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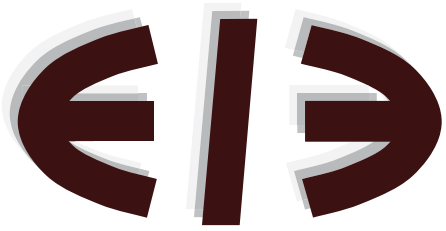

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Causes and timing of the European debt crisis: An econometric evaluation.

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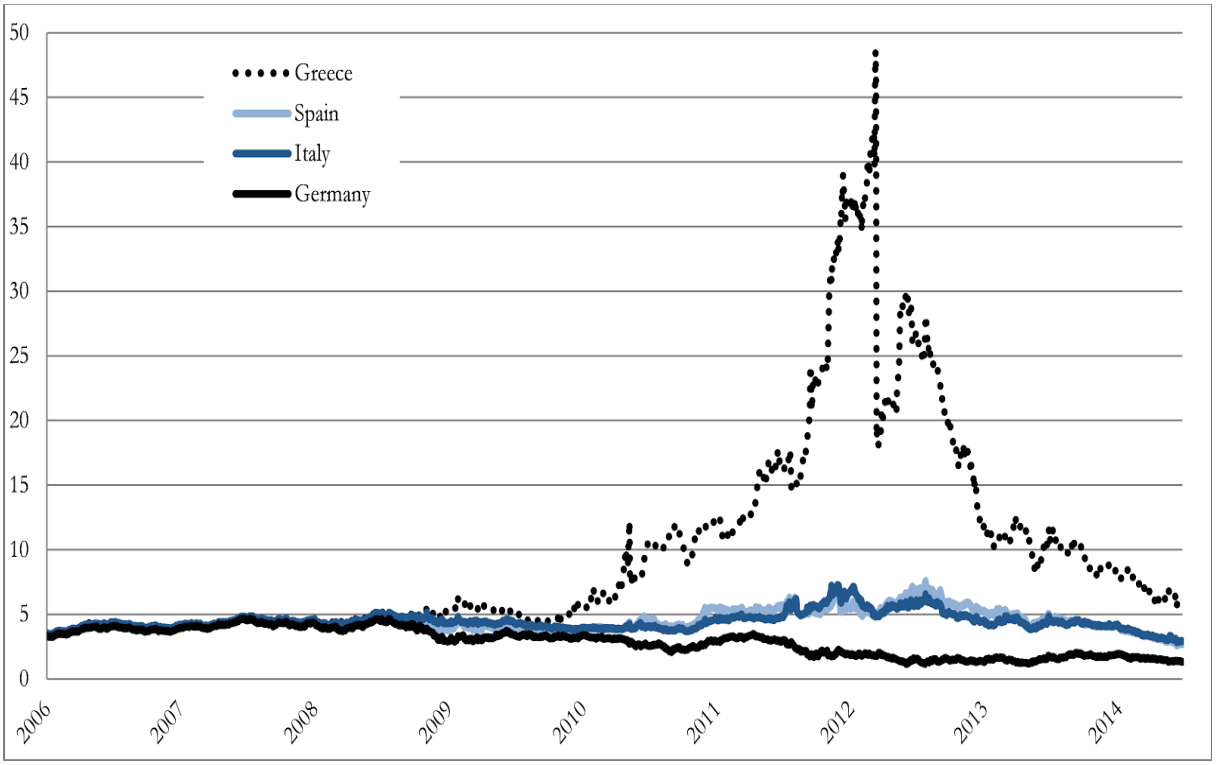
Abstract
According to the literature, two main factors sparked the European debt crisis: (1) macroeconomic imbalances originated by national governments and (2) institutional design flaws leading to feeble response by European authorities; still, economists disagree on the factors' strength. Using Bai and Perron's technique, we contribute to the debate by identifying break dates in Greece, Italy and Spain daily values of 10-year public bonds' interest rates and link them to key political and institutional events. Also, employing GARCH and EGARCH models, we investigate how interest rates spreads' volatility reacted to crucial and long-lasting events. Our results uncover the following facts about the crisis: a) it began in May 2010, while the first aid programme for Greece was approved; b) worsened after summer 2011, as the European authorities hastened restructuring the Greek sovereign debt; c) improved only during summer 2012, when the ECB Governing Council approved a programme for the purchase of sovereign bonds. On the whole, our results point at institutional failures as the main cause of the European debt crisis.

Keywords European debt crisis · Interest rates · Public debt · Event study
JEL Classification G12 · G14 · H63

1. Introduction

Economists debating the European debt crisis tend to agree that interest rates respond to market information and adjust to key news. They would allow that studying how the rates change alongside major economic and political events can hint at the proximate causes of the crisis.

Figure 01 – Secondary market yields of government bonds with maturity closed to ten years (2006 – 2014, June)
(percentages per annum, daily values)



Source: Our elaborations on Trading Economics dataset

The aim of this paper is to contribute to this debate by examining the daily values of 10-year government bonds' interest rates of Greece, Italy and Spain, which have undergone dramatic changes in recent years due to speculative attacks (Figure 1). We present an econometric analysis based on the Bai and Perron (1998) method to identify break dates in the time series of the sovereign bonds' interest rates. Moreover, to take into account that the events of the period considered may have produced long-lasting effects and changes in the volatility of bond yields, we also investigate the variability of the spread between the 10-year German Bund by estimating a GARCH and an EGARCH model. We then use the econometric results obtained to propose an interpretation of the causes of the European debt crisis. Break dates and changes in yields' volatility are so employed to identify some important triggering events. The results will support an interpretation of the European debt crisis that considers as main cause the defects of the institutional organization of the monetary union.

At the cost of some simplification one can say that when economists discuss the causes of financial crises, they tend to identify two main causes: macroeconomic imbalances (MIs) and institutional failures (IFs). The debate's sides concede that both motives play some role but they question their relative strengths.[1] The participants in the dispute on the causes of the European debt crisis too acknowledge that both macroeconomic imbalances and the flaws in the institutional organization have affected the movements of the interest rates. Yet, they interpret the influence of these elements in different ways and consequently propose alternative policy solutions. The diversity of positions often reflects dissimilar degrees of confidence in the capacity of the price mechanism to restore efficient equilibrium conditions and in the ability of financial markets to correctly evaluate the risk originated by macroeconomic imbalances.

A first interpretation of the causes of the European debt crisis attributes the main role to the mistaken choices of the governments of the countries under attack. Although it acknowledges the existence of nontrivial differences among their fundamentals (Sinn and Wollmershäuser 2011, 2012), this interpretation maintains that the crisis hit countries where labour unions are strong and governments and central banks are weak. The high wage rates imposed by the unions raised prices and generated deficits in the current account of the balance of payments (Rother et al. 2010; Sinn and Wollmershäuser 2011, 2012). The international capital markets, unable to price the implicit risks, funded these deficits before 2007, but the crisis led the markets to correct the mispricing. The interest rates paid by the countries with strong labour unions rose, heading to a stop of funds coming from abroad and to the debt crisis, which, for these authors, started in autumn 2009 when the newly elected Greek government revealed that the public deficits were higher than previously announced (Sinn and Wollmershäuser 2011, p. 19; Honkapohja 2014).[2] Mistrusting the upright behaviour of the national authorities and confiding in the working of the price mechanism, these authors propose austerity

[1] The increased frequency of financial crisis over recent decades (Laeven and Valencia 2008) has enhanced a literature on this issue, which proposes three generations of models. The "first generation models" focus on the role of macroeconomic imbalances (Salant and Henderson 1978; Krugman 1979; Flood and Garber 1984). They provide the theoretical background from which the International Monetary Fund (IMF) drew its policies for the Latin American debt crisis of the 1980s. The "second-generation models" focus on the possibility that the crises occur because the operators believe that it is going to happen because, for instance, the authorities are unable to control speculative movements (Obstfeld 1994; Kaminsky and Reinhart 1999; Goldfajn and Valdés 1997; Chang and Velasco 2000; Sarno and Taylor 2002; Buiter 2007). The events concerning the speculative attacks against the European Monetary System in 1992 and the Mexican and the Asiatic crises in 1994 and 1997 stimulated them. The "third-generation models" underline the role of news that change the views of financial operators on the quality of specific debts (Kaminsky and Schmukler 2002; Kamisky et al. 2003; Kaminsky et al. 2009; Reinhart and Rogoff 2011).

[2] Fahrolz and Freytag (2012, pp. 79-80) also refer to two subsequent dates that have negatively marked the evolution of the crisis. These are July and October 2011, when in two subsequent EU summits the rescue packages were substantially broadened to include a debt reduction, a second round of bailout loans by IMF and the EU and a release of European structural funds to assist the Greek economy.

measures, severe penalties for misaligned national behaviours and labour markets' reforms to come out of the distress.

A second interpretation considers that the flaws in the institutional organization are the major cause of the crisis. The existence of macroeconomic imbalances and of mistakes in the national policies is not denied. Yet, the crisis began when financial operators realised that the flaws in the institutional organization would have prevented the European institutions from playing the role for which they had been created, i.e. to defend the economies and the citizens from the instability of the international financial markets.

There is some diversification within the literature proposing this second interpretation related to the flaw of the institutional setting that is considered the most important. Before and after the financial crisis of 2007 this literature has identified several related flaws and some gaps and contradictions in the Treaties of the Union[3], which the European authorities have been unable to eliminate.

Among the weaknesses in the institutional organization this literature has underlined

- the obstacles set to the central bank in guaranteeing the smooth working of the transmission mechanism of monetary policy;
- the inability to guarantee a satisfactory solution to the moral hazard problem in the behaviour of the national fiscal authorities;
- the inability to deal with asymmetric tendencies within the area;
- the inability to limit the space for national conflicts in the solution of problems.

According to some authors (see De Grauwe, 2011a; 2011b; 2011c; 2012; Kopf 2011; Valiante, 2011), the European debt crisis began because the European Central Bank (ECB) failed to play the role of lender of last resort in the sovereign bond markets, a role that other central banks, like that of Japan, UK and USA, perform.[4] According to De Grauwe (2011b), this event occurred in Spring 2010. Those holding this position recognise that movements of fear and panic can drive the spreads away from the underlying fundamentals (De Grauwe, 2012; Gros 2012; De Grauwe and Ji 2014; Gerner-Beuerle et al. 2014).

For other authors (Wyplosz 2010, 2011; 2013b; Buiter and Rahbari, 2012), the ECB could not act as lender of last resort in the sovereign bond markets because policy coordination had yet to be re-organised to minimise the moral hazard regarding the behaviour of the national fiscal authorities.

Von Hagen and Mundschenk (2003) also clarified that policy coordination in EMU eliminates discretion by establishing rigid fiscal rules that ignore differences among the economies. It follows a "restricted approach",

[3] Art. 105.2, which attributes to the Eurosystem the task of guaranteeing the smooth working of the transmission mechanism of monetary policy, can come in contradiction with Art. 123 that forbids the direct purchase of sovereign bonds and the bailout of national governments. Art. 125.1, which claims that euro countries cannot guarantee the sovereign debt of another member state, can contradict Art. 122.2, which states that countries threatened by severe difficulties can receive assistance by other Union members.

[4] Since they issued their government debt in dollars, Latin American countries lacked a central bank stabilising the sovereign debt markets. This deficiency made them vulnerable to changes in expectations and set in motion in the 1980s a devilish interaction between liquidity and solvency crises (Calvo 1988; Calvo et al. 2003; Eichengreen et al. 2005).

which focuses on monitoring the national authorities and uses incentives based on punishments of misaligned behaviours. This approach generates non-cooperative attitudes and should be replaced by a "broad one" that favours the involvement of the actors of the process by enhancing the common identification of interests, problems and policies and by using a system of incentives based on prizes and punishments. As had occurred in monetary policy in the 1980s, the rigid rules should be replaced by an institutional re-organization able to restore flexibility and the effective use of fiscal policy in the area (see Pisani-Ferry 2007; von Hagen, 2004; Wyplosz, 2005).

Finally, for several writers (Silbert 2010; De Grauwe 2011a; De Grauwe and Ji 2012; Buiter and Rahbari 2012; Mohl and Sondermann 2013; Panico and Purificato 2013), the faults of the coordination process and the discrepancies in the Treaties have introduced uncertainty as to the mechanisms regulating its working. Under these conditions, conflicting national interests have prevailed over those of the whole area in the solution of problems. For these authors, macroeconomic imbalances and the false declarations denounced by the newly elected Greek government raised the volatility of the interest rates. Yet, the crisis began in May 2010 when market operators realised that, owing to conflicting national interests, the European institutions would not perform the tasks for which they had been designed.

There is a large econometric literature supporting both sides of the debate on the causes of the European debt crisis. Some authors (de Haan et al. 2014; Gödl and Kleinert 2016) detect an increase in the sensitivity of financial markets to the deterioration of fundamentals. Others point out that elements like time-dependent market sentiments and herding behaviours have an important bearing on the distress (Dewachter et al., 2015; De Grauwe and Ji 2013; Beirne and Fratzscher 2013). Yet, econometric studies of the timing of the crisis are scarce and the few works dealing with this topic differ from this paper. Gómez-Puig and Sosvilla-Rivero (2014) and Tamakoshi and Hamori (2014) employ a Bai-Perron approach. The former however uses it to examine contagion effects during the crisis. The latter, although it tests the existence of structural changes, uses, unlike the present paper, monthly data, only consider Greece, and finds one break date in April 2010. Finally, Inoue et al. (2013) check the existence of one structural break in a GARCH model of the public bond interest rate of ten European countries, while in this paper we search for multiple structural changes applying the approach of Bai and Perron (1998).

The econometric exercises presented in this paper, which examines the sovereign bond markets by distinguishing two periods (June 1999–May 2009 and June 2009–June 2014), reach the following results:

- The first "break date" in the time series occurred on the 10th of May 2010, rather than in Autumn 2009, as stated by the first interpretation recalled above.
- The other break dates took place from October 2011 to August 2012.
- From June 1999 to May 2009 the movements of the interest rates of the sovereign bonds of Germany, Greece, Italy and Spain were highly synchronised.

- From June 2009 to June 2014 the close positive connection between the movements of these rates significantly weakened in size falling by a factor of two from almost perfect collinearity (0.95, p = 0.000) to a much lower level of 0.31.
- During this second period, the effects of good news on the government bonds' yields of the latter countries became more destabilising than those of bad news.

These results lend support to the second interpretation. They are consistent with the view that up to 2007 market operators solved the contradictions existing in the Treaties of the Union by assuming that, in the presence of speculative attacks, the European institutions would have chosen to defend the citizens from the instability of financial markets. They so priced the sovereign bonds in such a way to generate small spreads among their yields. The international financial crisis raised the volatility of the interest rates, but the crisis began in May 2010, when the operators realised that, owing to conflicting national interests, the European institutions were not able to perform the tasks for which they were designed. The situation worsened after summer 2011, when the European authorities, under the pressures of national interests and disregarding the warnings of the ECB, hastened to restructure the Greek sovereign debt and insisted on proposing austerity measures and severe punishments for misaligned behaviours to solve the crisis. It improved during summer 2012, when the ECB Governing Council approved an effective programme for the purchase of sovereign securities, trying to amend one of the fallacies of the institutional organization of EMU.

The paper is so organised. Section 2 and 3 present the results of the econometric exercises. Section 4 presents a chronology of the debt crisis compatible with the outcomes of the previous exercises. Section 5 concludes.

2. Econometric analysis of structural breaks in sovereign bond yields during the crisis

Assuming with the literature that changes in financial markets are the result of specific events, we present an econometric analysis of the daily time series of the interest rates of the 10-year government bonds of Greece, Italy and Spain from January 1999 to June 2014 to identify the existence of "breaks" in their parameters.

The main part of our analysis focuses on the period June 2009 - June 2014, when the major turbulences in European markets for sovereign bonds manifested themselves. The data concerning the previous period will however be used to test for the presence of a unit root in the series. This is a preliminary question for our econometric analysis because different methods to detect multiple structural breaks should be applied in the case of stationary or of time series with a unit root (Aue and Horvath, 2013), with the second analytical context being more complex than the first. Moreover, the likely presence of structural changes in time series significantly complicates the testing of a unit root. [5] Data on the period preceding the crisis offer a way to skip these complexities because the European sovereign bonds' markets were not hit by significant shocks and there is no

[5] Sudden changes in a time series could bias the test towards the acceptance of the stochastic trend hypothesis even when the true data generating process is piecewise stationary (Perron, 2006).

evidence of structural change in the series of Greece, Italy and Spain from 2000 to 2007. Hence, we test for a unit root in the times series of the years 2000-2007, and then assume that the results of the test apply to the whole period. What would distinguish the two sub-periods is the presence of break points in the most recent one.

The null hypothesis of a unit root with a drift in the time series of 10-year government bond yields of Greece, Italy and Spain was tested using three methods: the Augmented Dickey-Fuller test (Dickey and Fuller, 1979); the test proposed by Elliott, Rothenberg, and Stock (1996) that generalizes the Augmented Dickey-Fuller test; the Phillips–Perron test (Phillips and Perron, 1988). All these testing procedures gave the same outcome: we cannot reject the hypothesis that the time series of the three countries contain a unit root. The same result was obtained by using the test proposed by Kwiatkowski et al. (1992). Accordingly, in the following we investigate the time series of the interest rate on government bonds by assuming that it follows the autoregressive equation:

$$(1) \qquad r_t = \mu + \sum_{i=1}^{n} \delta_i r_{t-i} + \varepsilon_t, \qquad t = 1,2,\dots,T, \;\; i = 1,2,\dots,n$$

where t is a time index, n is the maximum lag, μ is a drift parameter, and ε_t is the random disturbance. The presence of a unit root in r implies the condition: $1 - \sum_{i=1}^{n} \delta_i = 0$. Hence, the data generating process (DGP) of r_t is characterized by a deterministic trend, with slope coefficient equal to μ, and a stochastic trend. We obtain a more convenient equation for the econometric analysis of breaks in the DGP of r_t writing equation (1) in terms of the first difference of bond interest rates, Δr_t:

$$(2) \qquad \Delta r_t = \mu + \sum_{i=1}^{n} \beta_i \Delta r_{t-i} + \varepsilon_t,$$

where $\beta_i = -\sum_{j=i+1}^{n} \delta_i$.

We then introduce structural changes in equations (1) and (2) by assuming that the parameters μ and β_i can change because of m breaks:

$$(3) \qquad \Delta r_t = \mu_j + \sum_{i=1}^{n} \beta_{i,j} \Delta r_{t-i} + \varepsilon_t, \qquad t = T_{j-1} + 1, \dots, T_j,$$

where $j = 1,2,\dots,m+1$ denotes the regime, and the convention that $T_0 = 0$ and $T_{m+1} = T$ is used. According to equation (3) the time series of bond yields can be subject to changes of the drift parameter μ, and the passage from one regime to the next occurs gradually as implied by the autoregressive component.

This econometric model considers two fundamental questions. One is the estimation of the parameters in each regime, and the other is the estimation of the unknown break points. We apply the methodology proposed by Bai and Perron (1998; 2003) - described in the Appendix - to the daily data of the 10-year government bond yields of Greece, Italy and Spain to detect structural change in the period between the 1st of June 2009 and the

23rd of June 2014. We focus on this period because it contains some major events associated with the sovereign debt crisis in the three countries.

Table 01 – Break dates

Country	Break dates	Confidence interval, α=5%
Greece	10/05/2010	29/04/2010 – 09/06/2010
	08/11/2011	29/09/2011 – 15/12/2011
	13/02/2012	08/02/2012 – 14/02/2012
	09/03/2012	08/03/2012 – 14/03/2012
	11/05/2012	03/05/2012 – 15/05/2012
Italy	24/10/2011	10/10/2011 – 27/10/2011
	09/11/2011	08/11/2011 – 18/11/2011
	25/11/2011	04/11/2011 – 29/11/2011
	09/01/2012	02/01/2012 – 18/01/2012
	03/02/2012	27/01/2012 – 15/02/2012
	30/07/2012	09/05/2012 – 04/12/2012
Spain	14/11/2011	08/11/2011 – 17/11/2011
	02/12/2011	25/11/2011 – 08/12/2011
	15/06/2012	13/06/2012 – 25/06/2012
	04/07/2012	28/06/2012 – 06/07/2012
	02/08/2012	20/07/2012 – 20/08/2012

Source: Our elaborations on Trading Economics dataset

The main interest of our study is to identify the changes of the drift parameter μ that summarizes the deterministic component of the dynamics of the interest rate of sovereign bond in the long run. Yet, the autoregressive component of equation (3) also transmits important information on the reaction of financial markets. For instance, the short-run dynamics of the interest rates can give some indications on how financial operators evaluate new events that change the degree of uncertainty and volatility of the markets. The point estimates and confidence intervals of break dates are shown in Table 1, while Table 2 presents the parameters of model (3). A glance to the figures displayed in Table 2 reveals some significant differences in the way the three countries were affected by financial market speculation that we resume in the following findings.

Finding 2.1. *Speculative attacks to Greek public bonds.*

During the examined period Greek bonds were first affected by a sequence of negative events that increased the trend of r_t; then by other events that in May 2012 changed the direction of this trend downwards. These shocks were accompanied by important changes in the short run dynamics of the interest rate.

Table 02 – Parameter estimates of the model (3) for every detected regime.

Country	Regime (Start date – End date)	μ	β_1	β_2	β_3	β_4
Greece	01/06/2009 – 09/05/2010	0.028	-0.066	0.127	-1.015	
		(1.469)	(-1.152)	(1.119)	(-8.053)	
	10/05/2010 – 07/11/2011	0.043	0.411	-0.083	-0.080	
		(2.485)	(8.269)	(-1.915)	(-1.981)	
	08/11/2011 – 10 /02/2012	0.120	-0.182	-0.036	0.080	
		(1.535)	(-1.529)	(-0.303)	(0.680)	
	13/02/2012 – 08/03/2012	1.771	-0.566	-1.613	-3.427	
		(2.194)	(-1.394)	(-4.052)	(-7.812)	
	09/03/2012 – 10/5/2012	0.208	-0.012	0.041	0.009	
		(2.356)	(-0.558)	(1.928)	(0.448)	
	11/05/2012 – 23/06/2014	-0.029	0.409	-0.129	-0.016	
		(-2.822)	(10.843)	(-3.183)	(-0.431)	
	Breusch–Godfrey test: 0.012		P-value: 0.913			
Italy	01/06/2009 – 23/10/2011	0.002	0.216	-0.128		
		(0.821)	(5.430)	(-3.211)		
	24/10/2011 – 08/11/2011	0.080	-0.626	0.73		
		(1.342)	(-2.206)	(2.085)		
	09/11/2011 – 24/11/2011	0.044	0.373	-0.618		
		(1.479)	(2.826)	(-5.437)		
	25/11/2011 – 08/01/2012	-0.003	0.164	0.205		
		(-0.091)	(0.937)	(1.192)		
	09/01/2012 – 02/02/2012	-0.145	-0.164	-0.699		
		(-5.043)	(-0.979)	(-4.043)		
	03/02/2012 – 29/07/2012	0.003	0.264	-0.179		
		(0.327)	(3.021)	(-2.051)		
	30/07/2012 – 23/06/2014	-0.007	-0.055	0.007		
		(-2.149)	(-1.220)	(0.146)		
	Breusch–Godfrey test: 0.521		P-value: 0.470			
Spain	01/06/2009 – 13/11/2011	0.003	0.279	-0.124	-0.040	-0.006
		(1.039)	(6.983)	(-2.986)	(-0.960)	(-0.148)
	14/11/2011 – 01/12/2011	-0.106	0.029	0.685	0.371	0.205
		(-3.162)	(0.142)	(3.444)	(1.378)	(0.752)
	02/12/2011 – 14/06/2012	0.013	0.192	-0.002	-0.105	-0.080
		(1.411)	(2.372)	(-0.021)	(-1.303)	(-1.034)
	15/06/2012 – 03/07/2012	-0.074	-0.154	-0.162	-0.387	-0.851
		(-3.411)	(-1.191)	(-1.433)	(-3.627)	(-6.828)
	04/07/2012 – 01/08/2012	0.003	0.559	0.228	-0.757	0.216
		(0.106)	(2.863)	(1.092)	(-3.361)	(1.003)
	02/08/2012 – 23/06/2014	-0.008	0.271	-0.155	0.135	-0.173
		(-2.560)	(6.093)	(-3.456)	(3.021)	(-3.975)
	Breusch–Godfrey test: 0.286			P-value: 0.593		

Notes: *t* statistics are in parentheses.
Source: Our elaborations on Trading Economics dataset.

Finding 2.2. *Uncertainty in the market of Italian public bonds.*

The different regimes showing in the series of the Italian bond rate were generated by events changing both the drift and the parameters of short run dynamics. Indeed, in five regimes the parameter μ is not statistically different from zero, while in two regimes the estimate of μ is significantly negative. In six of the seven regimes our estimates detect substantial changes in the parameters of the short run dynamics. One may deem that, during periods in which operators were expressing doubts about the credibility of governments' actions, some negative events increased the uncertainty on the sustainability of the Italian public debt. The opposite, which seems more in line with the Italian macroeconomics fundamentals, may have occurred when the trend reverted towards lower interest rates.

Finding 2.3. *Quick response to financial crisis in Spain.*

Interestingly, the case of Spain seems different from the other two countries. Inspection of the time series of the Spanish public bonds' yields (see Figure 1) shows the existence of one sudden increase in the interest rate at the end of 2010 (in November the rate increases from 4.07 to 5.52). The approach we use in our estimates does not allow us to perceive this phenomenon, which consists of a change in the level of the series. In November 2011 the drift parameter μ of the Spanish bond rate becomes negative. Subsequently, in our estimates the deterministic trend takes nil or negative values. The different regimes of the Spanish bond yields are also characterized by important changes in the short run dynamics. Favourable events, rather than adverse ones, are thus identified by our analysis of the time series of Spanish sovereign bonds.

3. Volatility in sovereign bonds' yields during the crisis

During the period considered in this work, while the time series of sovereign bonds' yields are non-stationary, with volatility happening in clusters and extreme spikes for Greek, Italian, and Spanish rates, the series describing the German rates have mostly experienced a downward trend (Figures 01 and 02). Changing interest rates reflect how markets move among investment opportunities and sharp increases in uncertainty may lead operators to concentrate their investment on a smaller set of assets that are considered "safe". This may contribute to spread financial panic and crises. Retrospectively, one can relate periods of prolonged or extreme volatility to policy measures and to other events that may help interpreting turning points.

In this section we employ several GARCH models to investigate the volatility of 10-year spreads on Greek, Italian, and Spanish bonds using the German bonds as baseline. German public bonds are generally considered a valid benchmark for the evaluation of the performance of other European public bonds of the same maturity since the former are perceived as virtually risk free. Before the financial crisis there was a close and stable relationship between the rates of these bonds. After then, things have changed.

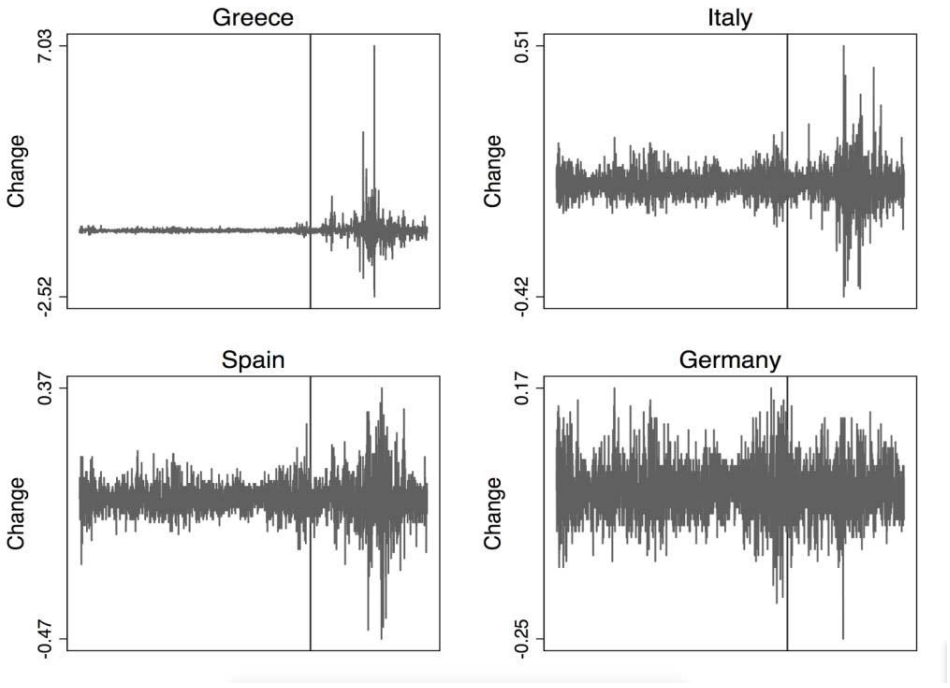
To investigate some issues related to the nature of the interest rates of the European public bonds we estimate a model of the type:

(4) $\Delta r_t^i = \beta_0 + \beta_1 \Delta r_t^G + u_t, \qquad$ with $u_t \sim N(0, \sigma_t)$

$\sigma_t = \alpha_0 + \alpha_1 u_{t-1}^2 + \alpha_2 \sigma_{t-1}^2$

where r_t is the interest rate for the i-*th* country (Greece, Italy, or Spain), r_t^G is the German interest rate and u_t is a random error with a time-varying variance σ_t which follows a GARCH(1,1) process displayed in the second line of the equation. The model is estimated separately over two time windows: (1) June 1999–May 2009 and (2) June 2009–June 2014.

Figure 02 – Interest rate changes



Source: Our elaborations on Trading Economics dataset

While the estimates over the second time window reflect an unprecedented and largely unexpected financial turmoil, the numbers for the first period reflect the long period of financial stability that preceded the international financial crisis of 2007-2008, with parameters likely representing the long-run relations between the variables of interest. The relevant estimates are reported in the following Table 03 and several interesting findings emerge from them.

Finding 3.1. *During the first period the Greek, Italian and Spanish interest rates followed closely the German ones.*

The parameter β_1 is close to 1 during the period June 1999–May 2009: this translated into an almost perfect one-to-one change in European rates. According to investors, there was a high degree of substitution among different sovereign debts.

Table 03 – GARCH(1,1) model
(Estimation in differences before and after June 2009)

	Greece		Italy		Spain	
	Before	**After**	**Before**	**After**	**Before**	**After**
β_1	0.951	0.300	0.941	0.274	0.967	0.307
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
β_0	0.000	-0.003	0.000	-0.002	0.000	-0.003
	(0.977)	(0.177)	(0.731)	(0.136)	(0.954)	(0.056)
α_1	0.123	0.839	0.193	0.158	0.243	0.145
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α_2	0.884	0.589	0.789	0.861	0.738	0.867
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α_0	0.000	0.001	0.000	0.000	0.000	0.000
	(0.000)	(0.004)	(0.000)	(0.001)	(0.000)	(0.000)

Note: The dependent variable is the daily change in the level of 10y public bond for each country considered, before and after June 2009; p–values in brackets.
Source: Our elaborations on Trading Economics dataset.

Finding 3.2. *The crisis disrupted the close link between the Greek, Italian, Spanish and German interest rates.*

During the second period, the linear dependence between the rates dropped by two thirds on average. Other European rates still depended positively on the German ones, but the link was significantly weakened in size.

Finding 3.3. *During the second period the volatility of Greek bonds increased its sensitivity to unexpected shocks.*

The parameter α_1, which reflects how σ_t responds to innovations u_{t-1}^2, increased from 0.123 to 0.839: the financial crisis seemed to make Greek bonds extremely sensitive to orthogonal shocks; correspondingly, the inertial factor α_2 decreases its size from 0.884 to 0.589. These two facts signal an increased unpredictability of changes in Greek bond rates.

Finding 3.4. *During the second period the volatility of Italian bonds did not change substantially.*

Italian bonds slightly decreased their sensitivity to orthogonal shocks (from 0.193 to 0.158), with this change partly compensated by an increase in α_2 (from 0.789 to 0.861).

Finding 3.5. *Spanish bonds decreased their sensitivity to innovations while increasing their dependence on past values.*

The GARCH(1,1) model shows that the unpredictability of Spanish bonds diminished after June 2009.

Table 04 – Nelson's EGARCH model
(Estimation in differences before and after June 2009)

	Greece		Italy		Spain	
	Before	**After**	**Before**	**After**	**Before**	**After**
β_1	0.949	0.439	0.941	0.265	0.964	0.266
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
β_0	-0.000	0.000	-0.000	0.001	0.000	-0.001
	(0.037)	(1.000)	(0.150)	(0.423)	(0.148)	(0.474)
α_1	-0.038	0.139	-0.038	0.111	0.016	0.092
	(0.000)	(0.000)	(0.000)	(0.000)	(0.010)	(0.000)
α_2	0.215	0.697	0.275	0.185	0.220	0.180
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α_3	0.986	0.953	0.953	0.989	0.964	0.990
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α_0	-0.078	-0.031	-0.348	-0.045	-0.272	-0.043
	(0.000)	(0.012)	(0.000)	(0.000)	(0.000)	(0.000)

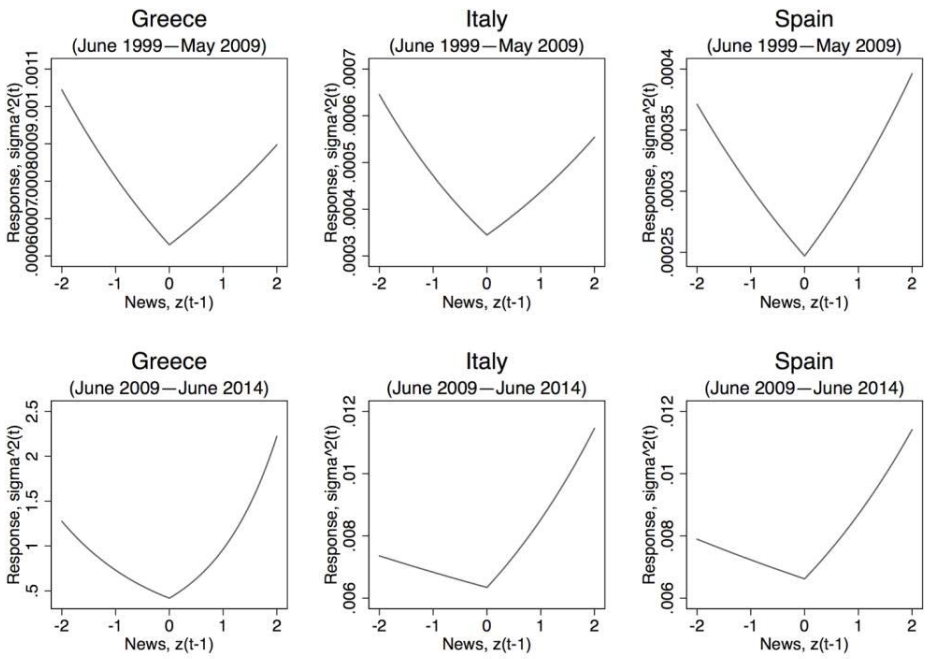
Note: The dependent variable is the daily change in the level of 10y public bond for each country considered, before and after June 2009; p–values in parentheses.
Source: Our elaborations on Trading Economics dataset.

Whereas the GARCH model assumes that good and bad news (unexpected shocks) have the same effect on variance, it is possible to model the two kinds of shocks as having potentially different impacts. This is performed by using a Nelson (1991)'s exponential GARCH (EGARCH) model of the type:

(5)
$$\Delta r_t^i = \beta_0 + \beta_1 \Delta r_t^G + \varepsilon_t,$$
$$z_t = \varepsilon_t / \sigma_t,$$
$$\ln \sigma_t^2 = \alpha_0 + \alpha_1 z_{t-1} + \alpha_2 \left(|z_{t-1}| - \sqrt{2/\pi} \right) + \alpha_3 \ln \sigma_{t-1}^2$$

The error term now is modelled according to equation (5), a stochastic process which includes the term $\alpha_1 z_{t-1}$: when the estimated value for this parameter is not zero, shocks have asymmetric effects; more specifically, when $\alpha_1 > 0$, positive shocks (good news) generate more volatility than negative shocks (bad news). The overall marginal impact of news on volatility is obtained by summing α_1 to α_2. The estimated results for the EGARCH(1,1) model are reported in Table 04. An alternative assessment of how innovations change volatility can also be obtained using the news impact curves, a graphical device for the conditional variance of interest rates on the vertical axis as a function of unexpected shocks to the same variables on the horizontal axis: when a shock equals zero on the centre of the x-axis, the corresponding y-axis value displays the unconditional variance, whereas, when a shock differs from zero, the corresponding values on the vertical axis display the whole conditional variance; finally, as the right arm of the curve significantly differs from the left one, we have evidence that positive and negative shocks affect volatility asymmetrically. The news impact curves for the interest rates under study are reported in Figure 03.

Figure 03 – News functions



Source: Our elaborations on Trading Economics dataset

As previously found for the simpler GARCH(1,1) model, the EGARCH(1,1) results confirm that the interest rates of Greece, Italy and Spain sensibly decreased their dependence from the German rate during the period June 2009 - June 2014.

Finding 3.6. *During the first period considered in this analysis (*June 1999–May 2009*) the effects of shocks or news are symmetric.*

The estimated values of α_1 are almost negligible for the period June 1999–May 2009. As displayed in Figure 03, the news impact curves are symmetric around zero: good (positive) and bad (negative) news have essentially the same effect on volatility. While Greece and Italy displayed a very weak asymmetry toward bad news ($\alpha_1 = -0.038$), Spain's rates were weakly more destabilized by good news ($\alpha_1 = -0.016$) than bad news.

Finding 3.7. *During the second period the effects of news became asymmetric, with good news being more destabilizing than bad news.*

The European debt crisis increases the responsiveness of variance to positive news: in all cases, the estimated values for α_1 are of substantive size (ranging from 0.092 to 0.139). Greece testifies this tendency with the highest values. The graphical depiction of the news impact curves shows clearly this change from almost complete symmetry to marked asymmetry in the responsiveness of variability to news.

Finding 3.8. *Greece experienced a substantial increase in the responsiveness to the news, while Italy and Spain's responsiveness remained substantially unchanged.*

Summing the terms α_1 and α_2 of each country and comparing the values of the two periods considered by the analysis, we find that Greece experienced the largest increase (from 0.177 to 0.836), while Italy and Spain followed similar trends: Italy moved from 0.237 to 0.296, while Spain moved from 0.236 to 0.272. The evidence indicates that the events of the second period had disruptive effects on the volatility of the Greek interest rates, whereas Italy and Spain, which were exposed to the same events as Greece, did not substantially change the degree of volatility of their interest rates during the same period.

Finally, the graphs related to the GARCH and EGARCH residuals (Appendix B) show their remarkable increase in some period. Key events for the evolution of the European crisis, which we will explain in more details in the next section, took place close to the peaks of these increases; nevertheless, they not always determined a regime-changing as those detected in the previous section. For the moment, we confine our econometric analysis only to measure the volatility effects of these events, and, as they can extend their influence over long periods, we introduce the following indicator to translate our results based on daily observations into a measure for changes in volatility over periods of twenty days after the event of interest:

$$E = \frac{Var - E(Var)}{E(Var)} = \frac{Var}{E(Var)} - 1 \quad (6)$$

where the numerator is the cumulated error of prediction in a given period of twenty days and the denominator is the cumulated expected variance in the same period.

This number provides an easily interpretable metric for the error of prediction express as a percentage. The value of the indicator E will be closer to zero (E≈0), the better the model predicts volatility. The opposite holds if the value of E in absolute terms is distant from zero. What's more, sudden increases in the absolute values of E indicate that some unexpected events significantly impacted on volatility, which calls for an explanation in terms of relevant news. The following Table 05 gives an account of the dating of some significant changes in the volatility of the time series.

We will use this metric in the next sections to describe the impact of news and events that have proved relevant for the evolution of the debt crisis.

Table 05 – Error in Predicted variance

	Date	Greece	Spain	Italy
Staff agreement on the first adjustment programme for Greece	02/05/2010	22,8	435,7	649,5
Formal approval of the first adjustment programme for Greece	09/05/2010	-24,2	-4,9	56,9
Announcement by the ECB of the Securities Market Programme	10/05/2010	325,7	699,7	698,1
Staff agreement on the adjustment programme for Ireland	28/11/2010	132,1	128,1	226,0
Formal approval of the adjustment programme for Ireland	07/12/2010	670,1	16,9	158,2
Staff agreement on the adjustment programme for Portugal	03/05/2011	255,1	186,2	342,7
Formal approval of the adjustment programme for Portugal	17/05/2011	-11,0	-135,5	-11,8
Support by the European institutions to a partial default for Greece	21/07/2011	179,6	450,9	506,1
New restrictive measures requested by EC/ECB/IMF to Greece	02/09/2011	44,9	-217,1	-375,5
Approval of a new round of austerity measures in Greece	12/02/2012	-33,8	-155,0	-150,1
Formal agreement on the Private Sector Involvement	09/03/2012	-3,8	384,5	298,9
Speech of Mario Draghi at the Global Investment Conference	26/07/2012	-24,2	-4,9	56,9

Note — The figures are the ratio between the cumulated error in predicted variance of the GARCH model over the twenty days following a given date and the predicted variance.
Source: Our elaborations on Trading Economics dataset

4. A chronology to interpret the evolution of the sovereign debt markets

4.1. Macroeconomic fundamentals and the evolution of the spreads before the debt crisis

The analysis of macroeconomic fundamentals shows the existence of large differences among the countries hit by speculative attacks. Before 2007 the average annual growth rates of Ireland, Greece and Spain were among the highest in the Eurozone; the Italian and Portuguese ones were among the lowest. Ireland enjoyed

persistent surpluses in the current account of the balance of payments; Italy showed surpluses and deficits and Greece and Spain persistent deficits. As to fiscal behaviour, the European authorities and some literature celebrated Ireland and Spain as "virtuous countries". On the contrary, Greece persistently exceeded the 3% limit on the current deficit to GDP ratio set by the Stability and Growth Pact (SGP), even if its government debt to GDP ratio did not increase owing to the rise in the denominator. From 2005, when the European authorities reformed the SGP, Greece increased the deficit to GDP ratios and began to pass false information on it to the authorities. Its government debt to GDP ratio started to rise.

In spite of the differences in the fundamentals, the start of EMU generated convergence and correlated movements among the interest rates on 10-year government bonds (Section 3: Finding 3.1). The spreads shrunk and stabilised, indicating that financial operators were confiding that the European authorities would have resolved the gaps existing in the Treaties of the Union by giving priority to the task for which they had been created, i.e. defending the citizens from the instability of financial markets.

After the collapse of Lehman Brothers, financial operators selected the German government bonds as a safe form of investment. The interest rates on 10-year government bonds began to undergo diverging movements, which strengthened the economic and political position of Germany within EMU. From September 2008 the interest spreads on 10-year sovereign bonds underwent an upward movement, which became downward in March 2009 (Figure 01).[6] Another upward movement began in October 2009, when a centre-left coalition took power in Greece and disclosed the accounting tricks of the previous government. This event raised again the spreads,[7] thus reinforcing the tendency of interest rates to diverge, as shown by our econometric analysis (Section 3: Finding 3.2). Yet, it did not change, as the analysis presented in the Section 2 points out, the drift parameter of the interest rates' time series. The first break date in the series shows up on 10 May 2010 (Table 02 and 03). At this date the drift parameter increases - from 0.028 to 0.043 - and one may resolve that it was around that date that the debt crisis began because financial operators changed view on the ability of the authorities to control the speculative movements in the sovereign bonds' markets.

4.2. The start of the European debt crisis

The previous statement argues against the interpretation in terms of macroeconomic imbalances (MIs) and in favour of that in terms of institutional failures (IFs). It makes a case for setting the start of the European debt crisis at the date primarily indicated by the latter interpretation, rather than that proposed by the former. To further appraise the previous conclusion, let's consider the events occurred during the second part of 2009 and the first months of 2010 in details.

[6] The spread between the Greek and German rates moved from a monthly average of 0.79 in September 2008 to 2.85 in March 2009. Then, it fell to 1.21 in August 2009.
[7] The spread between the Greek and German rates moved from a monthly average of 1.36 in October 2009 to 3.14 in March 2010.

In the second half of 2009 the European authorities thought it was time to abandon the fiscal stimuli introduced in December 2008 to counteract the recession and to deal with the crisis by adopting restrictive policies.[8] The change was related to the escalating fiscal imbalances and to the improving economic situation in some countries in the second part of 2009. This decision can be seen as an example of the inability of EMU institutional organization to cope with asymmetric tendencies within the area. Economic activity in Spain was still depressed and the change in fiscal policy amplified the distress of the banking system and collided with the interventions of the national government to restructure it.

The tendency to return to restrictive fiscal policy built up in October 2009, when the newly elected Greek government revealed that the previous one had concealed the true dimension of the fiscal deficits. The unearthing of false declarations and the drive towards restrictive fiscal policies caused the reaction of the agencies that lowered the rating of the sovereign debts of Greece on the 8th and 22nd of December 2009.

In February 2010 the ECOFIN called on Greece for a detailed report on the measures to be introduced to reduce the deficit and approved the content of the report during the meeting held on March 15-16. In spite of that, by the end of March the interest rate on the 10-year sovereign bonds started to rise. On April 11 the Eurogroup recommended the introduction of a consolidation plan and of an extraordinary mechanism for financial support. Yet, the delays and the lack of support of the German authorities, engaged in an electoral process in Renania-Westfalia[9], led to a further rise in the interest rates on the Greek sovereign bonds, which increased from the 6.7% on the 11nd of April to 8.8% on the 22nd, forcing the Greek government to ask for a rescue plan on the 23rd of April. The request was unattended until May 2, when the Eurogroup proposed that the other members of the Union approved the proposal of the concession of bilateral loans to Greece under the conditions set by an agreed consolidation plan.[10] In spite of this proposal, the interest rate on the Greek 10 year government bonds kept rising, overtaking 12%. During the weekend of 7-9 May, the ECOFIN eventually held an "extraordinary" meeting to approve the creation of the European Financial Stability Fund (EFSF) and a rescue

[8] In the meeting held on the 12th of December 2008, the European Council adopted the European Economic Recovery Plan, a programme of national budgetary stimulus packages prepared by the European Commission (EC). In the fall of 2009, the ECOFIN called on the governments to abandon the stimuli to aggregate demand and start a fiscal consolidation. Moreover, on the 2nd of December of 2009, the ECOFIN approved an Excessive Deficit Procedure against eight countries of the euro area (Belgium, Germany, Holland, Austria, Italy, Portugal, Slovenia and Slovakia) and revised the recommendations and the time schedules for the countries (Greece, France, Spain and Ireland) that had already been submitted to these procedures (ECB 2009). These events signal the change in the European authorities' position on the stance of fiscal policy: the authorities returned to consider the Stability and Growth Pact essential for the achievement of fiscal equilibrium.

[9] To oppose the position of those attributing the delays of the German authorities to the elections, Schwarzer (2014, p. 7) argues that international issues play a limited role in regional polls. These issues can however be raised during local elections against the ruling party, persuading the national government that it is convenient to postpone decisions on them. The Chronology of the Greek crisis, published by the Spanish newspaper *El Pais*, points out that on April 20 the German social democratic opposition announced that it will not allow a fast approval of loans to Greece in the Bundestag: the interest rate on the Greek 10-year government bonds rose to 8.4%. On April 26 Angela Merkel stated that to receive German loans Greece had to accept a more restrictive consolidation plan than that approved by the Eurogroup on April 11. The interest rate on the Greek 10-year sovereign bonds reached 11.4%.
(See http://www.rtve.es/noticias/20150527/cronologia-crisis-grecia/329528.shtml, accessed on 03 December 2016).

[10] See http://www.consilium.europa.eu/uedocs/cmsUpload/100502-%20Eurogroup_statement.pdf., accessed on 03 December 2016.

package for Greece.[11] The results of the meeting were made public on the 9th of May after the urns in Renania-Westfalia had closed (see Panico and Purificato, 2013).

When the market opened on Monday 10 the interest rate on the Greek 10-year sovereign bonds was 12.4%. A few hours later it went down to 6.3%, but then it rose again and closed at 7.8%. The quick return of the interest rate to 6.3% suggests that the operators had been gambling on the view that the European authorities would not have reacted to the speculative attack until the elections in Renania-Westfalia had ended. The subsequent rise of the interest rate spells out that the management of the Greek problems and the poor results of the ECOFIN meeting were starting to persuade the operators that conflicting national interests were preventing the European institutions from carrying out the tasks for which they had been created, i.e. to defend the citizen from the instability of financial markets.[12]

In the face of the poor results of the ECOFIN meeting, the ECB announced, on the 10th of May, the start of the Securities Market Programme (SMP), which allowed the purchase of sovereign debt to stabilise the transmission mechanism of monetary policy disrupted by the speculative attack. The ECB formally deliberated it on the 14th of May. Some events related to the introduction of the SMP, namely the criticisms raised by the then President of the Bundesbank in a German newspaper the day after its announcement and other similar occurrences of the subsequent months (see Panico and Purificato 2013), highlighted the existence of national conflicts within the Governing bodies of the ECB. Owing to the procedures chosen, these conflicts were able to make the SMP ineffective. It intervened late, when the situation had decayed to such a point as to require emergency operations (see Panico and Purificato 2013).

This set of events supports the interpretation of the European debt crisis in terms of defects of the institutional organization. The first break date in the parameters of the time series shows up on May 10, the day after the regional elections in Renania-Westfalia and the "extraordinary" ECOFIN meeting. The delays in the decision making, the poor results of the meeting and the events related to the introduction of the SMP persuaded the operators that conflicting national interests had come to dominate the scene and were preventing the European authorities from performing the task for which they had been created.

4.3. The decision to restructure the Greek sovereign debt.

The analyses of the previous sections point out that from May 2010 to Fall 2011 there were no other breaks in the parameters of the time series of Greece, Spain and Italy. Nevertheless, the series show some significant increases in volatility in connection with specific events.

[11] The meeting was extraordinary also because the ECOFIN had never held one during a weekend owing to the high cost of its organization.

[12] For Silbert (2010), the decision of some euro-countries to provide financial assistance to Greece was dictated by the desire to favour their own banks, which had invested in Greek sovereigns and were heavily involved in the problem. Thus, the Treaties' statement that the European authorities must adopt a supranational perspective when taking decisions did not play a significant role. Christodoulakis (2016) and Schwarzer (2014) also propose this standpoint.

The ratio between the residual variance and the variance predicted by the model had gone up to 128.1 for Spain and to 226.0 for Italy when the staff level agreement on the Irish adjustment programme was reached in December 2010. It further jumped to 186.2 and 342.7 respectively for the two countries when the agreement on the Portuguese programme was reached in May 2011. These events thus affected the volatility of sovereign bonds' yields, setting off a period of anxiety and disorder in the financial markets.

In July 2011 the Dutch, French and German authorities, motivated by electoral interests[13], made declarations in favour of an agreement between the government and the credit institutions for a partial reduction of the face value of Greek sovereign bonds. The ECB had opposed this solution fearing its negative effects on the management of the Greek and other sovereign debts.[14] Nonetheless, on July 21 the European Council, composed of the Heads of State or Government of the European Union, decided to support the so-called "Private Sector Involvement" (PSI) in the second adjustment programme for Greece, in the form of a partial write down of the face value of the Greek sovereign bonds.

As the ECB had dreaded, the approval of this resolution raised uncertainty in sovereign debt markets.[15] The operators increasingly lost confidence in the idea that the authorities would have operated in such a way as to protect the solvability of government debts. The downfall of this implicit guarantee converted many economic and political events in potential sources of tensions. The volatility of the Italian and Spanish sovereign bonds' yields underwent a larger increase than that occurred when the assistance programmes for Greece, Ireland and Portugal were launched: following the statement of the European Council, the ratio between the residual and the expected variance reached 450.9 for Spain and 506.1 for Italy (Table 05). Moreover, the shares of the Italian and Spanish sovereign debts held by foreign investors fell, the interbank loans to their financial institutions shrank, and the Eurosystem had to step in through its TARGET payment system in order to replace the funding of the interbank markets, as had happened after the collapse of Lehman Brothers.[16]

Under these conditions, the deficient results achieved by the restrictive policies proposed by the European authorities and the political instability that they were generating raised further tensions in the markets. The recognition of the discrepancies between the results predicted by the Greek adjustment programme and those actually achieved, the rise of the government debt – GDP ratio of this country, and the request of a partial reduction of the face value of its sovereign bonds could be seen as evidence of the inadequacy of the policy

[13] In the Netherlands general elections were held in September. In France, in the face of the presidential elections of July 2012, President Sarkozy, with the support of the German Chancellor Merkel, was trying to make up for the loss of consensus, which the electorate was assigning to the socialist candidate Hollande, by declaring that the private sectors responsible for the crisis had to pay for the damage caused.

[14] President Trichet warned about the consequence of a partial default stating that this event would have raised the volatility of the debt markets (ECB 2011a; 2011b) .

[15] The PSI had a negative impact on banks' balance sheets (ECB, 2011c, pp. 43) and on the transmission mechanism of monetary policy (ECB 2012a, p. 59).

[16] The share of the Italian sovereign debt held by foreign investors fell from 46.2 per cent of June 2011 to 35.8 of June 2012. During the same period the Spanish one fell from 39.3 per cent to 29.2. In June 2011 the Italian TARGET balance was a positive figure equal to 6 bn. euro. In June 2012 it was -274.3. At the same dates the Spanish TARGET balance were -45.4 and -408.4 bn. euros respectively.

imposed by the European authorities.[17] The joint mission of EC/ECB/IMF, however, did not change positions and left Athens on the 2nd of September, in the context of the fifth review of the first program, requesting the introduction of new restrictive measures to stabilize the Greek economy. This event again increased the volatility of the Greek sovereign bonds' yields, with the residual variance equal to 44.9 per cent of the predicted variance (Table 5). Moreover, it led the three main rating agencies to downgrade the Italian and Spanish sovereign bonds between the 4th and the 18th of October. The first break in the parameters of the Italian interest rates' series, a negative change detected on October 24, can be placed in the context of poor growth perspectives of the austerity measures and of the related uncertainty in the political situation.

Two days later, on October 26, the ECOFIN approved a plan that increased the requirements of own capital of the major European banks[18] and ratified an agreement for the concession of the sixth instalment of the first assistance programme to Greece. Moreover, it started the negotiation of the second assistance programme, which contained new restrictive measures.

The request of new restrictive measures led the Greek Prime Minister Papandreou on the 31st of October to call for a referendum on the introduction of measures that were opposed by the large majority of the population and were causing social distress and political uncertainty.

The new breaks in the parameters of the interest rates' series detected by the analyses presented in Section 2 can be accounted for in this context of high political uncertainty. The first break, dated November 8, was a negative shock in the Greek series. It was related to the anxiety that Papandreou's request of a referendum generated among the European institutions, which made strong pressures on the Prime Minister to call it off. On the 3rd of November, acting in accordance with these pressures, Papandreou withdrew the referendum and announced that he was stepping down to let a new government to be formed. The events of the subsequent days, related to the strong reactions to Papandreou's decisions within his party, further fuelled uncertainty, which was at its highest level on the 8th and 9th of November, when the prospect of a national unity government led by Lucas Papademos, a former Vice President of the ECB, was refused. Uncertainty faded away during the next days when, conforming to the aspirations of European authorities, the national unity government became a viable solution and Papademos took power on the 11th of November.

Meanwhile, the Italian sovereign bonds' market was showing a tendency to rise. In this context the Prime Minister Berlusconi announced his intention to resign. The analysis presented above in section 2 identifies a second break date for this country in the form of a positive change on November 9. The drift parameter of the time series of the Italian bonds' yields decreased from 0.08 to 0.044.

[17] For the early years of the European debt crisis, Blanchard and Leigh (2013) find empirical evidence that stronger planned fiscal consolidation was negatively related to lower growth than expected; the natural interpretation proposed by the authors of this result is that forecasters underestimated the size of the fiscal multipliers.

[18] The plan raised some capital requirements and imposed to the banks a buffer of own resources to absorb losses coming from the holding of the sovereign debt. Moreover, it allowed the banks to ask the financial support of the EFSF in case of necessity (http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/125644.pdf.). The new measures forced five Spanish banks to acquire additional capital.

On the 12th of November, Berlusconi did resign and on the 16th the former EU commissioner Mario Monti took power as the Prime Minister of a "technical government". In this case too, the choice was conformed to the aspirations of the European authorities. The change of government further reduced the tensions in the markets and the two subsequent breaks in the Italian interest rates' series, two positive changes detected on November 25 and on the 9th of January 2012, can also be placed in this context of reduced political uncertainty.

The changes of the Greek and the Italian governments of mid-November calmed down the financial markets of these countries, but increased the tensions in the Spanish ones, where the application of the austerity measures imposed by the European authorities were progressively worsening the conditions of the economy and of the banking system, which was under reconstruction through repeated government interventions [19] In this contradictory context, which again testifies to the inability of the policy coordination process to take account of the different needs of the EMU economies, we can place the first break in the interest rates' series of this country on the 14th of November 2011: the drift parameter diminished from 0.003 to -0.106, while the coefficients of the lagged variables of the model in equation (3) rose (Table 2). These diverging trends testify to the high short-run variability of the Spanish sovereign bonds' yields.

During the subsequent days new events generated opposite bearings on the financial turmoil. On the 20th of November the centre-right party led by Mariano Rajoy won the Spanish general elections, achieving an absolute majority in the Parliament. On the 21st the Fund for Orderly Bank Restructuring (FROB, for its Spanish name "*Fondo de reestructuración ordenada bancaria*"), set up by the Spanish government to restructure and recapitalise the banking sector, had to intervene in favour a saving bank called "Caja Valencia". On the 29th the sixth instalment the financial assistance to Greece was eventually conceded calming the tensions and driving down the interest rate on the Spanish sovereign debt. The second break in the interest rates' series, detected on the 2nd of December, can be placed in this context. It was a negative shock: the drift parameter rose from -0.106 to 0.013 and marking a reversal of the trend of the Spanish sovereign bonds' interest rates.

Tensions mounted again at the beginning of 2012 on account of the progressively diminishing confidence of the international financial markets in the ability of austerity policies to solve the debt crisis. On the 13th of January, in spite of the syntonic proximity between the positions of the Italian government and of the European authorities and in spite of the strict implementation of austerity measures, Standard and Poor's again downgraded the sovereign debt of this country, together with those of Spain and other seven euro-countries. The rating agency justified its decision by explicitly referring to the inability of European institutions and policies to provide an adequate response to the crisis. In this context one can place the break date in the Italian interest rates

[19] In May 2010, following the ECOFIN's requests (fn. 8 above), the Spanish government adopted a set of consolidation measures that anticipated some diminutions of government expenditure to be taken during 2010-2011, introduced some additional reductions of expenses, and increased the VAT (ECB 2010). In September 2010 the Parliament approved a reform of the labour market and in August 2011 that of the pension system. On September 27 it reformed the Constitution in order to strengthen the sound operation of the budget of Public Administrations.

series, detected on the 3rd February, when sovereign bonds' returns went back to a non-decreasing path with the drift parameter rising to zero (0.003).

Something similar occurred in Greece where, in spite of the Parliament's approval of a new round of austerity measures demanded by European authorities on the 12th of February. The analyses of the previous sections detect a break date, in the form of an increase in the trend of the interest rates series, on the 13th of February (see Section 2: Table 2), accompanied by a decrease in the volatility of these rates, as shown by the reduction of ratio between the residual and the expected variance (Section 3: Table 05).

On the 9th of March the Greek Finance Minister announced the good news of a participation rate of 85.5 per cent in the PSI. The large majority of private lenders had officially agreed to write down 53.5% of the sovereign debt in their hands. The analyses presented in the previous sections detect another break date in the Greek interest rate series on the same day: it was a positive shock that reduced the pace at which the interest rates were rising, but did not lead to a downward trend (Section 2: Table 2). Based on the result of the PSI, the joint mission of EC/ECB/IMF presented a positive report to European institutions that decided to launch the second adjustment program for Greece.

The Greek sovereign bonds' yields finally began to decline when, in spite of the outcome of the legislative elections held on May 6, where no party reached the majority of seats in the Parliament, the major political forces declared their firm will to keep Greece within EMU. The analyses presented in the Section 2 above detect another break date for the trend of the Greek interest rates' series on May 11. Starting from that date the trend becomes negative, with the drift parameter decreasing from 0.208 to -0.029.

Following the European authorities on the new lines of the economic governance and on the requirements to be imposed on the European banks, the Spanish authorities introduced other measures to stabilise the economy.[20] The economic conditions however were not improving. On the contrary, the negative growth rates of two successive semesters and the increased deterioration of private debt, particularly in the residential housing sector, was making the support of the banking system more and more necessary.[21]

At the end of April, the provisional conclusions of IMF report on the Spanish banking system (see IMF 2012) clarified that one bank, which the report did not identify but later turned out to be "Bankia", had to strengthen its balance sheet and that the government had to increase the amount of resources devoted to the restructuring of the

[20] In November the ECOFIN approved new rules on government budget supervision, reinforcing the Stability and Growth Pact and on the 2nd of March 2012 the Council of Europe, composed of the Heads of State or Government of the EU signed the Treaty on Stability, Coordination and Governance of the EMU, known as Fiscal Compact. As to the requirements of the banking sector, following the ECOFIN's approval of a plan to recapitalise the European banks on October 26 (fn. 18 above), the Spanish authorities imposed new provisions on the banks on February 3, 2012 (RDL 2/2012), raising their needs of new funding up to 50 billion euros (ECB 2012b).

[21] To facilitate its access to the liquidity of the international markets, the Spanish banking system was restructured in 2010 through the unification of small financial institutions, whose number diminished from 45 to 18. Legislation also imposed higher capital requirements foreseeing some support of public capital. This process led to the practical disappearance of the "*Cajas de ahorro*" (Saving Banks).

sector. On May 9 the FROB nationalised "Bankia"[22] and on May 12, following the recommendations of the IMF, the government approved a Decree (RDL 18/2012), which raised the provisions on the real assets inscribed in the banks' balance sheets and imposed a further increase, amounting to 29 bn. euros, in the funds required for their recapitalisation.[23] The amount of resources that the government had to devote to the rescue of "Bankia", while respecting the constraints on the budget imposed by the European authorities, pushed the spread further up. Between the end of May and the beginning of June, Standard and Poor's and Moody's downgraded the rating of the Spanish debt and the tensions in the markets rose once again.

On the 9th of June the government expressed to the Eurogroup its intention to activate the procedures for the support of the financial sector, but not for full financial assistance.[24] This event reduced the spread and the break date in the interest rates' series, a positive change detected on the 15th of June, reflects the markets' pacification that it produced. The Spanish government formally asked the procedures for the support of the financial sector on the 25th of June.

During the same days a complex set of new events affected the movements of the interest rates in opposite directions. On the one side, Cyprus's request for full financial assistance at the end of June and the delays and the uncertainty on the approval of the European reforms of the banking union and on the German ratification of the EMS tended to raise the interest rates. On the other hand, the news coming from the ECOFIN meeting and from the Euro area Summit of 28 and 29 June on the EMU's reforms and on the possibility to use financial assistance to directly recapitalise the banks even before the EMS started to operate, induced some optimism in the markets and a tendency for the interest rates to move downwards. On the 3rd of July, however, the Finnish authorities clarified that the ECOFIN meeting and the Euro area Summit had failed to achieve an agreement on these crucial issues generating disappointment among the operators and a tendency for the interest rates to rise. Once again, news regarding the faulty functioning of the Euro area's mechanisms of policy coordination can be considered responsible of the new break date in the Spanish interest rates series, detected on the 4th of July.

4.4. The changing role of the ECB in the debt markets.

By the end of July and the beginning of August 2012, the Italian and Spanish debt crisis evolved towards a positive outcome. The two break dates detected by the analyses of the previous sections, on the 30th of July for the Italian time series and on the 2nd of August for the Spanish one, are related to the turnaround of the sovereign bonds' yields and of their volatility, which began to decline. The key events were those leading to the

[22] Bankia had been set up in 2010 to foster the integration of the "*Cajas de ahorro*". With the support of public capital it rapidly became the fourth larger Spanish financial institution. In 2011 it had access to the Stock Exchange to collect funds. The access was however based on untrue accounts, which banking supervision failed to uncover. In May 2012 it was nationalised. On that occasion the accounts regarding 2011, which showed a profit of 309 million euros, had to be corrected. They had instead to exhibit a loss of 4,369 million euros (Berges and Ontiveiros 2013, p.108).

[23] On May 25, after reformulating its accounts, Bankia asked the government to provide additional 19 bn. euros for the required recapitalisation.

[24] The Spanish government announced its intention to ask for a 100 billion euros financial support to the banking sector. It amounted to approximately 10% of the Spanish GDP.

introduction of the Outright Monetary Transactions (OMTs) by the ECB. On the 26th of July the President of the ECB, Mario Draghi, in the Global Investment Conference held in London stated that 'within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough' (ECB 2012c). This statement clarified that the President of the ECB was determined to defeat the conflicting national interests within the governing board and was going to propose new measures in order to fortify the euro. The ECB announced the guideline of these measures on the 2nd of August and approved the OMTs on the 6th of September (ECB 2012d; 2012e). To guarantee the smooth working of the transmission mechanism of monetary policy the programme allows the central bank to make unlimited purchases in the secondary markets of the bonds issued by the governments fulfilling the fiscal conditions set by the European authorities. The impact on the sovereign bonds' markets was favourable.

In response to this commitment by the ECB, the interest rates went rapidly and decidedly down. This corroborates the conclusion that during the sovereign debt crisis the increased sensitivity to news (Section 3: Finding 3.8) became markedly *asymmetric* (Section 3: Finding 3.7) especially for Greece, with positive news having a stronger impact than negative news on interest rates' volatility. This tendency did not manifest itself during the first period of persistent stability that preceded the sovereign debt crisis (Section 3: Finding 3.6). The different impact of positive news detected by the analysis concerning the second period can be interpreted by assuming that financial operators tend to consider a continuation of the euro area more likely than a breakdown.

5. Conclusions

According to the literature, the two main explanations of the European debt crisis are focused on the following factors: first, the macroeconomic imbalances due to mistaken choices of the national governments; second, the flaws in the institutional organization that implied an ineffective reaction of European authorities.

The previous analysis argues in favour of the latter underlining first that the crisis began in May 2010, when, on account of the resistance and delays of the Eurosystem to intervene to defend the smooth working of the transmission mechanism of monetary policy, the yields of Greek government bonds underwent a break-date in their time series and the Spanish and Italian bonds' yields suffered an increase in the volatility. The analysis has then pointed out a second event that further destabilised the sovereign debt markets, increasing the volatility of the Spanish and Italian sovereign bonds' yields. It occurred in July 2011, when the Euro Area leaders decided to support the voluntary involvement of the private sector in the second adjustment program for Greece, namely, the first partial default of an EMU country. The analysis has thirdly pointed out that, from October 2011 to March 2012, in Greece, Spain, and Italy the instability of the sovereign bond markets further increased in spite of the fact that new pro-European governments took office and quickly adopted severe packages of austerity measures. Fourthly the analysis has shown that in July 2012 the Spanish sovereign bonds' yields went back to rise owing to the failure of the European institutions to achieve an agreement on a set of measures consistent with the on-going restructuring of the banking system. The analysis has finally revealed that when the ECB has

eventually been able to employ an efficient programme, like the OMTs, to stabilise the sovereign bond markets, it has been able to cope with the "destructive" tendencies set in motion by speculation. This case has confirmed the result achieved by the analysis that good news generate stronger effects than bad news on the variability of the interest rates' time series.

These outcomes highlight the need to intervene on the institutional organization of the coordination process to stabilise the euro area economy and foster its growth.

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Appendix A. The Bai-Perron (BP) methodology

The framework used by Bai and Perron (1998; 2003) for the analysis of multiple structural change is based on the objective of the minimization of the sum of squared residuals of equation (3). Indeed, for each sequence of break dates we have the function of the parameters $(\mu_j, \beta_{i,j})$:

(A1) $$\sum_{l=1}^{m+1} \sum_{t=T_{l-1}+1}^{T_l} \left[\Delta r_t - \mu_j - \sum_{i=1}^{n} \beta_{i,l} \Delta r_{t-i}\right]^2$$

The minimization of the sum of squared residuals, equation (A1), provides the estimates of the parameters $(\mu_j, \beta_{i,j})$, which are function of the particular partition of the period: $\hat{\mu}(\{T_j\}), \hat{\beta}_i(\{T_j\})$. Substitution of these estimates in equation (A1) provides a function of $\{T_j\}$ that we denote $S_T(T_1, \dots, T_m)$. Among all possible partitions of the period, the optimal break points minimize the sum of squared residuals $S_T(T_1, \dots, T_m)$:

(A2) $$(\hat{T}_1, \dots, \hat{T}_m) = argmin_{T_1,\dots,T_m} S_T(T_1, \dots . T_m)$$

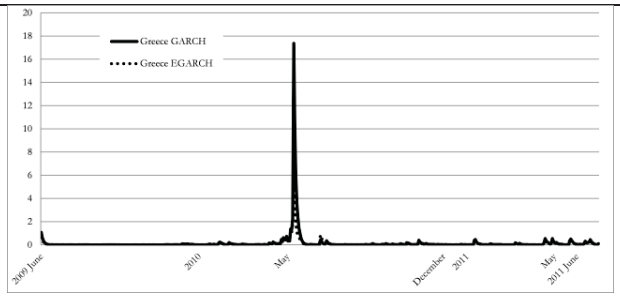
This problem is constrained by the restriction that the segments between two break points define regimes with a minimum length, h. The constraint has a technical justification (BP, 1998; 2003) but is also consistent with intuition and econometric practice. In the autoregressive model of equation (3), the BP methodology admits different distributions for the random errors across regimes but does not allow for serial correlation.[25]

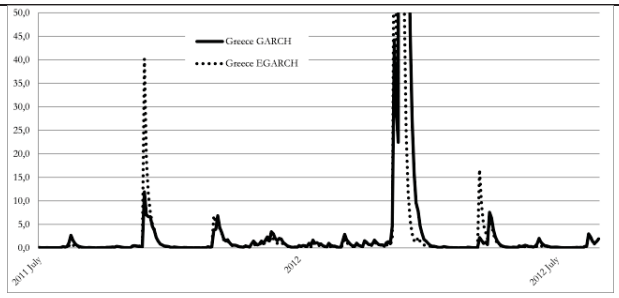
The procedure to detect multiple structural changes depends on the number of breaks, m. An important part of the contribution of Bai and Perron (1998) is the proposal of some test statistics for the determination of m. The asymptotic distributions of the tests depend on the trimming parameter that defines the minimum distance between two consecutive break dates. Bai and Perron (1998) provide asymptotic critical values via simulations assuming the minimum distance between two break points is the 5% of T, the size of the time series. In our case, $T = 1380$ and the 5% amounts to 69 observations. When we assumed this value of h, some of the estimated break dates occurred at exactly 69 days from the next, meaning that these dates were unreliable. Actually, the period under consideration is characterized by significant turbulence. Accordingly, we chose small minimum distances between consecutive break dates in our implementation of the Bai-Perron methodology. These are 12 days for Italy and Spain and 17 days for Greece. To determine the value of m we proceeded by using an approach based on the assumption made by Bai and Perron (1998) that serial correlation is absent in the error term in equation (3). Starting from low values of both the maximum number of breaks, m, and order of the autoregressive model, n, we increased m and n until we chose the model whose residuals display the absence of serial correlation, tested by the Breusch–Godfrey serial correlation LM test. If the number of breaks in the series are greater than the one we assume, the undetected change would be present in the residuals too: the latter would signal the presence of other breaks by displaying significant autocorrelation.

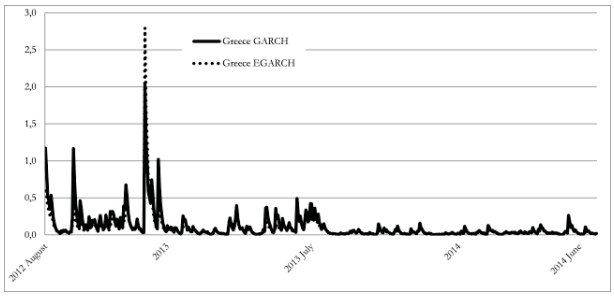
[25] The optimization problem just described implies complex computations that Bai and Perron simplify by proposing a sequential algorithm based on dynamic programming. We performed all computations using the package *strucchange*, version 1.5-0 (Zeileis et al. 2002) that is a component of the R system for statistical computing.

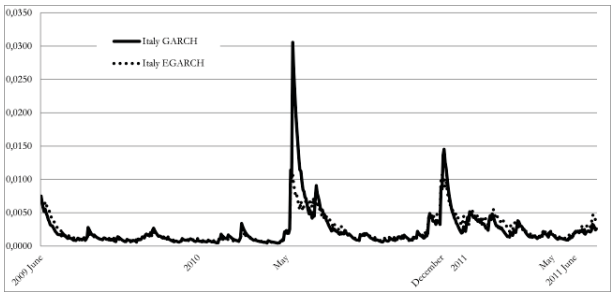
Appendix B. The GARCH and EGARCH residuals

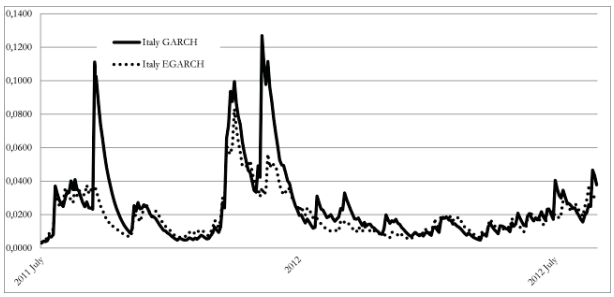
Table B1 – GARCH and EGARCH residuals

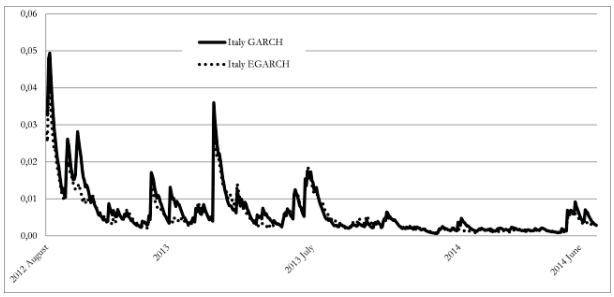


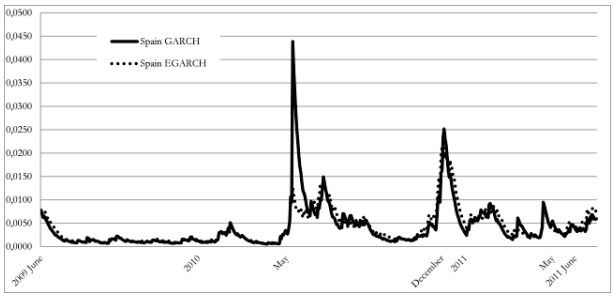


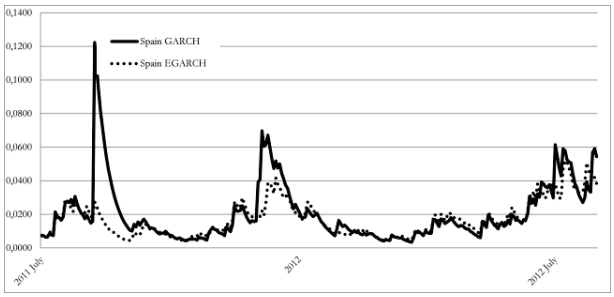


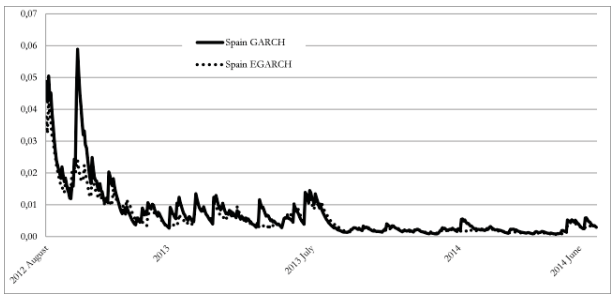












Note – Each graph uses a different scale on the y-axis in order to allow a more clear visual inspection of the changes in the GARCH and EGARCH residuals.
Source: Our elaborations on Trading Economics dataset