0.13	−0.19	0.09
$s_{t\|t} \times \Delta RV_t$	−0.26 $**$	0.07	−0.16 $*$	−0.19	−0.26	0.10	−0.18	−0.14	−0.19	0.09
$s_{t\|t} \times VP_t$	−0.00	−0.01	0.00	−0.01	0.01 $*$	−0.01	0.00	−0.01	−0.02	−0.01
$R^2_{adj.}$	0.28	0.03	0.28	0.18	0.13	0.10	0.35	0.25	0.24	0.01
b_{HAC}	0.20	0.20	0.20	0.23	0.21	0.20	0.20	0.20	0.20	0.20
$crit_{0.975}$	2.55	2.55	2.55	2.66	2.59	2.55	2.58	2.55	2.55	2.55
$crit_{0.95}$	2.08	2.08	2.08	2.16	2.11	2.08	2.10	2.08	2.08	2.08

Table 6: Regression of the rolling window estimate $\hat{d}(s_{it})$ on the filtered state probability $s_{t|t}$ and controls for the period 01/01/1999–03/08/2009. $*$ and $**$ indicate significance at the 10% level and 5% level, respectively.

Since the regression problem with rolling window estimates of the dependent variable is non-standard, we conduct a further robustness check, where we estimate the memory parameters $d(s_{it})$ separately for each quarter. Similarly, we form quarterly means of the explanatory variables before taking fractional differences of all persistent regressors and standardizing. The results of this exercise are given in Tables 10 and 11 in the appendix. The estimated coefficients for the bull-market dummy as well as the model

	ES	IT	PT	IE	GR	BE	AT	FI	NL	FR
$const.$	0.88 **	0.89 **	0.95 **	1.01 **	0.94 **	0.95 **	0.93 **	0.87 **	0.87 **	0.92 **
$s_{t\|t}$	−0.01	−0.00	0.01	−0.02	0.01	−0.02	−0.07 **	−0.01	−0.01	0.01
RV_t	−0.11	0.00	−0.02	−0.07	−0.00	−0.05	0.01	0.16 **	−0.09	0.12 **
ΔRV_t	−0.10	0.00	−0.01	−0.05	0.01	−0.05	0.02	0.16 **	−0.08	0.12 **
VP_t	0.00	−0.00	−0.00	0.00	−0.00	0.00	−0.00	−0.00*	0.00	−0.00
r_t	−0.01	−0.00	−0.00*	−0.00	−0.01	−0.01*	−0.00	0.00	−0.00*	−0.00*
BBB_t	−0.01 **	−0.01 **	−0.01 **	0.00	−0.01	−0.01*	−0.01 **	0.00	−0.01 **	−0.01*
$Euribor_t$	−0.00	−0.00	−0.01 **	0.00	−0.00	−0.01	−0.02	−0.02 **	−0.02*	−0.01
$s_{t\|t} \times RV_t$	0.05	−0.06	−0.00	0.06	−0.09	0.05	−0.01	−0.09	0.09	−0.16
$s_{t\|t} \times \Delta RV_t$	0.04	−0.06	−0.01	0.04	−0.10	0.04	−0.03	−0.09	0.08	−0.16*
$s_{t\|t} \times VP_t$	−0.01	0.00	0.00	−0.00	0.01	0.00	0.01*	0.01	0.00	0.01
$R^2_{adj.}$	0.09	0.01	0.04	0.01	0.02	0.07	0.10	0.08	0.09	0.03
b_{HAC}	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.25	0.25	0.25
$\text{crit}_{0.975}$	2.72	2.72	2.72	2.73	2.73	2.72	2.74	2.73	2.72	2.72
$\text{crit}_{0.95}$	2.20	2.21	2.20	2.21	2.22	2.20	2.22	2.21	2.20	2.20

Table 7: Regression of the rolling window estimate $\hat{d}(s_{it})$ on the filtered state probability $s_{t|t}$ and controls for the period 03/09/2009–08/08/2017. $*$ and $**$ indicate significance at the 10% level and 5% level, respectively.

fit are comparable in their magnitude, even though fewer of the estimated coefficients are statistically significant. This can be attributed to the lower number of observations. All evidence for a positive effect of increased risk disappears. Similarly, when using nowcasts of the bull-market probability instead of the bull-market dummy, the effect of the bull-market probability is estimated to be even higher in magnitude and statistically significant in most cases. Again, the evidence for a positive effect of the risk and future risk variable disappears.

Overall, we find that the time variation in the estimated memory parameters is well explained by a bull-market indicator. This finding holds true for ex post defined bull and bear markets as well as an endogenously determined nowcast of the bull-market probability. Considering the evolution of current and future risk can help to explain the changes in persistence if the volatility is not part of the definition of the market phases and is on a daily frequency. However, this effect disappears on a quarterly frequency, or if the volatility also drives the definition of market phases, as it is the case in the Markov-switching model.

7 Interpretation of the Results

The previous sections establish that the EMU government bond markets were integrated during bull-market periods but disintegrated in bear-market periods. To gain a deeper economic understanding of the mechanisms driving this effect, reconsider the decomposition of the spreads in equation (5), according to which

$$s_{it} = \delta_{it} + l_{it}.$$

As outlined above, the spreads are the cointegrating residuals between the yields so that their persistence determines whether there is an equilibrium or not. From the equation above, the spreads consist of two components — the liquidity risk premium l_{it} and the default risk premium δ_{it}. Since credit default swap data is not available for most of the time period before the subprime mortgage crisis, we cannot use this information to disentangle the default and liquidity risk premiums as for example in Longstaff et al. (2005).

We can, however, draw some conclusions based on properties of long-memory processes. Denote the memory of the default risk premium for country i at time t by $d(\delta_{it})$ and let $d(l_{it})$ denote the memory of the liquidity risk premium. To see how the persistence of the aggregate s_{it} relates to the components δ_{it} and l_{it}, the properties of linear combinations of long-memory time series have to be considered. With constant unconditional mean and variance of the component series, it was shown by Chambers (1998) that the memory of a linear combination of long-memory processes is determined by the most persistent series in the combination. For two long-memory series a_t and b_t with memory parameters d_a and d_b this means that $c_t = a_t + b_t$ has long memory of order $d_c = \max\{d_a, d_b\}$. The memory of the spreads s_{it} is therefore either $d(\delta_{it})$, or $d(l_{it})$, according to which is larger.

The reasoning behind this result of Chambers (1998) is as follows. If a_t and b_t are mutually independent, the spectral density of c_t local to the origin is given by

$$f_c(\lambda) \sim G_a|\lambda|^{-2d_a} + G_b|\lambda|^{-2d_b},$$

as $\lambda \to 0$. Here G_a and G_b denote the long-run variance of the short memory components in the respective series. Obviously, both of the components on the right-hand side generate poles and the smaller one is dominated by the larger one.[2]

These results are based on the assumption that G_a and G_b are fixed, finite, and positive. In practice, however, there could arise situations in which one of the components is very small compared to the other one. A more fitting theoretical framework for such a situation would be to assume that $G_a/G_b \to 0$, as $T \to \infty$. In this case, the ratio of the long-run variances of the short memory components depends on the sample size and goes to zero. More formally, let $c_t = a_t + b_t$, with $d_a > d_b$ and $G_a(T)/G_b(T) \to 0$, then

[2]If a_t and b_t are dependent, there is also an interaction term in $f_c(\lambda)$, but the mechanism remains the same.

	ES	**IT**	**PT**	**IE**	**GR**	**BE**	**AT**	**FI**	**NL**	**FR**	(s.e.)
$\hat{d}(s_{it})$	0.92	0.86	0.93	1.02	0.98	0.92	0.92	0.81	0.83	0.83	(0.03)
$\hat{d}(ba_{it})$	0.27	0.29	0.06	0.55	0.24	0.09	0.41	0.24	0.13	0.26	(0.04)

Table 8: Memory estimates for the yield spreads s_{it} and the bid-ask spreads ba_{it} in the period from 12/01/2001–03/08/2009. The standard error of the estimate for the bid-ask spread of Ireland is 0.05.

$d_c = d_b$. This result implies that in practice the estimated degree of persistence in the spreads s_{it} will be a convex combination of $d(l_{it})$ and $d(\delta_{it})$ that depends on the relative scale of the variation of the two risk premiums.

To gain an insight into the memory of the liquidity risk premium, we consider the bid-ask spreads of the benchmark bonds (ba_{it}) as a proxy (insofar as those are available). Estimates of their memory parameters are provided in Table 8, along with estimates of the memory in the spreads for the same period. It can be observed that the level of persistence in the bid-ask spreads is much lower than that in the spreads. From the theoretical results on the memory of linear combinations discussed above, the persistence of the spreads and thus the periods of integration and disintegration therefore could not have been caused by changes in the persistence of the liquidity risk premium. This would require the persistence of the bid-ask spreads to be as high as that of the spreads. Instead, it has to be caused by changes of the persistence or relative variability of the default risk premium. Further support of this argument is provided by rolling window estimates of the memory in the bid-ask spreads in Figures 9 and 10 in the appendix. Here, the estimated memory parameters for the core countries are mostly in the lower stationary region — with the exception of a brief period during the EMU debt crisis, where they reach values around 0.6. Similarly, the bid-ask spreads of the majority of periphery countries show low and stable persistence prior to the EMU crisis and higher levels afterwards.

Based on these results, it seems reasonable to assume that $d(\delta_{it}) \geq d(l_{it})$ for all $i = 1,...,N$ and $t = 1,...,T$. Hence, the theoretical arguments discussed above give rise to two mechanisms that generate the observed time variation in the memory of the spreads that tends to be one in bear markets but much lower in bull markets: (i) breaks in $d(\delta_{it})$ from $d(\delta_{it}) < 1$ to $d(\delta_{it}) = 1$, or (ii) $d(\delta_{it}) = 1$, for all t, but the relative scale of variations in δ_{it} compared to l_{it} differs for bull and bear markets.

Since the default risk is driven by the macroeconomic and fiscal conditions in the respective country, mean reverting default risk premiums imply the existence of a stable equilibrium relationship between the countries' default risk and the default risk of the benchmark country (Germany). In contrast to that, integrated default risk premiums imply divergence between the respective country and Germany, since the variance of integrated series grows linearly with time.

The conclusion in situation (i) would therefore be that market participants considered the possibility of economic and fiscal divergence within the EMU area in bear markets, whereas they expected economic convergence within the currency area in bull markets. In situation (ii), market participants would permanently anticipate the possibility of economic and fiscal divergence between the EMU countries, but the level and variability of the default risk premium is so low during bull markets that the memory properties are dominated by those of the less persistent liquidity risk premium. Conversely, during bear markets risk and risk aversion are high so that the variability of the default risk premium increases relative to that of the liquidity risk premium and the persistence of the spreads is dominated by that of the default risk premium.

These findings provide clear support for the assertion that the persistence of the spreads can be attributed to time variation in either the persistence of the default risk premium or its variability. Both of these arguments ((i) and (ii)) lead to the conclusion that (at least in crisis times) the pricing of EMU government bonds implied the possibility of macroeconomic and fiscal divergence between the EMU countries.

8 Conclusion

The analysis in this paper is based on a consideration of the interrelations between the dynamics driving interest rates and spreads, the persistence of these series, and the implications for the existence or non-existence of equilibria in the EMU government bond market.

Contrary to common belief, it is found that EMU government bond markets were not continually integrated prior to the EMU debt crisis. Even though the level of the spreads was very small compared to that of the yields, we establish that there are periods during which the spreads become unit root processes so that there is no correction mechanism that would drive the yields back to their equilibrium relationship. This is a critical component of the law of one price, which is therefore not fulfilled. These periods of disintegration tend to coincide with bear-market periods, whereas EMU bond markets tend to be economically integrated if stock markets are bullish. Furthermore, the integration among the core countries used to be more intense than that among the periphery countries and especially the degree of integration between the core and the periphery countries was already low in periods prior to the EMU debt crisis.

It is found that the effect of market sentiment on the persistence of the spreads is robust to changes in the definition of the market sentiment variable; in addition current volatility and future changes in volatility provide additional explanatory power, whereas the volatility risk premium does not.

Altogether, these results imply that investors do not only shift their portfolios from (comparatively) risky stocks to safer bonds in bear markets as described by flight-to-quality effects, there is also a stronger differentiation between sovereign default risks during these periods. As discussed in the previous section, the nature of this differentiation between the default risks of the different countries implies that at least in bear markets investors did consider the possibility of macroeconomic and fiscal divergence between the EMU countries, even though the low magnitude of the spreads shows that this was considered very unlikely.

Appendix

		ES	IT	PT	IE	GR	BE	AT	FI	NL	GER
Bull 1	NS07	0.56	0.31	0.64	0.54		0.65	0.50	0.64	0.65	0.64
	SRF16	0.50		0.54	0.49		0.42	0.56	0.81	0.61	0.65
	MV04	0.63	0.30	0.67	0.59		0.66	0.52	0.75	0.67	0.71
	WWC15	0.63	0.31	0.67	0.59	0.09	0.66	0.52	0.75	0.67	0.71
	R08	0.56	0.31	0.64	0.54		0.65	0.50	0.64	0.65	0.64
	CH06	0.59	0.31	0.67	0.54		0.67	0.52	0.74	0.66	0.71
	HV08	0.63	0.31	0.67	0.59		0.66	0.52		0.67	0.71
	N10			0.66	0.58			0.52	0.55	0.63	0.71
Bear 1	NS07	0.22	0.12	0.12	0.10	0.10	0.20	0.17	0.38	0.25	0.33
	SRF16	0.32		0.26			0.22	0.30	0.37	0.26	0.31
	MV04	0.25	0.12	0.13	0.14		0.22	0.23	0.40	0.27	0.28
	WWC15	0.25	0.12	0.13	0.14	0.14	0.22	0.23	0.40	0.27	0.29
	R08	0.22					0.20	0.17	0.38	0.25	0.33
	CH06	0.26						0.24	0.39	0.25	0.33
	HV08	0.25					0.22	0.23	0.40		
	N10									0.26	
Bull 2	NS07	0.52	0.08	0.38	0.49	0.41	0.29	0.46	0.43	0.55	0.32
	SRF16	0.53		0.36	0.43	0.30	0.22	0.44	0.27	0.38	0.25
	MV04	0.52		0.38	0.50	0.40	0.28	0.45	0.46	0.57	0.32
	WWC15	0.52		0.37	0.50	0.40	0.28	0.45	0.46	0.57	0.32
	R08	0.52		0.38	0.49	0.41	0.29	0.46	0.43	0.55	0.32
	CH06	0.52		0.38	0.50	0.41	0.28	0.45	0.46	0.56	0.32
	HV08	0.52				0.40		0.45	0.46	0.57	
	N10	0.52			0.49		0.29	0.46	0.43	0.55	0.32
Bear 2	NS07	0.15	0.14	0.06	-0.04		-0.02	0.10	0.34	0.29	0.15
	SRF16							0.33	0.33	0.34	0.25
	MV04		0.17				0.07	0.18	0.33	0.31	
	WWC15		0.17					0.18	0.33	0.31	0.26
	R08					-0.04			0.34	0.29	0.15
	CH06								0.35	0.32	0.26
	HV08										0.26
	N10										
Crisis	NS07						0.18	0.09	0.12	0.07	0.11
	SRF16						0.14				
	MV04						0.17				
	WWC15										
	R08	0.08				0.02	0.18				
	CH06						0.18				
	HV08										
	N10										

Table 9: Strengh of the fractional cointegration relationship between the yields of bonds of the respective country and France. Empty fields indicate the absence of a significant fractional cointegrating relationship at the 5%-level.

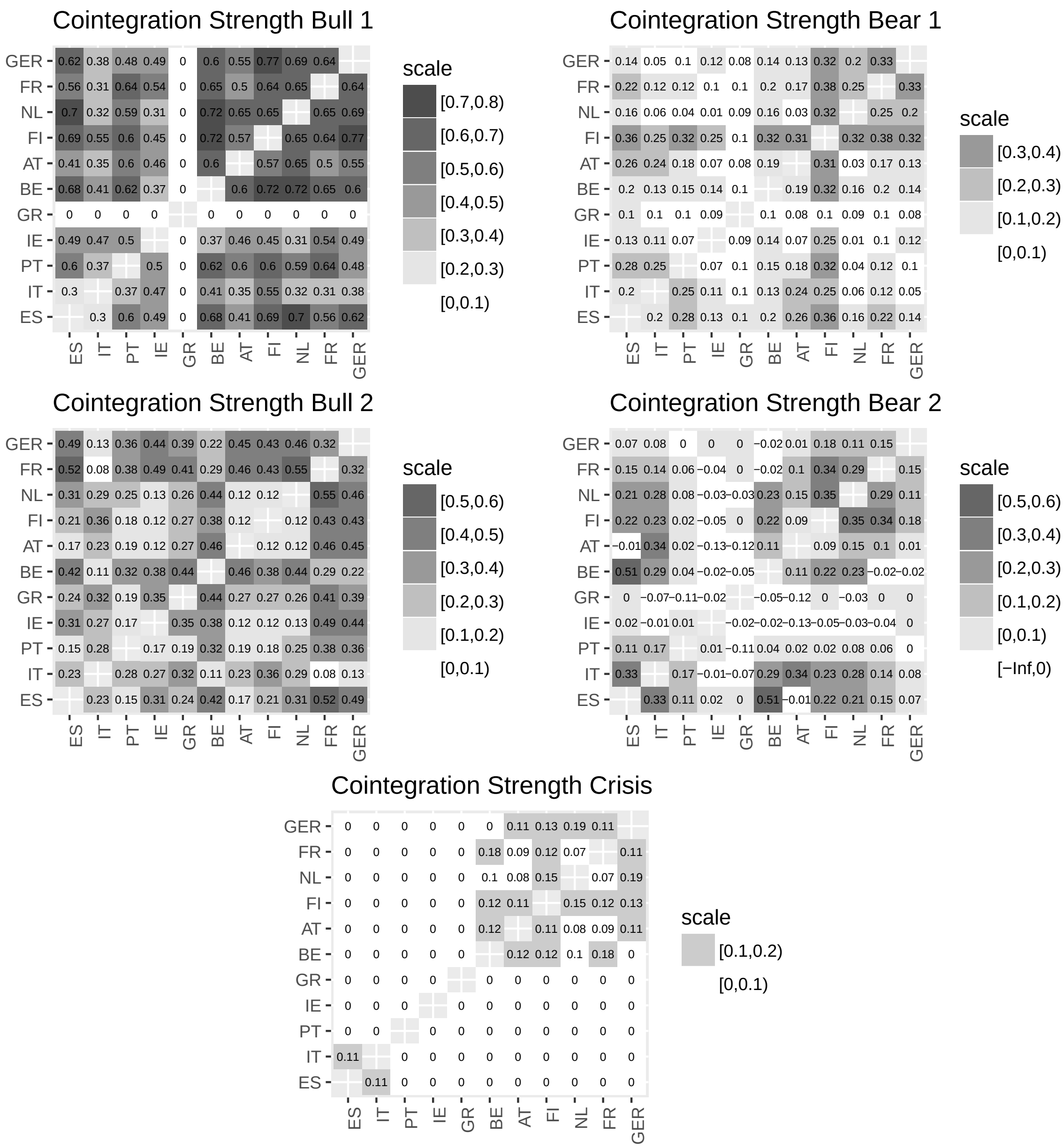

Figure 8: Heatmaps for the strength of pairwise cointegration relationships between EMU government bonds for different subperiods obtained using the method of Nielsen and Shimotsu (2007).

	ES	IT	PT	IE	GR	BE	AT	FI	NL	FR
$const.$	0.54 ∗∗	0.81 ∗∗	0.66 ∗∗	0.59 ∗∗	0.62 ∗∗	0.70 ∗∗	0.57 ∗∗	0.50 ∗∗	0.50 ∗∗	0.52 ∗∗
$\mathbb{1}_{bull,t}$	−0.18	−0.03	−0.25 ∗∗	−0.27∗	−0.17	−0.03	−0.26∗	−0.21 ∗∗	−0.18	0.13
RV_t	−0.05	−0.01	−0.01	−0.13	−0.02	−0.12	−0.07	−0.11	−0.05	0.10
ΔRV_t	0.00	−0.01	0.05	0.00	−0.11	−0.06	−0.08	−0.19∗	−0.06	0.14
VP_t	−0.09	−0.13	−0.02	−0.13	−0.19	−0.09	−0.06	−0.13	−0.06	−0.06
r_t	−0.13∗	−0.05	−0.15∗	−0.14∗	0.06	−0.06	−0.06	−0.02	−0.08	−0.16 ∗∗
BBB_t	0.14∗	0.12∗	0.07	0.15∗	0.17∗	0.13∗	0.11	0.10	0.09	0.06
$Euribor_t$	−0.09	−0.11 ∗∗	−0.01	−0.06	−0.13∗	−0.14 ∗∗	−0.06	−0.03	−0.08	−0.06
$\mathbb{1}_{bull,t} \times RV_t$	0.04	0.42 ∗∗	−0.05	−0.11	−0.20	0.60 ∗∗	0.10	0.19	0.15	0.13
$\mathbb{1}_{bull,t} \times \Delta RV_t$	−0.07	0.09	−0.07	−0.09	−0.24	0.21	0.06	0.16	0.11	−0.05
$\mathbb{1}_{bull,t} \times VP_t$	−0.16	−0.05	−0.21	0.08	0.10	−0.06	−0.24	0.09	0.05	−0.08
$R^2_{adj.}$	0.31	0.15	0.26	0.29	0.21	0.25	0.18	0.20	0.11	0.04

Table 10: Regression of the estimated $\hat{d}(s_{it})$ for each quarter on the bull-market dummy $\mathbb{1}_{bull,t}$ and controls for the period 01/1999–01/2009. $*$ and $**$ indicate significance at the 10% level and 5% level, respectively.

	ES	IT	PT	IE	GR	BE	AT	FI	NL	FR
$const.$	0.67 ∗∗	0.76 ∗∗	0.88 ∗∗	0.69 ∗∗	0.67 ∗∗	0.63 ∗∗	0.73 ∗∗	0.56 ∗∗	0.62 ∗∗	0.54 ∗∗
$s_{t\|t}$	−0.50 ∗∗	0.01	−0.79 ∗∗	−0.56 ∗∗	−0.25	0.04	−0.61 ∗∗	−0.37 ∗∗	−0.53 ∗∗	0.12
RV_t	0.03	−0.08	−0.0001	−0.09	−0.05	−0.17	−0.01	−0.10	−0.02	0.07
ΔRV_t	0.11	−0.05	0.12	0.13	−0.01	−0.06	0.09	−0.05	0.06	0.19
VP_t	−0.06	−0.11	−0.002	0.05	−0.07	−0.06	−0.09	−0.03	0.08	0.03
r_t	−0.12∗	−0.09	−0.09∗	−0.13∗	0.04	−0.12∗	−0.07	−0.06	−0.07	−0.15 ∗∗
BBB_t	0.10	0.12	0.06	0.05	0.12	0.12	0.12	0.04	0.01	0.02
$Euribor_t$	−0.07	−0.11∗	−0.05	−0.09	−0.15 ∗∗	−0.13 ∗∗	−0.07	−0.04	−0.10	−0.06
$s_{t\|t} \times RV_t$	−0.10	0.71 ∗∗	0.21	0.16	0.01	0.84 ∗∗	0.04	0.36	0.33	0.31
$s_{t\|t} \times \Delta RV_t$	−0.18	0.25	0.10	−0.09	−0.39	0.27	−0.15	0.06	0.14	−0.16
$s_{t\|t} \times VP_t$	−0.14	−0.29	−0.20	−0.43	−0.11	−0.33	−0.004	−0.18	−0.32	−0.43
$R^2_{adj.}$	0.49	0.08	0.63	0.43	0.23	0.13	0.42	0.21	0.27	0.08

Table 11: Regression of the estimated $\hat{d}(s_{it})$ for each quarter on the filtered state probability $s_{t|t}$ and controls for the period 01/1999–01/2009. $*$ and $**$ indicate significance at the 10% level and 5% level, respectively.

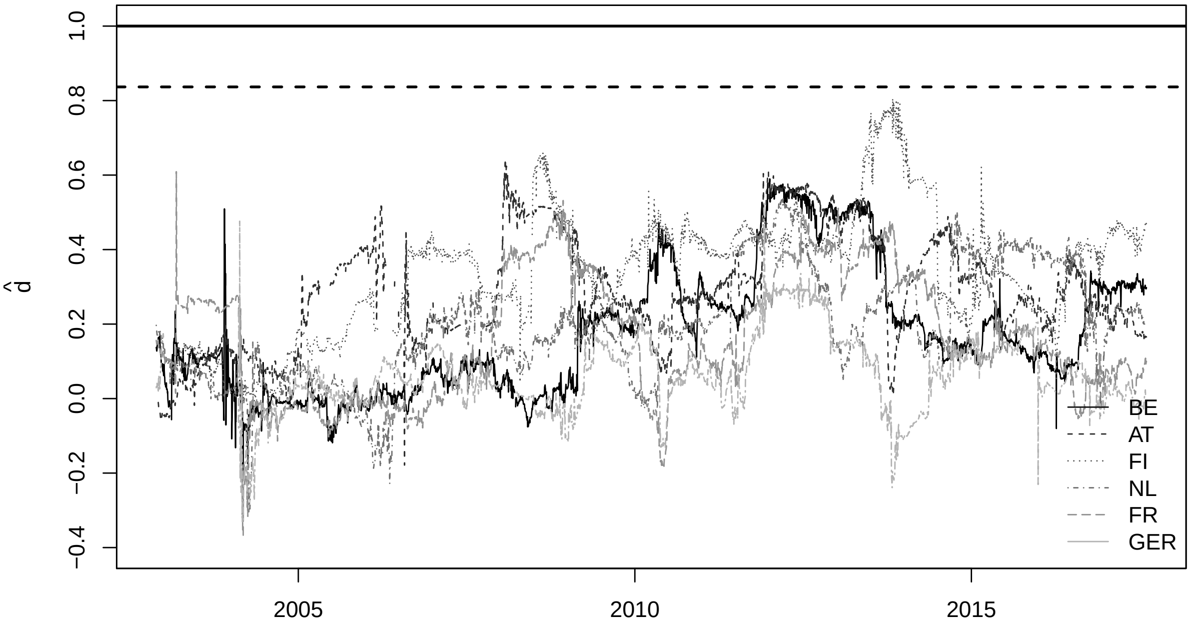

Figure 9: Rolling window estimates of the memory $d(ba_{it})$ in the bid-ask spreads of the core countries.

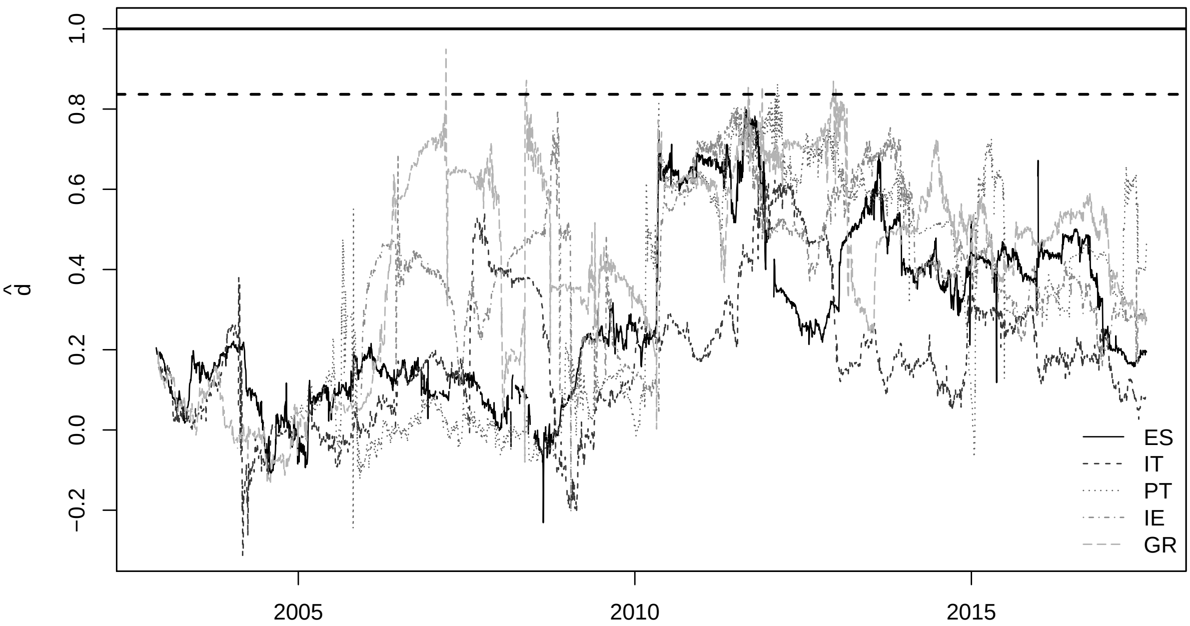

Figure 10: Rolling window estimates of the memory $d(ba_{it})$ in the bid-ask spreads of the periphery countries.

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