Title: Flight-to-quality and contagion in the European Sovereign Debt Crisis: the cases of Portugal and Greece

Structured abstract

Purpose: This work analyses the co-movements between the Portuguese, Greek, Irish and German government bond markets after the subprime crisis (2007 to 2013), with a special focus on the European sovereign debt crisis. It aims to assess the existence of contagion between the Portuguese, Greece and Irish bond markets, and to explore the phenomenon of flight-to-quality from the Portuguese and Greek bond markets to the German market.

Methodology: The analysis is undertaken using a DCC-GARCH model with daily data for 10-year yield government bonds. The change in correlation from the stable periods to the crisis periods is used to identify contagion or flight-to-quality.

Findings: Results suggest there was contagion between the Greek and Portuguese markets, and to a lesser extent between the Irish and Portuguese markets. During most of the identified crisis periods, there are evident flight-to-quality flows from the Portuguese and Greek bond markets to the German market.

Originality/value: This paper contributes to the literature by applying the methodology DCC-GARCH to several crisis episodes for the analysis of contagion and flight-to-quality during the European sovereign debt crisis.

Keywords: financial contagion; flight-to-quality; European sovereign debt crisis; DCC-GARCH model, Portugal, Greece.

JEL Codes: E44, F34, F32

1. Introduction

The European sovereign debt crisis was a dramatic event that rocked the foundations of the euro area. As its causes are diverse and debatable, it is important for policy purposes to understand whether the public debt yields of peripheral countries grew due to credit risk or to contagion.

Contagion destroys economic value and creates instability and overreaction in financial markets; this disturbs transactions and financial institutions and has strong negative consequences on employment and GDP. Kristoufek (2012) shows that financial crises have reduced market efficiency in a number of stock markets around the world. For example, the 2009 Greek crisis led to the exit of foreign investors, which induced herding behaviour in local investors and caused a decline in liquidity (Cajueiro et al., 2009). Herding behaviour was also found in the Portuguese stock market in the recent periods of market stress (Dos Santos and Lagoa, 2017).

Greece has been blamed for triggering a contagion effect that gave rise to the eurozone crisis. For example, Missio and Watzka (2011) and Arghyrou and Kontonikas (2012) conclude that there was contagion from Greece to various countries in the euro area. This paper complements the above works by investigating the relationship between the bond markets of countries that were most affected by the European sovereign debt crisis and requested external financial assistance (Portugal, Greece and Ireland). As we are interested in periods of acute crisis that could produce contagion or flight-to-quality phenomena, our analysis goes from January 2007 to March 2013, when spreads started to decrease sharply.

This paper has three main goals. Firstly, it aims to determine whether there was contagion between Portugal, Greece and Ireland. Secondly, it endeavours to confirm the existence of flight-to-quality flows from the Portuguese and Greek bond markets to the German bond market during crisis periods. Thirdly, as Ireland is considered less risky than Greece or Portugal, we will establish whether the Portuguese bond market is drawing closer to the Irish as some market news suggests (Diário Económico, 2013) or, alternatively, continues to be highly correlated with the Greek market.

We use daily data for 10 year maturity yields of government bonds. The methodology is based on a DCC-IGARCH model (Dynamic Conditional Correlation - Integrated Generalised

Autoregressive Conditional Heteroskedasticity) to obtain dynamic correlations between pairs of yields.

This paper contributes to the literature by combining the DCC-IGARCH methodology with the identification of several crisis periods during the European sovereign debt crisis to assess the existence of contagion and flight-to-quality.

Results reveal that there was contagion between the Greek and Portuguese bond markets in most of the crisis periods identified. Although less marked, significant contagion was also observed between Portugal and Ireland. Portugal's sovereign bond market does not seem to be decoupling from that of Greece or coupling with the Irish bond market. Moreover, we conclude that there was flight-to-quality from both Portugal and Greece to Germany in most of the identified crisis periods.

The paper is organised as follows. Section 2 presents the theoretical framework and literature review on contagion and euro area public debt crisis. In Section 3, we set out the hypotheses, describe the data and methodology. In Section 4, we provide the results of the empirical analysis and Section 5 concludes.

2. Theoretical Framework and literature review

This section reviews the literature on the origins of the eurozone crisis and on financial contagion.

The origin of the European sovereign debt crisis

The reasons given for the European sovereign debt crisis range from the design of the European Monetary Union (EMU) to country-specific situations. According to De Grauwe (2011) a national bond market in a monetary union is very vulnerable because domestic policy makers have no control over issuing money and are therefore unable to guarantee the necessary liquidity to pay debt holders. Contagion between different bond markets can only be stopped if a central bank is available to assume the position of lender of last resort; the ECB was slow to do this.

According to Arghyrou and Tsoukalas (2011) and Arghyrou and Kontonikas (2012) contagion can be understood in the context of second generation exchange rate crisis models. The authors state that by late 2008/early 2009, agents believed that the deterioration of Greek macroeconomic fundamentals made its position in the monetary union unsustainable.

Moreover, as multiple equilibria derive from problems in market coordination, fundamentals cannot in themselves explain how a country moves from one equilibrium to another (Pericoli and Sbracia, 2003); however, they can explain why certain countries are more vulnerable to crises than others.

The sovereign debt crisis in the euro area highlighted some of its weaknesses, notably the large structural differences between member-states, the peripheral economies' macroeconomic disequilibria and the strong correlation between country and banks risks. According to Reinhart and Rogoff (2010), sovereign debt crises tend to be preceded by crises in the banking system.

Higgins and Klitgaard (2011) also stress the asymmetry between economies in the euro area. They claim that the low interest rates available to all countries joining the EMU led to an increase in external debt (both public and private); this was particularly true of the peripheral economies where interest rates used to be much higher. Before joining the EMU, peripheral countries helped sustain exports and economic growth by means of a weak currency, but as their ability to adjust the exchange rate was removed following the introduction of the euro, they faced the challenge of controlling domestic expenditure to maintain sustainable growth. Whereas both Portugal and Greece increased indebtedness to finance the deterioration of domestic savings, Spain and Ireland used debt to finance investment in real estate, causing a bubble in this sector. Furthermore, Ireland was facing problems related to toxic subprime products and the growth potential in Portugal, Spain and Greece did not increase to pay for the accumulated debt. While Portugal suffered from excess indebtedness in both private and public sectors, high public debt was the main problem in Greece.

Greece already had high levels of public debt before the EMU (Figure 1) and the low interest rates and easy access to credit after joining the euro allowed it to continue increasing public debt. On the other hand, until 2004Q1, public debt in Portugal was lower than 60%, and even less than this in Ireland.

[Figure 1 around here]

As some European countries were experiencing macroeconomic imbalances, the US Subprime crisis created the conditions for the emergence of the EA sovereign debt crisis (Moro, 2016). Trade links between both Europe and the US and within Europe facilitated the propagation of the Subprime crisis to Europe (European Commission, 2009). On the other hand, European banks suffered losses from holding US Subprime "toxic assets", the exact location of

which was unknown, generating an overall distrust between banks. Interbank lending stopped and this resulted in a reduction not only of credit to firms and households but also of economic confidence. The Subprime crisis increased risk aversion, leading markets to reassess the risk of European countries and producing more marked differences between countries' yields than before the crisis.

Countries like Portugal, Ireland, and Spain that had imbalances or were heavily dependent on external capital were the most severely affected by the sudden stop of capital during the sovereign debt crisis. In Ireland and Spain, this caused real estate bubbles to burst with implications for banks' nonperforming loans (Lane, 2012). On the other hand, Portugal and Greece suffered mainly from low structural economic growth, which raised doubts about the sustainability of public debt.

The problems in the banking system caused by the Subprime downturn (toxic assets and non-performing loans) played a central role in triggering the euro sovereign debt crisis. In the last months of 2008, government and central banks took increasing steps to support the financial system in an attempt to mitigate the effects on the real economy. In addition, the crisis reduced tax revenues and increased public expenditure (through fiscal stabilisers and an accommodative fiscal policy). Several European countries followed a counter-cyclical fiscal policy to respond to the deceleration of economic activity caused by the crisis (European Commission, 2009). This ultimately translated into an increase in public deficits and debt in a number of European countries. Greece proved to be the most dramatic case; at the end of 2009, it announced its public deficit was substantially higher than previously estimated (12.7% of GDP and not 6%), raising concerns about the sustainability of the debt and pushing public debt yields of both Greece and other countries higher. Moreover, the fiscal deficits before 2009 were also revised upward (Lane, 2012).

This situation ended in the external joint-intervention of the IMF (International Monetary Fund), ECB (European Central Bank) and the European Commission in Greece. The effects of the Greek crisis quickly spread to other countries in the euro area, where there was an unprecedented crisis of confidence together with speculative attacks on sovereign securities and successive debt downgrading. As a result, Ireland, Portugal and later Cyprus requested international financial aid. The problems in the sovereign debt fed back into banks, which were owners of large amounts of public debt (Baldwin and Gros, 2015), thus amplifying the effect of the crisis.

As shown by Balli (2009), the risk perception of eurozone government bonds changed dramatically with the sovereign debt crisis. After the creation of the euro, fiscal and other

macroeconomic variables ceased to explain yield fluctuations. The general belief was that if one country could not honour its commitments, the payment would be ensured by the whole EMU, so all the yields were similar. But confidence in the monetary union evaporated after the onset of the sovereign debt crisis, and the yields for each country started to reflect their debt levels and economic indicators (Afonso et al., 2012).

During the crisis, Portugal, Greece and Ireland had to support higher interest rates spreads on treasury bonds than Germany (Figure 2). These spreads were essentially linked to the credit risk premium, which depends on the level of public debt and on fiscal policies (Hsing, 2010), and on the risk related with recession and macroeconomic factors (Ludvigson and Ng, 2009).

[Figure 2 around here]

Spreads for Ireland started to decrease from mid-2011, for Portugal from the start of 2012, and for Greece from mid-2012. The decrease in spreads in 2012 is linked to both the ECB's July statement that it would do everything necessary to support the euro, and the announcement that it was ready to make Outright Monetary Transactions (OMTs) in secondary markets of euro area sovereign bonds (summer 2012) – see the ECB Annual Reports of 2010 to 2014 for a description of the monetary policy and bond market situation in 2010-14. In 2009, the ECB had already initiated a programme to buy covered bonds in euros (Covered Bonds Purchase Programme - CBPP). This was extended in 2011 (CBPP II) primarily to re-establish monetary policy transmission given the malfunctioning of markets. The Security Market Programme, which began in May 2010 with the aim of buying public and private debt securities, was another non-conventional policy adopted.

A further factor contributing to the decline in spreads was the ECB's decision in December 2011 to follow non-standard monetary policy measures to ensure liquidity to banks, namely longer-term refinancing operations (LTROs) with a maturity of three years and an increase in the type of collateral accepted for the concession of loans to banks. In the first quarter of 2012, these operations had a positive effect on the markets. In the same period, there was a private sector swap of Greek debt that improved the sustainability of its public debt.

Overall, the spreads of the peripheral countries continued to decrease in 2013 due to better prospects of economic growth that fostered the search for higher yields, as well as the more expansionary ECB policy both in terms of LTROs and the reduction of key interest rates (two cuts were made in 2013) - (Banco de Portugal, 2013). In July 2013, the ECB's forward

guidance stated that it would maintain interest rates at low levels for a long period. The successful end of financial assistance for Ireland and Spain also helped reduce spreads in 2013. The improvement in the conditions in Portugal and Ireland permitted future access to primary bond markets.

However, uncertainties emerged in the euro area bond market between January and May 2013 with flight-to-quality movements that were explained largely by the financial assistance programme for Cyprus.

In 2014, Portugal's successful exit from the financial support programme contributed to the continued decline of its yields and those of the peripheral countries, and allowed Portugal to regain access to the bond market. The euro area countries with the best macroeconomic and fiscal fundamentals registered the biggest decline in yields (ECB, 2014). From June to October 2014, the ECB continued to lower key interest rates and maintained LTROs; it also started the purchase of selected private sector assets (Asset-Backed Security – ABSPP) and continued the covered bond programme (CBPP III). At the beginning of 2015 the ECB decided to buy, in the secondary market, securities issued by governments following a policy of quantitative easing, which reduced yields considerably.

The ABS programme aimed to increase banks' liquidity, liberate capital and allow them to take full advantage of the LTROs (Altomonte and Bussoli, 2014). The announced programme of buying unlimited public debt on the secondary market from countries in difficulty had a significant downward effect on the yields of Italy and Spain, with spillovers to the credit market and economic growth (Altavilla et al., 2014).

Financial contagion

Studies of financial contagion have focused largely on the crises in emerging countries. Due to the recent subprime and euro sovereign debt crises and their rapid spread to several countries that were initially free of problems, the contagion of crises has now become a subject of special interest. Despite the vast literature, there is no consensus on the definition of financial contagion or on the methodology to test it. Nevertheless, it is generally accepted that contagion implies that the links between markets intensify after the occurrence of a shock in one market, and thus the collapse of one of them leads to the fall of the others (Forbes and Rigobon, 2002).

This concept cannot be confused with interdependence, which does not imply an increase in the relationship between markets (Gonzalo and Olmo, 2005).[1]

Contagion is defined herein as a significant increase in the co-movement of asset prices across markets, relative to a standard period, conditional on a crisis occurring in one market or group of markets (Pericoli and Sbracia, 2003). Consequently, the methodology used in this work is based on the calculation of the correlation coefficient, as employed by most authors adopting this definition.

In the literature on financial contagion, the authors are divided into those advocating that contagion is due to changes in macroeconomic fundamentals in each country, and those who argue that contagion is the result of action by international investors (Masson, 1999; Pritsker, 2001; Forbes and Rigobon, 2002).

The first group of authors state that changes in a country's macroeconomic fundamentals create vulnerability during a crisis. The existence of strong trade links between countries in the eurozone and the effect of the sovereign debt crisis on the banking system constitute potential channels of contagion (Sachs et al., 1996).

On the other hand, the authors allocating the responsibility for contagion to international investors claim that certain behaviour, such as "herd behaviour", panic or changes in the investor's sentiment, increases systemic risk (Forbes and Rigobon, 2002). Brunnermeier and Pedersen (2005) studied the role of predatory trading, and Kyle and Xiong (2001) addressed wealth constraints. Boyer et al. (2006) analysed portfolio rebalancing, that is when investors adjust their portfolios to changes in the risk of each country after a shock, moving funds from countries that did not suffer a direct shock but that are perceived as affected. Contagion by portfolio rebalancing may occur either through flight-to-quality from stocks to bonds in the same country or through cross-market rebalancing (involving different national markets).

Contagion has been studied in several financial markets, including the bonds market. Caceres and Unsal (2013) analyse the yields and volatility of treasury bonds in the Asian market after the collapse of the Lehman Brothers. They conclude that contagion did take place and that the effect of the overall risk aversion factor varied from one country to another: countries such as Australia benefited from the increase in the overall risk (the yields decreased) because of safe-haven flows; on the other hand, countries like the Philippines, India and Malaysia were penalised and their sovereign bond yields increased. Finally, the fundamentals of each country had an impact on spreads, namely with spreads increasing when fiscal balances deteriorated.

[1] In this case, there is no contagion because the correlation between markets does not increase.

Dajcman (2012) finds that after the start of the sovereign debt crisis in the eurozone, flight-to-quality from stocks to sovereign bonds ceased in most of the affected countries. Horta et al. (2014) concluded that the 2010 Greek crisis generated contagion assessed in terms of market efficiency across stock markets, including Portugal and the UK.

Regarding contagion in eurozone bond markets, Missio and Watzka (2011) use a DCC-GARCH model to analyse contagion in a group of six euro area countries (Portugal, Spain, Italy, Belgium, Netherlands and Austria) between December 31, 2008 and December 31, 2010. They conclude that in summer 2010 there was contagion from Greece to Portugal, Spain, Italy and Belgium. However, the authors emphasise that contagion worsened the pre-existing fundamental problems in the countries.

Similarly, Afonso et al. (2012), Arghyrou and Kontonikas (2012) and Constâncio (2012) show that there was contagion from the Greek sovereign debt crisis to most countries of the Monetary Union, but that it was more marked in Portugal, Ireland and Spain which had weaker macroeconomic fundamentals. For selected European countries from 2007 to 2010, Arezki et al. (2011) find that flight-to-quality and contagion explain the variation in sovereign CDS spreads in response to rating changes.

In conclusion, empirical work confirms there was contagion from Greece to other peripheral countries and it is explained by the eurozone's characteristics, namely: some countries with weak fundamentals, strong commercial links, change in expectations about countries remaining in the EMU, the fact that the central bank did not act as lender of last resort, and heavy link between bank risk and sovereign risk. The contagion effect was stronger for Greece, Ireland and Portugal; Ireland displayed fewer structural problems, and Greece had the worst situation in terms of public debt and the greatest difficulty in implementing recessionary fiscal measures. The flight-to-quality effect, i.e. increase in flows to assets and countries considered safe-havens, was present in the Asian and European crises.

3. Data, methodology and hypotheses.

This section sets out the hypotheses and describes the data and methodology.

Contagion and flight-to-quality test

There are several possible definitions of contagion. We use one of the five definitions identified by Pericoli and Sbracia (2001), namely that contagion occurs when there is an increase in the co-movement between asset prices among countries as a result of a crisis in one of them. This definition has the advantage of reflecting what is commonly interpreted as contagion.

In order to test contagion and flight-to-quality, we look at changes in the correlation between bond markets following Baur and Lucey (2009), who study the co-movement between the bond and the stock markets in the same country. According to these authors, there is evidence of contagion when the correlation coefficient between both markets increases significantly in a crisis period, relative to a benchmark period of normality, and the correlation is positive. Flight-to-quality occurs when there is a significant decrease in the correlation coefficient in a crisis period, and it assumes negative values. When the study is conducted on the relationship between the stock and the bond market, flight-to-quality means a movement of flows from stocks to bonds. In our case, we are studying only the bond market, so flight-to-quality occurs from the market where losses are more marked (the market in crisis) to the market where losses are smaller or non-existent (Table 1).

[Table 1 around here]

This methodology demands the definition of the crisis periods. We identified these in line with the behaviour of the Portuguese, Greek and Irish bond markets. A crisis period is defined as one in which there are at least two days in a space of three weeks or less when the daily changes in yields are larger than 1.65 times the returns' standard deviation from the total sample (this threshold corresponds to less than 5% probability of occurrence in a normal distribution). When the same characteristics are observed in less than ten days, it means that the crisis is prolonged. The "at least two days in three weeks" rule best identified the crisis periods given the prior knowledge about these periods. A benchmark period is required to calculate the change in the correlation in the crisis period; it is defined as thirty days prior to the crisis.

The existence of contagion between the Portuguese and the Greek bond markets, and the Portuguese and Irish bond markets are the first and the second hypotheses to test, respectively. The existence of flight-to-quality from the Portuguese and Greek bond markets to the German bond market are the third and fourth hypotheses.

Data and econometric methodology

As usual in the literature, we use yields of treasury bonds with 10 years' maturity taken from Bloomberg. The data frequency is daily and covers the period from 1 January 2007 to 28 March 2013, except for Ireland which covers the period from 1 November 2007 to 28 March 2013 due the unavailability of previous data. The change in yields was computed as:

$$\text{Change in yields}_t = ln(\frac{Y_t}{Y_{t-1}}) \quad (1)$$

, where Y_t is yield in *t*.

In line with the definition adopted herein, contagion during a crisis is associated with increased co-movements in the returns of financial assets (measured by increased correlation). However, the correlation coefficient between assets returns is biased when the volatility of returns is not constant. Forges and Rigobon (2002) show that the correlation coefficient depends positively on the volatility of returns; as this increases during crises, we may have wrong signs of contagion. Therefore, we explicitly model the conditional variance and correlation of the series over time by using a bivariate-GARCH model (for each pair of countries). Namely, we adopt the Dynamic Conditional Correlation – GARCH model (DCC-GARCH) (Engle, 2002) that computes dynamic correlations correcting for heteroskedasticity, and thus no bias arises from changing volatility. Multivariate GARCH are commonly used in the analysis of the co-movement of asset returns (Dajcman, 2012) and DCC is an appropriate way of measuring the relationship between markets during crises (Boyer et al., 2006; Rajwani and Kumar, 2016). The DCC-GARCH model is parsimonious (with a small number of parameters), the correlation matrices estimated are positive definite, the results are easy to interpret and have an immediate theoretical reading, and the correlation between assets changes over time as required in a study of contagion that compares crises and stable periods.

The DCC-GARCH model describes the conditional variance and correlation of various series and consists of a non-linear combination of univariate GARCH-models. According to Naoui et al. (2010) and Missio and Watzka (2011), the model set-up involves two steps: first, the conditional variance is estimated for each variable using a univariate GARCH process; second, the standardised residuals from the first step are used to model the conditional correlation. Each asset follows a GARCH process, the order of which needs to be identified. The simplest case, the GARCH (1,1), takes the following form for asset *i*:

$$h_{i,t}=\omega_i + \alpha_i e^2_{i,t-1} + \beta_i h_{i,t-1} \quad (2)$$

, where h_t represents the conditional variance, e_t the filtered residual with zero mean and ω_i, α_i and parameters to be estimated.

The residuals are filtered previously using an ARIMA model to eliminate autocorrelation and to get zero average. Through the estimation of univariate GARCH models - equation (2), it is possible to obtain the matrix of standardised residuals, ε_t, required to create the DCC-GARCH model.

In a DCC(1,1) model, the dynamic covariance is estimated using the following equation[2]:

$$Q_t=(1- \alpha - \beta)\, \hat{O} + \alpha\varepsilon_{t-1}\, \varepsilon'_{t-1} + \beta Q_{t-1} \qquad (3)$$

, where Q_t is the time-varying covariance matrix of the standardised residuals ε_t, resulting from applying the univariate GARCH equation; $\hat{O}$ is the unconditional covariance matrix of the standardised residuals; the α's and the β's are non-negative parameters to be estimated by the DCC model and $\alpha + \beta \leq 1$. More precisely, the α's represent the reaction of the covariance to past shocks and the β's represent the reaction of the covariance to the previous covariance.

The unconditional covariance matrix $\hat{O}$ is positive definite and past shocks ($\varepsilon_{t-1}\, \varepsilon'_{t-1}$) are positive semidefinite; therefore, Q_t will also be positive definite because it is a weighted average of a positive definite matrix and a positive semidefinite matrix.

The normalisation of equation (3) is then performed to obtain the dynamic correlation matrices R_t:

$$R_t = Q^*_t{}^{-1}\, Q_t\, Q^*_t{}^{-1} \qquad (4)$$

, where Q^*_t is a diagonal matrix with the square roots of the diagonal of Q_t as diagonal elements. The elements of R_t will be $\rho_{ijt} = q_{ijt} / \sqrt{q_{ii} q_{jj}}$, ρ_{ijt} is the correlation coefficient between two assets, with the diagonal of R_t containing the correlation coefficients of an asset with itself; that is, 1. R_t allows us to derive the dynamic conditional correlation to test our hypotheses.

The covariance matrix of filtered residuals (and not of the standardised residuals) that vary over time is derived using the following equation:

[2] The DCC model can be generalised to have more lags of Q or more lags of the cross product of errors.

$$H_t = D_t R_t D_t \quad (5)$$

, where H_t is the covariance matrix; D_t is the diagonal matrix of standard deviations time variant, i.e. $D_t = \text{diag}(h_{11t}^{1/2},..., h_{nnt}^{1/2})$ and each h_{iit} is the conditional variance described as a univariate GARCH model (equation 2). [3]

To illustrate the model, take the DCC (1,1) – GARCH (1,1) for Portugal (PT) and Greece (GR):

$r_{GR,t} = \gamma_{GR} + e_{GR,t}$

$r_{PT,t} = \gamma_{PT} + e_{PT,t}$

$h_{GR,t} = \omega_{GR} + \alpha_{GR} * e^2_{GR,\,t-1} + \beta_{GR} * h_{GR,t-1}$

$h_{PT,t} = \omega_{PT} + \alpha_{PT} * e^2_{PT,\,t-1} + \beta_{PT} * h_{PT,t-1}$

$Q_t = (1- \alpha - \beta)\hat{O} + \alpha\varepsilon_{t-1}\,\varepsilon'_{t-1} + \beta Q_{t-1}$

4. Empirical analysis

Preliminary analysis and definition of the crisis periods

First, we confirmed that the series of returns are stationary using the ADF test.[4] Next, using the methodology described above, we estimated the most appropriate ARIMA model for each series of the yields' return using the Schwarz criterion. The autocorrelation in each series was eliminated with an ARMA model (12,4) for Portugal [5], an ARMA (6,8) [6] for Greece, an AR (1) model for Ireland and an AR (3) for Germany. The residuals of these models are the ones used in the multivariate GARCH and denominated filtered residuals.

Using the methodology described in the previous chapter, we identified 12 crisis periods for the Portuguese bond market and 10 periods for the Greek bond market from January 2007 to March 2013. As some periods are common to both markets, a total of 18 crisis periods were studied for the two markets. Where there was a crisis in both countries, the longer crisis was

[3] GARCH-Multivariate model was estimated using RATS 8.0 program.

[4] These results were confirmed using the Phillips-Perron and the KPSS tests.

[5] The autoregressive terms from -2 to -5 and from -7 to -11 and the *moving-average* terms from -1 to -3 were not significant and were removed.

[6] The autoregressive terms -1, -4 and -5 and the *moving-average* terms from -2 to -7 were not significant and were removed.

considered for the purposes of our analysis. Regarding the relationship between the Portuguese and Irish markets, only two crisis periods originated in the Irish market.

In what follows, we first tested the hypothesis by making a graphic and qualitative analysis of the evolution of the DCC-GARCH correlations over the periods under study. We examined the correlation trend over long periods and looked for relevant evidence to test the hypotheses, namely the decoupling of Greece and Portugal. We then conducted a more detailed analysis to test for the existence of contagion or flight-to-quality in the identified crisis periods.

Portugal and Greece

To determine whether there was contagion between the Portuguese and Greek markets, we used the DCC (1,1) – IGARCH (1,1) model to obtain the correlation coefficient. An integrated model was used because the sum of conditional variance coefficients of the GARCH model was higher than 1. We performed tests for the absence of ARCH effects, no autocorrelation and normality of residuals (Table A1). Only the normality assumption was rejected, and thus a multivariate student distribution was used with the estimated degrees of freedom. [7]

[Figure 3 around here]

Until the start of the Subprime Crisis (fourth quarter of 2008), the Portuguese and Greek government 10-year bond yields were very similar (Figure 3) and the correlation between both was close to 1 (Figure 4). Although the correlation remains positive, from the Subprime Crisis onwards there is a downward trend and the yields also become more distant from each other. It is important to highlight the significant increase in the correlation after the Portuguese Financial Assistance Programme in April 2011. This occurred in conjunction with the increase in yields in both markets, showing evidence of contagion due to risk premium increases for both countries.

From August 2011 to January 2012, the correlation decreased, reaching -0.25, indicating a decoupling of the Greek and Portuguese situations. Later in 2012, the correlation grew again from its negative point at the beginning of the year. Although both countries' yields

[7] In all the models below we use IGARCH and the student distribution for the same reasons.

also increased, Greek yields went up more. Therefore, evidence does not confirm the news of consistent decoupling of the two markets up to March 2013.

[Figure 4 around here]

Turning now to the hypothesis of contagion during the crisis periods, we performed a more detailed analysis of the correlation between the two markets and studied the 18 identified periods in both bond markets (Table 2). There was contagion in 11 of those periods (61% of the crisis episodes). We found evidence of contagion in all main crisis episodes – subprime, crisis in Greece, Portugal and Cyprus.

[Table 2 around here]

Portugal and Ireland

We also studied the relationship between the sovereign bond markets of Portugal and Ireland to assess whether contagion is specifically a Portuguese and Greek phenomenon as these countries were the most affected by the crisis.

The graphical analysis of yields (Figure 5) shows that they remain relatively close until the Irish request for external intervention (November 2010), though Portuguese yields were slightly lower. Subsequently, Irish yields grew rapidly and Portuguese yields reached the same level in April 2011. Thereafter, the Irish yields began to decline but Portuguese yields kept growing.

It can be observed in Figure 6 that the correlation between the two markets obtained with the DCC (1,1) – IGARCH (1,1) model is always positive (except in May 2012) and that it has a downward trend until the end of 2011, when it starts fluctuating. It is important to mention that after the Irish intervention in November 2010, there is a sharp drop in the correlation of Portuguese and Irish yields.

[Figure 5 around here]

[Figure 6 around here]

In 2013, the correlation grew but at the same time both countries' yields fell. During this period, investors had the perception that Portugal was following Ireland on the road to recovery, moving away from Greece. In March 2013, the correlation fell again despite remaining positive; this is probably explained by the difficulties in the negotiation of the Cyprus rescue plan. It is important to remember that the correlation between Portugal and Greece increased (see above) during this period, which might indicate that Portugal was coming closer to Greece than to Ireland.

In a more detailed analysis of the crisis periods identified in the Portuguese and Irish markets, contagion was found in 6 of the 12 crisis periods, that is in 50% of the periods (Table 3). This confirms contagion between Portugal and Ireland; however, the market perceived the distance between the Irish and Portuguese cases to be greater than that of Greece and Portugal.

[Table 3 around here]

Discussion of results on contagion in the periphery

Our analysis concludes that contagion episodes between peripheral countries are common. Moreover, they are associated with a larger increase in yields than in the other crisis episodes where contagion is not prevalent: the correlation between the change in the yield during crises and the binary variable indicating contagion is 0.35 (p-value: 0.0719).[8]

The contagion between Ireland and Portugal occurred during the Portuguese, Greek and Irish crises. In the Portuguese and Irish episodes, the contagion took place at the first signs of crisis, showing an anticipation of events by the market. Other episodes of contagion were in response to news about crises in larger EA countries (Spain or Italy) or concerns about several countries.

The contagion between Portugal and Greece took place in similar situations, but not in response to the first signs of problems as in the Portuguese/Irish case. There was also contagion between Portugal and Greece in the Subprime crisis.

The episodes of simultaneous contagion in the pairs of countries - Portugal/Greece and Portugal/Ireland - came at the start of the Portuguese and Greek crises, and also when there

[8] A Spearman correlation coefficient was used. The binary variable of contagion takes the value one if there is contagion in that crisis episode and zero otherwise (in which case nothing occurs or there is flight to quality). In this analysis, we excluded the crisis episodes related with the Subprime crisis.

were events that affected large euro area countries (downgrading of Italian debt; political instability in Spain and Italy).

We can see that contagion usually occurs at the onset of a country's crisis. This is confirmed when analysing the 26 crisis episodes in the Portugal/Greece and Portugal/Ireland pairs: we correlated the binary variable for contagion with the binary variable taking the value one when the first signs of a crisis appear in Portugal, Greece, Ireland, Italy, Spain or Cyprus: the correlation obtained was 0.35 (p-value=0.0734).[9] In the specific case of Greece, this result was expected because the start of this country's crisis was a striking event; it led to a regime shift in which markets started to believe that the exit of Greece and other countries from the EA was a real possibility (Arghyrou and Kontonikas, 2012). The beginning of each national crisis is also when markets reassess the macroeconomic country risk and the potential sustainability of the public debt, adjusting portfolios and moving funds to safer countries.

Contagion also occurred when there was evidence that the crisis affected large EA countries as it means the problem was no longer restricted to the peripheral countries and started to have a systematic impact on the EA.

Note that there were more contagion episodes between Portugal and Greece than between Portugal and Ireland. One possible reason for that is that Greece and Portugal had weaker fundamentals than Ireland, notably growth potential, budget deficit and public debt (Afonso et al., 2012; Arghyrou and Kontonikas, 2012; and Constâncio, 2012). The Irish economic crisis was less severe and the recovery was faster than the Portuguese and Greek crises: in 2013 Ireland GDP growth was already 1.6%, whereas there was only some timid growth in Portugal and Greece in 2014 (0.9% and 0.7%, respectively). The greater alignment between countries' macroeconomic variables, namely economic growth, has been found to be related with contagion (Luchtenberg and Vu, 2015). The contagion between Portugal and Greece is also facilitated by the fact investors tend to see these Southern European countries as sharing similar characteristics.

Portugal and Germany

Now, we turn to the relationship between the German and Portuguese government bond markets. The aim is to test whether there was evidence of fight-to-quality from Portugal to

[9] A Spearman correlation coefficient was used. In this analysis we excluded the crisis episodes related with the Subprime crisis. See the previous footnote for the definition of the contagion binary variable.

Germany. According to the result from the DCC (1,1) – IGARCH (1,1) model, the correlation between 10-year German and Portuguese government bond yields (Figure 8) is close to 1 from 2007 to Q2 2008, and subsequently declined sharply due to the Subprime crisis. The same picture is obtained by analysing the yield levels, which were very similar in the two countries until September 2008 (Figure 7). By the end of 2009, the correlation between the two markets was close to zero, becoming negative with the Greek sovereign debt crisis in early 2010, which ultimately led to the request for external intervention on April 23rd 2010. The yields of both countries started to diverge at the end of 2009; while Portuguese yields reached more than 16%, German yields decreased to values close to 1%. Between November 2009 and April 2010, the correlation declined dramatically from 0.8 to -0.7. Thereafter, the correlation oscillated between positive and negative values, but were mostly negative. We can observe from Figure 7, which shows the Portuguese and German yields from 2010 to 2012, that the yields moved in opposite directions most of this time, with German yields declining and Portuguese yield growing. This confirms the higher demand for low risk bonds due to the increase in risk aversion during the euro sovereign debt crisis.

[Figure 7 around here]

Taking into account two paradigmatic periods of the Portuguese sovereign debt crisis - Portugal's external financial support (April 2011) and the downgrading of Portugal's rating to non-investment by the three main rating agencies (January 2012) - , we conclude that the correlation decreased in (Figure 8) and went from positive to negative. This suggests the occurrence of flight-to-quality in both periods.

[Figure 8 around here]

A deeper analysis of the crisis periods shows evidence of flight-to-quality from the Portuguese to the German market in 8 of the 12 identified crisis periods for the Portuguese market (2/3 of the periods) - (Table 4). It should be noted that one of the periods with no evidence of flight-to-quality is directly related to the sovereign debt crisis of the whole eurozone. Moreover, contagion only occurs in crisis episodes not directly related to Portugal,

which indicates that the crisis in Portugal did not impose a systemic risk for the eurozone and Germany.

[Table 4 around here]

Greece and Germany

Turning now to the analysis of the Greek and German markets during the crisis periods identified for the Greek market, we can see from the yields in Figure 9 the subprime crisis in late 2008 caused markets to diverge. Correlations (Figure 10) computed through the DCC (1,1) – IGARCH (1,1) model show that the values are close to 1 from 2007 to Q2 2008. We also observe evidence of flight-to-quality at the end of 2009, with correlation shifting from positive to negative values, as in the Portugal-Germany case; values became even more negative in early 2010 before the IMF-EU programme for Greece was initiated. It is interesting to note that the large drop in the correlation between Portugal and Germany and Greece and Germany occurred at the end of 2009 when incorrect statistical practices were unveiled in Greece; this revealed the true value of the Government deficit and debt and led immediately to the downgrading of Greek bonds to non-investment grade. Thereafter, the correlations between the Portuguese and German bond markets and the Greek and German bond markets were negative most of the time. However, the Greek rescue plan led to a temporary increase in the correlation with Germany. The same benign effect of the respective international financial support plan is observed for Portugal (with an increase in the correlation with Germany and above all a decrease in the correlation with Greece) and for Ireland (with a decrease in the correlation with Portugal).

[Figure 9 around here]
[Figure 10 around here]

It should be noted that when the correlation felt sharply between September 2012 and March 2013, the yields increased in the Greek market and decreased in the German market; this indicates increasing risk aversion. This behaviour is also verified in the Portuguese market, albeit with less intensity. In any case, the decrease in the correlation between the two peripheral

countries and Germany could be indicative that the European government bonds market was far from reaching stability in March 2013.

A deeper analysis of the correlation between the Greek and German markets shows evidence of flight-to-quality in 7 of the 10 identified crisis periods (in 70% of the periods) (Table 5). In contrast, there are two periods of contagion: one related with the Greek crisis in April 2010, and the other with instability in Greece and Spain in May 2012. This suggests that, unlike Portugal, Greece posed some danger to the functioning to the euro area, which justifies the contagion effect to Germany.

[Table 5 around here]

5. Conclusion

The results of this paper show that contagion occurred between peripheral countries (Portugal-Ireland and mostly Portugal-Greece) in most of the crisis periods. On the other hand, there was evidence of flight-to-quality from the Portuguese and Greek bond markets to the German market during most of the crises identified over the period.

Contrary to financial news, we do not confirm decoupling between the Portuguese and the Greek bond markets until early 2013. As for the relationship between the Portuguese and Irish bond markets, there was an upward trend in the correlation from May 2012, albeit with significant fluctuations. However, this rise is smaller than the increase in the correlation between Greece and Portugal. This suggests there was no significant coupling between Portugal and Ireland.

We also observe that the major structural break in the correlation between Portugal and Germany, and Greece and Germany was between the end of 2009 and May 2010, i.e. between the discovery of the real amount of Greek debt and the approval of the Greek rescue plan. This shows the importance of the Greek episode at the onset of the euro sovereign debt crisis. During that period, there was contagion even to Germany showing that Greece posed a threat to the functioning to the euro area, unlike Portugal.

The existence of contagion in most of the crisis periods identified highlights the importance of concerted action by regulatory authorities, governments and investors to block the channels of contagion. Claessens and Forbes (2004) indicates three areas where action is

needed to prevent contagion episodes: sound country policies, good private investor strategies, and better actions by international institutions. Regarding country policies, key areas of intervention include the promotion of sound fiscal policies that ensure sustainable debt burdens, the control of credit growth and real estate bubbles, and the strengthening of regulation and supervision of the financial system. National and European institutions should stress the monitoring of macroeconomic imbalances, notably those related with banking credit, real estate prices, and current account. Afonso et al. (2012) and Constâncio (2012) argue that the crisis can be solved through substantial improvements in countries' fundamentals

At the first signs of crisis, governments and central banks should act promptly to avoid the worsening of the situation. In the presence of contagion, it is reasonable for governments to request external assistance (Missio and Watzka, 2011). Constâncio (2012) also notes that central banks play a vital role in containing financial contagion. From the onset of a crisis, central banks and/or the European Stability Mechanism should provide affected countries with financing to avoid a liquidity crisis turning into a solvency crisis (De Grauwe, 2011). The mitigation of the link between the sovereign risk and banking risk, notably through the deepening of the European Banking Union, is an important element to improve crisis management and prevent escalation (Carbó-Valverde et al., 2015). The resilience of banks can also be improved by an increase in capital requirements for investments in sovereign debt bonds (Barth et al. 2012).

Private investors also play a relevant role in containing contagion by using adequate tools to manage and assess country risks, which allow an objective assessment and enable them to avoid herding behaviour. Our results have important implications for portfolio risk diversification, a key element in stable financial systems. Firstly, the existence of contagion shows that the advantages of international risk diversification will be reduced in periods of crisis and financial institutions will be more exposed to risk (Longin and Solnik, 2001). One way to improve risk management is to hold bonds from both peripheral countries and core countries (like Germany) to benefit from flight-to-quality movements.

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Tables

Table 1 - Interpretation of correlation coefficient between bond market A and bond market B.

Situation	Larger decline in market A	Larger decline in market B
Coefficient is positive, varies positively and stays positive	Contagion	
Coefficient is positive, varies negatively and stays positive.	Nothing happens	
Coefficient is positive, varies negatively and becomes negative.	Flight to market B	Flight to market A
Coefficient is negative, varies positively and stays negative.	Nothing happens	
Coefficient is negative varies negatively and stays negative.	Flight to market B	Flight to market A
Coefficient is negative, varies positively and becomes positive.	Contagion	

Table 2 - Identified Crises in the Portuguese and Greece markets.

Cause	Period	Number of crisis days	Number of days with market stress	Yield change in crisis period	Correlation before the crisis period	Correlation during the crisis period	Results
Subprime I	04-12-2008 to 08-12-2008	3	2	0.0661 (PT[10])	0.8418	0.8512	Contagion
Subprime II	06-01-2009 to 22-01-2009	13	3	0.1670 (PT)	0.7463	0.7206	Nothing takes place
Downgrade of Greek rating (Note 1)	09-12-2009 to 15-12-2009	5	2	0.0680 (GR[11])	0.7493	0.6343	Nothing takes place

[10] PT: Crisis identified in the Portuguese sovereign bond market.
[11] GR: Crisis identified in the Greek sovereign bond market.

Maintenance of the negative outlook for Portuguese rating (Note 2)	27-01-2010 to 03-02-2010	6	3	0.1008 (PT) 0.1417 (GR)	0.6607	0.7911	Contagion
Sovereign debt crisis in Greece	06-04-2010 to 14-05-2010	29	8	0.8086 (GR)	0.4700	0.6040	Contagion
Market instability (Greek crisis) (Note 3)	15-06-2010 to 23-06-2010	7	2	0.2359 (GR)	0.6072	0.6997	Contagion
Market instability related to Ireland (Note 4)	16-09-2010 to 20-09-2010	3	2	0.1060 (PT)	0.5691	0.4973	Nothing takes place
Sovereign debt crisis in Ireland	27-10-2010 to 10-11-2010	11	4	0.2432 (PT)	0.4105	0.4511	Contagion
Downgrade of Greek rating to non-investment grade (Note 5)	06-01-2011 to 18-01-2011	9	2	0.0607 (PT)	0.4747	0.3669	Nothing takes place
Market instability related to Portugal (Note 6)	18-04-2011 to 27-04-2011	8	2	0.1667 (GR)	0.3487	0.4879	Contagion
Sovereign debt crisis in Portugal	06-07-2011 to 11-07-2011	4	2	0.1978 (PT)	0.3744	0.3836	Contagion
Downgrade of Italian rating (Note 7)	05-09-2011 to 20-09-2011	12	2	0.1333 (PT)	0.5535	0.5698	Contagion
Market instability related to Greece (Note 8)	26-10-2011 to 01-11-2011	5	2	0.0243 (GR)	0.3194	0.2027	Nothing takes place
Political instability in Spain and Italy	24-11-2011 to 30-11-2011	5	4	0.2350 (PT)	0.1617	0.2919	Contagion
Rating downgrade of several countries (Note 9)	16-01-2012 to 30-01-2012	11	2	0.3696 (PT)	-0.1370	-0.0659	Nothing takes place
Granting of second international aid package to Greece.	22-03-2012 to 23-03-2012	2	2	0.1071 (GR)	0.0199	-0.2983	Flight to Portuguese market

Instability related to Greece and Spain (Note 10)	04-05-2012 to 18-05-2012	11	2	0.1357 (PT)	0.0397	0.1559	Contagion
Sovereign debt crisis in Cyprus	19-03-2013 to 27-03-2013	7	2	0.1344 (GR)	0.4303	0.6136	Contagion

Note:

- No. of days with stress: no. of days in which the yield variance exceeded the standard deviation of the series times 1.65.

- Yield variation in the crisis period: proportional change in yields accumulated during the period. (using a geometric average);

- Correlation between the crisis periods: the average correlation 30 days before the start of the period.

- Correlation during the crisis period: average correlation during the crisis period.

- Causes of crisis periods:

1- Rating agencies Fitch and Standard & Poor´s (S&P) downgraded Greek sovereign debt; 2 - Fitch declares it would keep the negative outlook for Portuguese sovereign debt, also stating that a downgrading would be more likely to happen. The Portuguese Treasury and Public Debt Agency (IGCP) had difficulty issuing debt; 3- Market instability associated to Greek sovereign debt crisis; 4- Ireland´s central bank announced that the cost of the bailout of Anglo Irish Bank (nationalised by the Irish government in January 2009) could reach €34.3 bn. This situation would push the budget deficit to 32% of GDP. Investors also had concerns about Portugal's public accounts; 5 – Rating agency Fitch downgrades the rating of Greek sovereign debt to non-investment grade, with negative outlook, making it equivalent to the rating assigned by the agencies S&P and Moody´s; 6- Market instability related to the request for economic and financial assistance programme by Portugal; 7 – Rating downgrade of Italian sovereign debt by S&P with negative outlook; 8 – Instability related to the financial assistance programme for Greece; 9 –S&P's downgrading of rating of the sovereign debt of 9 euro area countries, including Portugal, which attained a non-investment grade from the three major rating agencies; 10 – Political instability in Greece; bailout request by the fourth largest Spanish bank (Bankia).

Table 3 - Identified Crises in the Portuguese and Irish markets.

Cause	Period	Number of crisis days	Number of days with market stress	Yield change in crisis period	Correlation before the crisis period	Correlation during the crisis period	Results
Subprime I	04-12-2008 to 08-12-2008	3	2	0.0661 (PT[12])	0.8687	0.8271	Nothing takes place
Subprime II	06-01-2009 to 22-01-2009	13	3	0.1671 (PT)	0.8650	0.8512	Nothing takes place
Maintenance of the negative outlook for Portuguese rating (Note2)	28-01-2010 to 03-02-2010	5	2	0.1008 (PT)	0.7430	0.7674	Contagion

[12] PT: Crisis identified on Portuguese sovereign bond market.

Sovereign debt crisis in Greece	22-04-2010 to 06-05-2010	11	6	0.2677 (PT)	0.6271	0.7843	Contagion
Market instability related to Ireland (Note4)	25-08-2010 to 23-09-2010	22	5	0.2012 (IR[13])	0.7248	0.7773	Contagion
Sovereign debt crisis in Ireland	19-10-2010 to 24-11-2010	27	11	0.4543 (IR)	0.7562	0.7256	Nothing takes place
Greek debt was downgraded to a non-investment rating (Note5)	06-01-2011 to 18-01-2011	9	2	0.0607 (PT)	0.7436	0.5717	Nothing takes place
Sovereign debt crisis in Portugal	06-07-2011 to 11-07-2011	4	2	0.1977 (PT)	0.3583	0.2495	Nothing takes place
Italian debt was downgraded (Note7)	05-09-2011 to 20-09-2011	12	2	0.1333 (PT)	0.3797	0.3815	Contagion
Political instability in Spain and Italy	24-11-2011 to 30-11-2011	5	4	0.2350 (PT)	0.3224	0.4078	Contagion
Rating downgrading of several countries (Note9)	16-01-2012 to 30-01-2012	11	2	0.3696 (PT)	0.2621	0.4368	Contagion
Instability related to Greece and Spain (Note10)	04-05-2012 to 18-05-2012	11	2	0.1357 (PT)	0.1865	0.0786	Nothing takes place

Note: notes on crisis periods: see Table 2.

[13] IR: Crisis identified in Irish sovereign bond market.

Table 4 - Identified crisis for the Portuguese government bond market.

Cause	Period	Number of crisis days	Number of days with market stress	Yield change in crisis period	Correlation before the crisis period	Correlation during the crisis period	Results
Subprime I	04-12-2008 to 08-12-2008	3	2	0.0661	0.7666	0.8678	Contagion
Subprime II	06-01-2009 to 22-01-2009	13	3	0.1671	0.8795	0.7508	Nothing takes place
Maintenance of negative outlook for Portuguese rating (Note2)	28-01-2010 to 03-02-2010	5	2	0.1009	0.2585	-0.0303	Flight to German market
Sovereign debt crisis in Greece	22-04-2010 to 06-05-2010	11	6	0.2678	0.2188	-0.4108	Flight to German market
Market instability related to Ireland (Note4)	16-09-2010 to 20-09-2010	3	2	0.1060	0.0169	0.1552	Contagion
Sovereign debt crisis in Ireland	27-10-2010 to 10-11-2010	11	4	0.2432	0.0571	-0.0124	Flight to German market
Greek debt was downgraded to a non-investment rating (Note5)	06-01-2011 to 18-01-2011	9	2	0.0607	-0.1067	-0.1382	Flight to German market
Sovereign debt crisis in Portugal	06-07-2011 to 11-07-2011	4	2	0.1978	-0.1523	-0.3122	Flight to German market
Italian debt was downgraded (Note7)	05-09-2011 to 20-09-2011	12	2	0.1334	-0.0922	-0.1366	Flight to German market
Political instability in Spain and Italy	24-11-2011 to 30-11-2011	5	4	0,2350	0.0300	0.2498	Contagion
Rating downgrading of several countries (Note9)	16-01-2012 to 30-01-2012	11	2	0,3696	0.1005	-0.0247	Flight to German market
Instability related to Greece and Spain (Note10)	04-05-2012 to 18-05-2012	11	2	0,1357	0.0106	-0.0830	Flight to German market

Note: notes on crisis periods: see Table 2.

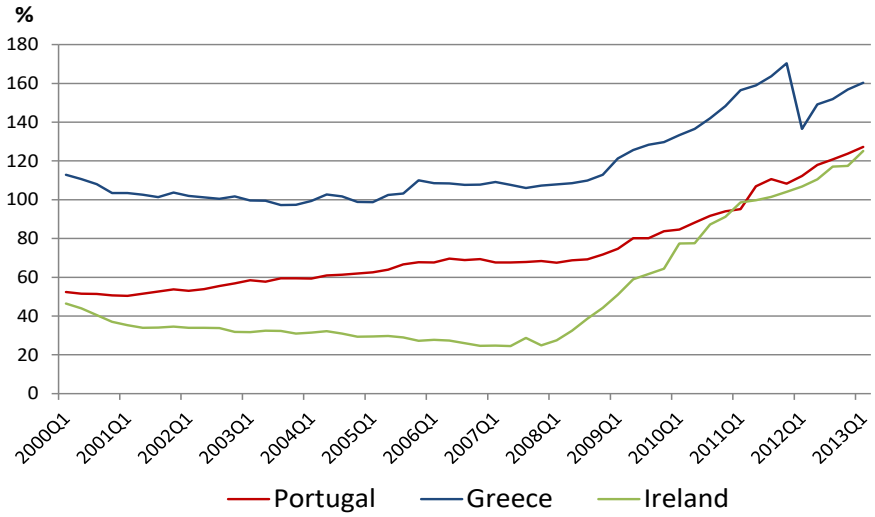
Table 5- Identified Crisis for the Greek Bond market.

Cause	Period	Number of crisis days	Number of days with market stress	Yield change in crisis period	Correlation before the crisis period	Correlation during the crisis period	Results
Downgrading of Greek rating (Note 1)	09-12-2009 to 15-12-2009	5	2	0.0680	0.5112	-0.2285	Flight to German market
Maintenance of negative outlook for Portuguese rating (Note2)	27-01-2010 to 28-01-2010	2	2	0.1418	-0.1242	-0.1982	Flight to German market
Sovereign debt crisis in Greece	06-04-2010 to 14-05-2010	29	8	0.8087	-0.0657	-0.2523	Flight to German market
Market instability related to Greece (Note3)	15-06-2010 to 23-06-2010	7	2	0.2359	-0.3508	0.0327	Contagion
Market instability related to Portugal (Note6)	18-04-2011 to 27-04-2011	8	2	0.1667	0.0291	-0.5383	Flight to German market
Downgrading of Italian rating (Note7)	05-09-2011 to 19-09-2011	11	4	0.2270	-0.0677	-0.2364	Flight to German market
Market instability related to Greece (Note8)	26-10-2011 to 01-11-2011	5	2	0.0243	-0.1540	-0.2185	Flight to German market
The second programme of external aid to Greece.	22-03-2012 to 23-03-2012	2	2	0.1071	-0.1719	-0.0854	Nothing takes place
Instability related to Greece and Spain (Note10)	07-05-2012 to 15-05-2012	7	3	0.4095	-0.2660	0.0309	Contagion
Sovereign debt crisis in Cyprus	19-03-2013 to 27-03-2013	7	2	0.1344	-0.4929	-0.7137	Flight to German market

Note: notes on crisis periods: see Table 2

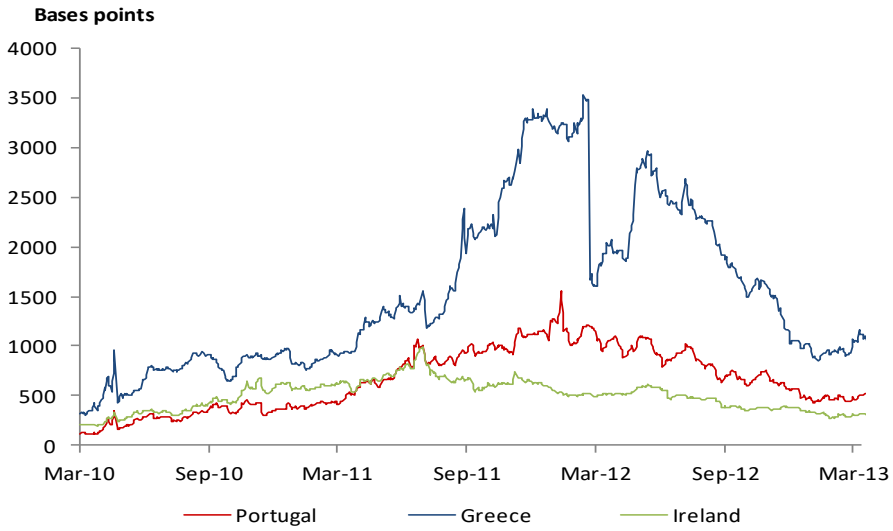
Figures

Figure 1 - Public debt as a percentage of GDP, quarterly data



Source: Eurostat, 2013

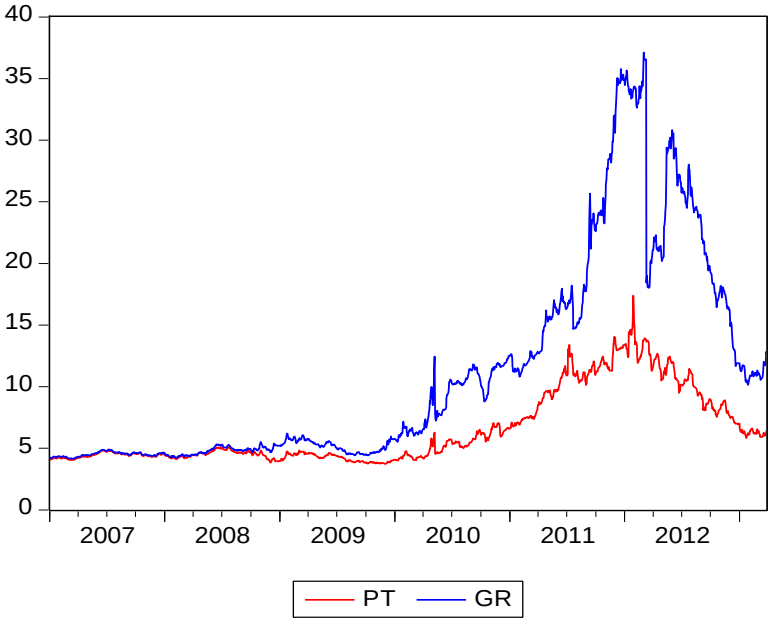
Figure 2 - Difference between 10-year government bond yields of Portugal, Greece[14] and Ireland compared to Germany, in base points (bp), from March 2010 to March 2013, daily data.



Source: Bloomberg, 2013

[14] The sharp drop in yields on government bonds of Greece, in March 2012, was due to the restructuring of Greek debt that consisted of a swap of debt with private creditors (implementation of the PSI-*Private Sector Involvement*). The operation involved the forgiveness of € 100 billion by these investors, reducing the weight of the debt.

Figure 3 - 10-year Portuguese and Greek government bond yields, as a percentage



Source: Bloomberg, 2013

Figure 4 - Correlation between 10-year Portuguese and Greek bonds (DCC (1,1)-IGARCH(1,1) Model).

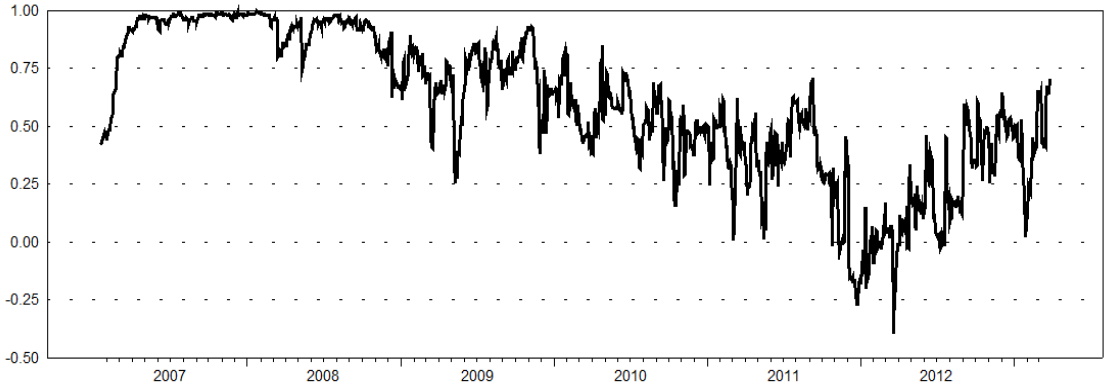
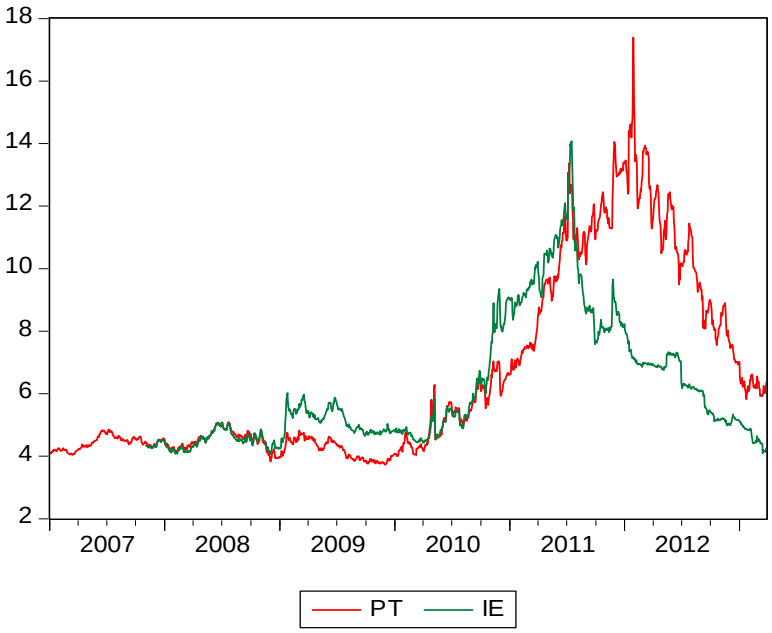


Figure 5- Portuguese and Irish 10-year Government Bond Yields, as a percentage.



Source: Bloomberg, 2013.

Figure 6 - Correlation between Portugal and Ireland (DCC (1,1)-IGARCH(1,1)Model).

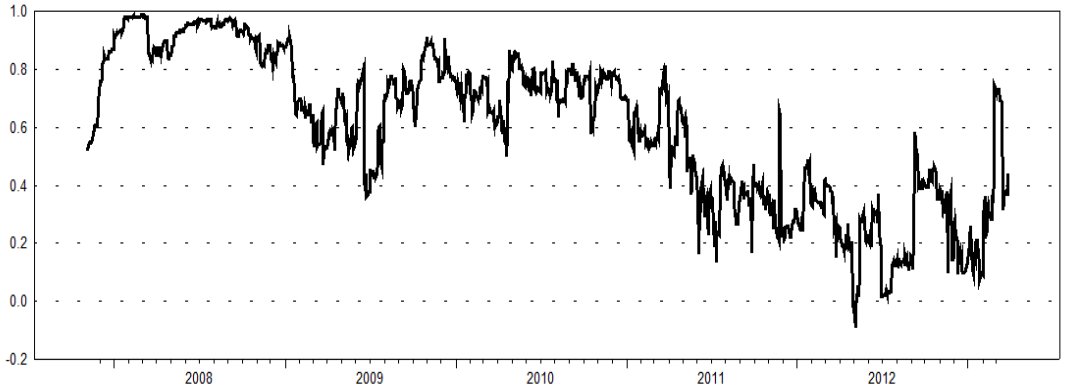
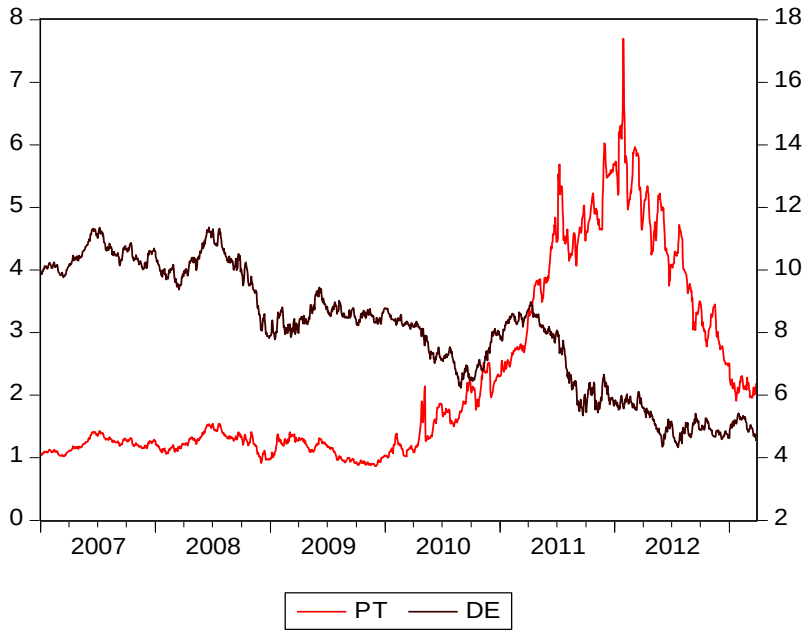


Figure 7- Portuguese (right side scale) and German 10-year government bond yields, as a percentage.



Source: Bloomberg, 2013

Figure 8 - Correlation between Portugal and Germany (DCC (1,1)-IGARCH(1,1) Model).

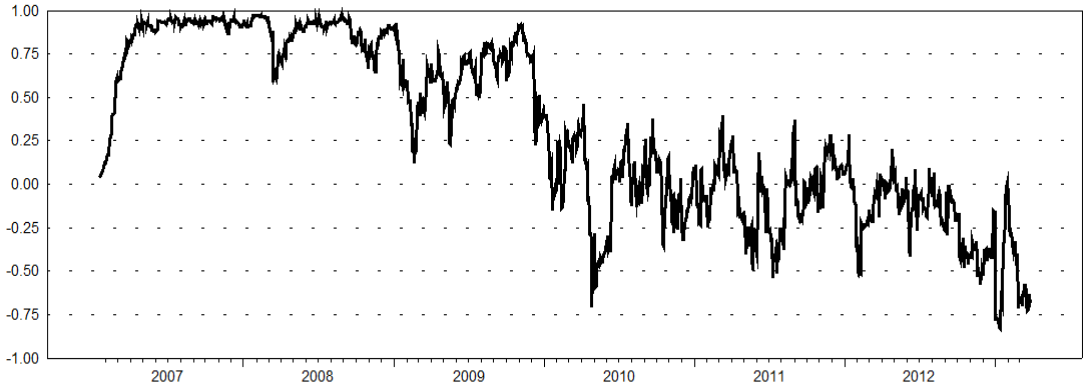
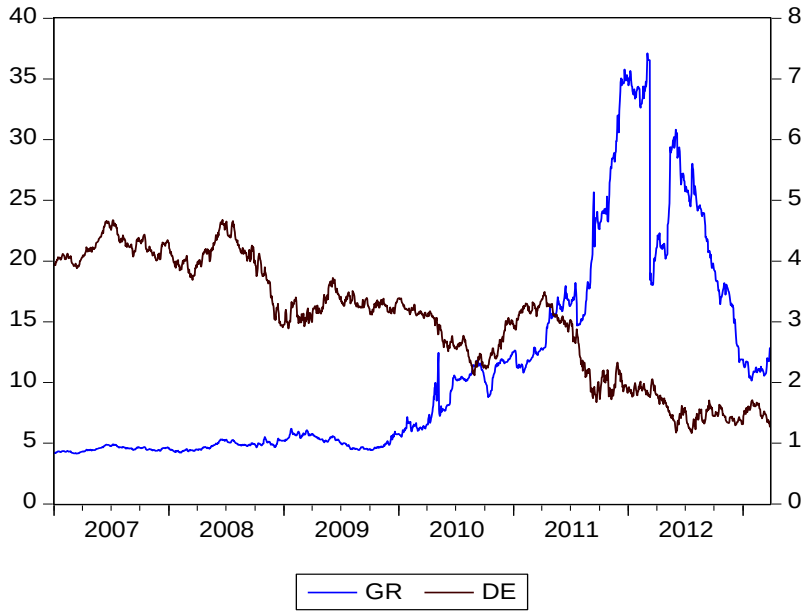
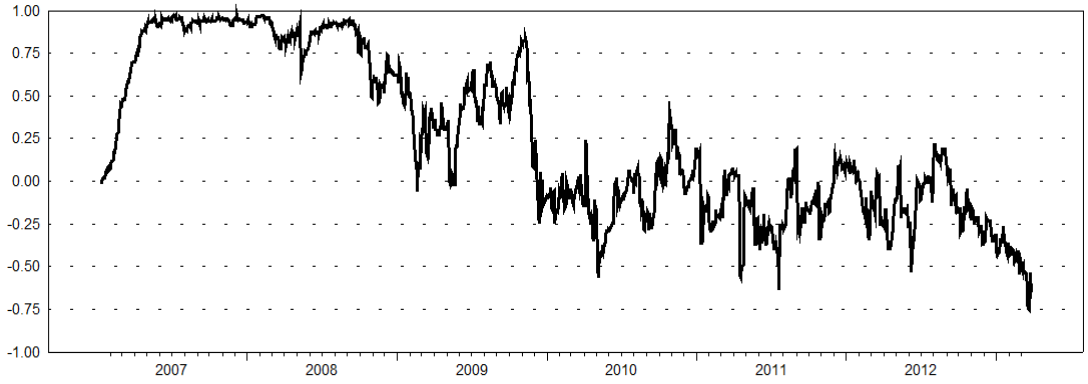


Figure 9- German (right side scale) and Greek 10-year government bond yields, as a percentage.



Source: Bloomberg, 2013

Figure 10 – Correlation between Greece and Germany (DCC (1,1)-IGARCH(1,1))



Appendix

Table A1 – Test on no ARCH effects, no autocorrelation, and normality of residuals.

Countries	**ARCH Test (multivariate)** **p-value of estat. χ^2**	**Autocorrelation Test (univariate)** **p-value of estat. Ljung Box lag (40)**	**Normality Test (univariate)** **p-value of Jarque Bera statistics**
Portugal and Greece	0.9974	PT: 0.2234 GR: 0.2352	PT: 0 GR: 0
Portugal and Ireland	0.9944	PT: 0.4189 IE: 0.2647	PT: 0 IR: 0
Portugal and Germany	0.1582	PT: 0.3425 DE: 0.4182	PT: 0 AL: 0
Greece and Germany	0.4816	GR: 0.2289 DE: 0.4223	GR: 0 AL: 0