Volatility Co-movements and Spillover Effects within the Eurozone Economies: A Multivariate GARCH Approach using the Financial Stress Index

Ronald MacDonald[#] — *University of Glasgow*

Vasilios Sogiakas[&] — *University of Glasgow*

Andreas Tsopanakis[§] — *University of Salford*

Abstract

Aim of this paper is the deeper empirical investigation of potential cross-covariances and spillover effects between the Eurozone economies and financial markets. Our work is innovative, in certain aspects. Focusing on the analysis of volatility comovements and spillovers, we employ financial stress indexes, as systemic risk metrics in our model. We construct such systemic risk indices for the first eleven Euro Area members. Additionally, extra indices for the four most important financial markets (namely, banking, money, equity and bond markets) are also provided. We decide to employ a multivariate GARCH framework, which is able to capture markets' dependencies and volatility spillovers. Thus, a full GARCH-BEKK model is estimated, both on a market (or country) wide level and, then, one with the full spectrum of Euro Area markets. In other words, we complete an empirical examination, both "within" and "between" Eurozone economies and markets. The results reveal a number of interesting insights: on country wide level, there is strong volatility transmission channel from the most heavily hit, from the crisis, economies towards the rest. Additionally, the crucial importance and role on this transmission from the banking and bond markets is underlined. Contrary to common wisdom, Greece is not the main propagator of volatility uncertainty, while it is between the most important receivers of volatility risk. The same holds for other peripheral economies, while the importance of money market is also evident in the large, "between", empirical approach. Overall, this work provides further insights to the ongoing debate, regarding the volatility comovements and financial stress spillovers within the EMU economies.

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[#] Economics Section, Adam Smith Business School, *University of Glasgow*, Glasgow, UK. Email: Ronald.MacDonald@glasgow.ac.uk

[&] Economics Section, Adam Smith Business School, *University of Glasgow*, Glasgow, UK. Email: Vasilios.Sogiakas@glasgow.ac.uk

[§] IFAE Section, Salford Business School, *University of Salford*, Salford, UK. Email: a.tsopanakis@salford.ac.uk

1. Introduction

Unquestionably, the recent financial and sovereign crisis outbreak, within the Euro Area countries, is one of the most important economic events of the last decade. It creates an unprecedented reaction, in terms of non conventional monetary and fiscal policies, from the side of the global and local policy makers. The main reason for them to proceed to such a large scale bail out programs, for financial institutions as well as for a number of heavily indebted countries, indicate the heightening uncertainty for the already identified financial, fiscal and real economic meltdown, together with the uncertainty for even worse future conditions. Furthermore, the lack of a consistent and supra-national macroprudential and crisis mitigating framework, leads to even more intensive uncertainty.

Bearing all the above in mind and, given the lack of conclusive and clear cut evidence for the potential risk transmission channels within the Eurozone economies, we aim to shed further light in the issue of volatility comovement and spillover effects among the EMU countries. In contrast to the existing literature, we move beyond the usual focus on sovereign and, sometimes, banking risk channels. Instead, we try to investigate a full set of potential volatility transmission channels, by implementing a number of financial stress indices for a wide group of financial markets.

Until now, most researchers have focused on the sovereign risk and the relevant contagion issues, arising from it. In this paper, we proceed one step further. Instead of focusing only to CDS spreads or governmental bond yields, to unveil the risk of sovereign default, we employ the aforementioned stress indices, in order to provide a more conclusive picture of the risk transmission channels from one country and market to another. In order to do this, a number of multivariate GARCH-BEKK model are being employed, where the returns of financial stress indices for the Eurozone countries are incorporated. The empirical work is conducted into two directions: "within" each one of the sectors we produce financial stress indexes for (banking sector, money market, equity and bond market) and "between" all of the above markets and countries. The outcome of the empirical investigation reveals some innovative and very interesting features for the links of the Eurozone economies.

We extend the relevant economic research in several respects. First of all, the employment of financial stress indices, within the specified analytical and theoretical framework, takes place for the first time. Moreover, the estimation of multivariate GARCH model for this kind of analysis is rather neglected. Also, it is the first time that such a detailed, in terms of the number of countries and markets examined, empirical investigation is conducted. Another important innovation in our work is the cross market analysis of spillover effects, since the relevant research has focused to specific markets only, until now.

The structure of this paper is as follows. First, a section where we discuss some important papers examining the volatility spillovers or contagion issues, due to the Eurozone crisis, is provided. Thereafter, a description of our financial stress indices and their components, along with the aggregation method, is presented. Moreover, the GARCH-BEKK modeling approach is analyzed. Section 4 is where the estimations outcome is discussed, for both the market level and the cross market cases. The last part recaps.

2. Eurozone Crisis and Modeling of Spillover Effects

As it has been previously implied, the empirical investigation of contagion effects and spillover situations among markets and countries is one of the most important areas of research for economists in the field of international finance and macroeconomics. Especially, given the current multi-faceted crisis in Eurozone, the relevant literature has mushroomed again. Of course, the focus here in this strand of the literature is somehow diverted from ours, since most researchers work solely for the empirical examination of the sovereign risk transmission, neglecting the others channels of risk transmission. Additionally, they do not always work with multivariate GARCH models. For instance, Bruttin and Saure (2012) employ SVAR analysis of sovereign CDS for eleven Eurozone countries. They find that exposure to Greek sovereign debt and Greek banks assets are sources of intensive transmission of risk. On the other hand, Kohonen (2012) uses ten year government bond yield differentials for the PIIGS countries, into a similar SVAR framework. Here, the author suggests that there was a default risk transmission from the Greek bonds, but only at the beginning of the crisis and, also, this was not the only risk channel within the countries under scrutiny. Similar argument (for the intensity of the risk propagation channel from countries like Greece to the rest of the euro union) is provided by Caporin et. al (2013). Here, using a number of econometric approaches, the authors indicate that contagion effects were not that strong, even though peripheral countries went through serious strains because of their heightened fiscal burden. On the other hand, Metiu (2012) identifies strong contagion effects for the period 2008 to 2012, using the canonical contagion model. It appears a lack of clear identification of the true effects among the Eurozone countries, based on these papers.

Turning now to the case of multivariate volatility models, Audige (2013) employs a smooth transition conditional correlation (STCC-GARCH) model, with long term governmental bond yields, in order to check for spillover effects from the Greek crisis. Once more, the author pinpoints contagion effects from Greece to Ireland and Portugal in 2010, while such effects weaken after that year. In a similar piece of research, Grammatikos and Vermeulen (2012) examine the transmission of financial and sovereign debt shocks through the Eurozone stock markets, for the period 2007 – 2010. In order to do this, GARCH modeling of stock returns are employed, while the effect of US markets is also taken into consideration. They split EMU into three groups of countries, namely the North, South and Small economies. Their findings show strong crisis transmission from US non-financials to European non-financials[1], while the financial ones from both sides of the world are not that interconnected. Additionally, Greek CDS spreads seem to play a much more important role in the period after the Lehman collapse, but not for the non-financial firms. Another interesting paper is the one by Dajcman (2012), who using flight-to-quality indicator to examine the co-movements of stock returns with bond yields for Germany and PIIGS. The results, using a DCC modeling approach, are concurrent with Kohonen (2012) and Caporin et. al (2013), where the Greek debt crisis, along with the ones in Portugal and Italy do not indicate important contagion effects to the rest of the Eurozone. Moreover, the flight-to-quality indicator has higher value prior to 2010, indicating increasing uncertainty for investors, who turned towards the safe haven of German Bunds.

[1] Non-financials consists of the returns of stocks, if the financial institutions listed to the market are excluded from the sample.

3. Dataset and Methodological Approach

3.1 Dataset Description and Aggregation Method

Since our aim is the depiction of systemic risk on a timely and up to date basis, we proceed with the creation of aggregate financial stress indices (FSIs). These indexes provide information on the financial markets conditions, based on a range of stand-alone indicators representing important features of these markets. Our focus is on Eurozone crisis and, thus, the sample of our countries consists of the initial eleven euro economies (excluding Luxembourg). These countries are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. Once again, our interest is in the calculation of four market-level indicators, along with a systemic risk index for each country individually. These markets are the banking one, money, equity and bond markets. We develop our FSIs on weekly frequency. The reasons are twofold: first, we decided to examine the spillover effects of the Euro Area crisis, both within each market (and countries) level, together with a deeper cross-sectional investigation of this crisis effects. That is, we explore the transmission channels existing between different markets and different countries (e.g. whether there are stress spillovers from the, say, Greek banking sector to the French bond market or if the Irish equity market affects the Italian money market and so on). Secondly, since such an empirical work requires the employment of multivariate GARCH modeling and such an econometric approach is highly demanding, in terms of degrees of freedom, there is a necessity to employ high frequency dataset. Hence, the variables that are used are restrained to those that can be retrieved in such frequencies.

Table 1: Indicators of Financial Stress

Variables Used in Financial Stress Indices	
Banking Sector	***Money Market***
Dividend Yield	TED Spread
Market Value	Inverted Term Spread
Turnover by Volume	Treasury Bill Realized Volatility
P/E	Main Refinancing Rate - 2yr Government Bond Yield
Bank Equities Realized Volatility	Main Refinancing Rate - 5yr Government Bond Yield
Banking Sector Beta	
Bank Equities Returns	
Equity Market	***Bond Market***
Stock Returns	Sovereign Spread
Dividend Yield	Government Bond Realized Volatility
P/E	Corporate Spread
Stocks Realized Volatility	Government Bond Duration
Market Value	

Table 1 summarizes the variables included in the financial stress indices of the economies in our sample. Our dataset is of weekly frequency, covering the period from January 2001 until 20th of September 2013. There are 664 observations in total, which covers the pre- and post-crisis period. We do not use daily data for avoiding potential mismatches in public holidays and trading days (Yiu *et al.*, 2010). In this way, a uniform dataset is created, without any discrepancies in the countries' series used. Getting into more details, the banking sector index comprises of seven variables, while five variables are used in the case of money and equity markets and four for the case of bond market. Focusing to the banking market, variables representing banks' sensitivity to market conditions, along with their level of profitability and risk level there are included. Dividend yield is negatively related to fundamentals of banking institutions and, thus, excessive dividend yields can be a signal of increasing default risk for them. On the same time, market value is also important, since its size directly affects the stability of the market. Increasing uncertainty can lead to a significant adverse effect to market value, which is also tied to these institutions' book value. Thus, their financial health is at stake. Another strong indicator of instability for banks is the turnover by volume. This increases, according to market sentiment and the perceived level of risk and uncertainty by the investors. Profitability is also an important metric here, represented by the P/E ratio. Here, since banks' operational efficiency and profitability is indicated by higher values for the aforementioned ratio, we impose a negative sign to this variable (so, higher P/E ratio coincides with excessive financial stress). Finally, the three last variables here (these are, realized volatility of banks equity index, the beta coefficient of the aforementioned index and the (negative) stock returns) depict the risk perception and the volatility level of this market.

The aggregate index for the money market sector includes some of the most important liquidity, credit and counterparty risk indicators. TED spread (the difference between the 3-month Euribor and the respective Treasury bill of the same maturity) is one of these measures. It is expected to observe increasing values for this spread, in periods of worsening financial conditions. In such times, interbank funding markets seize to operate smoothly, while the risk perception reaches unprecedented levels. In the same line of thought, inverted term spread is incorporated, as indicator of interest rate setting expectations, along with the representation of default risk in money markets. Moreover, the spreads of the main refinancing rate from the short term governmental bills yield is another indicator of deteriorating liquidity conditions. Negative values in these spreads coincide with higher financial stress and, hence, the need to incorporate them in our aggregate index with a negative sign. Lastly, the realized volatility of the Treasury bills of the countries in our sample depicts the formed risk volatility in this market.

The conditions in the equity markets are captured by five variables. The (negatively signed) stock returns are a good indication of investors' uncertainty and lack of trust to listed firms underlying fundamentals. In periods of increasing financial stress, it is expected to have higher volatility in the stock markets. Then, market value is included and the dividend yield as well. The rationale is similar to the case of the banking sector, emphasizing the level of default risk, lack of credibility and funding sources in the market. Again, the level of financial sustainability of the firms is sketched by the P/E ratio, while the realized volatility of the general equity market index is indicative of the historical risk perception on the specific equity market.

The last market considered here is the most scrutinized in the current Eurozone crisis research. That is, the bond market. Here, we employ the sovereign bond spread, vis-à-vis German bond yield, which is considered as a safe haven for bond market investors. This is a strong and popular indicator of the perceived sovereign risk of the countries under investigation. Then, the realized volatility of the long term governmental bond yields is used, as another variable illustrating the volatility risk of this market. Then, the corporate bond spread (towards the government long term bond yield) is a factor showing the default risk and the financial obstacles operating firms in each one of the EMU countries face. Bond duration is also included (for the long term government bonds). It is expected that decreasing credit ratings and increasing concerns for the countries solvency, will lead to lower duration for their bonds. Hence, decreasing duration represents increasing financial stress and uncertainty.

The FSIs are computed, following the variance-equal aggregation method. Based on this approach, an equal weight is attributed to all variables in each of the markets. In this way, the market - level indices are computed, while the same approach is followed for the country – wide one. Before the aggregation, each one of the single indicator is standardized. That is, its mean value is subtracted by each observation and, then, divided by its standard deviation. In this way, problems of mis-measurement are avoided. Then, all series are expressed as deviations from the long run mean value of them. Thus, there is no any issue, regarding the units of measurement of variables that can be of very different nature otherwise. The variance – equal approach is rather frequently used in the relevant literature. The most important reason for this has to do with the simplicity of the relevant calculations, while it is quite efficient approach for the creation of well behaved financial stress indices. This means that the aggregate indices produced in this way effectively represent the conditions in the financial markets and there is not important value added if the relevant weights and aggregation is made through some more sophisticated approach.

3.2 Volatility Transmission Models: Empirical Methodology

Turning now to the MGARCH model employed, the decision is to use one of the most successful models in relevant applications, namely the BEKK model (Marcal and Pereira, 2008). It is quite useful, in ensuring that the variance covariance matrix will be always positive definite and, as a consequence, the estimation of a model with a significantly high number of parameters is less burdensome. Additionally, they are also helpful for studying the time-varying properties of covariances and correlations.

As already mentioned, the GARCH-BEKK model is an alternative to the prototype multivariate VEC model, proposed by Bollerslev *et al.* (1988), ensuring the positive definiteness of the conditional variance matrix H_t (Bauwens *et al.*, 2006). Let us first describe the BEKK model, as introduced by Engle and Kroner (1995). The basic set up includes the mean equation

$$r_t = \mu_t(\theta) + \varepsilon_t, \text{ where } \varepsilon_t \left| \Omega_{t-1} \sim N(0, H_t) \right. \tag{1}$$

where r_t is a Nx1 vector of the financial stress indices returns, $\mu_t(\theta)$ is the conditional mean vector of the indices returns (again of the same dimensions as the previous vector) and ε_t is the vector of the model's vector of residuals. The latter, based on the information set available until period t-1 (Ω_{t-1}), is assumed to follow a zero mean distribution, with a variance covariance matrix H_t. According to this model, the NxN matrix H_t has the following form:

$$H_t = C_0^{'}C_0 + A^{'}\varepsilon_{t-1}\varepsilon_{t-1}^{'}A + B^{'}H_{t-1}B \tag{2}$$

where C_0 is the constants vector, A and B are parameter matrices, ε_{t-1} is the lagged disturbance vector and H_{t-1} is the lagged variance covariance matrix. The constants vector is restricted to be upper triangular, while the parameter matrices are not restricted. As emphasized by Bollerslev (2010), this quadratic parameterization guarantees that the covariance matrix is positive definite, while the number of parameters to be estimated is more compact, compared with the MGARCH model firstly proposed by Bollerslev *et al.*(1988)[2]. Since out interest is in the potential spillover effects of each Eurozone country (or market) to the other participants in the common currency area, the main focal point here is on the estimated coefficients of matrices A and, especially, B. The type of BEKK model that interests us is the one allowing for interactions between the variances of the markets. These are represented

[2] In this way, model's convergence is more easily achieved. See, among others, Bauwens *et al.* (2006) and Brooks (2008).

by the off-diagonal elements of matrix B. Additionally, matrix's A coefficients depict the effects of lagged innovations in equation (4.2) to the conditional variance covariance matrix. As it is commonly said in the relevant literature, matrix A provide information on "news effect", while matrix B depict the "volatility spillover" effect (Kim *et al.*, 2012). Both effects can provide important insights for the potential volatility transmission channels established within the Euro Area countries and markets.

Given the number of variables and the ensuing computational procedures, we proceed with the estimation of bivariate BEEK models, for all the cases examined here. These are, the BEKK models for the countries and the market level indices (banking, money, equity and bond markets), while the same holds for the case of the intra-markets analysis. Thus, for the bivariate case, the model will look as follows:

$$\begin{aligned} H_t = C_0^{'} C_0 &+ \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}^{'} \begin{pmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \\ &+ \begin{pmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{pmatrix}^{'} H_{t-1} \begin{pmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{pmatrix} \end{aligned} \tag{3}$$

In more details, after the matrices' multiplications, the detailed representation of the conditional variance elements is:

$$\begin{aligned} h_{11,t} &= \alpha_{11}^2 \varepsilon_{1,t-1}^2 + \alpha_{21}^2 \varepsilon_{2,t-1}^2 + 2\alpha_{11}\alpha_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{11}^2 h_{11,t-1} + \beta_{21}^2 h_{22,t-1} + 2\beta_{11}\beta_{22}h_{12,t-1} \\ h_{22,t} &= \alpha_{12}^2 \varepsilon_{1,t-1}^2 + \alpha_{22}^2 \varepsilon_{2,t-1}^2 + 2\alpha_{12}\alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{12}^2 h_{11,t-1} + \beta_{22}^2 h_{22,t-1} + 2\beta_{11}\beta_{22}h_{21,t-1} \end{aligned} \tag{4}$$

Given the above description of the model, our interest is focused on the statistical significance of α_{21} and β_{21} in the first part of (4.4). These two coefficients represent the volatility spillover from market (or country) 2 to market 1. On the other hand, for the second part of the previous equation, α_{12} and β_{12} are the coefficients of interest. It should be noted here that, since all of these parameters are squared, their signs do not have any importance. The models are estimated, using the quasi maximum likelihood estimator, using the Matlab algorithms provided by Kevin Sheppard. In what follows, a detailed presentation of these computations, along with a discussion on them is provided. All models here are estimated, using the quasi maximum likelihood (QML) estimator under a multivariate student distribution. In this way, any issues arising from the potential non normality of the models' residuals can be statistically accommodated.

4. Discussion of Results

4.1 Indexes Descriptive Statistics and Stationarity

The following table (2) provides a complete descriptive analysis of all the financial stress series returns used here. They are organized in five different panels, according to the type of indices and the market they represent. The table provides a full set of statistics for the distribution of the indexes returns, together with their normality and the type of their data generating process. Moreover, the results of the ADF test are reported, in order to account for the existence or not of unit roots. The inspection of these results provides useful insights to the nature of our dataset. First of all, it is evident that the banking and equity stress indexes exhibit the highest standard deviations. In almost all cases, the series' distributions are positively skewed, while the statistically significant kurtosis coefficients indicate the non-normality of returns. The latter is strongly verified by the Jarque-Berra test, which offers a clear indication of the non-acceptance of the null hypothesis of normally distributed FSIs returns.

On top of the above, table 2 reports the Ljung-Box Q and Q^2 statistics. Here, the purpose of this test is the verification for the existence or not of serial correlation for the returns and the squared returns, respectively. Again, in the majority of the cases examined, the results are in favor of serially correlated series, exhibiting higher order correlation and non-linear dependencies as well (indicated by the Q^2 statistic). The only exception here is the Dutch bond market financial stress index, while the Ljung-Box Q^2 test fails to provide relevant evidence for the cases of Greece, Portugal and Spain (in the case of the bond markets indices). The same holds for the money market stress indexes of Greece and Finland. Nevertheless, the aforementioned are limited exceptions to the general conclusion of the existence of autocorrelation. The Engle's ARCH test is also concurrent with the previous findings, emphasizing the need to employ GARCH models for the implementation of our empirical work that aims to study the spillover effects of financial stress among the Euro Area markets and countries. The last row in each one of the table's panels provides the ADF unit root test. As expected, all series are proved to be stationary.

We also report the unconditional correlation matrices for each one of the groups of financial stress indexes used here. Almost all correlation coefficients are positive, indicating a positive relation between the levels of financial stress in these economies. In the case of country-wide indicators, the core countries are stronger related, as it is the case with the periphery ones. Larger correlation exists for the cases of the equity and banking markets, while Greece does not seem to be strongly tied to the rest of the Euro Area economies. Similar evidence exists for the cases of Ireland and Portugal, especially for the case of the bond market and, even more importantly, towards the larger economies of the monetary union (Germany and France).

Table 2: Descriptive Statistics of Financial Stress Indexes Returns

Descriptive Statistics for Financial Stress Indexes Returns											
Countries	**Austria**	**Belgium**	**Finland**	**France**	**Germany**	**Greece**	**Ireland**	**Italy**	**Netherlands**	**Portugal**	**Spain**
Panel A: Country Indexes											
Mean	0.0002	0.0002	-0.0003	0.0000	-0.0007	0.0007	-0.0004	-0.0003	-0.0004	-0.0002	0.0010
Std. Deviation	0.0563	0.0520	0.0748	0.0431	0.0609	0.0525	0.0715	0.0489	0.0799	0.0595	0.0503
Skewness	0.039	0.212**	-0.073	0.496**	-0.074	0.07	0.204*	0.804**	-0.152	-0.366**	0.787**
Kurtosis	2.71**	2.428**	7.562**	3.99**	3.741**	7.705**	7.201**	4.812**	8.855**	9.067**	6.783**
J-B Test	203.06**	167.9**	1580.7**	467.19**	387.34**	1640.7**	1437.4**	711.26**	2169.1**	2286.3**	1339.6**
Q(10)	67.78**	29.06**	102**	20.83*	61.15**	89.91**	116.81**	24.12**	56.16**	113.81**	72.2**
Q^2(10)	378.06**	93.87**	121.08**	173.83**	77.18**	396.18**	161.23**	121.66**	77.2**	188.18**	140.33**
ARCH(5)	24**	9.07**	40.45**	18.15**	11.32**	36.94**	28.09**	10.36**	11.3**	30.68**	23**
ADF	-18.51**	-15.23**	-18.51**	-14.53**	-18.54**	-17.65**	-19.39**	-15.63**	-18.89**	-17.05**	-17.73**
Panel B: Banking Sector Indexes											
Mean	0.0000	-0.0001	0.0016	0.0007	-0.0009	0.0008	0.0008	0.0002	-0.0014	0.0008	0.0021
Std. Deviation	0.2268	0.2204	0.2578	0.2361	0.2328	0.2414	0.2443	0.2263	0.2197	0.2251	0.2344
Skewness	0.257**	0.591**	0.423**	0.283**	0.885**	0.852**	-0.077	0.828**	0.948**	0.445**	0.911**
Kurtosis	3.303**	6.676**	10.316**	3.03**	7.001**	10.927**	8.691**	3.93**	13.021**	6.381**	6.277**
J-B Test	309.9**	1270**	2959.6**	262.61**	1440.8**	3378.8**	2087.5**	502.65**	4783.2**	1147**	1180.4**
Q(10)	147.03**	149.63**	178.02**	198.72**	156.15**	169.08**	179.32**	173.05**	118.52**	136.88**	157.4**
Q^2(10)	481.28**	305.53**	145.51**	566.97**	387.89**	492.56**	209.03**	155.27**	290.14**	172.64**	160.34**
ARCH(5)	24.67**	20.99**	57.54**	45.99**	33.11**	49.52**	42.78**	11.86**	28.72**	23.77**	21.59**
ADF	-21.85**	-21.02**	-22.24**	-22.32**	-21.75**	-18.67**	-22.39**	-20.23**	-21.25**	-22.09**	-23.43**
Panel C: Money Market Indexes											
Mean	-0.0008	-0.0007	-0.0006	-0.0006	-0.0007	-0.0001	-0.0001	0.0003	-0.0003	-0.0010	0.0001
Std. Deviation	0.0867	0.0885	0.0748	0.0980	0.0738	0.0483	0.0578	0.0911	0.1739	0.0437	0.0568
Skewness	1.419**	0.911**	1.731**	1.296**	1.241**	3.215**	3.036**	1.14**	-0.861	0.118	-0.177
Kurtosis	8.958**	8.602**	11.555**	6.288**	7.973**	77.115**	84.406**	13.077**	30.869**	11.913**	4.431**
J-B Test	2439.8**	2136.3**	4019.3**	1278.1**	1926.7**	165420**	197830**	4867.8**	26405**	3921.8**	545.88**
Q(10)	25.84**	11.30	26.47**	19.01*	21.57*	21.61*	100.95**	15.81	59.74**	37.56**	62.18**
Q^2(10)	55.58**	140.53**	7.21	89.33**	77.54**	4.53	75.04**	44.25**	85.82**	297.05**	144.62**
ARCH(5)	2.99*	22.37**	1.31	6.08**	2.88*	0.86	2.72*	4**	22.48**	29.07**	13.42**
ADF	-16.42**	-14.54**	-13.48**	-15.74**	-15.68**	-15.4**	-13.88**	-14.65**	-18.43**	-12.99**	-15.6**
Panel D: Equity Market Indexes											
Mean	0.0011	0.0007	-0.0023	-0.0010	-0.0003	-0.0013	-0.0011	-0.0010	-0.0011	-0.0001	0.0007
Std. Deviation	0.2802	0.2689	0.2610	0.2777	0.2760	0.2636	0.2808	0.2738	0.2759	0.2687	0.2803
Skewness	0.655**	0.469**	0.292**	0.506**	0.51**	0.477**	-0.01	-0.838	-0.367**	-0.641**	-0.542**
Kurtosis	10.015**	3.601**	2.098**	4.415**	4.73**	4.575**	8.246**	7.547**	4.952**	5.807**	3.859**
J-B Test	2818**	382.75**	131.02**	567.04**	646.89**	603.48**	1878.5**	1651.2**	692.43**	977.27**	444.11**
Q(10)	199.94**	203.66**	209.86**	250.71**	263.4**	167.36**	226.7**	228.91**	217.08**	206.24**	256.23**
Q^2(10)	383.69**	206.51**	233.54**	541.81**	539.49**	101.5**	455.26**	256.27**	388.87**	400.24**	459.89**
ARCH(5)	32.92**	21.35**	22.02**	55.04**	67.92**	16.75**	41.68**	42.12**	40.05**	67.98**	64.76**
ADF	-25.33**	-24.41**	-22.34**	-23.93**	-24.63**	-24.65**	-27.96**	-23.33**	-23.95**	-24.26**	-24.58**
Panel E: Bond Market Indexes											
Mean	0.0005	0.0010	0.0002	0.0011	-0.0007	0.0033	-0.0013	-0.0009	0.0013	-0.0006	0.0010
Std. Deviation	0.0704	0.0642	0.0833	0.0748	0.0982	0.0357	0.0918	0.0561	0.1050	0.0768	0.0555
Skewness	1.331**	0.735**	1.28**	0.87**	0.928**	9.693**	-1.873	0.617**	1.947**	-0.722**	1.592**
Kurtosis	17.613**	14.634**	20.532**	2.688**	13.601**	173.17**	57.139**	5.564**	16.422**	52.808**	11.774**
J-B Test	8766.1**	5976.2**	11827**	283.41**	5205.2**	838780**	90579**	897.48**	7869.5**	77095**	4109.8**
Q(10)	21.54*	30.26**	22.1*	38.98**	21.77*	172.7**	59.1**	24.65**	6.3	27.67**	26.88**
Q^2(10)	2.06	32.38**	109.1**	55.73**	21.64*	0.49	89.04**	208.85**	0.98	0.55	6.73
ARCH(5)	0.35	3.95**	25.1**	6.66**	1.95	0.04	17.98**	15.02**	0.13	0.01	0.76
ADF	-13.83**	-14.94**	-14.65**	-13.81**	-14.58**	-10.63**	-12.66**	-13.96**	-14.36**	-15.46**	-14.43**

Notes: J-B test is the Jarque-Bera test for normality. Q(10) and Q^2(10) is the Ljung-Box statistic for serial correlation in raw series and squared series, respectively. ARCH(5) is the Engle's ARCH effects test. ADF is the Augmented Dickey-Fuller test for stationarity. * and ** denote statistical significance at the 5% and 1% level, respectively.

4.2 BEKK Results

4.2.a Market Level and Country – Wide Models

The following ten tables report the estimation results of the MGARCH-BEKK models employed in our empirical investigation. Each set of tables has the same structure. The first table is always the estimated coefficients for the "news surprises" effects between the markets examined. They are the α_{ij} coefficients from equation (4.4), representing the lagged squared innovations effect on the conditional covariance of each one of the sample series. Moreover, the second table in each case depicts the β_{ij} estimated coefficients of our models. As previously mentioned, these coefficients represent the volatility spillovers between the markets, while it is also an indicator of the persistence of the news shocks among them. In all cases, the p-values are reported under each one of the reported coefficients, while statistical significance is marked with asterisks, right next to the significant parameters.

Table 3: BEKK-MGARCH Model for α_{ij}: Countries Case

α_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		-0.071	-0.012	-0.002	-0.036	-0.016	0.001	0.017	0.020	0.012	-0.087
		0.305	*0.965*	*0.549*	*0.904*	*0.801*	*0.665*	*0.701*	*0.899*	*0.124*	*0.240*
BE	0.133		0.056	-0.001	-0.106 *	-0.008	0.004	0.098	0.044	-0.032	-0.057
	0.547		*0.582*	*0.753*	*0.091*	*0.837*	*0.725*	*0.241*	*0.987*	*0.993*	*0.809*
FI	0.003	0.059		-0.431	-0.033	0.003 ***	-0.172	0.002	-0.006	-0.046	0.154 **
	0.979	*0.342*		*0.244*	*0.499*	*0.002*	*0.183*	*0.620*	*0.978*	*0.614*	*0.016*
FR	0.228	0.061	0.051		0.004	-0.113 ***	0.118	-0.062	0.206	0.073	-0.014
	0.206	*0.521*	*0.735*		*0.676*	*0.000*	*0.218*	*0.451*	*0.184*	*0.901*	*0.653*
GE	0.062	0.009	-0.064	0.003		0.017	-0.005	0.007	0.056	0.048	0.132 ***
	0.198	*0.330*	*0.390*	*0.616*		*0.820*	*0.888*	*0.929*	*0.944*	*0.473*	*0.004*
GR	0.002	-0.037	-0.046 ***	0.167 ***	0.017		0.085 ***	0.045	-0.123 **	-0.079 **	0.007 ***
	0.749	*0.405*	*0.000*	*0.000*	*0.937*		*0.000*	*0.817*	*0.021*	*0.017*	*0.000*
IR	0.080	0.031	0.008	-0.002	-0.079 ***	0.003 ***		0.048	0.054	0.016	-0.013 ***
	0.143	*0.975*	*0.440*	*0.888*	*0.004*	*0.002*		*0.837*	*0.741*	*0.799*	*0.000*
IT	-0.079 *	-0.174	-0.061	0.024	-0.022	-0.167 **	-0.006		0.069	0.072 ***	-0.008 ***
	0.079	*0.263*	*0.507*	*0.475*	*0.815*	*0.011*	*0.985*		*0.675*	*0.000*	*0.000*
NE	-0.025	-0.002	0.042	-0.049	-0.019	0.057 ***	0.058	-0.204 *		-0.041	-0.055 **
	0.795	*0.986*	*0.863*	*0.185*	*0.986*	*0.005*	*0.388*	*0.050*		*0.490*	*0.030*
PO	0.004	-0.003	0.002	-0.032	-0.026	0.045	0.036 *	-0.219 ***	0.006		-0.065 ***
	0.651	*0.994*	*0.983*	*0.490*	*0.688*	*0.332*	*0.060*	*0.000*	*0.958*		*0.000*
SP	0.106	-0.072	-0.039	-0.123 **	-0.021	-0.042 ***	0.184 ***	0.140 ***	0.228 **	0.043 ***	
	0.302	*0.504*	*0.711*	*0.030*	*0.707*	*0.000*	*0.000*	*0.000*	*0.024*	*0.000*	

Notes: This table reports the "news surprises" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

Before proceeding with the discussion of the results, we should also explain the tables' diarthosis. In the first column and row, the initials of the countries are reported. Because of that, the main diagonal of each table is empty, since there is no point in reporting own effects for the economies we examine. Then, the correct way to read the tables is by following each row towards each column. For instance, the first row reports the estimated coefficients for the news and volatility spillover effects from Austria (or the Austrian markets, respectively) to the rest of the sample economies. The same is true for Belgium, in the case of the third row, until the Spanish case that concludes each one of the tables[3]. In other words, the spillovers' direction here is from the rows towards the columns (the rows represent the volatility spillover sources while the columns the shocks' recipients).

Table 4: BEKK-MGARCH Model for β_{ij}: Countries Case

β_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		0.039	-0.021	0.012	-0.048	0.024	0.004	0.008	0.041	-0.035	0.055
		0.113	*0.987*	*0.891*	*0.388*	*0.845*	*0.817*	*0.780*	*0.473*	*0.000*	*0.028*
BE	-0.048		0.007	0.061 **	-0.004	-0.030	0.125	0.007	0.058	-0.005	0.037
	0.255		*0.822*	*0.029*	*0.602*	*0.417*	*0.822*	*0.737*	*0.906*	*0.992*	*0.564*
FI	0.038	-0.022		-0.022 ***	0.098	0.021 ***	0.157 ***	0.043 **	0.046	0.074	-0.076 ***
	0.944	*0.418*		*0.000*	*0.629*	*0.000*	*0.000*	*0.021*	*0.908*	*0.955*	*0.000*
FR	-0.106	-0.131 **	0.000		-0.051	0.182 ***	0.036 *	-0.025	-0.048	-0.064 *	0.014 **
	0.568	*0.015*	*0.178*		*0.347*	*0.000*	*0.065*	*0.758*	*0.511*	*0.098*	*0.030*
GE	0.034	0.015 **	-0.014	0.005		0.023	0.006	0.007	-0.031	0.001	0.104
	0.808	*0.016*	*0.829*	*0.870*		*0.891*	*0.831*	*0.817*	*0.854*	*0.936*	*0.102*
GR	-0.003	0.008	-0.003 ***	-0.093 ***	-0.050		-0.096 ***	0.003	-0.084 ***	-0.117 ***	-0.030 ***
	0.836	*0.684*	*0.000*	*0.000*	*0.768*		*0.000*	*0.948*	*0.000*	*0.001*	*0.000*
IR	-0.082 **	-0.277	-0.002 ***	-0.002	-0.167	0.175 ***		-0.031	-0.027	-0.064 *	0.002 ***
	0.017	*0.824*	*0.000*	*0.904*	*0.506*	*0.000*		*0.374*	*0.859*	*0.065*	*0.000*
IT	-0.017	0.000	-0.019	0.047	-0.008	0.004	0.023		0.038 ***	-0.001 ***	-0.009 ***
	0.611	*0.677*	*0.704*	*0.458*	*0.891*	*0.428*	*0.827*		*0.000*	*0.000*	*0.000*
NE	-0.011	-0.041	-0.033	0.018 **	0.017	0.008 ***	-0.015	-0.126 **		-0.038	0.104 ***
	0.750	*0.488*	*0.383*	*0.047*	*0.838*	*0.000*	*0.840*	*0.042*		*0.192*	*0.000*
PO	0.019 ***	0.003	-0.010	0.013	0.007	0.023 ***	0.022 ***	-0.026 ***	0.009		0.076 ***
	0.000	*0.997*	*0.976*	*0.418*	*0.905*	*0.001*	*0.008*	*0.000*	*0.856*		*0.000*
SP	-0.069	-0.020	0.045	-0.036 ***	-0.072 **	0.160 ***	-0.049 ***	0.011 ***	-0.216 ***	-0.020 ***	
	0.358	*0.873*	*0.179*	*0.000*	*0.050*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	

Notes: This table reports the "volatility spillover" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

We initialize the results discussion with tables 4.3 and 4.4. Here, the investigation of the country-wide financial stress spillovers is examined. According to

[3] As it is easily understandable, each country's case uses two rows from the table: one for the estimated parameters, the other one for the p-values. Hence, in the case of Belgium, the analysis starts from the third row. The same holds for all countries and markets analysed here.

the estimations, the most heavily affected countries are those with the strongest spillovers to the rest of the Euro Area countries. Especially Greece and Spain present significant news and volatility spillover effects to the rest of the economies. On the same time, these two countries are the major recipients of financial stress spillovers, together with France. It is interesting to notice that Germany is highly immune to volatility transmission in this respect. As a first comment, we can say that surprises, regarding the financial conditions in Greece and Spain, are widely dispersed with the monetary union and this is a long lasting effect (as it is evident from the volatility risk transmission depicted in table 4.4). On the hand, the effects on the Greek case are rather small, judging by the size and magnitude of the relevant parameters. Moreover, there is a bidirectional spillover effect between Greece and France, while the respective French – Spanish comovements are rather weak. Ireland has a statistical significant and strong effect to Greece. Finally, Portugal is also an important contributor to the financial stress transmission, at least in terms of statistical significance. The size of the relevant estimated parameters is quite small. Another interesting feature of our results is the strong links between the economies of North Europe. A bidirectional link exists between Belgium and France, while Germany spillovers to the former as well.

Turning now to the case of the banking stress transmission, the picture is somewhat different. In general, Ireland, together with the Italian and Portuguese banking sector is the major volatility risk recipients. Similar vulnerability is indicated for the case of Austria, even though, on a more limited size compared to the aforementioned cases. Italian banks seem to greatly affect the Irish and Portuguese market, with strongly significant parameters. Once again, it is interesting to underline the total lack of volatility spillover towards German banking market, with similar results holding for the French case as well. Overall, even though there seem to be some transmission channels of banking stress among the economies of our sample, the effects are not strong enough or lasting (comparing the news effect with the results from the second table of this group of stress indexes).

The next two tables analyze the case of the money market volatility spillovers. Once more, the main recipients of the relevant effects are, mainly, Greece and Portugal (for the case of "news effects" coefficients), with Ireland and Portugal to take the lead in the volatility transmission risks. Nevertheless, the strong statistical results are accompanied by very small parameters. On top of that, Greek money market shocks greatly affect the Finnish and Spanish cases, as it is evident by table 4.7. Stronger volatility spillovers can be traced in the cases of Spain and Portugal, with Greece being another important contributor here. Most of the estimated β_{ij} coefficients in the latter case are positive, transmitting turmoil to Belgium, France and Netherlands. Portugal and Spain perform poorly here (coefficients with almost negligible size). The only exception here is the strong positive effect towards Ireland. Another interesting finding here is the case of France. As an extra evidence of the

Table 5: BEKK-MGARCH Model for α_{ij}: Banking Sector Case

α_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		0.071	-0.017	0.056	0.036	0.008	0.179	0.128 ***	0.029	-0.051 ***	0.015
		0.851	*0.900*	*0.396*	*0.287*	*0.888*	*0.128*	*0.000*	*0.829*	*0.000*	*0.520*
BE	0.283		0.001 ***	-0.022	0.020	0.238	0.044	0.058	0.072	-0.092 ***	-0.141 ***
	0.690		*0.000*	*0.780*	*0.994*	*0.403*	*0.433*	*0.962*	*0.192*	*0.000*	*0.003*
FI	0.011	0.076 ***		0.025	0.008	0.330 ***	-0.207 ***	0.010	0.018	-0.027 ***	0.120 ***
	0.920	*0.000*		*0.494*	*0.797*	*0.000*	*0.000*	*0.992*	*0.457*	*0.000*	*0.003*
FR	0.004	-0.073	-0.023		0.096	-0.071 ***	0.040	-0.060	0.049	-0.015	0.102
	0.926	*0.741*	*0.708*		*0.541*	*0.000*	*0.488*	*0.924*	*0.949*	*0.761*	*0.783*
GE	-0.036	-0.129	-0.001	-0.046		0.020	-0.123	0.087	0.001	-0.021	-0.019
	0.236	*0.975*	*0.791*	*0.758*		*0.904*	*0.136*	*0.348*	*0.977*	*0.993*	*0.950*
GR	-0.161 ***	-0.125	-0.060 ***	0.059	0.001		0.130	0.003	0.117	-0.013 ***	0.002
	0.002	*0.689*	*0.001*	*0.344*	*0.993*		*0.955*	*0.999*	*0.938*	*0.000*	*0.809*
IR	-0.025	-0.047	-0.025 ***	0.065	-0.086	0.048		0.113 **	-0.095	-0.309 ***	-0.085
	0.574	*0.356*	*0.000*	*0.404*	*0.167*	*0.971*		*0.014*	*0.709*	*0.000*	*0.902*
IT	-0.049 ***	-0.034	0.018	0.022	-0.050	0.155	-0.068 **		0.000	0.071 ***	-0.028
	0.000	*0.963*	*0.953*	*0.925*	*0.654*	*0.811*	*0.015*		*0.804*	*0.000*	*0.865*
NE	-0.028	-0.022	-0.014	-0.011	-0.005	-0.130 ***	0.055	-0.075		-0.001	-0.021
	0.929	*0.847*	*0.918*	*0.979*	*0.960*	*0.002*	*0.930*	*0.159*		*0.984*	*0.778*
PO	-0.217 ***	0.186 ***	0.052	0.000	0.114	0.115 ***	0.011 **	-0.007 ***	0.024		0.015
	0.000	*0.000*	*0.172*	*0.976*	*0.990*	*0.000*	*0.016*	*0.000*	*0.683*		*0.279*
SP	0.033	0.097	0.040	-0.007	0.033	-0.020	0.085	0.012	-0.002	0.009	
	0.759	*0.516*	*0.146*	*0.832*	*0.786*	*0.981*	*0.246*	*0.929*	*0.922*	*0.387*	

Notes: This table reports the "news surprises" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

Table 6: BEKK-MGARCH Model for β_{ij}: Banking Sector Case

β_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		0.003	0.001	0.018	-0.003	0.001	0.036 ***	0.031 ***	0.005	0.021 ***	0.002
		0.971	*0.971*	*0.657*	*0.712*	*0.974*	*0.008*	*0.000*	*0.960*	*0.000*	*0.412*
BE	-0.080		-0.014 ***	0.052	-0.015	0.500	0.013	-0.009	-0.004	0.012 ***	0.063
	0.361		*0.000*	*0.143*	*0.990*	*0.629*	*0.701*	*0.860*	*0.905*	*0.009*	*0.323*
FI	0.018	0.059 ***		0.012	0.013	0.008 **	-0.043 ***	0.060	0.013	0.001	0.058 **
	0.922	*0.000*		*0.850*	*0.767*	*0.028*	*0.000*	*0.976*	*0.815*	*0.437*	*0.015*
FR	-0.002	0.001	0.020		-0.022	-0.014	0.020	-0.004	-0.032	0.065	0.042
	0.918	*0.987*	*0.729*		*0.877*	*0.293*	*0.145*	*0.886*	*0.941*	*0.374*	*0.680*
GE	-0.020 ***	-0.038	0.000	0.008		0.028	0.033 ***	-0.100 *	-0.001	0.020	0.011
	0.000	*0.929*	*0.727*	*0.941*		*0.789*	*0.003*	*0.051*	*0.980*	*0.990*	*0.968*
GR	0.024 **	-0.032	0.002	0.006 ***	-0.024		-0.001	-0.001	0.024	-0.123 ***	0.003
	0.042	*0.149*	*0.417*	*0.002*	*0.884*		*0.996*	*0.999*	*0.960*	*0.000*	*0.987*
IR	-0.021	-0.015	0.037 ***	-0.029	0.005	-0.011		-0.088 ***	-0.186	0.016	0.030
	0.520	*0.725*	*0.000*	*0.380*	*0.766*	*0.969*		*0.000*	*0.748*	*0.157*	*0.831*
IT	-0.098 ***	0.003	-0.012	0.026	0.071	0.036	0.069 ***		-0.043	0.195 ***	0.002
	0.000	*0.965*	*0.991*	*0.911*	*0.118*	*0.860*	*0.000*		*0.454*	*0.000*	*0.967*
NE	-0.029	-0.113 ***	-0.010	0.005	-0.016	-0.020	0.015	0.064		0.040	-0.050
	0.865	*0.000*	*0.950*	*0.988*	*0.901*	*0.925*	*0.464*	*0.237*		*0.759*	*0.652*
PO	-0.136 ***	-0.028 ***	-0.007 **	0.000	-0.096	0.022 ***	-0.001	-0.033 ***	-0.028		0.035 ***
	0.000	*0.000*	*0.015*	*0.929*	*0.948*	*0.000*	*0.516*	*0.000*	*0.828*		*0.000*
SP	-0.025 ***	-0.021	-0.026 *	0.000	-0.020	-0.011	-0.014	0.078	0.010	-0.124 ***	
	0.000	*0.504*	*0.057*	*0.989*	*0.615*	*0.975*	*0.618*	*0.523*	*0.495*	*0.000*	

Notes: This table reports the "volatility spillover" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

Table 7: BEKK-MGARCH Model for α_{ij}: Money Market Case

α_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		0.015	-0.064	0.048	0.143	0.037	-0.027	-0.199	0.102	-0.075	0.046
		0.821	*0.541*	*0.277*	*0.815*	*0.616*	*0.774*	*0.375*	*0.930*	*0.215*	*0.240*
BE	-0.062		-0.004	-0.031	-0.156	0.006	-0.055	-0.094	-0.013	0.109	-0.095
	0.338		*0.832*	*0.798*	*0.600*	*0.938*	*0.208*	*0.377*	*0.992*	*0.521*	*0.481*
FI	0.105	-0.015		0.006	-0.045	-0.147	0.004	0.186 *	-0.059	0.007 ***	0.045 ***
	0.329	*0.620*		*0.782*	*0.690*	*0.121*	*0.310*	*0.056*	*0.981*	*0.000*	*0.000*
FR	-0.057	-0.063	-0.003		-0.055	0.070 **	0.002	-0.095	-0.225	-0.240 ***	-0.296 ***
	0.110	*0.651*	*0.985*		*0.949*	*0.032*	*0.991*	*0.991*	*NaN*	*0.009*	*0.000*
GE	-0.021	-0.009	0.025	-0.007		0.046	0.005	-0.002	-0.065	-0.033	-0.002
	0.984	*NaN*	*0.193*	*0.997*		*0.151*	*0.953*	*0.928*	*0.974*	*0.912*	*0.431*
GR	-0.002	0.020	0.122 **	-0.138 **	-0.032		-0.156	-0.045	0.054	0.003 ***	0.256 ***
	0.938	*0.975*	*0.015*	*0.037*	*0.322*		*0.353*	*0.363*	*0.825*	*0.005*	*0.000*
IR	0.009	0.108	-0.110	0.039	-0.012	0.070		-0.020	-0.052	0.004	-0.002
	0.861	*0.164*	*0.152*	*0.895*	*0.941*	*0.669*		*0.227*	*0.801*	*0.983*	*0.947*
IT	-0.043	0.126	0.138	-0.007	0.002	-0.001	0.075		-0.004	-0.064 ***	-0.037
	0.882	*0.413*	*0.619*	*1.000*	*0.956*	*0.993*	*0.241*		*0.995*	*0.000*	*0.165*
NE	-0.118	-0.015	-0.007	0.041	-0.006	-0.080 ***	0.016	-0.026		-0.020	-0.015
	0.812	*0.964*	*0.958*	*NaN*	*0.972*	*0.008*	*0.482*	*0.994*		*0.492*	*0.699*
PO	-0.018	-0.267	0.000 ***	-0.024	0.108	-0.023 ***	0.043	0.032 ***	0.077		-0.014
	0.883	*0.611*	*0.000*	*0.771*	*0.918*	*0.000*	*0.951*	*0.000*	*0.772*		*0.128*
SP	0.008	0.096	-0.065 ***	-0.057 ***	-0.013 ***	-0.080	0.027	0.171	0.000	0.010	
	0.795	*0.739*	*0.000*	*0.000*	*0.003*	*0.361*	*0.433*	*0.331*	*0.896*	*0.823*	

Notes: This table reports the "news surprises" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

Table 8: BEKK-MGARCH Model for β_{ij}: Money Market Case

β_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		-0.001	0.015	-0.001	-0.027	0.039	0.004	-0.028	0.014	0.021	0.031
		0.858	*0.576*	*0.920*	*0.990*	*0.450*	*0.924*	*0.905*	*0.976*	*0.325*	*0.138*
BE	0.013		0.005	-0.004	0.089	-0.002	0.020	-0.026	-0.090	0.024	-0.018
	0.516		*0.856*	*0.953*	*NaN*	*0.942*	*0.442*	*0.209*	*0.887*	*0.441*	*0.822*
FI	-0.005	0.009		0.013	-0.035	0.029	-0.006 ***	0.053	0.006	0.001 ***	-0.002
	0.806	*0.741*		*0.522*	*0.440*	*0.510*	*0.006*	*0.548*	*0.962*	*0.001*	*0.582*
FR	0.002	0.021	0.000		0.015	-0.048 ***	0.014	0.003	0.002	-0.091 ***	0.115 ***
	0.867	*0.469*	*0.928*		*0.989*	*0.000*	*0.735*	*1.000*	*NaN*	*0.000*	*0.000*
GE	0.004	-0.001	0.001 ***	0.002		0.045	0.000	0.025	0.029	0.023	0.007
	0.994	*NaN*	*0.010*	*0.999*		*0.213*	*0.948*	*0.600*	*0.987*	*0.806*	*0.801*
GR	-0.003	0.161 *	-0.051 ***	0.140 *	-0.019		0.044	0.012	0.138 **	0.002 ***	-0.081 ***
	0.952	*0.070*	*0.000*	*0.090*	*0.498*		*0.345*	*0.995*	*0.036*	*0.000*	*0.000*
IR	0.000	-0.070	0.013	-0.092	-0.025	0.013		0.021 ***	0.041	-0.001	-0.002
	0.879	*0.281*	*0.853*	*0.837*	*0.736*	*0.940*		*0.000*	*0.221*	*0.943*	*0.407*
IT	0.023	0.035	-0.045 *	0.005	-0.002	-0.026	-0.122 ***		-0.029	0.003 ***	0.015
	0.943	*0.505*	*0.080*	*0.999*	*0.949*	*0.957*	*0.000*		*0.994*	*0.000*	*0.108*
NE	0.012	0.007	0.005	0.001	0.034	-0.013 **	-0.116 ***	0.025		-0.001	-0.016
	0.768	*0.921*	*0.976*	*NaN*	*0.893*	*0.040*	*0.000*	*0.975*		*0.905*	*0.884*
PO	-0.069	0.003	-0.131 ***	0.040 *	-0.220	-0.090 ***	-0.096	0.010 ***	0.155		0.002
	0.540	*0.986*	*0.000*	*0.056*	*0.877*	*0.000*	*0.749*	*0.000*	*0.468*		*0.883*
SP	-0.003	0.071	0.004	-0.026 ***	-0.007	0.071 ***	0.173 ***	-0.072	0.004	-0.050 ***	
	0.610	*0.625*	*0.645*	*0.000*	*0.885*	*0.000*	*0.000*	*0.142*	*0.978*	*0.000*	

Notes: This table reports the "volatility spillover" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

tight links of this country with the more vulnerable economies of Eurozone, the cross-volatility relation this country exhibits with Greece, Portugal and Spain are statistically significant. But, once more, only Spain's parameter is not negligible.

A very different situation appears in the case of equity markets' volatility spillovers. In essence, the identified links are scarce. In both cases, cross-innovations and variance volatility transmission parameters, there are very few statistically significant parameters. In the case of news shocks, Greece has the prominent role. The effect from the Greek stock market is strong for the cases of Germany, Italy and Netherlands. Nevertheless, this is not a long lasting effect, since the reflecting parameters in the second table are not significant. In fact, only three cases are found to be non negligible in table 4.10. Still, the lack of evidence in favour of volatility spillovers in the case of equity markets is rather unexpected. It could, probably, be a sign of the, rather limited, financial risk propagation taken place through that market in the Eurozone case.

The final set of markets under consideration is the bond ones. In general, there is stronger evidence here for the existence of spillovers between the EMU economies. The results, reported at table 4.11, indicate the existence of significant and sizeable "news effect" between most of the markets. The case of Spain is the most profound one, with results being very strong but, on the same time, with very small parameters values. Surprisingly, the same does not hold for this country in table 4.12. There, the only significant parameter is the one representing the spillover effect to Portugal. Beyond the previous results, it is also interesting the fact that other heavily criticized economies (for their role as sources of financial instability propagators), like Greece and Ireland, do not perform as it would be expected. They are both limited to a minor initial shock to Austria while, in the case of volatility spillover parameters, their contribution to the financial stress interspersion is rather limited. In the same vein, Portuguese bond risk is transmitted to the other member of the PIIGS groups of countries but, again, with the size of this transmission to be minimal. This is the only sector where the German case produces some significant results, both as propagator and received or spillover effects. Another aspect of the bond financial stress conditions is the links between the core Euro economies. Austria has a bidirectional connection with Belgium, while the same holds for Finland and Germany. The Dutch

Table 9: BEKK-MGARCH Model for α_{ij}: Equity Market Case

α_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		0.024	0.006	0.032	0.012	-0.019	0.018	0.135	0.014	0.022	0.057
		0.990	*0.912*	*0.953*	*0.904*	*0.971*	*0.951*	*0.931*	*0.925*	*0.935*	*0.420*
BE	0.006		0.193 ***	0.003	0.006	-0.051	-0.025	0.248	0.141	-0.004	0.047
	0.981		*0.005*	*0.893*	*0.969*	*0.733*	*0.974*	*0.934*	*0.898*	*0.991*	*0.940*
FI	-0.011	-0.160 *		-0.015	-0.060	-0.291 *	-0.027	-0.009	0.001	-0.024	0.075
	0.893	*0.065*		*0.934*	*0.438*	*0.055*	*0.862*	*0.941*	*0.988*	*0.727*	*0.790*
FR	-0.003	-0.002	0.006		-0.007	-0.101	-0.033	-0.080	0.001	-0.028	0.052
	0.948	*0.799*	*0.967*		*0.989*	*0.641*	*0.971*	*0.792*	*0.869*	*0.838*	*0.820*
GE	-0.001	0.009	-0.079	-0.011		0.013	-0.010	0.009	0.009	0.017	0.007
	0.813	*0.946*	*0.528*	*0.963*		*0.946*	*0.967*	*0.976*	*0.968*	*0.840*	*0.986*
GR	0.020	0.056	0.048	0.067	0.137 **		0.002	0.247 **	0.178 ***	0.002	0.009
	0.946	*0.784*	*0.489*	*0.345*	*0.038*		*0.935*	*0.027*	*0.006*	*0.938*	*0.970*
IR	-0.010	0.007	-0.016	0.016	-0.011	-0.039		0.044	0.039	0.107 ***	-0.036
	0.943	*0.960*	*0.965*	*0.978*	*0.958*	*0.604*		*0.643*	*0.719*	*0.000*	*0.869*
IT	-0.024	-0.018	0.001	0.099	0.001	0.007	-0.013		0.011	0.006	-0.004
	0.974	*0.949*	*0.964*	*0.688*	*0.775*	*0.872*	*0.939*		*0.891*	*0.986*	*0.966*
NE	0.009	0.042	0.017	0.008	-0.009	-0.039	-0.007	0.000		-0.010	-0.027
	0.952	*0.975*	*0.908*	*0.948*	*0.945*	*0.769*	*0.995*	*0.936*		*0.956*	*0.847*
PO	-0.012	0.023	0.013	0.056	0.112	0.000	-0.006	0.033	0.003		0.179
	0.983	*0.931*	*0.890*	*0.304*	*0.235*	*0.902*	*0.225*	*0.938*	*0.987*		*0.791*
SP	0.048	0.013	0.069	0.034	0.011	-0.094	-0.023	0.012	0.075	0.037	
	0.517	*0.950*	*0.680*	*0.793*	*0.993*	*0.396*	*0.922*	*0.928*	*0.574*	*0.926*	

Notes: This table reports the "news surprises" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

Table 10: BEKK-MGARCH Model for β_{ij}: Equity Market Case

β_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		-0.028	-0.037 ***	-0.020	-0.033	0.024	-0.019	-0.060	0.009	-0.027	-0.026
		0.986	*0.000*	*0.970*	*0.665*	*0.952*	*0.962*	*0.994*	*0.929*	*0.804*	*0.435*
BE	-0.002		-0.045	0.000	0.009	0.052	0.038	-0.265	0.115	-0.012	0.006
	0.986		*0.208*	*0.887*	*0.954*	*0.813*	*0.944*	*0.839*	*0.942*	*0.954*	*0.982*
FI	0.028	0.040		-0.005	0.030	0.111 ***	-0.013	0.003	-0.003	0.008	0.012
	0.680	*0.357*		*0.973*	*0.703*	*0.004*	*0.898*	*0.936*	*0.989*	*0.902*	*0.931*
FR	0.011	-0.002	0.024		0.002	0.006	0.030	0.014	0.021	-0.026	0.014
	0.778	*0.799*	*0.849*		*0.978*	*0.977*	*0.947*	*0.951*	*0.855*	*0.760*	*0.918*
GE	0.024	-0.007	0.058	0.039		-0.037	0.027	0.009	-0.005	-0.005	0.019
	0.599	*0.953*	*0.440*	*0.815*		*0.890*	*0.917*	*0.979*	*0.980*	*0.947*	*0.943*
GR	-0.025	-0.058	-0.009	0.043	-0.026		-0.001	-0.119	0.000	0.000	0.006
	0.923	*0.834*	*0.905*	*0.246*	*0.696*		*0.946*	*0.130*	*0.860*	*0.946*	*0.981*
IR	0.059	-0.004	0.043	-0.022	-0.002	0.052		-0.009	-0.025	-0.007 **	0.024
	0.861	*0.952*	*0.856*	*0.960*	*0.993*	*0.475*		*0.928*	*0.869*	*0.039*	*0.841*
IT	0.015	0.020	0.003	0.095	-0.011	0.001	-0.004		0.011	-0.019	0.004
	0.974	*0.984*	*0.905*	*0.650*	*0.980*	*0.869*	*0.918*		*0.836*	*0.982*	*0.947*
NE	-0.005	-0.091	-0.001	-0.005	-0.013	-0.029	0.016	0.000		-0.020	0.013
	0.968	*0.962*	*0.975*	*0.914*	*0.973*	*0.824*	*0.984*	*0.936*		*0.888*	*0.898*
PO	0.003	0.016	-0.004	-0.001	-0.056	-0.001	-0.005 ***	0.026	0.012		-0.046
	0.994	*0.964*	*0.943*	*0.960*	*0.499*	*0.907*	*0.000*	*0.891*	*0.921*		*0.938*
SP	-0.012	-0.014	-0.067	-0.016	-0.012	0.015	-0.013	-0.010	-0.039	-0.016	
	0.754	*0.975*	*0.290*	*0.843*	*0.995*	*0.731*	*0.944*	*0.811*	*0.805*	*0.947*	

Notes: This table reports the “volatility spillover” estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

Table 11: BEKK-MGARCH Model for α_{ij}: Bond Market Case

α_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		0.093 ***	0.013	-0.051	-0.026	-0.021 ***	0.197	-0.071 ***	-0.096	0.205 ***	0.176 ***
		0.000	*0.960*	*0.620*	*0.759*	*0.000*	*0.213*	*0.000*	*0.841*	*0.005*	*0.000*
BE	0.108 ***		0.009	-0.124 **	0.100	-0.047	-0.019	-0.072	0.007	0.044	0.025
	0.000		*0.749*	*0.035*	*0.227*	*0.180*	*0.641*	*0.338*	*0.856*	*0.984*	*0.828*
FI	-0.005	0.000		-0.106	-0.097 ***	-0.019	0.013	-0.075	0.110 ***	0.098	0.000
	0.959	*0.878*		*0.174*	*0.000*	*0.594*	*0.669*	*0.279*	*0.001*	*0.240*	*0.960*
FR	0.008	0.200 ***	0.222 *		0.110	-0.017	0.069 *	0.004	-0.161 *	0.035	0.005
	0.934	*0.005*	*0.053*		*0.565*	*0.290*	*0.062*	*0.890*	*0.066*	*0.130*	*0.846*
GE	0.074 ***	-0.098 *	0.008 ***	0.015		0.041 ***	0.216	0.020	0.027	-0.184	-0.004 ***
	0.002	*0.065*	*0.000*	*0.720*		*0.006*	*0.146*	*0.345*	*0.340*	*0.125*	*0.000*
GR	0.093 ***	0.290	0.030	0.146	-0.028		0.144 **	-0.067	0.031 ***	0.144	0.007
	0.000	*0.152*	*0.988*	*0.319*	*0.597*		*0.021*	*0.136*	*0.009*	*0.711*	*0.920*
IR	-0.169 ***	0.017	0.078	-0.022	-0.048	-0.018		-0.040	-0.003	-0.052	0.000
	0.000	*0.606*	*0.532*	*0.771*	*0.650*	*0.322*		*0.158*	*0.931*	*0.127*	*0.934*
IT	0.060 ***	0.081	-0.004	-0.125	-0.081	0.001	0.020		0.212 ***	-0.009	0.004
	0.000	*0.382*	*0.959*	*0.350*	*0.277*	*0.954*	*0.896*		*0.000*	*0.920*	*0.958*
NE	0.101	0.010	0.111 ***	0.072 **	0.079	-0.291 ***	-0.007	-0.002		0.024 ***	-0.036
	0.481	*0.284*	*0.002*	*0.014*	*0.139*	*0.000*	*0.914*	*0.836*		*0.000*	*0.195*
PO	-0.106 *	0.183	-0.050	0.039	0.088	0.008	0.120 ***	0.268 *	-0.024 ***		-0.031
	0.087	*0.950*	*0.444*	*0.687*	*0.591*	*0.173*	*0.000*	*0.068*	*0.000*		*0.435*
SP	0.029 ***	0.047 ***	0.001 ***	0.001 ***	-0.006 ***	-0.059 ***	0.004 ***	0.015 ***	-0.093 ***	0.022 ***	
	0.269	*0.614*	*0.963*	*0.080*	*0.129*	*0.193*	*0.976*	*0.952*	*0.606*	*0.502*	

Notes: This table reports the “news surprises” estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

Table 12: BEKK-MGARCH Model for β_{ij}: Bond Market Case

β_{ij}	AU	BE	FI	FR	GE	GR	IR	IT	NE	PO	SP
AU		0.007 ***	-0.005	0.147 ***	-0.033 **	0.002 ***	-0.051	0.031 ***	0.000	-0.045	-0.028 **
		0.008	*0.964*	*0.000*	*0.019*	*0.000*	*0.441*	*0.000*	*0.940*	*0.138*	*0.034*
BE	-0.011 ***		0.001	-0.026	-0.031	0.002	0.002	-0.011	-0.021	0.012	0.014
	0.000		*0.798*	*0.728*	*0.773*	*0.920*	*0.957*	*0.737*	*0.718*	*0.966*	*0.877*
FI	0.000	-0.004		0.005	0.102 ***	0.026	-0.037 **	-0.034	0.018	-0.046 ***	0.002
	0.992	*0.650*		*0.900*	*0.000*	*0.777*	*0.040*	*0.859*	*0.215*	*0.000*	*0.955*
FR	0.000	0.041 **	-0.143		-0.016	0.013 **	0.018	0.076 ***	-0.027 ***	0.074	0.003
	0.866	*0.028*	*0.131*		*0.806*	*0.042*	*0.801*	*0.000*	*0.000*	*0.418*	*0.900*
GE	0.021 *	0.026	-0.011 ***	0.011 *		0.047 ***	0.045 ***	0.025	0.034 ***	0.064	0.000
	0.075	*0.122*	*0.000*	*0.092*		*0.002*	*0.000*	*0.198*	*0.000*	*0.244*	*0.640*
GR	-0.012 ***	-0.039	-0.021	-0.040	-0.088 ***		-0.025	-0.052 ***	-0.006 ***	-0.022	0.089
	0.000	*0.812*	*0.978*	*0.193*	*0.000*		*0.111*	*0.000*	*0.000*	*0.196*	*0.234*
IR	0.049	0.022 ***	0.122	-0.036	-0.003	0.019 ***		0.002	-0.002	0.040 ***	0.003
	0.209	*0.009*	*0.209*	*0.871*	*0.833*	*0.003*		*0.929*	*0.924*	*0.000*	*0.858*
IT	0.004 ***	0.001	0.003	-0.066	-0.014	0.000	0.014		-0.099 ***	0.014	0.000
	0.000	*0.958*	*0.970*	*0.445*	*0.891*	*0.944*	*0.694*		*0.000*	*0.390*	*0.868*
NE	0.004	0.019 **	-0.044 *	0.095 ***	-0.035 ***	0.040 ***	0.034	0.008 ***		0.020 ***	-0.008
	0.932	*0.038*	*0.069*	*0.000*	*0.000*	*0.000*	*0.297*	*0.005*		*0.000*	*0.170*
PO	0.022 *	-0.015	0.021	-0.035	-0.034	0.001 **	-0.004 ***	-0.036 **	-0.002 ***		0.028 ***
	0.087	*0.985*	*0.229*	*0.333*	*0.370*	*0.046*	*0.000*	*0.012*	*0.000*		*0.000*
SP	0.007	-0.021	-0.001	-0.001	0.000	-0.035	-0.004	0.008	0.105	-0.151 ***	
	0.469	*0.817*	*0.964*	*0.846*	*0.794*	*0.305*	*0.967*	*0.964*	*0.371*	*0.000*	

Notes: This table reports the "volatility spillover" estimated coefficients from bivariate BEKK-GARCH models. P-values are reported in italics, under each parameter reported. The direction of the effects is from each row towards the columns. Countries/Markets are reported, according to their initials: AU (Austria), BE (Belgium), FI (Finland), FR (France), GE (Germany), GR (Greece), IR (Ireland), IT (Italy), NE (Netherlands), PO (Portugal) and SP (Spain).

bond stress is also evident of its volatility spillover towards, mostly, the stronger EMU economies (Belgium, Germany, and France). In general terms, the bond market is profoundly succumbed to strong volatility spillovers, from both peripheral and core bond markets. The news shocks turn into important and enduring stress transmission, so that it can be said that this Eurozone financial sector is one of the most volatile and susceptible to increasing financial distress and episode of financial catastrophes.

Overall, the market-level analysis provides some useful insights in the conditions prevailing to Euro Area economies and markets. We find evidence of strong spillover effects among most of the economies under scrutiny. Moreover, the most volatile and vulnerable to risk transmission are the bond market (mostly representing sovereign risk) and the banking sector (sketching the operational efficiency, profitability and risk tolerance of financial institutions). A notable exception is the equity markets analysis, where no suitable conditions for volatility spillover were detected. With regards to the sector analyzed, the main risk spillover propagators vary but, again, there is no clear cut evidence whatsoever against a specific country or group of countries as the major contributors of these financial risks.

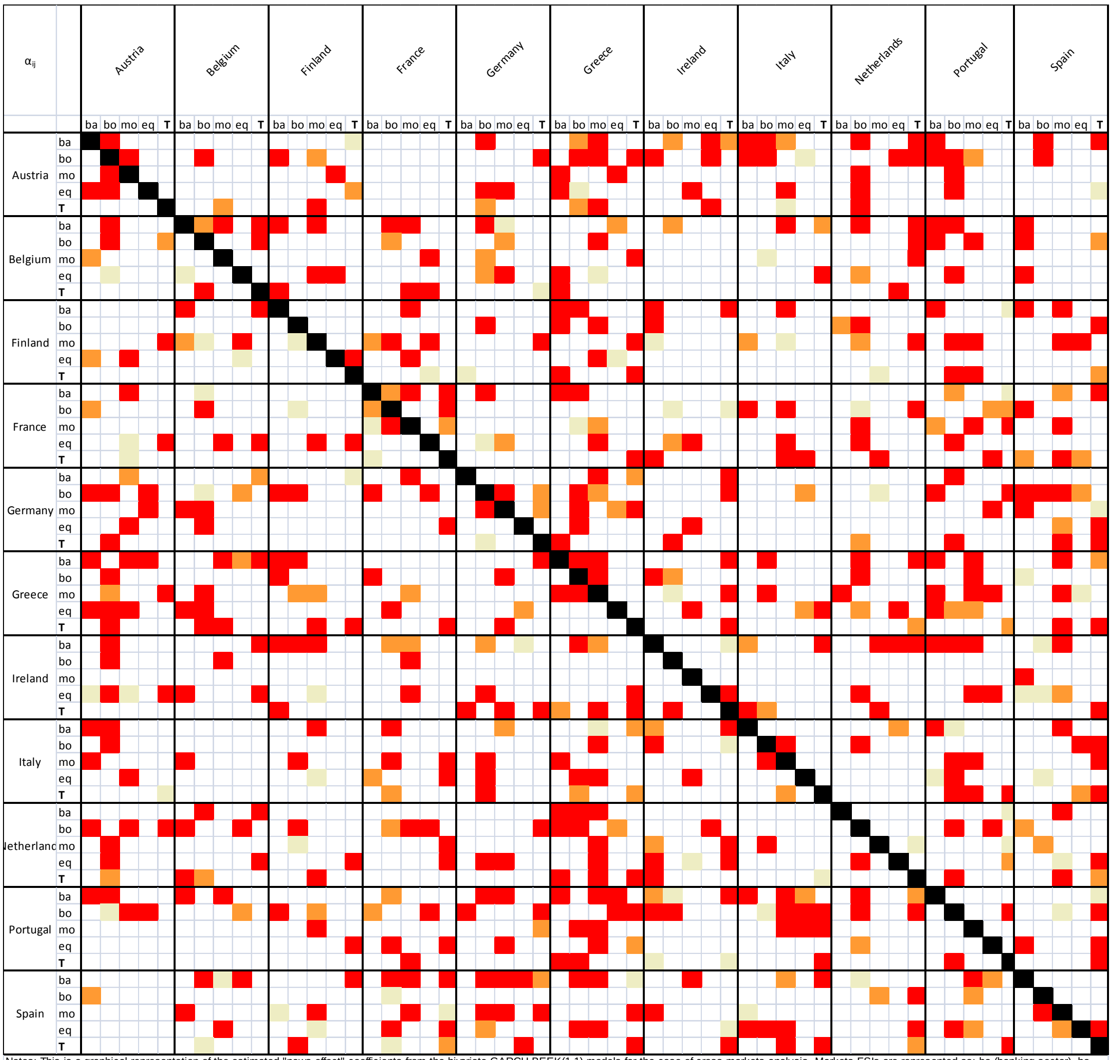
4.2.b Cross-Market Models

The previous section provided interesting insights into the links and causality-in-variance relations between the different financial stress levels of the markets under consideration. Some useful points were made, together with directions toward the macroeconomic and financial policies should be switched to. In order to provide further insight, we proceed to the empirical investigation of the potential spillover effects among all the previous financial markets together. Instead of isolating the possible sources of instability within each one of them, the models employed here allows for any kind of volatility transmission channels. To put it differently, the analysis is cross-sectional, in the sense that any market can influence any other of them. It is a major step further in this research area, for a number of reasons. First, it is the first ever effort to apply such a multivariate GARCH framework for the analysis of the Eurozone case, in such detailed level and markets' decomposition. Then, it is also interesting the chance to implement this empirical work, using financial stress indices, since they successfully bespeak the past, present and forthcoming financial conditions. Finally, it should be emphasized that this is the first piece of research applying such computational effort and in such deep analysis (in terms of countries and markets included in the empirical work) for the EMU economies. Instead of eliminating the scope of our research in a few countries and only in indicators of sovereign risk or banking instabilities, we provide evidence based on many more features of the financial system. In this respect, a deeper understanding of the comovements and financial links of the economies under the recent financial strain can be provided. Such fully fledged work can be proved fruitful for the market participants, along with the interested policymakers.

As it is easily understood, that the complexity of the econometric computations, together with the number of cases taken into account, make it almost impossible to present the results with tabulated estimated parameters and relevant statistics. In order to make things more comprehensible, we present the results using a graphical representation of them. Tables 4.13 and 4.14 summarize the relevant parameters of interest, as in the previous section. The difference is the usage of coloured cubes, which represent the statistically significant coefficients. For the sake of consistency and for emphasizing the importance of the spillover effects, we use three different colours (depending on the level of statistical significance). The red cubes are indicative of meaningful spillovers, for which the model provides evidence of strong significance (1%). Then, the orange ones are those with a milder effect (significant at 5% level), while the light grey ones are those that have a smaller statistical power (10% level). As in the previous case, the direction of the spillover effects is from the rows towards the columns of these tables.

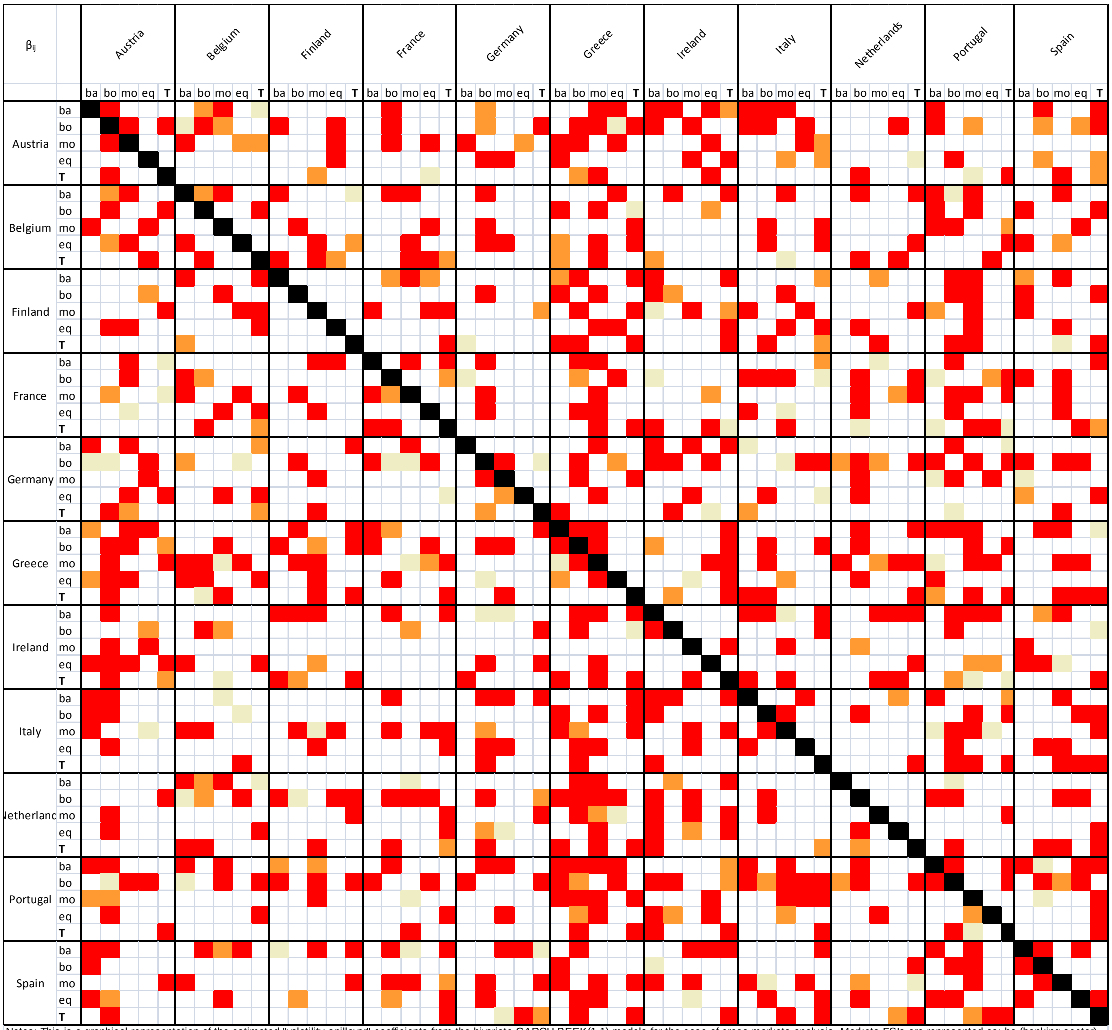
Table 4.13 summarizes the cross-markets case of financial stress spillovers, for the surprises effects from the Euro Area markets. It is obvious the large number of news leakages, although, they are not as many as in the following table that presents the volatility spillover persistence. In the case of α_{ij} parameters, we detect the importance of banking sector and bond markets, as the sectors from which most of the cross-innovations are sourced from. Especially for the case of PIIGS, the banking sector is the market with the greatest importance, based on the above terms. The same holds for the case of Belgium, from the group of the more robust Euro Area economies. On the country financial stress level (as measured by the total aggregate index), we detect an intensive transmission of news surprises from Ireland and Greece, predominantly. Also, the Italian index contributes significantly here. This outcome is in accordance with the priors of the Eurozone financial conditions and the evolution of the relevant crisis, since all of these countries were at the epicenter of the debate between economists, market participants and politicians, regarding their potential contribution to the aggravation of the union's financial instability. These countries affect, in a certain degree, the bond markets' conditions, for both core and peripheral economies of our sample. On top of that, the money markets are also affected by Greece and Ireland, emphasizing the important role of liquidity and interbank funding strains in the current crisis. Another interesting finding is the fact that Greece is also a news shocks receiver, especially for the case of bond and money markets. This tight link of all countries and markets within the Euro Area is sensible, given the existence of a common monetary policy maker, the formation of markets' expectations from the ECB decisions and, also, the commonality of the unconventional monetary policies followed by the union members. Again, as in the case of single markets analysis in the previous section, some countries are less responsive to cross-innovations, such as Germany, Finland and France. Spain is also rather neutral, in this respect. Portuguese news effects are primarily spill over to Greece and, secondarily, to Italy. In line with this, we also pinpoint the bidirectional banking spillovers from this peripheral economy to most of the other markets (with the exception of Finland, France and Spain.

Table 13: BEKK-MGARCH Model for α_{ij}: Cross-Markets Case



Notes: This is a graphical representation of the estimated "news effect" coefficients from the bivariate GARCH-BEEK(1,1) models for the case of cross-markets analysis. Markets FSIs are represented as: ba (banking sector), bo (bond market), mo (money market), eq (equity market) and T (country). Red colour is the strong effect (1% significance level), orange the mild effect (5% significance level) and the light grey is the marginal effect (10% significance level). The white cubes represent the lack of any statistically significant effect.

Table 14: BEKK-MGARCH Model for β_{ij}: Cross-Markets Case



Notes: This is a graphical representation of the estimated "volatility spillover" coefficients from the bivariate GARCH-BEEK(1,1) models for the case of cross-markets analysis. Markets FSIs are represented as: ba (banking sector), bo (bond market), mo (money market), eq (equity market) and T (country). Red colour is the strong effect (1% significance level), orange the mild effect (5% significance level) and the light grey is the marginal effect (10% significance level). The white cubes represent the lack of any statistically significant spillover effect.

In contrast to the previous discussion, the table representing the cross-markets volatility persistence indicates the existence of significant and multiple spillover effects. It is of great importance and interest that the GIIPS are among the major receiver of such spillovers. On the same time, a number of them (namely Portugal, Italy and Greece) are also significant contributors to the cross-volatility persistence effects. Again, this is reasonable, if we take into account the uncertainty, lack of credibility and the crisis unfolding in the past few years. Additionally, table 4.14 provides further evidence for the main drivers of these spillover channels. Again, the banking and bond markets are the most influential ones, in the case of North European economies, while the money market case is, also, of interest for the peripheral countries. In either way, especially in the latter case, this can be perceived as an indication of the crisis changing nature. It has evolved from a purely banking and liquidity meltdown to a sovereign crisis. Furthermore, the results here are supportive of the existence of markets' segregation, given the very strong ties between the Club Med countries (like Greece, Portugal, Spain and Italy) and the North European economies. Especially for the cases of periphery, the statistical significance of the estimated parameters is very strong (almost all of them significant at 1% level). Finally, again against the common wisdom, the spillover effects towards the larger European economies (i.e. Germany, Netherlands, Finland, Belgium and France) exist but are relatively limited. Overall, these findings dictate the necessity for the implementation of custom-made policies, based on the distinctive features and economic imbalances of each economy or groups of economies. Nevertheless, the lack of unanimity in the relevant economic research, regarding the major propagators of financial stress transmission, indicates the need for further analysis and investigation in this field of research.

5. Concluding Remarks

Our aspiration for this paper is the Eurozone crisis that is fully fledged and prevalent to the economic profession debates during the last four years. On its peak, this crisis rendered the European economy under severe strains, while a prolonged recessionary period is its reflection to the real economy. Additionally, both governments and market participants were alerted for the eventuality of crisis transmission from the most vulnerable economies of the EMU to the rest of them. It is not by chance that the economic research interest soon turned towards the quest of empirical verification of such conditions. Lately, there is a growing production of pieces of research focusing on the examination of contagion among some of the major protagonists of the Euro crisis.

Our work aims to extend the relevant literature in several ways. First of all, our interest is to study the crisis to its fully diverse nature. That is, we do not limit our study only to the sovereign risk or the banking instability issues, as most of the research have done until now. Instead, we try to encapsulate the necessary information into a number of metrics that are able to provide clear cut insights to the crisis and its constituents. In order to do it, we employ the so-called financial stress indices. These are aggregate indicators, representing the level of systemic risk in each one of the markets we analyze. These are, the banking sector, the money market, the equity and bond markets, while we also provide an index for each national economy. The next important extension is the adoption of a multivariate GARCH framework for the empirical investigation of potential spillover effects among the aforementioned markets. To the best of our knowledge, it is the first time that such a modeling approach is used in conjunction to such successful systemic risk indicators. In our view, it is an excellent combination, given the very nature of the financial stress indexes and the ability of the MGARCH type of models to estimate time-varying co-variances. Another important step further in our research is the simultaneous assessment of potential volatility spillover channels between and within the previously mentioned markets and countries. Finally, our dataset covers the Eurozone crisis until very recent, since our sample stops at September 2013.

In brief, our results shed new light into the Euro Area's volatility transmission. There is strong evidence that there exist multiple links between the EMU markets. Depending on the sector discussed, the main receivers and transmitters of the spillover effects vary. For instance, it is true that the GIIPS countries significantly contribute to the cross-volatility, especially in the case of the country level analysis and the banking and bond markets. On the same time, the core is also an important channel of variance volatility transmission, both within the North European countries, but also towards the peripheral ones. Such a, somewhat surprising, result for part of the profession is in accordance to latest findings (Antonakakis and Vergos, 2013, Kohonen, 2012). Moreover, we find strong bidirectional effects between countries of the same group (for instance between Germany, Belgium and France as well as between Greece, Portugal and Spain). Equity market, on its single market analysis, does not provide convincing evidence as a sector where volatility spillovers take place. On the contrary, the banking and bond markets are, in both the "within" and the "between" econometric investigation, found to be the most volatile and risky from the markets scrutinized. Also, the case of money market is interesting. In the cross-markets case, it proves itself as a major player in the volatility spillovers. Given the representation of the interbank funding conditions, along with the relative volatility measures and the yield curve, this sector manifests itself as one which central bankers should pay special attention to. Once more, the aforementioned facts underline the direction towards macroprudential policies should aim to.

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