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Abstract

In this paper we examine the linkages of government bond yield spreads (BYS) between Euro zone countries over the period March 3, 2007 - June 18, 2012, thus considering the intriguing features of BYS spillovers during the global financial and the Euro zone debt crisis. Splitting our sample to Euro zone periphery and core countries, and using the VAR-based spillover index approach of Diebold and Yilmaz (2012), we find that: (i) on average, BYS shocks tend to increase future BYS, and are related to news announcements and policy changes; (ii) BYS spillovers between Euro zone countries are highly intertwined, originating mostly from the periphery (Greece, Ireland, Italy, Portugal and Spain (GIIPS)) and to a lesser extent from the core (Austria, Belgium, France and Netherlands (ABFN)). The within-effect of BYS spillovers is of greater magnitude within the periphery than that within the core; iv) The between-effect (core vs periphery) of BYS spillovers suggests directional spillovers of greater magnitude from the periphery to the Euro zone core than vice-versa. Generalized impulse response analyses provide additional support to these findings. Our findings highlight the increased vulnerability of Euro zone from the destabilizing shocks originating from the beleaguered Euro zone countries in the periphery.

Keywords: Government bond yield spread, Euro Zone debt crisis, Spillover, Vector autoregression, Variance decomposition, Impulse response

JEL codes: C32, G01, G11, G12, G15, H63

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1. Introduction

During the recent global financial crisis and especially the Euro zone debt crisis, extraordinary measures were taken by governments and central banks to prevent a potential collapse of the Euro zone. Given the debt crisis was accompanied by a slowdown in economic activity, the impact of fiscal consolidation has been limited, and many Euro zone countries, especially in the periphery, face rising risks to long-term sustainability. As a consequence, international markets have started requesting higher sovereign risk premia since the beginning of the debt crisis, surrounded by fears of further fiscal worsening and spillovers from the Euro zone periphery.

Yet, very little is known about what the effects would be on the interdependencies and the detailed linkages between sovereign bond yield spreads exposures within the Euro zone during the financial and debt crisis. This paper tries to fill in this gap by examining the directional linkages of government bond yield spreads (BYS) between Euro zone countries over the period March 3, 2007 - June 18, 2012, thus considering the intriguing features of BYS spillovers during the Euro zone debt crisis. To achieve that, we employ a VAR-based spillover index approach initially introduced by Diebold and Yilmaz (2009) and generalized in Diebold and Yilmaz (2012). Results of the generalized approach and impulse response function analyses reveal several interesting empirical regularities. Specifically, we find that: (i) on average, BYS shocks tend to increase future BYS, and are related to news announcements and policy changes; (ii) BYS spillovers between Euro zone countries are highly intertwined, originating mostly from the periphery (Greece, Ireland, Italy, Portugal and Spain (GIIPS)) and to a lesser extent from the core (Austria, Belgium, France and Netherlands (ABFN)). The within-effect of BYS spillovers is of greater magnitude within the periphery than that within the core; iv) The between-effect (core vs periphery) of BYS spillovers suggests directional spillovers of greater magnitude from the periphery to the Euro zone core than vice-versa. Generalized impulse response analyses provide additional support to

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these findings. Our findings highlight the increased vulnerability of Euro zone from the destabilizing shocks originating from the beleaguered Euro zone countries in the periphery.

The remainder of the paper is organized as follows. Section 2 presents a brief literature review of the most related studies on government bond yield spreads spillovers. Section 3 discusses the application of the spillover index approach to disentangle the intricate relationships between government bond yield spreads in the Euro zone and describes the data used. Section 4 presents the empirical findings. Section 5 summarizes the results and concludes.

2. Literature Review

From a theoretical standpoint, fear of international financial contagion and spillovers may develop in an economic environment described by multiple equilibria with heterogenous market outcomes and self-fulfilling characteristics. In such a case, macroeconomic fundamentals are usually neither so strong as to prevent a speculative attack on a market nor so weak as to make it unavoidable. Hence, revealing a country's distressed debt position, as that of Greece in late 2009, may trigger a sudden loss of investor confidence which eventually can lead to self-fulfilling waves of cross-border portfolio rebalancing with the corresponding adjustment of market prices. Obstfeld (1996) and Masson (1999) provide theoretical justification of these arguments.

Whilst early empirical studiers that examine the behaviour of sovereign bond yield spreads from 1999 to 2006 show convergence of spreads in EMU countries, studies that examine spreads from 2007 onwards in the same countries show that risk factors from the capital markets, sovereign risk rating changes and increasing bank credit risk lead to a divergence of spreads of the countries that have weaker macroeconomic data. Thus, weak euro-zone countries have faced disproportionately high spreads especially from 2010 onwards probably showing that the benefits of a single euro currency for countries with weak macroeconomic factors had no longer outweighed the risks.

In the following subsections we discuss the most related empirical studies during the pre- and post-crisis period.

2.1. Pre-crisis period (1999-2006)

During the pre-crisis period, on the one hand, Pagano (2004) shows that credit risk alone explaines a considerable portion of 10-year average yield differentials in EURO-zone countries during the 2001-2004 period, as a result of convergence after the transition to EMU. On the other hand, Balli (2009), who examines spillover effects on bond yields in Euro zone during 1999-2005, finds that unlike other bond markets, the credit risk factor and other macro and fiscal indicators are not sufficient to explain sovereign bond yield in these Euro countries after the beginning of the monetary union. Christiansen (2007) brakes down volatility to local, regional and global components, and finds evidence of substantial differences between the nature of the volatility of bonds of EMU member countries and non EMU member countries. Skintzi and Refenes (2006) find that price and volatility spillover coefficients increase from January 1999 to 2001. Similar are the findings of Cappiello et al. (2006) from the perspective of examining the response of bond yields of EMU countries in bad news before and after Euro period.

2.2. Post-crisis period (2007-2012)

Concerning the studies on the post-crisis period, Diebold and Yilmaz (2009) examines return and volatility spillovers in equity markets and finds divergent behaviour of the dynamics of spillovers. This divergent behaviour has been attributed, by other studies, to contagion effect, unconditional correlation of spreads between countries, or to asymmetric growth of risks in Euro countries. Caporale and Girardi (2011) examine fiscal spillovers in the euro area and find that euro-denominated government yields are strongly linked to each other. Afonso (2010) examines the relation of economic forecasts and 10-year bonds in ten Euro markets, including Greece, for quarterly data during the period 1998-2008, and finds that yields increase with better growth forecasts and budget decreases. Arezki et al. (2011) note that sovereign rating downgrades of one euro country affects also other euro area countries, but it is more widespread when it originates from a non-eastern European economy. Tamakoshi and Hamori (2013) who examined causality in mean and causality in variance in PIIGS, Germany and France during the 2007-2011 period, find mean spillover effects before the crisis and variance spillover after the crisis. Sosvilla-Rivero and Morales-Zumaquero (2012) who examine bond yields of 11 EMU countries during the period 2001-2010 find that causality runs one-way from Austria to Belgium, Germany and Italy; from Belgium to Greece and Italy; from France to Austria, Belgium, Germany, Italy and Portugal; from Germany to Italy; from Finland to Germany; from Italy to Ireland and from Spain to Germany, Ireland and Portugal but not the other way. Similarly, Bhanot et al. (2011), who examine yield spreads during the 2007-2011 period, found an increase in unconditional correlation between yield spreads of Greece and other markets, but no evidence of contagion. Claeys and Vasicek (2012) find that spillover relates to the currency. While CEE countries affect each other mutually, Denmark, Sweden and the UK are insulated from the impact of other EU countries. Similarly, Comelli (2012) who estimates bond spreads of 28 emerging economies found that bond spread prediction model fails to explain the increase in bond spreads since 2010, underscoring the importance for emerging economies of reducing external vulnerability. De Santis (2012), examine the period 2008-2011 and finds that sovereign credit risk in PIIGS countries is higher and statistically significant, and the spillover effect from Greece and impulse responses point to severe contagion risk hitting the other PIIGS countries as well as Belgium and France. The spillover effect from Greece explains sovereign spreads during the financial crisis.

3. Empirical Model, Methodology, and Data

3.1. Government Bond Yield Spreads Spillover Index Definitions

In the following, we outline our application of the spillover index approach introduced by Diebold and Yilmaz (2009). Building on the seminal work on VAR models by Sims (1980) and the well-known notion of variance decompositions, it allows an assessment of the contributions of shocks to variables to the forecast error variances of both the respective and the other variables of the model. Using rolling-window estimation, the evolution of spillover effects can be traced over time and illustrated by spillover plots.

For the purpose of the present study, we use the variant of the spillover index in Diebold and Yilmaz (2012), which extends and generalizes the method in Diebold and Yilmaz (2009) in two respects. First, they introduce refined measures of directional spillovers and net spillovers, providing an 'input-output' decomposition of total spillovers into those coming from (or to) a particular source (variable) and allowing to identify the main recipients and transmitters of spillovers.

Second, in line with Koop et al. (1996) and Pesaran and Shin (1998), and Diebold and Yilmaz (2012), we use a generalized vector autoregressive framework, in which forecast-error variance decompositions are invariant to the ordering of the variables (in contrast to Cholesky-factor identification used (Diebold and Yilmaz, 2009)). In the context of the present study, this is particularly important since it is hard if not impossible to justify one particular ordering of the variables on government bond yield spreads among the Euro zone countries. Of course, the generalized VAR framework has advantages and drawbacks. A disadvantage is that it aggravates the identification of causal effects in a strict sense in the impulse response analysis. On the other hand, by fully accounting for the pattern of observed correlation between shocks it increases the relevance from a policy perspective in light of the increased synchronization of shocks.

Starting point for the analysis is the following P-th order, K-variable VAR

$$y_t = \sum_{p=1}^{P} \Phi_i y_{t-p} + \varepsilon_t \tag{1}$$

where $y_t = (y_{1t}, y_{2t}, \ldots, y_{9t})$ is a vector of K endogenous variables, $\Phi_i, i = 1, ..., P$, are $K \times K$ parameter matrices and $\varepsilon_t \sim (0, \Sigma)$ is vector of disturbances that are independently distributed over time; $t = 1$, ..., T is the time index and $k = 1$, ..., K is the variable index. For each of the 9 Euro zone countries considered (Austria, Belgium, France, Netherlands, Greece, Ireland, Italy, Portugal and Spain), the VAR given by Equation (1) contains daily observations 10-year government bonds yield spreads (BYS). Hence, our VAR is made up of $K = 9$ variables.

Our key variable, long-term government bond yield spread, is defined as the difference between the 10-year government bond yields of nine euro zone countries, namely Austria, Belgium, France, Netherlands (henceforward, ABFN), Greece, Ireland, Italy, Portugal and

Spain (hereafter, GIIPS), and German government bond yields of the same maturity.[1] Data on sovereign bond yields were collected from Bloomberg database over the period from March 3, 2007 to June 18, 2012 (1163 observations), thus covering the turbulent period during the Euro zone debt-crisis.

Figure 1 presents the 10-year government bond yield spreads in the ABFN countries (upper panel) and the GIIPS countries (lower panel). One can observe an increasing trend till the beginning of 2009 followed by a declining trend till the end of 2009. Afterwards, deteriorating macroeconomic fundamentals in the peripheral countries, led to increasing government bond yields spreads in both the peripherals and the core Euro zone countries. In addition, spreads in the GIIPS countries are approximately tenfold those in the ABFN countries.

As the raw series, BYS, are found to be non-stationary, we transform the series to stationary ones by taking the first differences of government bond yield spreads in each country. That is, we obtain government bond yield spread returns.[2] Results from the Augmented Dickey-Fuller (ADF) tests, which are reported in Table 1 below, reject the null hypothesis of a unit root only for the differenced series, $DBYS$, in each country, justifying the use of a VAR model for the subsequent analysis.

Key to the dynamics of the system is the moving average representation of model (1), which is given by $y_t = \sum_{j=0}^{\infty} A_j \varepsilon_{t-j}$, where the $K \times K$ coefficient matrices A_j are recursively defined as $A_j = \Phi_1 A_{j-1} + \Phi_2 A_{j-2} + \ldots + \Phi_p A_{j-p}$, where A_0 is the $K \times K$ identity matrix and $A_j = 0$ for $j < 0$.

To avoid the use of identification schemes (such as Cholesky factorization) that make the variance decompositions dependent on the ordering of the variables, Diebold and Yilmaz (2012) use the generalized VAR framework of Koop et al. (1996) and Pesaran and Shin (1998), which produces variance decompositions invariant to the variable ordering.

[1]The choice of these specific Euro zone countries and time span is due to data availability.

[2]In the remaining we use the terms 'government bond yield spread returns' and 'government bond yield spread' interchangeably unless mentioned otherwise.

According to this framework, the H-step-ahead forecast error variance decomposition is

$$\theta_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}, \tag{2}$$

where Σ is the (estimated) variance matrix of the error vector ε, σ_{ii} the (estimated) standard deviation of the error term for the i-th equation and e_i a selection vector with one as the i-th element and zeros otherwise. This yields a $K \times K$ matrix $\theta(H) = [\theta_{ij}(H)]_{i,j=1,\dots 14}$, where each entry gives the contribution of variable j to the forecast error variance of variable i. The main diagonal elements contains the (own) contributions of shocks to the variable i to its own forecast error variance, the off-diagonal elements show the (cross) contributions of the other variables j to the forecast error variance of variable i.

Since the own and cross-variable variance contribution shares do not sum to one under the generalized decomposition, i.e., $\sum_{j=1}^{K} \theta_{ij}(H) \neq 1$, each entry of the variance decomposition matrix is normalized by its row sum, such that

$$\tilde{\theta}_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{K} \theta_{ij}(H)} \tag{3}$$

with $\sum_{j=1}^{K} \tilde{\theta}_{ij}(H) = 1$ and $\sum_{i,j=1}^{K} \tilde{\theta}_{ij}(H) = K$ by construction.

This ultimately allows to define a total (volatility) spillover index, which is given by

$$S(H) = \frac{\sum_{i,j=1, i\neq j}^{K} \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{K} \tilde{\theta}_{ij}(H)} \times 100 = \frac{\sum_{i,j=1, i\neq j}^{K} \tilde{\theta}_{ij}(H)}{K} \times 100 \tag{4}$$

which gives the average contribution of spillovers from shocks to all (other) variables to the total forecast error variance.

This approach is quite flexible and allows to obtain a more differentiated picture by considering directional spillovers: Specifically, the directional spillovers received by variable i from all other variables j are defined as

$$S_{i\leftarrow j}(H) = \frac{\sum_{j=1, j\neq i}^{K} \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{K} \tilde{\theta}_{ij}(H)} \times 100 = \frac{\sum_{j=1, j\neq i}^{K} \tilde{\theta}_{ij}(H)}{K} \times 100 \tag{5}$$

and the directional spillovers transmitted by variable i to all other variables j as

$$S_{i\rightarrow j}(H) = \frac{\sum_{j=1, j\neq i}^{K} \tilde{\theta}_{ji}(H)}{\sum_{i,j=1}^{K} \tilde{\theta}_{ji}(H)} \times 100 = \frac{\sum_{j=1, j\neq i}^{K} \tilde{\theta}_{ji}(H)}{K} \times 100. \tag{6}$$

Notice that the set of directional spillovers provides a decomposition of total spillovers into those coming from (or to) a particular source.

Finally, subtracting Equation (5) from Equation (6) we obtain the net spillover from variable i to all other variables j as

$$S_i(H) = S_{i \to j}(H) - S_{i \leftarrow j}(H), \tag{7}$$

providing information on whether a country (variable) is a receiver or transmitter of shocks in net terms.

The spillover index approach provides measures of the intensity of interdependence across variables and allows a decomposition of spillover effects by source and recipient. The magnitude of the spillovers will then be quantified using impulse response analyses.

3.2. Descriptive statistics

Table 1 presents descriptive statistics of the government BYS series and their first differences in each country. Results for the raw series in Panel A indicate that on average BYS are higher in the GIIPS compared to those in the ABFN countries. The maximum value government bond yield spreads reached was 31.9 basis points in Greece, followed by Portugal (14.81), Ireland (12.16), Spain (5.71) and Italy (5.51). In the remaining countries (ABFN), BYS did not exceed the 3.55 basis point threshold on any given day during our sample. Moreover, the raw series are found to be non-stationary for each country as the ADF test cannot reject the null hypothesis of a unit root.

Turning to the results obtained for the (stationary) first difference of BYS series in each country, the picture remains qualitatively similar. That is, the GIIPS are experiencing substantially larger changes in BYS than the ABFN countries. Looking at the unconditional correlations of BYS returns we observe that pairwise correlations are higher for countries within each group, that is, within the ABFN and within the GIIPS than between the two groups. For instance, the highest correlations are between Italy and Spain (0.8041), Austria and France (0.7357) and Belgium and France (0.7009), while the lowest exist between Greece and the Netherlands (0.1276) and Greece and France (0.1484).

[Insert Table 1 here]

4. Empirical findings

In this section we present the results from our empirical analysis, starting with the estimates of the spillover index and its subindices, defined in Eq. (4)-(7). We then consider the time-varying nature of spillovers indices and finally turn to the results from the impulse response function analyses.

4.1. Spillover Indices

Table 2 presents the results of the spillover indices based in 10-days ahead forecast error variance decompositions. Before discussing the results, however, let us first describe the elements of the table. The $ij-$th entry in Table 2 is the estimated contribution *to* the forecast error variance of variable i coming *from* innovations to variable j (see Equation (2)). Note that each variable is associated with one of the Euro zone countries' government bond yield spreads returns. Hence, the diagonal elements ($i = j$) measure own-variable spillovers of BYS returns within countries, while the off-diagonal elements ($i \neq j$) capture cross-variable spillovers of BYS returns between countries. In addition, the row sums excluding the main diagonal elements (labeled 'Directional from others', see Eq. (5)) and the column sums (labeled 'Directional to others', see Eq. (6)) report the total volatility spillovers 'to' (received by) and 'from' (transmitted by) each variable. The difference between each (off-diagonal) column sum and row sum, respectively, gives the net spillovers from variable i to all other variables j (see Equation (7)). The total volatility spillover index defined in Eq. (4), given in the lower right corner in Table 2, is approximately[3] equal to the grand off-diagonal column sum (or row sum) relative to the grand column sum including diagonals (or row sum including diagonals), expressed in percentage points.

[Insert Table 2 here]

[3]The approximate nature of the claim stems from the fact that the contributions of the variables in the variance decompositions do not sum to one and have to be normalized (see Eq. (3)).

Several interesting results emerge from Table 2. First, own-country BYS return spillovers explain the highest share of forecast error variance, as the diagonal elements receive higher values compared to the off-diagonal elements. For example, innovations to BYS in Greece explain 69.9% of the 10-day forecast error variance of BYS in Greece, while only 0.9% in the Netherlands. Second, BYS return spillovers between country pairs within the Euro zone core (ABFN), and within the periphery (GIIPS), are greater compared to spillovers between country pairs between the periphery and the croe. For instance, innovation to BYS returns in France explain 16.8%, 13.8% and 13.6% of the 10-day ahead forecast error variance of BYS in Austria, Belgium and the Netherlands, respectively, but only 10.5%, 9.2%, 4.2%, 3.9% and 2.9% in Italy, Spain, Ireland, Portugal and Greece, respectively.

Third, Belgium is the dominant transmitter of government BYS return spillovers followed by Italy and Spain, while Greece, Portugal and the Netherlands are the dominant receivers of BYS return spillovers. This result is supported by the 'directional to others' row and the 'directional from others' column in Table 2. These findings are also supported by the net directional return spillovers values, which measure the net spillovers from country i to all other markets j, reported in the last column of Table 2. Specifically, Belgium is the dominant BYS in return transmission with a net spillover of 14% to all other countries' BYS followed by Italy (12%), Spain (11%), France (5%) and Austria (4%), while Greece is the dominant net receiver of BYS spillovers from all other countries' BYS returns with a net return spillover of -15%, followed by the Netherlands (-13%), Portugal (-12%) and Ireland (-7%). These results are of great importance as, for instance, changes of government bond yield spreads in other Euro zone countries can be a good indicator of futures changes in BYS and their repercussions in the country of interest.

Fourth, and most importantly, according to the total spillover index reported at the lower right corner of Table 2 and which effectively distils the various directional return spillovers into a single index suggest that, on average, across the nine Euro zone countries' BYS, 61.1% of the return forecast error variance in all nine bond markets comes from spillovers.

In summary, the results reported in Table 2 suggest that both the total and directional spillovers of government bond yield spreads within the Euro zone during the financial and debt crisis were extremely high.

4.2. Spillover Plots

While the use of an average measure of government bond yield spreads spillovers over the financial and debt crisis provides a good indication of BYS spillovers during extreme periods, it might mask potentially interesting information on movements in spillovers due to specific news and policy announcements. Hence, we estimate the model in Eq.(1) using 120-day rolling windows and calculate the variance decompositions and spillover indices. As a result, we obtain time-varying estimates of spillover indices, allowing us to judge the evolution of total and directional sovereign bond yield spread spillovers within and between Euro zone countries over time.

[Insert Figure 2 here]

Figure 2 presents the results for the time-varying total spillover index obtained from the 120-day rolling windows estimation. Indeed large variability in the total spillover index is present, and the index is very responsive to economic events and news announcements. For instance, the total spillover index followed an increasing trend starting mid of 2008 and reached a peak (point A in Figure 2) during the collapse of Lehman Brothers in September 2008. The European stimulus plan proposed by the European Commission on November 26, 2008 led to a relatively short-lived reduction of spillovers only to reached another peak during November 2009 (point B in Figure 2), when the Greek government revised its public sector deficit to 12.7% of GDP from the 6% originally stated.[4] Greece's application for bailout on April 2010 from the EU and the International Monetary Fund and acceptance on May 2010 led to another peak in spillovers (point C in Figure 2), amid fears that others countries would follow the same course of action which ultimately could lead to the breakdown of the Euro zone. Other events, such as the agreement of a second Greek bailout package in July 2011 (point D) and the call for referendum by the Greek Prime Minister Papandreou in

[4]Actually, the Greek deficit in 2009 had been revised upwards twice since then by Eurostat to 13.6% and 15.4%.

November 2011 (point E) who later resigned, led to additional increases in spillovers within the Euro zone. Since then, spillovers have declined to 60%, a still very high percentage yet.

Despite that results for the total volatility spillover index are suggestive, they might discard directional information that is contained in the "Directional to others" row (Eq. (5)) and the "Directional from others" column (Eq. (6)) in Table 2. Figure 3 presents the estimated 120-day rolling windows directional spillovers from each of the BYS to others (corresponding to the "Directional to others" row in Table 2), while Figure 4 presents the estimated 120-day rolling windows directional spillovers from the others to each of the BYS (corresponding to the "Directional from others" column in Table 2).

[Insert Figure 3 here]

[Insert Figure 4 here]

According to these two figures, the bidirectional nature of government bond yield spread returns spillovers between the nine Euro zone countries is evident. Nevertheless, they behave rather heterogeneously over time. Specifically, according to Figure 3, only in the case of Greece and in the Netherlands directional spillovers from each of these two countries' BYS exceeded the 15% threshold on few instance. Other than that, directional spillover from or to each bond market range between 5%-10%.

A similar pictures emerges when looking at the net directional spillover indices obtained from the rolling window estimation. According to Figure 5, which plots the time-varying net directional spillovers, we see that Italy, Portugal, Spain, Belgium and, to some extent, France were mostly net transmitters of BYS return shocks, while Austria, Ireland and the Netherlands were mostly at the giving ends of net BYS return transmissions. Greece was a net transmitter of volatility since the crisis erupted till the beginning of 2010, and a net receiver of BYS return spillovers thereafter.

[Insert Figure 5 here]

4.3. Impulse Responses

Having established the strong role of spillover effects, we next turn to an impulse response analysis in order to shed more light on the intricate relationships between government bond yield spreads within and between the Euro zone countries during the financial and debt crisis. As already outlined above the results should be interpreted with care. In particular, the effects of shocks to single variables should not be interpreted as causal (in the sense of 'all else being equal'), given that the generalized impulse responses account for the observed correlation of shocks across countries. This is a limitation on the one side. However, given the increased synchronization of shocks and business cycles across countries, we do not expect shocks to countries to appear in isolation from each other; and since there is no strong reason to assume that the correlation pattern of shocks to countries will change fundamentally in the short- to the medium-run, we argue that the generalized impulse responses can be regarded as indicative for the effects of future shocks.

Results of the generalized impulse response analysis are reported using one standard deviation shocks to each of the countries' government bond yield spreads (see Pesaran and Shin, 1998). We first report the results for shocks to a selective number of countries in the periphery and the core,[5] and then provide a broader picture in terms of cross-country averages of impulse response effect of shocks to single countries.

Generalized impulse responses (GIR) of shocks to the Austria, France, Greece and Ireland are presented in Figure 6. In general, we observe that the immediate response of a shock in each country is positive and is generally of higher magnitude within the core Euro zone countries or within the peripheral Euro zone countries than between core and periphery. For instance, a one standard deviation shock in France's BYS leads to an immediate response of around 0.03 in the ABFN and 0.01 in the GIIPS, while a one standard deviation shock in Greece's BYS leads to an immediate response of around 0.22 in the GIIPS and 0.10 in the ABFN. Another interesting feature of Figure 6, is that shocks originating in the GIIPS lead

[5]Impulse responses of shocks to other countries are qualitatively similar and not presented for the sake of brevity.

to responses of higher magnitude in the Euro zone than shocks originating in the ABFN. In addition, shocks have generally short-lived effects, dissipating after approximately 10 days the shock occurred.

[Insert Figure 6 here]

In order to provide a broader picture on the bottom line effect of government bond yield spreads shocks within and between the GIIPS and the ABFN countries in the Euro zone, we calculate: (i) for each country in each of the two groups (core and periphery, or ABFN and GIIPS) the cumulative effects of a one-standard deviations shock to BYS on the respective country's BYS in the respective group, referred to as 'within-group' response in the following.[6] (ii) For each country in each of the two groups (ABFN and GIIPS) the cumulative effects of a one-standard deviations shock to BYS on each country's BYS in the other group, referred to as 'between-group' response in the following.

Table 3 reports the averages of the cumulative effects i) of core countries' government bond yield spreads shocks on the core and the periphery (first column), and ii) of peripheral countries' BYS shocks on core and the periphery (second column). The cumulative effects are reported for time horizons of 5, 10, and 20 days. Since the effects of shocks have fully materialized after 20 days (compare Figure 6), the cumulative 20-days responses can be interpreted as overall bottom line effect of incipient shocks including spillover effects and the associated repercussions.

[Insert Table 3 here]

In terms of the directional effects, note that - as expected - government BYS shocks in the core and the periphery have positive and multiplicative effects on both within and between the core and the periphery. Of particular interest are the 'within-group' impulse response effects. In particular, we find that the impulse responses of shocks within the Euro zone

[6]Notice that with a stationary VAR the cumulative BYS return effects of one-time shocks have to be interpreted as level effects and should not be confused with permanent effects on the BYS return.

periphery are (positive and) of greater magnitude compared to those within the Euro zone core. Specifically, a 100 basis point shock in the periphery leads, on average, to an overall increase of 22.5 basis points in the periphery (last column) while, a 100 basis point shock in the core Euro zone countries leads, on average, to an overall increase of 3.3 basis points in the core (first column). Regarding the 'between-group' effects of impulse responses we observe that the impact of impulse responses to BYS shocks of periphery are greater on the core than vice-versa. A 100 basis point shock in the periphery leads, on average, to an overall increase of 4.5 basis points in the core while, a 100 basis point shock in the core leads, on average, to an overall increase of only 1.3 basis points in the periphery.[7]

Summing up, spillovers within the Euro zone periphery and from the periphery to the Euro zone core are of greater magnitude compared to those within the core or from the core to the periphery. Put differently, the major source of government bond yield spreads spillovers within and between the Euro zone are the beleaguered countries in the periphery.

5. Conclusions

This study examines the development of yield bond spreads (BYS) of Euro zone countries. In particular we examine BYS spillovers between and within the periphery and core Euro zone countries since 2007, a period of escalating economic risks that led to the economic crisis of 2008, until the mid of 2012 when the financial crisis has been transformed to a fully developed sovereign debt crisis for many EU countries.

First, by examining spillover indices based on a 10-day forecast error variance decomposition, shows that own-country BYS return spillovers explain up to 70% of the forecast error variance. Second, BYS return spillovers between country pairs within the periphery countries and within the core countries are greater compared to spillovers between the country pairs between these two groups of countries. Third, surprisingly, Belgium followed by Italy and Spain, is found to be the dominant transmitter of BYS spillovers, while Greece,

[7] It worth emphasizing once again that the long-term cumulative impulse responses reflect level, that is basis points, rather than permanent BYS return effects.

Portugal and Netherlands are the dominant receivers of BYS return spillovers. Fourth, and most important, 61.1% of return forecast error variance in all examined markets comes from spillovers. By examining the plots of time-varying net directional spillovers, we found that Greece is a major net transmitter of volatility since the crisis erupted till the beginning of 2010, and a net receiver of BYS return spillovers thereafter. In addition, generalized impulse responses (GIR) of shocks were found positive and are generally of higher magnitude within the core Euro zone countries or within the peripheral Euro zone countries (Greece, Ireland, Italy, Portugal and Spain (GIIPS)) than between core and periphery. Finally, the between-group effects of impulse responses to shocks of periphery are greater on the core (Austria, Belgium, France and Netherlands (ABFN)) than vice-versa.

Our findings highlight the increased vulnerability of the Euro zone from the destabilizing shocks originating from the beleaguered Euro zone countries in the periphery. These findings are partly in contrast to findings of early studies that showed yield convergence among European countries before the financial crisis. Overall, the findings of our study have policy implications, because they may challenge the arguments for a single currency in the examined countries and indicate the need for re-examining the role of a single currency in the new, after crisis era, and probably the need for re-assessing the effectiveness of the EU directorate economic policies.

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Figure 1: 10-year government bond yield spreads in ABFN and GIIPS countries

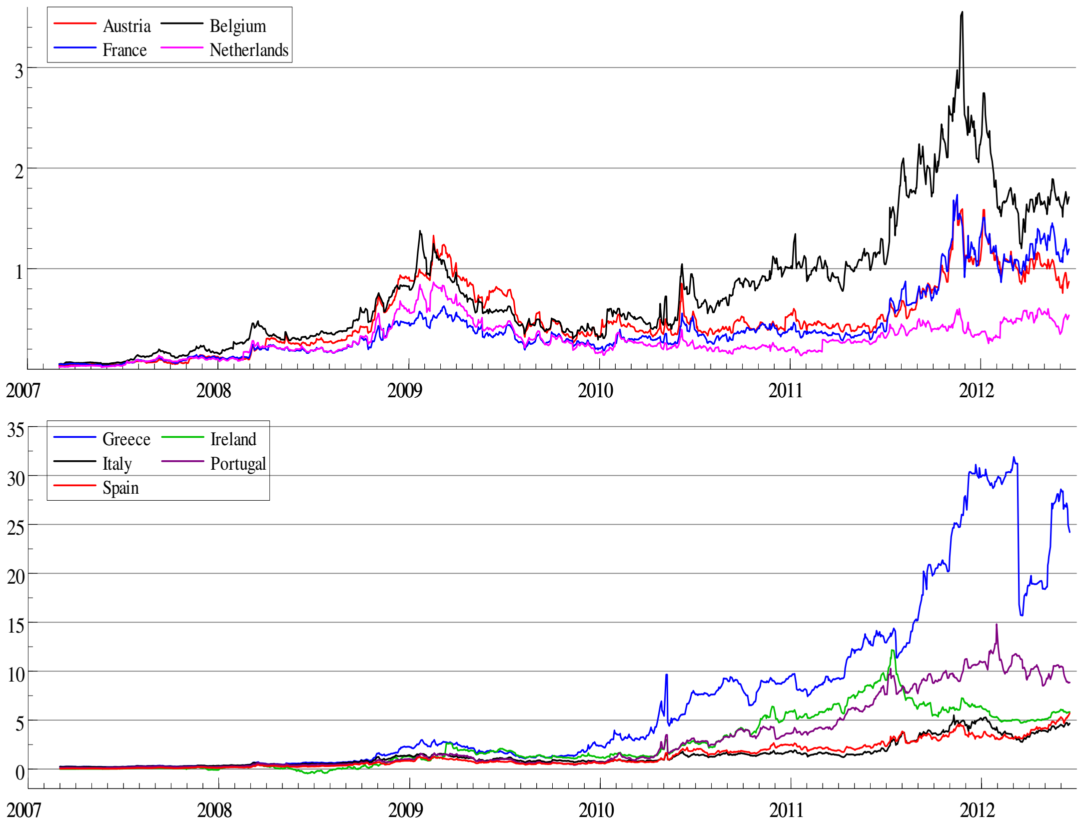
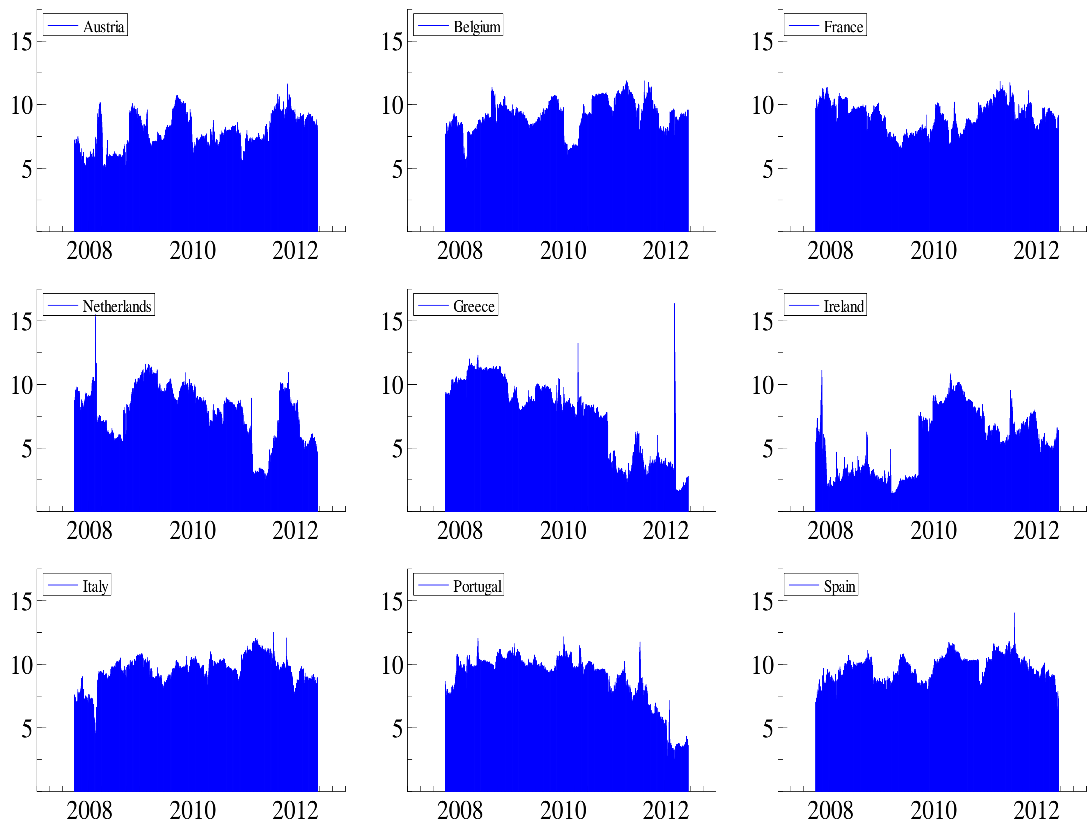


Figure 2: Total spillover index

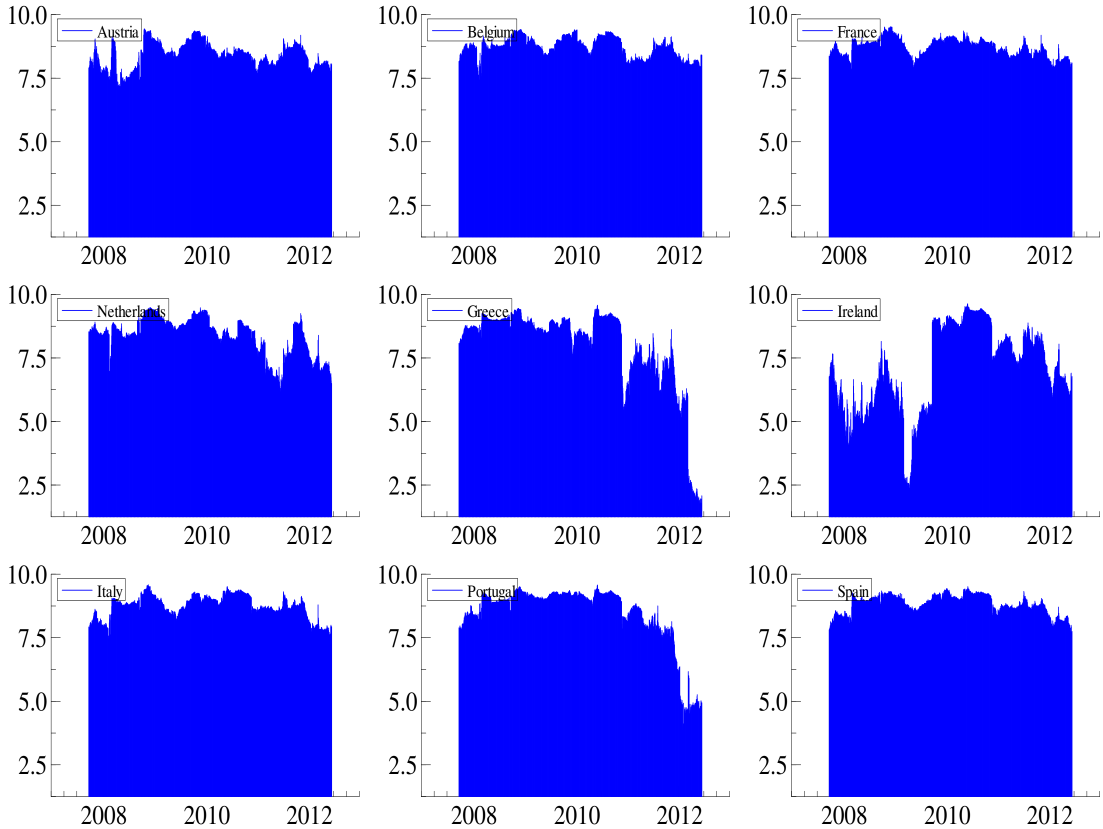
Note: Plots of moving total spillover index estimated using 120-day rolling windows.

Figure 3: Directional spillovers *from* each countries' government bond yield spreads



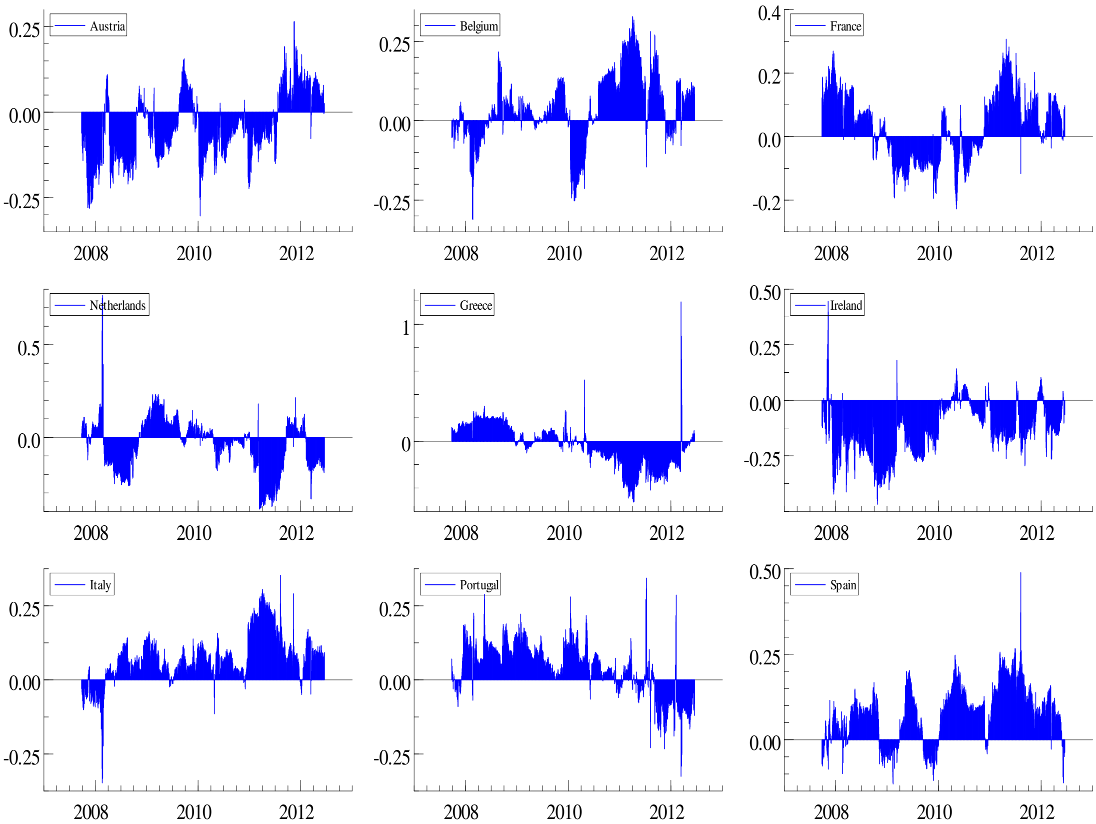
Note: Plots of moving directional spillovers estimated using 120-day rolling windows.

Figure 4: Directional spillovers *to* each countries' government bond yield spreads



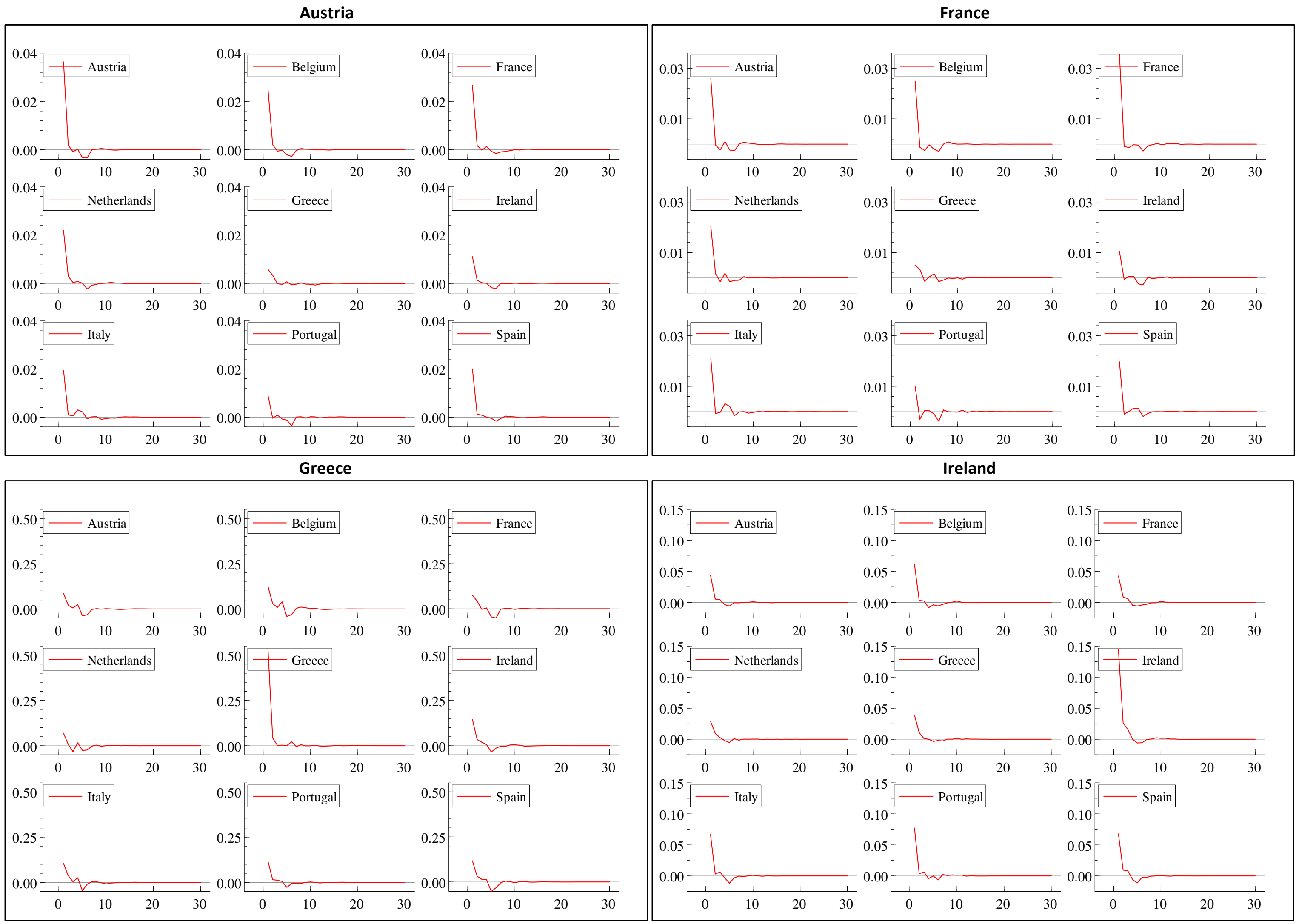
Note: Plots of moving directional spillovers estimated using 120-day rolling windows.

Figure 5: Net spillovers of sovereign bond yield spread shocks for each country



Note: Plots of moving directional spillovers estimated using 120-day rolling windows.

Figure 6: Generalized impulse responses to BYS shocks of selective Euro zone core and periphery countries



Note: Generalized impulse responses to one standard deviation shock to BYS of Austria, France, Greece and Ireland.

Table 1: Descriptive statistics of 10-year government bond yield spreads

Panel A: Raw series									
	AUT	BEL	FRA	NED	GRC	IRL	ITL	PRT	ESP
Mean	0.5012	0.7967	0.4145	0.2882	6.8689	2.6463	1.4511	3.0689	1.3752
Std	0.3416	0.6400	0.3454	0.1728	8.5908	2.7256	1.2601	3.6019	1.2915
Min	0.03300	0.0480	0.0300	0.0200	0.2000	-0.4520	0.1880	0.1120	0.0340
Max	1.6920	3.5540	1.7350	0.8650	31.903	12.162	5.5070	14.814	5.7070
ADF	-0.0202	-1.578	-0.0133	-0.0227	-0.3155	-0.0083	-0.0023	-0.0046	0.0088
Panel B: First differences									
	AUT	BEL	FRA	NED	GRC	IRL	ITL	PRT	ESP
Mean	0.0718	0.1428	0.0985	0.0441	2.0626	0.5015	0.3806	0.7495	0.4871
Std	3.8565	6.2993	3.7670	2.2584	55.605	15.051	9.5969	20.225	9.2338
Min	-25.900	-29.900	-24.200	-12.200	-1440.7	-136.80	-93.700	-238.60	-99.400
Max	35.200	63.400	22.500	17.500	443.20	133.80	66.600	202.70	65.800
ADF	-30.81**	-31.12**	-34.06**	-32.04**	-31.12**	-28.11**	-36.39**	-32.59**	-33.11**
	Correlations								
AUT	1.0000								
BEL	0.7006	1.0000							
FRA	0.7357	0.7009	1.0000						
NED	0.5798	0.4676	0.5654	1.0000					
GRC	0.1667	0.2218	0.1484	0.1276	1.0000				
IRL	0.2942	0.4269	0.2872	0.1928	0.2733	1.0000			
ITL	0.5251	0.6932	0.5960	0.4111	0.1963	0.4691	1.0000		
PRT	0.2427	0.3591	0.2635	0.1820	0.2304	0.5311	0.4571	1.0000	
ESP	0.5373	0.6625	0.5462	0.4469	0.2169	0.4794	0.8041	0.4177	1.0000

Note: ADF denotes augmented Dickey Fuller tests with 5% (1%) critical values of -2.86 (-3.44). * and ** indicate significance at 5% and 1% level, respectively.

Table 2: Spillover table

To (i)	From (j)									Direct. From Others
	AUT	BEL	FRA	NED	GRC	IRL	ITL	PRT	ESP	
AUT	31.3	15.3	16.8	11.5	1.1	3.1	9.2	2.3	9.4	69
BEL	14.0	28.0	13.8	6.7	2.0	5.9	12.9	4.7	12.0	72
FRA	16.6	15.3	30.3	10.2	1.0	3.0	11.1	3.0	9.5	70
NED	14.9	9.8	13.6	40.6	0.9	1.9	7.6	2.2	8.4	59
GRC	2.6	5.1	2.9	1.8	69.9	5.8	3.6	3.6	4.6	30
IRL	4.2	8.2	4.2	2.0	3.5	45.3	9.7	12.7	10.2	55
ITL	8.3	13.4	10.5	5.2	1.6	6.9	28.5	7.0	18.7	72
PRT	3.3	6.7	3.9	2.4	3.0	14.4	10.3	47.4	8.7	53
ESP	8.8	12.8	9.2	6.0	1.7	7.2	19.3	5.8	29.0	71
Direct. to others	73	86	75	46	15	48	84	41	82	Total Spillover
Direct. incl. own	104	114	105	87	85	94	112	89	111	Index = 61.1%
Net spillovers	4	14	5	-13	-15	-7	12	-12	11	

Note: Spillover indices, given by Equations (2)-(7), calculated from variance decompositions based on 10-step-ahead forecasts.

Table 3: Cumulative impulse responses

		From (j)	
	To(i)	Core	Periphery
5-days	Core	3.5241	5.3146
	Periphery	1.4765	22.4885
	To(i)	Core	Periphery
10-days	Core	3.2473	4.5496
	Periphery	1.2794	22.3436
	To(i)	Core	Periphery
20-days	Core	3.2594	4.5396
	Periphery	1.2792	22.3332

Note: Cumulative generalized impulse response to 100 basis points shock.