DOCUMENTOS DE ECONOMÍA Y FINANZAS INTERNACIONALES

Working Papers on International Economics and Finance

DEFI 11-03
Abril 2011

Volatility in EMU sovereign bond yields: Permanent and transitory components

Simón Sosvilla-Rivero
Amalia Morales-Zumaquero

Asociación Española de Economía y Finanzas Internacionales
www.aeefi.com
ISSN: 1696-6376

Volatility in EMU sovereign bond yields: Permanent and transitory components

Corresponding author: Simón Sosvilla-Rivero

Departmento de Economía Cuantitativa, Facultad de Ciencias Económicas y Empresariales, Universidad Complutense de Madrid, Campus de Somosaguas, 28223 Madrid, Spain, sosvilla@ccee.ucm.es

Amalia Morales-Zumaquero

Departamento de Teoría e Historia Económica, Facultad de Ciencias Económicas y Empresariales, Universidad de Málaga, Campus de El Ejido 29071 Málaga, Spain, amalia@uma.es

April 2011

Abstract

This paper explores the evolving relationship in the volatility of sovereign yields in the European Economic and Monetary Union (EMU). To that end, we examine the behaviour for daily yields for 11 EMU countries (EMU-11), during the 2001-2010 period. In a first step, we decompose volatility in permanent and transitory components using Engel and Lee (1999)´s component-GARCH model. Results suggest that transitory shifts in debt market sentiment tend to be less important determinants of bond-yield volatility than shocks to the underlying fundamentals. In a second step, we develop a correlation and causality analysis that indicates the existence of two different groups of countries closed linked: core EMU countries and peripheral EMU countries. Finally, in a third step, we make a cluster analysis that further support our results regarding the existence of two different groups of countries, with different positions regarding the stability of public finance.

Keywords: Conditional variance, Component model, Cluster analysis, Sovereign bond yields, Economic and Monetary Union

JEL Codes: C32, F33, G12, G13

1. Introduction

Since the introduction of the euro, the eurozone's monetary authorities have shown great interest in the integration and the efficient functioning of financial systems of countries of the Economic and Monetary Union (EMU). This interest is explained by the relevance of its implications: their contribution to economic growth, the disappearance of trade barriers, a more efficient allocation of capital among different investment opportunities and consumption, and increased competitiveness and the functioning of market discipline, among others. Additionally, a robust and integrated financial system facilitates the efficient functioning of the monetary transmission mechanism and is capable of promoting better absorption of any financial shocks of the different economies (European Central Bank, 2010). However, there are also some critical voices to that integration process. An eventual reduction of opportunities for diversification of risk by private investors and a potential increase in the spread between markets, as highlighted the crisis of sovereign debt in the euro area in 2010, are some of the arguments most commonly used in this sense.

Unlike the extensive literature on the interrelationships in the equity markets (see Bessler and Yang, 2003, among others), few empirical studies about the relationships that have the returns of assets in fixed income markets. In addition, the scare empirical literature has focused on the transmission of volatility between international bond markets (see Cappiello *et al.*, 2003; Christiansen, 2003, or Skintzi and Refenes, 2006 among others), been neglected the research on the interrelationships of the public debt markets in the context of EMU. The few exceptions include Cuñado and Gómez-Puig (2010), Geyer and Pischler Kossmeier (2004), Gómez-Puig (2009a and 2009b) or Pagano and von Thadden (2004).

The objective of this paper is to analyse the volatility behaviour of sovereign bond yields in different euro zone countries. To that end, examine behaviour for daily yields 11 EMU countries (EMU-11) during the 2001-2010 period. We decompose volatility in permanent and transitory components using Engel and Lee (1999)´s component-GARCH model. Furthermore, we develop a correlation and causality analysis between permanent and transitory volatilities and we look for clusters in permanent and transitory volatilities of sovereign yields.

The paper is organised as follows. Section 2 describes the econometric methodology adopted in this study. Section 3 presents the data and the empirical result, and Section 4 offers some concluding remarks.

2. Econometric Methodology

Engle and Lee (1999) proposed a “component-GARCH” (C-GARCH) model to decompose time-varying volatility into a permanent (long-run) and a transitory (short-run) component.

Consider the original GARCH model:

$$\sigma_t^2 = \omega + \alpha(\varepsilon_{t-1}^2 - \omega) + \beta(\sigma_{t-1}^2 - \omega) \tag{1}$$

As can be seen, the conditional variance of the returns here has mean reversion to some time-invariable value, ω. The influence of a past shock eventually decays to zero as the volatility converges to this value ω according to the powers of (α+β). The standard GARCH model therefore makes no distinction between the long-run and short-run decay behavior of volatility persistence.

For the permanent specification, the C-GARCH model replaces the time-invariable mean reversion value, ω, of the original GARCH formulation in equation (1) with a time variable component q_t:

$$q_t = \hat{\omega} + \rho(q_{t-1} - \hat{\omega}) + \varphi(\varepsilon_{t-1}^2 - \sigma_{t-1}^2) \tag{2}$$

where, q_t is the long-run time-variable volatility level, which converges to the long-run time-invariable volatility level $\hat{\omega}$ according to the magnitude of ρ. This permanent component thus describes the long-run persistence behaviour of the variance. The long-run time-invariable volatility level $\hat{\omega}$ can be viewed as the long-run level of returns variance for the relevant sector when past errors no longer influence future variance in any way. Stated differently, the value $\hat{\omega}$ can be seen as a measure of the 'underlying' level of variance for the respective series. The closer the estimated value of the ρ in equation (7) is to one the slower q_t approaches $\hat{\omega}$, and the closer it is to zero the faster it approaches $\hat{\omega}$. The value ρ therefore provides a measure of the long-run persistence.

The second part of C-GARCH model is the specification for the short-run dynamics, the behaviour of the volatility persistence around this long-run time-variable mean, q_t:

$$\sigma_t^2 - q_t = \gamma(\varepsilon_{t-1}^2 - q_{t-1}) + \lambda(\sigma_{t-1}^2 - q_{t-1}) \tag{3}$$

According to this transitory specification, the deviation of the current condition variance from the long-run variance mean at time t ($\sigma_t^2 - q_t$) is affected by the deviation of the previous error from the long-run mean $(\varepsilon_{t-1}^2 - q_{t-1})$ and the previous deviation of the condition variance from the long-run mean $(\sigma_{t-1}^2 - q_{t-1})$. Therefore, in keeping with its GARCH theoretical background, the C-GARCH specification continues to take account of the persistence of volatility clustering by having the conditional variance as a function of past errors. As the transitory component describes the relationship between the short-run and long-run influence decline rates of past shocks values of (γ+λ) closer to one imply slower convergence of the short-run and long-run influence decline rates, and values closer to zero the opposite. The value (γ+λ) is therefore a measure of how long this short-run influence decline rate is.

Together, these two components of the C-GARCH model describe, just like the original GARCH formulation, how the influence of a past shock on future volatility declines over time. With the C-GARCH model however, this persistence is separated into a short-run and long-run component, along with the estimation of the underlying variance level once the effect of both components has been removed from a series.

3. Data and Empirical Results

3.1. Data

We use daily data of 10-year bond yields from 26 March 2001 to 31 December 2010 taking from Thomson Reuters Datastream for the EMU-11 countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Portugal and Spain.

Figure 1 plots the log differences of daily 10-year bond yields for each country in our sample. A simple look at these figures indicates the differences in the yield volatility before and after 2006 for most of the countries, as well as during the recent turmoil in 2008.

[Insert Figure 1 here]

3.2. Empirical Results

3.2.1. Permanent and transitory components

Coefficient estimates for the C-GARCH model obtained by maximum likelihood are reported in Table 1. Regarding the permanent component, the long-run average volatility, $\hat{\omega}$, is significant at the 1% level for all countries except for Greece where it is significant at the 10% level. The coefficient $\hat{\rho}$ is also significant at the 1% level for all countries except for Italy where it is significant at the 5% level, confirming the presence of long-run volatility persistence. In particular, the coefficient estimates suggest that this long-run volatility persistence is consistently very high, at 0.983 for Italy, 0.992 for Austria, Finland, Germany, and The Netherlands, 0.993 for Belgium, France and Portugal, 0.995 for Greece and Spain, and 0.998 for Ireland. These results indicate that permanent conditional volatility exhibits long memory. More specifically, long-run component half-live decay is 88 days for Austria, 94 days for Belgium, 87 days for Finland, 97 days for France, 91 days for Germany, 130 days for Greece, 331 days for Ireland, 41 days for Italy, 83 days for The Netherlands, 99 days for Portugal, and 137 days for Spain[1]. Finally, the coefficient $\hat{\varphi}$ that gives the initial effect of a shock to the long-run component, it is significant at the 1% level in nine out of the eleven cases examined.

[Insert Table 1 here]

As for the transitory components, the coefficient $\hat{\gamma}$, which quantifies the initial impact of a shock to the transitory component of the C-GARCH model, is only significant (at least at the 5% level) in five out of the eleven cases considered, while the coefficient $\hat{\lambda}$, which indicates the degree of memory in the transitory component, is also significant (at least at the 5% level) in five out of the eleven cases examined. Shock persistence in the transitory components is nevertheless also fairly high for Belgium, Greece, Ireland, Italy and Spain, as measured by the sum of the transitory parameters, $(\hat{\gamma}+\hat{\lambda})$, being 0.871, 0.882, 0.878, 0.749 and 0.888, respectively. The short-run component half-live decay is less than one day in Austria, France, Germany and Portugal; five days in Belgium, Greece, Ireland and Spain; one day in Finland and The Netherlands; and two days in Italy, indicating full decay of a shock to the transitory components within few days[2].

Before proceeding further, we compare the performance of the C-GARCH model to the GARCH model. Note that the C-GARCH model reduces to the

---

[1] The long-run half-life measure is computed using the formula: $LR_{HL}(\hat{\rho}) = Ln(1/2)/Ln(\hat{\rho})$.

[2] The short-run half-life measure is computed using the formula: $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2)/Ln(\hat{\gamma}+\hat{\lambda})$.

GARCH(1,1) model if either $\hat{\gamma} = \hat{\lambda} = 0$, or $\hat{\rho} = \hat{\varphi} = 0$. The Wald test on this coefficient restrictions are reported in the last columns of Table 1. As can be seen, the null hypothesis is decisively rejected in all cases at the 1% level, favouring C-GARCH specification over the GARCH(1,1) specification.

´ In order to have a visual representation of the role played by the two volatility components of the conditional variance, Figure 2 plots the time evolution of the total variance, permanent variance and transitory variance for the daily difference in 10-year bond yields for the EMU-11 countries under study. In general, the plots indicate that the permanent component has smooth movements and approaches a moving average of the GARCH volatility, while the transitory component responds largely to market fluctuations, tracking much of the variation in conditional volatility. Consistent with the findings of Engle and Lee (1999), Alizadeh *et al*. (2002) and Brandt and Jones (2006), we show that the long-run component is characterised by a time varying but highly persistent trend, while the short run component is strongly mean-reverting to this trend. For all countries and periods, the temporary component of volatility is much smaller than the permanent component, suggesting that transitory shifts in debt market sentiment tend to be less important determinants of bond-yield volatility than shocks to the underlying fundamentals. Yet, relative to its lower mean level, the transitory component is in all cases much more volatile than the long-run trend level of volatility, as one would expect.

[Insert Figure 2 here]

3.2.2. Correlation analysis

To gain further insights in the behaviour of the permanent and transitory components of the conditional variance, we examine the correlation coefficients between each series. The results for the permanent component are shown in Table 2. As can be seen, relatively strong correlations of over 0.75 are found between Austria, Belgium, Finland, France, Germany, Italy and The Netherlands, suggesting the existence of some degree of commonality between them. Further strong correlation is also found between the permanent volatilities of Portugal and Greece, Belgium and Spain, and Spain and Ireland. Correlations of lesser but still notable magnitude also are detected between Spain and Austria, Finland, France, Germany, The Netherlands and Portugal; and between Italy and Ireland.

[Insert Table 2 here]

Correlations between the transitory components of volatility are presented in Table 3. These results show very weak correlation between the series, with all correlation coefficients lower than those found for the permanent components. Nevertheless, we detect relatively positive strong correlations between the transitory components of volatility in ten out of the fifty five cases examined (Austria and Finland, Austria and France, Finland and France, Belgium and Germany, Italy and Ireland, Austria and The Netherlands, Finland and The Netherlands, France and The Netherlands, Ireland and Spain, and Italy and Spain), whereas relatively strong negative correlations is found in three cases (Italy and The Netherlands, Greece and Portugal, and Greece and Spain). Given that transitory volatility could be related with the arrival of information specific to each market, we could take the presence of these correlations as evidence of speculation and hedging positions.

[Insert Table 3 here]

3.2.3. Causality analysis

In this section we present results from the Granger (1969) approach to causality to explore the relationship between all possible pairs in our sample, given that the previous analysis of correlation does not necessarily imply causation in any meaningful sense of that word. Granger's approach is based on the time series notion of predictability: given two variables, variable X causes variable Y if the present value of Y can be predicted more accurately by using the past values of X and Y than by using only past values of X. Tables 4 and 5 report the value of F-Statistic used to test the null hypothesis that all the coefficients of the past values of the auxiliary variable are zero for the permanent and transitory components, respectively.

Regarding the relationship between permanent volatility (Table 4), we find Granger causality running one-way from Austria to Belgium, Finland, Italy, The Netherlands and Spain, from France to Austria, Belgium and Finland, from Germany to Austria, Belgium and Italy, from Finland to Belgium, Italy and The Netherlands, from Belgium to Italy and Spain, from France to Italy, from The Netherlands to Italy, from Portugal to Ireland, and from Italy to Spain, but not the other way. In addition, we detect two-way causation between the following pairs: France and The Netherlands, Germany and The Netherlands, Greece and Ireland, Italy and Greece, Greece and Portugal, Greece and Spain, and Ireland and Spain.

[Insert Table 4 here]

As for the relationship between transitory, results in Table 5 suggest Granger causality running 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, from The Netherlands to Belgium and Germany, and from Spain to Germany, Ireland and Portugal, but not the other way. In addition, two-way causation is found between the following pairs: Austria and Finland, Austria and The Netherlands, Belgium and Germany, Belgium and Ireland, France and The Netherlands, Greece and Ireland, Greece and Italy, Greece and Portugal, Greece and Spain, Ireland and Portugal, Italy and The Netherlands, Italy and Portugal, and Italy and Spain.

.

[Insert Table 5 here]

3.2.4. Cluster analysis

Hitherto, when analysing of permanent and transitory volatilities of sovereign yields, a pattern seems to arise linking on the one hand core EMU countries and on the other peripheral EMU countries. As can be seen in Figure 3, we find relationships linking countries with similar positions regarding the stability of public finance as specified in the Maastricht Treaty to the euro as their currency and in the Stability and Growth Pact to facilitate and maintain the stability of EMU (i. e.: public debt and fiscal deficit not exceeding 60% and 3% of GDP, respectively). It is interesting to note that these two groups roughly correspond to the distinction made by the European Commission (1995) between those countries whose currencies continuously participated in the European

Exchange Rate Mechanism (ERM) from its inception maintaining broadly stable bilateral exchange rates among themselves over the sample period, and those countries whose currencies either entered the ERM later or suspended its participation in the ERM, as well as fluctuating in value to a great extent relative to the Deutschmark. These two groups are also roughly the same found in Jacquemin and Sapir (1996), applying multivariate analysis techniques to a wide set of structural and macroeconomic indicators, to form a homogeneous group of countries. Moreover, these two groups are basically the same that those found in Ledesma-Rodríguez *et al.* (2005) according to the perception of economic agents with respect to the commitment to maintain the exchange rate around a central parity in the ERM. Therefore, there seems to be an association between in permanent and transitory volatilities of sovereign yields between countries with similar degree of confidence that economic agents assign to the announcements made by policymakers.

[Insert Figure 3 here]

To further explore this classification, we look for clusters in the permanent and transitory volatilities of sovereign yields. Cluster analysis groups countries that share the same characteristics using only information based on the data. The goal is that countries within a group should be similar to one another and different from countries in other groups. The greater the similarities within a group (i.e, the smaller the intra-cluster distances) and the greater the differences between groups (i. e., the larger the inter-cluster distances), the more distinct the clustering. Two clustering methods have been used: the hierarchical and the partitioning algorithms. The first starts by forming a group for each country. Employing some criterion of similarity, the countries are grouped at different levels. The procedure goes on until all countries are in a single cluster. The sequence of clustering is displayed in a typical plot called a tree diagram, where we can see the detailed process. This diagram offers us a first approximation of the number of clusters, *m*, present in our set of permanent or transitory components of volatility.

The next step is to apply a partitioning clustering method called *k-means* that requires previously deciding the numbers of groups. The *k-means* clustering creates a single level of clusters and assigns each country to a specific cluster. In addition, this technique uses the actual observations of the individuals and not their proximities, which means that it is more suitable for clustering large amounts of data such as temporal series. The algorithm finds a partition in which countries within each cluster are as close to each other as possible and as far from the countries in other clusters as possible. Each cluster is defined by its cluster centre, or centroid, the point at which the sum of the square Euclidean distances from all the countries is minimized. The iterative algorithm minimizes these square distances within all the clusters, but the final results depend on the first random assignation. To overcome the two disadvantages of the *k-means* method (the selection of the number of clusters and the dependence of the results on the initial partition), we have repeated the algorithm for a different randomly selected set of initial centroids and select, among the different local minima, the one with the create their silhouette plots that display a measure of how close each point in one cluster is to a point in the neighbouring clusters. This procedure allows us to the check the robustness of the number of clusters selected.

We apply this method to the permanent and transitory components of the volatility of sovereign yields. Looking at the results of the hierarchical method (not shown here to save space), 2 or 3 clusters seems to be the most suitable decision for the permanent component and 3 for the transitory one. The *k-means* method selects 2 and 3 clusters, respectively. So, we should select 2 clusters for the permanent components and 3 for the transitory one.

Regarding permanent volatility, the results for m=2 groups determine that Greece, Ireland and Portugal are included in the first cluster and the rest of countries in the second, although Spain and Italy would be outliers in this second cluster because they present the highest distance from the cluster centroid. Figure 4 illustrate these results. The vertical axis represents the inter-cluster distance and the horizontal axis represents the number of countries. The size of the balls represents the value of the cluster centre, which can be interpreted as the average behaviour of the cluster with respect to the permanent volatility (i. e., the bigger the ball, the higher the permanent volatility). As can be see, countries in the first cluster, characterised by characterized by a high ratio of both public debt to GDP and deficit/GDP, had asked for financial assistance after being under pressure due to doubts regarding the compliance of debt payments and the need of restructuring their debt. On the other hand, countries in the second cluster either present a high record in both variables (Italy and to a lesser extent the Netherlands) or have a high deficit (Spain). Finally, countries in the third cluster show a better performance on both criteria of fiscal solvency, with the possible exception of Belgium.

[Insert Figure 4 here]

As for the transitory volatility, the algorithm clearly identifies three clusters: Group 1 formed by Ireland; Group 2 composed of Spain, Portugal, Italy and Greece; and Group 3 consisting of the rest of the countries. Figure 5 illustrate these results. As can be seen, the size of the balls in Group 2 and 3 is very similar, while the size of the ball in the first cluster (Ireland) is much bigger. Note also that, within Group 3, Belgium is very distant from the rest.

4. Concluding Remarks

This paper has explored the evolving relationship in the volatility of sovereign yields in the European Economic and Monetary Union (EMU) during the 2001-2010 period. To that end, we have made use of Engel and Lee (1999)´s component-GARCH model to decompose volatility in permanent and transitory components.

Our results suggest that permanent conditional volatility exhibits long memory (with long-run component half-live decay ranking from 83 days in The Netherlands to 331 days in Ireland), being the temporary component of volatility much smaller (with short-run component half-live decay ranking from is less than one day in Austria to two days in Italy). These findings indicate that transitory shifts in debt market sentiment tend to be less important determinants of bond-yield volatility than shocks to the underlying fundamentals. Furthermore, our correlation and causality analyses between permanent and transitory volatilities of sovereign yields indicate the existence of two different groups of countries closed linked (core EMU countries and peripheral EMU countries), with different degree of credibility assigned to the announcements made by policymakers and with different positions regarding the stability of public finance.

We believe it is highly relevant in the current context, especially since it has not yet been addressed in sufficient depth by the literature.

Acknowledgements

The authors would like to acknowledge financial support from the Spanish Ministry of Science and Innovation (ECO2008-05565). We are also very grateful to Lola Gadea for providing us with the Matlab codes for the cluster analysis.

References

Abad, P., Chuliá, H. and Gómez-Puig, M. (2010) EMU and European Government Bond Market Integration, *Journal of Banking and Finance*, **34**, 2851–2860.

Alizadeh, S., Brandt, M. W., and Diebold, F. X. (2002) Range-Based Estimation of Stochastic Volatility Models, *Journal of Finance*, **57**, 1047–1091.

Barr, D.G. and Priestley, R. (2004) Expected Returns, Risk and the Integration of International Bond Markets, *Journal of International Money and Finance,* **23**, 71-97.

Bessler, D.A. and Yang, J. (2003) The Structure of Interdependence in International Stock Markets *Journal of International Money and Finance* **22**, 261-287

Cappiello, L., R. F. Engle, and Sheppard, K. (2003) Asymmetric dynamics in the correlations of global equity and bond returns, Working Paper No.204, European Central Bank.

Brandt, M. and Jones, C. (2006) Volatility Forecasting With Range-Based EGARCH Models, *Journal of Business and Economic Statistics*, **24**, 470–486

Christiansen, C. (2003) Volatility-Spillover Effects in UE-15 Bond Markets, Working Paper Series No.162, Centre for Analytical Finance. University of Aarhus.

Cifarelli, G. and Paladino, G. (2006) Volatility Co-Movements Between Emerging Sovereign Bonds: Is There Segmentation Between Geographical Areas, *Global Finance Journal* **16**, 245-263.

Cuñado, J. and Gómez-Puig, M. (2010) Monetary Integration and Risk Diversification in EU-15 Sovereign Debt Markets, Working Paper 498, FUNCAS.

Engle, R. F. and Lee, G. G. J. (1999) A permanent and transitory component model of stock return volatility, in R. Engle and H. White (eds.), *Cointegration, Causality, and Forecasting: A Festschrift in Honor of Clive W.J. Granger*, Oxford University Press, Oxford, 475-497.

European Central Bank (2010) *Financial Integration in Europe*, April.

European Commission (1995) The impact of exchange-rate movements on trade within the single market, *European Economy*, **4**.

Geyer, A., S. Kossmeier and Pichler, S. (2004) Measuring Systematic Risk in EMU Government Yield Spreads, *Review of Finance* **8**, 171-197

Gómez-Puig, M. (2006) Size Matters for Liquidity: Evidence from EMU Sovereign Yield Spreads, *Economics Letters* **90**, 156-162.

Gómez-Puig, M. (2008) Monetary Integration and the Cost of Borrowing, *Journal of International Money and Finance* **27**, 455-479.

Gómez-Puig M. (2009a) The Immediate Effect of Monetary Union over UE-15's Sovereign Debt Yield Spreads, *Applied Economics* **41**, 929-939.

Gómez-Puig, M. (2009b) Systemic and Idiosyncratic Risk in UE-15 Sovereign Yield Spreads After Seven Years of Monetary Union, *European Financial Management* **15**, 971–1000.

Granger, C. W. J. (1969) Investigating Causal Relations by Econometric Models and Cross-spectral Methods, *Econometrica* **37**, 24-36.

Hardouvelis, G.A., D. Malliaropulos and Priestley, R. (2006) EMU and UE-15 Stock Market Integration, *Journal of Business* **79**, 365-392.

Hardouvelis, G.A., D. Malliaropulos and Priestley, R. (2007) The Impact of EMU on the Equity Cost of Capital, *Journal of International Money and Finance* **26**, 305-327.

Jacquemin, A. and Sapir, A. (1996) Is a European hard core credible? A statistical analysis, *Kyklos*, **49**, 105-117.

Ledesma-Rodríguez, F., Navarro-Ibáñez, M, Pérez-Rodríguez, J. and Sosvilla-Rivero, S. (2005) Assessing the credibility of a target zone: Evidence from the EMS, *Applied Economics*, **37,** 2265-2287.

Pagano, M. and von Thadden, E. L. (2004) The European Bond Markets under EMU, *Oxford Review of Economic Policy* **20**, 531-554.

Skintzi, V.D., and Refenes, A. N. (2006) Volatility Spillovers and Dynamic Correlation in UE-15 Bond Markets, *Journal of International Financial Markets, Institutions and Money* **16**, 23-40.

Stock, J.H., and Watson, M. W. (2011) Dynamic Factor Models, in M.P. Clements and D. Hendry (eds.), *Oxford Handbook of Economic Forecasting*, Oxford University Press, Oxford.

Table 1. Behaviour of volatility persistence: 10-years sovereign yields, EMU countries

	Permanent component				Transitory component			Wald tests[c]	
	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	LR half life	$\hat{\gamma}$	$\hat{\lambda}$	SR half life	$\hat{\gamma}=\hat{\lambda}=0$	$\hat{\rho}=\hat{\varphi}=0$
AUS[d]	0.002* (7.492)	0.992* (3.447)	0.031* (6.097)	88	-0.009 (-0.527)	0.475 (0.336)	0.91	171385.9*	38.04*
BEL	0.002* (7.407)	0.993* (3.425)	0.029* (6.363)	94	-0.008** (-1.966)	0.879* (6.572)	5.02	172852.7*	42.78*
FIN	0.002* (3.648)	0.992* (3.648)	0.030* (6.191)	87	-0.018 (-1.140)	0.543 (0.855)	1.07	188495.2*	38.34*
FRA	0.002* (6.503)	0.993* (3.082)	0.032* (6.155)	97	-0.022 (-1.194)	0.420 (0.680)	0.75	139076.1*	37.95*
GER	0.002* (6.214)	0.992* (3.086)	0.036* (7.032)	91	-0.003 (-0.687)	0.375* (2.049)	0.70	159832.6*	51.71*
GRE	0.007*** (1.661)	0.995* (2.610)	0.111*** (1.634)	130	-0.006 (-0.611)	0.888* (4.858)	5.51	1183951*	368.16*
IRE	0.005* (2.385)	0.998* (7.520)	0.026* (5.090)	331	0.081* (6.963)	0.797** (1.838)	5.34	4075961*	106.91*
ITA	0.002 (1.224)	0.983** (1.847)	0.037* (4.228)	41	0.034* (2.275)	0.715* (3.296)	2.40	40915.99*	32.66*
NET	0.002* (7.063)	0.992* (2.985)	0.035* (6.210)	83	-0.021 (-1.280)	0.537 (0.974)	1.03	130019.9*	38.58*
POR	0.004* (3.781)	0.993* (3.484)	0.071 (1.550)	99	0.029** (1.713)	0.219 (0.410)	0.49	585864*	253.07*
SPA	0.003* (4.826)	0.995* (3.718)	0.032* (3.842)	137	0.044* (4.418)	0.844 (1.149)	5.82	264895.6*	64.82*

Notes:

a.. Parentheses are used to indicate z-statistics. *, **, *** indicate significance at 1%, 5% and 10%, respectively.

b. The long-run and short-run half lives are measured using the following formulae: $LR_{HL}(\hat{\rho}) = Ln(1/2)/Ln(\hat{\rho})$ and $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2)/Ln(\hat{\gamma}+\hat{\lambda})$.

c. Wald tests on coefficient restrictions are Chi-square statistics with 2 degrees of freedom.

d. AUS: Austria, BEL: Belgium, FIN: Finland, FRA: France, GER: Germany, GRE: Greece, IRE: Ireland, ITA: Italy; NET: Netherlands, POR: Portugal, SPA: Spain.

Table 2. Permanent volatility component analysis: Correlation coefficients

	AUS	BEL	FIN	FRA	GER	GRE	IRE	ITA	NET	POR	SPA
AUS	1	0.950	0.934	0.961	0.941	0.025	0.279	0.830	0.947	0.121	0.695
BEL		1	0.933	0.952	0.952	0.026	0.390	0.866	0.956	0.163	0.785
FIN			1	0.965	0.963	0.015	0.226	0.792	0.971	0.091	0.648
FRA				1	0.962	-0.019	0.215	0.808	0.983	0.060	0.639
GER					1	0.084	0.321	0.831	0.975	0.181	0.730
GRE						1	0.418	0.360	0.018	0.936	0.365
IRE							1	0.514	0.253	0.661	0.761
ITA								1	0.822	0.493	0.847
NET									1	0.105	0.677
POR										1	0.561
SPA											1

Table 3. Transitory volatility component analysis: Correlation coefficients

	AUS	BEL	FIN	FRA	GER	GRE	IRE	ITA	NET	POR	SPA
AUS	1	0.086	0.705	0.831	0.098	0.020	-0.102	-0.462	0.765	-0.073	-0.293
BEL		1	0.084	0.109	0.798	0.012	-0.025	-0.052	0.092	-0.050	-0.033
FIN			1	0.830	0.110	0.073	-0.150	-0.478	0.835	-0.105	-0.354
FRA				1	0.131	0.044	-0.126	-0.491	0.925	-0.094	-0.323
GER					1	0.018	-0.021	-0.049	0.116	-0.052	-0.038
GRE						1	-0.726	-0.521	0.066	-0.622	-0.568
IRE							1	0.586	-0.157	0.493	0.659
ITA								1	-0.545	0.475	0.735
NET									1	-0.113	-0.401
POR										1	0.395
SPA											1

Table 4. Pairwise Granger causality tests among permanent volatility components

Null Hypothesis:	F-Statistic	Prob.
BEL does not Granger cause AUS	1.543	0.214
AUS does not Granger cause BEL	10.866	0.000*
FIN does not Granger cause AUS	2.795	0.061***
AUS does not Granger cause FIN	4.147	0.016**
FRA does not Granger cause AUS	5.785	0.003*
AUS does not Granger cause FRA	0.523	0.593
GER does not Granger cause AUS	3.887	0.021**
AUS does not Granger cause GER	1.543	0.214
GRE does not Granger cause AUS	0.622	0.537
AUS does not Granger cause GRE	0.034	0.966
IRE does not Granger cause AUS	0.440	0.644
AUS does not Granger cause IRE	0.038	0.963
ITA does not Granger cause AUS	1.797	0.166
AUS does not Granger cause ITA	8.854	0.000*
NET does not Granger cause AUS	2.331	0.097***
AUS does not Granger cause NET	8.989	0.000*
POR does not Granger cause AUS	1.198	0.302
AUS does not Granger cause POR	0.002	0.998
SPA does not Granger cause AUS	0.215	0.807
AUS does not Granger cause SPA	2.585	0.076***
FIN does not Granger cause BEL	4.254	0.014**
BEL does not Granger cause FIN	0.524	0.592
FRA does not Granger cause BEL	8.428	0.000*
BEL does not Granger cause FRA	0.315	0.730
GER does not Granger cause BEL	9.294	0.000*
BEL does not Granger cause GER	1.916	0.147
GRE does not Granger cause BEL	1.080	0.340
BEL does not Granger cause GRE	0.294	0.745

Table 4. Pairwise Granger causality tests among permanent volatility components (cont.)

Null Hypothesis:	F-Statistic	Prob.
IRE does not Granger cause BEL	1.443	0.236
BEL does not Granger cause IRE	0.077	0.926
ITA does not Granger cause BEL	2.722	0.066***
BEL does not Granger cause ITA	9.782	0.000*
NET does not Granger cause BEL	1.574	0.207
BEL does not Granger cause NET	1.959	0.141
POR does not Granger cause BEL	2.210	0.110
BEL does not Granger cause POR	0.076	0.927
SPA does not Granger cause BEL	0.427	0.653
BEL does not Granger cause SPA	2.405	0.091***
FRA does not Granger cause FIN	3.908	0.020**
FIN does not Granger cause FRA	0.325	0.723
GER does not Granger cause FIN	1.979	0.138
FIN does not Granger cause GER	0.351	0.704
GRE does not Granger cause FIN	0.029	0.971
FIN does not Granger cause GRE	0.219	0.804
IRE does not Granger cause FIN	0.271	0.762
FIN does not Granger cause IRE	0.043	0.958
ITA does not Granger cause FIN	0.050	0.951
FIN does not Granger cause ITA	8.320	0.000*
NET does not Granger cause FIN	0.862	0.422
FIN does not Granger cause NET	4.490	0.011**
POR does not Granger cause FIN	0.141	0.869
FIN does not Granger cause POR	0.043	0.958
SPA does not Granger cause FIN	0.359	0.699
FIN does not Granger cause SPA	1.007	0.365
GER does not Granger cause FRA	0.885	0.413
FRA does not Granger cause GER	0.711	0.491

Table 4. Pairwise Granger causality tests among permanent volatility components (cont.)

Null Hypothesis:	F-Statistic	Prob.
GRE does not Granger cause FRA	0.107	0.898
FRA does not Granger cause GRE	0.307	0.736
IRE does not Granger cause FRA	0.205	0.814
FRA does not Granger cause IRE	0.014	0.986
ITA does not Granger cause FRA	0.090	0.914
FRA does not Granger cause ITA	9.852	0.000*
NET does not Granger cause FRA	6.012	0.003*
FRA does not Granger cause NET	12.245	0.000*
POR does not Granger cause FRA	0.225	0.798
FRA does not Granger cause POR	0.046	0.955
SPA does not Granger cause FRA	0.208	0.812
FRA does not Granger cause SPA	1.305	0.272
GRE does not Granger cause GER	0.054	0.947
GER does not Granger cause GRE	0.310	0.733
IRE does not Granger cause GER	0.344	0.709
GER does not Granger cause IRE	0.513	0.599
ITA does not Granger cause GER	0.661	0.517
GER does not Granger cause ITA	10.325	0.000*
NET does not Granger cause GER	4.868	0.008*
GER does not Granger cause NET	7.231	0.001*
POR does not Granger cause GER	0.175	0.839
GER does not Granger cause POR	0.027	0.974
SPA does not Granger cause GER	2.503	0.082
GER does not Granger cause SPA	1.182	0.307
IRE does not Granger cause GRE	25.286	0.000*
GRE does not Granger cause IRE	33.999	0.000*
ITA does not Granger cause GRE	2.741	0.065***
GRE does not Granger cause ITA	4.052	0.018**

Table 4. Pairwise Granger causality tests among permanent volatility components (cont.)

Null Hypothesis:	F-Statistic	Prob.
NET does not Granger cause GRE	0.187	0.829
GRE does not Granger cause NET	0.069	0.934
POR does not Granger cause GRE	92.020	0.000*
GRE does not Granger cause POR	92.427	0.000*
SPA does not Granger cause GRE	10.445	0.000*
GRE does not Granger cause SPA	7.581	0.001*
ITA does not Granger cause IRE	1.598	0.203
IRE does not Granger cause ITA	0.221	0.802
NET does not Granger cause IRE	0.093	0.911
IRE does not Granger cause NET	0.436	0.647
POR does not Granger cause IRE	7.396	0.001*
IRE does not Granger cause POR	2.792	0.062***
SPA does not Granger cause IRE	4.130	0.016**
IRE does not Granger cause SPA	4.285	0.014**
NET does not Granger cause ITA	10.737	0.000*
ITA does not Granger cause NET	0.557	0.573
POR does not Granger cause ITA	0.524	0.592
ITA does not Granger cause POR	0.043	0.958
SPA does not Granger cause ITA	0.422	0.656
ITA does not Granger cause SPA	5.756	0.003*
POR does not Granger cause NET	0.332	0.718
NET does not Granger cause POR	0.005	0.995
SPA does not Granger cause NET	0.028	0.973
NET does not Granger cause SPA	0.519	0.595
SPA does not Granger cause POR	0.094	0.910
POR does not Granger cause SPA	1.789	0.168

Note: *, **, *** indicate significance at 1%, 5% and 10%, respectively.

Table 5. Pairwise Granger causality tests among transitory volatility components

Null Hypothesis:	F-Statistic	Prob.
BEL does not Granger cause AUS	1.558	0.211
AUS does not Granger cause BEL	3.505	0.030**
FIN does not Granger cause AUS	7.135	0.001*
AUS does not Granger cause FIN	2.306	0.100
FRA does not Granger cause AUS	8.371	0.000*
AUS does not Granger cause FRA	1.831	0.161
GER does not Granger cause AUS	1.744	0.175
AUS does not Granger cause GER	2.569	0.077***
GRE does not Granger cause AUS	0.187	0.829
AUS does not Granger cause GRE	0.063	0.939
IRE does not Granger cause AUS	0.743	0.476
AUS does not Granger cause IRE	0.215	0.807
ITA does not Granger cause AUS	1.060	0.347
AUS does not Granger cause ITA	3.744	0.024**
NET does not Granger cause AUS	7.554	0.001*
AUS does not Granger cause NET	5.906	0.003*
POR does not Granger cause AUS	0.704	0.495
AUS does not Granger cause POR	0.093	0.912
SPA does not Granger cause AUS	0.509	0.601
AUS does not Granger cause SPA	0.989	0.372
FIN does not Granger cause BEL	1.832	0.160
BEL does not Granger cause FIN	0.264	0.768
FRA does not Granger cause BEL	4.243	0.015**
BEL does not Granger cause FRA	0.285	0.752
GER does not Granger cause BEL	2.789	0.062
BEL does not Granger cause GER	2.770	0.063
GRE does not Granger cause BEL	0.638	0.529
BEL does not Granger cause GRE	2.950	0.053***

Table 5. Pairwise Granger causality tests among transitory volatility components (cont.)

Null Hypothesis:	F-Statistic	Prob.
IRE does not Granger cause BEL	2.567	0.077***
BEL does not Granger cause IRE	3.466	0.031**
ITA does not Granger cause BEL	1.564	0.210
BEL does not Granger cause ITA	6.347	0.002*
NET does not Granger cause BEL	0.497	0.608
BEL does not Granger cause NET	0.788	0.455
POR does not Granger cause BEL	0.550	0.577
BEL does not Granger cause POR	3.202	0.041**
SPA does not Granger cause BEL	0.187	0.829
BEL does not Granger cause SPA	1.097	0.334
FRA does not Granger cause FIN	0.912	0.402
FIN does not Granger cause FRA	0.676	0.509
GER does not Granger cause FIN	0.013	0.987
FIN does not Granger cause GER	2.789	0.062***
GRE does not Granger cause FIN	0.229	0.795
FIN does not Granger cause GRE	0.824	0.439
IRE does not Granger cause FIN	1.748	0.174
FIN does not Granger cause IRE	0.036	0.964
ITA does not Granger cause FIN	0.942	0.390
FIN does not Granger cause ITA	4.081	0.017**
NET does not Granger cause FIN	0.557	0.573
FIN does not Granger cause NET	0.674	0.510
POR does not Granger cause FIN	0.114	0.892
FIN does not Granger cause POR	0.215	0.806
SPA does not Granger cause FIN	0.381	0.683
FIN does not Granger cause SPA	0.956	0.385
GER does not Granger cause FRA	0.442	0.643
FRA does not Granger cause GER	4.029	0.018**

Table 5. Pairwise Granger causality tests among transitory volatility components (cont.)

Null Hypothesis:	F-Statistic	Prob.
GRE does not Granger cause FRA	0.158	0.854
FRA does not Granger cause GRE	0.507	0.603
IRE does not Granger cause FRA	1.387	0.250
FRA does not Granger cause IRE	0.059	0.943
ITA does not Granger cause FRA	1.395	0.248
FRA does not Granger cause ITA	4.984	0.007*
NET does not Granger cause FRA	4.327	0.013**
FRA does not Granger cause NET	5.385	0.005*
POR does not Granger cause FRA	0.218	0.805
FRA does not Granger cause POR	0.115	0.892
SPA does not Granger cause FRA	0.132	0.877
FRA does not Granger cause SPA	1.777	0.169
GRE does not Granger cause GER	0.068	0.934
GER does not Granger cause GRE	0.526	0.591
IRE does not Granger cause GER	1.059	0.347
GER does not Granger cause IRE	0.480	0.619
ITA does not Granger cause GER	0.595	0.552
GER does not Granger cause ITA	4.755	0.009*
NET does not Granger cause GER	6.819	0.001*
GER does not Granger cause NET	1.453	0.234
POR does not Granger cause GER	0.144	0.866
GER does not Granger cause POR	0.048	0.953
SPA does not Granger cause GER	2.486	0.084***
GER does not Granger cause SPA	0.044	0.957
IRE does not Granger cause GRE	33.104	0.000*
GRE does not Granger cause IRE	33.047	0.000*
ITA does not Granger cause GRE	22.244	0.000*
GRE does not Granger cause ITA	12.485	0.000*

Table 5. Pairwise Granger causality tests among transitory volatility components (cont.)

Null Hypothesis:	F-Statistic	Prob.
NET does not Granger cause GRE	1.305	0.271
GRE does not Granger cause NET	0.174	0.840
POR does not Granger cause GRE	101.981	0.000*
GRE does not Granger cause POR	104.939	0.000*
SPA does not Granger cause GRE	15.103	0.000*
GRE does not Granger cause SPA	13.212	0.000*
ITA does not Granger cause IRE	12.898	0.000*
IRE does not Granger cause ITA	1.747	0.175
NET does not Granger cause IRE	0.128	0.880
IRE does not Granger cause NET	1.907	0.149
POR does not Granger cause IRE	3.149	0.043**
IRE does not Granger cause POR	12.046	0.000*
SPA does not Granger cause IRE	3.303	0.037**
IRE does not Granger cause SPA	0.591	0.554
NET does not Granger cause ITA	8.038	0.000*
ITA does not Granger cause NET	4.671	0.009*
POR does not Granger cause ITA	2.890	0.056**
ITA does not Granger cause POR	9.902	0.000*
SPA does not Granger cause ITA	6.191	0.002*
ITA does not Granger cause SPA	25.136	0.000*
POR does not Granger cause NET	0.305	0.737
NET does not Granger cause POR	0.432	0.649
SPA does not Granger cause NET	0.074	0.929
NET does not Granger cause SPA	0.848	0.428
SPA does not Granger cause POR	3.614	0.027**
POR does not Granger cause SPA	0.770	0.463

Note: *, **, *** indicate significance at 1%, 5% and 10%, respectively.

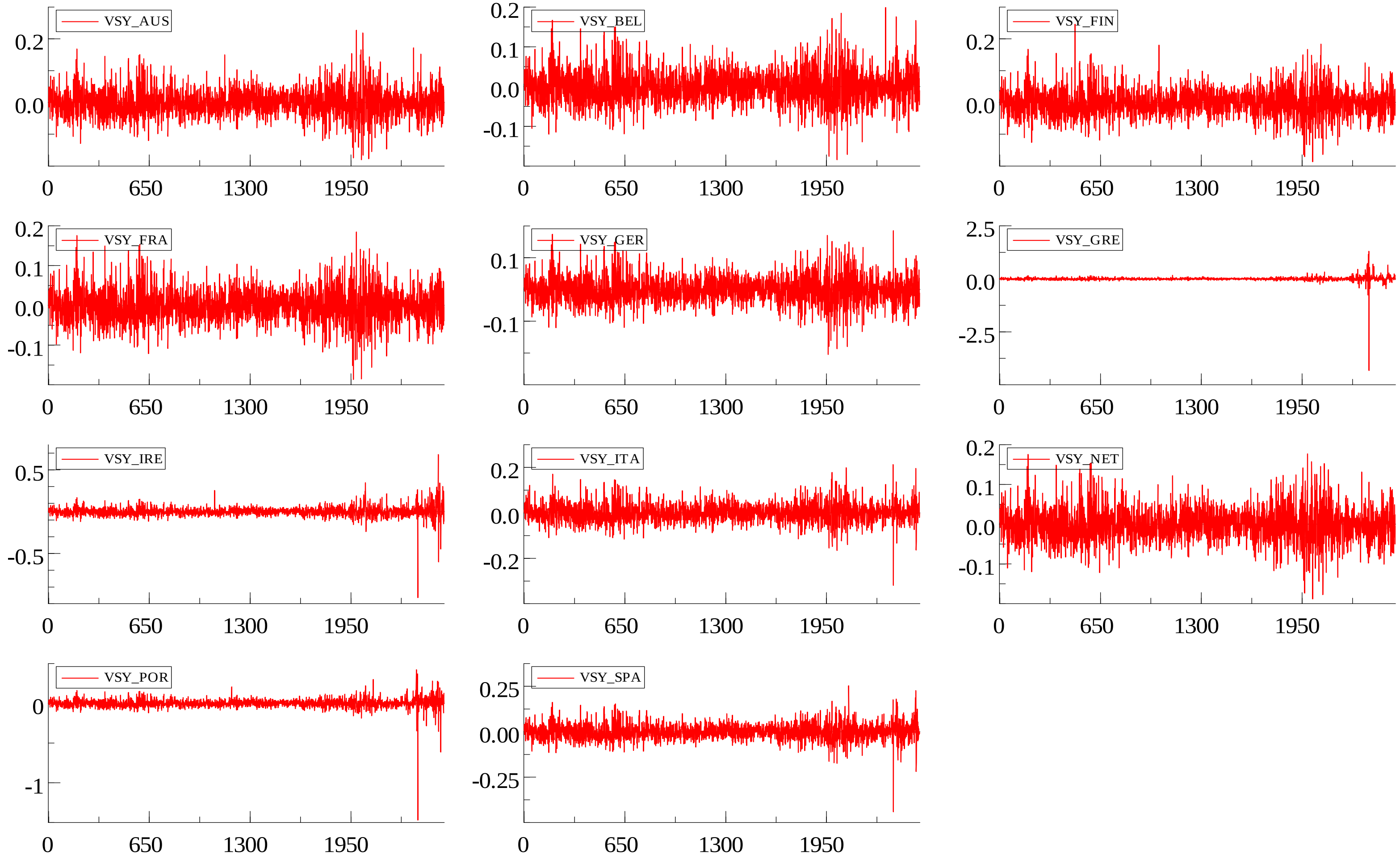

Figure 1. Daily rate of change of 10 Years Sovereign Yields (SY) in EMU-11 countries

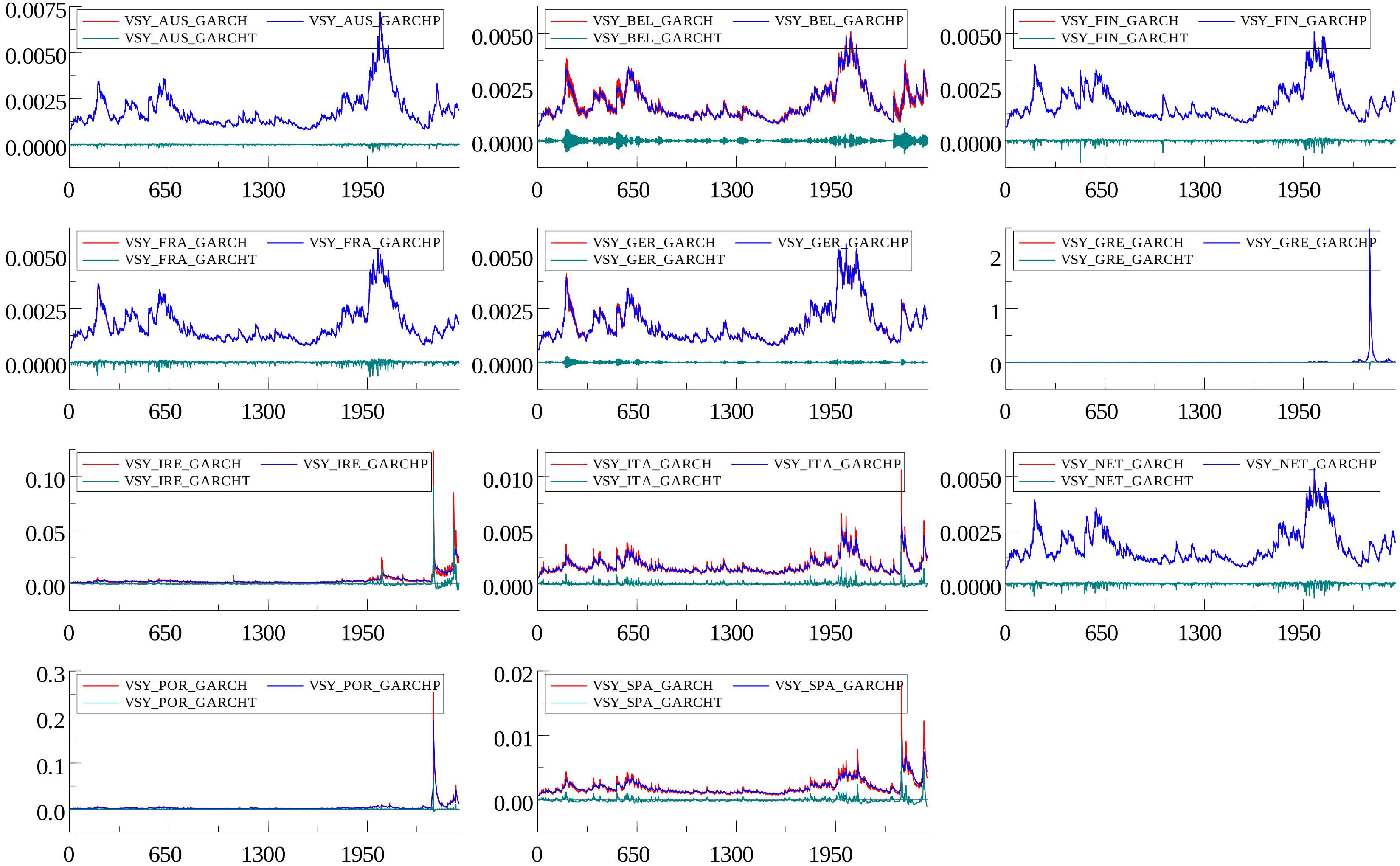

Figure 2. Total, permanent and transitory variance of 10 Years Sovereign Yields (SY) in EMU-11 countries

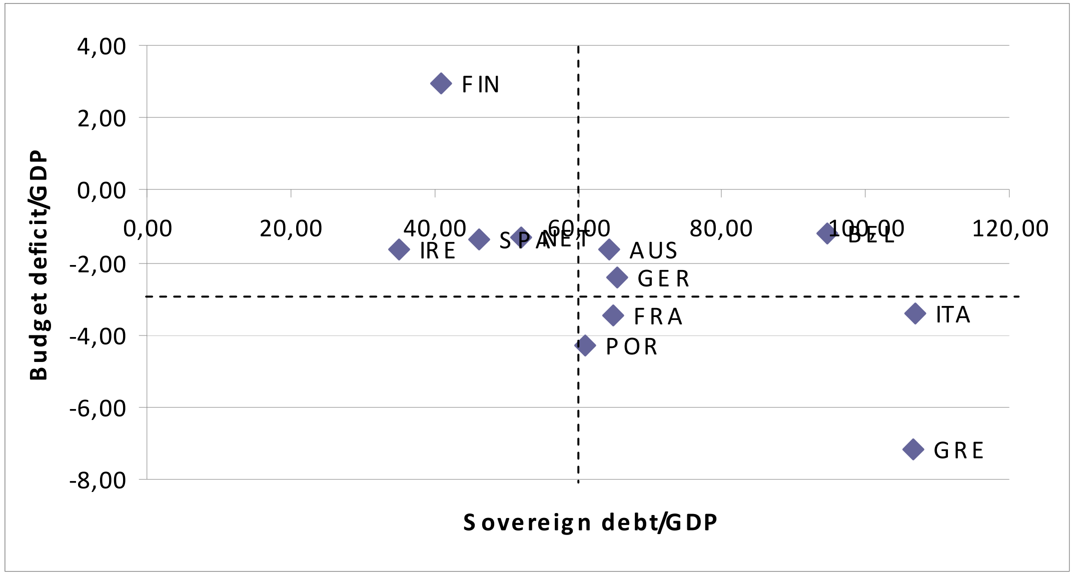

Figure 3: Sovereign debt and budget deficits as percentage of GDP in EMU-11 countries (annual average 2001-2009)

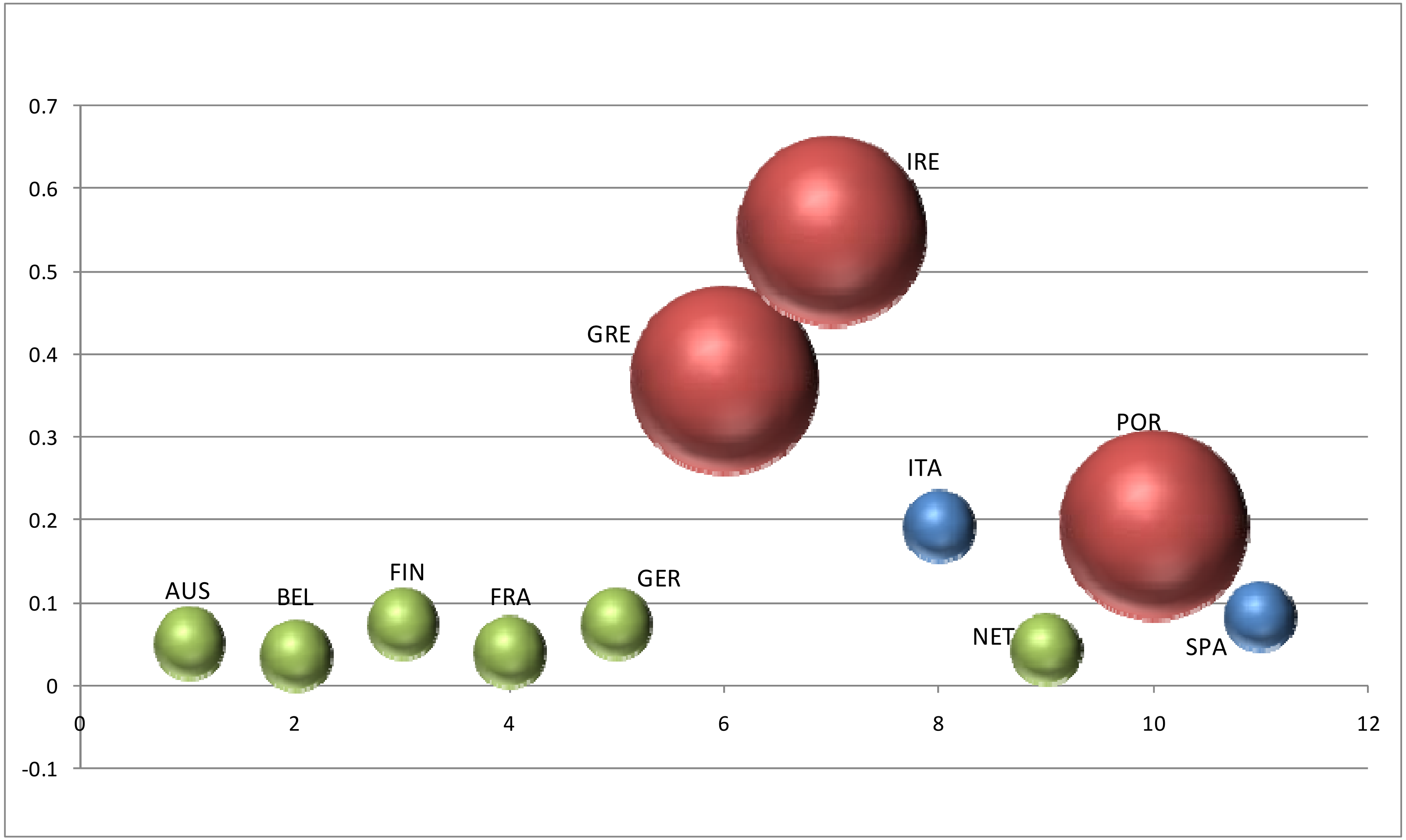

Figure 4. Centroides and distance inter clusters: Permanent components

Note: The size of the balls represents the value of the centroid (i. e., the average behavior of the cluster with respect to the permanent volatility). The vertical axis represents the inter cluster distance and the horizontal axis represents the number of countries.

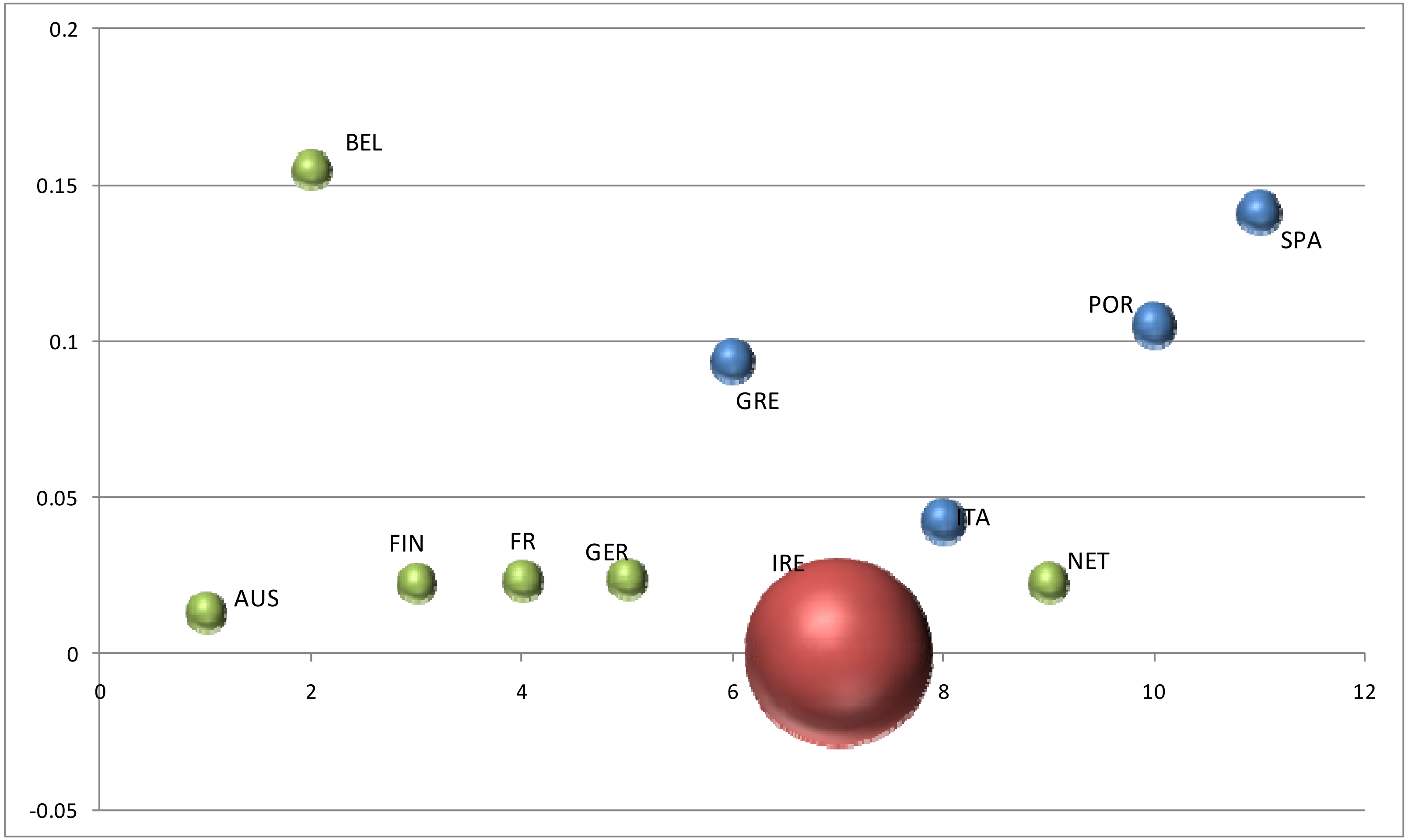

Figure 5. Centroides and distance inter clusters: Transitory components
Note: The size of the balls represents the value of the centroid (i. e., the average behavior of the cluster with respect to the transitory volatility). The vertical axis represents the inter cluster distance and the horizontal axis represents the number of countries.