Contagion in CDS, Banking and Equity Markets[☆,☆☆]

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Abstract

We develop a strategy for testing endogenously contagion within banking sector, stock market indices and Credit Default Swap Spreads. We present evidence of strong contagion in several cases and markets. Contagion seems to be widespread during the Global Financial Crisis of 2008 and the recent European Debt Crisis. Our results are important for a better understanding of contagion and the development of macroprudential tools for financial stability surveillance.

Keywords: Contagion; Correlation; Coskewness; Endogenous Testing.

JEL Classification: G01; G15.

[☆]The opinions expressed here are those of the authors and do not necessarily represent neither those of the Banco de Central do Brasil nor of its Board of Directors. As usual, all errors and omissions in this work are the responsibility of the authors.

[☆☆]The authors acknowledge financial support from CNPQ Foundation.

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1. Introduction

The study of financial contagion is becoming increasingly relevant as financial crises such as the Global Financial Crisis[1], and the European Sovereign Debt Crisis[2] had their effects spread throughout the world. The understanding of changes in the volatility of worldwide financial markets, the way such changes spread and its impact on the financial stability has become of great importance for governments and regulatory agencies.

There is an increasing number of works that are concerned with financial contagion due to the recent crises. Bengtsson [11] studies the Global Financial Crisis and its impact in the European Money Market Fund (MMF) industry and discusses the effects of this contagion channel in the European economy and its influence in the financial instability that reached Europe from 2007. Analyzing fluctuations in the sovereign risk of the countries that belong to their sample, Beirne and Fratzscher [9] examine the effects of the European Sovereign Debt Crisis in various economies. Their work covers 31 countries, which mostly presented contagion evidence.

We aim to develop a framework for the analysis of contagion in the recent crises which does not require a previously defined dating of a crisis period. Our study includes an empirical analysis of the most affected countries due to financial instability in the Global Financial Crisis and the European Sovereign Debt Crisis.

Contagion tests such as those developed by Forbes and Rigobon [27] and Fry-McKibbin et al. [28] compare a previously defined "crisis period" with a "tranquil period" and find contagion through statistically significant structural breaks. The proper choice of those periods are generally regarded as "an essential component" (Hsiao et al. [32]). However in the literature those two periods are usually defined exogenously from the model, with the boundaries gathered from some general consensus, which identifies certain events with the start and end of a crisis. We believe that such arbitrary dating may be hiding patterns in contagion effects that would be interesting to study. Also it is our understanding that in many crises this arbitrary dating may not be easy or even possible to make with any precision.

Because of this difficulty in defining the proper dating of each crisis, we propose a contagion test which does not rely on exogenous definition of contagion dates, but uses the same testing framework as the tests developed by Forbes and Rigobon [27] and Fry-McKibbin et al. [28]. For such ends an endogenous search for contagion is proposed in which a window is moved along all possible dates and each window is tested for contagion. The results of all tests are gathered and analysed. We apply this endogenous search to both the Global Financial Crisis and the ongoing European Sovereign Debt Crisis and find evidence of contagion consistent with general consensus of the contagion periods.

The remainder of this paper is structured as follows: section 2 reviews current literature on contagion mea-

[1] The crisis which started with the collapse of the subprime market in the USA in 2007.
[2] The crisis that started in late 2009 with the discovery of the fiscal problems of the Greek government and is still under way.

surements, section 3 describes the datasets used in this paper, section 4 describes the contagion measurement tests developed by Forbes and Rigobon [27] and Fry-McKibbin et al. [28] used in this paper, section 5 outlines our proposal for endogenous contagion tests, 6 presents the results and a commentary, and section 7 concludes the paper.

2. Literature review

There is a growing body of literature on the topic of financial contagion. We mostly find studies related to this subject using the correlation tests created by Forbes and Rigobon [27] and Fry-McKibbin et al. [28]. However, there are papers that develop alternative approaches to examine contagion channels, for example, Manz [38] and Castiglionesi [14]. Manz [38] explores a global game model of information-based financial contagion, where the failure of a single firm can trigger the failure of another. Castiglionesi [14] investigates the impact of a central bank intervention in preventing financial contagion. Thus, we present the Tables 1 and 2 to provide a summary of the contributions related to this topic.

< Place Tables 1 and 2 About Here. >

Overall we can infer from this literature that there are various competing models and approaches to test for contagion. For the purposes of this paper, the main method is the one proposed by Forbes and Rigobbon which looks for structural breaks in correlations between markets, with proper adjustments for heteroscedasticity. This method was further developed by Fry-McKibbin et al. [28] including an important addition as it proposes a framework for contagion tests in higher-order moments of the distribution.

Despite the recent developments in the financial contagion literature, there seems to be a gap regarding the definition of the sample to be tested. Mandilaras and Bird [37] contribute to this puzzle performing a contagion analysis using a Markov-switching vector autoregression to determine the crisis and non-crisis observations. However, the question still remains: How long should be periods before and after contagion? Thus, our main contribution is the proposal of a search for contagion while the dating of the contagion period is endogenously set since the crisis and pre-crisis periods are usually defined exogenously and arbitrarily for each crisis.

3. Data

In this paper we perform endogenous tests for contagion through three distinct channels or dimensions: the equity market, the banking system and the sovereign Credit Default Swaps (CDS) market. Testing for contagion in different channels allows for a better characterization of how a given crisis might have affected a country, and also help in pointing the direction for finer-grained studies.

The rationale for the choice of channels is as follows. Contagion in CDS spreads indicates that during a crisis, the market expects it to trigger a rise in the country's probability of default, and therefore a decrease in its ability to finance itself and pay its debts. Contagion in the banking sector reflects a loss of capital or of funding in the affected country's banking system. Contagion in the equity market indicates an increased risk aversion in investors and less availability of funding for listed companies in that specific country.

We obtain our sample of the banking sector in Data Stream Bank Sector index (the banking sector data has 58 countries and the period is from January 2006 to August 2013). For the country equity market we use the Morgan Stanley Capital International (MSCI) standard country index (the equity market data has 66 countries and the period is from January 2006 to August 2013). For CDS spreads, Thomson Reuters Sovereign CDS (the CDS market data has 69 countries and the period is from January 2008 to August 2013). We use the daily US Federal Funds Rate and Commodity Research Bureau Total Return Index for controlling for fundamentals (this data covers the period of January 2006 to August 2013). All the data that we obtain are from Datastream.[3]

4. Contagion testing

In our paper we adopt the same definition of contagion as that of Forbes and Rigobon [27]: "*a significant increase in cross-market linkages after a shock to one country (or group of countries)*". This definition is formal enough for statistical testing and is broad enough to signal various forms of contagion. Given this definition we consider three possible measures of contagion. One based on correlation, and two based on coskewness.

The logic of contagion tests based on correlation is that during a crisis contagion from one market to another is signalled is through a significant increase in the correlation of these markets. That is, if the prices of one market fall, the prices of the the other also fall in a way that is stronger than predicted by their expected co-movements. Regarding correlation tests for contagion, Forbes and Rigobon [27] observe that the higher volatility in times of crisis tends to increase the correlation coefficients and therefore bias the contagion tests towards false positives, and thus a better correlation-based test should take this into account. Fry-McKibbin et al. [28] develop the final form of the correlation-based contagion test used in this paper, which we call the *FR* test.

The coskewness test are derived from an extension to the CAPM model due to Kraus and Litzenberger [34], which incorporates skewness, and a further development by Harvey and Siddique [31] which refined this model to include conditional skewness. Both argues that risk aversion in a CAPM model which incorporates skewness implies a preference for positive skewness. That is, a risk averse investor will seek assets that

[3] We do not have data to analyze contagion during the Global Financial Crisis in the CDS market, because our sample starts at January 2008. Thus, we can not perform our endogenous test for contagion in the CDS market during this crisis.

increase the coskewness of a portfolio. On the other hand, in order to add an asset to its portfolio that impacts its skewness negatively, the risk averse investor will demand higher returns. Based on this observation, Fry-McKibbin et al. [28] argued that another signal of a crisis would be a shift towards positive skewness as risk averse investors trade off smaller returns for positive skewness. From this observation , Fry-McKibbin et al. [28] developed two coskewness based tests, *CS1* and *CS2*, which build on the *FR* test. Both tests aim to identify significant changes in coskewness between the periods before a crisis and during a crisis.

The *CS1* test for contagion verifies whether there is a significant decrease in the source market returns and a related increase the volatility in the second market. This implies that the crisis in the source market has been identified with positive skewness (investors are seeking safer assets and accepting lower returns), and the second market suffers contagion in the form of higher volatility.

The *CS2* test for contagion verifies whether there is a significant increase in volatility in the source market and a significant decrease of the average returns in the second market, that is, the higher volatility in the source market affects investors in the second market, which turn to safer assets (smaller returns) seeking positive skewness.

4.1. Contagion tests

In order to test for the occurrence of contagion from one market to another, we separate each series i and j into a pre-crisis and a crisis period, and then compare the joint behaviour of i and j. If the resulting statistic is greater than a critical value, there is indication of contagion.

The first statistic (which in this paper is identified by *FR*) tests for an increase in the correlation of the two series in the crisis period. The second and third statistics (in this paper, *CS1* and *CS2*) test for an increase in volatility in j and smaller returns in i (*CS1*), and for smaller returns in j and increased volatility in i (*CS2*).

4.2. Correlation Contagion testing

The correlation-based testing for contagion used in this paper follows the proposal by Forbes and Rigobon [27] and further refined by Fry-McKibbin et al. [28].

Let ρ_c and ρ_{pre} be the correlations between i and j in the crisis and pre-crisis periods. The correlation of the crisis period is adjusted for the greater volatility of the crisis period as per Forbes and Rigobon [27], and the adjusted correlation ν_c is then used for the calculation of the *FR* statistic:

$$\nu_c = \frac{\rho_c}{\sqrt{1+\delta(1-\rho_c^2)}}, \tag{1}$$

$$\delta = \frac{s_{c,i}^2 - s_{pre,i}^2}{s_{pre,i}^2}, \tag{2}$$

Define $s^2_{c,i}$ and $s^2_{pre,i}$ as the variances of i in the crisis and pre-crisis periods. Let T_c be the number of observations in the crisis period and T_{pre} the number of observation in the pre-crisis period.

$$FR(i \to j) = \left(\frac{\nu_c - \rho_{pre}}{\sqrt{Var(\nu_c - \rho_{pre})}} \right)^2, \tag{3}$$

where

$$\begin{aligned}
Var(\nu_c - \rho_{pre}) &= Var(\nu_c) + Var(\rho_{pre}) - 2Cov(\nu_c, \rho_{pre}), && (4)\\
Var(\nu_c) &= \frac{1}{2}\frac{(1+\delta)^2}{[1+\delta(1-\rho_c^2)]^3}\left[\frac{1}{T_c}\left((2-\rho_c^2)(1-\rho_c^2)^2\right) + \frac{1}{T_{pre}}\left(\rho_c^2(1-\rho_c^2)^2\right)\right], && (5)\\
Var(\rho_{pre}) &= \frac{1}{T_{pre}}(1-\rho_{pre}^2)^2, && (6)\\
Cov(\nu_c, \rho_{pre}) &= \frac{1}{2}\frac{1}{T_{pre}}\frac{\rho_c\rho_{pre}(1-\rho_c^2)(1-\rho_{pre}^2)(1+\delta)}{\sqrt{[1+\delta(1-\rho_c^2)]^3}}. && (7)
\end{aligned}$$

Under the null hypothesis of no contagion, the two-tailed adjusted correlation test is asymptotically distributed χ^2_1. Although the test is two-tailed, this paper only concerns itself with increases in correlations, therefore the test indicates contagion only if $FR(i \to j)$ is greater than some critical value in χ^2_1 and $\nu_c > \rho_{pre}$.

4.3. Coskewness contagion testing

Fry-McKibbin et al. [28] propose coskewness tests for contagion, which identifies contagion from the value of i to the volatility of j and from the volatility of i to the value of j.

Let $\hat{\mu}_{T,k}$ the mean of k in period T and $\hat{\sigma}_{T,k}$ the standard deviation of k in T, where T can be either T_c ou T_{pre} and k can be either i or j.

The coskewness contagion test from i to the volatility of j, $CS_1(i \to j; i^1, j^2)$, and the coskewness contagion test from the volatility of i to j, $CS_2(i \to j; i^2, j^1)$ are given by:

$$\begin{aligned}
CS_1(i \to j; i^1, j^2) &= \left(\frac{\psi_c(i^1, j^2) - \psi_{pre}(i^1, j^2)}{\sqrt{\frac{4\nu_c+2}{T_c} + \frac{4\rho^2_{pre}+2}{T_{pre}}}} \right)^2, && (8)\\
CS_2(i \to j; i^2, j^1) &= \left(\frac{\psi_c(i^2, j^1) - \psi_{pre}(i^2, j^1)}{\sqrt{\frac{4\nu_c+2}{T_c} + \frac{4\rho^2_{pre}+2}{T_{pre}}}} \right)^2, && (9)
\end{aligned}$$

where

$$\begin{aligned}
\psi_c(i^m, j^n) &= \frac{1}{T_c}\sum_{t=1}^{T_c}\left(\frac{i_t - \hat{\mu}_{c,i}}{\hat{\sigma}_{c,i}}\right)^m\left(\frac{j_t - \hat{\mu}_{c,j}}{\hat{\sigma}_{c,j}}\right)^n, && (10)\\
\psi_{pre}(i^m, j^n) &= \frac{1}{T_{pre}}\sum_{t=1}^{T_{pre}}\left(\frac{i_t - \hat{\mu}_{pre,i}}{\hat{\sigma}_{pre,i}}\right)^m\left(\frac{j_t - \hat{\mu}_{pre,j}}{\hat{\sigma}_{pre,j}}\right)^n. && (11)
\end{aligned}$$

Under the null hypothesis of no contagion, the two-tailed adjusted correlation test is asymptotically distributed χ_1^2.

5. Endogenous test for contagion

In section 4.2 we presented contagion tests based on the structural break of some property of a distribution. Those tests require the definition of two periods in the series that are being tested, a crisis period and a pre-crisis period. However the proper dating of the crisis and pre-crisis period can be difficult. Even when it is possible to identify the start of a crisis more easily, the choice of its end may not be so clear. In addition, a crisis may have recurring critical events, and multiple rounds of contagion, or there might be many sources of contagion, and the contagion from each source may be stronger at different dates.

Instead of an exogenously defined crisis and pre-crisis periods, in this paper we define test windows over the entire period, test each window for contagion and then consolidate the results, looking for the dates of the windows where the contagion statistics are higher than a critical value. For additional robustness checks, we define multiple window sizes. In this way we overcome the problem of crisis dating through endogenous testing.

Given the series we are testing for contagion, we define a fixed length window and move it across the sample. Each window consists of a pre-crisis period — which for this paper was set to two years — and a crisis period — which for robustness testing was defined to be of three lengths: 4, 6 and 8 months. Each window starts one week after the previous window's start. We did this for each pair of markets i and j in each test dimension (country equity, sovereign CDS, bank equity indexes).

We test each window by estimating a Vector Auto Regressive (VAR) model of the source and destination market in each period (crisis and pre-crisis), controlling for the pre-defined exogenous variables (US Federal Funds rate and Commodities index). Each VAR is calculated with a fixed lag of 5 observations in order to eliminate residual autocorrelation. We then test the *residuals* for contagion as described in section 4. The result is a set of statistics for that particular test instance $T_{i,j,D,W,L}$(where i is the source market, j the destination market, D the dimension being tested, W the period window, and L the crisis window length). Such test instance is said to be an instance of contagion if the following conditions are met:

- The volatility of the crisis period residuals must be greater than that of the pre-crisis period.
- For the FR statistic, the correlation of the crisis period residuals must be greater than that of the pre-crisis period (we are only testing one tail of the distribution).
- The tests results (Forbes-Rigobon correlation, CoSkewness Testing in both directions) must be greater than a pre-established critical value (in this paper, 5.9915, which is the critical value for the χ^2 distribution at 95% confidence and 2 degrees of freedom).

These instances of contagion which meet all conditions above are all points in time at which there was a structural break in the relationship of pairs of markets (be it correlation of coskewness). The next step is the endogenous choice of contagion periods. We opted to include all contagion periods in our analysis of results, as the aim of this paper is to validate a method for finding the periods of contagion through endogenous testing.

6. Empirical results

The empirical tests generated large volumes of data. We test contagion using 3 windows sizes and three contagion channels (bank, equity, CDS), each having its own sample size and represented countries. We have chosen to present the results in graphs with an accompanying analysis. The empirical results have shown that even in absence of precise dating, the fixed-length moving window tests were capable of identifying the

most significant periods of contagion, which is further corroborated by the fact that in most cases tests with different contagion windows agree with each other.

We present contagion graphs for visualization, in which we show the evolution of the relevant indexes (normalized towards the initial value of each index) and draw shaded areas to indicate contagion according to a color scale. The shaded areas indicate the strength of the contagion in window that starts at each date. In this paper the strength of contagion is the number of different countries for which the relevant statistic indicates contagion[4] at that date. Each graph that we show is the analysis of contagion through a specific test (we apply the *FR*, *CS1* and *CS2* tests).

Most of the events that were referred to in the following analyses can be found in US Federal Reserve [49], Deutsche Bundesbank [19, 20], European Central Bank [24] and US Federal Reserve St Louis [50]. We also use the study of Dwyer and Tkac [23] to justify some of our next arguments about the Global Financial Crisis. This paper presents a precise description of the problems that the US fixed-income market faced in this crisis.

6.1. The Global Financial Crisis

Our tests for contagion through the banking sector show evidence of contagion in the banking sector indexes throughout 2008 and into early 2009. These results are shown graphically in Figures 1 and 2. Most of this contagion is detected through structural breaks in coskewness.[5] Both coskewness tests are consistent with each other regarding countries affected and the contagion periods (with the *CS2* statistic detecting more instances of contagion). The results identify occurrences of contagion from the USA to 49 countries (out of 53) at some time in this period. The results are also consistent across all contagion window sizes tested (four, six and eight months).

< Place Figures 1 and 2 About Here. >

The number of countries affected by contagion peaks in late February and early March, which is consistent with the increasing uncertainty fueled by events such as the collapse of the subprime mortgage market stemming up to 400 billion dollars in losses (February 10th, 2008) and the nationalization of the Northern Rock (February 17th, 2008). This uncertainty persisted in spite of actions by the Federal Reserve and other Central Banks beginning in December 2007 trying to increase liquidity available to banks, culminating with a fund of 200 billion dollars made available to banks by the US Federal Reserve (March 7th, 2008). After this period, the number of countries simultaneously affected by contagion drops, and raises again in late September 2008 and early October 2008 as great uncertainty returns in the wake of the Lehman Brothers bank filling for bankruptcy and the increasing instability in the European banking sector.

The results for contagion in the MSCI equity indexes are shown graphically in Figures 3 and 4. [6] The tests for contagion through equity also show ample contagion throughout 2008, where 58 countries out of 66 tested positive for contagion. The initial identification of contagion in the equity market (which is in early 2008) is in the tests with 8-month contagion windows, then we observe contagion in the 6-month and 4-month windows. We also notice increased levels of contagion as the end dates of the windows reach the year's fourth quarter we notice. This indicates that for the general equity markets, as opposed to banks, the bulk of the contagion is concentrated at the end of each contagion period, related to the events of September and October 2008 (the Lehman collapse, the nationalization and partial nationalization of European funds, the bail out funds approved by the US and European governments). We also observe that the equity market is hit after the bank sector in our sample.

< Place Figures 3 and 4 About Here. >

[4] Contagion, in this paper, is indicated as a structural break in a statistic.

[5] We omit the *FR* test results because this test do not find significant evidence of contagion. We can provide them upon request.

[6] We omit the *FR* test results because this test do not find significant evidence of contagion. We can provide them upon request.

6.2. The European Sovereign Debt Crisis

Regarding the European Sovereign Debt Crisis, we tested for contagion originating from the following countries: Portugal, Greece, Ireland, Italy and Spain. These countries are at the forefront of most stories on the ongoing crisis. Also in accordance to most coverage, the contagion tests for the European Debt Crisis have indicated two clearly distinct periods of contagion, the first in early 2010 and the second in late 2011.

The banking sector tests suggest that contagion in the European Sovereign Debt Crisis is as widespread as in the Global Financial Crisis. The results of the *CS1* and *CS2* tests applied to study the bank and the equity markets are show in Figures 5, 6, 7 and 8.[7]

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In the first period contagion is stronger starting from February 2010 according to our *CS1* and *CS2* tests. The epicenters of this first period seem to be the uncertainty caused by the large Greek budget deficit, and downgrades in ratings of the Greek (starting in December 2009), Portuguese and Spanish debts (April 2010). By May 2010 the European Union agrees on a 750 billion dollars bailout plan and no new instances of contagion are found until the second period. This suggests that such tests may be helpful in assessing whether specific policies that are being undertaken are effective. Initially it seems to be the case, for beginning in May 2010 both the MSCI and bank sector indexes for most of the source countries show a limited recovery. However by late 2010 and early 2011 they drop once again and the second period of contagion begins.

The second period of contagion that we identify is different from the first because the contagion is more relevant at the end of each window. Analyzing the contagion windows, we note that contagion is verified initially in the 8-months windows, then the 6-months windows present some evidence and finally the 4-months windows. All of the contagion periods shown end in October 31^{th}, 2011, which is the last date of the sample period in this study. It is also important to notice that the evidence of contagion in this period it is stronger than the results that we find applying the *CS2* and *CS1* tests to study the first period in the bank sector.

This is consistent with the stronger drops in the MSCI and bank sector indexes of the source countries (and the rise in CDS spreads for their debts), and also with events such as the resignation of Portugal's Prime Minister (March 2011), Portugal's request for financial support from the European Union (April 2011) and its ratings downgrades, the further downgrade of Greece's and Ireland's debts, and the increasing uncertainty regarding Italy (which had its debt rating downgraded in September 2011) and Spain, both having to increase the yields on government issued bonds.

The equity indexes show a very similar picture, however with a different contagion strength. This indicates that unlike the subprime crisis, in which the bank sector is hit first and then the equity market, in the European crisis both markets suffer contagion at the same time with different intensities. In the bank sector most instances of contagion are in the second period, while in the equity market they occur with the same frequency in both periods with a decreased strength.

The analysis of the CDS spreads also divides the crisis into two periods. In the first period, the contagion peak is in early March 2010 as CDS spreads start to rise. The contagion peak in the second period occurs in June 2011. The results for the CDS tests are show in Figure 9. The findings of the *FR* and *CS2* tests corroborates what we observe with the *CS1* test. The results that we identify of contagion in this market is similar with our evidence in the others. The only difference is that in the CDS market we observe a higher intensity of contagion in relation to the banking sector and the equity market. [8]

< Place Figure 9 About Here. >

[7] As in the subprime crisis, the *FR* tests do not present relevant evidence of contagion in both markets. Therefore, we omit the results of this test applied in both markets. We can provide them upon request.

[8] We can provide the *FR* and *CS2* tests results upon request.

It seems to us that contagion tests can be an important tool for regulators and policy makers to assess the effectiveness of their policies and of the communication of their actions.

7. Concluding remarks

In this paper we develop a framework for the timing of the contagion in a financial crisis through endogenous testing. We show that in the case of the Global Financial Crisis and the European Sovereign Debt Crisis the timing thus obtained is consistent with the important events and the general consensus of the crisis dating.

Because of the difficulty in defining the proper dating of each crisis, we propose a contagion test which does not rely on exogenous definition of contagion dates. Our framework applies the tests developed by Forbes and Rigobon [27] and Fry-McKibbin et al. [28], however we define the period of contagion moving a window along all possible dates and testing each window for contagion. We call this approach an endogenous test, since we apply the contagion tests to study all the periods that our sample allows.

We apply three contagion tests which are the *FR*, *CS1* and *CS2* tests. Aiming to obtain detailed conclusions about our endogenous test methodology, we study three markets (the banking sector, the equity market and the sovereign CDS). We also use a large data which include 53 countries in the banking sector data, 66 countries in the equity market data and 68 countries in the CDS market data to search for contagion.

The framework obtains findings related to contagion that are justified by the facts and events that describe the Global Financial Crisis and the European Sovereign Debt Crisis. We also obtain results related to the capacity of the tests in identifying contagion. We observe that the *FR* tests generate scarce evidence of contagion in periods that the *CS1* and *CS2* tests verify strong evidence. This finding corroborates the results of Fry-McKibbin et al. [28] which affirm that the coskewness based tests identify channels of contagion that correlation based tests do not find.

Our results show that contagion is pervasive in the Global Financial Crisis and also in the European Sovereign Debt Crisis. Our approach allows identifying contagion for a wide range of markets and countries. It is our understanding that these tests might be an additional tool for regulators and policy makers to assess the effectiveness of their policies and the communication of their actions.

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Table 1: Summary of the contributions

Authors	Period	Contagion	Market	Method	Contagion evidence
Baele and Inghelbrecht [5]	1973-2007	14 European countries	Equity markets	Dynamic factor model	Mixed findings
Longstaff et al. [35]	2006-2008	CDOs - other markets in US	CDOs market	Correlation test	YES
Manconi et al. [36]	2004-2007	Securitized bond market - corporate bond market in US	Bond Market	Correlation test	YES
Martinez-Jaramillo et al. [40]	2007-2009	Mexico	Interbank market	Systemic Risk Network Model (SyRNet)	YES
Ahlgren and Antell [1]	1980-2006	Effects between Germany, Japan, UK and US and between Hong Kong, Korea, Mexico and US	Stock market	Correlation break	NO
Rijckeghem and Weder [46]	1994, 1996 and 1997	Mexican, Thai, and Russian currency crises - 18 industrialized countries	Bank lending market	Correlation test	YES
Corsetti et al. [17]	October 1997	Stock market returns in Hong Kong - 10 emerging economies as well as the G7 countries	Stock market	Correlation break	YES
Rodriguez [47]	1993-1998	Asian crisis and Mexican crisis	Stock market	Copula	YES
Candelon et al. [13]	1994 and 1997	Mexican crises in Argentina, Venezuela, Colombia, Chile and Hong Kong crisis in Indonesia, Korea, Malaysia, Singapore, Taiwan and Thailand	Stock market	Common cyclical features	NO
Aloui et al. [2]	2004-2009	US - Brazil, Russia, India, China (BRIC)	Stock market	Copula	NO
Baur and Lucey [8]	1994-2006	Thailand (July 1997), Hong Kong (October 1997) and Russia (August 1998) - eight developed countries	Stock and bond market	Test for flight-to quality, flight-from-quality and cross-asset contagion	YES
Mendoza and Quadrini [41]	1982-2008	Effects of shocks to bank equities on asset prices	Net credit market	Model's quantitative predictions	YES
Dungey et al. [21]	1998	Russian bond default and the LTCM recapitalization announcement - 12 countries	Bond market	Latent factor model	YES
Baur and Schulze [6]	1997-2001	Asia - Latin America and Europe	Stock market	Quantile regression	YES
Fong et al. [25]	1987-2008	Between financial assets (US stocks and Treasury bonds), commodities (oil and gold) and real estate assets (US Case-Shiller index)	Stock market	General Markov switching model	Mixed findings
Markose et al. [39]	2008	US banks	CDS market	Systemic Risk Ratio, Complex Adaptive System (CAS), Agent-based Computational Economics (ACE) and SCAP Stress Test	YES
Andenmatten and Brill [3]	2008-2010	Greek debt crisis - 39 countries	CDS market	Approach proposed by Forbes and Rigobon [27]	YES
Baele and Inghelbrecht [5]	1973-2007	The Mexican crisis, the Asian crisis, the Russian/LTCM crisis, the Nasdaq Rash, 09/11 terrorist attacks, the Global Financial Crisis and periods of high market volatility	Stock market	The test developed by Bekaert et al. [10] (BHN test)	Mixed findings

Table 2: Summary of the contributions

Authors	Period	Contagion	Market	Method	Evidence of Contagion
Coudert and Gex [18]	2004-2007	General Motors (GM) and Ford crisis in 2005 - US and European firms	CDS market	Dynamic measures of correlations(EWMA and DCC-GARCH)	YES
Rigobon [44]	1994-1998	The Asian, Mexican, Russian/LTCM crisis	Bond and stock markets	OLS, PCA and new procedure based in Rigobon [45]	Mixed findings
Dungey and Yalama [22]	2004-2009	US - European equity markets during the global financial crisis	Stock market	The FR test and Hong test	Mixed findings
Forbes and Rigobon [27]	1987-1996	The Asian, Mexican and 1987 U.S. market crash	Stock market	Heteroskedasticity biases tests for contagion based on correlation coefficients	Mixed findings
Fry-McKibbin et al. [28]	1997-1998 and 2007	Hong Kong crisis and the Global Financial Crisis	Real estate and equity markets	Coskewness and Lagrange multiplier tests	YES
González-Hermosillos et al. [29]	1997-1998	Asian crisis	Equity market	Model of interdependence, Bivariate and Multivariate testing, AR and heteroskedastic dynamics, Forbes and Rigobon [27]contagion test, the BKS test and the DFGM test	Mixed findings
Forbes and Rigobon [26]	1982-2000	Mexican Debt Crisis, Asian Flu, the Russian Crisis, the Brazilian Crisis, Dot-com crisis - Latin America	Bond and stock markets	GARCH model and Heteroskedasticity biases tests	NO
Bodart and Candelon [12]	1994 and 1997	Mexican crisis - 4 Latin America countries and Asian crisis - 7 Asian countries	Equity market	Frequency domain approach	YES
Cipollini and Kapetanios [16]	1997-1998	East Asian countries	Stock market	Dynamic Factor model	YES
Khan and *Ken* Park [33]	1994-1999	Asian crisis - Thailand, Malaysia, Indonesia, Korea and Philippines	Stock market	Kalman filter	YES
Mistrulli [43]	1989-2008	Italy	Interbank market	Maximum entropy method	YES
Chiang et al. [15]	1990-2003	Asian crisis - 9 Asian market and US	Stock market	Dynamic conditional-correlation model	YES
Serwa and Bohl [48]	1997-2002	6 Crisis markets - Western European markets, and emerging markets in Central and Eastern Europe	Stock market	Heteroscedasticity-adjusted correlation	YES
Baur [7]	1979-2009	Financial sector - real economy of ten sectors in 25 developed and emerging countries	Stock market	Test four alternative types of contagion	YES
Mink and De Haan [42]	2010 (all year)	Greece - 48 European banks (that comprehend 17 European countries)	Stock market	The method examine excess returns in response to particular events, which are news about Greece and about Greek bailout	Mixed findings
Asgharian and Nossman [4]	1982-2007	US - 11 European coutries	Equity market	A stochastic volatility model with correlated jumps and a spillover model	YES
Grammatikos and Vermeulen [30]	2003-2010	Global Financial Crisis and European Sovereign Debt Crisis - 15 EMU countries	Stock market	Their is based on GARCH and factor models	YES

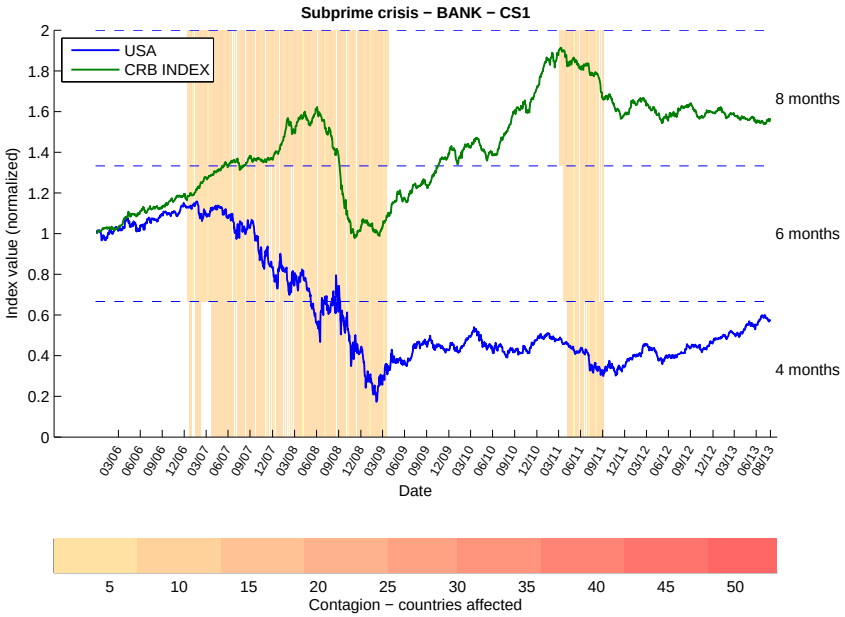

Figure 1: Global Financial Crisis contagion - Bank sector - CS1

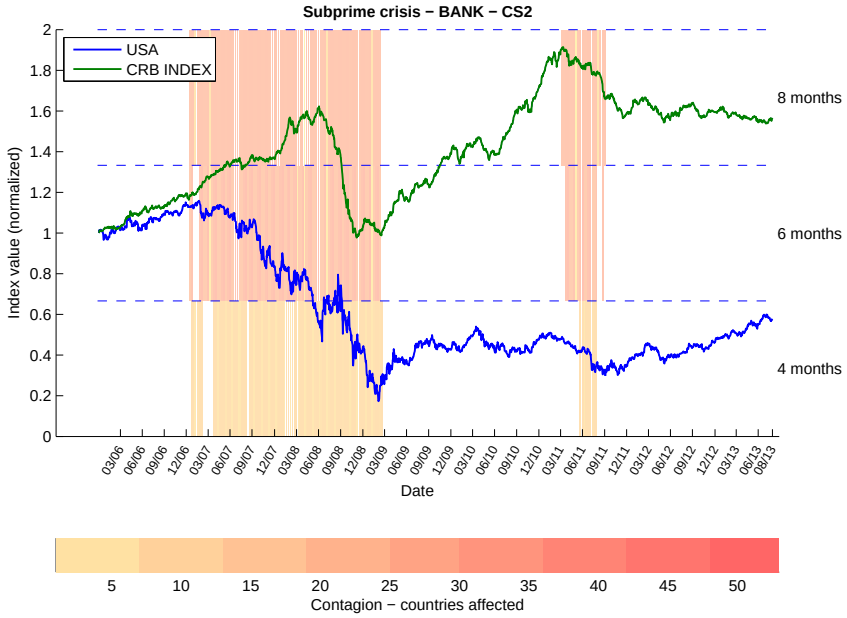

Figure 2: Global Financial Crisis contagion - Bank sector - CS2

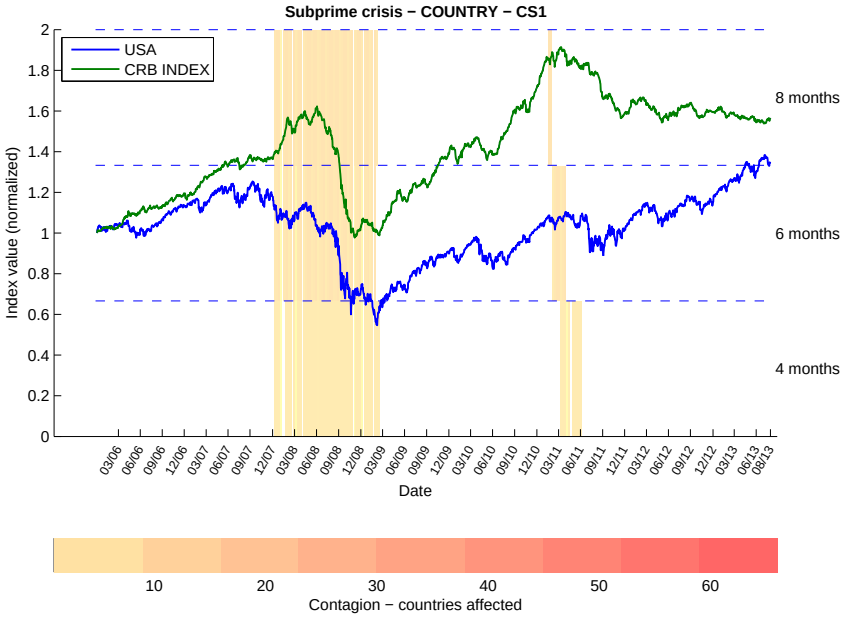

Figure 3: Global Financial Crisis contagion - Equity - CS1

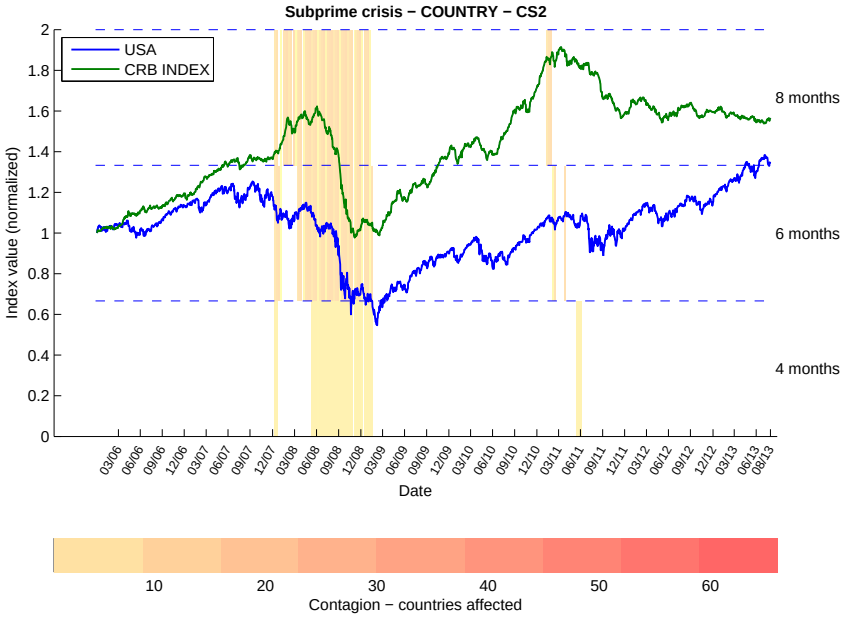

Figure 4: Global Financial Crisis contagion - Equity - CS2

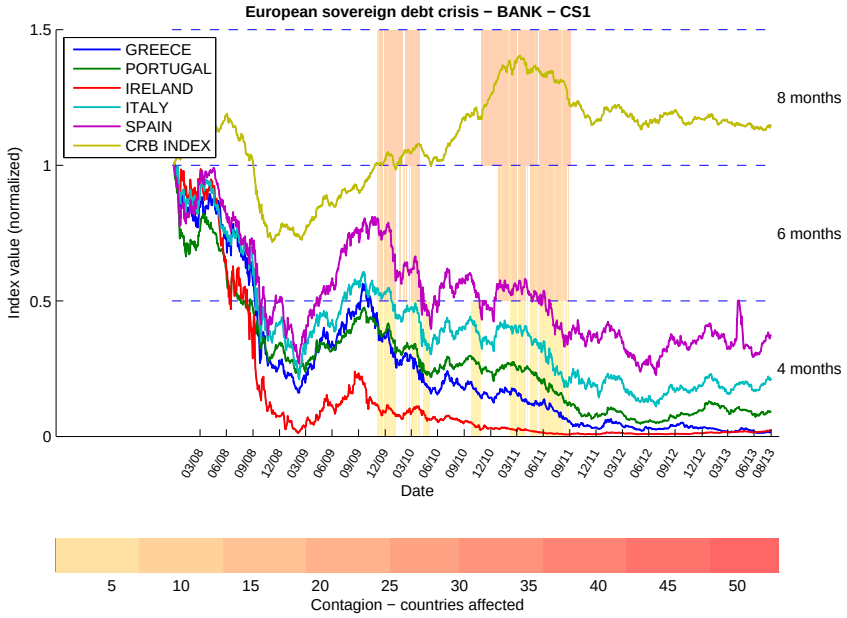

Figure 5: European Sovereign Debt Crisis contagion - Bank sector - CS1

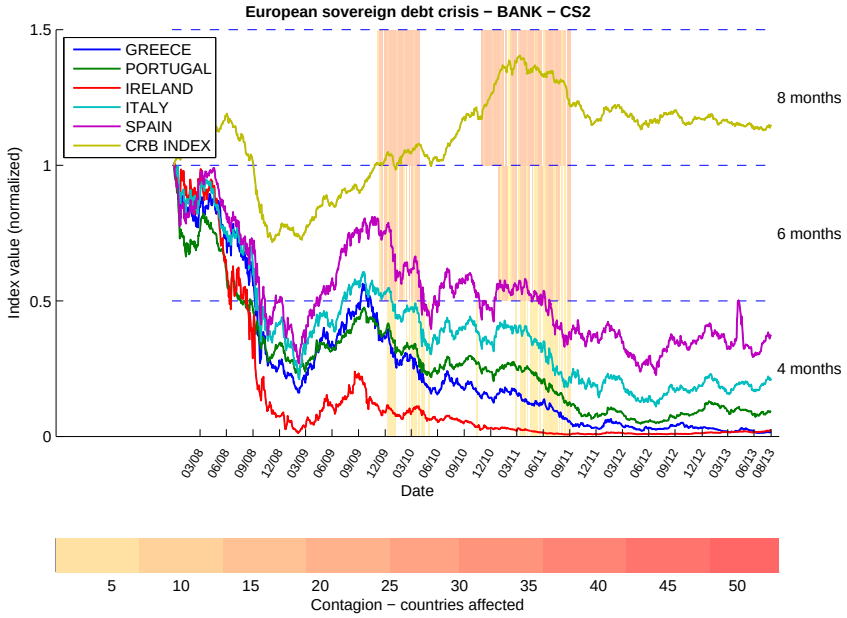

Figure 6: European Sovereign Debt Crisis contagion - Bank sector - CS2

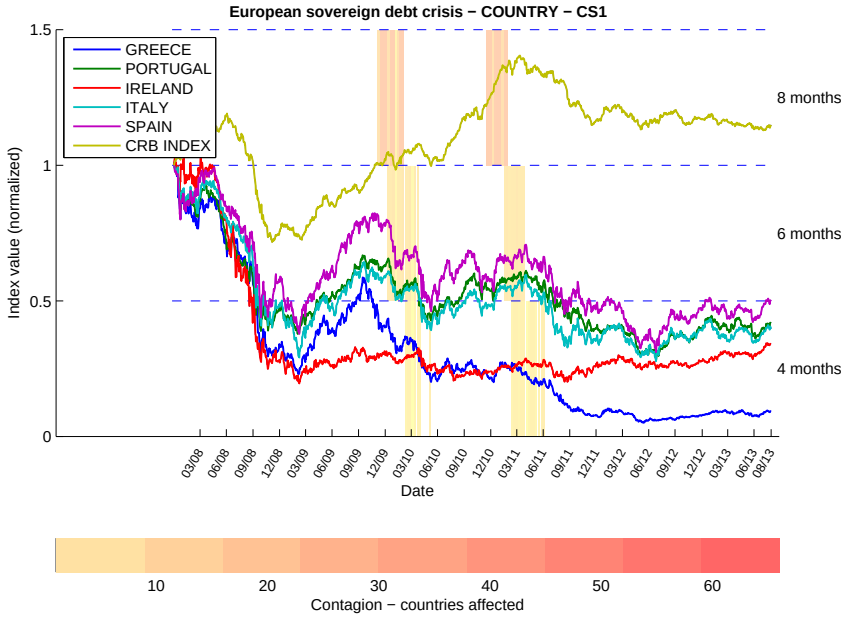

Figure 7: European Sovereign Debt Crisis contagion - Equity - CS1

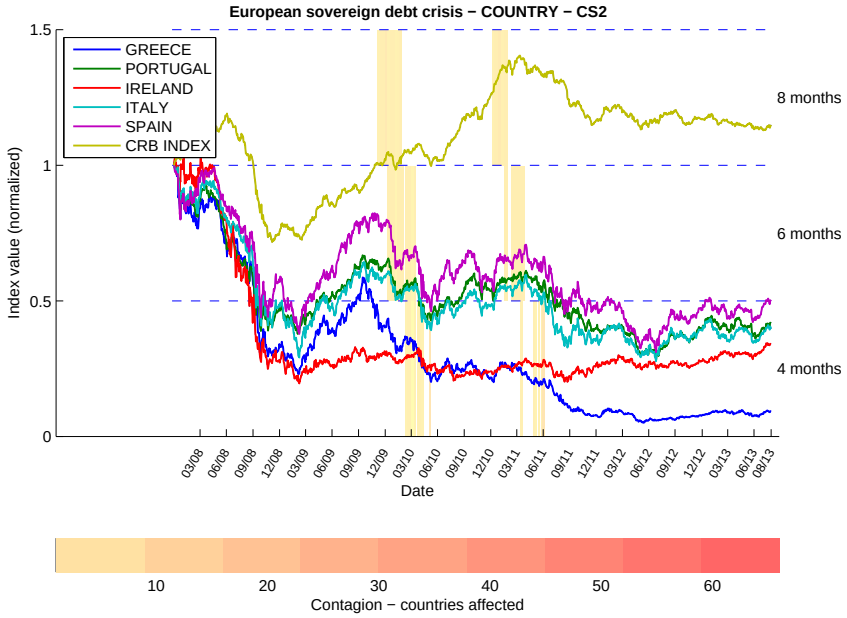

Figure 8: European Sovereign Debt Crisis contagion - Equity - CS2

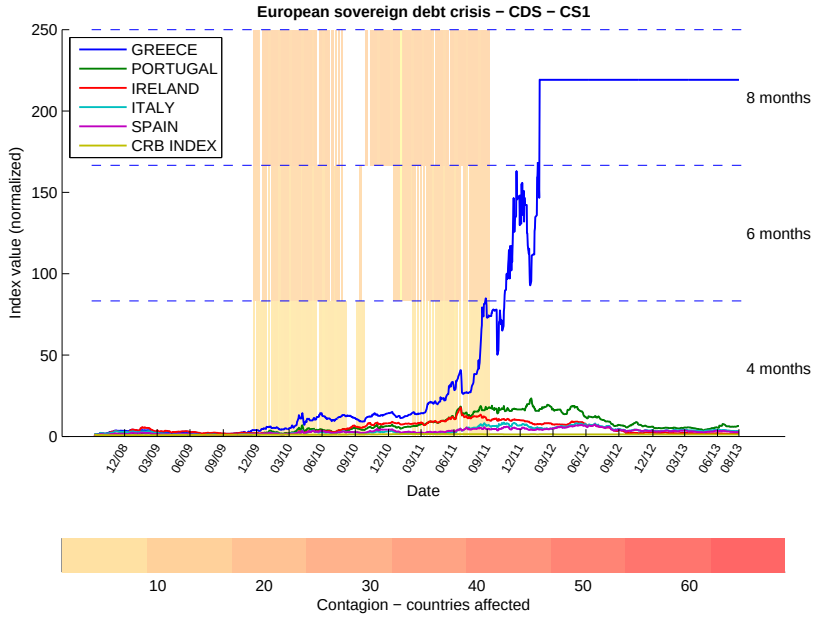

Figure 9: European Sovereign Debt Crisis contagion - CDS - CS1