Department of
Economics and Finance

Economics and Finance Working Paper Series

Working Paper No. 16-03

Guglielmo Maria Caporale and Luis A. Gil-Alana

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January 2016

http://www.brunel.ac.uk/economics

LONG-TERM INTEREST RATES IN EUROPE:

A FRACTIONAL COINTEGRATION ANALYSIS

Guglielmo Maria Caporale
Department of Economics and Finance
Brunel University London

and

Luis A. Gil-Alana[*]
Faculty of Economics
University of Navarra
Pamplona, Spain

January 2016

Abstract

This paper uses fractional integration/cointegration techniques to examine the stochastic behaviour of long-term interest rates (on government securities with 10-year maturity) in various European countries as well as their long-run linkages on a pairwise basis over the period January 2001-October 2011. The results are mixed and sensitive to the (parametric and semi-parametric) estimation methods. Evidence is found for both unit roots and mean reversion in the series analysed. Various rates appear to be fractionally cointegrated, but interestingly German rates are not found to be linked to any others.

Keywords: Long-terminterestrates, fractionalintegration, fractionalcointegration

JEL classification: C22, C32, G15

Corresponding author: Professor Guglielmo Maria Caporale, Department of Economics and Finance, Brunel University, London, UB8 3PH, UK. Tel.: +44 (0)1895 266713. Fax: +44 (0)1895 269770. Email: Guglielmo-Maria.Caporale@brunel.ac.uk

[*]The second named author acknowledges financial support from the MINECO (Ministerio de Economía y Competitividad, Spain) research grant ECO2014-55236).

1. Introduction

The aim of this paper is to examine the stochastic behaviour of long-term interest rates in Europe as well as their long-run linkages on a pairwise basis by using fractional integration and cointegration techniques respectively. It is well known that most interest rate series exhibit high persistence; however, the debate on the most appropriate statistical model for them is still open. Earlier studies were normally based on the I(0)/I(1) dichotomy. For instance, Cox, Ingersoll and Ross (1985) characterized the short-term nominal interest rate as a stationary and mean-reverting I(0) process, whilst Campbell and Shiller (1987) concluded that it exhibits a unit root.

More general I(d)-type specifications have been adopted in subsequent studies. For instance, Shea (1991) found some evidence for the expectations hypothesis of the term structure estimating a long-memory model. Backus and Zin (1993) argued that the hyperbolic decline of the volatility of bond yields can be modelled using a fractionally integrated specification. Lai (1997) and Phillips (1998) and Tsay (2000) both found that a fractional integration framework is appropriate for US real interest rates as well (see also Barkoulas and Baum, 1997; Meade and Maier, 2003; Gil-Alana, 2004a,b), and Couchman, Gounder and Su (2006) presented similar evidence for sixteen countries. Caporale and Gil-Alana (2009) reported that in the case of the Federal Funds effective rate the fractional integration parameter is sensitive to the specification for the error term, whilst Caporale and Gil-Alana (2012) obtained evidence of long memory and fractional integration with cycles repeating every eight years. Finally, Gil-Alana and Moreno (2012) estimated a fractional integration model for the short-term interest rate and the term premium.

Concerning the euro area in particular, Busch and Nautz (2009) used a long memory framework and found that the persistence of the spread between market and policy rates has decreased, i.e. monetary policy can control interest rates more effectively. However, Hassler and Nautz (2008) and Cassola (2008) estimated a fractional integration parameter around 0.25, which suggests less controllabity (see also Cassola and Morana, 2008, in the case of interest rates of one-week maturity). Most recently, Caporale and Gil-Alana (2016) concluded that the Euribor rate can be characterised as a highly persistent process with a cycle length of 6 years approximately.

An interesting issue is whether interest rates are linked in the long run. According to the theory of interest rate parity, given perfect capital mobility, fixed exchange rates and perfect capital markets, interest rates will be equal across countries. However, the presence of market imperfections implies that interest rate differentials across countries will still be found. Stronger linkages should be expected between international real rates than nominal rates, given the 'Fisher-open condition' implying equality between expected real rates of interest in different countries.

Interest rate linkages have often been investigated in the literature by carrying out cointegration analysis. For instance, unit root and cointegration tests were performed by DeGennaro et al. (1994) to examine the stochastic properties of the long-run relationships between interest rates on long-term government bonds issued by the US, Canada, Germany, UK and Japan, and by Mougoue (1992) in the case of short-term interest rates. Regarding Europe specifically, Karfakis and Moschos (1990) and Kirchgassner and Wolters (1995) both investigated short-term nominal interest rate interdependencies between Germany and other EMS rates using Granger Causality and cointegration tests. Caporale and Pittis (1995, 1996) adopted a similar framework, but pointed out that cointegration should only be expected once convergence has occurred: during the process of convergence the interest rate differential will be decreasing over time and therefore will be non-stationary. Wang et al. (2007) examined linkages among major Eurocurrency interest rates during 1994-2002 using a cointegrated VAR and found much stronger linkages when allowing for contemporaneous causality as well.

Barkoulas et al. (1997) extended earlier studies on the system of long-term international interest rates by allowing for a fractionally integrated error correction term; in this case, even though mean reversion still occurs, the adjustment process towards the long-run equilibrium relationship can be very slow, i.e. shocks are allowed to have highly persistent effects, albeit disappearing in the long run. The motivation for this type of modelling approach is that the assumptions imposed by standard unit root and cointegration tests might be too restrictive; therefore it is important to consider the possibility of fractional orders of integration/cointegration with a slow rate of decay. Following their study, we also use a fractional integration/cointegration framework, but focus instead on long-term European rates. The layout of the paper is the following: Section 2 outlined the methodology; Section 3 presents the empirical results; Section 4 offers some concluding remarks.

2. Methodology

In this paper we use fractional integration and cointegration techniques widely employed for analyzing macroeconomic and financial time series (Gil-Alana and Robinson, 1997; Gil-Alana, 2003; Gil-Alana and Hualde, 2009). For our purposes, we define an I(0) process as a covariance stationary one with a spectral density function that is positive and finite at the zero frequency. This includes white noise as well as any type of stationary ARMA processes. Specifically, a process $\{x_{t,\ t} = 0, \pm 1, \dots \}$ is said to be I(d) if it can be represented as

$$(1 - L)^d x_t = u_t, \quad t = 1, 2, ... \qquad (1)$$

where L is the lag operator, d can be any real number, and u_t is assumed to be I(0).

We first consider parametric models where x_t from (1) can be the errors in a regression model of the form:

$$y_t = \beta_0 + \beta_1 t + x_t, \qquad t = 1, 2, \qquad (2)$$

y_t being the observed time series (in our case the long-term interest rates), and β_0 and β_1 the coefficients of the intercept and the time trend. We consider both uncorrelated (white noise) and autocorrelated u_t under the I(0) assumption. In the latter case, we use the exponential spectral model of Bloomfield (1973), which is a non-parametric method for approximating ARMA processes with only a few parameters (Gil-Alana, 2004c). Our approach is based on the Whittle function in the frequency domain (Dahlhaus, 1989), but we also use the Lagrange Multiplier (LM) test of Robinson (1994) for the null $d = d_o$ in (1) for any real value of d_o. In addition, we apply a semi-parametric method that does not impose any functional form on the I(0) error term; this is based on a "local" Whittle approach developed by Robinson (1995), Velasco (1999) and Abadir et al. (2007) among others.

We then test for cointegration between long-term interest rates on a pairwise basis. A necessary condition for cointegration is that the two parent series display the same degree of integration. We use the statistic proposed by Robinson and Yajima (2002) to test homogeneity in the orders of integration of the two series denoted by d_x and d_y respectively, i.e. the null H_o: $d_x = d_y$. Finally we perform the Hausman test of Marinucci and Robinson (2001) for the null of no cointegration against the alternative of fractional cointegration.

3. Data and Empirical Results

The series analysed are the harmonized monthly long-term interest rates on government securities with 10-year maturity over the period January2001-October 2011; these are denominated in euros for Germany, Austria, Belgium, Ireland, Greece, Spain, Italy, Cyprus, Luxembourg, Malta, Netherlands, Austria, Portugal, Slovakia, Finland, in Czech korunas for the Czech Republic, in Danish krones for Denmark, in Latvian lats for Latvia, in Lithuanian litas for Lithuania, in Hungarian forint for Hungary, in Polish zlotys for Poland, in Swedish kronas for Sweden, and in pound sterling for the UK. The sample period is chosen on the basis of the data availability for most European countries.[1]

[1]The data source is http://www.ecb.int/stats/money/long/html/index.en.html

First we follow the parametric approach of Robinson (1994) with the Whittle estimates in the frequency domain (Dahlhaus, 1989). We consider the standard cases of i) no regressors, ii) an intercept, and iiii) and an intercept with a linear time trend. The results for the case of white noise disturbances are displayed in Table 1.

[Insert Table 1 about here]

The most appropriate specification appears to be the one including an intercept only, since the time trend coefficients (not reported) are found to be statistically insignificant in all cases. The estimated values of d are always above 1, ranging from 1.07 (Hungary) to 1.44 (Slovakia), and the unit root null hypothesis (i.e., d = 1) cannot be rejected in the cases of France, Belgium, Spain, Austria and Hungary). In all the other countries the value of d is significantly higher than 1.

[Insert Table 2 about here]

Table 2 focuses on the case of autocorrelated (Bloomfield) errors. The estimated values of d are now substantially smaller, and significantly higher than one only for Lithuania (1.32), Portugal (1.31), Luxembourg (1.30) and Greece (1.17). The unit root null cannot be rejected in 15 cases (Germany, Belgium, Ireland, Italy, Cyprus, Luxembourg, Malta, Netherlands, Austria, Slovakia, Finland, Latvia, Poland, Sweden and the UK), while evidence of mean reversion (i.e., d < 1) is found in the cases of Hungary (0.41), Denmark (0.62), the Czech Republic (0.68) and Spain (0.74). Given the fact that the results are different depending on the specification of the error term, we also estimated d using semi-parametric methods. Table 3 displays the results obtained from a "local" Whittle method (Robinson, 1995), using a selected number of bandwidth parameters.[2]

[Insert Table 3 about here]

We find evidence of mean reversion (d < 1) for Belgium, France, Netherlands, Austria, Finland, Denmark, Poland, Sweden and the UK; the unit root null cannot be rejected for Belgium, Ireland, Spain, Italy, Cyprus, Luxembourg, Malta, Slovakia, the Czech Republic and Hungary;

[2] Very similar results were obtained when using the extension to this approach by Abadir et al. (2007).

finally, there is evidence of d > 1 for Greece, Portugal, Latvia and Lithuania. When d < 1 mean reversion takes places and shocks have only transitory effects that disappear in the long run. This is generally the case for the countries belonging to Western Europe and Scandinavia (Belgium, France, Netherlands, Austria, Finland, Denmark, Sweden and the UK), as well as Poland.

Next, we carry out the cointegration analysis. First we test the homogeneity condition using the statistic proposed in Robinson and Yajima (2002). The results are displayed in Table 4.

[Insert Table 4 about here]

The same degree of integration is displayed by France, the Netherlands, Austria, Finland and Denmark vis-à-vis Germany; Belgium, the Netherlands, Austria, Finland, Denmark and Hungary vis-à-vis France; Malta, the Netherlands, Austria, Slovakia, Finland and Hungary vis-à-vis Belgium; Spain, Italy, Luxembourg, Slovakia and the Czech Republic vis-à-vis Ireland; Portugal, Latvia and Lithuania vis-à-vis Greece; Italy, Luxembourg, Slovakia and the Czech Republicvis-à-vis Spain; Cyprus and Luxembourg vis-à-vis Italy; Cyprus vis-à-vis Lithuania; Slovakia and the Czech Republic vis-à-vis Luxembourg; Austria, Slovakia, Finland, the Czech Republic and Hungary vis-à-vis Malta; Austria, Finland, Denmark and Hungary vis-à-vis the Netherlands; Finland, Denmark and Hungary vis-à-vis Austria; Latvia and Lithuania vis-à-vis Portugal; Slovakia vis-à-vis the Czech Republic, and finally Denmark, Hungary vis-à-vis Finland, and Denmark vis-à-vis Hungary (see Table 5).

[Insert Table 5 about here]

Table 6 displays the cointegration results. German interest rates are not cointegrated with any others. Interest rates in France are cointegrated with those in the Netherlands, Austria and Finland, with a reduction in the degree of integration of about 0.2-0.3 with respect to the parent series. Belgian interest rates are cointegrated with those in Malta and Slovakia, with a reduction in the degree of integration of about 0.5. Irish interest rates are cointegrated with those in Spain and

Italy, Greek ones with those in Portugal, Italian ones with those in Cyprus.[3] Other fractionally cointegrated relationships are found between the interest rates of Cyprus and Lithuania, Malta and Slovakia, and Austria and the Netherlands with Finland and Denmark.

4. Conclusions

This paper has used fractional integration and cointegration techniques to examine the stochastic behaviour of long-term interest rates (on government securities with 10-year maturity) in various European countries as well as their long-run linkages on a pairwise basis over the period January 2001-October 2011. Our modelling approach allows for the possibility of a slow rate of decay of the effects of shocks (i.e. a slow mean-reversion process) instead of imposing the restrictive assumptions underlying the standard unit root and cointegration tests. The results are mixed and sensitive to the (parametric and semi-parametric) estimation methods. Evidence is found for both unit roots and mean reversion in the series analysed. Various rates appear to be fractionally cointegrated, which suggests that they are driven a common set of fundamentals exhibiting long memory. Interestingly, however, German rates are not found to be linked to any others. The implications of these findings should be carefully considered by both policy makers and market participants.

[3] For some pairs evidence of fractional cointegration is partial, i.e. it is provided by only one of the two bilateral regressions. We do not consider cointegration to hold in such cases.

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Table 1: Estimated values of d and 95% confidence bands with white noise errors

	No regressors	An intercept	A linear trend
GERMANY	0.98 (0.86, 1.15)	**1.20 (1.03, 1.43)**	1.20 (1.03, 1.43)
FRANCE	1.00 (0.88, 1.18)	**1.13 (0.96, 1.37)**	1.13 (0.96, 1.37)
BELGIUM	1.02 (0.90, 1.18)	**1.13 (0.98, 1.34)**	1.13 (0.98, 1.34)
IRELAND	0.95 (0.85, 1.10)	**1.16 (1.02, 1.35)**	1.16 (1.02, 1.35)
GREECE	1.11 (1.03, 1.22)	**1.13 (1.06, 1.23)**	1.13 (1.06, 1.24)
SPAIN	0.99 (0.88, 1.14)	**1.08 (0.94, 1.30)**	1.08 (0.94, 1.30)
ITALY	1.05 (0.95, 1.19)	**1.13 (1.00, 1.29)**	1.13 (1.00, 1.29)
CYPRUS	1.05 (0.94, 1.18)	**1.21 (1.09, 1.37)**	1.21 (1.09, 1.37)
LUXEMBOURG	0.99 (0.87, 1.17)	**1.30 (1.16, 1.51)**	1.30 (1.16, 1.51)
MALTA	0.99 (0.88, 1.14)	**1.24 (1.07, 1.47)**	1.24 (1.07, 1.47)
NETHERLANDS	0.98 (0.86, 1.14)	**1.16 (1.00, 1.38)**	1.16 (1.00, 1.38)
AUSTRIA	1.00 (0.88, 1.17)	**1.15 (0.99, 1.38)**	1.15 (0.99, 1.38)
PORTUGAL	1.10 (1.02, 1.15)	**1.15 (1.07, 1.24)**	1.15 (1.07, 1.25)
SLOVAKIA	1.00 (0.89, 1.15)	**1.44 (1.28, 1.66)**	1.44 (1.27, 1.66)
FINLAND	0.98 (0.87, 1.15)	**1.18 (1.02, 1.40)**	1.18 (1.02, 1.41)
CZECH REP.	0.94 (0.82, 1.11)	**1.24 (1.08, 1.47)**	1.24 (1.08, 1.47)
DENMARK	0.98 (0.86, 1.14)	**1.17 (1.01, 1.38)**	1.17 (1.01, 1.38)
LATVIA	1.08 (0.96, 1.24)	**1.24 (1.13, 1.40)**	1.24 (1.13, 1.40)
LITHUANIA	1.10 (0.98, 1.26)	**1.22 (1.11, 1.36)**	1.22 (1.11, 1.36)
HUNGARY	1.03 (0.90, 1.21)	**1.07 (0.90, 1.33)**	1.07 (0.90, 1.33)
POLAND	1.01 (0.90, 1.15)	**1.37 (1.22, 1.58)**	1.37 (1.22, 1.58)
SWEDEN	0.98 (0.87, 1.14)	**1.21 (1.05, 1.41)**	1.21 (1.05, 1.42)
UNITED	1.01 (0.89, 1.19)	**1.29 (1.10, 1.53)**	1.28 (1.10, 1.53)

The values in bold refer to the significant cases according to the deterministic terms.

Table 2: Estimated values of d and 95% confidence bands with autocorrelated errors

	No regressors	An intercept	A linear trend
GERMANY	0.79 (0.63, 1.01)	**0.62 (0.43, 1.06)**	0.70 (0.44, 1.07)
FRANCE	0.82 (0.65, 1.05)	**0.62 (0.42, 0.97)**	0.67 (0.47, 0.99)
BELGIUM	0.88 (0.71, 1.12)	**0.75 (0.54, 1.03)**	0.77 (0.58, 1.03)
IRELAND	0.83 (0.72, 0.97)	**0.93 (0.76, 1.24)**	0.93 (0.75, 1.24)
GREECE	1.23 (1.09, 1.40)	**1.17 (1.06, 1.32)**	1.19 (1.06, 1.34)
SPAIN	0.90 (0.75, 0.97)	**0.74 (0.60, 0.93)**	0.74 (0.59, 0.93)
ITALY	1.06 (0.87, 1.33)	**0.95 (0.75, 1.25)**	0.96 (0.75, 1.25)
CYPRUS	1.09 (0.89, 1.35)	**1.05 (0.82, 1.30)**	1.05 (0.84, 1.30)
LUXEMBOURG	0.81 (0.63, 1.04)	**0.99 (0.80, 1.25)**	0.99 (0.83, 1.24)
MALTA	0.89 (0.73, 1.12)	**0.83 (0.61, 1.13)**	0.84 (0.67, 1.14)
NETHERLANDS	0.82 (0.63, 1.04)	**0.67 (0.45, 1.05)**	0.72 (0.48, 1.05)
AUSTRIA	0.83 (0.41, 1.07)	**0.68 (0.46, 1.02)**	0.72 (0.53, 1.03)
PORTUGAL	1.17 (1.03, 1.33)	**1.31 (1.14, 1.50)**	1.31 (1.15, 1.51)
SLOVAKIA	0.93 (0.75, 1.17)	**1.07 (0.83, 1.40)**	1.06 (0.86, 1.39)
FINLAND	0.82 (0.66, 1.06)	**0.68 (0.46, 1.04)**	0.75 (0.53, 1.06)
CZECH REP.	0.77 (0.58, 1.03)	**0.68 (0.43, 0.98)**	0.75 (0.56, 0.99)
DENMARK	0.80 (0.63, 1.06)	**0.62 (0.44, 0.92)**	0.67 (0.45, 0.88)
LATVIA	0.95 (0.73, 1.24)	**1.09 (0.94, 1.29)**	1.09 (0.94, 1.29)
LITHUANIA	0.98 (0.74, 1.32)	**1.32 (1.05, 1.71)**	1.31 (1.05, 1.70)
HUNGARY	0.82 (0.59, 1.10)	**0.41 (0.21, 0.68)**	0.41 (0.19, 0.68)
POLAND	0.97 (0.77, 1.29)	**1.02 (0.83, 1.33)**	1.02 (0.84, 1.33)
SWEDEN	0.83 (0.68, 1.05)	**0.72 (0.50, 1.12)**	0.73 (0.42, 1.12)
UNITED	0.85 (0.66, 1.11)	**0.72 (0.52, 1.15)**	0.71 (0.45, 1.15)

The values in bold refer to the significant cases according to the deterministic terms.

Table 3: Estimated values of d with a semi-parametric method

	8	9	10	11	12	13
GERMANY	0.682	0.577	0.646	**0.601***	0.574	0.582
FRANCE	0.805	0.646	0.718	**0.633***	0.596	0.605
BELGIUM	1.047	0.833	0.904	**0.784**	0.752	0.771
IRELAND	0.818	0.912	1.001	**0.983**	1.074	1.135
GREECE	1.385	1.406	1.402	**1.416****	1.481	1.500
SPAIN	1.240	1.041	1.132	**0.975**	0.950	0.967
ITALY	1.292	1.138	1.123	**1.104**	1.048	1.050
CYPRUS	1.070	1.276	1.345	**1.150**	1.025	1.082
LUXEMBOURG	0.963	0.966	0.976	**0.992**	1.005	1.019
MALTA	0.885	0.817	0.853	**0.822**	0.715	0.706
NETHERLANDS	0.797	0.706	0.772	**0.670***	0.647	0.660
AUSTRIA	0.940	0.792	0.863	**0.706***	0.668	0.682
PORTUGAL	1.423	1.500	1.494	**1.361****	1.421	1.475
SLOVAKIA	0.959	0.990	1.075	**0.931**	0.980	1.030
FINLAND	0.870	0.734	0.801	**0.706***	0.686	0.699
CZECH REP.	1.121	1.221	1.211	**0.943**	0.910	0.939
DENMARK	0.706	0.586	0.647	**0.623***	0.617	0.630
LATVIA	1.500	1.500	1.500	**1.500****	1.500	1.288
LITHUANIA	0.811	0.944	1.104	**1.293****	1.401	1-316
HUNGARY	0.500	0.606	0.682	**0.759**	0.773	0.775
POLAND	0.532	0.500	0.500	**0.500***	0.500	0.500
SWEDEN	0.500	0.500	0.505	**0.500***	0.500	0.526
UNITED	0.532	0.500	0.500	**0.500***	0.500	0.500
95% LowerIntv.	0.709	0.725	0.739	0.752	0.762	0.771
95% UpperIntv.	1.290	1.274	1.260	1.247	1.237	1.228

*: Evidence of mean reversion at the 95% level; **: Evidence of orders of integration above 1.

Table 4: Homogeneity condition tests (Robinson and Yajima, 2001)

	F	B	IRE	GR	E	I	CYP	L	MA	NL	A	P	SVK	FIN	CZE	DK	LTV	LTH	H
D	**-0.35**	-2.01	-4.20	-8.96	-4.11	-5.53	-6.03	-4.30	-2.43	**-0.76**	**-1.15**	-8.51	-3.62	**-1.15**	-3.76	**-0.24**	-9.88	-7.61	-1.73
F	Xxx	**-1.64**	-3.84	-8.61	6.31	-5.14	-5.68	-3.94	-2.07	**-0.40**	**-0.80**	-8.00	-3.27	**-0.80**	-3.41	**0.11**	-9.53	-7.26	**-1.38**
B	Xxx	xxx	-2.19	-6.95	-2.10	-3.51	-4.02	-2.28	**-0.42**	**1.25**	**0.85**	-6.34	**-1.61**	**0.85**	-1.74	1.77	-7.87	-5.59	**0.27**
IRE	Xxx	xxx	xxx	-4.76	**0.08**	**-1.33**	-1.83	**-0.09**	1.77	3.44	3.04	-4.15	**0.57**	3.04	**0.44**	3.95	-5.67	-3.41	2.46
GR	Xxx	xxx	xxx	xxx	4.85	3.43	-2.92	4.66	6.53	8.20	7.81	**0.60**	5.33	7.81	5.20	8.72	**-0.92**	**1.35**	7.22
E	Xxx	xxx	xxx	xxx	xxx	**-1.41**	-1.92	**-0.18**	1.68	3.35	2.96	-4.24	**0.48**	2.95	**0.35**	3.87	-5.77	-3.49	2.37
I	Xxx	xxx	xxx	xxx	xxx	xxx	**-0.50**	**1.23**	3.10	4.77	4.37	-2.82	1.90	4.37	1.77	5.29	4.35	-2.07	3.79
CYP	Xxx	xxx	xxx	xxx	xxx	xxx	xxx	1.73	3.60	5.27	4.88	-2.32	2.40	4.88	2.27	5.79	-3.85	**-1.57**	4-30
L	Xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1.87	3.54	3.14	-4.05	**0.67**	3.14	**0.53**	4.05	-5.58	-3.31	2.56
MAL	Xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1.67	**1.27**	-5.92	**-1.19**	**1.27**	**-1.33**	2.19	-7.45	-5.18	**0.69**
NL	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	**-0.39**	-7-60	-2.87	**-0.39**	-3.00	**0.51**	-9.13	-6.85	**-0.97**
A	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	-7.20	-2.47	**0.01**	-2.60	**0.91**	-8.74	-6.45	**-0.58**
P	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	4.73	7.20	4.59	8.11	**-1.53**	**0.74**	6.62
SVK	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	2.47	**-0.13**	3.38	-6.25	-3.98	1.89
FIN	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	-2.60	**0.91**	-8.73	-6.45	**-0.58**
CZE	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3.52	-6.12	-3.85	2.02
DK	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	-9.64	-7.37	**-1.49**
LTV	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	2.27	8.15
LTH	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	5.87

Table 5: Summary of the homogeneity test results

GERMANY	France, Netherlands, Austria, Finland and Denmark
FRANCE	Germany, Belgium, Netherlands, Austria, Finland, Denmark and Hungary
BELGIUM	France, Malta, Netherlands, Austria, Slovakia, Finland and Hungary
IRELAND	Spain, Italy, Luxembourg, Slovakia and Czech Republic
GREECE	Portugal, Latvia andLithuania
SPAIN	Ireland, Italy, Luxembourg, Slovakia and Czech Republic
ITALY	Ireland, Spain, Cyprus and Luxembourg
CYPRUS	Lithuania
LUXEMBOURG	Ireland, Spain, Italy, Slovakia and Czech Republic
MALTA	Belgium, Austria, Slovakia, Finland, Czech Republic and Hungary
NETHERLANDS	Germany, France, Belgium, Austria, Slovakia, Finland, Czech Rep and Hungary
AUSTRIA	Germany, France, Belgium, Malta, Netherlands, Finland, Denmark and Hungary
PORTUGAL	Greece, Latvia and Lithuania
SLOVAKIA	Belgium, Ireland, Spain, Luxembourg, Malta and Czech Republic
FINLAND	Germany, France, Belgium, Malta, Netherlands, Austria, Denmark and Hungary
CZECH REPUB.	Ireland, Spain, Luxembourg, Malta, Slovakia
DENMARK	Germany, France, Netherlands, Austria, Finland and Hungary
LATVIA	Greece and Portugal
LITHUANIA	Greece, Cyprus and Portugal
HUNGARY	France, Belgium, Malta, Netherlands, Austria, Finland and Denmark

Table 6: Testing the null hypothesis of no cointegration against fractional cointegration

Countries		H_{10}	H_{20}	d_1	d_2	d*
GERMANY	FRANCE	0.755	0.317	0.601	0.633	0.692
	NETHERLANDS	0.350	0.004	0.601	0.670	0.663
	AUSTRIA	0.044	1.471	0.601	0.706	0.579
	FINLAND	2.605	0.373	0.601	0.706	0.770
	DENMARK	1.662	1.164	0.601	0.623	0.736
FRANCE	BELGIUM	0.265	0.858	0.633	0.784	0.687
	NETHERLANDS	**4.578**	**6.213**	0.633	0.670	0.409
	AUSTRIA	**3.327**	**6.357**	0.633	0.706	0.442
	FINLAND	3.468	**6.551**	0.633	0.706	0.418
	DENMARK	0.029	0.071	0.633	0.623	0.651
	HUNGARY	0.446	3.504	0.633	0.759	0.563
BELGIUM	MALTA	**18.062**	**21.279**	0.784	0.822	0.339
	NETHERLANDS	1.014	0.033	0.784	0.670	0.651
	AUSTRIA	0.015	0.385	0.784	0.706	0.771
	SLOVAKIA	**22.079**	**37.244**	0.784	0.931	0.292
	FINLAND	0.296	0.040	0.784	0.706	0.727
	HUNGARY	2.219	1.565	0.784	0.759	0.628
IRELAND	SPAIN	**20.580**	**19.892**	0.983	0.975	0.508
	ITALY	**8.429**	**16.475**	0.983	1.104	0.679
	LUXEMBOURG	2.393	2.667	0.983	0.992	0.821
	SLOVAKIA	**3.988**	1.517	0.983	0.931	0.702
	CZEK REP.	2.574	1.494	0.983	0.943	0.815
GREECE	PORTUGAL	**53.660**	**46.240**	1.416	1.361	0.649
	LATVIA	1.561	**4.216**	1.416	1.494	1.285
	LITHUANIA	3.292	0.409	1.416	1.293	1.226
SPAIN	ITALY	0.421	0.339	0.975	1.104	1-043
	LUXEMBOURG	0.118	0.033	0.975	0.992	1.011
	SLOVAKIA	3.223	1.891	0.975	0.931	0.787
	CZECH REP.	0.131	0.003	0.975	0.943	0.937
ITALY	CYPRUS	**16.553**	**20.324**	1.104	1.150	0.678
	LUXEMBOURG	0.246	2.453	1.104	0.992	1.156

In bold the cases with significant evidence of (fractional) cointegration at the 5% level.

PORTUGAL	LATVIA	3.054	**9.457**	1.361	1.494	*1.178*
	LITHUANIA	2.922	1.123	1.361	1.293	*1.182*
CYPRUS	LITHUANIA	**4.909**	**12.826**	1.150	1.293	0.918
SLOVAKIA	CZECH REP.	2.277	2.636	0.931	0.943	0.773
LUXEMBOURG	SLOVAKIA	0.124	0.052	0.992	0.931	0.955
	CZECH REP.	1.185	0.385	0.992	0.943	0.878
MALTA	AUSTRIA	**8.822**	3.468	0.822	0.706	0.511
	SLOVAKIA	**40.458**	**54.785**	0.822	0.931	0.156
	FINLAND	**4.061**	0.823	0.822	0.706	0.611
	CZECH REP.	1.787	**6.213**	0.822	0.943	0.682
	HUNGARY	0.105	0.076	0.822	0.759	0.788
AUSTRIA	FINLAND	**90.667**	**90.485**	0.706	0.706	-0.291
	DENMARK	**8.319**	**4.374**	0.706	0.623	0.404
	HUNGARY	0.513	1.494	0.706	0.759	0.631
FINLAND	DENMARK	**4.495**	1.762	0.706	0.623	0.484
	HUNGARY	0.339	1.185	0.706	0.759	0.645
NETHERLANDS	AUSTRIA	3.258	**4.617**	0.670	0.706	0.481
	FINLAND	**24.380**	**27.894**	0.670	0.706	0.153
	DENMARK	**13.102**	**10.054**	0.670	0.623	0.291
	HUNGARY	0.176	1.613	0.670	0.759	0.626
DENMARK	HUNGARY	0.124	2.729	0.623	0.759	0.586

In bold the cases with significant evidence of (fractional) cointegration at the 5% level.