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# Contagion Dynamics in EMU Government Bond Spreads

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## Abstract

There is a growing consensus that part of the surge in government bond spreads during the EMU debt crisis can be explained by wake-up-call contagion. Evidence on pure contagion however is very mixed and there are no insights into the dynamics of these effects. As a contribution to fill this gap, we apply the canonical contagion framework of [Pesaran and Pick \[2007\]](#), similar to [Metiu \[2012\]](#), for daily data from January 2002 until May 2013. By adapting the contagion function used by [Metiu \[2012\]](#), we are able to identify the contagion effects originating from each of the crisis countries using a two-stage least squares estimator in a rolling window. This procedure allows us to analyze changes of the contagion coefficients over time. We find that pure contagion appears as early as February 2007 (coinciding with the very first manifestations of the subprime mortgage crisis) which is before the bankruptcy of Lehman Brothers and thus much earlier than the Greek deficit revision. The effects have a stronger impact during the subprime crisis than during the EMU crisis and the main sources of pure contagion effects are Spain, Italy and Ireland whereas Greece plays only a minor role.

JEL codes: C32, C36, G01, G15

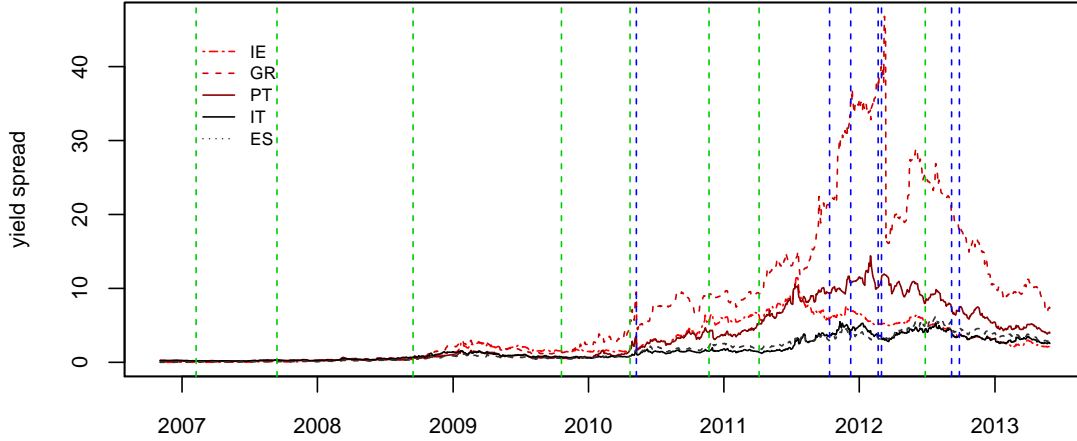
Keywords: contagion, sovereign risk, bond spreads

## 1 Introduction

Since the beginning of the subprime mortgage crisis in 2007 financial markets have experienced a long ongoing period of turmoil. Starting with the announcement that HSBC would have to increase provisions for losses on bad mortgages as early as February 2007, the subprime mortgage crisis accelerated with the bank run on the British bank Northern Rock and reached its climax with the bankruptcy of Lehman Brothers in September 2008.

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**Figure 1:** displays yield spreads of crisis countries relative to Germany. Vertical lines mark crisis events (green) and rescue measures (blue). The respective events and dates can be found in Table 1.

After the revision of the Greek deficit figures in October 2009, the Economic and Monetary Union government debt crisis (EMU crisis) began, during which not only Greece, but also Ireland, Portugal, Spain and Cyprus requested help by the Eurozone members. In this context, several stability mechanisms were established, comprising the European Financial Stability Facility (EFSF), the European Financial Stability Mechanism (EFSM), a restructuring of the private sector debt of Greece, the establishment of the European Stability Mechanism (ESM) and the introduction of the Outright Monetary Transactions (OMT) programme. An overview of these events is presented in Table 1.

As one can see from Figure 1, bond spreads relative to Germany surged during this period from nearly zero percent in 2007, before the beginning of the crisis, to 11.73 percent for Ireland, 14.41 percent for Portugal and around 6 percent for Spain and Italy in late 2011 and early 2012. The Greek spread even spiked up to 46.80 percent.

There is a growing consensus in the literature that part of this surge can be explained by a wake-up-call effect that lead investors to reassess credit risk associated with weakening fiscal positions and macroeconomic fundamentals - particularly in the southern part of the EMU. But there are mixed findings about the presence of pure contagion effects - a concept that is widely used in the classical contagion literature. [Metiu \[2012\]](#) finds evidence for the presence of pure contagion effects by applying the canonical contagion model suggested by [Pesaran and Pick \[2007\]](#).

We build on these results and apply the canonical contagion model in a rolling window regression. This allows us to gain new insights into the dynamics of pure contagion between the main EMU countries. By conducting F-tests about subsets of the coefficient vector, we are able to test various hypotheses about the changing dependence structures in the EMU. This allows us to draw

Date	Event	Color
08.02.2007	HSBC announces higher provisions for bad mortgage loans	green
14.09.2007	Northern Rock needs emergency funding from BoE	green
15.09.2008	Bankruptcy of Lehman Brothers	green
20.10.2009	Greek deficit revision	green
23.04.2010	Greece seeks support of Eurozone	green
09.05.2010	Agreement on establishment of EFSF	blue
22.11.2010	Ireland asks for support by the Eurozone	green
06.04.2010	Portugal asks for support by the Eurozone	green
13.10.2011	EFSF becomes operational	blue
09.12.2011	Euro leaders agree on stronger fiscal controls	blue
21.02.2012	Second rescue package for Greece, including restructuring of private debt	blue
01.03.2012	Greek bonds re-approved as collateral	blue
27.06.2012	Spain requests support	green
06.09.2012	Outright Monetary Transaction programme is introduced	blue
27.09.2012	ESM is created	blue

**Table 1:** shows key dates of subprime mortgage and EMU crisis.

conclusions about the timing and direction of pure contagion effects during the aforementioned crisis periods.

The following section provides an overview of the main contagion concepts and the relevant literature. Section 3 discusses the methodology used in our analysis. The data and the results are presented in Section 4. Section 5 comprises an interpretation of the results and concludes.

## 2 Literature Review

In the early contagion debate seminal articles such as those of [King and Wadhvani \[1990\]](#), [Calvo and Reinhart \[1996\]](#) and [Baig and Goldfajn \[1999\]](#) defined contagion as a significant increase in co-movement across markets conditional on the existence of a crisis in one of the markets considered. Later authors, such as [Masson \[1999\]](#), argued that an increase in co-movement across countries could be caused by so called monsoonal effects. This term refers to a situation in which several countries depend on a common factor and an increase in the variance of this factor leads to an increase in the correlations between the countries' markets even though there is no direct effect of one of the markets on the other.

For this reason [Masson \[1999\]](#) suggests to focus on pure contagion, which is defined as a significant increase in co-movement across markets that cannot be explained by movements in the countries' fundamentals.

This notion of pure contagion is also favored by other influential papers such as [Forbes and Rigobon \[2002\]](#), who strongly advocate to differentiate between dependence and contagion.

Another prominent concept in the context of the EMU crisis is wake-up-call contagion that was put forward by [Goldstein \[1998\]](#) in the context of the Asian crisis. It occurs if events in one country prompt investors to re-evaluate the risks of other countries with similar properties.

There is growing evidence supporting this wake-up-call hypothesis for the EMU crisis. Most contributions use a dynamic panel approach and build on the standard model for spreads as discussed by [Favero \[2013\]](#).

In the standard model spreads of country  $i$  at time  $t$  ( $s_{it}$ ) are treated as a persistent mean-reverting process, whose time varying mean is determined by a set of common international risk factors collected in the vector  $z_t$  and a set of country-specific exogenous variables in vector  $x_{it}$ , such as macroeconomic or fiscal variables, that also include a constant and lagged observations  $s_{i,t-j}$  with  $j = 1, \dots, p$ :

$$s_{it} = \alpha_i' x_{it} + \beta_i' z_t + \varepsilon_{it}, \quad (1)$$

where  $\varepsilon_{it}$  follows a white noise process. In the standard model monsoonal effects could be caused by an increase in the variance of  $z_t$ . A wake-up-call would occur, if there are structural breaks in the coefficients  $\alpha_i$  or  $\beta_i$ .

Evidence for this effect is provided by [Bernoth and Erdogan \[2012\]](#) who estimate a non-parametric fixed effects panel model with time varying coefficients. They thus assume that  $\alpha_i$  and  $\beta_i$  are constant over  $i$  and  $t$ . Using quarterly data from 1999 to 2010, they find that the coefficients of the spread between US BBB-rated corporate bonds and treasuries as well as the debt-to-GDP ratio are indeed time-varying and already start to be significant in the forerun of the subprime mortgage crisis.

In the model of [Beirne and Fratzscher \[2012\]](#) the risk factor  $z_{kt}$  is an equally weighted average of the spreads within the same region  $k \in \{1, \dots, K\}$ . They augment the model by interaction terms of all variables with a crisis dummy that distinguishes between observations before and after the bankruptcy of Lehman Brothers. In accordance with [Bernoth and Erdogan \[2012\]](#) and the wake-up-call hypothesis, their results show that a large proportion of the change in spreads between 2008 and 2011 can be attributed to changes in the pricing of the macroeconomic fundamentals. A similar approach is used by [Giordano et al. \[2012\]](#), who choose a dummy variable for the beginning of the EMU crisis in October 2009 instead of the bankruptcy of Lehman Brothers.

[Arghyrou and Kontonikas \[2012\]](#) use the second principal component of the spreads as the global risk factor  $z_t$  and interpret it as a proxy for core-periphery divergence between the EMU countries. They run univariate time series regressions and a dynamic panel analysis for different sub-periods and confirm that several country-specific variables in  $x_{it}$  become significant during the crisis.

[Favero \[2013\]](#) extends the Global VAR (GVAR) by [Pesaran et al. \[2004\]](#) where the risk factor  $z_{it}$  is a country-specific weighted sum of the spreads of the other countries. In the extended version of [Favero \[2013\]](#) the weighting scheme is time varying and depends on the distance of the macroeconomic and fiscal variables, such that for each  $i$  the spreads of those countries with

similar properties have a higher weight in  $z_{it}$  than those which are more dissimilar. This allows to explain a higher proportion of the change in the spreads.

While all these results provide conclusive evidence for the presence of wake-up-call contagion, the evidence for pure contagion is very mixed and methodologies to capture pure contagion vary widely.

Arghyrou and Kontonikas [2012] interpret the second principal component of the spreads as a contagion variable and conclude that there is pure contagion because the variable gains influence during the crisis. Beirne and Fratzscher [2012] interpret a clustering of extreme innovations as evidence for pure contagion. Giordano et al. [2012] on the other hand, conclude that there is no pure contagion since there is no significant change in the constant.

We will hereafter build on Metiu [2012], who applies the canonical contagion framework developed by Pesaran and Pick [2007] to daily data from January 2008 to February 2012 and provides evidence for pure contagion effects. The method applied is discussed in detail in the next section.

### 3 Econometric Model Specification

To gain insight into the timing and direction of contagion effects during the subprime mortgage crisis and the EMU crisis, we use a slightly modified version of the canonical contagion model suggested by Pesaran and Pick [2007] and apply it in a rolling window of size  $T$ . The analysis is similar to that of Metiu [2012], but adapted to the smaller sample size in the rolling window. The model can be seen as an extension of the standard model from Equation (1), where an additional contagion variable  $C_{jt} = C(s_{1t}, s_{2t}, \dots, s_{i-1,t}, s_{i+1,t}, \dots, s_{Nt})$  is introduced, that is a function of the spreads in all other countries  $j \neq i$ . A significant effect of this variable can be interpreted as a pure contagion effect. In the two-country case the model can be represented by:

$$\begin{aligned} s_{1t} &= \alpha'_1 x_{1t} + \beta'_1 z_t + \gamma_1 C(s_{2t}) + \varepsilon_{1t}, \\ s_{2t} &= \alpha'_2 x_{2t} + \beta'_2 z_t + \gamma_2 C(s_{1t}) + \varepsilon_{2t}. \end{aligned} \tag{2}$$

In this simultaneous equations system, the spreads  $s_{1t}$  of country 1 depend on those of country 2 and vice versa, so that the model can no longer be estimated consistently by OLS due to the resulting endogeneity problem.

Contrary to the usual assumption that bond spreads are mean-reverting, we carry out the analysis using the first differences ( $\Delta s_{it}$ ) of the spread series to avoid spurious results caused by instationarities. If one considers the plot of the spread series in Figure 1, the spread series seem to be I(1). The validity of this hypothesis is supported by unit root tests conducted for each country in a rolling window of size  $T = 300$  that are available upon request. This evidence is further supported by a recent study of Sibbertsen et al. [2013], who apply the test of Sibbertsen and Kruse [2009] to EMU spreads and find an increase in the persistence between 2006 and 2008. After this break the estimated long-memory parameters for the post-break period are close to one. Consequently the mean-reversion assumption may no longer be justified.

Since we are restricted to a relatively small sample of  $T$  observations in each window, we specify

$$C_{jt} = C(\Delta s_{jt}) = \mathbf{I}(\Delta s_{jt} > \hat{F}^{-1}(q)),$$

where  $\mathbf{I}$  is the indicator function,  $\hat{F}^{-1}$  is the empirical quantile function of  $\Delta s_{jt}$  in the respective window and the variable  $q$  determines the quantile considered. This specification guarantees that there are always  $(1 - q) \cdot T$  observations in the sample for which the contagion variable  $C_{jt}$  is equal to one, whereas [Metiu \[2012\]](#) specifies  $C(\varepsilon_{jt})$  as an indicator function that takes on the value 1 if the innovations exceed their 99 percent VaR, so that the number of observations for which  $C_{jt} = 1$  is random and much lower given a fixed sample size.

Our full model can thus be represented for a multi-country setup by:

$$\Delta s_{it} = \alpha'_i x_{it} + \beta'_i z_t + \sum_{\substack{j \in \mathbb{C} \\ j \neq i}} \gamma_{ij} C_{jt} + \varepsilon_{it}, \quad (3)$$

where  $\mathbb{C}$  is the subset of  $J$  crisis countries, that are possible sources for contagion effects. As suggested by [Pesaran and Pick \[2007\]](#) we use the first  $m$  powers of the first  $r$  lags of  $\Delta s_{jt}$  for all  $j \in \mathbb{C}$  as instruments for the respective  $C_{jt}$ .

To gain further insights about the relevant dynamics, we conduct various F-tests on subsets of the estimated coefficient vector. We conclude that pure contagion takes place if the elements of the vector  $\gamma_i = (\gamma_{i1}, \dots, \gamma_{iJ})$  are jointly significant. In addition to that, we test for joint significance of the contagion variables of Italy and Spain, for joint significance of the contagion variables of Greece, Ireland and Portugal and for joint significance of the all elements in  $\alpha_i$  and  $\beta_i$  except for the constant and the autoregressive coefficients.<sup>2</sup>

## 4 Empirical Analysis

### 4.1 Data Description and Analysis

We apply model (3) to daily spreads of 10 year maturity benchmark bonds relative to Germany from 03.01.2002 to 31.05.2013. As customary in the literature, we subdivide the countries into the five crisis countries  $\mathbb{C} = \{\text{Greece, Ireland, Italy, Portugal and Spain}\}$  and the five non-crisis countries  $\mathbb{N} = \{\text{Belgium, the Netherlands, Austria, Finland and France}\}$ .

Our model specification follows [Metiu \[2012\]](#) in including lagged stock market returns of the respective country in  $x_{it}$  and log-returns of the VSTOXX in  $z_t$ , but since we use differenced data, we only include the first lag  $\Delta s_{i,t-1}$  for the autoregressive part. As a second common regressor we use log-returns of the lagged 3 month Euribor instead of the lagged difference between 3 month Euribor and German bunds, since the variable is mostly insignificant in Metiu's specification while the Euribor has explanatory power for the spreads as shown, for example, in [Manganelli and Wolswijk \[2009\]](#). We also follow [Metiu \[2012\]](#) in assuming that pure contagion can only

<sup>2</sup>The results for the latter coefficients are not discussed in the paper, but they are available upon request.

	const	$\Delta s_{i,t-1}$	Stock	VSTOXX	Euribor	IE	GR	PT	IT	ES
IE	0.0038 (0.0061)	<b>0.2557</b> (0.0572)	0.0234 (0.1003)	<b>0.3026</b> (0.0868)	-0.1194 (0.3820)	– –	-0.0330 (0.0467)	-0.0012 (0.0397)	-0.1232 (0.0837)	0.1400 (0.0817)
GR	-0.0456 (0.0249)	<b>0.1002</b> (0.0261)	-1.4911 (1.2947)	0.4867 (0.3128)	0.3034 (1.3170)	-0.1196 (0.4046)	– –	0.3089 (0.3498)	-0.5731 (0.3590)	<b>0.6204</b> (0.2883)
PT	-0.0016 (0.0094)	<b>0.2353</b> (0.0709)	0.3948 (0.2116)	<b>0.4000</b> (0.1177)	0.2140 (0.4724)	<b>0.1892</b> (0.0964)	-0.0488 (0.0554)	– –	-0.1124 (0.0806)	-0.0144 (0.1207)
IT	-0.0010 (0.0048)	<b>0.1478</b> (0.0397)	<b>0.3223</b> (0.1147)	<b>0.3007</b> (0.0484)	0.2041 (0.3424)	0.0523 (0.0579)	-0.0532 (0.0333)	-0.0565 (0.0376)	– –	0.0668 (0.0395)
ES	<b>-0.0105</b> (0.0050)	<b>0.2934</b> (0.0436)	0.2060 (0.1093)	0.1567 (0.0593)	<b>0.8470</b> (0.3436)	0.0695 (0.0606)	-0.0601 (0.0336)	-0.0863 (0.0461)	<b>0.1362</b> (0.0560)	– –
BE	<b>-0.0072</b> (0.0006)	<b>0.2543</b> (0.0445)	0.0706 (0.0524)	<b>0.1122</b> (0.0162)	<b>0.3314</b> (0.1465)	<b>0.0092</b> (0.0027)	-0.0051 (0.0030)	-0.0048 (0.0033)	<b>0.0245</b> (0.0031)	<b>0.0144</b> (0.0027)
FR	<b>-0.0045</b> (0.0004)	0.0837 (0.0443)	0.0263 (0.0332)	<b>0.0520</b> (0.0085)	0.1018 (0.1010)	<b>0.0080</b> (0.0021)	-0.0011 (0.0022)	-0.0044 (0.0026)	<b>0.0119</b> (0.0019)	<b>0.0090</b> (0.0018)
AT	<b>-0.0047</b> (0.0004)	<b>0.1533</b> (0.0401)	0.0482 (0.0346)	<b>0.0519</b> (0.0092)	0.0539 (0.1057)	<b>0.0080</b> (0.0019)	-0.0014 (0.0021)	-0.0029 (0.0023)	<b>0.0098</b> (0.0018)	<b>0.0105</b> (0.0020)
NL	<b>-0.0028</b> (0.0003)	-0.0139 (0.0319)	-0.0122 (0.0238)	<b>0.0201</b> (0.0061)	0.0877 (0.0558)	<b>0.0045</b> (0.0013)	-0.0001 (0.0013)	0.0011 (0.0016)	<b>0.0043</b> (0.0012)	<b>0.0053</b> (0.0013)
FI	<b>-0.0020</b> (0.0003)	-0.0163 (0.0358)	0.0043 (0.0183)	0.0073 (0.0068)	<b>0.0851</b> (0.0425)	<b>0.0058</b> (0.0014)	-0.0011 (0.0013)	0.0003 (0.0014)	<b>0.0026</b> (0.0011)	<b>0.0026</b> (0.0011)

**Table 2:** shows full sample estimation results of equation (3). Coefficients of the crisis and non-crisis countries are estimated via 2SLS and OLS respectively. HAC standard errors are in parentheses and bold values indicate significance for  $\alpha = 0.05$ .

originate from the crisis countries  $\mathbb{C}$  and not from  $\mathbb{N}$  meaning that  $J = 5$  contagion variables  $C_{jt}$  are considered in (3).

For the window size we select  $T = 300$  and we set  $q = 0.8$  so that an exceedance of the empirical 80 percent quantile is considered to be a possible contagion event. The instruments include the first  $m = 3$  powers of the first  $r = 2$  lags.<sup>3</sup> To avoid multicollinearity issues among the instruments, we exclude those instruments that have a correlation of more than 0.9 with any of the other instruments.

With those specifications, Model (3) is estimated univariately for each of the 10 countries. The crisis countries are estimated by 2SLS whereas the non-crisis countries are estimated consistently via OLS. All estimations are carried out using HAC standard errors.

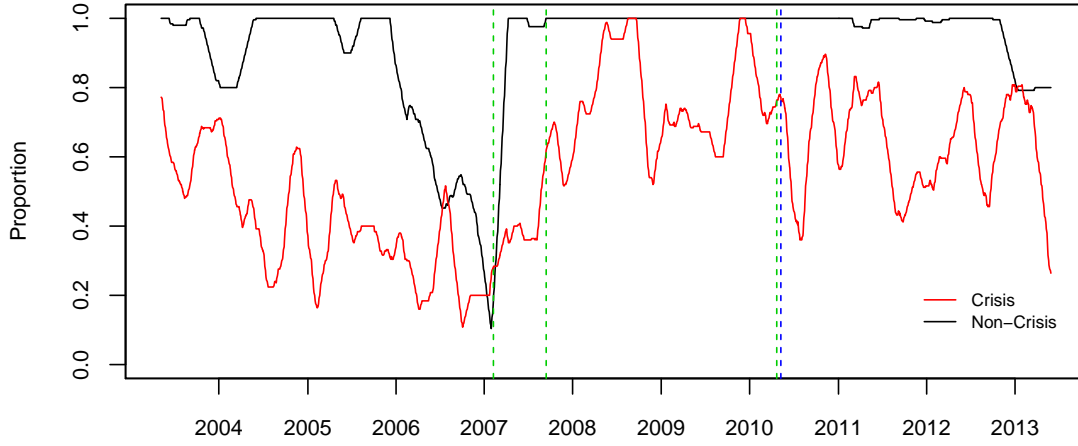
To obtain a first idea of the dynamics of the data, we look at the estimation results of Model (3) for each country over the full sample in Table 2.

Turning to the exogenous variables first, we observe a positive (if significant) autoregressive coefficient lying between 0.1 and 0.3 for all countries. The lagged stock index, on the other hand, does not seem to be of much importance in explaining the dynamics of the spreads.

Concerning the common factors, we observe a significantly positive influence of the VSTOXX on the spreads for the majority of the countries. Hence there is a positive impact of volatility expectations on the spreads. The positive influence of the Euribor is only significant for 3 out

<sup>3</sup>The results are robust to modifications of the window size. Additionally, we specified different contagion functions  $C(\cdot)$  as well as lag and power variations also not leading to qualitatively different results.





**Figure 2:** displays the proportion of significant F-statistics testing joint significance of the contagion variables on the crisis and non-crisis countries over time for  $\alpha = 0.05$ .<sup>4</sup>

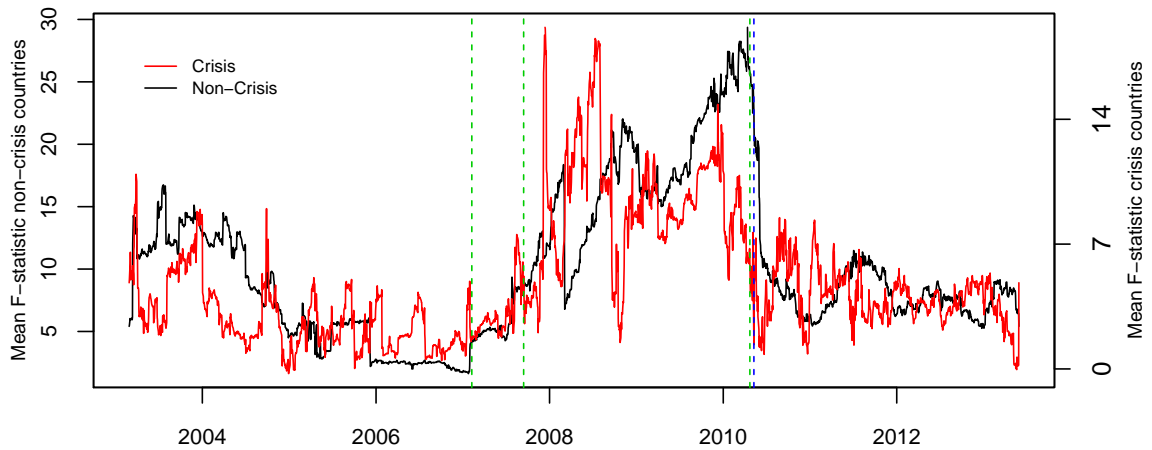
of 10 countries.

With regard to the contagion variables, two findings can be formulated. First, mainly Ireland, Italy and Spain can be identified as the main drivers for contagion and second, contagion seems to primarily affect the non-crisis countries. The latter result corresponds to the finding of [Metiu \[2012\]](#) stating that the “core Eurozone economies are broadly affected”. The former finding stands in contrast to those of Metiu who identifies Ireland, Greece and Portugal as the main sources of contagion.

## 4.2 Aggregated Rolling Window Results

A shortcoming of the analysis thus far is that contagion dynamics have been neglected, so that it is not possible to determine how contagion effects have developed over time. Hence, we estimate Equation (3) in a rolling window of  $T = 300$  observations yielding 2,674 estimation results for each country, i.e. a total of 26,740 estimation outputs. In each window we apply an F-test for the joint significance of the contagion variables, i.e. we test for  $H_0 : \gamma_i = 0$  vs.  $H_1 : \gamma_i \neq 0 \forall i = 1, \dots, N$ . In order to obtain aggregated results that are easier to interpret, we consider the proportion of countries in each of the subsets  $\mathbb{C}$  and  $\mathbb{N}$  that are affected by contagion in each rolling window regression. We conclude that a country is affected, if the F-test for insignificance of  $\gamma_i$  is rejected on the  $\alpha = 0.05$  level. This means that if the proportion is 1 for any of the subgroups, all 5 countries experience joint contagion from the 5 crisis countries. The results are displayed in Figure 2. Here and hereafter the results shown for a particular date  $t$  are always those of the

<sup>4</sup>To robustify against short term fluctuations that arise if test results change for one of the countries due to outliers that enter the sample, we always display the average of the last 50 proportions.



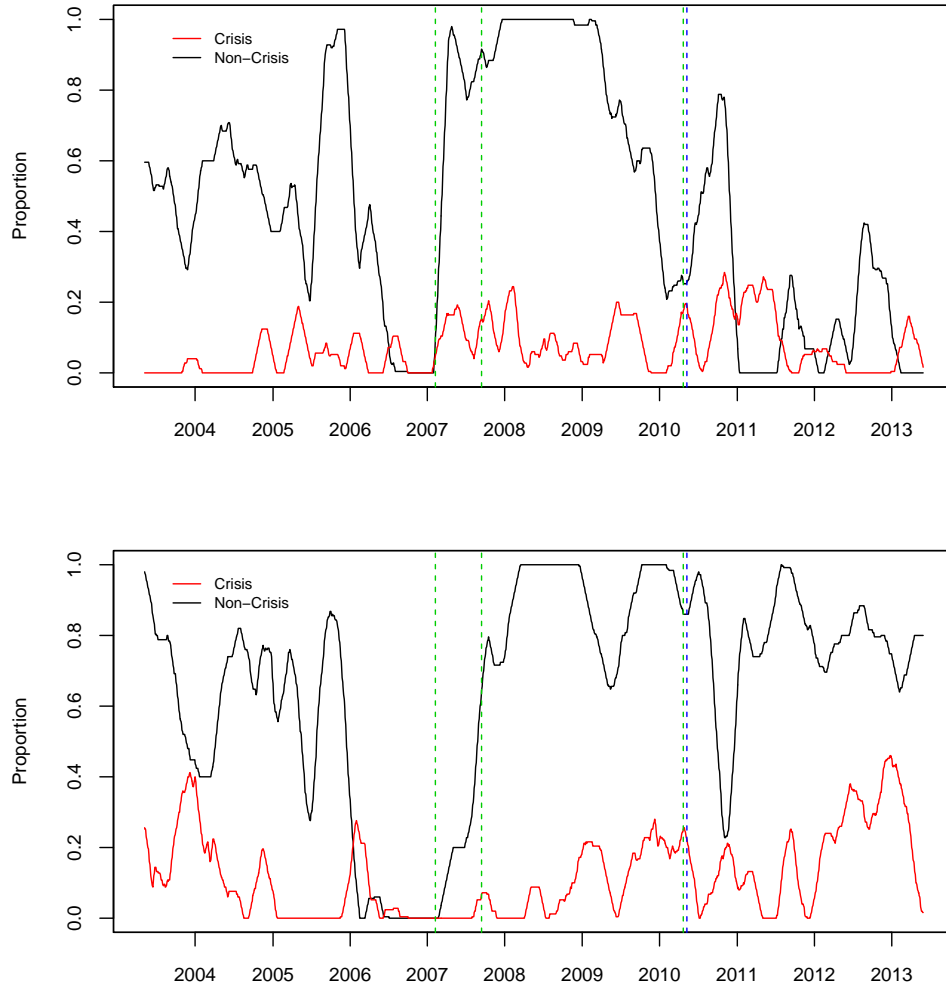
**Figure 3:** displays the mean value of the F-statistic testing joint significance of the contagion variables on the crisis and non-crisis countries over time for  $\alpha = 0.05$ .

window ending at time  $t$ .

Additionally, in Figure 3, we consider the average of the F-statistics within both subgroups for each  $t \in T$ . Looking at the Figures 2 and 3, one can observe a steep rise of the proportion of affected countries for both the crisis as well as the non-crisis group from the beginning of 2007 until 2009. The same result can be detected in the average F-statistic for both subgroups. In other words, we observe that the contagion variables become significant long before the beginning of the EMU crisis and even before the collapse of Lehman Brothers that is often specified as the beginning of the subprime mortgage crisis.

In fact, the intensification of the contagion effects starts almost simultaneously with the announcement of HSBC, that it would have to make higher provisions for bad mortgage loans on 08.02.2007 (first vertical dashed line). As argued in Section 1, this was one of the very first manifestations of the crisis that directed attention to the quality of mortgage loans and the related risks in the banking sector. Thereafter, the increase is intensified in the third quarter of 2007, coinciding with the bailout of Northern Rock by the Bank of England (second vertical dashed line).

The level of the F-statistic then maintains at a relatively high level and eventually drops after April 2010, coinciding with Greece's request for help from the other Eurozone countries (third vertical dashed line) and the establishment of the EFSF (fourth vertical dashed line). Hence there seems to be rather early evidence for the occurrence of pure contagion effects based on the results of these F-tests.



**Figure 4:** displays the proportion of significant F-statistics testing joint significance of Ireland, Greece and Portugal (upper panel) and of Italy and Spain (lower panel) on the crisis and non-crisis countries respectively over time for  $\alpha = 0.05$ .

### 4.3 Disaggregated Rolling Window Results

A deeper insight into the dynamics behind the patterns described in the preceding subsection can be obtained if the crisis countries are further subdivided into two groups: Spain and Italy (SI) on the one hand and Greece, Portugal and Ireland (GPI) on the other hand. Figure 4 (corresponding to Figure 2) illustrates the pure contagion effects originating from the two groups on the crisis and the non-crisis countries. The proportion of affected countries is constructed from the F-tests on joint significance of the respective variables in the contagion vector  $\gamma_i$ .

As one can observe, the high proportion of non-crisis countries suffering from pure contagion from 2009 onwards (displayed in Figure 2) is mainly due to contagion effects caused by Italy and Spain. Again we observe the increase of the contagion effects after the announcement of HSBC

$j/i$	IE	GR	PT	IT	ES	BE	FR	AT	NL	FI
- full sample -										
IE	–	0.0568	0.1085	0.1081	0.1376	0.5912	0.4334	0.6313	0.4619	0.6320
GR	0.0658	–	0.1200	0.1754	0.0176	0.1679	0.1821	0.1645	0.0553	0.0711
PT	0.2053	0.2554	–	0.0494	0.1589	0.2595	0.2498	0.1911	0.2304	0.3108
IT	0.0924	0.2913	0.0542	–	0.2592	0.4734	0.3934	0.2319	0.2461	0.1429
ES	0.1500	0.0434	0.1126	0.2371	–	0.5767	0.6178	0.5434	0.4581	0.3972
- pre-crisis period -										
IE	–	0.0841	0.0263	0.0704	0.0727	0.7151	0.5412	0.6997	0.6213	0.7408
GR	0.0738	–	0.1098	0.2557	0.0195	0.2111	0.1333	0.1356	0.0040	0.0801
PT	0.1568	0.2323	–	0.0692	0.1733	0.2769	0.3604	0.2809	0.3055	0.4388
IT	0.1093	0.4170	0.0378	–	0.1081	0.2220	0.1499	0.0029	0.0898	0.1287
ES	0.1058	0.0498	0.1579	0.0812	–	0.4405	0.4931	0.3478	0.4216	0.4388
- subprime crisis period -										
IE	–	0.0175	0.1783	0.0490	0.4580	0.3112	0.2657	0.8951	0.4266	0.4161
GR	0.0210	–	0.2657	0.0000	0.0455	0.2762	0.1748	0.2448	0.0000	0.0000
PT	0.2098	0.1958	–	0.0000	0.0420	0.4685	0.0000	0.0000	0.1154	0.1783
IT	0.1469	0.1049	0.1923	–	0.3147	0.8322	0.7657	0.3112	0.6958	0.2238
ES	0.5874	0.0035	0.0874	0.3322	–	0.5909	0.7517	0.7308	0.6853	0.6364
- EMU crisis period -										
IE	–	0.0000	0.3016	0.2375	0.1719	0.3781	0.2141	0.3266	0.0422	0.4313
GR	0.0641	–	0.0828	0.0344	0.0000	0.0016	0.3187	0.2078	0.2203	0.0781
PT	0.3359	0.3453	–	0.0172	0.1719	0.1187	0.0594	0.0312	0.0766	0.0203
IT	0.0219	0.0312	0.0375	–	0.6469	1.0000	0.8922	0.8219	0.4719	0.1453
ES	0.0750	0.0437	0.0000	0.6203	–	0.9422	0.8984	0.9938	0.4562	0.1766

**Table 3:** shows the proportions of how often the contagion coefficient of country  $j$  has been significant for country  $i$  for  $\alpha = 0.05$ .

(first vertical dashed line) and the intensification after the bailout of Northern Rock (second vertical dashed line) for both SI and GPI.

For both subgroups the contagion effects are no longer significant for some of the non-crisis countries in the beginning of 2009. In contrast to GPI however, the effect reinforces for SI in the second quarter of 2009 and stays at a relatively high level thereafter.

It is also interesting to see that with Greece seeking support from the Eurozone (third vertical dashed line) and the agreement on the establishment of the EFSF (fourth vertical dashed line) the effect of GPI rises to a temporary peak before dropping again in late 2010, whereas SI drops to a low point before rising again.

Another interesting disaggregation of the results is provided in Table 3. Here we divide the sample into 3 periods. A pre-crisis period (from 03.01.2002 to the HSBC announcement on 08.02.2007), the subprime crisis period (starting with the HSBC announcement and ending with the Greek deficit revision on 20.10.2009) and the EMU crisis period (starting with the Greek

deficit revision and ending with the end of the sample on 29.05.2013).

We then consider the rolling window estimation results within each of these periods and calculate the proportion of the time during which the contagion variable  $C_{jt}$  has a significant impact on the differenced spread  $\Delta s_{it}$  of country  $i$  for all countries  $i \in \{\mathbb{C} \cup \mathbb{N}\}$  and all sources of contagion  $\mathbb{C}$ .

If for example the value of Greece for Ireland is 0.0738 in the pre-crisis period, this means that Ireland was only affected by pure contagion from Greece during 7.38 percent of this period.

The first panel of the table corresponds to the results for the whole series, i.e. the proportions concerning the whole 2,674 regression results for country  $i$  are displayed. Here we observe that even over time the contagion from the crisis to the non-crisis countries seems to be stronger than the mutual contagion among the crisis countries. Over the full sample, Ireland, Italy and Spain are the main sources of contagion whereas Portugal and Greece seem to be of minor importance. In correspondence to [Metiu \[2012\]](#) we also identify Belgium as the country which is most often affected by contagion. Spain and Ireland, on the other hand, are the main sources of contagion. Turning to the subperiods, we find that Italy and Spain contribute a lot to the contagion effects in the two crisis periods and the influence of Italy is especially high during the EMU crisis. In addition to that, the mutual contagion between Spain and Italy becomes increasingly significant over time.

While Greece and Portugal on the one hand play only a minor role, Ireland on the other hand exhibits rather high values, but its influence diminishes during the EMU crisis.

Since the 2SLS estimation for the crisis countries is only necessary if there is indeed mutual dependence and there would be efficiency gains if one could use OLS instead, we run Hausman tests with each regression. Doing this, we find that the tests indeed reject the null of no endogeneity during the subprime mortgage crisis for over 20 percent of the time for Ireland, Greece and Spain.

## 5 Conclusion

The dynamic analysis conducted here leads to two main results. First, there are pure contagion effects, but those appear already during the subprime mortgage crisis where they are much stronger than during the EMU crisis. Second, the main sources for contagion during the EMU crisis are Spain and Italy but not Greece. Especially the second result is in contradiction to other findings in the literature, but it is consistent with economic reasoning, in the sense that Spain and Italy are much larger economies and their default would constitute a more serious threat to the Eurozone.

These results suggest that the two crises periods are more closely connected than it is presumed so far and more research about the dynamics of contagion effects during the crisis is needed to fully understand the underlying mechanisms.

It is a well-established finding that bond yield spreads narrowed in the EMU during the transition to the euro (cf. for example [Pagano and von Thadden \[2004\]](#)), since market participants expected

economic conditions in the euro area countries to converge and regarded bonds from different countries as nearly perfect substitutes.

Under these circumstances, market participants could attribute informational value for the spreads of country  $i$  to spread changes in country  $j$ , because news about country  $j$  also have informational value for country  $i$  if the economies of the two countries are regarded as nearly identical.

There is also a growing consensus that there has been a wake-up-call effect in the EMU crisis. After that markets started to differentiate between the default risks of the EMU countries that are connected to their different economic fundamentals.

These findings could well be linked with our results, if one assumes that market participants only attribute informational value to large spread changes in other countries, for example because smaller changes could be caused by microstructure effects.

In this case - i.e. under the convergence assumption, there would only be minor contagion effects during the pre-crisis period, where volatilities are low. When volatilities start to rise during the beginning of the subprime mortgage crisis, pure contagion would take place, because large changes in the spread of one country are assumed to be informative for the economic conditions in other countries.

This relationship would end with the wake-up-call effect at the beginning of the EMU crisis, where the convergence assumption is dropped by market participants, who start to take the economic conditions and the associated default risks into consideration. This could be the reason why pure contagion originating from Greece, Ireland and Portugal is no longer observable.

Changing expectations about Italy and Spain however have informational value especially for the non-crisis countries, because of their economic size and the resulting relevance for the stability of the Eurozone.

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