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Government bond market linkages within EMU: evidence from a multivariate Granger causality analysis

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Abstract

The paper investigates empirically and from a dynamic perspective the causality relationships between the different EMU's government bond markets. We focus on two main periods: the pre-crisis period (from November 2003 to September 2008), and the crisis period (from September 2008 to February 2013). Using a multivariate Granger causality approach, we find that the integration of government bond markets is week, and the number and the direction of causality change during the crisis. Furthermore, countries exhibit different paths of financial convergence with Germany that we consider to be virtually free of risk, especially during the crisis period. These findings have implications for investors in terms of the diversification of their portfolios, and for policymakers in terms of managing common monetary policy.

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1. Introduction

Since the recent global financial crisis began in 2008-2009, the issue of financial stability staged an impressive comeback on the agenda of most advanced and emerging economies. While deregulated international financial markets and large capital flows across borders of the last two decades has led to an expanding integration process of international equity and bonds markets, the evolution of the recent crisis has also shown that highly volatile capital flows may be risky for trade, investments and growth and that unstable financial markets inherently has an impact on fiscal sustainability. Therefore, the understanding of these mechanisms from theoretical and empirical fronts may offer findings to control risks enhance financial market stability and promote growth and development.

While international stock and money market integration have received large attention in the finance literature (e.g., Clare et al. (1995), Bessler and Yang (2003) on stock market integration; Fung and Lo (1995) on money market linkages), only a small number of empirical studies have analyzed the dynamic linkages in bond markets of advanced economies (e.g., Yang (2005), Christiansen (2007), Laopodis (2008) and Von Hagen et al. (2011)). Furthermore, the EU's sovereign debt crisis increased research interest into how financial disturbances transmit from one market to another among international bond markets and what basically drives the development in EU yield spreads: e. g., Manganelli and Wolswijk (2009), Mody (2009), Maltritz (2011), Matei and Cheptea (2012), Gómez-Puig and Sosvilla-Rivero (2012) and Gartner and Griesbach (2012). This is not surprising because previous crisis had the greatest impacts on the emerging economies while the current crisis strikes severely advanced countries as well.

The purpose of this paper is to empirically investigate the dynamic causal relationships between the different EMU's government bond markets. We focus on two main periods: the pre-crisis period (from November 2003 to September 2008) and, the crisis period (from September 2008 to February 2013, the latest available data). Using weekly observations for 12 EMU countries, we apply a multivariate Granger causality approach and check the difference in impacts for core-EMU and periphery-EMU countries, before and during the crisis. This approach allow us to (1) identify possible time-varying causal relationships, (2) detect episodes of significant increase in causality between yields on bonds issued by various EMU's countries and (3) judge on the potential benefits of financial integration after the introduction of the euro and the implementation of a common monetary policy for euro area member states.

Our contribution to this existing literature is threefold. Firstly, we test EMU's bond market linkages in terms of yield spreads to Germany using recent econometric techniques and recent data. Secondly, most of the existing papers look separately at «core-EMU» or «periphery-EMU» members without focusing on greater data samples (up to nine countries) and without taking into account the recent global crisis period. Thirdly, we distinguish between «core-EMU» and «periphery-EMU» members in order to explore the differences between the two groups.

Our results suggest that countries exhibit different paths of financial convergence with Germany that we consider to be virtually free of risk. Therefore, global investors can still obtain benefits from the diversification of their portfolios which can make more difficult the task of ECB's authorities to manage the common monetary policy.

The rest of the paper is structured as follows. In section 2, we expose data and econometric specifications to study bond market integration within Euro zone. Section 3 presents results obtained using different time series unit root tests, cointegration methods and Granger causality tests in the context of a set of somewhat homogeneous advanced countries. Section 4 concludes.

2. Methodology and data

2.1 Data and variables

The data panel contains monthly and weekly observations from 12 EMU countries and covers the 2003 to 2013 period. We included all countries for which the European Central Bank (ECB) and Datastream publish sovereign bond yields. Our panel does not include Germany given that it is taken as reference. Spreads on government bonds are calculated as the difference between the yields on 10-year bonds issued by each country in the panel and Germany (virtually considered as free of default risk) and can be interpreted as a pure measure of country risk (Sander and Kleimeier, 2003). The study of yield spread linkages allows us to detect if all bond markets exhibit the same convergence path or if there are fundamental risk factors and bond market frictions across the panel.

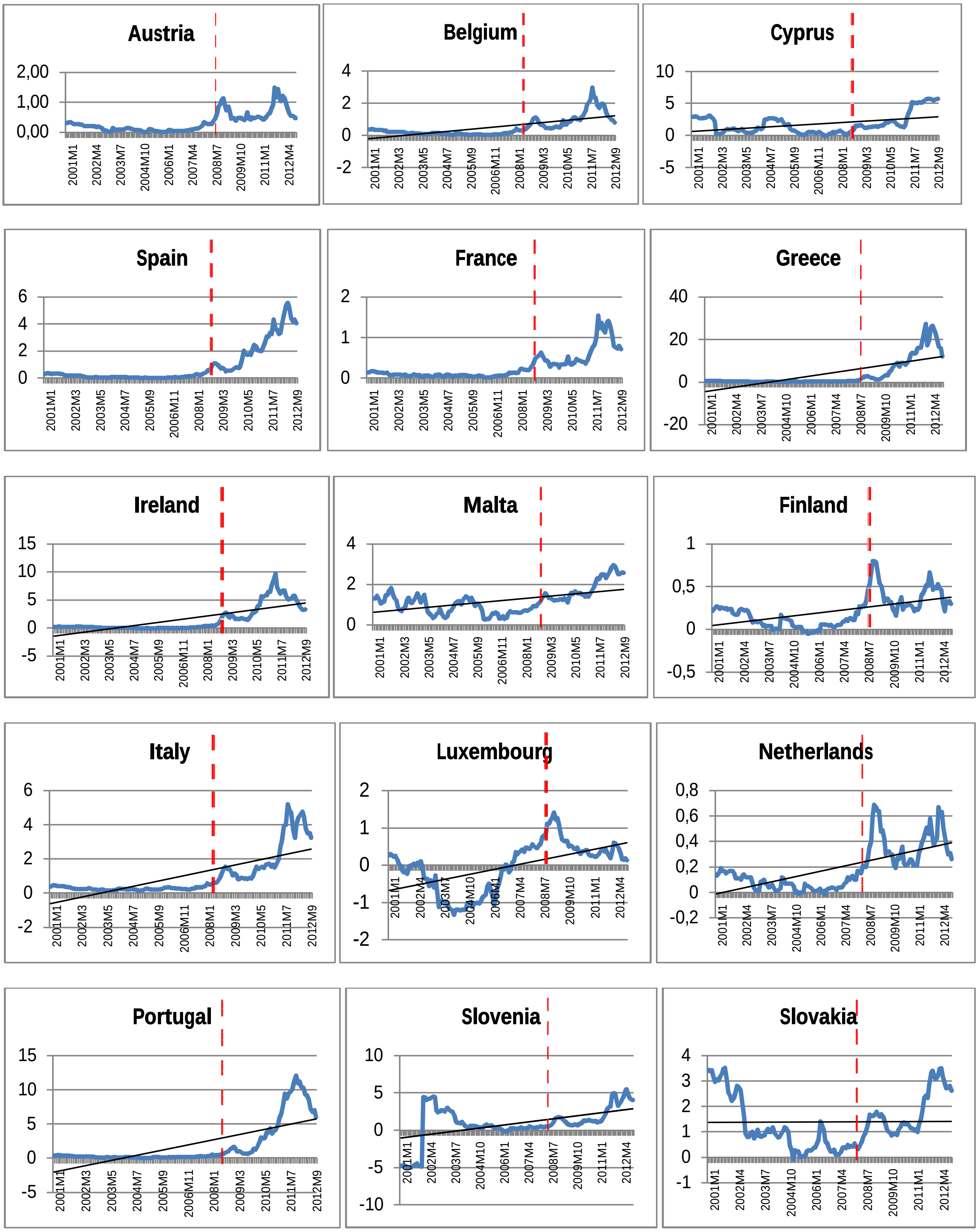
Figure 1 displays the evolution of monthly 10-year sovereign bond yield differential to Germany for each country considered in our sample. We can make several comments on the evolution of this variable. Firstly, a simple glance at these figures indicates differences in the yield spreads behavior before and after the financial crisis of 2008. While the financial environment remains somewhat accommodative in the pre-crisis period, although with greater variation of yield differentials across countries (especially in "EMU-periphery"), global financial conditions have become more volatile since 15th September 2008 when the financial institution Lehman Brothers collapsed. Since this date, the financial turmoil turned into a global financial crisis which began to affect the real sector. Furthermore, this also highlights certain imbalances within the euro zone and investors concerns on upcoming sovereign risks particularly in the euro area periphery. Secondly, we observe that, in the tranquil-period the mean yield spread range from -3.95/0.62 percentage for Portugal/Slovenia to 10.43/0.27/-2.68 percentage for Greece, Finland and Portugal in the crisis period. Greater convergence with the German bond yield is detected for Austria, Belgium, Finland, France, Greece, Italy, Luxembourg, Netherlands, Portugal and Spain during the tranquil-period. Interestingly, the new EMU members (i.e., Cyprus, Malta, Slovenia and Slovakia) do not convergence with the German bond. Consequently, cross-countries differentiations exist for EMU bond markets after the introduction of a common currency. This suggests that the elimination of the exchange rate risks and inflation expectations convergence across euro area members do not still improve enough the integration of European bond markets. Third, only some bond markets converge with their German counterpart during the crisis period. This is the case for Austria, Finland, France and Luxembourg.

Tables 1 and 2 expose some descriptive statistics for the variables integrated in our estimations over two periods: the pre-crisis period (2003:11:26-2008:09:12) and the crisis period (2008:09:15-2013:02:12). The results show that country credit risks rise during the crisis period compared to the pre-crisis period. The volatility of spreads reflected by the standard deviation remains consistently higher in the crisis-period than that of the tranquil period especially for Greece, Ireland, and Portugal and lesser for Cyprus, Italy, Spain and Slovenia.

2.2 The empirical specifications

In order to investigate the linkages between the EMU's bond markets, we use a multivariate Granger causality approach which involves the following three steps. The first step looks at the order of integration of the series by means of time series unit root tests. If the variables contain a unit root, the next step is to check the existence of cointegrating relationships between variables. In the case where a long-run relationship between our variables is found, the final step is to apply vector error correction model (VECM model) to infer the Granger causal relationship between the EMU's bond yield differentials. We use the software Eviews for empirical analyses.

Figure 1: Evolution of monthly 10-year sovereign bond yield spreads.



Note: the red dotted line indicates the start of the 2008 financial crisis

Table 1: Main statistics on yield spreads: the pre-crisis period (2003:11:26-2008:09:12)

Pre-crisis period	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	No. Obs.
AUSTRIA	0,028	0,028	0,489	-0,441	0,105	-0,452	6,833	251
BELGIUM	0,063	0,045	0,374	-0,128	0,082	1,231	4,976	251
FINLAND	0,007	0,030	0,343	-0,482	0,121	-1,379	6,305	251
FRANCE	0,043	0,033	0,174	-0,052	0,048	0,633	2,794	251
GREECE	0,278	0,227	0,775	0,060	0,153	1,238	3,845	251
IRELAND	-0,087	-0,044	1,054	-1,064	0,251	-1,783	9,691	251
ITALY	0,214	0,197	0,493	0,076	0,088	1,263	4,623	251
NETHERLANDS	0,029	0,036	0,334	-0,365	0,101	-0,631	6,005	251
PORTUGAL	-3,948	-4,008	-3,062	-4,695	0,388	0,409	2,296	251
SPAIN	0,023	0,002	0,290	-0,218	0,085	0,939	4,112	251

Note: Author's computations based on ECB database

Table 2: Main statistics on yield spreads: the crisis period (2008:09:15-2013:02:12)

Crisis period	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	No. Obs.
AUSTRIA	0,59	0,50	1,82	0,13	0,29	1,26	4,58	231
BELGIUM	0,97	0,80	3,23	0,08	0,59	1,19	4,05	231
FINLAND	0,27	0,29	1,58	-1,34	0,49	-0,50	5,07	231
FRANCE	0,50	0,31	1,92	0,06	0,38	1,20	3,49	231
GREECE	10,44	8,15	61,04	-13,57	11,78	1,48	6,04	231
IRELAND	3,76	4,12	8,69	0,16	2,10	0,05	1,68	231
ITALY	2,02	1,44	5,65	0,48	1,42	0,73	2,11	231
MALTA	1,60	1,35	2,91	0,61	0,62	0,55	1,89	231
NETHERLANDS	0,34	0,31	1,18	-0,13	0,21	1,39	5,78	231
PORTUGAL	-2,68	-3,00	-1,20	-4,33	0,81	0,29	1,83	231
SLOVAKIA	1,70	1,44	3,11	0,60	0,72	0,51	1,84	231
SLOVENIA	2,23	1,65	5,88	0,57	1,38	1,04	2,76	231
SPAIN	2,34	2,05	6,20	0,24	1,63	0,43	1,93	231

Note: Author's computations based on ECB database

2.2.1 Unit root tests

We first check the stationarity of the series (i.e., the order of integration of series). To this goal in mind, we apply two time series unit root tests: the Augmented Dickey-Fuller test (ADF test - Dickey and Fuller, 1979) and the Kwiatkowski et al. (KPSS, 1992).

The ADF test refers to the following regression: $\Delta X_t = \alpha + \gamma X_{t-1} + \sum^{k}_{i=1} \rho_i \Delta X_{t-i} + \varepsilon_t$ (1)
where X_t is a vector variable. The null hypothesis $\gamma = 0$ means that series are no stationary in level while the alternative assumption $\gamma<0$ implies that series are stationary in level (i.e., I(0)). If series are non-stationary under the null, the test statistic will have a non-standard distribution. The lag length k is chosen to generate a white noise error term ε_t by taking into account basic information criteria such as: the Akaike, Schwarz and Hannan-Quinn criterion.

The KPSS unit root test differs from the ADF test in that series are considered to be (trend-) stationary under the null hypothesis. Its statistic is based on the residuals from OLS regression of X_t on the exogenous variables Y_t and uses the Lagrange Multiplier statistic based on these OLS residuals (u_t). This regression can be written: $X_t = Y_t{}'\delta + u_t$ (2)

Note that if selected time series are stationary in level[1], we can directly apply the Granger causality test with the ordinary least squares. Alternatively, if the evidence suggests nonstationarity in level of the variables, the existence of cointegrating relationships between them should be tested to validate the empirical model.

2.2.2 Cointegration and Granger causality tests

The cointegration test shows whether a group of non-stationary series is cointegrated or not. To study the dynamic adjustment through the long run equilibrium path with a VAR specification, we apply the Johansen test (1991, 1995) illustrated briefly below. Be Z_t a vector of dimension (N×1) that follows an unrestricted VAR model in level:

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \ldots\ldots + A_k Z_{t-k} + \mu + \varepsilon_t \quad (3)$$

where each A_i (with i = 1,k) is an N×N matrix Z of parameters, μ is a constant term and ε_t is the error term identically and independently distributed, with zero mean and the contemporaneous covariance matrix Z Ω. The equation (3) written as a VECM model

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \ldots + \Gamma_{k-1} \Delta Z_{t-(k-1)} + \Pi Z_{t-k} + \mu + \acute{\varepsilon}_t \quad (4)$$

gives information about short term ($\Gamma_i = -I + \sum A_j$, with j = 1,..,k-1) and long term ($\Pi = -I + \Pi_1 + \Pi_2 +. \ldots + \Pi_k$) dynamic adjustments of the variables in the modeling. We test for cointegration through the rank $r \in (0, n-1]$ of the Π matrix by means of Johansen's (1988, 1990) maximum likelihood statistics: the trace statistic $\Lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1 - \widehat{\Lambda_i})$ and the maximal-eigenvalue statistic $\Lambda_{max}(r, r+1) = -T\ln(1 - \widehat{\Lambda_{r+1}})$, where $\hat{\Lambda}$ represents the estimated value of the i^{th} ordered eigenvalue of Π.

[1] The univariate unit-root tests may have low power and rejecting the unit root null may be erroneous. We also used the panel dimension of data by applying five first – and second-generation tests: Levin and Lin (1993), Taylor and Sarno (1998), Maddala and Wu (1999), Im, Pesaran and Shin (2003) and Pesaran (2003). Results available upon request suggest that series are stationary in first differences I(1).

Both statistics assume under the null hypothesis that there are, at most, r cointegration vectors. The max-eigenvalue alternative hypothesis (Λ_{max}) is that there are exactly "$r + 1$" cointegrating vectors, while that of trace test (Λ_{trace}) is there are more than r cointegrating vectors. If results are contradictory, we retain trace values which are considered more robust than the maximal eigenvalues in finite samples (Cheung and Lai, 1993).

After determining the number of the cointegration vectors that span the cointegrating space by using Johansen procedure, we check for multivariate Granger causality. We apply exclusion test and week exogeneity test: the first one shows whether all variables belong to the system and the second one whether series are captured by exogenous factors and are not adjusting for the long run parameters. To illustrate the procedure for testing the multivariate causality in the system, we consider some pairs of spread series, (X_t, Y_t), (X_t, K_t), and (Y_t, K_t) which are cointegrated of order r. We can specify an unrestricted vector error-correction model (VECM model), shown for the first series only, which includes the error correction term, EC_{t-1} as follows:

$$\Delta X_t = \alpha_x + \sum \beta_{x,i} \Delta X_{t-i} + \sum \delta_{x,i} \Delta Y_{t-i} + \gamma_x EC_{t-1} + \varepsilon_{x,t} \quad (5)$$

$$\Delta Y_t = \alpha_y + \sum \beta_{y,i} \Delta Y_{t-i} + \sum \delta_{y,i} \Delta X_{t-i} + \gamma_y EC_{t-1} + \varepsilon_{y,t} \quad (6)$$

where ($\beta_{x,i}$, $\beta_{y,i}$) and ($\delta_{x,i}$, $\delta_{y,i}$), if statistically significantly different from zero, reveal the short-run impact of own (bond market 1) and the other's (bond market 2) impact respectively (and vice-versa). The Granger causality is tested with a standard F-test whether all δ_i (where i =1, k) are equal to zero. We practically study how much of the current value of ΔY_t is explained by its past values, and whether adding lagged values of ΔX_t can capture better the explanation of ΔY_t. In this system, we can identify three cases: (i) an one-way Granger causality running from Y to X if in the first equation not all $\delta_{x,i}$'s are zero while in the second equation $\delta_{y,i}$'s are zero. If we cannot reject the null hypothesis H_0 (δ_x = 0) in equation (1), we tell "Y Granger causes X" (ie, we reject the hypothesis that Y does not cause X); an additional one-way Granger causality from X to Y if in the first equation all $\delta_{x,i}$'s are zero but, in the second equation not all $\delta_{y,i}$'s are zero; (ii) a two-way causality between Y and X if neither all $\delta_{x,i}$'s and $\delta_{y,i}$'s are zero; consequently, if causation cannot be rejected in both equations, the variables are interdependent, and finally (iii) no Granger-causality between Y and X if all $\delta_{x,i}$'s and $\delta_{y,i}$'s are zero.

The parameter $\varepsilon_{x,t}$ (respectively, $\varepsilon_{y,t}$) is a multivariate i.i.d sequence with zero mean and covariance matrix $\sum_x$ and the parameter γ_x (respectively, γ_y) captures the speed of adjustment to the long-run equilibrium. Obviously, if cointegration between the (or any) two series is not found, then the equations (5) and (6) should not have the residual of cointegration relation (EC_{t-1}). For example, a test of the null hypothesis H_0: $\gamma_x = 0$ in the equation (5) is a test of weak exogeneity since a rejection of the null means that there is evidence of a long-run causality going from the EC to X (Arestis et al., 2001). A stronger notion of exogeneity involves testing joint hypothesis of short-run and long-run causality (Charemza and Deadman, 1992). The rejection of the null hypothesis involves an overall causality without differentiating between short-run and long-run causality. Note that all previous tests are based on likelihood ratios that follow χ^2 distribution.

3. Empirical results

In this section, we look at the linkages between yield differentials for EMU countries with respect to Germany during two periods: the 2003:01-2008: 08 tranquil period and the 2008:09-2013:02 crisis period. Standard ADF test and KPSS test for the presence of a unit root in individual country specific data show that all yield differentials with respect to Germany are non-stationary in level but, stationary in first differences (see table 3 for evidence on stationarity). Therefore, individual yield spreads are integrated of order 1 (ie., I(1)).

Table 3: Unit root tests for EMU countries: the pre-crisis period and the crisis period

Bond spreads	ADF test					KPSS test	
Pre-crisis period	Level	DW stat	1st diff.	DW_stat	I(d)	LM stat - 1st diff.	I(d)
EMU countries							
Austria	-0,792	1,840	-8,889	2,003	I(1)	0,060	I(1)
Belgium	-0,342	2,070	-9,900	2,024	I(1)	0,111	I(1)
Cyprus	-1,987	1,968	-7,434	1,963	I(1)	0,082	I(1)
Finland	-0,687	2,205	-10,701	1,990	I(1)	0,358	I(1)
France	-1,477	1,970	-7,972	2,147	I(1)	0,399	I(1)
Greece	-0,486	2,116	-10,140	2,016	I(1)	0,717	I(1)
Ireland	0,130	2,150	-10,055	1,976	I(1)	0,130	I(1)
Italy	-0,669	2,110	-10,170	2,003	I(1)	0,493	I(1)
Luxembourg	-1,120	2,043	-9,702	2,013	I(1)	0,592	I(1)
Malta	-1,255	1,898	-7,289	1,898	I(1)	0,056	I(1)
Netherlands	-0,714	1,989	-9,528	2,001	I(1)	0,233	I(1)
Portugal	-0,869	1,932	-9,224	1,971	I(1)	0,070	I(1)
Slovakia	-2,193	1,986	-6,343	1,995	I(1)	0,327	I(1)
Slovenia	-2,482	1,929	-9,438	2,000	I(1)	0,145	I(1)
Spain	0,383	1,893	-7,493	1,941	I(1)	0,126	I(1)
Bond spreads	ADF test					KPSS test	
Crisis period	Level	DW_stat	1st diff.	DW_stat	I(d)	LM stat - 1st diff.	I(d)
EMU countries							
Austria	-0,682	2,118	-7,551	1,966	I(1)	0,114	I(1)
Belgium	-0,485	1,670	-5,985	2,033	I(1)	0,165	I(1)
Cyprus	0,654	2,100	-3,939	2,131	I(1)	0,166	I(0)
Finland	-0,687	1,656	-6,171	2,072	I(1)	0,080	I(1)
France	-0,349	2,009	-7,087	1,980	I(1)	0,104	I(1)
Greece	-0,284	1,773	-6,243	1,900	I(1)	0,137	I(1)
Ireland	-0,217	1,541	-5,566	2,015	I(1)	0,122	I(1)
Italy	0,231	1,503	-5,421	2,065	I(1)	0,127	I(1)
Luxembourg	-1,243	1,759	-5,556	2,014	I(1)	0,088	I(1)
Malta	1,538	1,489	-5,141	1,973	I(1)	0,069	I(1)
Netherlands	-0,662	1,700	-6,228	2,047	I(1)	0,085	I(1)
Portugal	0,270	1,492	-2,955	2,106	I(1)	0,168	I(1)
Slovakia	-0,074	1,821	-4,244	1,819	I(1)	0,114	I(1)
Slovenia	-0,201	1,782	-4,242	1,779	I(1)	0,073	I(1)
Spain	0,744	1,704	-5,900	2,007	I(1)	0,088	I(1)

Note: we also tested the stationarity of series for the whole period; results are available upon request.

The results on cointegration are presented in tables 4 and 5[2]. Columns 2 and 3 report parameter estimates of the trace statistic and the max-eigenvalue statistic. As concerns the pre-crisis period, we find evidence of five cointegrating vectors according to the trace statistic and only three cointegrating vectors according to the max-eigenvalue statistic. As previously highlighted, when cointegration statistics differ, we put more weight on the trace statistic considered more robust than the maximal eigenvalue statistic.

The fact that we have five stochastic trends in the considered group of countries it means that some EMU's government bond markets behave independently of the others in the long run. Regarding the crisis period, findings in the table 5 indicate two cointegrating vectors among bond markets under trace statistic and one cointegrating vector under max-eigenvalue statistics suggesting no convergence with the German counterpart. Note that, if yield spreads have only one common stochastic trend in a selected group, it means that bond markets have a single common long-run path, any one market is a representative market for the behavior of the others or financial markets are fully integrated. Accordingly, it will be sufficient for global investors to invest in only one of these markets and not in all of them because the financial conditions would be the same.

Next, we perform exclusion tests for both selected periods to establish which bond markets participate to the cointegrating space. The rejection of the null hypothesis of exclusion of a variable from the cointegrating space highlights the presence of close relationships among the variables considered in the system. In the pre-crisis period, exclusion test suggests that Netherlands and Portugal bond markets do not participate to the cointegrating space which means that there are not convergent with Germany. During the crisis period, Greece, France, Finland, Ireland, Italy, Malta, Netherlands and Portugal are not in the same cointegrating space which pledges in favor of country-specific differences among these countries (their bonds may be more risky than others or there are liquidity differences across markets).

Table 4: Cointegration results for the pre-crisis period: 2002:01-2008:08

	No. cointegrating equations	
Pre-crisis period	***Trace test***	***Max-eigen test***
lags 1	r = 5 at 5%	r = 3 at 5%
Test statistic	104.68**	42.059**
Critical value at 0.05	102.14	40.30
Critical value at 0.01	111.01	46.82

Note: - the cointegration test is based on weakly data

Table 5: Cointegration results for the crisis period: 2008:09-2012:12

	No. cointegrating equations	
Crisis period	***Trace test***	***Max-eigen test***
lags 1	r = 2 at 5% and r = 1 at 1%	r = 1 at 5% and 1%
Test statistic	164.4904**	58.21032***
Critical value at 0.05	175.77	59.06
Critical value at 0.01	187.31	65.21

Note: - the cointegration test is based on weakly data
- the sample does not include Slovakia and Slovenia (they acceded to euro zone in 2009 and 2007).

[2] Before presenting the long-run relationships in the multivariate model, we also study the presence of cointegrating vectors in the bivariate model. The results are not shown here but are available upon request.

Table 6: Exclusion tests (X^2 (1)) for the pre-crisis period

States *not* joining the cointegration space	States joining the cointegration space
Netherlands 14.018 (0.172), Portugal 7.221 (0.704)	Austria 22.994***(0.004), Belgium 37.830*** (0.000), Finland 16.369*** (0.090) France 19.384*** (0.036), Spain 19.355** (0.036), Greece 27.211*** (0.002), Ireland 30.334*** (0.000), Italy 27.903*** (0.002).

Note: the exclusion test is based on weakly data

Table 7: Exclusion tests (X^2 (1)) for the crisis period

States *not* joining the cointegration space	States joining the cointegration space
Finland 13.002 (0.293), France 11.957 (0.367), Greece 8.010 (0.712), Ireland 8.220 (0.694), Malte 6.160 (0.862), Italy 13.514 (0.141), Netherlands 9.418 (0.583), Portugal 10.815 (0.459).	Austria 33.488*** (0.000), Belgium 23.364**(0.016), Italy 20.895**(0.035), Spain 25.35*** (0.01).

Note: coefficient's p-values are in parenthesis; *** - significant at 1% level, ** - at 5% level.

Since the cointegration results are mixed, we propose to study causality linkages between any bond market pair. With this goal in mind, we develop an error-correction model for both sub-periods (the pre-crisis period and the crisis period) to examine if there are at least short-run connections between selected bond markets. Table 8 and table 9 show the short-run results and respectively, the long-run results on the causality patterns for both considered periods.

Given that this test is highly sensitive to the number of lags of right hand side variables, according to the Akaike Information Criterion the optimal number of lags for both sub-periods is one (this is also the case with the Schwarz and Hannan-Quinn criterion). The first two columns of table 8 report short-run connections between different EMU bond markets for the pre-crisis and the crisis period. Unidirectional causality (⇾) means that bond market X Granger causes bond market Y, while bi-directional causality (⇿) implies that there is two-way causality between bond markets X and Y. In both periods, we observe a large number of linkages between EMU's bond markets. From this finding, it is not clear which bond market seems to be the "leader" in terms of influencing the highest number of other bond markets. This result suggests a fragile connection between bond markets as well as a weak degree of financial integration of these markets overtime. Furthermore, the number and the direction of linkages are not similar in the two periods, except for the impact of Italy on Belgian and Spanish markets and of the Netherlands on the Belgian market. For all other countries the direction of causalities changes in the crisis period: Austria appears to influence the Netherlands (and vice-versa), a shock in the Belgium's bond market spreads to the French and Spanish markets, the Greek bond market impacts Austria, France and Italy, the Irish bond market affects Austria, Belgium, Finland, Portugal and Spain, while the Italian market impacts Austria, Belgium, France and Spain. Finally, Netherlands affects Belgium, a shock in Portugal impacts Malta, and a shock in Spain Granger causes Finland.

The fragility of the connections between these markets could be explained by several facts. First of all, several countries of the euro zone periphery (Greece, Ireland and Portugal) had several sudden increases in debt associated to huge fiscal deficits (from stimulus and cyclical factors). These budget deficits and liquidity problems during the crisis period (Greece leading the way with its $345 billion of debt) have generated the defiance of the capital markets in the governments capacity to align and coordinate economic policies with their more credible European partners (with whom they form a true economic and monetary union). Second, the existence of the financial barriers to the access of EMU's bond markets because of different taxation structures, fiscal policies and institutional features (Laopodis, 2008). Third, some countries specific-risk differences (e.g., a country bond can be more or less risky than others) may affect the transmission channels as well. Finally, a contagion effect from the Greece bond market to others bond markets could affect the previous transmission channels of shocks. Contagion effect refers to an increase in the number of causality relationships during the crisis period compared to the tranquil period as well as the modification in the direction of the causalities between bond markets (Forbes and Rigobon, 2000).

Although in the pre-crisis period France was not influenced by their European counterparts, the situation changes during the crisis period where Belgium, Italy and Greece bond markets affected it. Furthermore, a shock to Ireland and Greece bond markets influences the most part of the European partners. An explanation is that, during the crisis period, European authorities adopted two successive bailout plans for Greece (also for Ireland and Portugal) to restructure their debt and avoid concerns that a latent Greece's default would spiral into a financial crisis within the EMU.

Investigating the causality connections in terms of long-run equilibrium via a VECM model (explicitly, the error correction term EC_{t-1}, in equations (4) and (5)) we can made the following comments. First, some of the error correction terms are non-significant during the pre-crisis period (for Italy and Greece) confirming the fragility of the relationships between EMU's bond markets. Results are somewhat different during the crisis period. Some of the error terms are not statistically significant in the case of Belgium, France, Ireland, Netherlands and Portugal. For Spain the coefficient is statistical significant only at 10% level. These results suggest that the integration between bond markets is fragile and incomplete and that sovereign bond issues are not perfect substitutes which can influence the appreciation/depreciation of the euro.

4. Concluding remarks

The paper empirically investigates dynamic causal relationships between the different EMU's government bond markets. We focus on two main periods: the pre-crisis period (from November 2003 to September 2008), and the crisis period (from September 2008 to February 2013, the latest available data). Using a multivariate Granger causality approach, we find that the integration of government bond markets is week, and the number and the direction of causality, change during the crisis. Furthermore, not all countries exhibit the same path of financial convergence with Germany (e.g., Greece and Portugal in the pre-crisis period). The main implication of this finding is that although the financial integration increases after the introduction of the euro (in the pre-crisis sample), a certain number of bond markets are still not part of the entire system's long run equilibrium. This result pledges in favor of "core"- countries versus "periphery"- countries within the European Union. "Core"- countries seem to be more integrated in terms of bond markets compared to "periphery"- countries (Ireland, Greece, and Portugal). Accordingly, bond portfolios diversification benefits are still possible within euro area for countries that are not part of the cointegrating system. The increase of the causalities during the crisis period evokes a contagion effect and greater shocks transmission within euro area which can make more difficult the task for the ECB's authorities to manage the monetary policy (namely, long-term interest rates) to achieve the price stability. Finally, a potential benefit from greatest financial integration would be greater fiscal discipline within countries that form a true economic and monetary union.

Table 8: Short-run causality results: the pre-crisis period and the crisis period

Short - run relationships	
Pre-crisis period	**Crisis period**
Austria → Italy Finland → Greece Finland ↔ Italy Finland → Spain Ireland → Italy Italy → Belgium Italy → Spain Netherlands → Belgium Netherlands → Greece Netherlands → Italy Portugal → Finland Spain → Belgium Spain → Greece Spain → Netherlands Portugal → Spain	Austria ↔ Netherlands Belgium ↔ France Belgium → Spain Greece → Austria Greece → France Greece ↔ Italy Ireland → Austria Ireland → Belgium Ireland → Finland Ireland ↔ Portugal Ireland → Spain Italy → Austria Italy → Belgium Italy → France Italy → Spain Netherlands → Belgium Portugal → Malta Spain → Finland
1 - bidirectional causality	4 - bidirectional causalities
16 linkages	22 linkages

Table 9: Long-run causality results: the pre-crisis period and the crisis period

Long-run relationships		**Long-run relationships**	
Pre-crisis period		**Crisis period**	
Countries	**Error correction term, Et-1**	**Countries**	**Error correction term, Et-1**
Austria	-0.400198***(0.06678)	Austria	-0.01185**(0.00602)
Belgium	-0.118332**(0.05071)	Belgium	0.00443 (0.01081)
Finland	-0.482693***(0.06534)	Finland	-0.03341***(0.01325)
France	-0.368532***(0.05987)	France	-0.05278 (0.04253)
Greece	-0.013743 (0.03082)	Greece	-0.14766***(0.03185)
Ireland	-0.049012**(0.02310)	Ireland	-0.01069 (0.00659)
Italy	-0.054321*(0.03221)	Italy	-0.03575***(0.01372)
Netherlands	-0.318872***(0.05683)	Malta	-0.04324**(0.02078)
Portugal	-0.016692 (0.01418)	Netherlands	-0.00872 (0.01092)
Spain	-0.560022***(0.07823)	Portugal	-0.00122 (0.0035)
		Spain	-0.04488*(0.02699)

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