Master in Actuarial and Financial Sciences

MASTER THESIS

EFFECTS OF MACROECONOMIC AND RATING ANNOUNCEMENTS ON THE CORRELATION OF PERIPHERAL GOVERNMENT BOND MARKETS.

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ABSTRACT

In this study we investigate the impact of conventional and unconventional measures made by central banks and rating announcements made by rating agencies on peripheral bonds correlations during the financial crisis (2007-2009) and the sovereign debt crisis (2010-2013). Previously, we estimate these correlations using the Dynamic Conditional Correlation (DCC) model proposed by Engle (2002). Our results reveal that peripheral bond markets became less integrated during the sovereign debt crisis and we find that negative news on interest rates and Quantitative Easing (QE) announcements had a negative impact on dynamic correlations and provided diversification opportunities. The effect of downgrades was also negative in most of the cases suggesting that the increased sovereign risk among peripheral countries lead to lower correlations.

KEYWORDS: sovereign debt crisis, dynamic conditional correlations, peripheral European countries, interest rate surprises, Quantitative Easings.

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1. INTRODUCTION

During the period 2007-2013 Europe has experienced one of its worst economic crises. It is a crisis that has caused a greater impact on those countries that had both fiscal and financial problems in their economies and labor markets. Our study focuses on the impact of this turbulent period in the bonds of peripheral economies, commonly called "PIGS", Portugal, Italy, Ireland, Greece and Spain. We analyze the relation among themselves as well as their relation with the European reference, Germany, with the aim of exploring the implications of the turmoil period on portfolio diversification. We also explore the effect of monetary policy and rating announcements on the relationship of bond markets.

Recent literature has been interested in analyzing European government bond markets. Initial studies focused on the role that the European Monetary Union (EMU) played in the process of financial integration of European Union (EU)-15 bond markets *(see Geyer et al., 2004; Pagano and von Thadden, 2004; Kim et al. 2006; Gomez-Puig, 2009 and 2009 and Abad et al., 2010)*. However, since the onset of the financial crisis and the subsequent European sovereign debt crisis, the focus has moved to the impact of these crises on European government bond market integration *(see Pozzi and Wolswijk, 2012; Cipollini et al., 2013; Abad et al., 2014 and Christiansen, 2014).*

On the other hand, a number of studies have analyzed the impact of macroeconomic news releases on financial markets *(see Fleming and Remolona (1999), Gürkaynaket al. (2005), and Andersen et al. (2007) among others)*. These studies differ in terms of the panel of economic news considered, the financial instrument, the frequency of observation and the time period examined. Hence, findings regarding which news systematically moves markets, as well as their relative importance, are sometimes conflicting.

Our study makes a number of contributions to the relevant literature. First, we analyze the evolution of the correlation among peripheral Government Bond markets while the previous literature has focused on the correlation of each bond market with the European reference *(see Abad and Chuliá, 2014)*. Second, we analyze the effects of conventional and unconventional monetary policy announcements made by the European Central Bank (ECB), the Federal Reserve (FED) and the Bank of England (BoE) on the correlation of bond markets employing announcement data which has been previously used by *Fawley & Neely (2013)* and *Tatiana (2013)* to examine the impact of QE announcements on the stock markets of developing economies. The prior literature does not consider the effect of unconventional announcements. Third, we also look at the effects of downgrades and upgrades announcements made by rating agencies. Finally, our sample includes the financial and the sovereign debt crises which enable us to analyze whether the effects of news announcements are different in both periods.

To carry on with the study, we use the Dynamic Conditional Correlation (DCC) multivariate model of *Engle (2002)* and then we use the correlations estimated as a dependent variable in regression equations with dummy variables that enables us to explore the effects of monetary policy and rating announcements on correlations and if their impact differs across crises. The sample period goes from 2007 to 2013 when investors have sought to move their investments towards more reliable and robust markets, always trying to avoid markets that may have contagion symptoms.

Several important findings stem from our analysis. First, we find that peripheral countries became less integrated during the sovereign crisis due to the growing uncertainty. Second, we find that positive surprises during the sovereign debt crisis, had a negative impact on dynamic correlations and provided diversification opportunities while, negative surprises, lead to an increase of correlations. Also, we find that the impact of surprises on correlations was higher during the sovereign debt crisis rather than the financial crisis. Third, results show that QE announcements had a negative impact on correlations during the sovereign debt crisis, suggesting diversification opportunities. Finally, we find that downgrades made by rating agencies had a negative impact on correlations as well.

The rest of the paper is organized as follows. Section 2 presents the data employed and Section 3 explains the model and the methodology applied. Section 4 discusses the empirical results and Section 4 concludes.

2. DATA

2.1. BOND YIELDS

We collect daily bond yields from BLOOMBERG and DATASTREAM INTERNACIONAL for five peripheral countries: Spain, Ireland, Italy, Portugal and Greece. We also collect data for Germany as a European reference. The inclusion of the German bond yield in the sample is due to the fact that this market serves as a European reference to compare against peripheral bond yields.

The data runs from 1rst August 2007 through 31th December 2013. Weekend days are excluded. As a result, we have 1675 observations for each country. In order to be able to compare the results between the financial crisis and the Sovereign debt crisis, we will analyze two periods of time. The financial crisis goes from August 1, 2007 to December 31, 2009 and the Sovereign debt crisis goes from January 1, 2010 to December 31, 2013. These yield bonds are transformed into daily rates of returns taking the first difference of the natural log of each bond yield.

First of all, we apply the Augmented Dickey Fuller (ADF) statistic in order to show if each bond yield data is stationary. This test has the unit root as the null hypothesis. Table 1 shows the results of the statistic tests for bond yields and bond returns.

TABLE 1

	$p_t(t-statistic)$	$p-value$	$r_t(t-statistic)$	$p-value$
Unit root statistics				
Spain	-2.206	(0.204)	-23.437	(0.000)
Greece	-1.418	(0.574)	-36.522	(0.000)
Ireland	-1.178	(0.685)	-35.512	(0.000)
Italy	-2.423	(0.135)	-29.824	(0.000)
Portugal	-1.382	(0.592)	-22.706	(0.000)
Germany	-1.529	(0.518)	-39.695	(0.000)

Note: Numbers in brackets are p-values. Results have been achieved using Augmented Dickey Fuller Statistic from E-VIEWS. p_t are the yield bonds and r_t are the returns. Source: own elaboration.

Looking at the results, we can conclude for each country that bond yield data series are non-stationary while their returns are stationary.

Table 2 shows some summary statistics for the bond yields. Specifically, we report information on the mean, standard deviation, skewness coefficient, kurtosis coefficient, and the Jarque–Bera normality test. This information is important to have a first sight of the behavior of bond yields of peripheral countries and Germany during the financial and sovereign crises.

TABLE 2

	Mean	*Std. Dev.*	*Skewness*	*Kurtosis*	*Jarque-Bera*
Summary statistics					
Spain	4.71	0.742	0.933	3.318	250.433
Greece	10.988	7.177	1.182	3.394	401.098
Ireland	5.804	2.071	1.38	4.356	660.697
Italy	4.658	0.664	1.392	4.921	798.781
Portugal	6.494	2.605	1.041	2.908	303.416
Germany	2.747	0.978	0.084	1.782	105.383

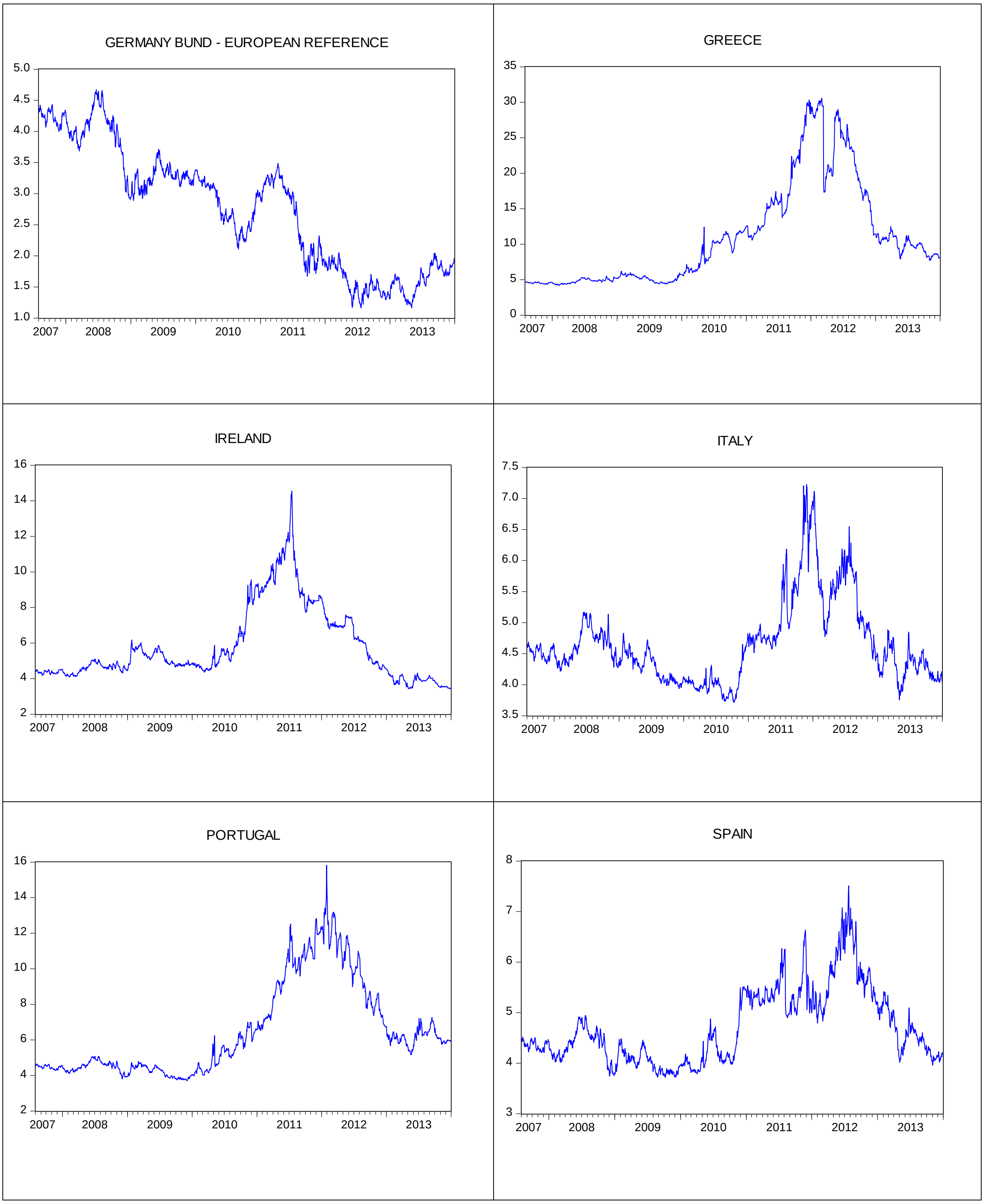
Note: Summary statistics have been obtained using E-VIEWS. Source: own elaboration.

As we expected, Greece has the greatest mean (10.998) while Germany has the lowest (2.747). This is due to the fact that Greece has had more problems during the financial and sovereign debt crisis to pay his debt as we will see later. The standard deviation will be the first step to see the volatility that each country reports. Greece has the greatest value (7.177) while Germany (as a reference) has the lowest (0.978).

For all bond markets the skewness is positive, which means that there are more values to the right of the mean while the kurtosis poses a platykurtic distribution and, therefore, a softer than a Normal elevation. Finally, the Jarque–Bera test confirms the existence of skewness and kurtosis and rejects the null hypothesis of normality.

Figure 1 displays the daily evolution of the bond yields in the analyzed period for each country. It is observed that Greece is the most unstable bond with a peak of 30.59. We find that yield bonds of peripheral countries experienced increases during 2011-2012 due to the growth of the uncertainty in this period of time while the European reference experienced a decreasing of its bond yield. Spain and Italy were the peripheral countries with lower increasing despite of the volatility displayed.

FIGURE 1



Note: Daily evolution of the peripheral and Germany bond yields. Source: own elaboration.

2.2. NEWS VARIABLES (ANNOUNCEMENT DATA)

Announcement data has been provided by BLOOMBERG and consists on unexpected changes in policy rates by the FED and the ECB *(see Chulia and Abad, 2014)*, Quantitative Easings made by ECB, FED and BoE *(see Fawley, Neely, 2013)*, changes in rating upgrades and rating downgrades in each peripheral country and the European reference. This data runs from 1rst August 2007 through 31th December 2013.

2.2.1. Changes in policyrates

An important finding in the existing literature about policyrates is that only the surprise component of monetary policy has a significant effect on asset returns whereas the effect of expected policy actions is statistically insignificant *(see Bomfin, 2003, Bernake and Kuttner, 2005, and Chulià and Abad (2014) among others)*. For this reason, we follow *Kuttner (2001)* to compute the "surprise effect". For an event taking place on day *d*, the unexpected, or "surprise" target rate change can be calculated as the change in the rate implied by the current-month futures contract, scaled up by a factor related to the number of days in the month affected by the change. In conclusion, we obtain the "surprise effect" as:

$$S = \frac{D}{D-d}(f_d - f_{d-1}) \qquad (2)$$

where *D* is the number of the days in the month and f_d is the current-month futures rate at the end of the announcement day *d*. Due to the fact that in the US the futures contract's payoff depends on the monthly average Federal funds rate, *Kuttner (2001)* uses a scaled version of the one-day change in current month federal funds future rate, and the scaled factor is included to reflect the number of remaining days in the month, which are affected by the change. This scaled factor is not necessary to obtain a measure of the surprise in the ECB announcement and, following *Bredinet al. (2007)*, we proxy surprise changes in the ECB policy rate by the one-day change in the three-month Euribor futures rate.

We separate negative and positive surprises by the BCE and the FED in order to investigate if their effects in correlations are different. A positive surprise means that the monetary policy rate was increased more or decreased less than markets anticipated. This represents bad news for bonds. In the same way, a negative surprise implies that the monetary policy rate ended up lower than expected, this is good news for bonds.

2.2.2. Quantitative Easings

Quantitative Easings are a kind of unconventional monetary policy measures where central banks purchase government securities in order to lower interest rates and increase the money supply. These measures have increased during the financial crisis and, specially, during the sovereign debt crisis. For instance BCE, FED and BoE have made important announcements of bonds purchases as we see in Tables 3, 4 and 5:

TABLE 3

QE announcements by the Federal Reserve

Date	*Program*	*Event*	*Brief Description*
11/25/2008	QE1	FOMC STATEMENT	LSAPs announced: Fed will purchase $100 billion in GSE debt and $500 billion in MBS.
12/01/2008	QE1	FOMC STATEMENT	First suggestion of extending QE to Treasuries.
12/16/2008	QE1	FOMC STATEMENT	First suggestion of extending QE to Treasuries by FOMC.
1/28/2009	QE1	FOMC STATEMENT	Fed stands ready to expand QE and buy Treasuries.
3/18/2009	QE1	FOMC STATEMENT	LSAPs expanded: Fed will purchase $1150 billion in long-term Treasuries, MBS and GSE debt
08/12/2009	QE1	FOMC STATEMENT	LSAPs slowed: All purchases will finish by the end of October, not mid-September.
9/23/2009	QE1	FOMC STATEMENT	LSAPs slowed: Agency debt and MBS purchases will finish at the end of 2010:Q1.
11/04/2009	QE1	FOMC STATEMENT	LSAPs downsized: Agency debt purchases will finish at $175 billion.
08/10/2010	QE1	FOMC STATEMENT	Balance sheet maintained: The Fed will reinvest principal payments from LSAPs in Treasuries.
8/27/2010	QE2	Bernake Speech	Bernanke suggests role for additional QE “should further action prove necessary.”
9/21/2010	QE2	FOMC STATEMENT	FOMC emphasizes low inflation
10/12/2010	QE2	FOMC minutes released	FOMC members’ “sense” is that “[additional] accommodation may be appropriate before long.”
10/15/2010	QE2	Bernake Speech	Bernanke reiterates that Fed stands ready to further ease policy.
11/03/2010	QE2	FOMC STATEMENT	QE2 announced: Fed will purchase $600 billion in Treasuries.
6/22/2011	QE2	FOMC STATEMENT	QE2 finishes: Treasury purchases will wrap up at the end of month, as scheduled
9/21/2011	Maturiry Extension Program	FOMC STATEMENT	(“Operation Twist”) announced: The Fed will purchase $400 billion of Treasuries
6/20/2012	Maturiry Extension Program	FOMC STATEMENT	The Fed will continue to purchase long-term securities and sell short-term securities
8/22/2012	QE3	FOMC minutes released	FOMC members “additional monetary accommodation would likely be warranted fairly soon…”
9/13/2012	QE3	FOMC STATEMENT	QE3 announced: The Fed will purchase $40 billion of MBS per month
12/12/2012	QE3	FOMC STATEMENT	QE3 expanded: The Fed will continue to purchase $45 billion of long-term Treasuries per month

Source: Fawley, Neely, 2013

TABLE 4

Date	*Program*	*Event*	*Brief Description*

QE announcements by the European Central Bank

3/28/2008	LTRO	Governing Council press release	LTRO expanded: 6-month LTROs are announced
10/15/2008	FRFA	Governing Council press release	Refinancing operations expanded
05/07/2009	CBPP/LTRO	Governing Council press release	The ECB will purchase €60 billion in euro-denominated covered bonds
05/10/2010	SMP	Governing Council press release	The ECB will conduct interventions in the euro area public and private debt securities markets
6/30/2010	CBPP	Governing Council press release	Purchases finish on schedule
10/06/2011	CBPP2	Governing Council press release	The ECB will purchase €40 billion in euro-denominated covered bonds
12/08/2011	LTRO	Governing Council press release	36-month LTROs are announced
08/02/2012	OMT	ECB press conference	Mario Draghi indicates that the ECB will expand sovereign debt purchases
09/06/2012	OMT	Governing Council press release	Debt purchased in unlimited amounts on the secondary market by the ECB.

Source: Fawley, Neely, 2013

TABLE 5

Date	*Program*	*Event*	*Brief Description*

QE announcements by the Bank of England

1/19/2009	APF	HM Treasury statement	The BOE will purchase up to £50 billion of “high quality private sector"
02/11/2009	APF	BOE Inflation Report	The BOE views a slight downside risk to meeting the inflation target
03/05/2009	APF	MPC statement	The BOE will purchase up to £75 billion in assets
05/07/2009	APF	MPC statement	The BOE will purchase up to £125 billion in assets
08/06/2009	APF	MPC statement	The BOE will purchase up to £175 billion in assets
11/05/2009	APF	MPC statement	The BOE will purchase up to £200 billion in assets.
02/04/2010	APF	MPC statement	The BOE maintains the stock of asset purchases financed by the issuance of reserves at £200 billion
10/06/2011	APF	MPC statement	The BOE will purchase up to £275 billion in assets financed by reserve issuance
11/29/2011	APF	HM Treasury decision	HM Treasury lowers the ceiling
02/09/2012	APF	MPC statement	The BOE will purchase up to £325 billion in assets
07/05/2012	APF	MPC statement	The BOE will purchase up to £375 billion in assets

Source: Fawley, Neely, 2013

This data has been provided by *Fawley and Neely (2013)* in *Four Stories of Quantitative Easings*. In this paper they present a brief description of each announcement of purchases by the Federal Reserve, the European Central Bank and the Bank of England as well as each purchase date provided by *Tatiana (2013)*.

2.2.3. *Ratings*

It is known that upgrades and downgrades in each peripheral country have had important consequences in their economies and we try to investigate their effect on the correlations of peripheral bond markets during the financial and sovereign debt crisis. Results could be important to show the behavior of these bond markets in the period of time investigated. Ratings have been separated into upgrades and downgrades to analyze if their effects on correlations are different. Table 6 displays downgrades and upgrades dates announced by S&P.

TABLE 6

Date	*Country*	*Date*	*Country*
Downgrades announcements		**Upgrades announcements**	
02/07/2009	Ireland	29/11/2013	Greece
22/12/2009	Greece		
22/04/2010	Greece		
14/06/2010	Greece		
13/07/2010	Portugal		
19/07/2010	Ireland		
30/09/2010	Spain		
17/12/2010	Ireland		
07/03/2011	Greece		
10/03/2011	Spain		
15/03/2011	Portugal		
05/04/2011	Portugal		
15/04/2011	Ireland		
01/06/2011	Greece		
05/07/2011	Portugal		
12/07/2011	Ireland		
25/07/2011	Greece		
04/10/2011	Italy		
18/10/2011	Spain		
13/02/2012	Spain, Italy and Portugal		
02/03/2012	Greece		
13/06/2012	Spain		
13/07/2012	Italy		

Source: own elaboration.

3. METHODOLOGY

Our study adopts two steps in order to explore the effects of the economic measures on each pair of bond yield correlations. First, we estimate the conditional correlation between each pair of bond yields using the DCC model of *Engle (2002)* and then we introduce these correlations as dependent variables in regression equations while the economic measures will be introduced as dummy variables. This approach will allow us obtain the impact of the interest rate changes, unconventional measures and rating announcements on peripheral bond market correlations.

3.1. DYNAMIC CONDITIONAL CORRELATION MODEL

The DCC model was proposed by *Engle (2002)* as a time - varying generalization of the constant conditional correlation (CCC) estimator proposed previously by *Bollerslev (1990)*. In the CCC model the covariance matrix can be expressed as the product of the diagonal matrix of standard deviations and the correlation matrix:

$$H_t = D_t R D_t \qquad (3)$$

Where:

- R contains a correlation matrix with constant conditional correlations
- D_t contains a diagonal matrix of standard deviations being

$$D_t = diag\{\sqrt{h_{i,t}}\} \qquad (4)$$

Engle (2002) proposed a time– varying correlation (R_t) in his work *Dynamic Conditional Correlation: A simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models* with the following covariance matrix:

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

This model allows us to obtain the dynamic conditional correlations between each pair of bond market correlations. As *Engle (2002)* proposed, we will estimate correlations in two steps. Firstly, we estimate a univariate GARCH(1,1) model for each variable and, secondly, the estimated variances are introduced as inputs in the estimation process. In equation (5):

- R_t contains a time-varying correlation matrix with dynamic conditional correlations.
- D_t contains a diagonal matrix of standard deviations.

- H_t contains a matrix of variances and covariances.

In other words:

$$H_t = \begin{bmatrix} \sigma_1^2 & \cdots & \sigma_{1,n}^2 \\ \vdots & \ddots & \vdots \\ \sigma_{1,n}^2 & \cdots & \sigma_n^2 \end{bmatrix}_t, R_t = \begin{bmatrix} 1 & \cdots & \rho_{1,n} \\ \vdots & \ddots & \vdots \\ \rho_{1,n} & \cdots & 1 \end{bmatrix}_t \, and \, D_t = \begin{bmatrix} \sqrt{h_{1,1}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{h_{i,t}} \end{bmatrix}_t \quad (6)$$

or equivalently,

$$\begin{bmatrix} \sigma_1^2 & \cdots & \sigma_{1,n}^2 \\ \vdots & \ddots & \vdots \\ \sigma_{1,n}^2 & \cdots & \sigma_n^2 \end{bmatrix}_t = \begin{bmatrix} \sqrt{h_{1,1}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{h_{i,t}} \end{bmatrix}_t \begin{bmatrix} 1 & \cdots & \rho_{1,n} \\ \vdots & \ddots & \vdots \\ \rho_{1,n} & \cdots & 1 \end{bmatrix}_t \begin{bmatrix} \sqrt{h_{1,1}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{h_{i,t}} \end{bmatrix}_t \quad (7)$$

Where $h_{i,t} \, for \, i = 1, \dots n$ shape a variance equation following a univariate GARCH (1,1) equation. We can also rewrite equation (5) as follows to obtain the correlation matrix:

$$R_t = D_t^{-1} H_t D_t^{-1} \quad (8)$$

Then, the standardized residuals are used to estimate the conditional correlations as follows:

$$R_t = (diag(Q_t))^{-1/2} Q_t (diag(Q_t))^{-1/2} \quad (9)$$

Where

- $Q_t = (1 - \alpha - \beta)\overline{Q_t} + \alpha(\varepsilon_{t-1}, \varepsilon_{t-1}^{'}) + \beta Q_{t-1}$ (10), being $\overline{Q_t}$ the unconditional covariance of the standardized residuals.

In equation (10), parameters α and β are scalars and allow this model to have a reverting mean if $\alpha + \beta < 1$

Finally, we obtain the time-varying correlation coefficient as:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}}; for \, i,j = 1,2 \dots n, and \, i \neq j \quad (11)$$

To sum up, we estimate the following equations in order to obtain the correlations:

$$Mean\ equation: r_{i,t} = \mu + \gamma_1 r_{i,t-1} + \varepsilon_{i,t}^2 \qquad (12)$$

$$Variance\ eqiation: h_{ii,t} = \omega_i + \alpha_{i,1}\varepsilon_{i,t-1}^2 + \beta_{i,1}h_{ii,t-1}\ for\ i = 1,2,\dots,n \qquad (13)$$

$$Q_t = (1-\alpha-\beta)\overline{Q_t} + \alpha(\varepsilon_{t-1}, \varepsilon_{t-1}') + \beta Q_{t-1}$$

$$DCC\ equation: \rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}; i,j = 1,2 \dots n, and\ i \neq j$$

3.2. REGRESSION EQUATIONS

Once the correlations have been estimated we use them in order to investigate the effects of each economic measure on the correlations. Each regression contains dummy variables whose coefficients indicate the impact of each announcement in the country-pair correlations. We also introduce in our regressions a dummy variable in order to investigate thoroughly if the dynamic behaviour of the correlation differs in each period of crisis.

3.2.1. Trend regression

First, we regress a time trend on the time-varying correlations to examine if they have changed over time. In this case the regression equation contains a constant and a time trend as an input. The regression equation is as follows:

$$\rho_{ij,t} = \omega + \alpha T_t + \varepsilon_{ij,t} (14)$$

Where

- $\rho_{ij,t}$ is the dynamic conditional correlation
- ω is a constant
- T_t is a time trend

3.2.2. Regression equation with dummy variable "crisis" as an input

We regress a dummy variable which allows us to analyze if the level of correlation differs between the two crisis periods. The regression equation is as follows:

$$\rho_{ij,t} = \omega + \alpha D_t^{crisis} + \varepsilon_{ij,t} \qquad (15)$$

Where

- $\boldsymbol{D_t^{crisis}}$ is a dummy variable that takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009) and the value 1during the sovereign debt crisis (01/01/2010 – 31/12/2013).

3.2.3. *Regression equation with the ECB and the FED interest rates surprises*

We regress ECB and FED interest rates surprises on correlations to examine if they have had an effect on them. We distinguish between positive and negative surprises and, in the same equation, we introduce a dummy variable in order to explore differences in the effects between crises. The regression equation is as follows:

$$\rho_{ij,t} = \omega + \alpha_1 D_t^{+ECB} + \alpha_2 D_t^{+ECB.C} + \alpha_3 D_t^{+FED} + \alpha_4 D_t^{+FED.C} + \alpha_5 D_t^{-ECB} + \alpha_6 D_t^{-ECB.C} + \alpha_7 D_t^{-FED} + \alpha_8 D_t^{-FED.C} + \varepsilon_{ij,t} \qquad (16)$$

Where

- $\boldsymbol{D_t^{+ECB}}$ is a dummy variable that takes the value of positive surprises by the ECB and 0 otherwise.

- $\boldsymbol{D_t^{+ECB.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value of positive surprises by the ECB during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_t^{+FED}}$ is a dummy variable that takes the value of positive surprises by the Fed and 0 otherwise.

- $\boldsymbol{D_t^{+FED.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value of positive surprises by the FED during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_t^{-ECB}}$ is a dummy variable that takes the value of negative surprises by the ECB and 0 otherwise.

- $\boldsymbol{D_t^{-ECB.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value of negative surprises by the ECB during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_t^{-FED}}$ is a dummy variable that takes the value of negative surprises by the Fed and 0 otherwise.

- $\boldsymbol{D_t^{-FED.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value of negative surprises by the FED during the sovereign debt crisis (01/01/2010 – 31/12/2013).

3.2.4. Regression equation with the ECB, the FED and the BoE Quantitative Easings (QE)

Quantitative Easings have become essential to mitigate the funding problems among peripheral countries within the sovereign debt crisis. We believe that this policy which has been promoted by central banks has had an important impact in the country-pair correlations that we have estimated. It is for this reason that we have decided to include a regression equation with the QE announcements as an input to investigate their effects on correlations. As we did previously, we have created a dummy variable in order to look into the differences on the impact of QE between the financial and sovereign debt crises.

The regression equation is as follows:

$$\rho_{ij,t} = \omega + \alpha_1 D_t^{ECB.QE} + \alpha_2 D_t^{ECB.QE.C} \alpha_3 D_t^{FED.QE} + \alpha_4 D_t^{FED.QE.C} + \alpha_5 D_t^{BoE.QE} + \alpha_6 D_t^{BoE.QE.C} + \varepsilon_{ij,t} \qquad (17)$$

Where

- $\boldsymbol{D_t^{ECB.QE}}$ is a dummy variable that takes the value 1 when there is a QE announcement promoted by the ECB and 0 otherwise.

- $\boldsymbol{D_t^{ECB.QE.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value 1 when there is a QE announcement promoted by the ECB during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_t^{FED.QE}}$ is a dummy variable that takes the value 1 when there is a QE announcement promoted by the FED and 0 otherwise.

- $\boldsymbol{D_t^{FED.QE.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value 1 when there is a QE announcement promoted by the FED during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_t^{BoE.QE}}$ is a dummy variable that takes the value 1 when there is a QE announcement promoted by the BoE and 0 otherwise.

- $\boldsymbol{D_t^{BoE.QE.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value 1 when there is a QE announcement promoted by the BoE during the sovereign debt crisis (01/01/2010 – 31/12/2013).

Is important to note that we are modelling the announcement impact effect, not the intensity of each QE due to the difficulties that could imply for the coefficients estimation process.

3.2.5. Regression equation with Upgrades & Downgrades Rating

Clearly upgrades and downgrades announcements made by rating agencies have become decisive to evaluate the financial solvency of each country and have had an important impact on their correlations. It is for this reason that we decide to introduce them as input variables in our regressions to analyse their effects on each country-pair correlation. The regression equation is as follows:

$$\rho_{ij,t} = \omega + \alpha_1 D_{i,1rt}^{Down} + \alpha_2 D_{i,1rt}^{Down.C} + \alpha_3 D_{i,1rt}^{Up} + \alpha_4 D_{i,1rt}^{Up.C} + \alpha_5 D_{i,2nd}^{Down} + \alpha_6 D_{i,2nd}^{Down.C} + D_{i,2nd}^{Up} + D_{i,2nd}^{Up.C} + \varepsilon_{ij,t} \qquad (18)$$

Where

- $\boldsymbol{D_{i,1rt}^{Down}}$ is a dummy variable that takes the value 1 when there is a downgrade announcement for the first country of each pair promoted by S&P and 0 otherwise.

- $\boldsymbol{D_{i,1rt}^{Down.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
  - Takes the value 1 when there is a downgrade announcement for the first country of each pair promoted by S&P during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_{i,1rt}^{Up}}$ is a dummy variable that takes the value 1 when there is an upgrade announcement for the first country of each pair promoted by S&P and 0 otherwise.

- $\boldsymbol{D_{i,1rt}^{Up.C}}$ is a dummy variable that:
  - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).

- Takes the value 1 when there is an upgrade announcement for the first country of each pair promoted by S&P during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_{i,2nd}^{Down}}$ is a dummy variable that takes the value 1 when there is a downgrade announcement for the second country of each pair promoted by S&P and 0 otherwise.

- $\boldsymbol{D_{i,2nd}^{Down.C}}$ is a dummy variable that:
    - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
    - Takes the value 1 when there is a downgrade announcement for the second country of each pair promoted by S&P during the sovereign debt crisis (01/01/2010 – 31/12/2013).

- $\boldsymbol{D_{i,2nd}^{Up}}$ is a dummy variable that takes the value 1 when there is an upgrade announcement for the second country of each pair promoted by S&P and 0 otherwise.

- $\boldsymbol{D_{i,2nd}^{Up.C}}$ is a dummy variable that:
    - Takes the value 0 during the financial crisis (01/08/2007 – 31/12/2009).
    - Takes the value 1 when there is an upgrade announcement for the second country of each pair promoted by S&P during the sovereign debt crisis (01/01/2010 – 31/12/2013).

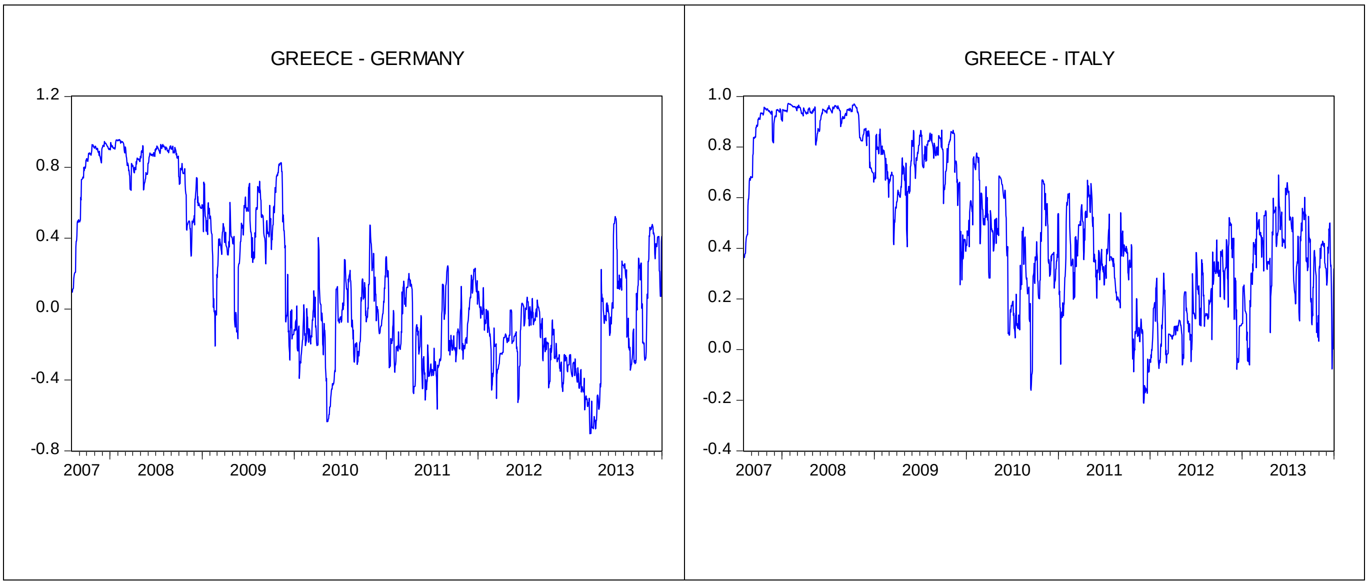
4. EMPIRICAL RESULTS

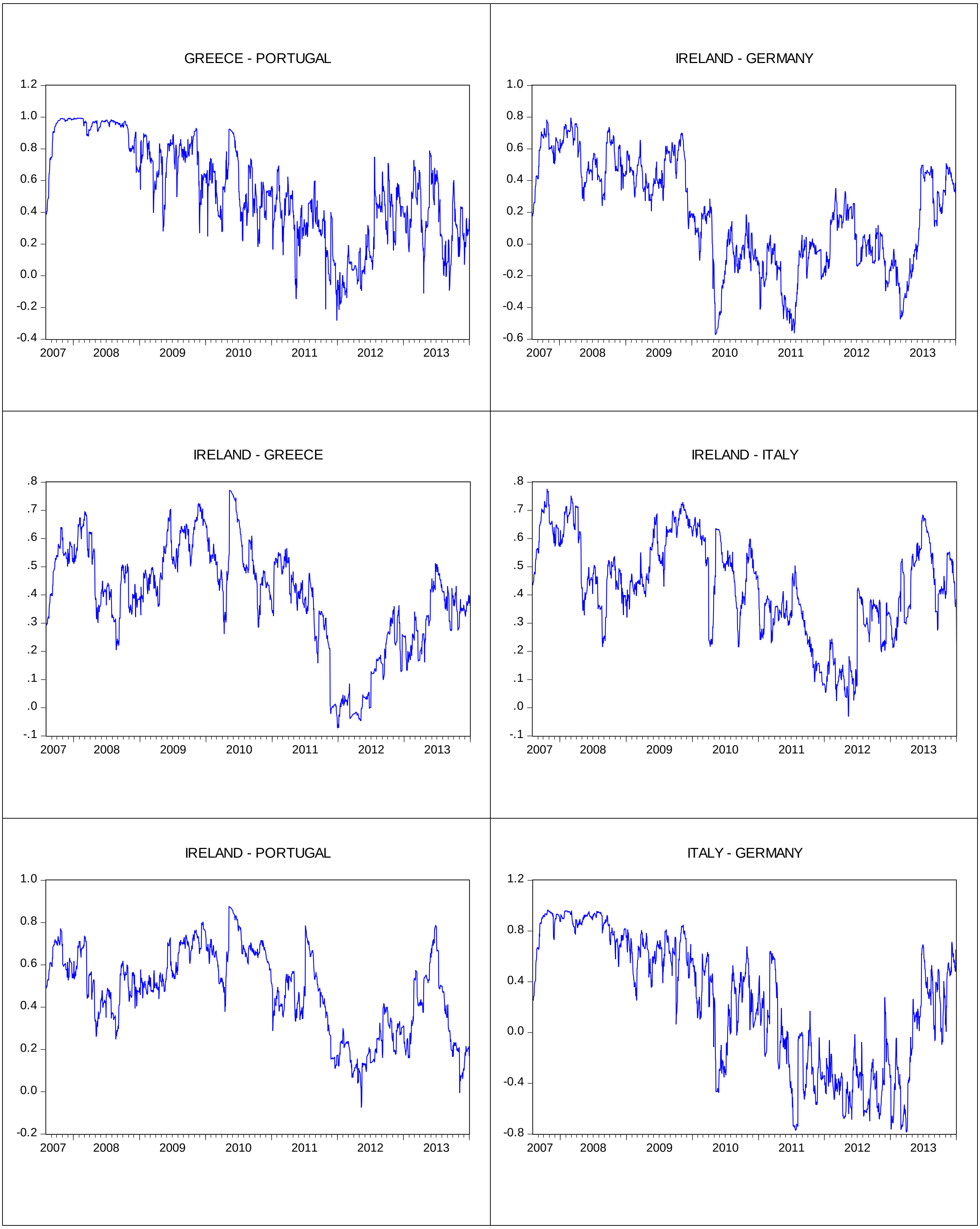
Firstly, we show the value of the estimated parameters of the DCC model of *Engle (2002)* and then the estimated series of correlations for each pair of peripheral countries will be displayed. Thirdly, we also show descriptive statistics of correlations like deviation and trend in both periods of times considered. Finally, we show the estimated effects of news announcements on correlations. As we mentioned before, we analyze the impact of interest rates, QE and rating changes.

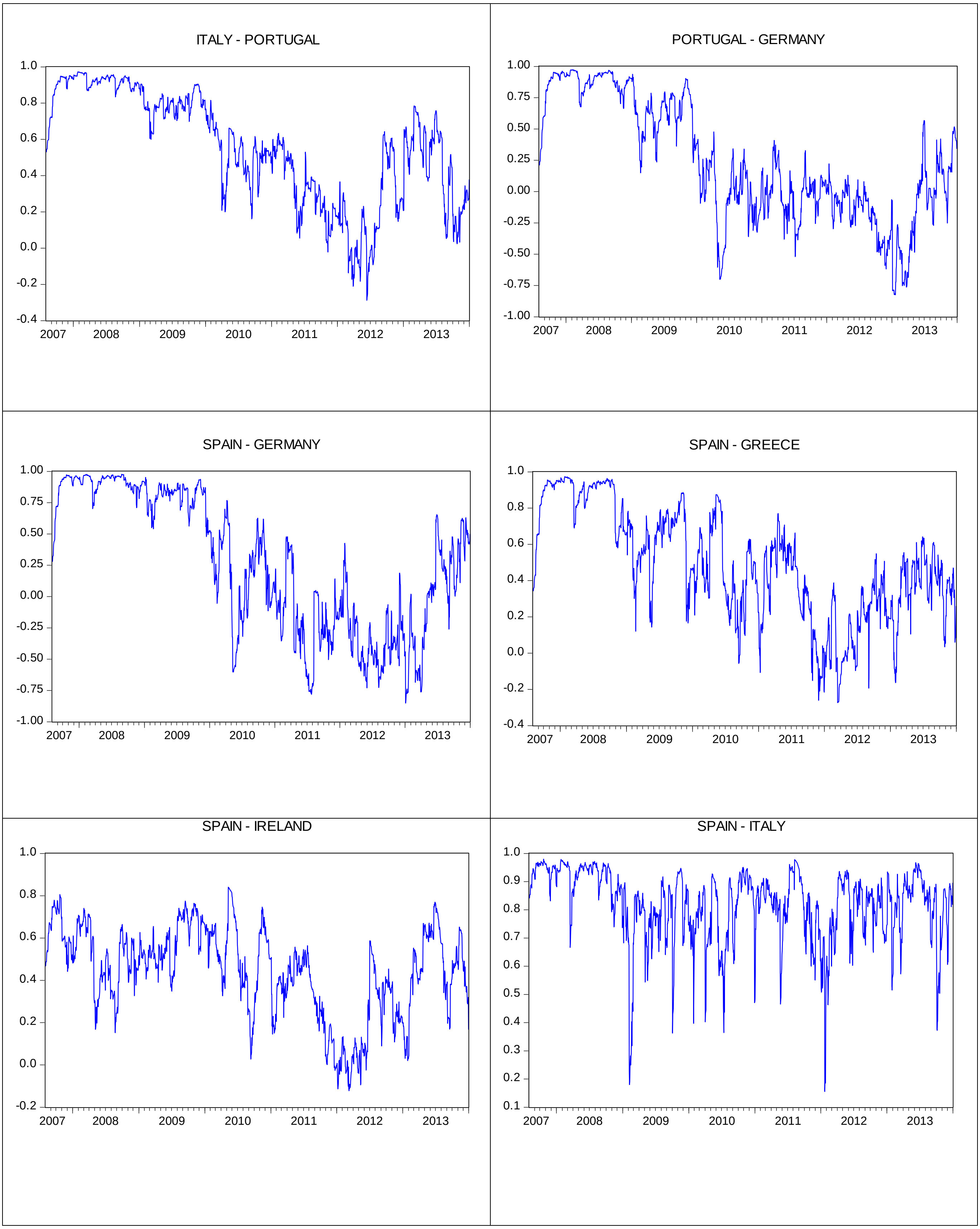
4.1. THE DCC MODEL AND ESTIMATION RESULTS

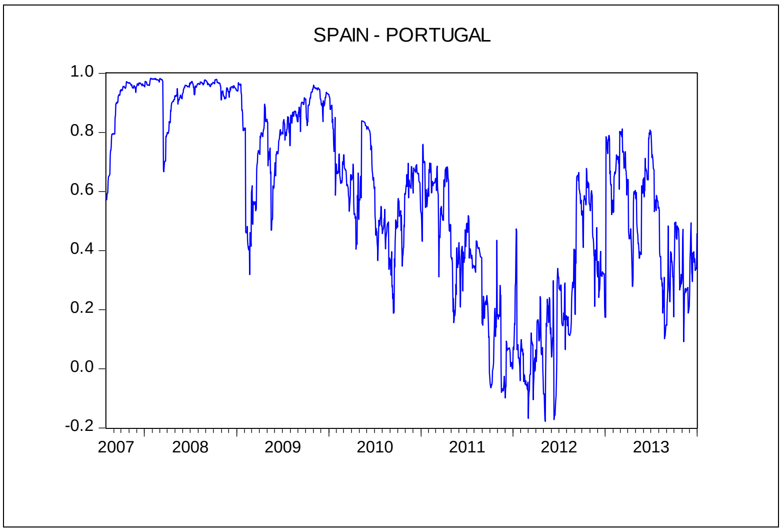
Figure 2 displays the country-pair correlations that have been obtained after estimating the DCC model for each pair of peripheral countries and each peripheral country with Germany as the European reference during the sample period.

FIGURE 2




GREECE - PORTUGAL
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
2007 2008 2009 2010 2011 2012 2013
IRELAND - GERMANY
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
2007 2008 2009 2010 2011 2012 2013
IRELAND - GREECE
.8
.7
.6
.5
.4
.3
.2
.1
.0
-.1
2007 2008 2009 2010 2011 2012 2013
IRELAND - ITALY
.8
.7
.6
.5
.4
.3
.2
.1
.0
-.1
2007 2008 2009 2010 2011 2012 2013
IRELAND - PORTUGAL
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
2007 2008 2009 2010 2011 2012 2013
ITALY - GERMANY
1.2
0.8
0.4
0.0
-0.4
-0.8
2007 2008 2009 2010 2011 2012 2013


ITALY - PORTUGAL
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
2007 2008 2009 2010 2011 2012 2013
PORTUGAL - GERMANY
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
2007 2008 2009 2010 2011 2012 2013
SPAIN - GERMANY
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
2007 2008 2009 2010 2011 2012 2013
SPAIN - GREECE
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
2007 2008 2009 2010 2011 2012 2013
SPAIN - IRELAND
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
2007 2008 2009 2010 2011 2012 2013
SPAIN - ITALY
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2007 2008 2009 2010 2011 2012 2013



Note: This figure displays the estimated country-pair correlation for each pair of peripheral bond markets and each peripheral bond market with the German bond market. Source: own elaboration.

As it is observed, all of the pair-wise correlations have in common that they start at high values at the beginning of the period of time analyzed. Then the correlations start to decrease until 2012, when there is a steep fall in correlations, for instance the deepest correlation values are observed in Greece-Germany and Italy-Germany correlations. Furthermore, last figure show us that Spain-Italy is the only pair-wise correlations which do not have negative values. Tables 7 and 8 present the results of the estimated multivariate DCC model. Table 7 shows the optimal parameters for the mean and variance equations, which were presented in last section while table 8 displays the optimal parameters for the correlation equation.

TABLE 7

	μ	γ_1	ω	α	β
Estimated parameters for mean and variance equations					
Spain	0.000	0.111	0.000	0.118	0.868
	(0.626)	(0.000)	(0.659)	(0.000)	(0.000)
Greece	0.000	0.174	0.000	0.278	0.669
	(0.873)	(0.000)	(0.000)	(0.278)	(0.669)
Italy	0.000	0.097	0.000	0.000	0.000
	(0.516)	(0.000)	(0.433)	(0.011)	(0.000)
Ireland	0.000	0.040	0.000	0.136	0.832
	(0.228)	(0.319)	(0.000)	(0.001)	(0.000)
Portugal	0.000	0.162	0.000	0.142	0.831
	(0.464)	(0.000)	(0.162)	(0.000)	(0.000)
Germany	0.000	0.019	0.000	0.063	0.933
	(0.487)	(0.450)	(0.603)	(0.021)	(0.000)

Note: Numbers in brackets are p-values. Source: own elaboration.

Results show that the autoregressive term in the mean equation, γ_1, is statistically significant and positive for all countries except for Ireland and Germany. We observe that the parameters α and β are significant for all bond markets except for Greece, indicating that the GARCH (1,1) model fits well the data. (α+β) is lower than one for all countries indicating that the model is stationary. Moreover, coefficient β is high for all countries indicating a high persistence of volatility. Table 8 presents the estimated parameters for the correlation equation. These parameters have been estimated for each country-pair.

TABLE 8

Estimated parameters for the correlation equation

	a	b
Spain-Greece	0.079	0.918
	(0.000)	(0.000)
Spain-Germany	0.091	0.907
	(0.000)	(0.000)
Spain-Ireland	0.051	0.939
	(0.000)	(0.000)
Spain-Italy	0.115	0.870
	(0.000)	(0.000)
Spain-Portugal	0.073	0.924
	(0.000)	(0.000)
Greece-Germany	0.083	0.914
	(0.010)	(0.000)
Greece-Italy	0.083	0.914
	(0.000)	(0.000)
Greece-Portugal	0.102	0.897
	(0.000)	(0.000)
Greece-Ireland	0.031	0.966
	(0.012)	(0.000)
Ireland-Germany	0.047	0.948
	(0.000)	(0.000)
Ireland-Italy	0.030	0.967
	(0.007)	(0.000)
Ireland-Portugal	0.036	0.958
	(0.017)	(0.000)
Italy-Germany	0.086	0.911
	(0.000)	(0.000)
Italy-Portugal	0.057	0.940
	(0.000)	(0.000)
Portugal-Germany	0.079	0.919
	(0.000)	(0.000)

Note: Numbers in brackets are p-values.

We observe that both parameters, a and b, are statistically significant, disclosing an important time-varying co-movement. Furthermore, the conditional correlations display high volatility persistence due to the value of parameter bb close to one.

Next, we examine table 9 which contains a group of descriptive statistics for each country-pair correlation estimated, like the mean and the standard deviation that will help us to understand better the correlations behaviour. We have also estimated a regression equation for the conditional return correlations on a constant and a trend in order to reveal how much these correlations have changed over time.

TABLE 9

	Mean	*Standard deviation*	*Trend(*1000)*	*t-statistic*	*$\Delta\rho$ 2007-2009*	*$\Delta\rho$ 2010-2013*
Dynamic Conditional Correlations descriptive Statistics						
Spain-Greece	0.487819	0.303729	-0.434	-39.06933	36.69%	-44.55%
Spain-Germany	0.269203	0.549962	-0.843	-45.10413	89.72%	-5.27%
Spain-Ireland	0.441407	0.210177	-0.179	-18.48802	42.74%	-74.30%
Spain-Italy	0.817952	0.129659	-0.0602	-9.421839	-10.27%	18.61%
Spain-Portugal	0.588076	0.304954	-0.444	-40.52159	62.08%	-50.26%
Greece-Germany	0.161973	0.443188	-0.664	-42.9333	-222.50%	-455.28%
Greece-Italy	0.50202	0.306143	-0.476	-46.60857	13.40%	-22.31%
Greece-Portugal	0.542479	0.310263	-0.486	-47.44003	64.37%	-43.02%
Greece-Ireland	0.3923	0.188279	-0.21	-26.24131	122.49%	-43.55%
Ireland-Germany	0.180347	0.331907	-0.395	-28.79569	11.04%	67.10%
Ireland-Italy	0.433066	0.171767	-0.168	-21.93839	42.57%	-63.10%
Ireland-Portugal	0.476632	0.197423	-0.211	-24.62393	54.56%	-76.96%
Italy-Germany	0.243195	0.518088	-0.771	-42.36921	132.14%	3.90%
Italy-Portugal	0.552657	0.304958	-0.468	-45.19302	45.00%	-50.73%
Portugal-Germany	0.234916	0.477266	-0.764	-49.91161	83.08%	3.59%

Note: $\Delta\rho$ is the difference between last and first values of each regression of conditional correlations and the t-statistic is associated to a time-trend. Source: own elaboration.

Firstly, we observe that Spain-Italy and Spain-Portugal are the highest country-pair conditional correlations with mean values of (0.817952) and (0.588076) respectively while the lowest mean correlation values are observed in the country-pair correlations of peripheral countries and Germany, such as Greece-Germany (0.161973) and Ireland-Germany (0.180347). Furthermore, the highest volatilities of conditional correlations are found in the country-pair correlations of peripheral countries and Germany, such as

Spain-Germany (0.549962) and Italy-Germany (0.518088). Secondly, we find a statistically significant decrease in correlations for all country-pair examined over the sample period, at the 5% level of significance, because of the negative trend coefficient estimated. The country-pair correlations of peripheral countries and Germany have the most negative slopes again like Greece-Germany (-0.664) and Spain-Germany (-0.843). Finally, we have measured this decreasing in correlation using the $\Delta\rho$ term which is the difference between de last and first values of each conditional correlation estimated. At the same time we have obtained this term for the two periods of time analyzed, the financial crisis (2007-2009) and the sovereign debt crisis (2010-2013). We find that the most important decrease in correlations take place in the sovereign debt crisis, suggesting that these countries have become less integrated during this crisis while during the financial crisis they became more integrated. Particularly interesting is the decrease in correlations found between Greece and Germany (-222.50%) during the financial crisis and (-455.28%) throughout the sovereign crisis. Furthermore, we find that the decrease in correlations between other peripheral countries and Germany is small suggesting that the level of integration of these countries with the European reference was stable. However, the level of integration within peripheral countries decreased. In addition these results suggest that the diversifications benefits of a portfolio which included bonds of these countries (Germany not included) might have increased during the sovereign debt crisis (2010-2013).

We can conclude that the Greece-Germany country-pair correlation has experienced the deepest fall while Spain-Germany and Italy-Germany had the highest volatilities in their correlations. Moreover, the correlations among the peripheral countries decreased over the sovereign debt crisis but not those of the peripheral countries with Germany.

4.2. CONDITIONAL CORRELATION COEFFICIENTS

Next, we analyze the impact of the economic news announcements on the dynamic correlations during the crises and provide potential reasons for the correlation's behavior during the sample period. We display a table for each regression equation introduced in last section.

4.2.1. Interest rates results

Table 10 shows the effect of interest rate "surprises" by the ECB and the FED during both crises. Firstly, we observe that positive surprises made by the ECB have a statistically significant and positive impact on the correlation of the majority of pairs examined with the exception of Spain-Italy during the total sample period.

TABLE 10

	α_i^{+ECB}	$\alpha_i^{+ECB.C}$	α_i^{+FED}	$\alpha_i^{+FED.C}$	α_i^{-ECB}	$\alpha_i^{-ECB.C}$	α_i^{-FED}	$\alpha_i^{-FED.C}$
ECB and FED interest rates								
Spain-Greece	**0.041**	**-0.058**	**0.020**	**-0.027**	**-0.024**	**0.062**	**-0.240**	**0.274**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Spain-Germany	**0.084**	**-0.155**	**0.037**	**-0.204**	**-0.061**	**0.127**	**-0.379**	**0.505**
	(0.000)	**(0.000)**	**(0.000)**	**(0.006)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Spain-Ireland	**0.015**	**-0.023**	**0.006**	**-0.189**	**-0.006**	**0.028**	**-0.092**	**0.072**
	(0.000)	**(0.031)**	**(0.163)**	**(0.000)**	**(0.118)**	**(0.000)**	**(0.000)**	**(0.062)**
Spain-Italy	**0.000**	**0.001**	**0.004**	**-0.093**	**-0.004**	**0.008**	**-0.081**	**0.091**
	(0.985)	**(0.894)**	**(0.000)**	**(0.000)**	**(0.160)**	**(0.057)**	**(0.000)**	**(0.000)**
Spain-Portugal	**0.039**	**-0.069**	**0.018**	**-0.112**	**-0.025**	**0.061**	**-0.203**	**0.225**
	(0.000)	**(0.000)**	**(0.000)**	**(0.151)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Greece-Germany	**0.071**	**-0.117**	**0.035**	**-0.292**	**-0.046**	**0.090**	**-0.406**	**0.546**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Greece-Italy	**0.052**	**-0.069**	**0.022**	**-0.278**	**-0.030**	**0.074**	**-0.228**	**0.314**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Greece-Portugal	**0.048**	**-0.079**	**0.021**	**-0.203**	**-0.027**	**0.060**	**-0.217**	**0.261**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Greece-Ireland	**0.014**	**-0.020**	**0.005**	**-0.088**	**-0.007**	**0.020**	**-0.057**	**0.014**
	(0.001)	**(0.007)**	**(0.002)**	**(0.003)**	**(0.080)**	**(0.034)**	**(0.103)**	**(0.739)**
Ireland-Germany	**0.050**	**-0.090**	**0.022**	**-0.182**	**-0.031**	**0.071**	**-0.261**	**0.385**
	(0.000)	**(0.000)**	**(0.000)**	**(0.003)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Ireland-Italy	**0.014**	**-0.023**	**0.006**	**-0.108**	**-0.006**	**0.026**	**-0.070**	**0.076**
	(0.004)	**(0.003)**	**(0.026)**	**(0.016)**	**(0.075)**	**(0.000)**	**(0.093)**	**(0.128)**
Ireland-Portugal	**0.012**	**-0.013**	**0.003**	**-0.088**	**-0.004**	**0.016**	**-0.070**	**0.011**
	(0.000)	**(0.144)**	**(0.391)**	**(0.024)**	**(0.249)**	**(0.028)**	**(0.003)**	**(0.771)**
Italy-Germany	**0.069**	**-0.138**	**0.035**	**-0.251**	**-0.052**	**0.103**	**-0.377**	**0.451**
	(0.000)	**(0.000)**	**(0.000)**	**(0.001)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Italy-Portugal	**0.046**	**-0.079**	**0.020**	**-0.126**	**-0.029**	**0.057**	**-0.207**	**0.247**
	(0.000)	**(0.000)**	**(0.000)**	**(0.109)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Portugal-Germany	**0.076**	**-0.128**	**0.036**	**-0.271**	**-0.054**	**0.100**	**-0.393**	**0.516**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**

Note: Numbers in brackets are p-values. Coefficients $\alpha_i^{+ECB.C}$, $\alpha_i^{+FED.C}$, $\alpha_i^{-ECB.C}$ and $\alpha_i^{-FED.C}$ refer to positive and negative monetary policy surprises by the ECB and the FED during the Sovereign debt crisis from 01/01/2010 to 31/12/2013. Source: own elaboration.

However, when we look at the impact of positive surprises exclusively during the sovereign debt crisis, we observe that these surprises have a negative impact on correlations. The same result is obtained with positive surprises made by the FED. Correlations decrease in response to positive surprises by the FED during the sovereign crisis with the exceptions of Spain-Portugal and Italy-Portugal. So the correlation of Portugal with closer countries like Spain and Italy has not been affected by positive surprises by the FED.

If we look at the impact of negative surprises by the ECB, we observe that they have a negative effect on the country-pair correlations during the total sample period with the exceptions of Spain-Ireland, Spain-Italy, Greece-Ireland and Ireland- Portugal. However, during the sovereign debt crisis the impact on correlations is positive and stronger. Negative surprises made by the FED have a negative impact on dynamic correlations for all pairs examined with the exceptions of Greece-Ireland, Ireland-Italy and Ireland-Portugal. However, if we focus on the sovereign debt crisis, we find that negative surprises have a positive and stronger impact on correlations with the exception of the correlation between Ireland and the other peripheral countries, Ireland-Italy and Ireland-Portugal which were statistically insignificant.

To sum up this table, we find that, in general, positive surprises, i.e. negative news, made by the ECB and the FED during the sovereign debt crisis have a negative impact on dynamic correlations and provide diversification opportunities. However, negative surprises, i.e. positive news made during the sovereign debt crisis lead to an increase of correlations, decreasing the opportunities of diversification. This result suggests that during the sovereign debt crisis, peripheral countries reacted to positive news in the same way but differently to negative news. Also we find that the impact of surprises on correlations was higher during the sovereign debt crisis rather than the financial crisis. On the other hand, we observe that positive surprises by the ECB have stronger effects while the impact of negative surprises by the FED is higher.

Finally, looking at the response of the country-pair correlations, we find that Ireland-Portugal and Spain-Italy were less influenced by the ECB and the FED monetary policy surprises while Spain-Germany, Greece-Germany, Italy-Germany and Portugal-Germany were the most influenced.

4.2.2. Quantitative Easings (QE) results

Table 11 shows the effect of income fixed purchases promoted by the ECB, the FED and the BoE during the sample period 2007-2013. This unconventional measure was implemented in order to mitigate the solvency problems of peripheral countries. We focus on the QE impact within the sovereign crisis (Coefficients $\alpha_i^{ECB.QE.C}$, $\alpha_i^{FED.QE.C}$ and $\alpha_i^{BoE.QE.C}$).

Firstly we find that QE announcements have had a negative impact on dynamic correlations of all country-pairs examined during 2010-2013, suggesting that diversification opportunities have increased after the QE purchases.

TABLE 11

	$\alpha_i^{ECB.QE}$	$\alpha_i^{ECB.QE.C}$	$\alpha_i^{FED.QE}$	$\alpha_i^{FED.QE.C}$	$\alpha_i^{BoE.QE}$	$\alpha_i^{BoE.QE.C}$
ECB, FED and BoE Quantitative Easings (QE)						
Spain-Greece	**0.272**	**-0.432**	**0.211**	**-0.488**	**0.117**	**-0.354**
	(0.005)	**(0.003)**	**(0.000)**	**(0.000)**	**(0.117)**	**(0.009)**
Spain-Germany	**0.430**	**-0.952**	**0.568**	**-0.840**	**0.437**	**-0.705**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Spain-Ireland	**0.135**	**-0.205**	**0.164**	**-0.297**	**0.119**	**-0.203**
	(0.037)	**(0.056)**	**(0.000)**	**(0.000)**	**(0.021)**	**(0.076)**
Spain-Italy	**0.056**	**-0.085**	**0.021**	**-0.022**	**-0.124**	**-0.016**
	(0.234)	**(0.157)**	**(0.347)**	**(0.474)**	**(0.178)**	**(0.881)**
Spain-Portugal	**0.195**	**-0.436**	**0.273**	**-0.470**	**0.112**	**-0.481**
	(0.032)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.207)**	**(0.000)**
Greece-Germany	**0.420**	**-0.656**	**0.387**	**-0.646**	**0.243**	**-0.450**
	(0.010)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.015)**	**(0.000)**
Greece-Italy	**0.308**	**-0.587**	**0.262**	**-0.535**	**0.216**	**-0.393**
	(0.006)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.005)**
Greece-Portugal	**0.266**	**-0.278**	**0.220**	**-0.340**	**0.194**	**-0.482**
	(0.010)	**(0.045)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Greece-Ireland	**0.119**	**-0.178**	**0.101**	**-0.169**	**0.097**	**-0.274**
	(0.015)	**(0.118)**	**(0.016)**	**(0.005)**	**(0.029)**	**(0.011)**
Ireland-Germany	**0.322**	**-0.606**	**0.378**	**-0.606**	**0.281**	**-0.411**
	(0.042)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Ireland-Italy	**0.122**	**-0.222**	**0.086**	**-0.182**	**0.047**	**-0.121**
	(0.079)	**(0.011)**	**(0.050)**	**(0.001)**	**(0.393)**	**(0.209)**
Ireland-Portugal	**0.052**	**-0.105**	**0.105**	**-0.084**	**0.074**	**-0.214**
	(0.056)	**(0.346)**	**(0.042)**	**(0.223)**	**(0.139)**	**(0.050)**
Italy-Germany	**0.365**	**-0.860**	**0.458**	**-0.633**	**0.318**	**-0.576**
	(0.042)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Italy-Portugal	**0.270**	**-0.488**	**0.271**	**-0.457**	**0.196**	**-0.446**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Portugal-Germany	**0.342**	**-0.667**	**0.497**	**-0.762**	**0.316**	**-0.463**
	(0.060)	**(0.001)**	**(0.000)**	**(0.000)**	**0.001**	**(0.000)**

Note: Numbers in brackets are p-values. Coefficients $\alpha_i^{ECB.QE.C}$, $\alpha_i^{FED.QE.C}$ and $\alpha_i^{BoE.QE.C}$ refer to Quantitative Easings of the ECB, the FED and the BoE during the Sovereign debt crisis from 01/01/2010 to 31/12/2013. Source: own elaboration.

If we analyze the QE promoted by the ECB, we observe that their impact was statistically significant for the majority of pairs with the exceptions of Spain-Ireland, Spain-Italy, Greece-Ireland and Ireland Portugal. We also observe that the higher impact of the QE executed by the ECB was produced in the correlations of the pairs Spain-Germany and Italy-Germany. This finding demonstrates that the assets purchased during the second stage summer-fall 2011 (40 billion € in Euro-denominated covered bonds, see *Fawley, Neeley (2013)*) were focused on Spanish and Italian debt.

Next, we look at the effects of QE announcements made by the FED. In March 2011 the Federal Reserve promoted a round of QE of about 600 billion USD in Treasuries. Results show that they had a statistically significant and negative impact on dynamic correlations with the exceptions of Spain-Italy and Ireland-Portugal. This decrease on the level of correlations appears to be related to the notion of "flight to quality effect", i.e. that during times of increased uncertainty, investors tend to move towards less risky assets and so the return co-movement between assets becomes negatively correlated as *Abad, Chulià (2012)* and *Beetsma et al. (2014)* pointed out.

Finally, if we analyze the impact of QE announcements implemented by the BoE we find that correlations decreased with less intensity that after QE promoted by the ECB and the FED and were statistically significant in all country-pair with the exceptions of Spain-Ireland, Spain-Italy and Ireland-Italy.

As a summary, we find that QE announcements had a negative impact on correlations during the sovereign debt crisis suggesting diversification opportunities and a "flight to quality effect" due to the increase of the uncertainty. Also we observe that Spain-Germany and Italy-Germany are the pairs which have been more affected by QE announcements during the sample period 2010-2013, especially by the unconventional measures promoted by ECB. Curiously, the correlations between Spain-Italy were not affected by QE announcements.

4.2.3. Upgrades & Downgrades Rating announcements results

Table 12 shows the impact of upgrades and downgrades announcements made by the S&P rating agency. Missing data means that there has not been any rating change during the sample period in that country. We will focus the analysis during the sample period 2010-2013.

Due to both, the crisis and the financial and fiscal problems, the majority of rating changes on peripheral countries have been downgrades. Greece is the only peripheral country which had an upgrade, its effect on correlation was statistically significant and had a negative impact on its correlation with Spain and a positive impact with Germany. But we have to focus in all downgrades. We find that their effect on correlations was significant with the exception of Spain-Germany, Spain-Italy and Portugal with the rest of countries with the exception of Spain.

TABLE 12

	$\alpha_{i.1rt}^{Down}$	$\alpha_{i.1rt}^{Down.C}$	$\alpha_{i.1rt}^{Up}$	$\alpha_{i.1rt}^{Up.C}$	$\alpha_{i.2nd}^{Down}$	$\alpha_{i.2nd}^{Down.C}$	$\alpha_{i.2nd}^{Up}$	$\alpha_{i.2nd}^{Up.C}$
Panel Upgrades & Downgrades Rating of peripheral countries								
Spain-Greece	-	-0.230	-	-	-0.022	-0.006	-	-0.173
	-	(0.006)	-	-	(0.284)	(0.938)	-	(0.000)
Spain-Germany	-	-0.179	-	-	-	-	-	-
	-	(0.231)	-	-	-	-	-	-
Spain-Ireland	-	-0.251	-	-	-0.093	0.121	-	-
	-	(0.001)	-	-	(0.000)	(0.018)	-	-
Spain-Italy	-	-0.025	-	-	-	-0.081	-	-
	-	(0.434)	-	-	-	(0.224)	-	-
Spain-Portugal	-	-0.369	-	-	-	-0.136	-	-
	-	(0.003)	-	-	-	(0.007)	-	-
Greece-Germany	-0.166	-0.224	-	0.257	-	-	-	-
	(0.000)	(0.000)	-	(0.000)	-	-	-	-
Greece-Italy	-0.086	-0.142	-	-0.183	-	-0.300	-	-
	(0.000)	0.018	-	(0.000)	-	(0.000)	-	-
Greece-Portugal	-	-0.226	-	-0.319	-	-0.211	-	-
	-	(0.021)	-	(0.000)	-	(0.052)	-	-
Greece-Ireland	0.277	-0.255	-	-0.043	0.117	-0.083	-	-
	(0.000)	(0.002)	-	(0.000)	(0.000)	(0.053)	-	-
Ireland-Germany	0.168	-0.523	-	-	-	-	-	-
	(0.000)	(0.000)	-	-	-	-	-	-
Ireland-Italy	0.086	-0.064	-	-	-	-0.148	-	-
	(0.000)	(0.026)	-	-	-	(0.000)	-	-
Ireland-Portugal	0.064	0.113	-	-	-	0.000	-	-
	(0.000)	(0.011)	-	-	-	(0.997)	-	-
Italy-Germany	-	-0.517	-	-	-	-	-	-
	-	(0.000)	-	-	-	-	-	-
Italy-Portugal	-	-0.422	-	-	-	-0.082	-	-
	-	(0.000)	-	-	-	(0.131)	-	-
Portugal-Germany	-	-0.170	-	-	-	-	-	-
	-	(0.062)	-	-	-	-	-	-

Note: Numbers in brackets are p-values. Coefficients $\alpha_{i,1rt}^{Down.C}$, $\alpha_{i,1rt}^{Up.C}$, $\alpha_{i,2nd}^{Down.C}$ and $\alpha_{i,2nd}^{Up.C}$ refer to downgrades and upgrades in the rating of peripheral countries during the Sovereign debt crisis from 01/01/2010 to 31/12/2013. Sub index 1^{rt} and 2^{nd} indicate the country in each pair-correlation. Source: own elaboration.

If we analyse the results for each country, we find that Spain had the strictest impact of the downgrades on its correlation with Portugal. Ireland had the strongest impact on its correlations with Germany during the sovereign debt crisis but in the previous sample period we observed a rise in correlations with the European reference. Also this table shows that the correlation between Italy and other countries such as Germany and Portugal decreased because of the downgrades.

To sum up, we find that Spain and Italy are countries that have been severely affected by the downgrades promoted by rating agencies. Furthermore, their effect was negative in most of the cases suggesting that the increased sovereign risk among peripheral countries lead to lower correlations and provided diversifications benefits if we invest in bonds of these countries.

5. SUMMARY

Recent studies have analysed the integration of European Government bond markets during the sovereign debt crisis. Our study contributes to this literature providing a detailed analysis of the short-run interrelationships among Government bond markets of European peripheral countries. To this end, we have used the multivariate DCC-GARCH model proposed by *Engle (2002)* in order to estimate the country-pair correlations and we employ daily yield bond data of each country during a sample period that covers both, the financial crisis (2007-2009) and sovereign debt crisis (2010-2013). Then, we have used the estimated correlations as dependent variables in regression equations to investigate how the conventional and unconventional measures of monetary policy and the rating announcements have impacted on these bond markets during the period of turmoil.

Our study reports some interesting findings. First of all, we have examined a group of descriptive statistics for each country-pair correlation estimated and we have also estimated a regression equation for the conditional return correlations on a constant and a trend in order to reveal if these correlations have changed over time. In the case of correlations, we have found that Spain-Italy and Spain-Portugal were the highest country-pair conditional correlations while the lowest correlation values were observed in the country-pair correlations of peripheral countries and Germany. This fact could be due to the "flight to quality" effect which suggests that investors tend to allocate their assets in safety bond markets during periods of turmoil. In the case of volatilities, the highest were found in the country-pair correlations of peripheral countries and Germany. Furthermore, we found that the most important decrease in correlations took place during the sovereign debt crisis, suggesting that these countries became less integrated during this crisis. However, in general, during the financial crisis they became more integrated. These results provide evidence of diversifications benefits of a portfolio which included bonds of these countries during the sovereign debt crisis.

Secondly, we have studied the impact of monetary policies and announcements made by central banks and rating agencies on each country-pair correlation during both crises considered. In the case of interest rates "surprises" made by the ECB and the FED, we found that positive surprises during the sovereign debt crisis, i.e. negative news, had a negative impact on dynamic correlations and provided diversification opportunities while, negative surprises, i.e. positive news, lead to an increase of correlations, thus, decreasing the opportunities of diversification. Also, we found that the impact of surprises on correlations was higher during the sovereign debt crisis rather than the financial crisis. Moreover, we analysed the impact of QE made by the ECB, the FED and the BoE on correlations and we found that QE announcements had a negative impact on correlations during the sovereign debt crisis, suggesting diversification opportunities.

Finally, we explored the impact of upgrades and downgrades announcements made by the S&P rating agency and we found that the effect of the downgrades was negative in most of the cases suggesting that the increased sovereign risk among peripheral countries lead to lower correlations and provided diversifications benefits.

Our results should help investors to make effective investment decisions, given that they need to have an understanding of the way in which monetary policy and rating announcements impact the interrelations of European government bond markets. Additionally, our findings should be of use to central banks to understand the effects of their monetary policy decisions on bond markets.

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7. ANNEX

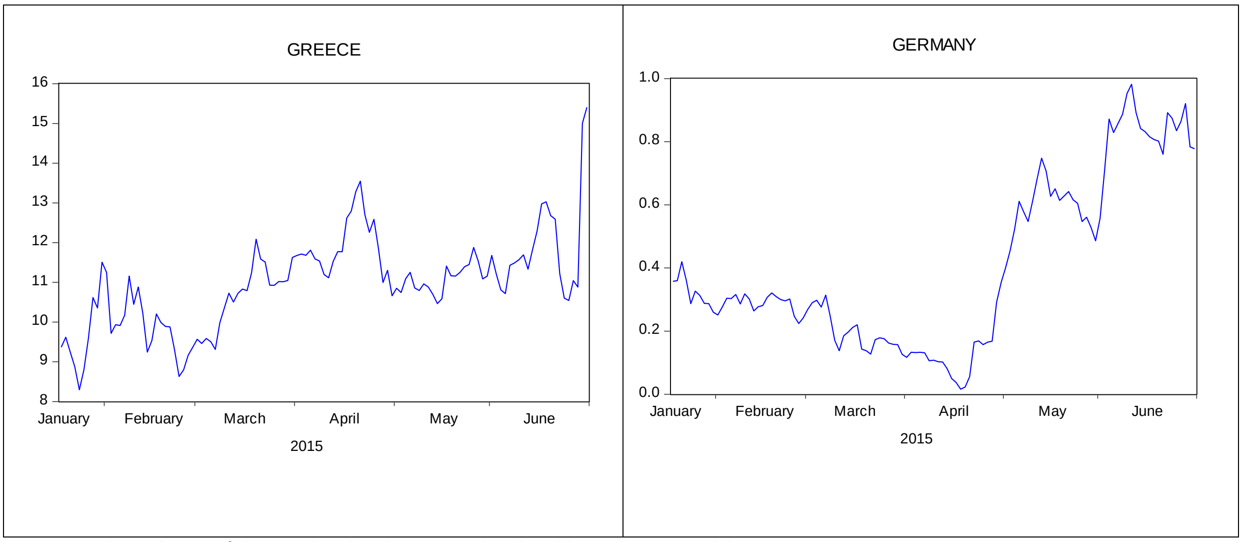
In this section we show last correlations estimated using the DCC methodology. In this case we analyze the current European debt crisis which is focused on Greek bond market given the increase of financial and uncertainty problems that Greek government have to pay back the FMI debt. Also, recently this government announced a citizen referendum to ask about his debt. We find interesting to investigate if have been financial contagion among peripheral countries during this period of turmoil.

Furthermore we contribute the R-script which has been used to estimate DCC correlations.

7.1. LAST SOVEREIGN DEBT CRISIS - 30 JUNE 2015

We collect daily bond yields for three peripheral countries: Spain, Italy and Greece. We also collect data for Germany as a European reference. The data runs from 19th January 2015 through 30th June 2015. Weekend days are excluded. As a result, we have 116 observations for each country. Last sovereign debt crisis has taken place during June 2015 because of the difficulties that Greek government has to pay back the FMI debt. There are not many studies that had analyzed correlations and contagion of this period previously. Firstly we display in Figure 3 the daily evolution of the bond yields in the analyzed period for each country.

FIGURE 3

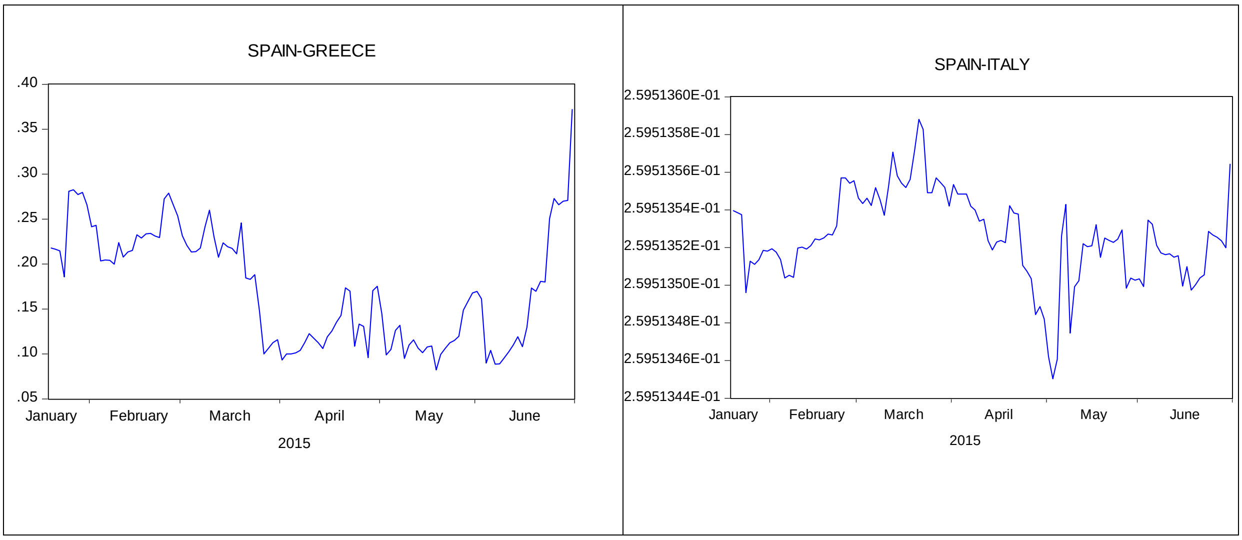


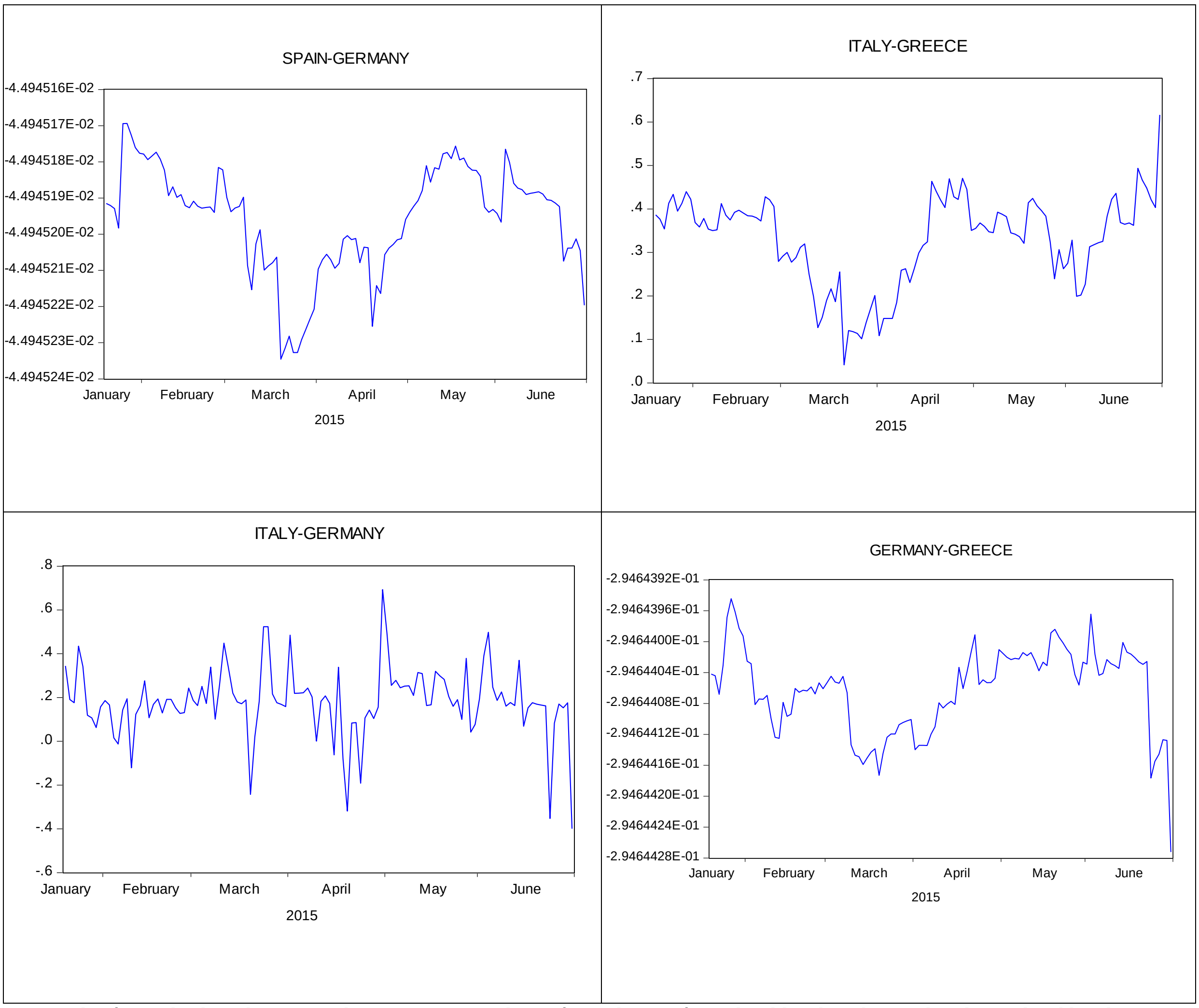
Note: Daily evolution of the peripheral and Germany bond yields. Source: own elaboration.

As we see in last figure, all bond yields have increased in last week due to the raise of uncertainty among peripheral bond markets after Referendum announcement and FMI debt.

Next figure 4 shows correlations estimated using DCC methodology proposed by Engel (2002) that allow us to investigate if there are any contagion symptoms of the Greek sovereign crisis.

FIGURE 4





Note: This figure displays the estimated country-pair correlation for each pair of peripheral bond markets and each peripheral bond market with the German bond market. Source: own elaboration.

As it is observed, Spain and Italy pair-wise correlations have in common that they are strongly affected by Greek bad news, showing the evidence of the contagion. Last data (30th June) reports an important raise on correlations between Spain-Greece and Italy-Greece. This increase in correlations is followed with a drop fall of them in Spain-Germany and Italy-Germany country-pair correlations because of the “flight to quality” effect that investors are looking for in Germany Bund. While the correlation between Spain and Italy remains stable during the period of time considered.

7.2. DCC R-SCRIPT

This section of the Annex will show the R-script information provided in order to execute the DCC methodology in all country-pair countries:

data<-read.table("germany-greece.txt", header=TRUE, sep="")

 # If you only want to work with some of the columns of the BDD,

values <- cbind(data[1],data[2],data[3])

 # With " cbind " combine data columns and rows # rbind you do row

 # " Attach () " allows you to attach the BDD to search path R. So you can access each so you can access each of the elements of the BDD simply typing their names

attach(values)

data

attach(values

germany

attach(values)

greece

 # Data conversion to date format. The format % d / % m / % Y refers to d = day, m = month number , Y = 4-digit year

date<-as.Date(data$data,"%d/%m/%Y")

 # Chart of the time series

plot(date,germany,type="l",col="blue",main="Prices")

plot(date,greece,type="l",col="blue",main="Prices")

rendgermany <- diff(log(germany))

rendgreece <- diff(log(greece))

date<-as.Date(data$data[-1],"%d/%m/%Y")

#plot(Dates,rendibex)

 # Here I indicate which of the series of log- returns want to use.

 # In this case I selected all rows in the first column of the BDD val.ln

 # is to say, " val.ln [have this empty space means I'm considering all rows , 1 = just want the first column]"plot(date,rendgreece,type="l",col="blue",main="returns")

returns = cbind(rendgermany,rendgreece) # rend combined in one vector

 # univariate normal GARCH(1,1) for each series

garch11.spec = ugarchspec(mean.model = list(armaOrder = c(1,0)), variance.model = list(garchOrder = c(1,1), model = "sGARCH"), distribution.model = "norm")

 # for a ar(1) for instance: armaOrder=c(1,0)

#for t student distribution: "std"

#sGarch es el garch(1,1) estandart

 # dcc specification - GARCH(1,1) for conditional correlations

dcc.garch11.spec = dccspec(uspec = multispec(replicate(2, garch11.spec)), dccOrder = c(1,1), distribution = "mvnorm")

dcc.garch11.spec

dcc.fit2 = dccfit(dcc.garch11.spec, data = returns)

 # many extractor functions - see help on DCCfit object

 # coef, likelihood, rshape, rskew, fitted, sigma,

 # residuals, plot, infocriteria, rcor, rcov

 # show, nisurface

#class(dcc.fit2)

#slotNames(dcc.fit2)

#names(dcc.fit2@mfit)

#names(dcc.fit2@model)

 # show dcc fit and estimated parameters

dcc.fit2

 # conditional sd of each series

 # plot(dcc.fit, which=2)

 # conditional correlation

 # plot(dcc.fit, which=4)

 # extracting correlation series

```
ts.plot(rcor(dcc.fit2)[1,2,])

write.table(rcor(dcc.fit2)[1,2,],file="correlaciones.csv")
```

#show(rcor(dcc.fit2)[1,2,])