BANK-SOVEREIGN CONTAGION IN THE EUROZONE: A PANEL VAR APPROACH

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Abstract

We study the empirical behaviour of sovereign and bank default risk over the period 2005:1-2014:10 within a panel VAR framework. We ask the question what is the correlation of default risk if we control for the effects of common external systemic risk factors. We also attempt to estimate the contribution of these systemic factors through a variance decomposition analysis. We conclude that the European banking sector reacted homogeneously during the 2007:1-2009:12 period but after 2010 peripheral euro-area countries became more "idiosyncratic". Also, we have calculated spillover effects among the variables in the panel VAR models. They indicate that the total contagion in the system did not change between the two sample periods and that peripheral countries are not to blame for the global financial crisis since they have been net receivers of shocks.

JEL classification: C35, C58, G15, G18

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1. Introduction

The outbreak of the sub-prime mortgage loans crisis and the ensuing near-collapse of a number of major financial institutions around the world forced governments to intervene in an attempt to prevent their banking sectors from collapsing. Various lines of action were adopted varying from injecting capital to their dilapidated banks and setting up bad banks to providing guarantees for banks' debt. These measures inevitably led to a dramatic increase of fiscal deficits and a severe deterioration of the sovereign debt viability in many countries with a subsequent consequence the downgrading of their creditworthiness. The ability of governments to bail out their "too-big-to fail" banks worsened and this then fed back to the credit ratings assigned to those banks. The outcome of these developments is the observed increase of the correlation between sovereign and bank default risk (see, Acharya et al., 2012; BIS, 2011). The issue of the close relationship between those two variables has acquired an interesting dimension when it is applied to the euro-area member countries. The common monetary policy shared by these countries has enhanced the risk of transmission of shocks from one country to other union member countries. This possibility was so worrying that speeded up the decisions that led to the introduction of new mechanisms like the European Financial Stability Fund (EFSF) and the Banking Union.

In this setting therefore an interesting topic for research has been the empirical determination of the relative contribution, made to the correlation between sovereign and bank credit risk, of common factors related to the systemic credit and liquidity risk conditions vis-à-vis the contribution associated to domestic and idiosyncratic factors. A convincing answer to this question is of paramount importance since the implications for the appropriate policy recipe are quite distinct. In the case where the systemic factors are the main contributors to the price of risk then the policy should be designed towards alleviating the causes of the problem, e.g. by introducing the EFSF, by creating the Banking Union, or by adopting the proposed joint issue of euro-area bonds. In the opposite case, when idiosyncratic factors prevail, the measures should be directed towards resolving the macroeconomic and financial instabilities of the countries under stress.

In the present paper we attempt to address this issue within the framework of a panel Vector Autoregressive Model (pVAR). This type of model is able to capture dynamic interdependencies, especially when scarcity of time-series data is a problem, and at the same time to account for cross sectional heterogeneities. Our testing strategy is to split our data between countries mostly hit by the sovereign debt crisis and those which appear to have escaped unscathed from it. Furthermore, we split each one of the previous two groups to three sub-periods representing the pre-2007 tranquil period, the global financial crisis period 2007-2009 and the Euro-area sovereign debt crisis period after 2010. Our main focus of interest is on two variables, the Credit Default Swap (CDS) spreads on sovereign and bank debt, when we control for the presence of variables representing global and euro-area credit and liquidity risk factors. We adopt the definition of contagion which describes a situation of cross-market correlation when the effect of common shocks has been controlled for. This approach of estimating "pure-contagion" has been widely used in the literature and it is contrasted with a "fundamentals-based contagion", also known as "spillovers" or "interdependence", which defines a situation of increased correlation between two sectors due to the presence of fundamental links through the financial or real sector of the economy (see among others, Kaminsky and Reinhart, 2000; or Gomez-Puig and Sosvilla-Rivero, 2014). In our case we associate the default risk in the european and global capital markets with CDS indices applying to these markets. Therefore we proceed under the assumption that the implications of shocks which are relevant for a great number of countries and/or markets will be captured by these indices and the "quasi-pure contagion" between different markets will be revealed by a "residuals-based" analysis. We make use of the term "quasi-pure contagion" because we control only for external common factors. In this sense the residual correlation will pick-up domestic shocks which work their effect through interconnected markets as well as the effect of idiosyncratic factors which are associated with the existence of asymmetric information, irrationality and herding behavior on the part of the investors (Masson, 1999). In conclusion, firstly we intend to test, for different groups of countries, if the residuals correlation changed over the crisis period when external factors have been accounted for, and secondly to measure quantitatively the contribution of those external factors in explaining the behavior of CDS spreads on sovereign and bank debt.

Our results make a contribution to a literature that only recently has gained importance, due to the european sovereign debt crisis, namely the examination of the default risk transmission at the bank and sovereign level (see, e.g. De Bruyckere et al., 2013). We deviate from previous studies first, by choosing to work with a pVAR methodology which relies on both the time and the cross sectional dimension of the variables in order to explain the underlying processes. Second, we test for changes in residual correlations over three different time periods and for two groups of countries. We document an increase in contagion, as define above, between the pre-2007 period and both the sub-prime crisis period 2007-2009 as well as the period after 2010. We also report that contagion changed between the second and third period only for peripheral euro-zone countries while it remained intact for the core countries. Third, we present results through Generalized Forecast Error Variance Decompositions that over the 2007-2009 period the contribution of the sovereign default risk to the bank default risk, and vice versa, is minimal, for both core and peripheral countries. Over the same period the only external factors that contribute to sovereign and bank default risk are those expressed by the CDS index covering the North America and emerging markets. During the 2010-2014 time interval, in addition to the North America CDS index, the European CDS index appears to influence the price of sovereign default risk and moreover the price of bank default risk for the peripheral countries only. For all the sub-periods and groups we were unable to establish the presence of liquidity risk and volatility indices for the behavior of sovereign and bank risk. Also, in all these cases we were unable to document a contribution from the peripheral countries' default risk to the european CDS index or the volatility indices. Finally, we present evidence for the spillover effects of shocks to each one of the variables in our pVAR model. We apply the methodology developed by Diebold and Yilmaz (2009, 2012), which is based on forecast error variance decomposition of VAR models, in order to measure the spillovers among the variables in VAR models. The general picture is that the overall spillover index remained almost the same between the 2007-2009 and 2010-2014 for both core and peripheral countries. We also document strong spillover effects between sovereign and bank risk, over 2010-2014, for peripheral countries only.

The remainder of this paper is organized as follows. In section 2 we present a short review of the relevant literature. Section 3 presents the data and the testing methodology. Section 4 reports our results and some empirical robustness checks. Section 5 summarizes the conclusions and discusses the policy implications.

2. A literature review on bank / sovereign contagion.

This paper touches upon two strands of literature. The first, and more general one, is about contagion in the financial system while the second is on the spillover / contagion effects from the recent sovereign risk crisis in Eurozone. The dominant economic thinking, up to fifteen years ago, treated the private sector as composed of rational agents whose decisions relied on inter-temporal optimization with full knowledge of the distributions of future returns. In such a world no defaults could have existed, finance did not matter for the real economy and banking, and capital markets in general, were absent from macroeconomic models. Also, shocks, if any, from the financial sectors were considered to be short-lived and their implications self-sustained.

The events that shook the financial world in the 1990s, like the Mexican peso crisis of 1994, the Asian "Flu" of 1997, the Russian financial crisis of 1998 and the burst of the dot-com bubble in 2001, have given the impetus for the growth of an enormous literature on contagion in the financial system. A common theme around which this literature revolves is the identification of systemic risks. In the context of the recent sovereign risk crisis, Longstaff et al. (2011) and Ang and Longstaff (2011) analyse sovereign spreads and conclude that sovereign credit risk should be attributed mainly to global systemic financial factors and only secondary to local economic fundamentals. Beirne and Fratzscher (2013) stress the importance of a "wake-up call" factor that makes the pricing of financial assets to be more sensitive to economic fundamentals during stressed periods than in tranquil times. In the same spirit, Gómez-Puig and Sosvilla-Rivero (2014) identify periods of increased causality between sovereign bond yield spreads and then proceed to assess the determinants of those periods. Their results suggest the importance of variables proxying not only macro-fundamentals but market sentiment as well. Also, Georgoutsos and Migiakis (2013) put an emphasis on the importance of uncertainty and investment confidence conditions in the pricing of sovereign debt.

On the other hand, De Santis (2012) examines the spillover effect from ratings changes and concludes that a downgrade of Greek sovereign bonds is associated with an increase in spreads of other countries with weak fiscal fundamentals. This result is replicated by Bhanot et al. (2014) who identify spillover effects from the Greek bond market to other peripheral countries' stock and bond prices on the days when news were released on the Greek economy.

One particular strand of this literature examines the contagion between sovereign and bank default risk. This is a sub-section of a major branch of the literature that looks at systemic risks, multiple failures of financial institutions and financial stability (Allen et al. 2010). One direction of this research looks at the channels through which sovereign risk has an impact on financial institutions. BIS (2011) identifies four risk transmission channels, i.e. the asset holdings, the collateral, the ratings and the guarantee channels. Angeloni and Wolff (2012) fail to find strong evidence of a correlation between Eurozone banks' asset holdings on peripheral sovereign debt and their stock market returns. Rather, bank stock prices appear to be more associated to the risk of the country these banks are located in. Correa et al. (2012) provide indirect evidence that European banks didn't have easy access to the U.S. money markets due to the reduction of the value of collateral, in the form of sovereign debt, they could provide. Arezki et al. (2012) find that downgrades of sovereigns have implications not only for the country involved but that they spillover to other markets and countries as well. Finally, a number of authors studied the "transfer of risk" between banks and sovereigns and found that the implicit guarantee offered by the governments had produced causality, before bail-outs, running from banks' CDS spreads to sovereign risk spreads (Ejsing and Lemke, 2011). De Bruyckere et al. (2013) identify contagion with the residuals correlation, when the impact of common factors has been accounted for. They establish that contagion exists between sovereign and bank risk, during the recent euro-area crisis, and then they proceed to investigate bank and country specific factors that explain this excess correlation. They provide empirical evidence for the presence of three channels: a guarantee, an asset holdings and a collateral channel. Alter and Beyer (2012) expand on the work of Diebold and Yilmaz (2009, 2012) and they provide calculation of contagion indices between banks and sovereigns. They document increasing spillover effects from banks to sovereigns and vice versa during periods of stress, among the EU/IMF program countries, which however decline sharply after the implementation of bailout procedures.

3. Data description and econometric methodology

We employ a pVAR methodology. In a pVAR all the variables in the system are treated as endogenous, as in a traditional VAR model, and also, in resemblance to a panel-data approach, the presence of unobserved individual heterogeneity is being considered too. Consider that Y_t is a stacked version of a *Gx1* vector of endogenous variables y_t, each one of which corresponds to *N* units, i.e. $Y_t = (y'_{1t}, y'_{2t}, ... y'_{Nt})$. Then a first order pVAR is given by:

$$y_{it} = A_0 + A_1(l) y_{i,t-1} + f_i + u_t, \quad i = 1,...., N \quad t = 1,...T \qquad (1)$$

where $u_t \sim iid\ (0,\Sigma)$ and f_i expresses the fixed effects.

In the pVAR shown in (1) we do not allow for dynamic interdependencies in the sense that the lags of the endogenous variables of the same unit only appear. Also, we do not allow either for cross sectional heterogeneities, since A_0 and A_1 are the same across all units, or for static interdependencies since we assume that $\text{cov}(u_{it}, u_{jt}) = 0$, for $i \neq j$ (see Love and Zicchino, 2006, Canova and Ciccarelli, 2013).

In our case we employ *G*=8 variables and N=5 units which represent either core euro zone countries (Austria, Belgium, Germany, France and The Netherlands) or peripheral euro zone countries (Spain, Portugal, Italy, Greece, Ireland). We have also estimated the model in (1) for a case of *N=3* non euro-area countries (Sweden, Denmark, United Kingdom). The variables refer to the arithmetic returns of sovereign and bank 5-year CDS spreads (see also De Bruyckere et al. 2013). For the latter variable the CDS spread is calculated as the weighted average of the CDS spreads of the banks which are included in our sample, for each particular country. The weights are calculated as the percentage of the total bank assets of each country that correspond to a specific bank (Table 5a presents the banks used in our study).[1] The global default risk conditions are represented by the CDX index, the world capital markets "fear" condition by the VIX-CBOE volatility index and the world liquidity conditions by the TED variable which is defined as the difference between the interest rates on interbank loans and on short-term U.S. government debt. Finally, the corresponding variables for euro-zone are the iTraxx for Europe, the Vstoxx and the KFW which is defined as the yield spread between German federal government bonds and German KfW agency bonds (all the variables have been transformed to arithmetic returns except for the liquidity variables).[2] The frequency of the data is monthly and they cover the period 2005:1 to 2014:10 (Table 1 offers a description of the variables and Table 2 some descriptive statistics on the levels of the data). The model (1) is estimated on three sub-periods which are: 2005:1-2006:12, 2007:1-2009:12 and 2010:1-2014:10. The first period covers the calm era of the world capital markets, the second one the sub-prime mortgage loans crisis and the third one the European sovereign debt crisis.[3]

Our chosen test for statistical differences in "quasi-contagion" between sovereign and bank CDS spreads, for different time periods and groups of countries, is the Fisher transformation of excess correlation coefficients. Fisher's z transformation converts Pearson's r correlation to a normally distributed variable z, which is defined as $z = 0.5[\ln(1+r) - \ln(1-r)]$. The standard error of z is given by $\sigma_z = (\sqrt{N-3})^{-1}$, where N is

[1] The CDS spreads have been obtained from Bloomberg, Credit Market Analysis. All the other data have been obtained from Datastream.

[2] Ejsing *et al.* (2012) present a justification for the choice of the KfW variable.

[3] A large number of papers date the start of the sub-prime crisis in the second quarter of 2007 and the sovereign risk crisis in the last quarter of 2009. Robustness tests have shown that our sub-sample choice is not critical for the evidence that is documented in this paper.

the number of observations. The test-statistic, *Z,* for the difference between two measures of excess correlation is given then by:

$$Z = \frac{(z_1 - z_2)}{\sqrt{\frac{1}{\sqrt{N_1} - 3} + \frac{1}{\sqrt{N_2} - 3}}} \quad , \qquad (2)$$

where N_1 and N_2 represent the number of observations of the two samples and Z is normally distributed (see, Hoyos and Sarafidis, 2007).

For the estimation of the pVAR we used the Stata program of Love and Ziccino (2006). The estimation method is the GMM where the individual country fixed effects have been removed through the Helmert transformation by applying forward mean-differencing.[4] Next, we apply a Cholesky decomposition of the variance-covariance matrix in order to obtain the dynamic response of the VAR dependent variables to shocks to each one of the variables. Impulse responses are obtained within a band representing a 95 percent confidence interval estimated by Monte Carlo simulations (200 iterations). Then, variance decompositions are calculated in order to provide a measure of the proportion of the movements in the dependent variables that are due to their own shocks or shocks to the other variables in the VAR model. We rely on variance decompositions in order to determine the contribution of systemic risk factors to the behaviour of sovereign and bank CDS spreads as well as the contribution of each one of the latter two to each other. Since the ordering of the variables has an effect on both the impulse responses and the variance decompositions we have also run robustness checks for the results we report. In a single case when the results

[4] The standard mean-differencing is inappropriate in our case since it would give biased estimates because of the correlation between lagged dependent variable regressors and the fixed effects (Arellano, 2003).

proved to be sensitive to the ordering, due to a high recorded residual correlation, we applied also the Generalized Impulse Response Analysis of Pesaran and Shin (1998).[5]

In the last part of our analysis we have applied the methodology of Diebold and Yilmaz (2009, 2012) in order to measure the intensity of the spillover effects from shocks to each one of the variables. This methodology relies on Generalized Impulse Response Functions (GIRF), obtained as shown in Pesaran and Shin (1998), which permits the calculation of a spillover matrix. The rows of this matrix show the individual impact, over a number of periods, of a shock to one variable (*impulse variable)* on each one of the other variables (*response variables*) in the system as well as the total sum of the impacts on all the variables (*Sum out*). In a similar way the columns of the matrix show the impact received of an individual variable from shocks on each one of the other variables as well as the total received impact (*Sum in*). This matrix facilitates the identification of the variables that are responsible for the instability caused in the system and it offers a *contagion index* which measures the total spillover effects. Through this approach we are able to offer supplementary evidence on the main drivers of sovereign and bank default risk over different euro-area zones and periods.

4. Empirical Evidence

We start with the presentation of panel unit root tests for the all the variables in our pVAR model. We have applied a batch of different test which gave us similar, qualitatively, results. Therefore we report, in Table 3, only the results from the Im et al. (2003) panel unit root test statistic which show that not in a single case we were not able to reject the null hypothesis for the existence of a unit root.

[5] Lütkepohl (1991) argues that the ordering of the variables makes little difference when the residuals' correlation is small.

In order to determine the number of lags in the pVAR model we report in Table 4 the overall coefficient of determination (CD) and from the Moment and Model Selection Criteria (MMSC) developed by Andrews and Lu (2001) the MMSC-Akaike's information criterion (MMSC-AIC). The evidence is supportive to the choice of one lag. Andrews and Lu's MMSC are based on Hansen's J statistic, which requires the number of moment conditions to be greater than the number of endogenous variables, and they conclude that the MMSC-AIC criterion works best, in comparison to other competitors, in small samples as the case is in this paper. In Table 6 we report evidence on the stability properties of the estimated pVAR model. The stability of the pVAR requires the moduli of the eigen-values of the dynamic matrix to lie within the unit circle which is the case in our estimated model. [6]

In Table 7 we present the results concerning the residual correlation between sovereign and bank CDS spreads. First, we note that during the period 2005:1-2007:12 the residual correlation was negative, although small in absolute terms, for both core and peripheral euro-zone countries. This is interpreted as providing support to the argument that there might have been a transfer of default risk from the banking sector to sovereign debt. Then, we test the hypothesis that the residual correlation was the same between the core and peripheral countries. The reported value of the Fisher test statistic indicates that the null hypothesis cannot be rejected. Then we apply the same test for the other two periods and we manage to reject the null that the residual correlations are the same for the last period of the

[6] The evidence in this section refers to the estimated pVAR for the entire sample period (2005:1-2014:10) and for all euro-zone countries. Similar qualitatively results have been obtained however for the sub-samples used in the rest of this paper and they are available upon request. Also we have excluded Greece from the set of peripheral countries due to the fact that sovereign CDS contracts did not exist after 2012. However we have run the models with Greece included, using instead sovereign bond yield spreads, and the evidence is almost identical to the one presented here. A preliminary Granger causality analysis, also, shows that all variables are *Granger caused*, and *Granger cause,* at least one other variable in the system and therefore are treated as endogenous.

sovereign risk crisis, 2010:1-2014:10, only. This result is attributed to the substantial increase of the residual correlation for the peripheral counties to a value of 0.7239. This result offers support to the argument that the consequences of the management of the sub-prime loans crisis, after 2010, have strengthened the links between the public and the banking sector in peripheral euro-zone countries. The same piece of evidence is also obtained for non-euro-area countries (United Kingdom, Denmark and Sweden) where we record a substantial increase in the residual correlation. This is in accordance, at least for the U.K., with the public debt increase that resulted from the rescue operations in their banking sector. We next test the hypothesis that the residual correlation has remained the same over the three sub-periods for each one of the two groups of countries. The values of the Fisher test statistic reveal that we are unable to accept the null, that the correlations have remained the same, when the basis of the comparison is the first period. However, when the period of reference is the second one and we test against it, the residuals correlation of the third period, we reject the null only for peripheral countries. This again reinforces the conclusion that even when we take into account the impact of external credit conditions the debt problems of the sovereigns and their banks have become inextricably interwoven.

In order to assess the contribution of external risk factors in the behaviour of sovereign and bank CDS spreads, we calculated their variance decomposition. The results are presented in Tables 8, 9 and 10 for the three consecutive testing periods. Our main interest is on the bottom two lines of the matrices with the results. In Table 8a, for the core countries, there is not a single case where a variable contributes more than 10% to the variance of the sovereign and bank CDS spreads (except for the own effect of course). For the peripheral countries however, we report that the CDX and iTraxx variables contribute more than 10% towards explaining the variance of sovereign CDS spreads. For the peripheral banks we get a similar pattern of results with the only difference that the TED variable, instead of the iTraxx, appears to be an important contributor (Tables 8a, 8b). In the second period, 2007:1-2009:12, we also record that the only "external risk" variable that contributes substantially to the sovereign and bank CDS spreads is CDX, and its influence is stronger for the peripheral countries (Tables, 9a, 9b). In the third period it is worth noticing that iTraxx starts to influence substantially the two CDS spreads. This change takes place at the expense of the influence exercised by the CDX variable. In conclusion, we can summarize by stating that the global default risk factors, expressed by the CDX variable, influenced substantially the CDS spreads during the sub-prime loans crisis but their impact was diminished during the sovereign risk crisis to the benefit of the variable expressing the euro-zone default risk situation, i.e. iTraxx. For the non- euro-area countries the influence of the aforementioned variables was substantial for the explanation of bank CDS spread only (Table 10c).

The results we report above are robust to a change in the ordering of the variables in the Choleski decomposition. There has only been one exception, this being the peripheral countries in the third period. We addressed this problem by calculating variance decompositions from the estimation of GIRFs. The results are reported in Table 11 for two cases, when the shocks originate either from sovereign CDS spreads or from banks' CDS spreads. The results confirm the importance of the CDX and iTraxx variables, as reported above, but they also indicate the close interaction between sovereign and bank default risk. This result is also in line with the evidence provided from the Fisher test for the same period.

In Figures 1-6 we present the Generalized Impulse Responses for two variables, the sovereign and bank CDS spreads, when they react to themselves and one to the other. In Figures 1 and 2 we record the negative, initially, reaction of sovereign (bank) CDs spreads to shocks in bank (sovereign) CDS spreads. This reaction turns to positive in the other two sub-periods. We also record that the reaction of spreads to shocks got much larger in the second period and declined slightly during the third period (Figures 3-6).

The next step of our investigation is the calculation of the total spillover effect caused by each variable in our system to each one of the others as well as its aggregate effect. We focus our attention to the *Sum Out* and *Sum In* columns and rows respectively which record the aggregate impact of shocks sent to the other and received from the other variables and especially to the last row that reports the *Net* impact. During the 2007:1-2009:12 period peripheral sovereign and bank CDS appear to receive a greater amount of shocks from the one the sent to other variables in the system (the *Net* value is negative but small in absolute terms). On the other hand, core banks appear to be *net senders* of shocks to the others (Table 12a, 12b). This is important evidence since it gives support to the argument that core banks, if any, were to blame for disturbing the world financial system and that the peripheral sovereigns and banks were the "victims" of this situation. Also, the contribution of spillovers from shocks on bank CDS to those of sovereigns, and vice versa, is very small. For the rest of the model we report that the CDX, iTraxx and the volatility indices had a positive net contribution to the total spillover effects. During the third period, 2010:1-2014:10, the picture from the previous period remains the same. Again peripheral banks and sovereigns appear to be *net receivers* of shocks produced elsewhere in the system and the same applies now for the core countries' variables as well. The overall picture is that now the global credit and liquidity risk factors appear to have a much smaller contribution to the explanation of total spillover effects. This implies that although the total spillover index for the two sub-periods is the same, the importance of idiosyncratic and internal factors in the explanation of the spillover of system shocks is much stronger. This is evident when we look at the high recorded number of the spillover effect from peripheral banks to sovereigns and vice versa.

5. Concluding remarks

We have studied the empirical behaviour of sovereign and bank credit risk over the last seven years of financial turmoil within a panel VAR framework. We have managed to identify an almost common pattern of transmission between those two variables for both core and peripheral countries over the period 2007:1-2009:12. This conclusion is based on tests for correlation index differences and on the composition of variance decompositions. During the european sovereign risk period, 2010:1-2014:10, we discovered a different pattern. The residual correlation for the core countries has remained the same but it has increased for the peripheral countries. This is an indication of a changing regime for the peripheral countries where systemic factors have receded in favour of domestic / idiosyncratic factors. Finally, we have calculated spillover effects among the variables in the pVAR models. They indicate that the total contagion in the system did not change between the two sample periods. They also show that for both periods peripheral countries have been net receivers of shocks generated elsewhere in system.

The policy implications of our results stem from the fact that the European banking sector appears to be dichotomized after 2010. In peripheral countries the sovereign and bank risk are much more interrelated and this simply mirrors the prevalence of idiosyncratic / domestic factors in the generation of these risks. Also the results show that peripheral countries are not to blame for the global financial crisis since systemic risk factors appear to influence them more than those countries affect the global systemic risk factors in return. Of course there remains an open question whether this piece of evidence is the outcome of measures already taken in Eurozone over the last years, i.e. the creation of the European Stability Mechanism, the actions of the European Central Bank and the creation of the Banking Union.

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Table 1: Description of endogenous variables

Variable name	Description
Sov_CDS	Sovereign CDS
Bank_CDS	Bank CDS
CDX	The family of tradable CDS indices covering North America and emerging markets
VIX	The volatility index of S&P500
TED	The difference between the interest rates on interbank loans and on short-term U.S. government debt
iTraxx	iTraxx Europe main index (125 investment grade companie, all sectors)
Vstoxx	The volatility index of EURO STOXX 50
KFW	The yield spread between German federal government bonds and German KfW agency bonds
Eurostoxx	EURO STOXX 50 Index (50 stocks from 12 eurozone countries)

Table 2 : Descriptive Statistics

Variables	Mean	Max	Min	Std. Deviation	No Obs
Sovereign CDS	0.04800	0.25539	-0.64285	1.69051	826
Bank CDS	0.05674	0.36200	-0.90396	4.8845	826
CDX	0.04166	1.32944	-0.47777	7.375	826
VIX	0.01995	0.20980	-0.31962	0.90750	826
TED	0.06423	0.45387	-1.78796	2.3971	826
iTraxx	0.01885	0.18342	-0.38051	1.07953	826
Vstoxx	0.01993	0.19731	-0.28612	0.91785	826
KFW	0.02950	0.21835	-0.69163	1.03214	826
Eurostoxx	0.00173	0.05001	-0.14694	0.14688	826

Table 3 : Panel-data unit-root tests

Panel	*Critical values*			*Test stat. (p-value)*	
	1%	**5%**	**10%**	***Sov. CDS***	**Bank CDS**
Core	-2.40	-2.15	-2.01	-9.88 (0.00)	-9.80 (0.00)
Core 1st	-2.46	-2.18	-2.04	-6.09 (0.00)	-5.52 (0.00)
Core 2nd	-2.43	-2.16	-2.02	-4.55 (0.00)	-5.37 (0.00)
Core 3rd	-2.42	-2.16	-2.02	-7.10 (0.00)	-6.31 (0.00)
Peripheral	-2.40	-2.15	-2.01	-9.52 (0.00)	-9.83 (0.00)
Peripheral 1st	-2.46	-2.18	-2.04	-4.73 (0.00)	-5.12 (0.00)
Peripheral 2nd	-2.43	-2.16	-2.02	-5.09 (0.00)	-5.18 (0.00)
Peripheral 3rd	-2.42	-2.16	-2.02	-7.83 (0.00)	-7.66 (0.00)
Non Euro-area	-2.42	-2.16	-2.02	-6.98 (0.00)	-7.00 (0.00)

Panel	*Test stat. (p-value)*		
	CDX	***iTraxx***	***VIX***
Core/Peripheral	-11.47 (0.00)	-9.77 (0.00)	-11.45 (0.00)
Core/Peripheral 1st	-5.48 (0.00)	-5.42 (0.00)	-7.03 (0.00)
Core /Peripheral 2nd	-4.54 (0.00)	-4.97 (0.00)	-4.99 (0.00)
Core/Peripheral 3rd	-8.95 (0.00)	-7.58 (0.00)	-8.89 (0.00)
Non Euro-area	-8.95 (0.00)	-7.58 (0.00)	-8.89 (0.00)

Panel	*Test stat. (p-value)*		
	Vstoxx	***TED spread***	***KfW spread***
Core/Peripheral	-11.62 (0.00)	-13.13 (0.00)	-11.95 (0.00)
Core/Peripheral 1st	-6.34 (0.00)	-6.45 (0.00)	-5.76 (0.00)
Core /Peripheral 2nd	-5.21 (0.00)	-7.12 (0.00)	-7.02 (0.00)
Core/Peripheral 3rd	-8.93 (0.00)	-8.20 (0.00)	-8.97 (0.00)
Non Euro-area	-8.93 (0.00)	-8.20 (0.00)	-8.97 (0.00)

Note: The reported values refer to the Im-Pesaran-Shin (2003) panel unit root statistic under which the panels contain a unit root under the null hypothesis. Variables refer to arithmetic returns except for the TED and KfW spreads.

Table 4: Lag-order selection statistics for panel VAR estimated using GMM

Lag	CD	MAIC
1	0.433	2.09e-29
2	0.678	1.66e-28
3	0.781	9.14e-28
4	0.861	3.81e-27

Note: CD is the overall coefficient of determination and MAIC the MMSC-Akaike's information criterion developed by Andrews and Lu (2001).

Table 5a: Banks per country

This table shows banks per country used. It contains the 34 banks used in our analysis. The home country for each bank is also reported. We do not use all of the 14 home countries reported in all periods. The reason is that in the cases of Greece, Ireland and Norway we do not have both Sovereign and Bank CDS.

Banks per Country					
No.	**Country**	**Bank**	**No.**	**Country**	**Bank**
1	Austria	Erste AG	19	Netherlands	SNS Reaal
2	Belgium	Dexia	20	Norway	DNB
3	Belgium	KBC	21	Spain	Bilbao Vizcaya
4	Denmark	Danske A/S	22	Spain	Banco Popular
5	France	BNP Paribas	23	Spain	Santander S.A.
6	France	Credit Agricole SA	24	Spain	Sabadell
7	France	Societe Generale	25	Portugal	Comercial Port.s
8	Germany	Commerzbank AG	26	Portugal	Espirito Santo
9	Germany	Deutsche BankAG	27	Italy	Monte Paschi
10	Sweden	Enskilda	28	Italy	Mediobanca
11	Sweden	Nordea Bank	29	Italy	Popolare di Milano
12	Sweden	Handelsbanken AB	30	Italy	Unicredit
13	Sweden	Swedbank	31	Italy	Intesa Sanpaolo
14	UK	Barclays PLC	32	Greece	National Bank
15	UK	HBOS PLC	33	Greece	Alpha Bank A.E.
16	UK	HSBC Holdings PLC	34	Ireland	Bank of Ireland
17	UK	LLOYDS			
18	Netherlands	ING GROEP N.V.			

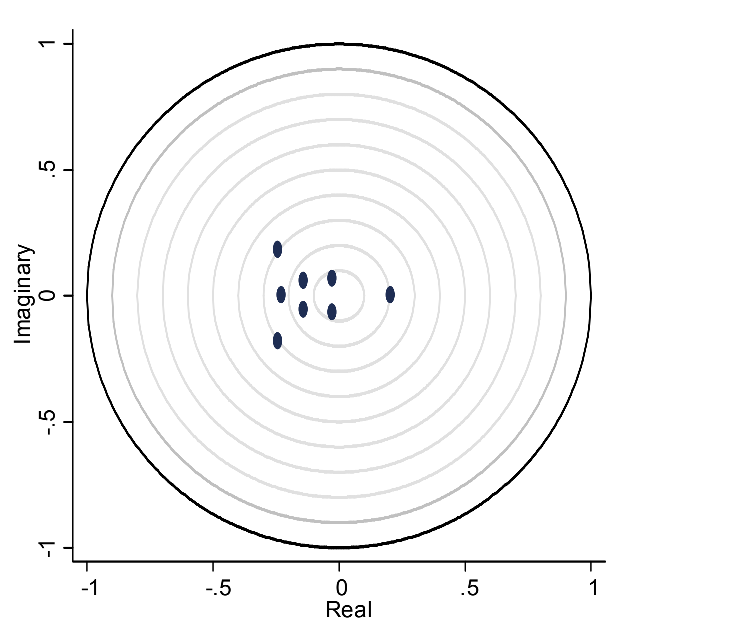
Table 5b: Sovereigns per group

Sovereigns					
No.	Core	No.	Peripheral	No.	Non euro-area
1	Austria	6	Spain	11	Sweden
2	Belgium	7	Portugal	12	Denmark
3	Germany	8	Italy	13	United Kingdom
4	France	9	Greece		
5	The Netherlands	10	Ireland		

Table 6: Eigen Value Stability condition of Panel VAR estimates

Eigenvalue		Modulus
Real	Imaginary	
-0.239517	-0.181418	0.300471
-0.239517	-0.181418	0.300471
-0.224995	0	-0.224995
0.227737	0	0.227737
-0.137591	0.057989	0.1493122
-0.137591	-0.057989	0.1493122
-0.248341	0.066750	0.071220
-0.248341	-0.066750	0.071220

Figure 1: Roots of the companion matrix



Note: The stability of the panel VAR requires the moduli of the eigen values of the dynamic matrix to lie within the unit circle. All of the eigen values lie inside the unit circle. Panel VAR satisfies stability condition.

Table 7: Residual Correlation - Fisher Z-transformation

January 2005 - December 2006			**January 2007 - December 2009**		
	Corr.	Fischer Z		Corr.	Fischer Z
Core	-0.2078	**1.26**	Core	0.1938	**-0.49**
Peripheral	-0.2457		Peripheral	0.2953	

January 2010 - October 2014			**January 2010 - October 2014**		
	Corr.	Fischer Z		Corr.	Fischer Z
Core	0.2229	**5.31***	Core	0.2229	**3.75***
Peripheral	0.7239		Non euro-area	0.5855	

January 2005 - December 2006(1st period) / January 2007 - December 2009(2nd period)					
	Corr.	Fischer Z		Corr.	Fischer Z
Core 1st	-0.2078	**3.60***	Peripheral 1st	-0.2457	**2.85***
Core 2nd	0.1938		Peripheral 2nd	0.2953	

January 2005 - December 2006(1st period) / January 2010 - October 2014(3rd period)					
	r correl.	Fischer Z		r correl.	Fischer Z
Core 1st	-0.2078	**4.19***	Peripheral 1st	-0.2457	**6.39***
Core 3rd	0,2229		Peripheral 3rd	0,7239	

Note: see equation (2) in the text.

Table 8: Forecast Error Variance Decomposition (January 2005 – December 2006)

Table 8a: Core

Response Variable	Impulse Variables						
	CDX	**VIX**	**TED**	**iTraxx**	**Vstoxx**	**Sovereigns**	**Banks**
CDX	73.93	2.70	1.31	10.14	2.03	4.34	5.52
VIX	39.24	32.05	6.88	8.78	6.11	5.53	1.38
TED	12.04	18.27	51.06	0.59	3.01	13.61	1.39
iTraxx	63.41	1.41	4.24	23.39	3.27	0.64	3.59
Vstoxx	36.07	18.32	9.52	7.18	16.20	10.57	2.11
Sovereigns	1.36	1.63	2.69	7.66	1.97	77.53	7.11
Banks	4.77	0.49	1.25	0.89	1.83	8.66	82.08

Table 8b: Peripheral

Response Variable	Impulse Variables						
	CDX	**VIX**	**TED**	**iTraxx**	**Vstoxx**	**Sovereigns**	**Banks**
CDX	79.12	5.17	2.14	7.22	3.72	1.88	0.71
VIX	40.58	34.57	79.09	5.52	7.22	0.49	3.67
TED	9.82	18.06	62.79	1.71	6.07	0.43	1.07
iTraxx	60.67	2.88	6.80	23.12	3.33	1.67	1.48
Vstoxx	37.77	22.46	14.03	5.55	18.50	1.17	0.48
Sovereigns	15.84	1.93	7.43	11.58	1.30	58.84	3.04
Banks	22.68	5.14	13.32	7.15	6.06	1.80	43.81

Notes: The tables reports the fraction (in percentage points) of the 10-months ahead forecast error variance of each variable. The Cholesky ordering used is CDX → VIX → TED → iTraxx → Vstoxx → KFW → Sovereign_CDS → Bank_CDS.

Table 9: Forecast Error Variance Decomposition (January 2007 – December 2010)

Table 9a: Core

Response Variable	Impulse Variables							
	CDX	**VIX**	**TED**	**iTraxx**	**Vstoxx**	**KFW**	**Sovereigns**	**Banks**
CDX	75.99	7.85	3.17	0.65	1.62	2.26	1.94	6.49
VIX	26.43	63.25	1.02	1.85	0.26	4.18	0.49	2.48
TED	28.66	12.48	53.76	0.49	1.08	0.52	0.78	2.19
iTraxx	72.00	4.49	2.19	8.16	2.28	1.82	1.64	7.3
Vstoxx	27.72	42.24	0.87	1.37	18.82	6.19	0.38	2.38
KFW	4.93	20.78	5.45	4.78	5.56	58.27	0.00	0.12
Sovereigns	14.45	12.06	0.68	0.82	2.32	3.75	62.94	2.94
Banks	26.55	2.23	0.96	1.27	2.46	1.21	0.22	65.06

Table 9b: Peripheral

Response Variable	Impulse Variables							
	CDX	**VIX**	**TED**	**iTraxx**	**Vstoxx**	**KFW**	**Sovereigns**	**Banks**
CDX	77.57	9.41	3.06	0.81	1.46	3.15	4.37	0.20
VIX	31.40	61.05	0.98	2.11	0.27	3.61	0.38	0.16
TED	31.12	9.16	49.11	0.12	0.34	0.74	6.83	2.54
iTraxx	75.70	6.51	2.09	7.81	2.09	2.49	3.16	0.11
Vstoxx	32.82	38.85	0.85	1.61	18.90	5.44	0.97	0.52
KFW	5.09	19.62	5.69	5.86	6.08	57.40	0.13	0.10
Sovereigns	27.61	8.62	1.17	3.89	8.73	7.03	42.83	0.09
Banks	39.09	3.16	2.98	2.98	1.16	0.74	2.17	47.68

Notes: The tables reports the fraction (in percentage points) of the 10-months ahead forecast error variance of each variable. The Cholesky ordering used is CDX → VIX → TED → iTraxx → Vstoxx → KFW → Sovereign_CDS → Bank_CDS.

Table 10: Forecast Error Variance Decomposition (January 2010 – October 2014)

Table 10a: Core

	Impulse Variables							
Response Variable	**CDX**	**VIX**	**TED**	**iTraxx**	**Vstoxx**	**KFW**	**Sovereigns**	**Banks**
CDX	85.17	4.69	0.64	4.13	1.22	1.50	2.6	0.00
VIX	50.15	35.61	8.52	1,9	0.55	2.08	0.53	0.62
TED	10.19	2.96	60.17	14.96	5.95	1.26	4.25	0.23
iTraxx	70.48	6.59	1.86	15.79	1.54	2.35	1.10	0.25
Vstoxx	44.27	13.61	5.23	9.95	20.51	4.72	0.67	1.00
KFW	1.54	4.86	1.01	2.52	1.88	81.87	6.1	0.00
Sovereigns	13.73	3.69	7.49	27.54	1.5	1.79	43.91	0.3
Banks	3.6	0.16	0.99	8.45	0.00	0.21	0.48	86.00

Table 10b: Peripheral

	Impulse Variables							
Response Variable	**CDX**	**VIX**	**TED**	**iTraxx**	**Vstoxx**	**KFW**	**Sovereigns**	**Banks**
CDX	86.10	4.55	0.82	4.80	1.40	1.48	0.35	0.47
VIX	50.66	35.25	7.93	2.63	0.47	2.3	0.29	0.44
TED	10.99	2.86	62.37	16.39	5.13	1.28	0.31	0.62
iTraxx	70.94	6.76	1.75	16.00	1.48	2.50	0.18	0.35
Vstoxx	44.33	13.54	4.41	12.22	19.45	5.23	0.27	0.50
KFW	2.20	3.64	1.44	4.30	1.82	86.14	0.14	0.27
Sovereigns	17.68	1.76	2.64	18.61	0.56	6.12	52.52	0.00
Banks	20.53	1.01	2.41	23.85	0.98	3.47	14.39	33.33

Table 10c: Non-euro area

	Impulse Variables							
Response Variable	**CDX**	**VIX**	**TED**	**iTraxx**	**Vstoxx**	**KFW**	**Sovereigns**	**Banks**
CDX	86.13	4.14	0.74	4.72	1.04	1.60	1.43	0.01
VIX	51.19	34.55	8.18	2.32	0.31	2.23	0.69	0.49
TED	9.86	2.74	59.08	16.11	4.85	1.65	3.46	2.22
iTraxx	70.40	6.29	1.48	15.92	1.23	2.63	1.18	0.83
Vstoxx	44.85	12.40	4.71	11.39	19.49	5.04	1.56	0.50
KFW	2.27	4.70	1.13	3.80	2.11	82.96	2.49	0.51
Sovereigns	8.9	1.43	3.87	15.31	1.43	1.44	64.39	3.19
Banks	24.84	7.95	1.43	24.57	0.42	3.31	6.26	31.18

Notes: The tables reports the fraction (in percentage points) of the 10-months ahead forecast error variance of each variable. The Cholesky ordering used is CDX → VIX → TED → iTraxx → Vstoxx → KFW → Sovereign_CDS → Bank_CDS.

Table 11a: Generalized Forecast Error Variance Decompositions / Sovereign CDS/ 3rd period from GIRFs 100 (Pesaran and Shin, 1998).

Sovereign CDS

Generalized innovations to								
h	**Sov_CDS**	**Bank_CDS**	**iTraxx**	**Vstoxx**	**CDX**	**VIX**	**TED**	**KFW**
1	100	54.03	33.75	30.47	18.88	16.76	3.52	1.01
2	91.69	49.60	31.02	27.95	17.61	15.41	4.72	5.27
3	91.40	49.57	31.05	27.86	17.69	15.34	4.75	5.3
4	91.33	49.53	31.03	27.87	17.68	15.34	4.75	5.3
5	91.31	49.51	31.03	27.87	17.69	15.34	4.75	5.3
10	91.30	49.52	31.03	27.87	17.70	15.34	4.76	5.3

Table 11b: Generalized Forecast Error Variance Decompositions / Bank CDS/ 3rd period

Bank CDS

Generalized innovations to								
h	**Sov_CDS**	**Bank_CDS**	**iTraxx**	**Vstoxx**	**CDX**	**VIX**	**TED**	**KFW**
1	54.03	100	38.16	29.38	21.39	12.80	5.36	0
2	48.84	89.48	34.26	26.4	20.57	11.56	5.34	2.98
3	48.46	88.86	34.04	26.17	20.56	11.46	5.54	2.95
4	48.39	88.68	34.01	26.23	20.53	11.47	5.55	2.95
5	48.38	88.64	34.01	26.24	20.53	11.47	5.55	2.95
10	48.37	88.64	34.01	26.24	20.53	11.47	5.55	2.95

Note: The table reports the fraction (in percentage points) of the h-months ahead forecast error variance of each variable, that is attributable to generalized innovations in Sovereign CDS and Bank CDS. The variance shares may not sum to 100 (Pesaran and Shin, 1998).

Table 12a: Core Countries Spillover Matrix (January 2007 – December 2009)

Spillover Matrix of Core Countries 2nd period									
Response / Impulse	*Core Sovereigns*	*Core Banks*	*CDX*	*VIX*	*TED*	*iTraxx*	*Vstoxx*	*KFW*	**Sum Out**
Core Sovereigns	87,83	4,52	16,73	18,14	3,87	14,52	20,02	2,25	80
Core Banks	10,12	92,78	30,89	12,29	8,79	31,18	15,88	1,53	105,96
CDX	14,45	26,55	75,99	26,43	28,66	72	27,72	4,93	200,74
VIX	23,79	9,59	32,44	88,91	8,14	26,21	67,47	24,31	191,95
TED	1,16	1,66	3,66	4,07	67,07	5,23	2,89	0,87	19,54
iTraxx	13,99	24,98	69,96	26,07	29,42	75,42	28,08	3,35	195,85
Vstoxx	26,18	14,37	34,35	69,02	8,09	29,96	86,79	10,14	192,11
KFW	1,52	1,53	4,56	21,91	1,78	2,51	8,71	94,78	43
Sum IN	91,21	83,2	192,59	177,93	88,75	181,61	170,77	47,38	**1.029**
Net	-11	22,76	8,15	14,02	-69,21	14,24	21,34	-5	-5

Spillover index is 60,40%

Table 12b: Peripheral Countries Spillover Matrix (January 2007 – December 2009)

Spillover Matrix of Peripheral Countries 2nd period									
Response / Impulse	*Peripheral Sovereigns*	*Per. Banks*	*CDX*	*VIX*	*TED*	*iTraxx*	*Vstoxx*	*KFW*	**Sum Out**
Per. Sovereigns	**75,18**	11,88	30,69	14,29	4,9	29,55	26,37	0,94	119
Per. Banks	9,06	**78,19**	23,7	9,64	17,38	25,88	10,34	0,66	93
CDX	27,61	39,09	**77,5**	31,4	31,12	75,7	32,82	5,09	242,83
VIX	24,51	11,35	36,21	**91,61**	7,12	31,05	68,92	23,1	202,26
TED	0,39	3,38	3,59	3,11	**59,33**	5,06	1,7	1,36	18,59
iTraxx	27,65	39,91	72,18	30,53	31,57	**80,11**	32,68	3,36	237,88
Vstoxx	34,55	11,83	38,68	71,39	7,09	35,57	**88,56**	9,49	208,6
KFW	0,63	0,75	4,26	21,14	2,47	2,41	7,87	**94,63**	40
Sum IN	124,4	118,19	209,31	181,5	101,65	205,22	180,7	44	**1.161**
Net	-6	-25,19	33,52	20,76	-83,06	32,66	27,9	-4	-4

Spillover index is 64,15%

Note: Variables in the first column are the impulse origin. Variables on the top row are the respondents to the shock. Values in the matrix represent the variance spillover effect over the first 10 months. In the last column we have the aggregated impact sent (Sum OUT) by each row variable (excluding the own response) and on the bottom row the aggregated spillover received (Sum IN) by each column variable. The bottom-right cell (in bold) shows total spillover in the system. We divide this value to the contribution including own response in order to take the Spillover/Contagion index. The last row shows the net spillover (received or sent) for each variable.

Table 13a: Core Countries Spillover Matrix (January 2010 – October 2014)

Spillover Matrix of Core Countries 3rd period									
Response / Impulse	*Core Sovereigns*	*Core Banks*	*CDX*	*VIX*	*TED*	*iTraxx*	*Vstoxx*	*KFW*	**Sum Out**
Core Sovereigns	**87,28**	8,04	13,04	10,3	6,05	29,23	24,97	1,89	94
Core Banks	5,4	**97,05**	4,55	2,5	1,75	7,78	3,94	0,14	26,06
CDX	13,73	3,59	**85,17**	50,15	10,19	70,48	44,27	1,54	193,95
VIX	13,24	2,59	46,69	**80,4**	6,84	44,84	50,93	2,16	167,29
TED	10,3	2,38	10,17	6,67	**68,41**	11,2	7,77	0,22	48,71
iTraxx	30,79	8,54	70,55	43,83	16,17	**83,25**	53,21	0,27	223,36
Vstoxx	28,56	5,88	41,16	47,99	21,02	55,08	**82,23**	2,12	201,81
KFW	1,12	0,17	0,72	3,15	1,15	1,07	5,5	**85,21**	13
Sum IN	103,14	31,19	186,88	164,59	63,17	219,68	190,59	8,34	**968**
Net	-10	-5,13	7,07	2,7	-14,46	3,68	11,22	5	**0**

Spillover index is 59,12%

Table 13b: Peripheral Countries Spillover Matrix (January 2010 – October 2014)

Spillover Matrix of Peripheral Countries 3rd period									
Response / Impulse	*Peripheral Sovereigns*	*Per. Banks*	*CDX*	*VIX*	*TED*	*iTraxx*	*Vstoxx*	*KFW*	Sum Out
Per. Sovereigns	**91,3**	48,37	16,01	14,11	9,96	28,9	25,81	1	144
Per. Banks	49,51	**88,64**	18,13	11,27	12,99	32,59	24,72	0,37	105,47
CDX	17,68	20,53	**86,1**	50,66	10,99	70,94	44,33	2,2	217,33
VIX	15,34	11,47	47,06	**80,68**	6,31	45,45	51,01	2,21	178,85
TED	4,76	5,55	12,07	6,41	**71,99**	10,63	6,93	0,67	47,02
iTraxx	31,03	34,01	71,5	45,1	10,31	**83,02**	54,9	0,38	247,23
Vstoxx	27,87	26,24	41,18	48,03	19,73	56,13	**82,64**	1,49	220,67
KFW	5,3	2,95	1,23	3,7	1,47	1,59	6,15	**90,98**	22
Sum IN	151,49	149,12	207,18	179,28	71,76	246,23	213,85	8,32	**1.183**
Net	-7	-43,65	10,15	-0,43	-24,74	1	6,82	14	-44

Spillover index is 62,18%

Note: Variables in the first column are the impulse origin. Variables on the top row are the respondents to the shock. Values in the matrix represent the variance spillover effect over the first 10 months. In the last column we have the aggregated impact sent (Sum OUT) by each row variable (excluding the own response) and on the bottom row the aggregated spillover received (Sum IN) by each column variable. The bottom-right cell (in bold) shows total spillover in the system. We divide this value to the contribution including own response in order to take the Spillover/Contagion index. The last row shows the net spillover (received or sent) for each variable.

Figure 1: Generalized Impulse Response Functions (GIRF): Sovereign_CDS and Bank_CDS for ***Core*** countries (January 2005 – December 2006)

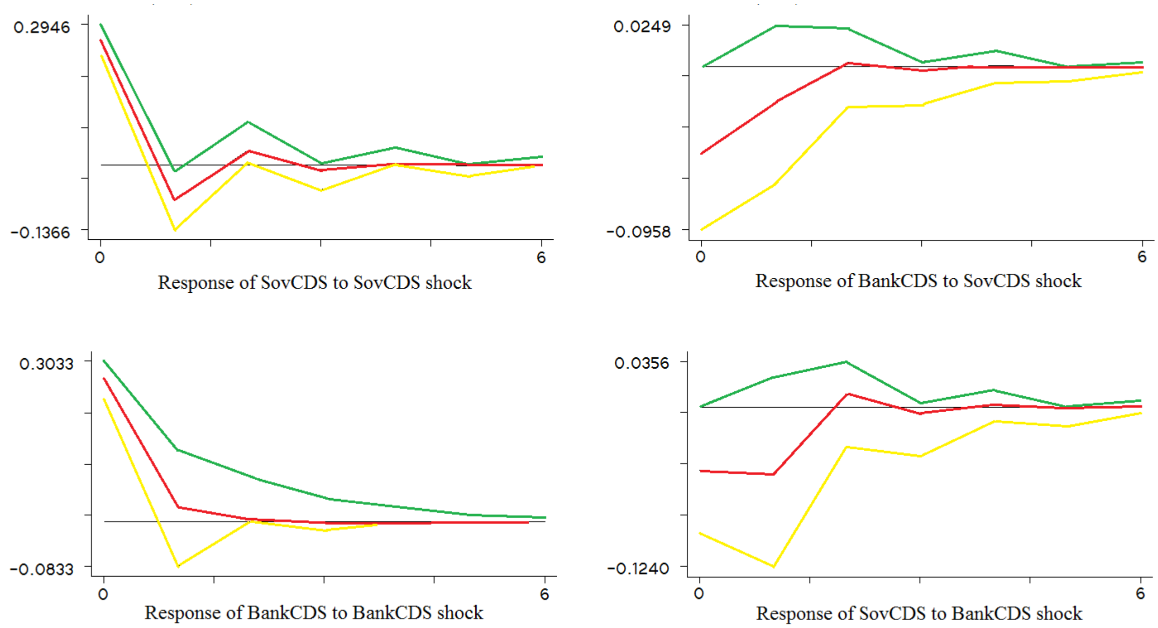
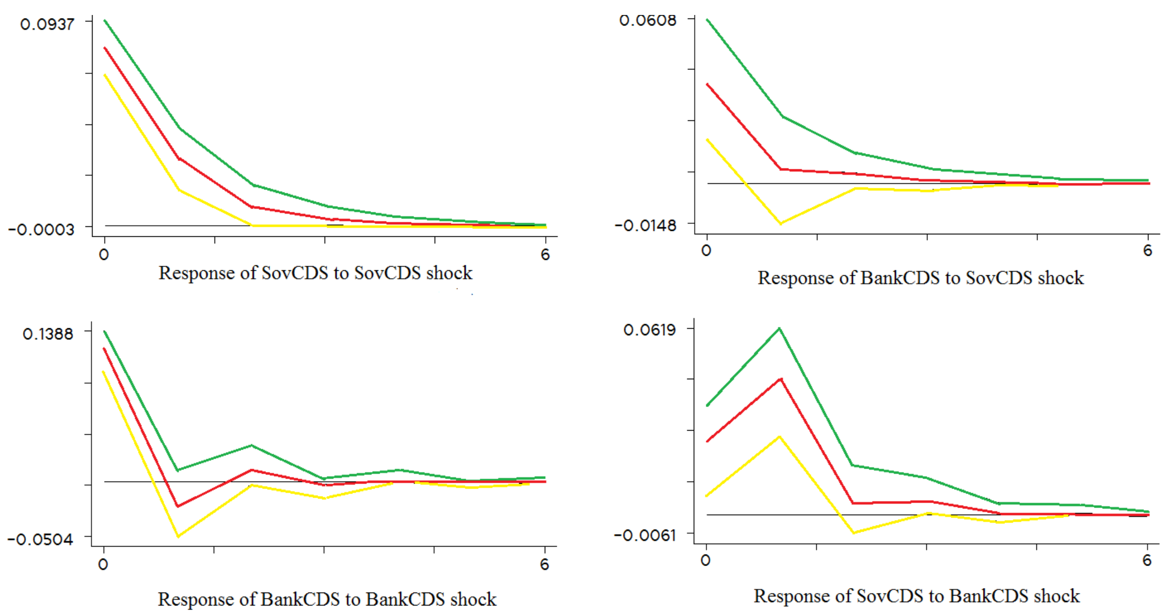


Figure 2: GIRF: Sovereign_CDS and Bank_CDS for ***Peripheral*** countries (January 2005 – December 2006)



Notes: Errors are 5% on each side generated by Monte-Carlo with 200 reps

Figure 3: GIRF: Sovereign_CDS and Bank_CDS for ***Core*** countries (January 2007 – December 2009)

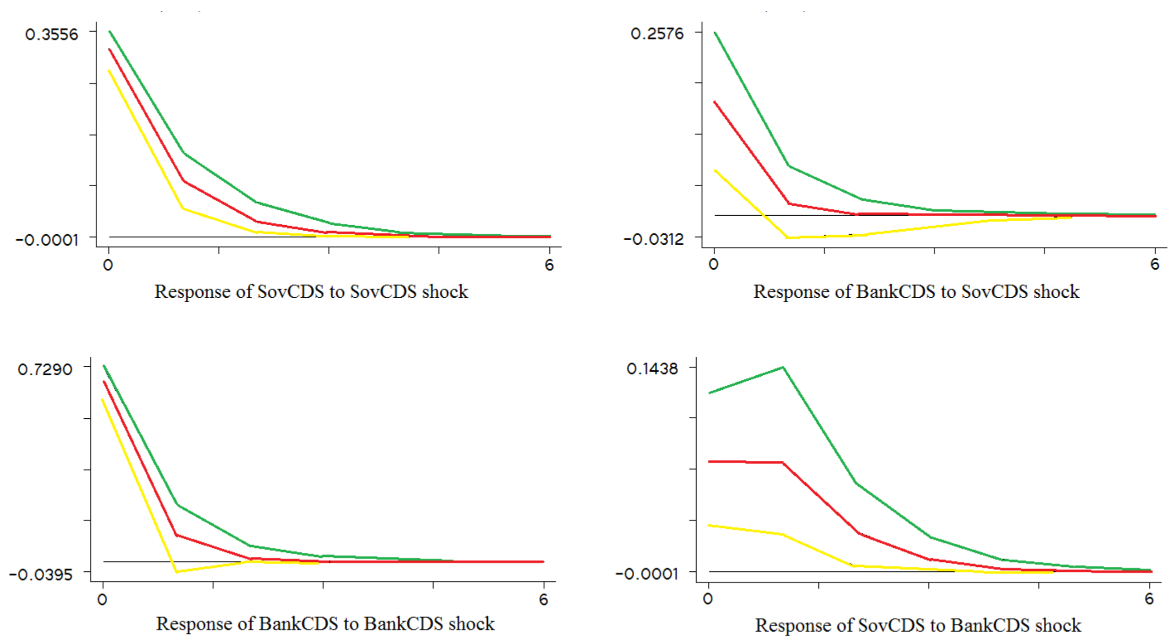
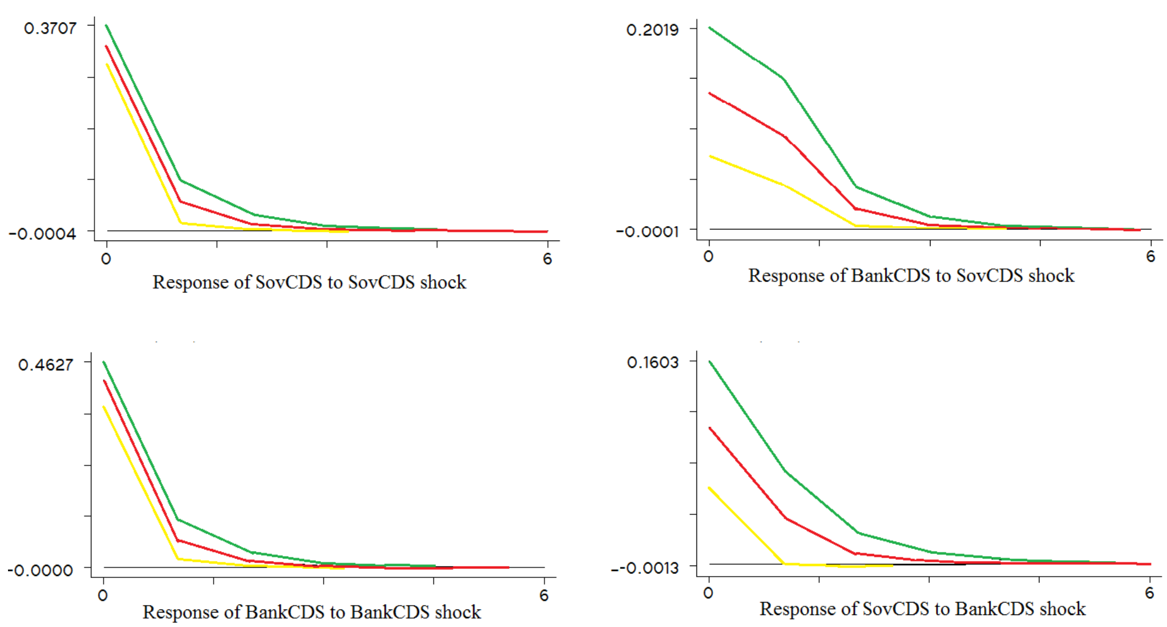


Figure 4: GIRF: Sovereign_CDS and Bank_CDS for ***Peripheral*** countries (January 2007 – December 2009)



Notes: Errors are 5% on each side generated by Monte-Carlo with 200 reps

Figure 5: GIRF: Sovereign_CDS and Bank_CDS for ***Core*** countries (January 2010 – October 2014)

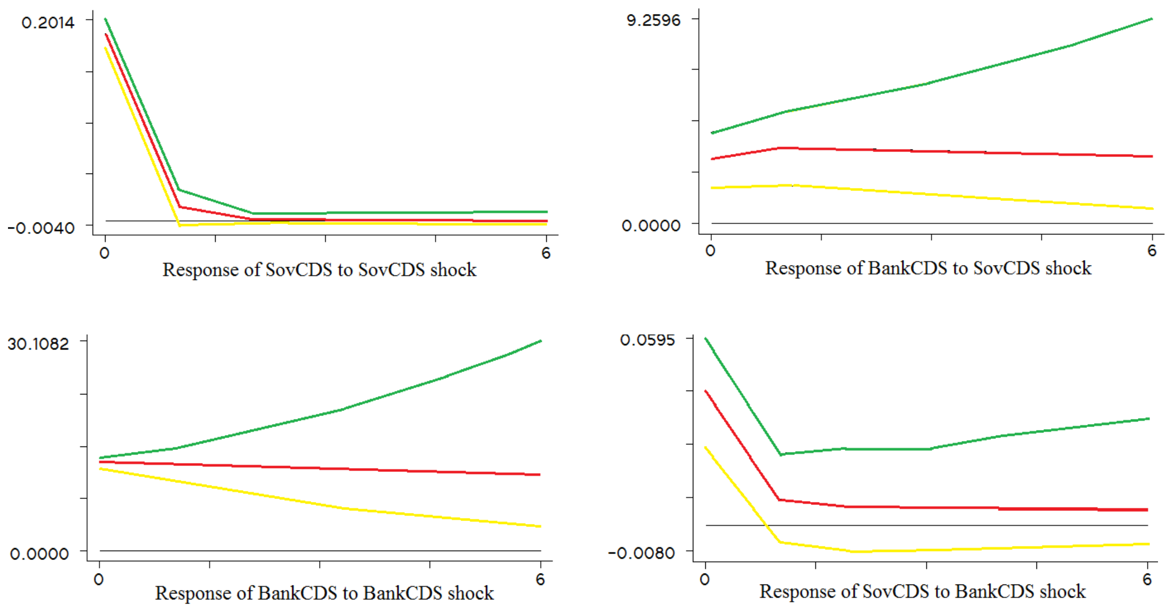
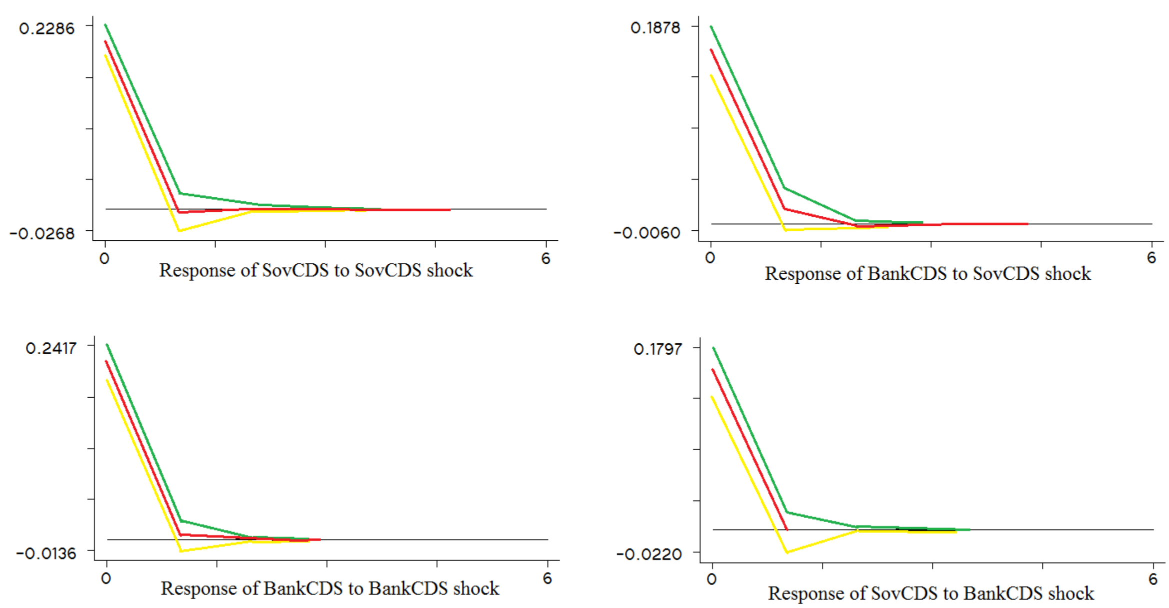


Figure 6: GIRF: Sovereign_CDS and Bank_CDS for ***Peripheral*** countries (January 2010 – October 2014)



Notes: Errors are 5% on each side generated by Monte-Carlo with 200 reps