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Sovereign CDS Spread Determinants and Spill-Over Effects During Financial Crisis: A Panel VAR Approach

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Abstract

This paper examines the determinants of CDS spreads and potential spillover effects for Eurozone countries during the recent financial crisis in the EU. We employ a Panel Vector Autoregressive (PVAR) model which combines the advantages of traditional VAR modelling with those of a panel-data approach. In addition to variables that proxy for global and financial market spread determinants we also employ variables that proxy for behavioral determinants. We find that the determinants of CDS variance are neither uniform nor stable during different periods and different countries. For instance, as we move from 2008 to 2014 the impact of the slope of the term structure on CDS spread variance is increasing for peripheral countries such as Spain, Portugal, Italy, Greece, Ireland, and decreasing for core countries such as Germany, France, Netherlands, Belgium and Austria. Other findings indicate that investor sentiment was an important CDS spread determinant during the subprime crisis, along with other factors, while spillover effects run from larger peripheral economies such as Spain and Italy to core countries; spillover effects from Portugal, Greece, and Ireland are of minor importance.

Keywords: Financial Crisis, CDS, Spreads, Panel VAR, Sentiment
JEL Classifications: G12, G14, G15

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1. Introduction

During the past two decades the Credit Default Swap (CDS) market has undergone a significant expansion. For instance, in early 1998 the value of this market was estimated at a few hundred billion US dollars; however, as of June 2007 the notional amount outstanding for OTC CDS was $45,179 billion, and by June 2014 at $19,462 billion (source: Bank for International Settlements). Peltonen et al. (2014) find that the CDS market is clustered around fourteen major dealers and exhibits a "small world" structure, where most CDS investors are net buyers. CDS spreads reflect the perception of market participants about the financial health of creditors and signal warnings about financial stability (Annaert et al., 2013).

Following this market growth, the emergence of CDS as an asset class, and motivated by the role of the CDS market in the global financial crisis, academic research on CDS instruments and spreads flourished. Also, as Ang and Longstaff (2013) argue, there is an important advantage in using CDS spreads compared to debt spreads when studying credit risk: debt spreads are determined by a plethora of other factors apart from credit risk. The literature on sovereign CDS, however, developed less rapidly compared to the literature on corporate CDS (Doshi et al., 2014). For instance, many recent studies focus on bank or corporate CDS spreads (e.g. Chiaramonte and Casu, 2013; Galil et al., 2014; Annaert et al., 2013; among others), or emerging market CDS spreads (see Hilscher and Nosbusch, 2010; Ammer and Cai, 2011; Fender et al., 2012; among others). Furthermore, the early literature on credit spreads mainly concentrates on bond yield spread determinants and documents the role of common global and financial market factors (Edwards, 1986; Berg and Sachs, 1988; Boehmer and Megginson, 1990; Eichengreen and Mody, 1998; Remolona, et al. 2008; among others). In terms of empirical approaches employed to study the CDS market, Doshi et al. (2014) point out that there are two different strands in the recent literature. Many studies employ reduced-form latent models to model credit risk (e.g. Pan and Singleton, 2008; Longstaff, et al., 2011), while other studies regress CDS spreads on variables that capture fundamental macroeconomic spread determinants (e.g. Dieckmann and Plank, 2012). For example, spillover effects are often examined with global vector autoregression (GVARs) models of sovereign debt across countries; usually a VAR model for each sample country is estimated that includes global variables (Caporale and Girardi, 2013; Eickmeier and Ng, 2011).

This paper examines the determinants of CDS spreads and potential spillover effects for Eurozone countries during the recent financial crisis in the EU. The results may have important implications for policy makers since the effective response to a crisis depends crucially on a deep understanding of the sources and determinants of sovereign credit risk. The paper contributes to the relevant literature in a number of ways. More specifically, we employ a research methodology that is based on a Panel Vector Autoregressive (PVAR) model which combines the advantages of traditional VAR modelling with the advantages of a panel-data approach. According to Love and Zicchino (2006) the PVAR is a combination of the traditional VAR "….which treats all the variables in the system as endogenous, with the panel-data approach, which allows for unobserved individual heterogeneity" (p. 193). Also a main difference between PVAR and Global VAR models is that the coefficients on the foreign variables are restricted to zero, and only one set of coefficients are estimated (not one set for each country, as in the GVAR). In other words, we are able to examine the extent to which CDS spreads in Eurozone countries are due to changes in global or country-specific factors while allowing for a country-specific unobserved heterogeneity in the levels of the variables (fixed effects). We also examine spillover effects, orthogonalized impulse-response functions, and variance decompositions through which we are able to separate the response of CDS spreads to shocks coming from each variable.

Furthermore, in addition to variables that proxy for global and financial market spread determinants we also employ variables that proxy for behavioral determinants. Note that the vast majority of previous studies focuses on macroeconomic or financial information in order to study the determinants of spreads and neglect behavioral variables that may capture investor and economic sentiment; many recent studies, however, show that behavioral biases and/or investor sentiment may affect stock and bond returns, especially during crisis periods (see, among others, Galariotis, et al. 2015; Kassimatis, et al. 2008; Fisher and Statman, 2003; Kumar and Lee, 2006). The variables we employ to proxy for sentiment are the Economic Sentiment Indicator (ESI) that is published monthly by the European Commission (DG ECFIN) and aims to assess the business and consumer confidence, and the ZEW Economic Sentiment indicator which is an amalgamation of the sentiment of approximately 350 economists and analysts regarding the economic climate in Europe for the next six months. Experts are asked for a qualitative assessment of the direction of inflation, interest rates, exchange rates and the stock market and as a result the indicator provides a medium-term forecast for the Eurozone economy. The ESI combines assessments and expectations stemming from business and consumer surveys for different sectors: industry, consumers, construction, and retail with the weights are as follows: industrial confidence indicator (40%), service confidence indicator (30%), consumer confidence indicator (20%), construction confidence indicator (5%), and the retail trade confidence indicator (5%). Rua (2002) argues that the ESI has information content for the GDP growth rate; in this sense, the domestic ESI may have significant information content for spreads. Note that we also employ a variable that has not been used in previous studies, the number of CDS contracts traded, which may serve as a twin proxy: on the one hand it may proxy for liquidity (for which we also use the bid-ask spread for robustness); on the other hand a measure of trading volume, such as the contracts traded, may capture optimism or pessimism and, thus, it may serve as a market-based proxy for sentiment (see Baker and Stein, 2004; Baker and Wurgler, 2006).

Several interesting results emerge from the analysis. We find that the determinants of CDS variance are neither uniform nor stable during different periods and different countries. For instance, as we move from 2008 to 2014 the impact of the slope of the term structure on CDS spread variance is increasing for peripheral countries (Spain, Portugal, Italy, Greece and Ireland) and decreasing for the core countries (Germany, France, Netherlands, Belgium and Austria); the effect of VIX, a proxy for global market risk, is not very important for the core countries, however, it is very important for peripheral countries between 2008 and 2012 (it contributes to CDS variance by approximately 31%). We also report evidence that investor sentiment may be an important CDS spread determinant during the period between 2008 and 2010, along with other factors, a result consistent with the results of Spyrou (2013) who reports similar findings for both the level and changes in bond yields (see also, Heinz and Sun, 2014).

Other findings indicate that spillover effects may run from Spain and Italy to core countries while spillover effects from Portugal, Greece, and Ireland are of minor importance. Italy and Spain, being much larger economies, could potentially destabilize the euro area, even though their likelihood of running into financial difficulties was perceived by the markets as comparatively smaller, based on their SCDS spreads. Moreover, following the first Greek debt restructuring in mid-2011, Greek CDS spread was persistently well above 1000 bps and probably carried little information for investors. Our finding is consistent with Kalbaska and Gatwoski (2012) who study contagion among several European countries and find that spillovers from Spain and Italy, especially until July 2012, were of a great importance. The rest of this paper is organized as follows. Section 2, reviews the relevant literature, section 3 discusses the data and methodology, section 4 presents the results, while section 5 concludes the paper.

2. Previous Studies

Longstaff, et al. (2011) examine monthly 5-year CDS for 26 countries between 2000 and 2010 and find that sovereign CDS spreads can be explained to a large extent by U.S. equity, volatility, and bond market risk premia. In addition, they find that important determinants are global financial market variables or a global risk premium, while the contribution of local macroeconomic variables is of minor importance; this implies that systemic sovereign risk is more related to financial markets than to country-specific variables. Heinz and Sun (2014) use a panel GLS error correction framework and find that European sovereign CDS spreads are largely driven by factors such as global investor sentiment, macroeconomic fundamentals and liquidity conditions in the CDS market, with their relative importance changing over time (see also Beirne and Fratzscher, 2013; Ejsing and Lemke, 2011).

Caporin et al. (2013) find that contagion in Europe remains subdued during their sample period and suggest that the common shift observed in CDS spreads is the outcome of the usual interdependence. Broto and Perez-Quiros (2013) employ a multivariate model with time-varying correlations and volatilities, and decompose the sovereign CDS spreads of ten OECD economies into three single components: a common factor, a second factor driven by European peripheral countries and an idiosyncratic component. They argue that since the onset of the sovereign debt crisis, contagion has played a role of major importance in the European peripheral countries. Anderson (2010) studies the source of the increase in the correlation CDS spread changes during the crisis and finds evidence suggesting that fluctuations in fundamental credit risk account for only a small fraction of the increase in correlation, and no evidence of increased correlations due to liquidity or counterparty risk. Focusing on contagion between sovereigns and banks, Gross and Kok (2013) document a number of salient facts: firstly, spill-over potential in the CDS market is particularly intense in 2008 and more recently in 2011-2012; secondly, while in 2008 contagion primarily moves from banks to sovereigns, the direction is reversed during

2011-2012; thirdly, spill-over indices indicate that the system of banks and sovereigns has become more connected over time (see also Alter and Schüler, 2012). Diebold and Yilmaz (2012) find that equity markets had an important contribution in transmitting spillovers to international markets and other asset classes, while Claeys and Vašíček (2012) based on a similar econometric framework find that spillovers among sovereign yields increased considerably since 2007.

Many studies also focus on price discovery. Fontana and Scheicher (2010) study the relationship between the relative pricing of euro area sovereign CDS and the underlying government bonds and find that, since September 2008, market integration for bonds and CDS varies across countries: in half of the sample countries, price discovery takes place in the CDS market, while in the other half, price discovery takes place in the bond market. Ammer and Cai (2011) find evidence that CDS premia and bond yield spreads are linked by a stable linear long-run relationship, while Palladini and Portes (2011) find that the CDS market moves ahead of the bond market in terms of price discovery.

Canova, et al (2012), use a PVAR model of the type developed in Canova and Ciccarelli (2009), and apply their approach to data of ten European countries in order to examine changes in European business cycles and the transmission of shocks. Ciccarelli, et al. (2012), using a Bayesian VAR model, examine heterogeneity and spillovers in macro-financial linkages across developed economies with a particular emphasis in the most recent debt crisis. Diebold and Yilmaz (2012) use a Generalized VAR framework and report that although significant volatility fluctuations exist in all their sample markets, cross-market volatility spillovers were quite bordered until the global financial crisis outburst in 2007. Bouvet, et al. (2014), employ a PVAR model for EMU countries to investigate the effect of yield spreads in fiscal variables.

3. Testing Methodology and Data

The spread on a sovereign CDS contract can be considered as an indicator of the sovereign credit risk of a country (see, among others, Blommestein, et al., 2016), in a similar manner as the sovereign bond yield spread. Studies show that CDS spreads and bond spreads move together in the long run (Zhu, 2006) and CDS premia and bond yield spreads are linked by a stable linear long-run relationship (Ammer and Cai, 2011). Edwards (1984) suggests that a country's probability of default is linked to its sovereign credit spread and investigates the relationship between macroeconomic determinants (i.e. proxies for ability and willingness to repay the debt) and spreads. Assuming competitive markets and risk neutral investors, Edwards suggests that the relationship is log-linear:

$$\log s_{it} = a + \sum_{j=1}^{J} \beta_{jt} X_{jt} + \varepsilon_{it} \qquad (1)$$

In (1) s_{it} is the sovereign yield spread of country i at month t, a is an intercept coefficient, β's are the slope coefficients, and J are the explanatory variables. Theory does not provide any specific guidelines as to the determinants of spreads, however, previous studies indicate that yield spreads reflect three types of risk: general market risk, default risk, and liquidity risk (see, among others, Codogno et al., 2003; Haugh et al., 2009; Hund and Lesmond, 2008; Gomez-Puig, 2006; Schwartz, 2009; Ferrucci, 2003). For example, Barbosa and Costa (2010) find that euro area sovereign spreads are affected by a common factor (international financial market risk premium) and factors that are related to local bond market credit and liquidity conditions.

In order to proxy for these types of risks we use financial market variables since, as Blommestein, et al. (2016) argue, financial variables reflect market participant expectations about future macroeconomics conditions rather than past information as macroeconomic variables often do. Blommestein, et al. examine sovereign CDS spread determinants for Greece, Ireland, Italy, Portugal, and Spain and find that global and/or European Monetary Union wide factors are the main determinants of CDS spreads (see also, Pan and Singleton, 2008; Fontana and Scheicher, 2010; Dieckmann and Plank, 2011; D'Agostino and Ehrmann, 2014). More specifically, in order to investigate what drives European sovereign CDS spreads, especially over the recent turbulent period, we employ a set of explanatory variables that proxy for credit risk, global risk aversion, European wide market risk, banking stress, investor market expectations about future conditions in financial market, country specific economic sentiment, and liquidity in the CDS market. The explanatory variables we employ are described in more detail below.

The Chicago Board Options Exchange Volatility Index (denoted as *VIX*). Since credit spreads are assumed to also compensate investors for pure expected losses (Hull et al., 2005), they may be sensitive to changes to investor risk aversion. The VIX is often considered as a measure of market expectations of near-term volatility conveyed by S&P500 stock index option prices. It is based on the weighted average of the implied volatilities for a wide range of strikes and is considered as a market estimate of future volatility. Implied volatility has the potential to reflect information that a model-based forecast could not; for instance the VIX index reflects information related to both past jumps and future jump activity (Becker et al., 2009).

The 3-month Euribor–Eonia Spread (denoted as *Eur-Eon*). This measure captures both credit risk/banking stress and market liquidity, and may be considered as an alternative to the Libor spread. The Euro OverNight Index (Eonia) is the 1-day interbank interest rate for the Euro zone, in other words it may be thought of as the 1-day Euribor rate. We employ the difference between the 3-month Euribor and the 3-month Eonia rate. Pelizzon et.al. (2015) use the Euribor-Eonia to examine the relationship between credit risk and liquidity, while Caporin et al. (2013) employ it to analyse sovereign risk contagion.

Corporate CDS Premium (denoted as *iTraxx*). In order to capture market-wide credit risk we use iTraxx Europe (non-financial firms). The iTraxx Europe is composed of the 125 most liquid investment-grade default swaps. The European index is further split up into several sector indexes, namely, a corporate index comprised of the largest non-financial names, a crossover index comprising the 25 most liquid sub-investment grade non-financial names and a HiVol index that consists of the 30 names with the widest CDS spreads. The iTraxx indices typically trade with 5 as well as 10 year maturities and new series are issued every 6 months. Berndt and Obreja (2010) find that a main spread determinants is the iTraxx Europe index, referred to as "the economic catastrophe risk".

The slope of the term structure (denoted as *termspread*). We define the slope of the term structure as the difference between the 10-year government bond yield for each country and the 3-month Euribor rate (see, among others, De Bruyckere, 2013; Estrella and Hardouvellis, 1991). A rising slope of the term structure may lower credit spreads (Longstaff and Schwarz, 1995) while inversions of the yield curve are often related to expected recessions (Estrella, 2005). To the extent that an increase in the slope of the term structure can be thought of as an indicator of an expected improvement in the level of future economic activity, it should result in a reduction in credit spreads.

Economic Sentiment Indicator (denoted as *ESI*). The ESI is published monthly by the European Commission (DG ECFIN), in order to assess business and consumer confidence. This indicator combines assessments and expectations stemming from business and consumer surveys. Such surveys include different sectors of the economy: industry, consumers, construction, and retail trade.

CDS trading volume (denoted as *NOC*). We use trading volume (number of CDS contracts traded on a weekly basis) as a liquidity proxy for the market of sovereign CDS. The Number of Contracts (NOC) is the total number of CDS contracts bought (or equivalently sold) for all Warehouse contracts in aggregate, by sector or for single reference entities displayed. Fontana and Scheicher (2010), use the NOC measure in order to investigate whether basis deviations from the parity predict CDS and bond trading activity. Note that it can also be thought of as a measure of investor sentiment: Baker and Stein (2004) note that if short-selling is costlier than opening and closing long positions, irrational investors are more likely to trade, while Baker and Wurgler (2006) use NYSE share turnover as investor sentiment proxy.

For the empirical analysis we employ monthly observations on 5-year Credit Default Swap (CDS) spreads for ten Eurozone markets: Germany, Austria, Belgium, France, Greece, Ireland, Italy, Netherlands, Portugal, and Spain, which we group to two sub-samples denoted for simplicity as the "core" countries (Germany, France, Netherlands, Belgium and Austria) and the "peripheral" countries (Spain, Portugal, Italy, Greece and Ireland). Changes are defined as the first differences of the logarithmic levels, apart from the termspread and Euribor-Eonia spread which are transformed in first differences; all data are monthly and obtained from DataStream International, Bloomberg, and the Depository Trust & Clearing Corporation (DTCC). The sample covers the period between November 2008 and April 2014 (the start date is dictated by the availability of number of CDS contracts data).

Table 1 presents descriptive statistics for the variables. In order to examine the stability of the results overtime we also split the sample into three sub-periods. The first is between November 2008 and April 2010 (that roughly coincides with the outbreak of the subprime crisis in the USA), the second is between May 2010 and July 2012 (that roughly coincides with the outbreak of EU financial crisis; see Hermosillo and Johnson, 2014), and the third is between August 2012 and April 2014 (which may be considered as a more tranquil period, comparatively). Note that Greek CDS trading data are not available during the second and the third period since in 2010 trading was halted. As a result we re-estimate all results for the second and third period with the unavailable Greek spread being replaced by the sovereign Greek bond yield spread (vs Germany) and the results are qualitatively the same to the reported results (available upon request). Also, Ireland is excluded from the third period due to lack of ESI data.

Table 1
Descriptive Statistics

Variables	Mean	Min	Max	Std. Deviation	No Obs
VIX	0.0066	-0.4242	0.4242	0.1844	660
iTraxxEu	-0.0118	-0.2464	0.3018	0.1286	660
Termspread	-0.0186	-0.6480	0.9030	0.2880	660
Eur-Eon	0.0418	-11.850	10.047	0.9396	660
ESI	0.0016	-0.1315	0.0896	0.0286	648
NOC	0.0277	-0.4187	0.3938	0.0768	634
Sov CDS	0.0021	-0.7054	0.7531	0.2053	629

Notes to Table 1
The Table presents descriptive statistics for the following variables: The Chicago Board Options Exchange Volatility Index (denoted as VIX), the Corporate CDS Premium (denoted as iTraxx), the slope of the term structure (denoted as termspread), the 3-month Euribor–Eonia Spread (denoted as Eur-Eon), the Economic Sentiment Indicator (denoted as ESI), the CDS trading volume (denoted as NOC), the Sovereign CDS spread (denoted as Sov CDS). Changes are defined as the first differences of the logarithmic levels, apart from the termspread and Euribor-Eonia spread which are transformed in first differences. All data are monthly and obtained from DataStream International, Bloomberg, and the Depository Trust & Clearing Corporation (DTCC). The sample covers the period between November 2008 and April 2014 (the start date is dictated by the availability of number of CDS contracts data).

For the empirical analysis, we use the Panel Data Vector Autoregression (PVAR) methodology, with all variables in the system treated as endogenous (VAR), while allowing for unobserved individual heterogeneity. Using a PVAR approach we are able to combine the traditional VAR model with a panel-data approach based on the PVAR routine as in Love & Zicchino (2006). We consider this to be a major advantage of this approach, as all variables in the system are treated as endogenous, as in a traditional VAR model, and unobserved individual heterogeneity is being allowed for, as in panel-data estimations. We specify a first-order seven-variable VAR model:

$$Z_{i,t} = \gamma_o + \gamma_1 Z_{i,t-1} + f_i + u_t \quad i = 1,\ldots, N \quad t = 1,\ldots T \qquad (2)$$

In (2), $u_t \sim$ *i.i.d. (0,Σ)* and f_i expresses the time invariant fixed effects. The PVAR, does not allow for dynamic interdependencies in the sense that the lags of the endogenous variables of the same unit only appear. Also, it does not allow either for cross sectional heterogeneities, since γ_o and γ_1 are the same across all units, or for static interdependencies since we assume that $\operatorname{cov}(u_{it}, u_{jt}) = 0$, for $i \neq j$ (see Love and Zicchino, 2006, Canova and Ciccarelli, 2013, Grossmann et al., 2014). We use the Love and Zicchino (2006) code for panel VAR estimation in STATA, and all of the results are estimated using a PVAR with one lag. The evidence from this analysis is mostly based on the results from the impulse-response functions and the variance decompositions.

Furthermore, we use a Cholesky decomposition of the variance-covariance matrix of residuals, since the actual variance-covariance matrix of the errors is highly unlikely to be diagonal. In this case, it becomes difficult to isolate shocks to one of the VAR errors; that is we decompose the residuals in a way that they become orthogonal.[1] With the Cholesky

[1] Note, that it is reasonable to assume that a change in one component has no effect on the other components because the components are orthogonal. Suppose we have a matrix *P*, such that $P'P = \Sigma$. Then

ordering we assume that the most exogenous variable is the VIX Index and the least exogenous is the sovereign CDS. An important restriction is that the underlying structure is the same for each cross-sectional unit, which however, may not hold. Thus, we allow for "individual heterogeneity" in levels by introducing fixed effects. Simple-mean differencing would give us biased estimators, as fixed effects are correlated with the repressors due to lags of the dependent variables. In order to avoid that we follow Love and Zicchino (2006); that is, we introduce the forward mean-differencing procedure also known as Helmert transformation.

According to Arellano and Bover (1995), the Helmert transformation removes only the forward mean. Since, dependent and lagged variables remain orthogonal we can estimate the coefficients by using system GMM. To analyze the impulse- response functions we need an estimate of their confidence intervals. Since the matrix of impulse-response functions is constructed from the estimated VAR coefficients, their standard errors need to be taken into account. We calculate standard errors of the impulse-response functions and generate confidence intervals which have been produced by Monte Carlo simulations with 200 replications. Therefore, whenever the zero line lies outside the confidence bands there is evidence of a statistically significant response to the shock inflicted.

4. Empirical Results

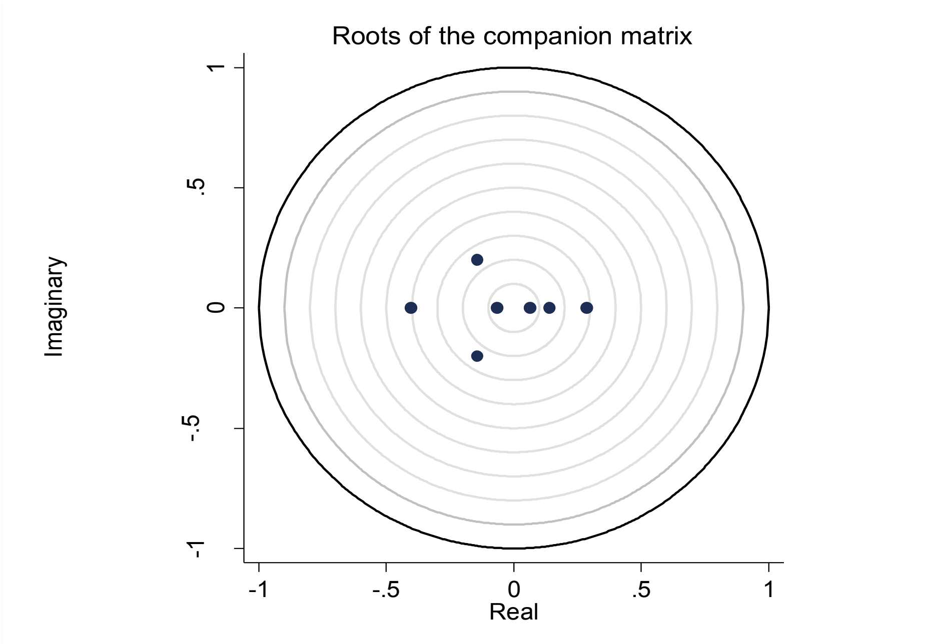
P may be used to orthogonalize the innovations as $e_{it}P^{-1}$ and to transform the VMA parameters into the orthogonalized impulse-responses $P\Phi_i$. The matrix P effectively imposes identification restrictions on the system of dynamic equations. We orthogonalize the shocks using the matrix P to isolate each variable's contribution to the forecast-error variance. The orthogonalized shocks $e_{it}P^{-1}$ have a covariance matrix I_k which allows straightforward decomposition of the forecast-error variance (Abrigo and Love, 2015)

Table 2 presents results for the panel unit root test of Im-Pesaran-Shin (2003; IPS test). As can be seen in the Table we cannot reject the null hypothesis of a unit root, for all sample variables. The next step is the lag selection for the PVAR model. In order to decide on the lag structure we use the overall coefficient of determination (CD) and the Moment and Model Selection Criteria (MMSC) developed by Andrews and Lu (2001) and the MMSC-Akaike's information criterion (MMSC-AIC). 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; the authors argue that the MMSC-AIC criterion works best, in comparison to other competitors, in small samples as the case is in this paper. The results are presented in Table 3 (Panel A) and indicate that the optimal lag structure is one lag. Panel B in Table 3, reports evidence on the stability properties of the estimated PVAR model. The stability of the PVAR requires the moduli of the eigenvalues of the dynamic matrix to lie within the unit circle which is the case in our estimated model (see Figure 1).

Following the Cholesky Ordering the variables are ordered as follows: VIX, Euribor-Eonia spread, iTraxx index, Termspread, Economic Sentiment Indicator, number of CDS contracts and sovereign CDS spreads. The recursive order dictates that the other countries' CDS spread responds to changes in the other variables contemporaneously. In contrast, the VIX index only responds to itself in time *t*, and only with a lag to the other variables. However, one could argue the other way if automatic stabilizers immediately change the ratio. We consider this alternative ordering, but the change in ordering does not greatly affect our analysis and conclusions. Note that Lutkepohl and Poskitt (1991) argues that the ordering of the variables makes little difference when the residuals' correlation is small.

As far as the estimated parameters of the Panel VAR are concerned, we suggest that the estimates do not convey much information. Instead, one should pay attention to the underlying moving average (MA) representation of the VAR model, namely the impulse response functions (IRFs) and the associated variance decompositions (VDs). These two combined, convey information on how each variable responds to a surprise change (a shock) to another variable in the system. Nevertheless, for indicative purposes, we present the results of the estimated parameters in Table 4, only for the case when the Sovereign CDS are treated as endogenous variable in the system (the rest of the results are available upon request).

Figure 1
Roots of the Companion matrix



Notes to Figure 1
The stability of the Panel VAR requires the moduli of the eigenvalues of the dynamic matrix to lie within the unit circle. Panel VAR satisfies stability condition as all eigenvalues lie inside the unit circle.

Table 2
Panel data unit-root tests

	Critical Values			Test Statistics (*p*-values)						
	1%	5%	10%	**VIX**	**iTraxx**	**Eur-Eon**	**termspread**	**ESI**	**NOC**	**Sov CDS**
Core	-2.40	-2.15	-2.02	-5.837 (0.00)	-5.772 (0.00)	-6.918 (0.00)	-5.031 (0.00)	-4.703 (0.00)	-5.243 (0.00)	-5.337 (0.00)
Core 1st	-2.50	-2.19	-2.04	-2.922 (0.00)	-2.886 (0.00)	-3.468 (0.00)	-2.072 (0.00)	-2.331 (0.00)	-2.486 (0.00)	-2.581 (0.00)
Core 2nd	-2.44	-2.16	-2.02	-3.738 (0.00)	-3.686 (0.00)	-4.346 (0.00)	-3.658 (0.00)	-2.831 (0.00)	-3.785 (0.00)	-3.432 (0.00)
Core 3rd	-2.46	-2.18	-2.04	-3.495 (0.00)	-3.713 (0.00)	-3.632 (0.00)	-3.274 (0.00)	-3.141 (0.00)	-3.281 (0.00)	-3.026 (0.00)
Peripheral	-2.50	-2.19	-2.04	-2.922 (0.00)	-2.886 (0.00)	-3.468 (0.00)	-2.105 (0.00)	-2.549 (0.00)	-2.978 (0.00)	-2.491 (0.00)
Peripheral 1st	-2.50	-2.19	-2.04	-2.922 (0.00)	-2.886 (0.00)	-3.468 (0.00)	-2.105 (0.00)	-2.549 (0.00)	-2.978 (0.00)	-2.491 (0.00)
Peripheral 2nd	-2.44	-2.16	-2.02	-3.738 (0.00)	-3.686 (0.00)	-4.34 (0.00)	-3.603 (0.00)	-3.718 (0.00)	-3.531 (0.00)	-3.882 (0.00)
Peripheral 3rd	-2.46	-2.18	-2.04	-3.427 (0.00)	-3.713 (0.00)	-3.632 (0.00)	-3.348 (0.00)	-3.487 (0.00)	-3.117 (0.00)	-2.871 (0.00)

Notes to Table 2
The Table presents results for the Im. Pesaran and Shin (2009) test (IPS test). The null hypothesis is that of a unit root. VIX is the Chicago Board Options Exchange Volatility Index; Eur-Eon is the 3-month Euribor–Eonia Spread; iTraxx is the corporate CDS Premium (iTraxx Europe non-financial firms); Termslope is the slope of the term structure, i.e. the difference between the 10-year government bond yield for each country and the 3-month Euribor rate; ESI is the Economic Sentiment Indicator; NOC is the number of CDS contracts traded on a weekly basis; Sov CDS is the Sovereign CDS spread. Changes are defined as the first differences of the logarithmic levels, apart from the termspread and Euribor-Eonia spread which are transformed in first differences. All data are monthly and obtained from DataStream International, Bloomberg, and the Depository Trust & Clearing Corporation, DTCC. The sample covers the period between November 2008 and April 2014.

Table 3
Lag Selection and Eigen Value Stability Condition

Panel A: Lag order selection statistics estimated using GMM				
Lag	**CD**	**MBIC**	**MAIC**	**MQIC**
1	0.5900	2.04E-30	2.04E-30	2.04E-30
2	0.8125	1.39E-29	1.39E-29	1.39E-29
3	0.8839	2.74E-29	2.74E-29	2.74E-29
4	0.9230	3.86E-29	3.86E-29	3.86E-29

Panel B: Eigen Value Stability Condition of Panel VAR estimates		
Eigenvalue		
Real	**Imaginery**	**Modulus**
-0.4023	0.0000	0.4023
0.2865	0.0000	0.2865
-0.1413	0.2011	0.2458
-0.1413	-0.2011	0.2458
0.1402	0.0000	0.1402
-0.0664	0.0000	0.0664
0.0632	0.0000	0.0639

Notes to Table 3

The Table presents test reults for the optimal lag structure. We employ the overall coefficient of determination (CD) and from the Moment and Model Selection Criteria (MMSC) developed by Andrews and Lu (2001) and the MMSC-Akaike's information criterion (MMSC-AIC). 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; the authors argue that the MMSC-AIC criterion works best, in comparison to other competitors, in small samples as the case is in this paper.

Table 4
Coefficients of the Panel VAR with Sovereign CDS as endogenous variable

	Core Countries			**Peripheral Countries**		
	1st Period	**2nd Period**	**3rd Period**	**1st Period**	**2nd Period**	**3rd Period**
VARIABLES	Sov_CDS	Sov_ CDS	Sov_ CDS	Sov_ CDS	Sov_ CDS	Sov_ CDS
L.VIX	-0.1180	-0.0289	-0.0633	-0.6630***	0.2560	-0.0217
L.iTraxx	0.4140	0.0640	-0.0139	-0.4260	0.1250	-0.2060
L.Eur-Eon	0.2211**	0.0794	0.4881***	0.1990**	0.0888	0.5970***
L.termspread	0.2260*	-0.0119	-0.0483	-0.0056	-0.0265	0.1270***
L.ESI	-2.3920**	-1.8810**	1.3101**	-2.5650***	-0.3650	1.5701
L.NOC	-1.894***	0.8740***	-0.0506	-2.3861**	0.7000***	0.4841***
L.CDS	0.1181	-0.1194	0.0468	0.2092	-0.1111	0.0187

Notes to Table 4

The Table reports coefficients of regressing the dependent variables on lags of the independent variables. ***, **, *, denote significance at the 1%, 5%, and 10% respectively. See also Notes to Table 1.

In order to assess the contribution of each determinant in the behavior of sovereign CDS spreads, we estimate their variance decomposition. The results for the three sub-periods are presented in Table 5 (for the period between November 2008 and April 2010), Table 6 (for the period between May 2010 and July 2012), and Table 7 (for the period between August 2012 and April 2014). The focus is on the last line of each panel matrix as it represents the sovereign CDS variance decomposition. As can be seen in Table 5 (Panel A), the main contributor in the first sub-period for the core countries' sovereign CDS variance decomposition (except for the own effect, 23.19%) is the iTraxx European index, with a 26.3% of the total sovereign CDS variance. The termspread and the number of CDS contracts traded are also important contributors each contributing to about 13% of the total variance, while Euribor-Eonia spread contributes close to 10% approximately. The VIX and ESI indices appear to be less important.

For the peripheral countries (Panel B), however, it is the VIX and the iTraxx that together contribute approximately 32% to the variance of peripheral countries CDS while second more important contributor is the number of CDS contracts traded with a further 16.61%. The Euribor-Eonia spread and the ESI contribute less than 10% to the total variance. The termspread contributes approximately 10%. The sovereign CDS own effect is approximately 23%. Note that the two variables that may proxy for sentiment (ESI & NOC) have a combined effect of around 20% for core countries and around 26% for peripheral countries.

During the second sub-period, for the core countries (Table 6, Panel A) the iTraxx contributes approximately 33% and together with the CDS own effect (41%) account for approximately 72% of variance. The number of CDS contracts contributes 8% to the total variance while the other variable contribution is of minor importance. For the peripheral countries (Panel B) the major contributors are the VIX (approximately 30%), the CDS own effect (37.45%), and the termspread with 18.77%, while the contribution of the other variables is minor. During the third sub-period (Table 7) the results indicate that for the core countries (Panel A) the most important contributors are the CDS own effect (61.84%), the Euribor-Eonia spread with 16.07% and the iTraxx with 11.39%. For the peripheral countries (Panel B) the determinant contributing the most to the variance of CDS is the Euribor-Eonia spread (32.8%), the termspread (21.35%), the CDS own effect (19.39%) and the iTraxx (14.78%). Note that the effect of the two sentiment variables is significantly reduced during the second and third sub-periods.

Several interesting results emerge from the analysis. More specifically, the results indicate that the determinants of CDS variance are neither uniform nor stable during sample periods and sample countries. For instance, the CDS own effect is increasing with time for the core countries and increases only during the second sub-period for peripheral countries; the iTraxx (a proxy for market-wide credit risk) is important for the core countries during the first and second period but less important during the third; for the peripheral countries its impact is reduced during the second period. Note also that the impact of the slope of the term structure on CDS spread variance is increasing as we move from 2008 to 2014 for the peripheral countries, and decreasing for the core countries for the respective period. The VIX, a proxy for global market risk, is not very important for the core countries, however, it is very important for peripheral countries during first and second sub-periods: for instance its effect for the peripheral countries is reduced between the second and third period from 30.49% to 5.13%. Also, the CDS trading volume (NOC) is important during the first sub-period for all countries (around 23%), but not important in the second and third sub-periods. Investor sentiment may be an important CDS spread determinant during the period between 2008 and 2010.

The Euribor-Eonia spread (that proxies for banking stress in Europe) is not very important for all countries during the first and second sub-period (in the aftermath of the subprime crisis in the US) but it becomes very important during the third: for example, for the peripheral countries it increases from 4.43% during the second sub-period to 32.8% during the third sub-period; for the core countries it increases from 1% to 16.07%, respectively. Note that following the failure of Lehman Brothers, the Euro-Eonia spread rose sharply, since the largest euro-area banks are highly global in their orientation (McGuire and von Peter, 2009; Shin, 2012); however, the ECB reduced interest rates and increased its own balance sheet and volume of loans to the banking sector. As a result the initial liquidity crush on euro-area banks did calm down, and rates in interbank markets returned to more normal levels by late 2009.

Table 5
Forecast Error Variance Decomposition
November 2008- April 2010

Panel A Core countries							
	Impulse Variables						
Response variable	VIX	Eur-Eon	iTraxx	Termspread	ESI	NOC	CDS
VIX	82.25	1.14	2.16	0.41	1.1	12.5	0.41
Eur-Eon	1.88	54.79	9.07	1.2	3.31	23.9	5.8
iTraxx	17.97	4.38	55.42	5.05	3.1	9.42	4.63
Termslope	12.96	1.54	8.33	52.93	14.16	8.54	1.5
ESI	2.41	1.83	11.81	24.14	48	8.33	3.44
NOC	1.53	5.24	5.57	11.71	5.09	69.81	1.01
CDS	**7.76**	**9.76**	**26.3**	**13.79**	**6.09**	**13.07**	**23.19**
Panel B Peripheral countries							
	Impulse Variables						
Response variable	VIX	Eur-Eon	iTraxx	Termspread	ESI	NOC	CDS
VIX	68.07	4.12	0.21	0.28	2.66	23.26	1.37
Eur-Eon	7.36	67	2.03	2.88	6.16	9.73	4.81
iTraxx	39.39	2.66	27.4	2.16	4.06	17.29	7.01
Termslope	15.48	1.96	14.75	50.7	7.85	8.3	0.94
ESI	8.2	6.77	10.99	13.21	50.69	7.25	2.84
NOC	8.65	19.97	3.28	7.47	4.93	55.29	0.38
CDS	**19.23**	**8.39**	**12.97**	**10.61**	**9.29**	**16.61**	**22.86**

Notes to Table 5
The Table reports the fraction (in percentage points) of the 10 months ahead forecast error variance of each variable that is attributable to VIX, Euribor –Eonia, iTraxx, termspread, ESI, NOC, Sovereign CDS. Our main interest is on the bottom line of each matrix as it represents the sovereign CDS variance decomposition. See also Notes to Table 1. The sample period is November 2008- April 2010.

Table 6
Forecast Error Variance Decomposition
May 2010- July 2012

Panel A Core countries							
	Impulse Variables						
Response variable	VIX	Eur-Eon	iTraxx	Termspread	ESI	NOC	CDS
VIX	96.53	0.5	0.06	0.69	1.42	0.72	0.04
Eur-Eon	0.62	81.39	1.16	1.01	0.81	12.74	2.24
iTraxx	19.38	11.23	52.86	0.56	5.63	8.94	1.37
Termslope	6.04	1	10.21	80.2	2.09	0.17	0.26
ESI	6.46	4.63	9.16	4.66	74.6	0.31	0.15
NOC	2.48	7.84	10.18	2.75	2.56	74.14	0.01
CDS	**10.07**	**1**	**32.89**	**3.1**	**3.88**	**8.02**	**41.01**
Panel B Peripheral countries							
	Impulse Variables						
Response variable	VIX	Eur-Eon	iTraxx	Termspread	ESI	NOC	CDS
VIX	89.18	1.03	1.43	6.39	0.6	1.02	0.32
Eur-Eon	2.89	69.41	8.72	4.6	4.3	4.51	5.47
iTraxx	58.69	10.72	20.35	5.04	0.69	1.39	3.08
Termslope	6.66	2.5	1	87.66	1.29	0.82	0.03
ESI	15.34	3.2	3.95	0.89	73.88	0.35	2.36
NOC	14.88	3.74	5.59	3.09	4.96	66.45	1.26
CDS	**30.49**	**4.43**	**2.19**	**18.77**	**0.53**	**6.1**	**37.45**

Notes to Table 6
The Table reports the fraction (in percentage points) of the 10 months ahead forecast error variance of each variable that is attributable to VIX, Euribor –Eonia, iTraxx, termspread, ESI, NOC, Sovereign CDS. Our main interest is on the bottom line of each matrix as it represents the sovereign CDS variance decomposition. See also Notes to Table 1. The sample period is May 2010- July 2012.

Table 7
Forecast Error Variance Decomposition
August 2012- April 2014

Panel A
Core countries

	Impulse Variables						
Response variable	VIX	Eur-Eon	iTraxx	Termspread	ESI	NOC	CDS
VIX	40.1	42.61	8.68	1.76	3.94	1.03	1.85
Eur-Eon	6.93	76.33	7.89	1.35	3.53	1.45	2.47
iTraxx	4.6	21.16	49.2	17.44	2.48	4.16	0.93
Termslope	1.87	8.42	11.36	70.74	2.76	4.65	0.17
ESI	4.48	32.6	11.47	6.14	39.65	4.22	1.42
NOC	3.4	32.92	6.21	4.83	6.44	45.41	0.74
CDS	**1.9**	**16.07**	**11.39**	**0.8**	**6.88**	**1.09**	**61.84**

Panel B
Peripheral countries

	Impulse Variables						
Response variable	VIX	Eur-Eon	iTraxx	Termspread	ESI	NOC	CDS
VIX	27.74	48.32	11.77	3.22	2.71	1.5	4.7
Eur-Eon	11.38	62.95	10.42	5.01	1.76	1.38	7.06
iTraxx	9.19	30.35	40.02	10.91	1.09	4.55	3.85
Termslope	7.56	30.94	15.2	37.81	4.01	1.14	3.3
ESI	4.19	32.77	5.42	14.96	38.23	2.28	2.12
NOC	9.98	36.75	6.58	5.84	3.88	33.21	3.72
CDS	**5.13**	**32.8**	**14.78**	**21.35**	**1.82**	**4.7**	**19.39**

Notes to Table 6
The Table reports the fraction (in percentage points) of the 10 months ahead forecast error variance of each variable that is attributable to VIX, Euribor –Eonia, iTraxx, termspread, ESI, NOC, Sovereign CDS. Our main interest is on the bottom line of each matrix as it represents the sovereign CDS variance decomposition. See also Notes to Table 1. The sample period is August 2012- April 2014.

4.1. Robustness tests

The results in the previous section indicate that the ESI index (a proxy for economic sentiment) is important during the first sub-period for the peripheral countries with almost 10% contribution and less important effect in core countries (6.09%). In order to test whether this is due to the choice of the proxy variable for sentiment or due to the importance of sentiment as a CDS determinant, in this section we recalculate the model and replace ESI with the ZEW Sentiment Indicator. The ZEW Economic Sentiment is an amalgamation of the sentiment of approximately 350 economists and analysts regarding the economic future of Europe for the next six months. The results are summarized in Table 8 and indicate that, when the ZEW Index is used as a sentiment proxy, the impact of sentiment on CDS variance is more significant for the core countries during the second and third sub-periods (around 10%) and more significant for the peripheral countries during the second period (4.68% from 0.55%). Thus, sentiment may indeed play a role in CDS spread determination.

In order to test the robustness of the results (the rest of the results discussed in this sub-section are available upon request) with respect to the proxy variable for global market risk, we replace the VIX index with the VSTOXX implied volatility index. The VSTOXX Indexes are based on EURO STOXX 50 real time options prices and are designed to reflect the market expectations of near-term up to long-term volatility by measuring the square root of the implied variance across all options of a given time to expiration (see also Collin-Dufresne et al., 2001; Heinz and Sun, 2014). In order to test the robustness of the results with respect to our proxy variable for the market liquidity, we replace the NOC variable (number of CDS contracts traded) with the bid-ask spread, i.e. the difference between the ask price and the bid price of a CDS contract. We obtain similar results with one exception: for the first period the bid-ask variable seems to have no effect on CDS variance, in contrast to the results reported in Table 5 where NOC contributed between 13.07% (core countries) and 16.61% (peripheral countries).

The assumption behind the Cholesky decomposition is that series listed earlier in the VAR order impact the other variables contemporaneously, while series listed later in the VAR order impact those listed earlier only with lag. Our motivation behind the chosen Cholesky ordering of the variables is as follows: CDS spreads are listed last since it is the variable of interest (all the other variables are treated as determinants of CDS spreads), and thus responds to itself in time t and only with a lag to the other variables. VIX, Euribor-Eonia spread, and iTraxx are listed first, second, and third in the ordering, respectively, since they represent global variables (US and EU) and empirical evidence indicates that global variables should be ordered first (Bouvet et al., 2014). The rest of the variables are listed next, as domestic variables. Note that the Cholesky ordering of VAR models may be sensitive to changes in the ordering of the variables in the system. In the case of a structural VAR analysis, the selection of ordering in Cholesky decomposition is generally ad hoc, and convincing identifying assumptions are hard to come by (see Hamilton, 1994, Lutkepohl, and Posskit, 1991). It is unlikely that this issue will affect our results since (a) it is pronounced in cases of high residual correlation and makes a small difference when correlation is small (Lutkepohl, and Posskit, 1991), as in our case, (b) we test for alternative decompositions of ordering variables (De Castro, 2004) and the results remain qualitatively the same, and (c) we apply a series of robustness tests and the results seem to support our choice.

More specifically, we have only one case where the residual correlation is relatively high (VIX and iTraxx for the peripheral countries during the second period), and thus the results may be sensitive to the ordering of variables. In this case we apply the Generalized Impulse Response Analysis (Pesaran and Shin, 1998) in order to estimate variance decompositions as this method is invariant to the ordering of the variables. The results from the Generalized Forecast Error Decompositions (GFEVD) are similar to the results obtained from the orthogonalized FEVDs, and seem to confirm our choices and in particular the choice of the CDS spread as the most endogenous variable (all results are available upon request) . As discussed above, for the estimation of the PVAR we used the Love and Zicchino code and the estimation method is the GMM where the individual country fixed effects have been removed through the Helmert transformation by applying forward mean-differencing. 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 and financial-sentiment factors to the behaviour of sovereign CDS spreads, as well as, the contribution of each one of the latter. 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.

Table 8
Forecast Error Variance Decomposition - Zew Sentiment

	Impulse Variables						
Periods	VIX	Eur-Eon	iTraxx	ZEW	Termslope	NOC	CDS
1st Period/Core	5.5	4.45	21.9	2.29	30.97	4	30.86
2nd Period/Core	9.86	0.83	32.24	**10.2**	3.71	3.71	39.6
3rd Period/Core	2.75	20.92	18.21	**10.52**	2.37	2	43.2
1st Period/Peripheral	13.38	0.54	15.49	7.05	30.79	10.52	22.2
2nd Period/Peripheral	26.93	3.29	3.04	**4.68**	19.21	8.07	34.75
3rd Period/Peripheral	2.67	27.11	13.51	0.43	22.91	2.78	30.56

Notes to Table 8
The ZEW Economic Sentiment is an amalgamation of the sentiment of approximately 350 economists and analysts regarding the economic future of Europe for the next six months. The survey shows the balance between those analysts who are optimistic about Europe's economic future and those who are not.

4.2. Impulse response functions

Figures 2, 3, and 4, present Orthogonalized Impulse Response Functions (IRFs) and the 5% and 95% error bands (in red) generated by Monte Carlo simulations (200 repetitions) for the three sub-periods for the core countries. Figures 5, 6, and 7, present the same IRFs for the peripheral countries. More specifically, we do not present all IRFs but only these with the response variable being the sovereign CDS spread (i.e. its response to a shock of the other variables). Note that for the first period, the pattern is quite similar across both the core and the peripheral countries, although the impact of the lagged determinants on the level of sovereign credit risk is much larger in the peripheral countries than it is in the core countries (Figures 2 and 5). Furthermore the responses are the expected ones. For instance, there is a positive response to a shock in iTraxx and the Euribor-Eonia spread, i.e. as wide market risks increases and banking stress intensifies, spreads also increase. Also there is a negative response to a shock in the ESI and the NOC, implying that increases in economic sentiment and liquidity lead to reduced spreads. During the second period, for all countries, credits spreads increase in response to an iTraxx shock and also exhibit a negative response to a shock in VIX.

For the core countries, there is a negative response to NOC as well, while the other variables have no significant effect on CDS spreads. For the peripheral countries, spreads also show a positive reaction to a termspread shock, while other variables have no significant effect on sovereign CDS. In the third period, for both groups, credit spreads respond positively to iTraxx shocks, showing the that financial turbulence still exists, while the response to Euribor-Eonia spread shock is negative and then turns to positive. Note the positive response of CDS spreads to termspread shocks only in peripheral countries.

Figure 2
Orthogonalized Impulse Response Functions: Core countries
(November 2008- April 2010)

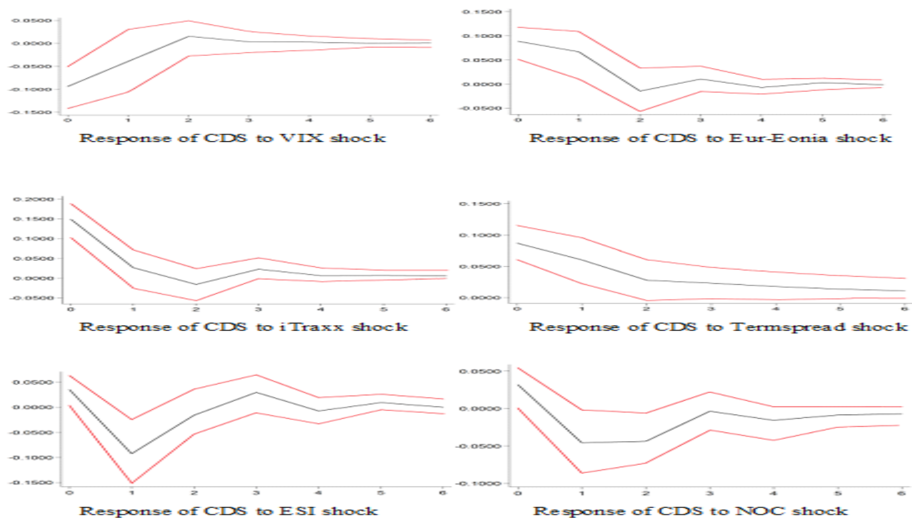


Figure 3
Orthogonalized Impulse Response Functions: Core countries
(May 2010- July 2012)

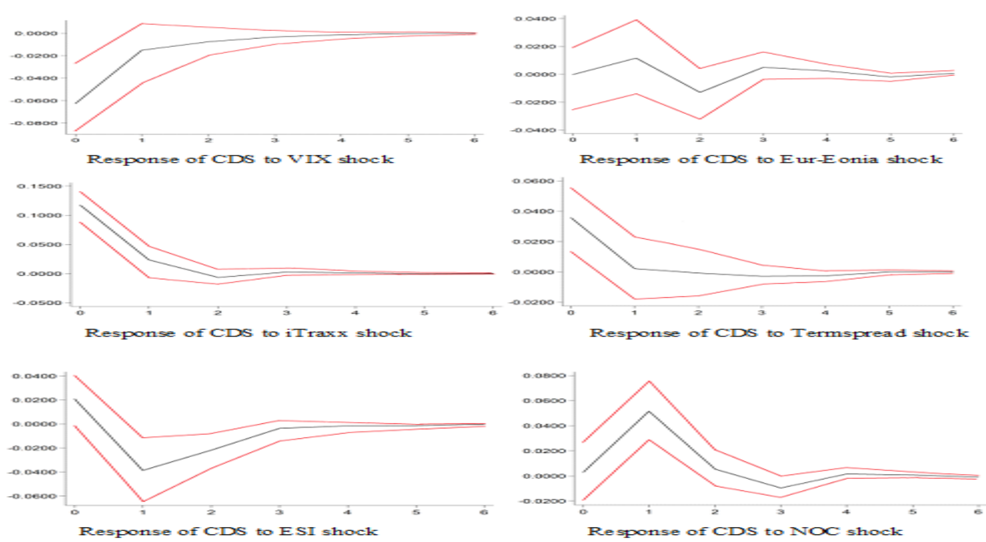


Figure 4
Orthogonalized Impulse Response Functions: Core countries
(August 2012- April 2014)

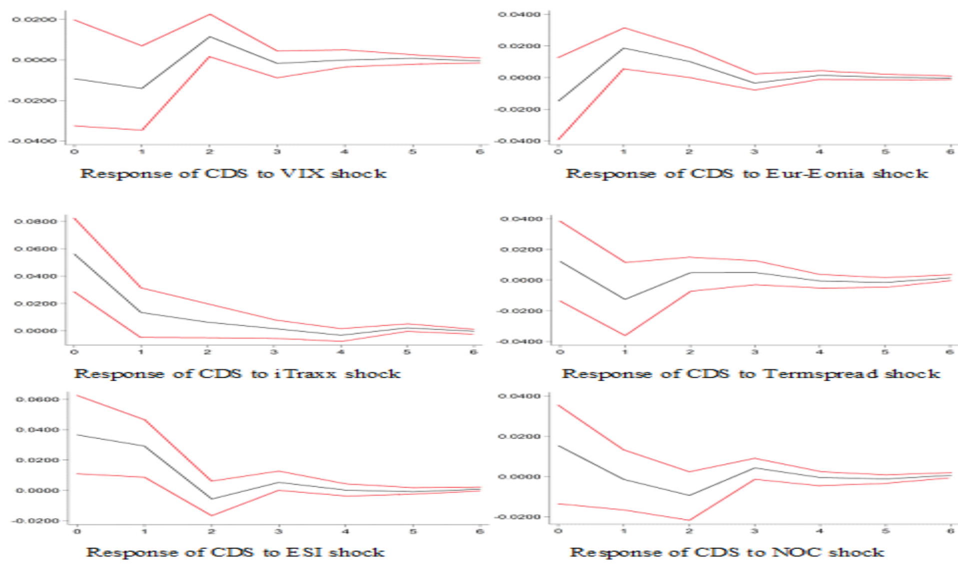


Figure 5
Orthogonalized Impulse Response Functions: Peripheral countries
(November 2008- April 2010)

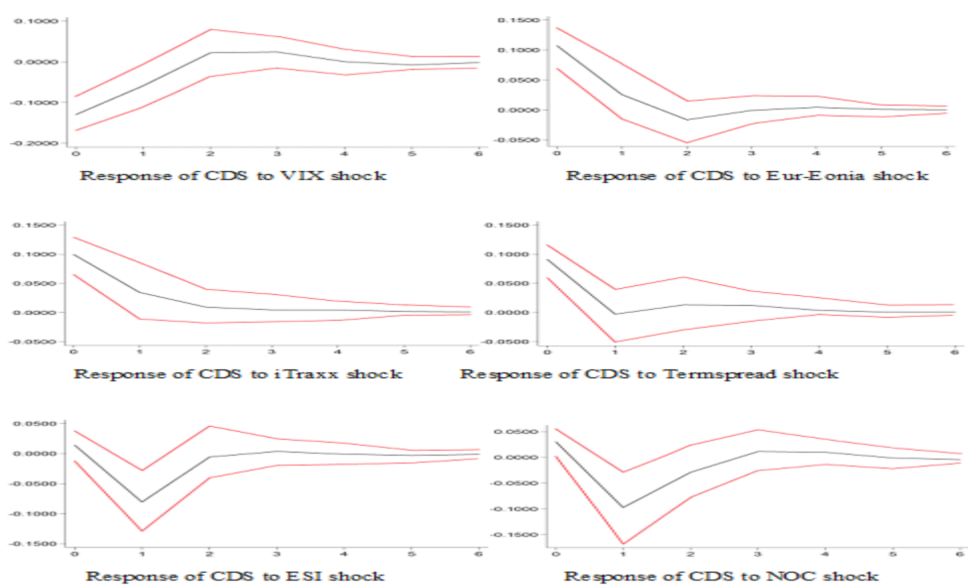


Figure 6
Orthogonalized Impulse Response Functions: Peripheral countries
(May 2010- July 2012)

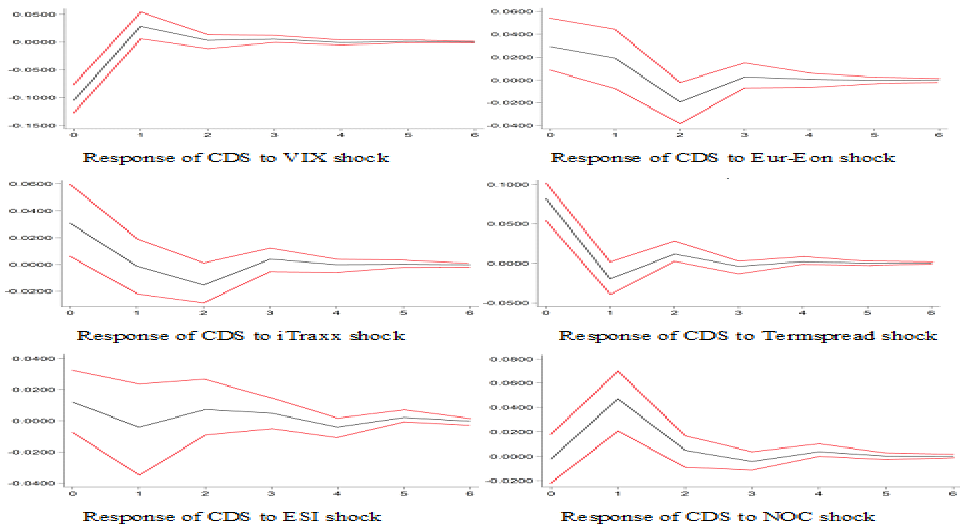


Figure 7
Orthogonalized Impulse Response Functions: Peripheral countries
(August 2012- April 2014)

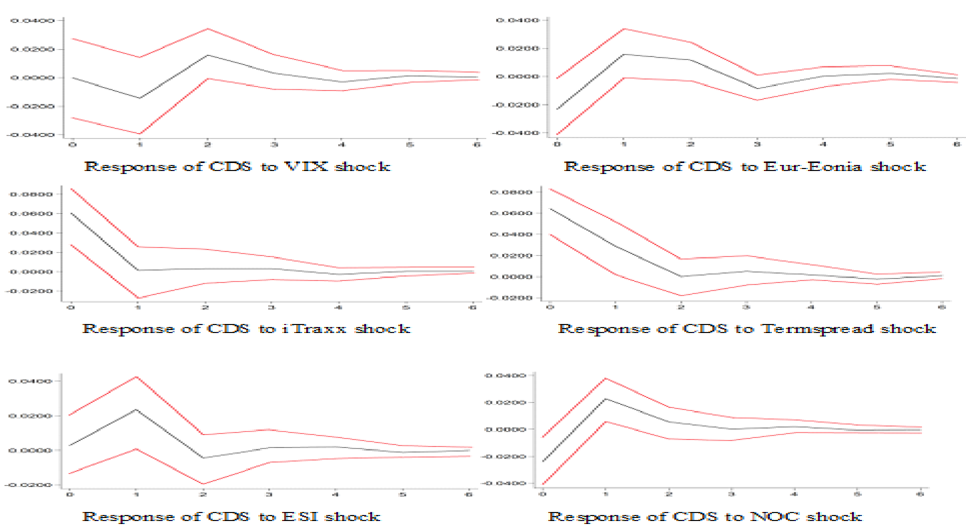
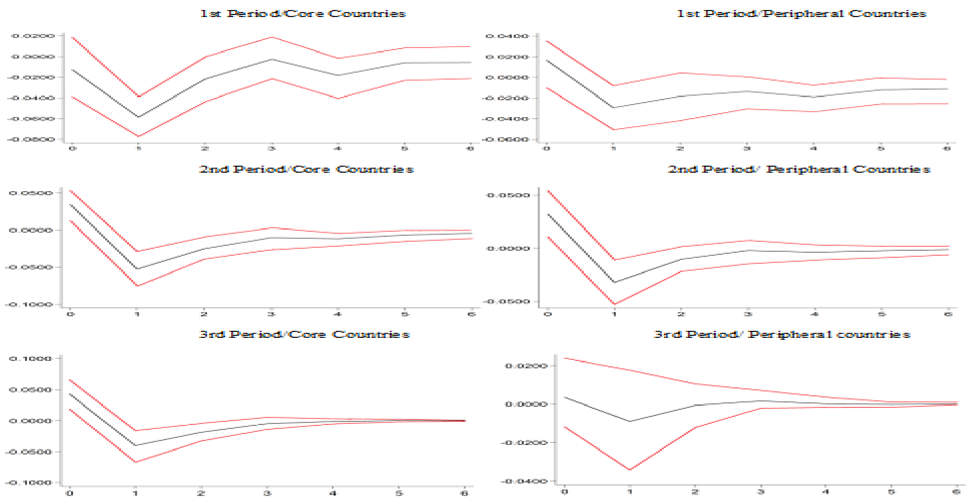


Figure 8
Orthogonalized Impulse Response Functions:
Sovereign CDS response to ZEW shock



4.3. Spillover Effects

In December 2011 Greece admitted a much larger than expected fiscal deficit, which lead to a series of downgrades by rating agencies, capital market turmoil, and fears that other peripheral European countries will soon be affected. Greece negotiated a bailout package with the European Commission (EC), the European Central Bank (ECB), and the International Monetary Fund. Within the following months, Ireland and Portugal negotiated their own bailout packages. As a result, sovereign yield spreads and CDS spreads for many European countries were affected. This section investigates potential spillover effects; more specifically we examine the forecast error variance of sovereign CDS in core and peripheral countries that is attributable to the variables that proxy for spread determinants. We also include in the analysis sovereign CDS spreads for Spain, Portugal, Italy, and Ireland and Greece (due to data availability for Greece we include sovereign bond yield spreads vs Germany). In other words we also test for the impact of shocks to core economies stemming from countries that experience financial difficulties. We also include the ZEW index as a proxy for sentiment (results with the ESI index are similar). Note that when the CDS spread of a country is included in the PVAR as a potential determinant it is deleted from the sample group. For example, when Greek spreads are included in the PVAR as explanatory variables, they are excluded from the "peripheral countries" sample in order to isolate its effect on the other countries' spreads. The results (Table 9, sample period between 2010 and 2012) indicate that for core countries, potential spillover effects may stem from Spain and Italy, as they appear the main sources of cross-country spillovers. More specifically, Spanish spreads contribute 14.92% to core CDS variance while Italian CDS contribute 15.8%. The Portuguese, Greek, and Irish spreads are of minor importance. As far as peripheral countries are concerned, it is Spanish and Portuguese spreads that contribute the most (17.69% and 14.91%, respectively). It is interesting to note that Greek spreads contribute the least to the variance decomposition (7.63%). This may reflect the fact that investor concerns about debt sustainability in Spain and Italy were linked much more to concerns about the future of the euro area as a whole, given the size of the two economies and their stronger ties to the core euro area countries, compared to Greece. Italy and Spain, being much larger economies, could potentially destabilize the euro area, even though their likelihood of running into financial difficulties was perceived by the markets as comparatively smaller, based on their SCDS spreads. Moreover, following the first Greek debt restructuring in mid-2011, Greek CDS spread was persistently well above 1000 bps and probably carried little information for investors.

Table 9
Spillover effects to core and peripheral CDS spreads through sovereign debt crisis

Response variable	Impulse Variables							
	VIX	**Eur-Eon**	**iTraxx**	**ZEW**	**Spanish_CDS**	**Termspread**	**NOC**	**CDS**
Core	9.06	0.74	31.71	11.18	14.92	1.54	4.85	26.47
Peripheral	29.11	3.89	1.1	3.12	17.69	8.68	6.82	29.56
	VIX	**Eur-Eon**	**iTraxx**	**ZEW**	**Portuguese_CDS**	**Termspread**	**NOC**	**CDS**
Core	9.05	1.15	32.27	10.41	1.65	3.91	2.66	38.83
Peripheral	26.13	3.53	4.39	3.89	14.91	10.8	4.71	31.6
	VIX	**Eur-Eon**	**iTraxx**	**ZEW**	**Italian_CDS**	**Termspread**	**NOC**	**CDS**
Core	7.75	0.40	29.71	13.54	15.8	5.28	3.93	23.55
Peripheral	24.23	3.28	1.7	2.41	11.36	23.64	10.84	22.5
	VIX	**Eur-Eon**	**iTraxx**	**ZEW**	**Greek_Bonds**	**Termspread**	**NOC**	**CDS**
Core	4.23	1.14	27.32	13.48	4.54	3.57	3	42.68
Peripheral	22.46	3.12	4.56	4.60	7.63	18.07	5.57	33.96
	VIX	**Eur-Eon**	**iTraxx**	**ZEW**	**Irish_CDS**	**Termspread**	**NOC**	**CDS**
Core	9.80	0.89	32.82	10.95	1.39	3.89	3.71	36.5
Peripheral	26.04	4.40	4.72	7.60	13.73	13.44	9.71	20.31

Notes to Table 9
The Table reports the fraction (in percentage points) of the forecast error variance of sovereign CDS in core and peripheral countries that is attributable to the variables that proxy for spread determinants. We also include in the analysis sovereign CDS spreads for Spain, Portugal, Italy, and Ireland. Due to data availability for Greece we include sovereign bond yield spreads (vs Germany). See also Notes to Table 5. Sample period: May 2010 to July 2012.

4.4. Further Robustness Tests

In order to shed more light to the results, we re-estimate results as follows: we employ alternative country groups and estimate their variance decomposition during the full sample period, as follows: “core and peripheral” or “Eurozone” (Germany, Austria, Belgium, France, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain), “core” (Germany, Austria, Belgium, France and the Netherlands) and “peripheral” (Ireland, Italy, Portugal, Spain and Greece). The results are presented in Table 10: Panel A presents the results for the Core and Peripheral countries (Full Sample), Panel B for the Core countries (Full Sample), Panel C for the Peripheral countries (Full Sample), Panel D for the Core and Peripheral countries (1st period), Panel E for the Core and Peripheral countries (2nd period), Panel F for the Core and Peripheral countries (3rd period).

As can be seen in Table 10 (Panel A) the main contributor for the “core and peripheral” countries’ sovereign CDS variance decomposition for the full sample period (except for the own effect, 58.83%), is the iTraxx European index, with 18.68% of the total sovereign CDS variance. The termspread and the VIX are also important contributors contributing to 7.7% and 9.03% of the total variance respectively, while the other factors appear to be less important. For the core countries (Panel B), the results remain approximately the same, with the contribution of VIX and termspread slightly reduced and the CDS own effect slightly increased. For the peripheral countries (Panel C) the effect of the termspread is significantly increased (13.34%) and the CDS own variance significantly reduced (46.53%). VIX seems to be an important contributor with almost

17% of the total variance. For the “core and peripheral” country group during the three sub-periods (Panels D, E, F) the main result that emerges is that investor sentiment (ESI) during the first sub-period contributes 7.07% to the total CDS variance, market sentiment (NOC) contributes 12.42% to the total CDS variance. Also, during the third sub-period the Eur-Eon variable becomes significantly important (22.02% from 2%-7.95%), that the iTraxx contribution is significantly reduced but still remains important (10.08% from 19.06%-21.82%), and that the CDS own contribution is increased during the third sub-period.

These results strongly indicate that the determinants of CDS variance are neither uniform nor stable during different sample periods and different sample countries. For instance, the CDS own effect for the “core and peripheral” group differs during the three periods, contributing 29.94%, 44.57% and 54.93% for the first, second and third period respectively. The iTraxx (a proxy for market-wide credit risk) is almost the same for the three different country groups, while it is more important as contributor for the “core and peripheral” group during the first and the second period; the CDS trading volume (NOC) is important during the first sub-period for the “core and peripheral” countries (around 12.42%), but not as important in the second sub-period and with no effect in the third sub-period. The ESI appears important for the first sub-period (7.07%) while it has no important effect during the other two sub-periods. The Euribor-Eonia spread (a proxy for banking stress in Europe) seems to be gaining importance during the third period for the “core and peripheral” group (22.02%) and is less importance during rest sub-periods.

Table 10
Robustness tests - Forecast Error Variance Decomposition

Response Variable	**Impulse Variables**						
	Panel A Core and Peripheral countries (Full Sample)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	Noc	Cds
Cds	9.03	2.59	18.68	7.7	0.54	2.6	58.83
	Panel B Core countries (Full Sample)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	Noc	Cds
Cds	6.53	2.52	19.21	4.99	0.92	2.69	63.1
	Panel C Peripheral countries (Full Sample)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	Noc	Cds
Cds	16.92	3.13	17.24	13.34	0.35	2.46	46.53
	Panel D Core and Peripheral countries (1st sub-period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	Noc	Cds
Cds	10.85	7.95	21.82	9.91	7.07	12.42	29.94
	Panel E Core and Peripheral countries (2nd period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	Noc	Cds
Cds	16.03	2.2	19.06	10.04	1.16	6.91	44.57
	Panel F Core and Peripheral countries (3rd period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	Noc	Cds
Cds	2.71	22.02	10.08	5.29	4.62	0.32	54.93

Notes to Table 10
The Table reports the fraction (in percentage points) of the 10 months ahead forecast error variance of the sovereign CDS variance decomposition that is attributable to VIX, Euribor –Eonia, iTraxx, Termspread, ESI, NOC, Sovereign CDS, for different periods and sample country groups. We employ three country groups as follows and estimate their variance decomposition during the full sample period: “core and peripheral” or “Eurozone” (Germany, Austria, Belgium, France, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain), “core” (Germany, Austria, Belgium, France and the Netherlands) and “peripheral” (Ireland, Italy, Portugal, Spain and Greece). Next, we re-estimate results for the “core and peripheral” countries for the three sub-periods. In “core and peripheral” full sample, “peripheral countries” full sample and “core and peripheral” 3rd period we exclude Greece and Ireland due to lack of data. In “core and peripheral” 2nd period we exclude Greece due to lack of data.

When the ZEW Eurozone Index is used instead of the ESI index (Table 11) the results are qualitatively similar with one exception: the sentiment proxy seems to be a very important spread determinant for all countries during the second period, since it contributes approximately 8.5% to CDS variance. This finding, further supports the notion that sentiment may be an important spread determinant during crisis periods.

Table 11
Forecast Error Variance Decomposition - ZEW Sentiment (Full period)

	Impulse variables						
Group / Period	Vix	Eur-Eon	iTraxx	ZEW	Termspread	Noc	Cds
Core and Peripheral countries (Full period)	7.57	1.82	17.18	6.55	6.95	3.4	56.51
Core countries (Full period)	5.49	1.87	16.74	6.42	6.16	3.3	59.98
Peripheral countries (Full period)	13.77	2.16	16.71	5.85	12.41	3.73	46.33
Core and Peripheral countries / 1st period	7.56	1.55	19.52	5.17	28.49	4.22	33.45
Core and Peripheral countries / 2nd period	14.32	1.42	18.17	8.34	10.6	5.83	41.81
Core and Peripheral countries / 3rd period	3.2	21.55	17.38	4.49	4.47	0.19	48.68

Notes to Table 11
The Table presents results with the ZEW Economic Sentiment variable instead of the ESI variable; see also notes to Table 8.

As a further robustness test, we also re-estimate the effect of sentiment on spreads, using the proxy index (ESI) in levels (ESI minus 100), rather than log differences, i.e. differences of the index from the optimism-threshold (see for details, Georgoutsos and Migiakis, 2013). We present the results for the three sub-periods for the "core" and the "peripheral" groups in the following Table 12. The results reveal that when the ESI is used in levels the effect of local sentiment has a strong effect during the first and the second sub-period in peripheral countries with an important contribution of 13.14% and 12.5%, respectively.

Table 12
Forecast Error Variance Decomposition (ESI in levels-100)

Response Variable	Impulse Variables						
	Panel A Core (1st period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	NOC	Cds
CDS	**4.46**	**4.09**	**7.14**	**34.5**	**6.84**	**4.21**	**38.74**
	Panel B Peripheral (1st period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	NOC	Cds
CDS	**9.71**	**6.35**	**13.44**	**29.96**	**13.14**	**3.08**	**24.3**
	Panel C Core (2st period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	NOC	Cds
CDS	**11.51**	**1.35**	**34.82**	**2.93**	**0.26**	**8.46**	**40.65**
	Panel D Peripheral (2st period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	NOC	Cds
CDS	**17.63**	**12.27**	**5.0**	**10.14**	**12.5**	**6.87**	**35.58**
	Panel E Core (3st period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	NOC	Cds
CDS	**2.92**	**14.22**	**12.55**	**0.93**	**4.84**	**0.49**	**64.03**
	Panel F Peripheral (3st period)						
	Vix	Eur-Eon	iTraxx	Termspread	ESI	NOC	Cds
CDS	**3.25**	**38.19**	**14.3**	**21.22**	**0.73**	**3.09**	**19.2**

Notes to Table 12
See Notes to Table 9

To formally test whether changes in excess correlation are also statistically significant between sovereigns (core/peripheral) and Country-of-Interest CDS spreads, for different time periods we make use of 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 $z = 0.5[\ln(1 + \mathrm{r}) - \ln(1 - \mathrm{r})]$. The standard error of z is given by $\sigma_z = (\sqrt{N-3})^{-t}$, where N is the number of observations. The test-statistic, Z, for the difference between two measures of excess correlation is given then by:

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

In (3) N_1 and N_2 represent the number of observations of the two samples and Z is normally distributed and hence significance can be assessed with the usual test statistics.

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The results concerning the residual correlation between sovereign and Country-of-Interest CDS spreads (we test for spillover effects steaming from Spain and Italy to the core countries as those two had the larger contribution in the core CDS variance) are available upon request, but are discussed here. First, we note a clear increase in excess correlations over the first two sub-periods and a drop in excess correlations during the third sub-period. To formally test whether the differences in correlations are also statistically significant, we make use of the Fisher transformation of (excess) correlation coefficients. This is interpreted as providing support to the argument that there might have been a transfer of default risk from peripheral countries to core countries during the crisis periods. We apply the same test for the three different periods, grouped pair-wise each time (1^{st}-2^{nd}, 2^{nd}-3^{rd} and 1^{st}-3^{rd}) for potential spillover effects steaming from peripheral to core countries and from peripheral to peripheral countries. In all cases we reject the null that the residual correlations are the same for the three different sub-periods. This result offers support to the argument that during the turbulent periods the links between core and peripheral countries have strengthened, while during the third the links decrease substantially. Moreover, even though during the first two sub-periods we detect increased residual correlation, the Fisher *Z* test shows that these correlations are statistically different between these two periods.

Similar results are obtained for peripheral countries (the spillover effects here steam from Spain, Portugal and Italy, the most contributive at the CDS variance decomposition - we do not test for Ireland due to missing data during the third period), where we test the hypothesis that the residual correlation has remained the same over the three sub- period. The values of the Fisher test statistic reveal that we are unable to accept the null (i.e. that correlations have remained the same), during all periods while the spillover effects steam from Spain and Italy to the peripheral countries. When the spillover effects come from Portugal we are unable to reject the null when we test for differences in correlation between 2^{nd} and 3^{rd} period, and 1^{st} and 3^{rd} period. This again reinforces the conclusion that the debt problems of the core and peripheral sovereigns and peripheral with peripherals, have become inextricably interwoven.

5. Conclusion

This paper examines the determinants of CDS spreads and potential spillover effects for Eurozone countries during the recent financial crisis in the EU. We employ a Panel Vector Autoregressive (PVAR) methodology that combines the advantages of traditional

VAR modelling with the advantages of a panel-data approach. In addition to variables that proxy for global and financial market spread determinants we also employ variables that proxy for behavioral determinants. Note that the vast majority of previous studies focuses on macroeconomic and fundamental information in order to study the determinants of spreads and neglect behavioral variables that may capture investor and economic sentiment.

The first main finding that emerges from the analysis is that the determinants of CDS variance are neither uniform nor stable during different periods and different countries. For instance, as we move from 2008 to 2014 the impact of the slope of the term structure on CDS spread variance is increasing for peripheral countries (Spain, Portugal, Italy, Greece and Ireland) and decreasing for the core countries (Germany, France, Netherlands, Belgium and Austria); the effect of global market risk (VIX) is not very important for the core countries, however, it is very important for peripheral countries between 2008 and 2012 (it contributes to CDS variance by approximately 31%).

The second main finding is that sentiment seems to play an important role in CDS spread determination. Note that we employ three different proxies for sentiment, in other words, we capture different aspects of sentiment. More specifically, ESI can be considered as a 'local' forward-looking sentiment proxy (specific to each country); ZEW can be considered as a 'regional' (Eurozone) proxy about six-month ahead expectations concerning the economy, inflation, interest rates, stock markets and exchange rates in the Eurozone as well as expectations concerning oil prices; and the number of contracts traded (NOC) may be considered as a CDS ‘market’ sentiment proxy. More specifically, we find that in peripheral countries local sentiment (ESI) during the financial crisis contributes to almost 10% in total CDS variance close to the contribution of iTraxx (approximately 13%), which is an important determinant according to the literature, while Eurozone sentiment (ZEW) also contributes approximately 10%, during the second and the third period for the core countries.

In terms of policy implications, the finding that determinants are neither uniform nor stable during different periods and different countries may imply limited financial market integration and homogeneity in the euro area. Also, the finding that sentiment is important suggests that, during crisis periods, policy makers should not only concentrate on economic indicators and ignore consumer and investor confidence but rather communicate effectively and signal their decisiveness to deal with the origins of the crisis and affect positively market expectations.

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