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ECONOMIC DYNAMIC CAUSAL LINKAGES IN THE EUROZONE

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Abstract

This study examines empirically the extent of linkages among Euro and non-government bond markets in the pre-crisis and during the crisis period. Multivariate Granger causality approach reveals that integration of euro bond markets is week while complete integration is found between the "periphery" EMU countries and the non-EMU countries in the pre-crisis period. Further, the number and the direction of causality change during the crisis. These findings have considerable implications for investors, in terms of diversification benefits, and for policymakers in terms of the proper conduct of the common monetary policy.

Keywords: bonds, Granger causality, cointegration, policy implications

Περίληψη

Η μελέτη αυτή εξετάζει την έκταση των δεσμών μεταξύ ομολόγων χωρών της Ευρωζώνης αλλά και μεταξύ ομολόγων χωρών της Ευρωζώνης και χωρών εκτός Ευρωζώνης τόσο κατά την περίοδο πριν από την κρίση όσο και κατά την περίοδο της κρίσης. Η προσέγγιση των σχέσεων αιτιότητας κατά Granger αποκαλύπτει ότι η συνολοκλήρωση των αγορών ομολόγων της Ευρωζώνης είναι ανεπαρκής ενώ διαπιστώνεται πλήρης συνολοκλήρωση μεταξύ των χωρών της "περιφέρειας" της ΟΝΕ και των χωρών εκτός ΟΝΕ κατά την περίοδο πριν την κρίση. Περαιτέρω, ο αριθμός και η κατεύθυνση των σχέσεων αιτιότητας αλλάζουν κατά τη διάρκεια της κρίσης. Τα ευρήματα αυτά έχουν σημαντικές επιπτώσεις για τους επενδυτές, όσον αφορά τα οφέλη της διαφοροποίησης, καθώς και για αρχές όσον αφορά την ορθή διεξαγωγή της κοινής νομισματικής πολιτικής.

Λέξεις κλειδιά: ομόλογα, σχέσεις αιτιότητας κατά Granger, συνολοκλήρωση

Contents

1. Introduction

Since the introduction of the Euro, two major forces are responsible for the growth in sovereign bond issuance. First, broad-based improvements in budgetary balances (such as reductions in budget deficits) enabled governments to have very low (net) borrowing requirements as well as adopt buyback programs and/or bond exchanges. Second, several significant changes in the issuance of sovereign bonds have fostered efficient competition for governments. Some include the coordination between governments in adopting similar bond coupon calculation conventions and greater transparency (standardization) in publishing information. As a result, the market for public debt is now regarded as highly liquid, competitive, and most important in the Euro area.

Moreover, a fact that pointed by the literature is that the market capitalization of international bond markets is larger than that of international equity markets. Despite that, compared to a large quantity of literature on international equity market linkages, the subject of international bond market linkages has investigated by only a few empirical. The extent of international bond market linkages and especially bond linkages within EMU is indeed worthy of further investigation, as it may carry important implications for forecasting of long-term interest rates, the cost of financing fiscal deficit, bond portfolio diversification and an independent monetary policymaking.

The theory, however, does not provide a definite prediction on the degree and the nature of international bond market linkages. Moreover according to Barassi (2001), bond yields can be considered either as policy instruments or as analogous to other asset prices. Hence, the market-driven comovement of bond yields may be confounded by the degree of national monetary policy independence and/or fiscal budget constraints. On the other hand, with massive capital flows across substantially deregulated international financial markets, bond yields as asset prices may be expected to move together to a certain degree, depending on the extent of the remaining barriers to market entry. For that reasons mentioned above, the extent of international government bond market linkages is essentially a subject of empirical testing.

2. Literature Review

Yang (2005) was among the first to investigate European government bond linkages. His study focuses on dynamic causal linkages between bond yield changes, long-run cointegration relationships and simultaneous correlations between bond yield innovations. Six representative major bond markets in Europe are examined: Germany, France, Italy, the UK, Belgium and Netherlands.

The data for this study include 192 monthly observations, concerning a 16-year period from January 1988 to December 2003 and the empirical analysis is based on a vector autoregression (VAR) framework. The author uses J.P. Morgan total return government bond indexes in this study. These indexes represent the total return (including reinvested coupon payments) to investors from a representative portfolio of government bonds and they are constructed to include fixed-rate sovereign debt with maturities from one year to whatever maturity may be outstanding in the market in question. Such indexes are more likely to capture any long-run aggregate bond market relationships, compared to the data of a single maturity, as pointed out by Smith (2002).

The results show that: 1) No stable long-run relationship exists among the six bond markets during the sample period, which is conflicting to more recent studies (Barassi et al., 2001; Smith, 2002) but consistent with past studies (DeGennaro et al., 1994; Clare et al., 1995). 2) The existence of strong simultaneous correlations between bond yield innovations, while causal linkages are generally not found. It is important to note that allowance for conditional heteroskedasticity is found by the author to be important to detect any statistically significant causal relationships and robust forecast error variance decomposition, combining both Granger causal relationships and contemporaneous correlation, suggests that European markets are generally interdependent. 3) European government bond markets are partially integrated in the short run, which is consistent with previous studies of Harm (2001) and Barr and Priestley (2004), and there is no evidence for a distinctive leadership role, referring to the well-known German dominance hypothesis. As (Uctum, 1999), the result does not support this hypothesis.

The implications of this study can be summarized as follow. First, long-term international investors with passive portfolio management strategies can benefit by diversifying their bond portfolios into each of these six major European bond markets to fully exploit risk reduction, even if they do that during the accelerated process of European economic integration. From the other hand, due to European markets tend to be much more closely linked in the short run, short-term investors may have less diversification potentials.

Second, his findings suggest that short-term forecasts of bond yields for a major European market should be based on both domestic and other European markets' macroeconomic variables.

Finally, as the markets are not integrated in the long run and only partially integrated in the short run and, EMU countries are currently paying too high rates in order to fund their deficits. However, as pointed out in Barr and Priestley (2004, p.94), governments might be willing to continue to pay unnecessarily high funding costs in order to avoid the discipline that would be exerted by a fully integrated world bond market.

Li, Refalo and Wu (2008) in their research test the same six major European government bond markets, as Yang (2005), for causality-in-variance for up to 12 monthly lags and they also test for causality-in-mean and then contrast their results against similar tests.

Their motive for that study was that despite evidence of volatility transmission and co-movement of bond markets, as pointed by Barr and Priestley (2004) and Yang (2005), no published study concerning bond markets has tested for causality-in-variance. It is important to test for causality-in-variance because it implies a general pattern to volatility transmission and because volatility can be transmitted between markets whose returns are otherwise statistically uncorrelated or exhibit no causality-in-mean. That kind of information will help future researchers or asset managers to forecast volatility in foreign markets, as awareness of the timing and direction of transmission facilitating the assumption of hedge positions in response to foreign information shocks.

Like Yang (2005) this study uses J. P. Morgan total return government bond indices and the data consist of 192 monthly index return observations, covering a 16-year period from January 1988 to December 2003. They apply two causality-in-variance tests developed in Hong (2001) while to investigate evidence of contemporaneous causality in-variance, they apply the method of Directed Acyclic Graphs (DAGs) which derives the causal pattern from the correlation structure of the data by applying logic arguments, and is unlike Granger causality, which infers causation by showing correlation between one time series and lags of another. The main advantage of this method is that solutions can be completely data-determined without requiring a priori assumptions about causal direction or invoking economic theory.

In their results, volatility spillover is characterized as short-lived in contrast to causality-in-mean, for which they find consistent patterns with as much as 12-month lead. In particular, results from (DAG) reveal that Italy, with the greatest amount of aggregate debt outstanding, to be less sensitive to volatility in other markets, while Germany is influenced by volatility from France, Belgium, Italy and Netherlands. They also find evidence of causality-in-mean for up to 12-month horizon while there is no evidence of distinctive leadership role, which is consistent with Yang (2005).

However, one-month Q-tests provide a pattern opposed to that formed for in the latter months. Furthermore, DAG tests provide no evidence of contemporaneous causality-in-mean while they show a market that is bidirectionally linked. In general, the results are consistent with well-integrated markets.

To sum up, their findings are useful because they provide evidence of volatility spillover, identify a pattern of transmission, and denote that volatility spillover is a short-lived phenomenon. Lastly, due to data frequency and lag periods tested, the main disadvantage of that study is that their results from both mean and variance tests are potentially subject to the effects of temporal aggregation, despite having examined for contemporaneous linkages. One possible solution to that problem for future researchers is to use higher frequency data and test intervening periods for causality.

Late in 2009, the downgrade of Greece credit rating, which triggered worries about its sovereign risks, lead Ireland and Portugal to deal with sharp increases in their government bond spreads and finally asked for support from European Union and IMF. The interesting part here is that historically high risks of sovereign debts had been connected with emerging countries, until European sovereign debt crisis, where the same risks were realized in relatively advanced economies such as Greece, Ireland, and Portugal.

These facts, drove Takamoshi (2011) to investigate the causality-in-mean and the causality-in-variance of long-term bond yields in seven countries including "PIIGS" (Portugal, Ireland, Italy, Greece, and Spain), Germany, and France. As noticed, this was the first study to evaluate the impacts of the recent European sovereign debt crisis on relationships among the long-term bond yields and according to the author, an investigation on dynamic relationships across those government bond markets will be helpful for policymakers in order to understand how contagion of sovereign risks is spread across markets.

The dataset of the study consists from daily observations on long-term bond yields ranging from January 1, 2007 to March 31, 2011 for seven European countries mentioned before and the approach followed in order to test for linkages among bonds is that developed by Hong (2001). Further on, in order to show the important changes in direction and magnitude of spillover effects both in terms of mean and variance through the crisis, the whole sample is categorized by the author into two sub-samples: Sample A is from January 1, 2007 to December 15, 2009, while Sample B is from December 16, 2009 to March 31, 2011. December 16, 2009 is considered as the beginning of the crisis, because Standard & Poor's downgraded Greece's credit rating from A1- to BBB+ with a negative outlook on the day, triggering sale of Euro, and markets began to strongly realize the country's structural sovereign debt issues and potential transmission of its crisis across European countries.

The results of the study confirm the occurrence of short-term mean spillover effects prevailing across all the countries, most notably seen in the effects from Portugal and France prior to the crisis and from Portugal and Italy after the crisis. Furthermore, Portugal and France were the major source of the volatility spillover effects before the crisis while after the crisis the effects from Germany strongly reinforced, in contrast to relatively weak causality-in-mean effects from the same country. It is interesting to note that Greece, although is generally reported as the source of concerns over creditworthiness of sovereign debts spread across Europe, during the pre-crisis period had influences in terms of causality-in-variance only on Italy and France. Looking these results from an investors' perspective, the awareness on changes in the direction of volatility spillovers might be useful when investors thinking of diversification strategies.

A point that certainly should not be ignored from investors is the volatility spillover effects from Germany on long-term bond yields of all other examined countries, despite its creditworthiness ability and sound fiscal policies opposed to those of European "PIIGS" suffering from high debt-GDP ratio. Finally, the possible implications of the 2007-2008 US sub-prime loan crises on the linkages among European bond markets are not analyzed in this paper due to its focus on the recent European sovereign debt crisis.

Gomez-Puig and Sosvilla-Rivero (2011) in their paper recognize that the development of the time-varying degree of causality and contagion between different European Monetary Union public debts markets has not yet been sufficiently analyzed by the literature.

Thus, their main targets were, a) to test for the occurrence of possible causal relationships between the evolution of the yield of peripheral EMU countries' issues b) to investigate the time-varying nature of these causal relationships and to scan episodes of contagion between them, and c) to analyze the determinants of these contagion events considering not only macroeconomic imbalances and banking linkages, but also indicators of investor sentiment.

The contributions of this paper to the existing literature can be summarized as follows: 1) It follows a dynamic approach to the analysis of the evolution of the extent of causality and contagion between different EMU public debt markets, 2) A new dataset, including private debt-to-GDP by sector (households, banks and non-financial corporations) in each EMU country, is built by the authors in order to analyze the role of the interconnection in the episodes of contagion and 3) Since "PIGS" considered the cause of the current sovereign debt crisis, the analysis is focused on these countries.

By making use of daily data of 10-year bond yields from 1 January 1999 to 31 December 2010 for EMU peripheral countries, "PIGS" and following the Hsiao's (1981) generalization of the Granger notion of causality, the results propose that there exist sub-periods of Granger causality in all pair-wise relationships. It is important to note at this point that due to the lack of consensus in the literature on how contagion should be defined; the authors have identified contagion episodes as sub-periods of significant raise in causality.

Having this in mind, the empirical results suggest that these episodes are focused around the first year of the beginning of the EMU in 1999, the introduction of the common currency in 2002 and the global financial crisis in the late-2000s. Furthermore, there is evidence of an increase in the contagion between peripheral EMU countries as the causality relationships between their yields have been significantly strengthened during the recent crisis. Concerning the analysis of the determinants of these contagion episodes, the results reveal that in all cases the variable that captures cross-border banking linkages is statistically significant. This finding highlights the importance of the case in which contagion is being transmitted from one country to the others through the banking system.

Specifically, in this scenario a notable factor has been the impact of the degree of integration of the banking system on the speed at which a sovereign crisis in a country can spill over to others. Nevertheless, this channel has generally been ignored by the recent literature despite its crucial relevance. We also need to keep in mind that macroeconomic imbalances in a specific country lead to rising sovereign spreads and a devaluation of the government debt that is mirrored in banks' balance sheets.

Regarding the role of private debt, the authors find evidence of its importance in the cases of Spain and Italy while private debt is not important in the case of Ireland, even though some authors have claimed that it was the main cause of the debt crisis in this country. However, they find a crucial effect of foreign bank claims on banking and non-financial private sector debt-to-GDP on the probability of contagion from Ireland which seems to emphasize the dependence of Ireland's rapid domestic expansion on foreign borrowing. Lastly, about the impact of investor sentiment, the credit rating scale points to be an important factor in six out of the 20 cases considered.

Considering that few things are known about what the effects would be on the interdependencies and the linkages between sovereign bond spreads exposures within the Eurozone during the debt crisis, Antonakakis and Vergos (2012) try to fill this gap in the literature by examining the directional linkages of government bond yield spreads between Eurozone countries over the period from 2007 to 2012. In particular they investigate bond yield spreads spillovers between and within the periphery and core Eurozone countries.

For their purposes, the authors adopt a VAR-based spillover index approach, which allows an estimation of the contributions of shocks to variables to the forecast error variances of both the respective and the other variables of the model. The main variable for this study is long-term government bond yield spread, which is defined as of nine euro zone countries, namely Austria, Belgium, France, Netherlands (or ABFN), Greece, Ireland, Italy, Portugal and Spain (or GIIPS), and German government bond yields of the same maturity. So, the dataset consists from 1163 observations covering the period from March 3, 2007 to June 18, 2012.

Their first finding, resulting from the examination of spillover indices, suggests that own-country bond yield spreads spillovers explain up to 70% of the forecast error variance. Secondly, bond yield spreads spillovers between country pairs within the periphery countries and within the core countries are proved to be larger compared to spillovers between the country pairs of these two groups of countries. Thirdly, the main transmitter of bond yield spreads spillovers is Belgium followed by Italy and Spain while Greece, Portugal and Netherlands are the dominant receivers of bond yield spreads return spillovers. The importance of these results comes from the fact changes of government bond yield spreads in other Euro zone countries can be a good indicator of futures changes in BYS and their repercussions in the country of interest.

Furthermore, the most important finding according to the authors, shows that 61.1% of return forecast error variance in all examined bond markets arises from spillovers. Another crucial result reveals that Greece is a major net transmitter of volatility since the crisis busted till the beginning of 2010, and a net receiver of bond yield spreads return spillovers afterwards. In addition, generalized impulse responses of shocks were found positive and are generally of higher significance within the core Eurozone countries or within the peripheral Eurozone countries (GIIPS) than between core and periphery. Finally, the effects in between groups of impulse responses to shocks of periphery (GIIPS) are greater on the core (ABFN) than vice-versa. Generally their results punctuate the vulnerability of the Eurozone from the shocks coming from the Eurozone countries in the periphery and finally these results are partly in contrast to results from previous studies that showed yield convergence among European countries before the crisis.

More recently, Matei (2013) examines the causality relationships between the different EMU's government bond markets from a dynamic perspective. Her study focuses on two main periods: the pre-crisis period (from November 2003 to September 2008) and the crisis period (from September 2008 to February 2013) while she uses weekly observations for 12 EMU counties, namely Austria, Belgium, France, Netherlands, Greece, Ireland, Italy, Portugal, Spain, Finland, Malta, Slovakia and Slovenia.

A multivariate Granger causality approach is followed by the author in order to check the difference in impacts for core-EMU and periphery-EMU countries, before and during the crisis. This method allows a) to track episodes of considerable increase in causality between yields on bonds issued by EMU's countries, b) to recognize possible time-varying causal relationships and c) critic on the potential benefits of financial integration after the introduction of the common currency and the execution of a common monetary policy for euro area member states. The contribution of her study to the existing literature lies on the greater data sample (up to nine countries examined) and the distinction between core-EMU and periphery-EMU countries in order to investigate the differences between the two groups.

The empirical findings reveal that the integration of government bond markets is weak and the number as the direction of causality also, changes during the crisis, while the impacts of Italy on Belgian and Spanish and of the Netherlands on the Belgian market are the only exceptions.

These fragile connections can be attributed to the following parameters. Firstly, increases in debt associated to large fiscal deficits of periphery countries (Greece, Ireland and Portugal) caused the defiance of the capital markets in the governments' ability of those counties to align and coordinate policies with their more credible European partners. Secondly, according to Laopodis (2008) one possible reason is the entity of the financial obstacles to the access of EMU's bond markets due to different taxation structures, fiscal policies and institutional features. Thirdly, some countries specific-risk differences that influence the riskiness of a country bond may affect the transmission channels as well. Fourthly, a contagion effect from the Greece bond market to others bond markets could affect the previous transmission channels of shocks by increasing the number of causalities and altering the direction of the causalities as well.

Another notable finding is that not all counties show the same route of financial convergence with Germany. Specifically in the pre-crisis period the Netherlands and Portugal are not convergent with Germany while during the crisis period Greece, France, Finland, Ireland, Italy, Malta, Netherlands and Portugal are not convergent with Germany which suggests the existence of country specific differences among these countries. Generally, core counties seem to be more integrated in contrast to periphery counties.

By comparing the previous finding to the increase of the financial integration after the introduction of the common currency we can conclude that certain government bond markets are still not part of the entire system's long run equilibrium. Further on, the author suggests that bond portfolios diversification benefits are still possible within Eurozone for countries that do not follow the cointegration system.

Finally the ECB's task to manage the monetary policy and so to achieve price stability might be more difficult in the future due to the increase of causalities during the crisis that challenge a contagion effect and larger shock transmission within Eurozone. However, a possible benefit from significant financial integration would be greater fiscal discipline within countries that compose a monetary union.

Sosvilla-Rivero and Morales-Zumaquero (2012) in their article try to analyze the volatility behavior of sovereign bond yields in different Eurozone countries. To achieve that, they analyzed the behavior of daily 10-year bond yields for 11 EMU countries (namely, Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Portugal and Spain) during the period 2001-2010. They also decomposed the volatility in permanent and transitory components using a C-GARCH model, while they developed a correlation and causality analysis between those two components and finally looked for clusters in permanent and transitory volatilities of sovereign yields.

The results indicate that permanent conditional volatility exhibits long memory (with long-run component half-life decay ranking from 83 days in the Netherlands to 331 days in Ireland), while the temporary component of volatility is much smaller (with short-run component half-life decay ranking from less than 1 day in Austria to 2 days in Italy), indicating full decay of a shock to the transitory components in a few days. These findings suggest that transitory shifts in debt market sentiment tend to be less important determinants of bond-yield volatility than shocks to the underlying fundamentals.

Furthermore, regarding the relationship between permanent and transitory volatilities, correlation and causality analysis in combination with cluster analysis display the existence of two different groups of countries closely linked, core EMU and peripheral EMU countries. These two groups have differences in terms of public finances and also in terms of creditability, which is related to the announcements made by policy makers. Finally in the case of the relationship between permanent volatility they find Granger causality running one-way from Austria to Belgium, Finland, Italy, The Netherlands and Spain, from France to Austria, Belgium and Finland, from Germany to Austria, Belgium and Italy, from Finland to Belgium, Italy and The Netherlands, from Belgium to Italy and Spain, from France to Italy, from The Netherlands to Italy, from Portugal to Ireland, and from Italy to Spain, but not the other way. In addition, they detect two-way causation between the following pairs: France and The Netherlands, Germany and The Netherlands, Greece and Ireland, Italy and Greece, Greece and Portugal, Greece and Spain, and Ireland and Spain.

In a different context, Christiansen (2007) focuses into the nature of the volatility of the international bond markets. In particular she investigates the effects of volatility spillovers from the US and aggregate European bond markets to a number of European bond markets; Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden and the UK. She applies a volatility spillover model in order to separate the shock to the individual country return into three effects; local (own country), regional (aggregate Europe) and global (US). Her study also analyses contagion effects into European bond markets and provides information about the impact of the introduction of the euro as well.

The dataset used includes JPMorgan total return (meaning that received coupons are re-invested into the bonds of the index) government bond indices for the US, Europe, six EU EMU-member countries (Belgium, France, Germany, Italy, the Netherlands and Spain), and three EU non-EMU member countries (Denmark, Sweden and the UK) covering the period from 6 January 1988 to 27 November 2002.

A remarkable finding is that all empirical results of this study group the countries into the EMU-member countries plus Denmark (EMU countries) and the non-EMU member countries. More specifically, results reveal strong evidence of volatility-spillovers effects from both the US and aggregate Europe to the individual bond markets. By analyzing the two groups, for EMU countries (plus Denmark) regional effects are most important, followed by local effects while US effects are minor and for non-EMU countries local effects are stronger, regional effects smaller and US effects larger.

Furthermore, findings suggest that EMU countries have become much more integrated after the introduction of the euro and also EMU countries' bond markets have become close to being perfectly integrated during the examined period, which can be attributed to the convergence in interest rates.

Finally, weak evidence of contagion effects is found from the US bond market into individual European bond markets, and only some evidence of contagion from the aggregate European bond market into individual European bond markets.

Considering the Euro-bond markets Laopodis (2008) was among first who investigated the trend in integration or interdependence in the European government bond market both before and after the introduction of the common currency. This research would be useful for international investors and policy makers. Concerning investors, diversification opportunities/benefits would be considerably decreased, if higher bond integration is present and sovereign bond issues are becoming close substitutes, with a wider consequence of the depreciation of the Euro, while a realization of the extent of comovement among Euro area bond markets is also significant in terms of the common monetary policy.

Further on, the author examines if important gains in integration were achieved following the use of the Euro after 2001. For that aims, the author firstly checks if each series is integrated of the same order, then tests for cointegration to find out if the bond markets share a common long-run trail and finally, in case of presence of a long-run relationship, he examines the possibility that short-run relationships among the bond markets might exist, using a causality test.

Daily data are used for that purposes, specifically nominal total returns (means that interest coupon are reinvested) on MSCI 10-year government bond indices from ten Euro area countries (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, and Spain) and four non-Euro area countries (Denmark, Norway, UK and US) for the 12/31/1994 to 7/27/2006 period.

Results from cointegration analysis results suggest that there is no evidence of cointegration among Euro bond markets in the pre-Euro period while evidence of weak cointegration is found in the post-Euro period. Conversely, there is evidence of strong cointegration among the non-Euro bond markets in the post-Euro period. Additionally, causality analysis shows that in in the post-Euro period a higher frequency of bivariate linkages exists among all of the Euro bond markets relative to the pre-Euro period, but it is also not clear which bond market acts as a "leader", in terms of causing most of the other bond markets, and thus a possible explanation of that result is a weak relationship among Euro bond markets.

About the US Treasury bond market, it appears to uni-directionally Granger cause all Euro bond markets in both subperiods. Furthermore, the UK's bond market does not present significant causality impacts on the Euro or non-Euro bond markets in either subperiod.

Finally, Laopodis concludes that the effects of the EMU, various institutional changes and market actions led to a substantial convergence in sovereign Euro bond yields since 2001. However, yield differences are still exist across Euro government bond, but factors like future advances/ developments both in the public and private bond market will lead in greater harmonization of bond yields with further reductions in diversification benefits. Moreover, the Euro bond area will keep growing as new Eastern European countries join the EMU and due to the fact that the degree of integration among these new markets is incomplete, these markets will still offer significant diversification opportunities for global investors.

Abad, Chulia and Gomez-Puig (2009) tried to analyze the impact of the Monetary Union on European debt markets looking at integration both with world debt markets and with Eurozone debt markets. As Christiansen (2007), they separated each individual country's Government bond return into three effects: a local (own country) effect, a regional (Eurozone) effect, and a global (world) effect and they tested whether there are important differences between countries that joined the euro in 1999 and those that did not. Their target was to investigate whether participation in the Monetary Union is an important factor that defines the difference in the impact of global and regional risk on each European Government bond market.

They used the 10-year government benchmark yields for all EU-15 countries (except Luxemburg and Greece) covering the period from January 1999 to June 2008 and applied that data to CAPM-based model which, in contrast to previous literature, is used to analyze the differences in the relative importance of two sources of risk, world and Eurozone risk.

Their findings show that apart from a set of world (regional) instruments, a set of local instruments are also able to predict local bond returns, implying that integration is still incomplete. Moreover, EMU and US government bond markets show a low degree of integration, suggesting that domestic rather than international risk factors mostly drive the evolution of government debt returns in EMU countries. Results also show that the degree of integration with the US and German bond markets differs between euro and non-euro participating countries.

In this context, government bond returns of non-EMU countries are more influenced by world risk factors while in contrast government bond returns of EMU countries are more influenced by Eurozone risk factors. Nevertheless, EMU countries are only partially integrated with the German market since their markets are still segmented and present differences in their market liquidity or default risk. That conclusion was also reached by Laopodis (2008), indicating that benefits from portfolio diversification are still possible within Monetary Union.

Tamakoshi and Hamori (2012) focus on the potential impacts of the European sovereign debt crisis by accessing cross-country transmission effects. In particular, they investigate for volatility and mean spillovers between Greek long-term government bond yields and the banking sector stock returns of four Southern European countries, namely Greece, Portugal, Italy and Spain. Due to the fact that these counties hold considerable amounts of Greek bonds and having in mind that a possible haircut on Greek bonds can cause losses in the banking sectors of those countries, it is interesting according to the authors to examine the causality between Greek government bond yields and the bank stock returns of those four above mentioned countries. It is also important to note that the results of the stress test conducted by the European Banking Authority in July 2011, showed that the exposure of banks in Greece, Portugal, Italy, and Spain to Greek sovereign debt amounts is 54.4, 1.4, 1.4, and 0.4 billion euro.

Previous studies have shown that the causal linkage between bank stock returns and bond yields can demonstrate different directions and signs. Present value models suggest that stock prices fall when long-term interest rates increase while a positive relationship between stock prices and long-term interest rates can also appear when changes in interest rates carry information about the outlook for future dividends. Furthermore, the opposite causality should also be considered, namely from stock returns to long-term interest rates, because stock markets have a forward-looking nature, implying that current stock prices, especially those of the banking sectors whose profit levels can be closely related to interest rates, may reflect expectations about future interest rates.

The study makes use of daily data on 10-year bond yields and daily values on the stock market indices in the banking sector of each country as well, while the approach followed is cross correlation function, developed by Hong (2001). The period covered by the sample is from January 2, 2007, to June 30, 2011 and the authors distinguish the sample into two sub-periods: the pre-crisis period (from January 2, 2007, to November 4, 2009) and the crisis period (from November 5, 2009, to June 30, 2011). They choose November 5, 2009, as the beginning of the debt crisis period because on that day the Greek authorities announced that the fiscal deficit was twice as much as they had announced previously, making the markets to realize that Greece was facing a serious solvency issue.

Their first finding reveals significant causality-in-mean effects from bank stock returns in Greece to Greek long-term bond yields—but only during the debt crisis period. However, the opposite causality (i.e., the negative impact of interest rate changes on the country's bank stock returns) is not significant. One possible explanation of this causality is that in the short run the crisis may have strengthened the forward-looking nature of stock returns in troubled banking sectors, as according to previous studies, banking sector stock prices can embody the expectations of the markets about the situation of the economy and future interest rates as well.

The second finding shows evidence of significant causality at the mean level from bank stock returns in Portugal, Italy, and Spain to Greek sovereign bond yields. A possible cause of this causality is that markets believe that Greece's solvency depends on its chances of being bailed out by the Eurozone members and thus any collapse in the bank stock returns in those countries may influence Greek bond yields.

Finally, the third finding presents evidence of bidirectional causality-in-variance between Greek long-term bond yields and the banking sector stocks in Portugal, Italy, and Spain during the debt crisis. The volatility spillovers from Greek bond yields to banking sector equity returns may imply that the banking sectors of

Portugal, Italy, and Spain were exposed to the solvency risks of the Greek bonds they held and as the crisis made the markets to fully understand that risks, the volatilities may have start to reflect such information flows significantly, even though they were not captured in the causality at the mean level.

Nevertheless, the authors point that the sovereign debt crisis may have affected all the studied countries simultaneously and that a common factor may have driven this bidirectional causality during the crisis period. So, if this case is true the detected causality would be considered to be false, because Hong's (2001) approach focuses on testing the short-term dynamics between only two variables and investigating the existence of such a common factor would require different methodologies.

Inoue, Masuda and Oshige (2013) investigate recent developments in the euro sovereign bond markets with particular focus upon crisis contagion and structural changes in the market. Their analysis is divides in four parts. In the first part, they test whether the announcement by the Greek government of the revision of its fiscal figures (on October 21, 2009) and the introduction of the €750 billion financial assistance facility (on May 10, 2010) mark the two main turning points into the euro sovereign bond markets, by testing the significance of these two events by dummy variables. In the second part, they examine the differences in the timings of structural changes in the countries by making the assumption that these timings are in fact unknown. Further on in the third part, they use a DCC M-GARCH model to show that the correlation among the euro sovereign bonds was generally high before the incident of the Greek shock and declined significantly during the period following the crisis. Finally in the fourth part, they apply causality tests in mean and variance to test whether the Greek shock was the originating point of the contagion or not.

The dataset consists of daily 10-year bond yields for Greece, Ireland, Portugal, Spain, Italy, France, Austria, Belgium, Netherlands and Germany covering the period from January 1, 2007 to July 22, 2011. This sample period except from the two turning points of the euro sovereign bond markets also includes two other major financial events, namely the Paribas shock and the Lehman shock.

Concerning the first part of their analysis, results show that the hypothesis that all the European countries went through structural changes simultaneously at the two abovementioned points is not statistically supported and specifically dummy variables were significant for some countries but insignificant for others. In particular, for Ireland only the financial assistance dummy was significant in both mean and variance model while for Greece, both dummies were significant in the mean model, but only the Greek shock dummy was significant in the variance model. The authors conclude that structural change might happen right away after these turning points, or it might evolve gradually over time and that the timings of such structural change vary among the countries.

Evidence from the second part reveal the existence of individual factors affecting the timings of structural change in the euro zone countries, in addition to common factors across the euro zone. The result implies intermittent changes in the parameters in the model. The authors confirmed that 1) the Greek shock in 2009 affected the countries with fiscal vulnerability, 2) the Paribas or the Lehman shock had a much larger effect for countries with a sound fiscal condition, and 3) the agreement on the emergency financial assistance facility in May 2010 was another source of structural change.

In the third part, the DCC M-GARCH model proves that the correlation among the euro sovereign bond yields lowered significantly after the Greek crisis happened. More specifically, before the Lehman shock, strong correlations were detected with the German bond yields. After the Lehman shock, these correlations gradually weakened, particularly for Greece, Ireland, Portugal, and Italy while Italy, Belgium, and Spain sustained correlations among themselves all over the sample period. This result also confirms that structural change was caused by no single significant event and that the timing of contagion depends on the country in question.

In the last part, the authors detect causalities from Greece to other euro countries, with causality-in-mean to appear in the early periods, while causality-in-variance tends to appear in the later periods. These results indicate that the contagion in yield level spread relatively quickly while shocks in the volatility were transmitted more slowly. Moreover, results also show causality in both mean and variance level from Ireland and Portugal to other euro countries. Finally, the contagion of the Greek shock to other countries' sovereign bond markets was also confirmed by results from causality tests.

Finally, Bouvet, Brady and King (2013) try to examine the extent to which rising debt to GDP ratios and government bond yield spreads in EMU countries are attributed to changes in countries' economic fundamentals and/or contagion from other troubled economies. Moreover, expect from analyzing contamination from Greece, they also investigate whether contagion from other larger southern countries, mainly Spain and Italy, consists a greater risk on the remaining euro area.

While previous papers define the sovereign spread as the difference between an EMU country's ten-year bond rate and the rate on the ten-year German bonds, the authors in this study choose to use the U.S. Treasury note as the risk-free asset benchmark in order to keep Germany in their analysis. The model used by the authors is a Panel Vector Autoregressive (PVAR) model and the sample consists of 11 EMU countries (Austria, Belgium, Finland, France, Ireland, Italy, Germany, Greece, the Netherlands, Portugal and Spain), using quarterly data over the period 1999Q1-2011Q4.

According to their results, there is evidence of interdependence and contagion within the EMU during the sample period. In particular, they find that during the pre-crisis period an increase in one country's sovereign spread leads to an increase in the other countries' borrowing costs and sovereign spreads, but does not affect their debt-to-GDP ratios, while after 2008 the same shock to sovereign spread has a great effect on countries' debt-to-GDP ratios, if the shock comes from Greece or Spain. The latest result suggests the existence of contagion. Furthermore, other countries barely see their borrowing costs rise in the case of a shock to Germany's sovereign spread while in the same time Germany loses some of its "status" as a safe haven for investors.

In the case when the shocks affect debt-to-GDP ratios, they do not find evidence of contagion, but how the shock affects the other EMU economies depends on the debt level of the country "shocked". Specifically, if Germany or Spain's debt-to-GDP ratios increase, other countries benefit from a liquidity effect and their sovereign spreads and borrowing costs tend to decrease, while in the case where the shock originates from Greece or Italy, then the authors do not observe any significant response in other countries.

A possible explanation of these conflicting results is that financial markets are able to discriminate among different debt-issuers. Finally , the authors share the approach past studies that the crowding-out effects of higher debt from Italy and Greece provides support for fiscal discipline, but probably with a little more flexibility than what is in place in the Stability and Growth Pact.

3. Data

We use daily data of 10-year bond yields from 26 March 1998 to 31 October 2013 collected from Bloomberg database for eleven EMU countries: Austria (AU), Belgium (BE), Finland (FI), France (FR), Germany (DE), Greece (GR), Ireland (IE), Italy (IT), Netherlands (NL), Portugal (PT) and Spain (ES), and three non-EMU countries: Denmark (DK), Sweden (SE) and United Kingdom (UK). We also calculate the first differences or return series using the following equation:

$$R_{it} = \log(P_t/P_{t-1})$$

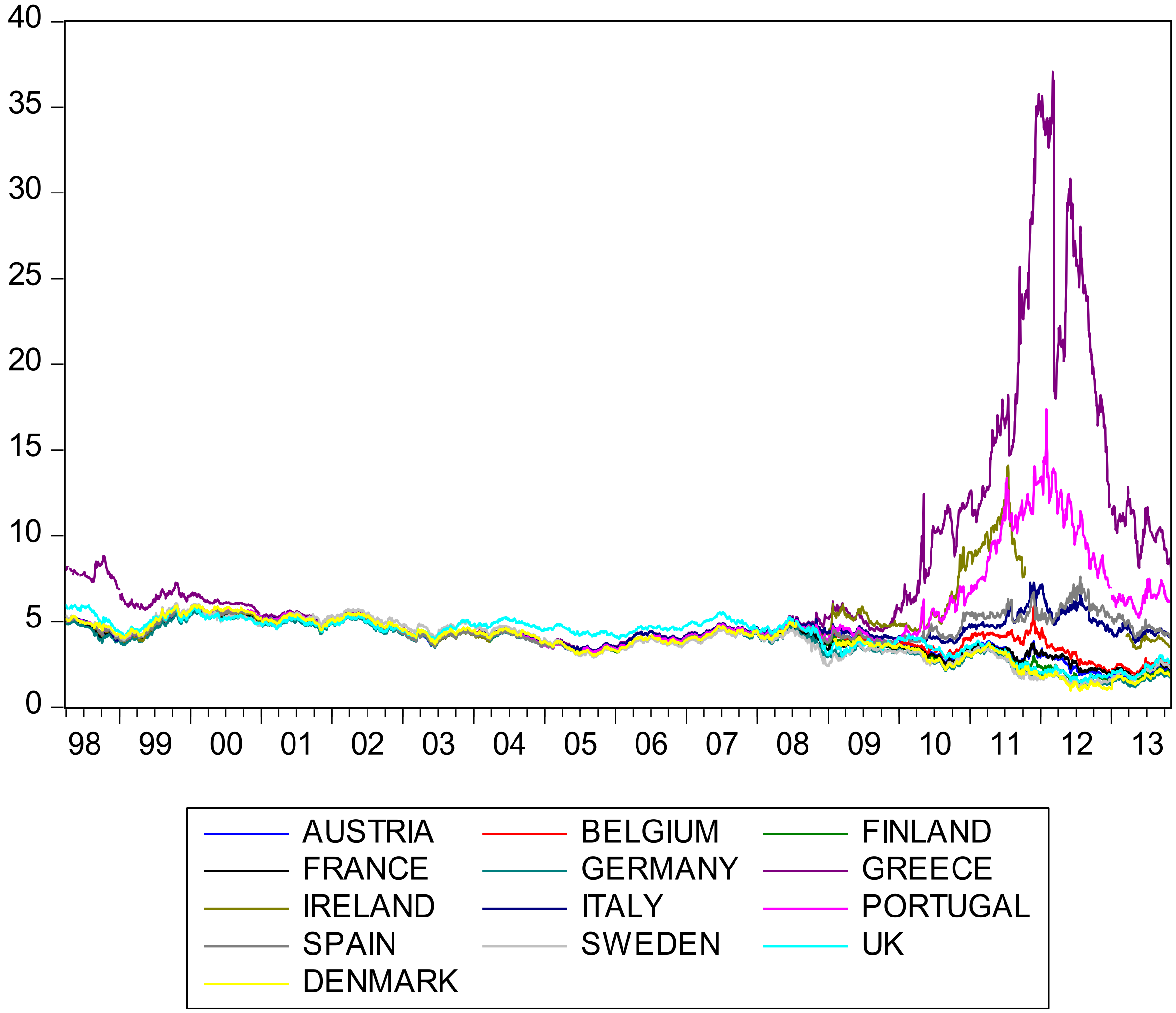
where P_t is the index value at time t and i the bond market.

The reason we chose to use daily data for our study is to avoid an issue of aggregation effects, which might be triggered by using monthly data and furthermore because with a daily dataset a adequate number of samples is available for our assessment of the European sovereign debt crisis.

In order to analyze the effects of the European sovereign debt crisis to the bond markets we divide the sample into two sub-periods: Sample A is from 26 March 1998 to 16 December 2009, while Sample B is from 17 December 2009 to 31 October 2013. We consider December 17, 2009 as the beginning of the crisis due to the fact that one day before Standard & Poor’s cut Greece’s credit rating from A1- to BBB+ with a negative outlook on the day.

Contrariwise, similar studies prefer to use September 15, 2008 as the start of the crisis, when the financial institution Lehman Brothers collapsed and global financial conditions become more volatile since then, but we think that the change on the credit rating mentioned above was the key fact that made market participants to strongly realize Greece’s structural sovereign debt issues and potential transmission of its crisis across European countries with similar macroeconomic imbalances.

Figure 1. Daily 10-year sovereign yields: 1998 - 2013



A simple first look at Figure 1, clearly indicates the differences in the yields behavior before and after the financial crisis. We can notice that after the introduction of the Euro in January 1999 and until the financial crisis bond yields moved in a narrow range with only slight differentiation across countries. This remarkable convergence and stability of yields was considered a hallmark of successful integration inside the euro area.

However, after the subprime crisis in 2007 and the collapse of the Lehman Brothers on 15 September 2008 the financial turmoil that emerged, affected not only EMU bond markets but turned into a global financial crisis which started to spread to real sector.

Therefore, the financial crisis revealed the macroeconomic imbalances within the euro area and this narrow range on which bond yields and yields spreads moving until then disappeared. Actually, the risk premium on EMU government bonds increased strongly in 2008, reflecting investor perceptions of imminent risks.

3.1 Descriptive Statistics

Table 1. Levels (26/3/1998-31/10/2013)

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Observations
AU	4.000	4.089	5.879	1.482	0.977	-0.442	2.784	138.1	4011
BEL	4.163	4.185	5.923	1.915	0.843	-0.292	2.894	59.50	4060
DEN	3.910	4.112	5.971	0.971	1.213	-0.632	2.680	278.3	3928
FIN	3.899	4.039	5.863	1.327	1.062	-0.521	2.670	202.1	4056
FR	3.953	4.006	5.758	1.662	0.894	-0.300	2.580	90.90	4063
GER	3.714	3.934	5.644	1.165	1.094	-0.630	2.625	292.7	4071
GR	7.678	5.324	37.101	3.230	6.158	2.652	10.05	13128	4044
IE	4.904	4.583	14.07	3.057	1.51	2.631	11.24	1409.2	3533
IT	4.630	4.502	7.261	3.217	0.666	0.609	3.418	280.2	4059
NL	3.890	4.022	5.797	1.489	1.018	-0.526	2649	206.8	4043
PT	5.493	4.722	17.39	3.160	2.205	2.187	7.400	62011	3867
SP	4.586	4.431	7.621	3.005	0.739	0.460	2.980	143.7	4067
SW	3.885	4.035	6.072	1.130	1.183	-0.419	2.279	206.0	4052
UK	4.215	4.548	5.970	1.439	1.069	-0.968	3.029	635.4	4070

Table 2. Returns (26/3/1998-31/10/2013)

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Observations
AU	-0.001	-0.002	0.269	-0.243	0.044	0.26	5.271	903.4	4011
BEL	-0.001	-0.001	0.408	-0.320	0.047	0.285	8.652	5442.4	4060
DEN	-0.001	-0.002	0.357	-0.246	0.043	0.363	5.865	1426	3928
FIN	-0.001	-0.001	0.26	-0.230	0.044	0.218	4.758	552.3	4056
FR	-0.001	-0.001	0.271	-0.286	0.044	0.255	5.515	1112	4063
GER	-0.001	-0.001	0.229	-0.257	0.044	0.159	4.674	492.1	4071
GR	0	0	2.989	-18.10	0.359	-32.24	1628.2	4.44E+08	4044
IE	0.001	-0.001	0.886	-1.130	0.074	-0.880	41.81	221648.5	3533
IT	0	0	0.477	-0.790	0.059	-0.740	24.88	81156.9	4059
NL	-0.001	-0.001	0.207	-0.233	0.043	0.216	4.526	423.1	4043
PT	0	-0.001	2.173	-1.630	0.117	2.305	103.8	1633946.0	3867
SP	0	-0.001	0.433	-0.884	0.063	-1.126	23.00	68601	4067
SW	-0.001	-0.001	0.309	-0.247	0.046	0.176	5.559	1122.5	4052
UK	-0.001	-0.001	0.331	-0.294	0.051	0.186	5.258	887.4	4070

Tables 1 and 2 present descriptive statistics for the levels and first differences of the 10-year government's yields in eleven EMU counties and three non-EMU countries during the sample period (1998-2013).

As can been seen, three countries faced fiscal crisis since the Greek shock, recorded high average yields. Specifically, Greece had the highest yield (7.678%), followed by Portugal (5.493%) and Ireland (4.904%). The large-market countries, such as Germany and France three core counties, such as Austria, Belgium and the Netherlands and the three non-EMU countries, recorded on average 4% yields. For these countries the median values are close to the mean values while the median values of Greece, Portugal and Ireland are lower than the mean values, suggesting that a rise in yields after the Greek shock distorted the yield distribution. Furthermore, the distance between the maximum and the minimum and the standard deviation as well also indicate the rise in yields during the crisis.

Moreover, the mean is not significantly different from zero for the first differences. Normality is tested with the Jarque - Bera test (which is distributed as $\chi^2(2)$ under the null) and strongly rejected for both the levels and the first differences. The rejection of normality can be attributed to either excess of kyrtosis or skewness.

Kyrtosis is a measure of the peakedness of the distribution and the value for the normal distribution is three. Our results suggest that the distributions of the yields of Greece, Portugal and Ireland are peaked relative to the normal, so these distributions are leptokurtic while for most of the other countries the distributions are flat relative to the normal.

Finally, skewness is a measure of asymmetry of a distribution. If the skewness is positive the tail on the right side is longer and if negative the tail on the left side is longer. On the other hand if the skewness is zero, it typically indicates that the distribution is symmetric. We find positive skewness for the so called “PIGS” in levels and for Portugal in the first differences while all other EMU and non-EMU countries present negative skewness in levels and positive skewness in first differences.

We further analyze the descriptive statistics for the daily returns of the two sub-samples we have set before, in order to investigate possible differences in the yields behavior before and after the financial crisis.

Table 3. Returns (26/3/1998-16/12/2009)
Pre-Crisis period

	Mean	Std. Dev.	Skewness	Kurtosis	Observations
AU	-0.000575	0.041812	0.247595	4.5465	4011
BEL	-0.000351	0.042052	0.298845	4.6374	4060
DEN	-0.000167	0.039764	0.399684	4.7437	3928
FIN	-0.000452	0.042309	0.244927	4.7146	4056
FR	-0.000487	0.042540	0.317612	4.6959	4063
GER	-0.000545	0.042154	0.221181	4.5902	4071
GR	-0.000577	0.049377	0.273712	8.6193	4044
IE	-0.000150	0.045958	0.759873	8.0166	3533
IT	-0.000290	0.040811	0.331103	4.8398	4059
NL	-0.000494	0.041875	0.257934	4.4285	4043
PT	-0.000442	0.042380	0.433921	5.1314	3867
SP	-0.000387	0.041688	0.275353	4.6556	4067
SW	-0.000599	0.045086	0.185902	5.3721	4052
UK	-0.000657	0.049749	0.210720	5.6923	4070

Table 4. Returns (17/12/2009-31/10/2013)
Post-Crisis period

	Mean	Std. Dev.	Skewness	Kurtosis	Observations
AU	-0.001492	0.048459	0.290409	6.2126	1009
BEL	-0.001146	0.059202	0.262377	10.1497	1009
DEN	-0.001724	0.052107	0.323538	6.2197	1009
FIN	-0.001526	0.048024	0.169367	4.6596	1009
FR	-0.001252	0.048202	0.130281	6.8119	1009
GER	-0.001507	0.050959	0.060113	4.4397	1011
GR	0.002582	0.715197	-16.412550	415.626	998
IE	0.004506	0.143012	-0.852499	16.0282	638
IT	0.000133	0.095268	-0.805916	14.4831	1009
NL	-0.001364	0.047543	0,136761	4.5297	1009
PT	0.002873	0.042380	0.433921	32.8596	1002
SP	0.000241	0.041688	0.275353	12.3176	1009
SW	-0.000945	0.045086	0.185902	5.9866	1009
UK	-0.001254	0.049749	0.210720	4.1787	1011

Tables 3 and 4 present descriptive statistics for the daily returns of all bond markets in the pre and post crisis periods.

For the pre-crisis period we observe that the average daily returns for the Euro area markets range from -0.000150 for Ireland to -0.00057 for Greece and for the non-Euro markets form -0.000167 for Denmark to -0.000657 for UK.

Regarding the post crisis-period, as can been seen the returns for all the bond markets were higher range from -0.000945 for Sweden to 0.004506 for Ireland.

The standard deviations for the pre-crisis period hovered around an average of 0.042, with Denmark having the lowest value and in the other hand Greece having the highest. The return's increase in the post-crisis period was accompanied by higher standard deviations for all bond markets and several markets experienced high increases in risk like Belgium, Denmark, Greece and Portugal.

The skewness and kyrtosis values suggest that the returns are asymmetric and leptokurtic. Note that skewness is positive for all countries in the pre-crisis period indicating that the tails of their distribution are fatter. By contrast, skewness becomes negative during the post-crisis period for Greece, Italy and Ireland. Kyrtosis in most cases was higher in the post-crisis period especially for Greece, Italy, Ireland, Portugal, Spain and Belgium.

In general the results reveal that country credit risks rise during the crisis period compared to the pre-crisis period and as a consequence the volatility of spreads reflected by the standard deviation remains consistently higher in the post-crisis period especially for Greece and Ireland.

4. Methodology

The methodological approach of this study is targeting to investigate the linkages between the bond markets of eleven EMU countries and three non-EMU counties. For this purpose we use a multivariate Granger causality approach which involves the following three steps.

The first step entails checking if each series is integrated of the same order, using unit root tests. The second step is to test for cointegration to check if the bond markets share a common long-run path using the Johansen and Juselius (1990) approach. Finally, in the case of where a long run relationship between our variables is found, the third step is to apply a vector error correction model (VECM) to infer the Granger causal relationship between the bond yields, using the Granger (1969) causality test.

4.1 Unit root tests

As we described before, in the first step we check the order of integration of the series. To this goal in mind, we apply two time unit root tests: The Augmented Dickey-Fuller test (ADF test) and the Phillips-Perron unit root test.

The ADF test tests the null hypothesis that a time series y_t is I(1) against the alternative that it is I(0), assuming that the dynamics in the data have an ARMA structure. The ADF test is based on estimating the test regression

$$y_t = \beta' D_t + \varphi y_{t-1} + \sum_{j=1}^{p} \psi_j \Delta y_{t-j} + \varepsilon_t$$

where D_t is a vector of deterministic terms (constant, trend etc.). The p lagged difference terms, y_{t-j} , are used to approximate the ARMA structure of the errors, and the value of p is set so that the error ε_t is serially uncorrelated.

The null hypothesis φ=0, suggests that series are no stationary in level while on the other hand the alternative assumption φ<0 means that series are stationary in level (i.e I(0)).

If series are non-stationary under the null assumption, then the test statistic will have a non-standard distribution. An important practical issue for the implementation of the ADF test is the specification of the lag length p. If p is too small then the remaining serial correlation in the errors will bias the test. If p is too large then the power of the test will suffer. For that reason the lag-length p is chosen to generate a white noise error term ε_t by taking account basic information criteria such as Schwarz and Hannan-Quinn criterion.

The Phillips-Perron (PP) unit root tests differ from the ADF tests mainly in how they deal with serial correlation and heteroskedasticity in the errors. In particular, where the ADF tests use a parametric autoregression to approximate the ARMA structure of the errors in the test regression, the PP tests ignore any serial correlation in the test regression. The test regression for the PP tests is:

$$\Delta y_t = \beta' D_t + \pi y_{t-1} + u_t$$

where u_t is I(0) and may be heteroskedastic. The PP tests correct for any serial correlation and heteroskedasticity in the errors u_t of the test regression.

One advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error term u_t. Another advantage is that the user does not have to specify a lag length for the test regression.

As we can conclude from tables 5 and 6 in the Appendix, the null hypothesis for both tests of the presence of a unit root in levels cannot be rejected (p-value>5%).

Moreover testing on the first differences of each bond yields series does not indicate the presence of a second unit root (p-value<5%), which means that they are stationary. Therefore, individual bond markets appear to be I(1).

We should also note that if series are stationary in level, I(0), we can directly apply the Granger causality test within a VAR framework. On the contrary, if the series suggest non-stationarity in level of the variables, the existence of cointegrating relationships between them should be examined to validate the empirical model.

4.2 Cointegration Test

The cointegration test reveals whether a group of non-stationary series is cointegrated or not. We apply the Johansen test in order to study the dynamic adjustment through the long run equilibrium path with a VAR specification. Let X a vector of dimension (N x 1) that follows an unrestricted VAR model in level:

$$Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + \ldots\ldots + B_k Y_{t-k} + \mu + \varepsilon_t$$

Where each Bi (i = 1,k) is an N x N matrix of Y parameters, μ is a constant term and ε_t is the error term independently and identically distributed, with zero mean and the contemporaneous covariance matrix Y Ω.

The above equation can be written as a vector error correction model (VECM) as follows:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \ldots + \Gamma_{k-1} \Delta Y_{t-(k-1)} + \Pi Y_{t-k} + \mu + \acute{\varepsilon}_t$$

This equation can give us information about

- the short term (Γ_i = -I + Σ A_j, j=1,…,k-1)
- and long term (Π = -I + $\Pi_1 + \Pi_2 + \ldots + \Pi_k$)

dynamic adjustments of the variables in the modeling.

Then we test for cointegration through the rank $r \in (0, n - 1]$ of the Π matrix using Johansen's maximum likelihood statistics:

the trace statistic: $\lambda_{trace}\,(r) = -T\sum_{i=r+1}^{n} ln\,(1 - \hat{\lambda}_t)$

and the maximal-eigenvalue statistic : $\lambda_{max}\,(r, r+1) = -Tln(1 - \widehat{\lambda_{r+1}})$

where $\hat{\lambda}$ stands for the estimated value of the i^{th} ordered eigenvalue of Π.

Both tests assume that under the null hypothesis there are, at most, r cointegrating vectors. In the case of trace test the alternative hypothesis is that there are more than r cointegrating vectors while on the on the other hand max-eigenvalue alternative hypothesis is that there are exactly $r + 1$ cointegrating vectors.

However it is possible that results from the two tests to be contradictory and in this case we prefer trace statistic test because its results considered more robust than the maximal-eigenvalues in finite samples.

Furthermore, due to the fact each return series may have each return series may have nonzero means, deterministic trends, and/or stochastic trends, the cointegrating equations may have intercepts and deterministic trends. As a result, the asymptotic distribution of the likelihood ratio test statistic for cointegration does not have the usual χ^2 distribution and may depend on the assumptions made with respect to deterministic trends. Consequently, we need to make several assumptions regarding the trends underlying the series. We will consider the following five assumptions:

1. The level data χ_t have no deterministic trends and the cointegrating equations do not have intercepts.
2. The level data χ_t have no deterministic trends and the cointegrating equations have intercepts.
3. The level data χ_t have linear trends and the cointegrating equations have only intercepts.

4. The level data χ_t and the cointegrating equations have linear trends.
5. The level data χ_t have quadratic trends and the cointegrating equations have linear trends.

We consider the third case as the most plausible one for our analysis. Nevertheless, for the purposes of exposition of a comprehensive multivariate cointegration test we included all possible assumptions. Again, the third case assumes a trend in both the cointegrating equation and the VAR

4.3. Granger causality

After specifying the number of the cointegration vectors that compose the cointegrating space by using Johansen cointegration test, we test for multivariate Granger causality. We also 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 amplify the procedure for testing the multivariate causality in the system, we a pair of series, ($X_t Y_t$), ($X_t K_t$), and ($Y_t K_t$) which are cointegrated of order r. We can define an unrestricted vector error-correction model (VECM model), shown for the first series only, which includes the error correction term, ECT_{t-1} as follows:

$$\Delta X_t = a_\chi + \Sigma\beta_{\chi,i}\Delta X_{t-i} + \Sigma\delta_{\chi,i}\Delta Y_{t-i} + \gamma_\chi ECT_{t-1} + \varepsilon_{\chi,t}$$

$$\Delta Y_t = a_y + \Sigma\beta_{y,i}\Delta Y_{t-i} + \Sigma\delta_{y,i}\Delta X_{t-i} + \gamma_y ECT_{t-1} + \varepsilon_{y,t}$$

where ($\beta_{\chi,i}$, $\beta_{y,i}$) and ($\delta_{\chi,i}$, $\delta_{y,i}$), if statistically significantly different from zero, present 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 (i =1, k) are equal to zero. We practically test what portion of the current value of ΔY_t is explained by its past values, and whether adding lagged values of ΔX_t can contribute to the explanation of ΔY_t.

In this framework, we can identify three cases:

1. An one-way Granger causality running from Y to X if in the first equation not all $\delta_{\chi,i}$'s are zero while in the second equation $\delta_{y,i}$'s are zero. If we cannot reject the null hypothesis H0 (δ_{χ} = 0) in the first equation, we denote that "Y Granger causes X" (in other words, 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 $\delta_{\chi,i}$'s are zero but, in the second equation not all $\delta_{y,i}$'s 's are zero.

2. A two-way (bidirectional) causality between Y and X if neither all $\delta_{\chi,i}$'s and $\delta_{y,i}$'s are zero; consequently, if causation cannot be rejected in both equations, the variables are interdependent.

3. No Granger-causality between Y and X if all $\delta_{\chi,i}$'s and $\delta_{y,i}$'s are zero.

The parameter $\varepsilon_{\chi,t}$ is multivariate i.i.d sequence with zero mean and covariance matrix Σ_{χ} and the parameter γ_{χ} measures the speed of adjustment to the long-run equilibrium within a single period. Apparently, if cointegration between the (or any) two series is not found, then the above equations must not have the residual of cointegration relation (ECT_{t-1}).

For instance, a test of the null hypothesis H_0: γ_{χ} = 0 in the first equation is a test of weak exogeneity since a rejection of the null means that there is evidence of a long-run causality running from the ECT to X.

5. Empirical Results

In this section we study the bond linkages and their evolution for eleven EMU counties and three non-EMU countries during the pre-crisis and post-crisis period. Our analysis is separated into two parts. In the first one we examine the bond linkages between only the eleven EMU countries during the pre-crisis and the crisis period while in the second part we research the bond linkages between the so-called 'PIIGS' counties, namely Portugal, Italy, Ireland, Greece and Spain, and the three non-EMU countries, Denmark, Sweden and UK for the same sub-periods.

Therefore, in the first part we can note how the crisis has affected the causal relationships of the EMU countries' bond yields and also to see the evolution of integration in the European government bond markets.

Furthermore, in the second part we consider if high increases in bond yields of 'PIIGS' counties had causality effects in bond markets outside the Eurozone such as Denmark, Sweden and UK.

5.1 Cointegration and Granger Causality Results

Tables 7 and 8 present the cointegration results for eleven EMU bond markets during the pre-crisis period and the crisis period. As it seems on the right columns of the table 7, we find evidence of seven cointegrating vectors according to the trace statistics while the max-eigenvalue statistic indicates six cointegrating vectors on four of five assumptions. On the other hand, regarding the crisis period, results on table 8 indicate the existence of two cointegrating vectors among bond markets under both the trace and max-eigenvalue statistic. As we previously highlighted, when cointegration statistics differ, we base on the trace statistic which considered more robust than the max-eigenvalue statistic

Table 7. Cointegration Results among 11 Euro bond markets, *Pre-crisis period*

Panel A: Cointegration Results		
Lags : 2 Significance level : 5% *Assumptions:*	***No. of Cointegrating Equations (CEs)***	
	Trace	**Max-Eigenvalue**
1. Deterministic trend in data but no intercepts in CEs	7	5
2. No deterministic trend in data with intercepts in CEs	7	6
3. Linear trend in data and intercepts in CEs	**7**	**6**
4. Linear trends in data and CEs	7	6
5. Quadratic trends in data and linear trends in CEs	7	6
Wald Test [χ^2] Results		
Countries **not** participating in the cointegrating space	Countries participating in the cointegrating space	
	Austria: 44.09580 (0.00000) Belgium: 66.55014 (0.00000) Finland: 75.47846 (0.00000) France: 65.98107 (0.00000) Germany: 61.96562 (0.0000) Greece: 59.4028 (0.00000) Ireland: 52.89678 (0.00000) Italy: 52.89632 (0.00000) Spain: 77.89649 (0.00000) Portugal: 56.79933 (0.00000) Netherlands: 100.6648 (0.00000)	

*Note: coefficient's p-values are in parenthesis

Intuitively, cointegration results can be interpreted as follows. If bond yields have only one common stochastic trend in a given group (number 1 for both the max-eigenvalue and trace statistic), it means that bond markets have a single common long-run path and any one market can be considered representative of the behavior of the group. Therefore, an investor should only invest in one of these bond markets and not in all of them, or in other words these markets can be handled as one asset class for the purposes of diversification in the bond-portfolio construction. In the opposite case, when two or more common stochastic trends are found (this corresponds to number 2, 5, 6 and 7 on our results), this means that some countries' government bond markets behave independently of the others in the short run.

Table 8. Cointegration Results among 11 Euro bond markets, *During-crisis period*

<u>Panel B</u>: Cointegration Results		
Lags : 1 Significance level : 5% *Assumptions:*	***No. of Cointegrating Equations (CEs)***	
	<u>Trace</u>	**<u>Max-Eigenvalue</u>**
1. Deterministic trend in data but no intercepts in CEs	2	2
2. No deterministic trend in data with intercepts in CEs	2	2
3. Linear trend in data and intercepts in CEs	**2**	**2**
4. Linear trends in data and CEs	2	2
5. Quadratic trends in data and linear trends in CEs	2	2

Wald Test [χ^2] Results	
Countries **not** participating in the cointegrating space	Countries participating in the cointegrating space
Belgium: 5.712326 (0.057489) Ireland: 2.800374 (0.246551) Portugal: 2.283746 (0.319221) Spain: 4.007665 (0.134818)	Austria: 14.13545 (0.000852) Finland: 7.827975 (0.019961) France: 21.87234 (0.000018) Germany: 7.019346 (0.029907) Greece: 11.16345 (0.003766) Italy: 7.955960 (0.018723) Netherlands: 11.23080 (0.003641)

*Note: coefficient's p-values are in parenthesis

In the next step in order to further shed light on the above results, we apply Wald tests for both sub-periods to determine which bond markets are participating in the cointegration space. The rejection of the null hypothesis of exclusion of a variable from the cointegrating space confirms the existence of close relationships among the variables considered in the system. Alternatively, in case of accepting the null hypothesis then the conclusion would be absence of cointegration among all variables or simply absence of close linkages among them.

The results from these tests, based on the test statistic distributed as χ^2, and are applied to the results from the third assumption, are displayed on the bottom of tables 7 and 8. In the pre-crisis period, Wald tests suggest that all eleven EMU countries participate in the cointegration space. However, during the crisis period four EMU countries, namely Belgium, Ireland, Portugal and Spain can be excluded from the group as they do not participate in the cointegrating space. The latest finding can be attributed to country specific differences among EMU countries and therefore a simple explanation would suggest that markers consider their bonds more risky than others or there are liquidity differences across markets.

Since our results from cointegration analysis are different it might be possible that short-run relationships among and between these bond markets still incur. More specifically, we would like to investigate if uni- and/or bi-directional linkages between any markets exist. Thus, we develop an error-correction model (VECM) for both sub-periods to study these linkages.

Given that the Granger causality test is highly sensitive to the number of lags of right-hand side variables, according to Schwarz and Hannan-Quinn criteria, the optimal number of lags for the pre-crisis period is 2 lags while for the crisis period is one lag. Table 9 reports the short-run linkages between different EMU bond markets for the pre-crisis and crisis period. Note that uni-directional causality (→) means that bond market X Granger causes bond market Y, while bi-directional causality (↔) indicates that there is a two-way causality between bond markets X and Y.

Table 9. Short-run causality results[1] during the two sub-periods

	AU	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT
AU							→ [5.6606] (0.0590) → [5.0112] (0.0252)	→ [6.1825] (0.0454) → [3.3912] (0.0665)	↔ [8.7419] (0.0126)		↔ [6.2753] (0.0434)
BE	→ [15.235] (0.0001)		↔ [13.397] (0.0003)		↔ [4.6693] (0.0968) → [13.585] (0.0004)	→ [10.813] (0.0010)	→ [6.0844] (0.0477)			→ [12.510] (0.0004)	
DE	→ [5.1999] (0.0743)	↔ [8.2213] (0.0041)						→ [12.246] (0.0022) → [6.7390] (0.0094)			→ [4.8216] (0.0897)
ES	→ [6.8961] (0.0318)	→ [11.670] (0.0029) → [3.4150] (0.0646)	→ [3.1167] (0.0775)		↔ [11.504] (0.0032) → [2.7626] (0.0965)	→ [7.9381] (0.0189) → [3.3018] (0.0692)		→ [3.0654] (0.0800)		→ [8.1980 (0.0166)] → [3.4183] (0.0645)	→ [8.0879] (0.0175)
FI	→ [4.9529] (0.0840)	↔ [5.5851] (0.0613)		↔ [7.1126] (0.0285)		→ [9.8354 (0.0073)			↔ [7.0794] (0.0290)	→ [7.7222] (0.0210)	↔ [5.7497] (0.0564)
FR											
GR			→ [3.2423] (0.0718)					↔ [4.5472] (0.0330)			
IE		→ [6.3827] (0.0411)					→ [12.853] (0.0016) ↔ [3.8961] (0.0484)				↔ [17.070] (0.0020) → [8.1116] (0.0044)
IT	↔ [5.7500] (0.05640	→ [6.2348] (0.0443) → [7.7127] (0.0055)		→ [7.6726] (0.0216)	↔ [5.5489] (0.06240		→ [6.4209] 90.04030 → [11.452] (0.0007)	→ [6.3304] (0.0422)			→ [18.614] (0.0001)
NL								→ [2.9417] (0.0863)			→ [4.5987] (0.0320)
PT	↔ [5.3426] (0.0692)	→ [6.7392] (0.0344)			↔ [5.0643] (0.0795)			↔ [7.5070] (0.0234)			

36 Linkages in the pre-crisis period
7 bi-directional linkages

23 linkages in the crisis period
2 bi-directional linkages

Note: (→) denotes linkages in the pre-crisis period while (→) indicates linkages in the crisis period

Coefficients [χ^2], p-values are in parenthesis – significant at 10% level[1]

Findings of table 9 do not clearly reveal which bond markets act as a "leader", in terms of affecting the highest number of other bond markets. This outcome

[1] Table 9a in the appendix presents a simpler display of the above results

suggests a fragile connection between the eleven EMU bond markets as well as a week degree of financial integration of these markets overtime. Moreover, the number and the direction of causal linkages are different in the two periods, except of the impact of Austria on Greek and Irish bond markets, Germany on Ireland, Spain on Belgium, France and the Netherlands and Italy on Belgium and Greece. For all other case the direction of causalities changes in the crisis period. It is worth noting that Spain in the crisis period causes the highest number of bond markets, a total of six including Belgium, Finland, France, Germany, Ireland and the Netherlands while Italy and Finland which both affect seven markets in the pre-crisis period, do not seem to follow the same pattern during the crisis where Italy affects only Belgium and Greece while Finland do not cause to anyone. Hence, we should keep in mind that past prices of Spain's bond yields can contribute in order to predict future bond yields for countries that being affected by Spain. Furthermore, Belgium appears to be the second more influential market after Spain during crisis as it impacts Austria, Finland, France, Germany and the Netherlands while this influence was limited to only two markets during pre-crisis, Finland and Greece. Additionally, another two important findings suggest that Greece Granger causes Germany and Ireland during crises even if in the pre-crisis period did not cause anyone market and lastly France appears to not cause anyone bond market in both sub-periods.

As we previously mentioned, in the second part we will examine if high increases in bond yields of 'PIIGS' counties had causality effects in bond markets outside the Eurozone such as Denmark, Sweden and UK.

Tables 10 and 11 present the cointegration results among "PIIGS" and Denmark, Sweden and UK markets during the pre-crisis period and the crisis period. As it seems on the right columns of the table 10, we find evidence of one cointegrating vectors according to the trace statistics and the max-eigenvalue statistic in all five assumptions. On the other hand, regarding the crisis period, results on table 11 denote no cointegration among bond markets under both the trace and max-eigenvalue statistic. This can be considered an important finding, as the long-run equilibrium of the system does not exist anymore.

Table 10. Cointegration Results among 'PIIGS' and UK, SWE & DEN-*Pre-crisis period*

Panel C: Cointegration Results		
Lags : 2 Significance level : 5% *Assumptions:*	***No. of Cointegrating Equations (CEs)***	
	Trace	**Max-Eigenvalue**
1. Deterministic trend in data but no intercepts in CEs	1	1
2. No deterministic trend in data with intercepts in CEs	1	1
3. Linear trend in data and intercepts in CEs	**1**	**1**
4. Linear trends in data and CEs	1	1
5. Quadratic trends in data and linear trends in CEs	1	1

Exclusion Tests [χ^2]	
Countries **not** participating in the cointegrating space	Countries participating in the cointegrating space
Portugal: 2.200610 (0.137956) Denmark: 0.269946 (0.603368) Sweden: 3.016931 (0.082399) UK: 3.189067 (0.074132)	Greece: 12.37864 (0.000434) Italy: 12.80951 (0.000345) Ireland: 7.590879 (0.005866) Spain: 7.753893 (0.005360)

*Note: coefficient's p-values are in parenthesis

The existence of one cointegration equation denotes that these bond markets are fully integrated and they also have a single common long-run relationship and any one market can be representative of the behavior of the group, so an investor should only invest in one of these bond markets and not in all of them. It is also important to recall that in a system of eight variables complete integration would require either one or seven cointegrating vectors.

Next, we apply Wald tests for both sub-periods to determine which bond markets are participating in the cointegration space. The rejection of the null hypothesis of exclusion of a variable from the cointegrating space confirms the existence of close relationships among the variables considered in the system. Alternatively, in case of accepting the null hypothesis then the conclusion would be absence of cointegration among all variables or simply absence of close linkages among them. The results from these tests, based on the test statistic distributed as χ^2, and are applied to the results from the third assumption, are displayed on the bottom of table 10.

Table 11. Cointegration Results among 'PIIGS' and UK, SWE & DEN-*During-crisis period*

Panel D: Cointegration Results		
Lags : 2 Significance level : 5% *Assumptions:*	***No. of Cointegrating Equations (CEs)***	
	Trace	**Max-Eigenvalue**
1. Deterministic trend in data but no intercepts in CEs	0	0
2. No deterministic trend in data with intercepts in CEs	0	0
3. Linear trend in data and intercepts in CEs	**0**	**0**
4. Linear trends in data and CEs	0	0
5. Quadratic trends in data and linear trends in CEs	0	0

*Note: coefficient's p-values are in parenthesis

In the pre-crisis period, Wald tests suggest that four periphery EMU countries, Greece, Ireland, Italy and Spain participate in the cointegration space, while the three non-EMU countries and Portugal can be excluded from the group as they do not participate in the cointegrating space.

Since our results from cointegration analysis are different it might be possible that short-run relationships among and between these bond markets still incur. More specifically, we would like to investigate if uni- and/or bi-directional linkages between any markets exist. Thus, we develop an error-correction model (VECM) for the pre-crisis period in order to study these linkages while on the contrary in the crisis period we will study these linkages into a (VAR) framework as a result of absence of cointegration.

Given that the Granger causality test is highly sensitive to the number of lags of right-hand side variables, according to Schwarz and Hannan-Quinn criteria, the optimal number of lags for the pre-crisis period is 2 lags while for the crisis period is one lag. Table 12 presents the short-run linkages between PIIGS" and Denmark, Sweden and UK markets for the pre-crisis and crisis period. Note that uni-directional causality (→) means that bond market X Granger causes bond market Y, while bi-directional causality (↔) indicates that there is a two-way causality between bond markets X and Y.

Table 12. Short - run relationships among 'PIIGS' & Denmark, Sweden, & UK

	ES	GR	IE	IT	PT	DK	SE	UK
ES			→ [4.9496] (0.0261)	↔ [12.178] (0.0023)	→ [9.1429] (0.0103)	↔ [22.447] (0.0000)	→ [20.329] (0.000)	→ [35.739] (0.000)
GR			→ [3.0766] (0.0794)			↔ [3.8257] (0.0505)		→ [8.2728] (0.0040)
IE			→ [4.6169] (0.0994)					↔ [7.9389] (0.0189)
IT	↔ [9.4461] (0.0089) → [4.3019] (0.0381)		→ [8.3606] (0.0153)		→ [15.1992] (0.0005)	↔ [8.2407] (0.0162)	→ [7.1487] (0.0280)	
PT								
DK	↔ [7.8777] (0.0195) → [5.8897] (0.0152)	↔ [6.6355] (0.0100)	→ [11.043] (0.0040)	↔ [5.7439] (0.0566) → [3.5847] (0.0583)	→ [8.3638] (0.0153)		→ [6.9540] (0.0309) → [6.1166] (0.0134)	→ [10.000] (0.0067) → [3.8238] (0.0505)
SE	→ [4.0670] (0.0437)	→ [6.9932] (0.0303)						
UK			↔ [13.507] (0.0012)					

21 Linkages during the pre-crisis period
4 bi-directional linkages

11 Linkages during the crisis period
1 bi-directional linkage

Note: (→) denotes linkages in the pre-crisis period while (→) indicates linkages in the crisis period

Coefficients [χ^2], p-values are in parenthesis – significant at 10% level[2]

[1] Table 12a in the appendix presents a simpler display of the above results

As previously in the first part of our analysis, results of table 12 do not clearly reveal which bond markets act as a “leader”, in terms of affecting the highest number of other bond markets. This finding suggests a fragile connection between the eleven EMU bond markets as well as a week degree of financial integration of these markets overtime. Moreover, the number and the direction of causal linkages are different in the two periods, except of the impact of Denmark to Sweden and UK. More analytically, Denmark, Spain and Italy seems to influence most of the other bond markets during the pre-crisis period but turning to the crisis period this large influence from Italy and Spain is restricted to only one marker for each case. On the other hand Denmark is retaining its influence as it still impacts five bond markets, namely UK, Sweden, Greece, Italy and Spain. Furthermore, while UK and Ireland Granger cause one and two markets respectively during pre-crisis, they do not cause any market in the crisis period. Portugal also, does not cause any bond markets in any of the two periods. Interestingly, Greece does not play a crucial role in the first period but in the second one Greece affects bond markets such as Denmark, Ireland and UK. Finally, the number of bi-directional linkages is reduced to only one during the crisis from four in the pre-crisis period.

Overall, this fragility in the linkages among the bond markets has not been explained adequately by the existing literature so far. Thus, this fragility it is possible to be explained by several facts.

First of all, many countries of the euro zone periphery, such as Greece, Ireland, Spain and Portugal) had several sharp increases in debt associated to huge fiscal deficits. Moreover, declining confidence among market participants in policy-makers, and the retreat of cross-border investors, contributed further to a market perception of worsening “fundamentals” and as a consequence, these budget deficits and liquidity problems during the crisis period have generated the defiance of the capital markets in the governments’ capacity to align and coordinate economic policies with their more credible European partners.

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Secondly, another key fact pointed by Clare et al., (1995) and Barassi et al., (2001) is the existence of financial barriers to the access of the European bond markets like different taxation structures and institutional features and also heterogeneous fiscal policies regarding long-term interest.

Thirdly, as Pagano and von Thadden (2004) noticed, some other factors contributing to the lack of a consistent long-run relationship among the bond markets may be country-specific risk differences, i.e., one country's bonds (like those from Greece, Ireland and Portugal) may be more risky than another country's (such as Germany or France) and liquidity differences across bond markets which implies that Euro area government bonds are not perfect substitutes.

Country specific-risk differences may also impact the transmission channels as well and specifically a contagion effect from Greece to other bond markets could affect these transmission channels of shocks. Intrusively, a contagion effect refers to an increase in the number of causality relationships between bond markets. In our analysis results indicate that a shock to periphery EMU countries influence an important part of other EMU and non-EMU counties as well. We should note that during the crisis period, European authorities adopted 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.

Furthermore, according to ECB's report for financial integration (2013) another possible explanation is risk aversion among investors. For instance, during 2003-2007, all euro area government bonds yields were similarly priced, irrelevant of ratings and differences in fiscal positions between countries, which were already pronounced at that time. This reflected a high risk tolerance and therefore low risk premium but since 2008, risk sensitivity has increased – and may in some cases have led to an overpricing of risk.

Closely related to the previous factor, the fragility of linkages in yields can also be explained by liquidity effects. In particular, during periods of high intensity, investors tend to shift transfer investment flows towards highly liquid bonds issued by non-distressed countries and as aftereffect such "safe haven" flows depress the bond yields of non-distressed countries, most notably Germany, and increase the bond yields of distressed countries, such as Greece, thereby widening sovereign spreads.

Finally, our findings have important implications for investors and policymakers alike. For international investors, an understanding of the extent of comovement among Euro area bond markets is of crucial importance for the structure and adjustment of their international portfolios while implications also exist for portfolio diversification opportunities. Specifically, in case of higher bond market integration these implications may have considerably been diminished sovereign as bonds are becoming closer substitutes with a wider consequence of the depreciation of the Euro. On the other side, for policymakers, knowledge of the extent of integration among sovereign bond markets is meaningful for the conduct of the common monetary policy. Putting it differently, greater interdependence of bond yields among European countries may reduce the capability of the European Central Bank to influence long-term interest rates and thus attain price stability (see Clare and Lekkos, 2000).

6. Concluding Remarks

This study empirically investigates the degree of integration in the European government bond market and also the dynamic causal relationships for eleven Euro markets and three non-Euro markets. Our analysis focuses on two main periods: the pre-crisis period (from March 1998 to December 2009), and the crisis period (from December 2009 to October 2013). By making use of a multivariate Granger causality approach, integration of Euro bond markets is week and the number and the direction of causalities change between the two periods. The main implication of this finding is that a certain number of bond markets are still not part of the entire system's long-run equilibrium, indicating that "core" countries are more integrated compared to "periphery" countries within EMU. Furthermore, another notable finding suggests that although during the pre-crisis period "PIIGS" counties and the three non-EMU counties were fully integrated, during the crisis we do not find out cointegration among these markets. Accordingly, diversification benefits for bond portfolios are still exist, not only within euro area but also among "periphery" countries and non-EMU countries for countries that are not part of the cointegrating system. Finally greater interdependence of bond yields among European countries which may be triggered by contagion effects it is possible to reduce the capability of the European Central Bank to influence long-term interest rates and thus attain price stability.

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Appendix

Table 5. Unit Root Tests on Levels

ADF unit root test in levels			
p-value	intercept	trend & intercept	none
GREECE	0.3398	0.4904	0.2279
AUSTRIA	0.7818	0.2550	0.1897
BELGIUM	0.4663	0.1484	0.2664
FINLAND	0.7730	0.2053	0.2021
IRELAND	0.7050	0.8828	0.7113
FRANCE	0.7141	0.2432	0.2110
GERMANY	0.8068	0.3399	0.1745
ITALY	**0.0410**	0.1400	0.4473
SPAIN	0.0671	0.2204	0.3953
PORTUGAL	0.7288	0.8402	0.6651
NETHERLANDS	0.7827	0.3530	0.1974
UK	0.5094	0.2415	0.1602
SWEDEN	0.5854	0.0679	0.2086
DENMARK	0.8974	0.6799	0.3185
Phillips-Perron unit root test in levels			
p-value	intercept	trend & intercept	none
GREECE	0.2944	0.4234	0.2070
AUSTRIA	0.8035	0.3053	0.1796
BELGIUM	0.6264	0.2443	0.3012
FINLAND	0.7997	0.2570	0.2052
IRELAND	0.7102	0.8870	0.7107
FRANCE	0.7042	0.2128	0.2120
GERMANY	0.8063	0.3297	0.1744
ITALY	0.0635	0.1991	0.4624
SPAIN	0.0946	0.2844	0.4374
PORTUGAL	0.4066	0.5846	0.5103
NETHERLANDS	0.7754	0.3313	0.1994
UK	0.5302	0.2673	0.1548
SWEDEN	0.7044	0.1163	0.1966
DENMARK	0.8872	0.7062	0.3216

Table 6. Unit Root Tests on First Differences

ADF unit root test in first differences			
p-value	intercept	trend & intercept	none
GREECE	0.0001	0.0000	0.0001
AUSTRIA	0.0001	0.0000	0.0001
BELGIUM	0.0001	0.0000	0.0001
FINLAND	0.0000	0.0000	0.0000
IRELAND	0.0001	0.0000	0.0001
FRANCE	0.0001	0.0000	0.0001
GERMANY	0.0001	0.0000	0.0001
ITALY	0.0001	0.0000	0.0001
SPAIN	0.0000	0.0000	0.0000
PORTUGAL	0.0000	0.0000	0.0000
NETHERLANDS	0.0001	0.0000	0.0001
UK	0.0001	0.0000	0.0001
SWEDEN	0.0001	0.0000	0.0001
DENMARK	0.0000	0.0000	0.0000
Phillips-Perron unit root test in first differences			
p-value	intercept	trend & intercept	none
GREECE	0.0001	0.0000	0.0001
AUSTRIA	0.0001	0.0000	0.0001
BELGIUM	0.0001	0.0000	0.0001
FINLAND	0.0001	0.0000	0.0001
IRELAND	0.0001	0.0000	0.0001
FRANCE	0.0001	0.0000	0.0001
GERMANY	0.0001	0.0000	0.0001
ITALY	0.0001	0.0000	0.0001
SPAIN	0.0001	0.0000	0.0001
PORTUGAL	0.0001	0.0000	0.0001
NETHERLANDS	0.0001	0.0000	0.0001
UK	0.0001	0.0000	0.0001
SWEDEN	0.0001	0.0000	0.0001
DENMARK	0.0000	0.0000	0.0000

Table 9a. Short-run causality results among 11 Euro bond markers

Short - run relationships	
Pre-crisis period: 26/3/1998-16/12/2009	***Post-crisis period: 17/12/2009-31/10/2013***
Uni-directional Causality	Uni-directional Causality
AU → GR, IE	AU → GR, IE
BE → GR	BE → AU, FI, FR, NL
FI → AU, FR, NL	*GR → DE*
DE → AU, IE, PT	DE → IE
IE → BE, GR	IE → PT
IT → BE, GR, IE, PT, ES	IT→ BE, GR,
ES → AU, BE, FR, PT, NL	ES → BE, FI, FR, DE, IE, NL
PT → BE	*NL → IE, PT*
Bi-directional Causality	Bi-directional Causality
AU ↔ IT	BE ↔ DE
AU ↔ PT	GR↔ IE
BE ↔ FI	
FI↔ IT	
FI ↔ PT	
FI ↔ ES	
IE ↔ PT	
Total : 36 Linkages	Total : 23 Linkages

Table 12a. Short - run relationships among 'PIIGS' & Denmark, Sweden & UK

Short - run relationships	
Pre-crisis period: 26/3/1998-16/12/2009	***Post-crisis period: 17/12/2009-31/10/2013***
Uni-directional Causality	Uni-directional Causality
IE→ Gr IT→ IE, PT, SE ES→ IT, PT, UK, SE SE → GR DK→ IE, PT, UK, SE	*GR → IE,UK* IT → ES ES → IE SE → ES DK→ IT, ES, UK, SE
Bi-directional Causality	Bi-directional Causality
DK ↔ IT DK ↔ ES IE ↔ UK ES↔ IT	GR↔ DK
Total : 21 Linkages	Total : 11 Linkages