Is there a credit risk contagion present among sovereign-bank-firm nexus in the euro zone? A panel VAR analysis of CDS premia

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Abstract

With jump increase in the CDS spreads of respective debt markets in the euro zone after the collapse of Lehman Brothers in late 2008, a symptom of credit risk contagion comes to forefront in the academics and policy makers circle. This study focuses on the contagion definition as an excessive spillover after controlling for idiosyncratic and common factors among financial markets to evaluate its importance in the evolution of risk premia during recent crisis episodes in the euro area. We include in the analysis real sector effect with sovereign-bank nexus which was overlooked by previous studies and determine realistic credit risk contagion measures while using a panel vector autoregression approach to treat this excessive spillover effect among said sectors and across countries in the euro zone. Our results report significant evidence of credit risk contagion, intra and inter sectors and across member states in corresponding financial markets during recent crisis periods in the EMU. In addition, there is a presence of significant contagion risk from Greece to the rest of euro zone. However, the credit risk contagion is not limited to sovereign CDS, whereas; we find evidence of contagion from feeble banking sector’s credit risk to the sovereign sector in the remaining euro area. In addition, simulation results to shock in the risk premia of core member states (especially, Germany) substantiate the peripheral countries findings and additionally report the “flight-to-safety” phenomenon. In turn, it shows that investors in respective debt markets are sensitive to turbulent times and search for quality in returns in the euro zone.

JEL codes: C58, G01, G18, G21, G32, H63

Keywords: Contagion, CDS spread, impulse responses, systemic risk, sovereign debt, PVAR
1 Introduction

The divergence of sovereign yields among the euro zone member states during the recent crisis episode is not simply subjected to volatility in the underlying fundamentals and global risk aversion factors as proposed in the related literature. In this respect, the policy makers and regulators lack to assess extensively the interconnectedness among financial markets regarding sovereign, bank and corporate sectors in order to rationally understand the consequences of the recent crisis episodes (BIS, 2011a).

Since the commencement of the great recession, the interactions between credit risk of public, financial and real sectors increased which play an important role in the emergence of adverse feedback loop that generated persistent distress in the euro area economy (IMF, 2013). Thus, in late 2009 there is an abrupt rise in system-wide probability of default especially in the euro area’s public and financial sectors. This increase, in turn induces a general fear among the respective debt markets which could potentially be explained as a prime symptom of contagion. Accordingly, there is a significant fall in investor’s confidence regarding the debt repayment ability of sovereigns in the euro area. When this occurs, it generates abrupt increase in the perceived sovereign risk that adversely affects the financial and corporate sectors among euro zone member states. This leads to indicate the presence of potential contagion risk.

In this respect, with the increasing importance to assess the credit risk dynamics among the corresponding financial markets, the existing empirical literature on the issue is still scarce and in its infancy. In general, mostly related studies focus on the emerging countries due to the presence of increased liquidity in the sovereign debt markets as a consequence of the late 90’s financial crisis. However, since the onset of a sovereign debt crisis in 2010 there is a rapid increase in empirical studies dealing with the potential effect of contagion especially in sovereign and financial debt markets in the euro zone. Despite the increased attention, there exists an empirical debate regarding the risk that triggers the recent euro crisis. Some of the studies’ argue that the deterioration in public finances and the subsequent increased budget deficits with feeble macroeconomic conditions cause the increase in loss of confidence in sovereigns’ ability to repay the respective debt which in turn generated the crisis. While other authors’ argue that the distress in the banking sector due to an adverse spillover effect of the sub-prime crisis resulted in the bail-out packages from respective governments, triggers the uncertainty in corresponding debt markets which transformed into a crisis situation in the euro zone. Moreover, there is a lack of consensus regarding the contagion risk transmission from distressed peripheral countries to the rest of euro zone during the public debt crisis period. On the other hand, some authors’ believe that the credit risk contagion is over-exaggerated and there are only increased interdependencies present among corresponding debt markets in the euro area member states during recent turbulent periods.

This study aims to extend the existing empirical work and attempts to evaluate the presence of contagion in credit risk dynamics by focusing simultaneously on the sovereign-bank-firm CDS markets during recent crisis periods in the context of euro zone. Moreover, the importance of real sector interconnectedness with sovereign and financial markets is totally overlooked while determining the credit risk contagion effect during turbulent times in euro area member states which has attracted increased importance by the academics and policy makers (Gray 2009, BIS 2011a). In addition, we attempt to furnish a solution to the said empirical debates between the order of credit risk contagion among public, financial and real sectors and across countries especially during the sovereign debt crisis period in the euro zone. On the other hand, in this work, following Battistini et al. (2014), we suggest that the increase in risk premia in sovereign-bank-firm nexus during the euro crisis in the EMU is partially due to a credit risk contagion which is in excess to the macro-fundamental and global risk factors.

However, the existing difference regarding the presence of credit risk contagion in the euro zone may be derived from the fact that there is no universally accepted definition of the term present to date. In this context, we follow the definition provided by Constâncio (2012) that the contagion effect among domestic economic sectors’ risk of

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3 See: Pan and Singleton (2008) and Remolona et al. (2007) among others.
4 See: Giordano et al. (2013), Caporin et al. (2013) and Missio and Watzka (2011) among others.
7 See: Koop and Korobilis (2016)
9 Non-financial firms
default occurs when the instability in one sector transmits to the other beyond what could be intended during a normal relationship between the said sectors. Given these definitions, Canova and Ciccarelli (2013), in their survey paper, indicate that the (panel) vector autoregression model is most suitable to evaluate the contagious effect of transmission of idiosyncratic shocks across units and time. Hence, in line with the existing literature, our empirical framework is based on (panel) vector autoregression model of credit risk measures for the sovereign-bank-firm nexus in the euro zone for a period of 5 years (i.e. from 2007-QIV to 2012-QIV).

In this vein, following the related literature, we use the credit default swaps (hereafter, CDS) premium as a measure of credit risk for the sovereign, bank and corporate sectors in the euro area. In this regard, the steady increase in empirical studies to use the CDS spread as a credit risk indicator for the sovereigns’ and banks’ is due to its higher sensitivity to the underlying market changes. In particular, a CDS contract is primarily an over-the-counter (hereafter, OTC) instrument. It basically allows the protection buyer to hedge against a default by the underlying borrower with a fee to the protection seller. Therefore, due to its inherent nature, the CDS spread is an ideal choice to use as a credit risk measure not only for sovereigns but also for banks and corporates in this study for the euro area member states.

Furthermore, following the contagion definition, in the first step we attempt to purge the variations from credit risk of sovereigns, banks and corporates due to the common and specific factors. As far as the common factors are concern, it basically means common to all the member states (for instance: like, the global risk aversion) whereas; the idiosyncratic factors include the macroeconomic, the bank-specific and the firm-specific variables in a particular country in the euro zone. Thus, we use a CDS spread’s residual risk after the net-off which reflects a realistic effect of the credit risk contagion for the sovereign-bank-firm sectors in the European Monetary Union (EMU) countries. In the words of Battistini et al. (2014), our sovereign credit risk measure refers to the fear of break-up of euro zone. However, we interpret these credit risk measures as an excessive spillover that are contagion by nature due to the market irrationality or herding behavior of investors as a consequence of general increase in the fear of default among respective debt markets in the euro zone during a recent crisis episode.

Our empirical analysis is based on the orthogonal impulse-response (hereafter, IR) functions derived on the (panel) vector autoregression (PVAR) estimations that are significantly different from zero. These impact multipliers are used to distinguish and detect the contagion among the sovereign-bank-firm credit risk and also from an individual member state to the rest of the euro area especially during the public debt crisis period. This study contributes to the existing empirical discussion in various ways. First, in addition to the sovereign-bank nexus, we include the real sector effect in the credit risk dynamics to extensively evaluate the presence of contagion in the euro area during a recent crisis period. Second, our credit risk parameters treat different contagion effects while providing evidence of excessive spillover between different debt markets simultaneously with a particular member state and across countries in the EMU. Finally, our third contribution is inherent in the methodology to use the residuals of CDS spread in PVAR after potential variations of common and idiosyncratic effects have been removed that led to realistically gauge the credit risk contagion impact among sovereign-bank-firm nexus in the euro zone.

To give a foretaste of our results, we find that the credit risk contagion affects systemically among the sovereign-bank-firm nexus during the recent crisis episodes in the euro zone which is time-varying inter sector and time-invariant intra sector by nature. In addition, during crisis periods, a contagion feedback loop among sovereign-bank credit risk is present as compared to the nexus with the real sector which simply outlines its weak integration with sovereign and financial CDS markets in the euro zone. Moreover, our results also report the presence of private-to-public transfer of credit risk with the banking sector ensuing a carry-trade behavior especially during the sovereign debt crisis period in the euro zone. However, these outcomes have been partially substantiated when we analyze

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10 In a similar respect, for a contagion across the countries, Forbes (2012) defines contagion as a cascade between cross-countries that occurs when the financial and or macroeconomic shocks generate a spillover risk which is in excess of the underlying economic fundamentals present in the state of normal interdependence among the member states.

11 Here, “Q” refers to the quarter.

12 See: Aizenman et al. (2013), Alter and Schüler (2012) and Blanco et al. (2005) among others.

13 As proposed in BIS (2011a) and also Alter and Beyer (2014)
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

individually the G-IPSI (Greece, Ireland, Portugal, Spain and Italy) and core countries (Germany and France) in the euro area. Furthermore, contrary to the general perception established in the recent empirical literature, we did not find a direct credit risk contagion from the Greek sovereign to the rest of euro zone public sector. Instead, our results manifest an excessive credit risk spillover from the Greek sovereign to the rest of euro zone’s financial sector which is a logical finding and in line with the actual events that occurred during the public debt crisis period. In a relative manner, these results support the findings of Koop and Korobilis (2016) and Caporin et al. (2013). Finally, in the case of core countries, simulation shocks to the German credit risk spills over contagiously to the euro area while simultaneously there is an evidence of “flight-to-quality” phenomenon during the recent public debt crisis period.

The remainder of this paper proceeds as follows. In Section 2, we review succinctly the related literature and furnish basis to elucidate our definition of a contagion and formulate the hypotheses. Section 3 outlines the analytical framework describing the (P)VAR model with the dataset used in this study. In Section 4, we present and analyze our impulse-response functions obtained from the (P)VAR estimations that are statistically significantly. Finally, in section 5 we draw some tentative conclusions and policy implications in the light of our results.

2 Literature review

The interactions between the credit risk of financial, real and public sectors play an important role in the emergence of adverse feedback loop between these debt markets in distressed economies especially in the context of euro zone. As reported by BIS (2011a), the sustainability of an economic system depends not only on a stable nexus between a bank and a non-financial firm but also on their link with a respective sovereign sector. In particular, to build and sustain a strong economic system, the interconnectedness of these three sectors holds principal importance. Often the related literature mainly focuses on the importance of an efficient financial system to attain long-term sustainable economic output (Reinhart and Rogoff, 2011). The proponents of a former notion have a valid reason to believe that an advanced and well-developed financial system is at the core of a sound economy. Specifically, not only it financially intermediates or fulfills the funding needs for itself and for its domestic sovereign but also for its local corporate (and house hold) sectors. Thus, if a domestic banking sector becomes fragile or receives any adverse exogenous shock that perniciously affects its financial situation then not only it propagates this vulnerability towards the real sector but also re-channel it back towards the respective sovereign sector. Nevertheless, the importance of the sovereign and real sectors’ credit risk should not be overlooked while analyzing the effectiveness of a sound economic system. The situation exacerbates if the governments were unable to provide the needed solvency cushion to the distressed financial system and in turn becomes a catalyst of credit risk for the banking system as a whole (Castro and Mencia, 2014; BIS, 2013). On the other hand, a fragile real sector makes matter worse due to the increase in the volume of non-performing loans and hence, reduces the economic activity (Abildgren et al., 2013; Holmstrom and Tirole, 1997). Therefore, the probability of default (i.e. credit risk) in these sectors is interconnected and an adverse shock in any one of the sectors advances the vulnerability to another. Moreover, there exists a potential unfavorable causal effect of this uncertainty that travels back to the sector through which it was originated and thus, it gives birth to the incessant cycle of credit risk spillover between the said sectors (Bornhorst and Arranz, 2013). As a consequence, a contagion of default risk emerges between the sovereign-bank-corporate nexus which becomes ominous to the sustenance of a healthy economic system. This vicious cycle can be portrayed with the help of figure (1):

17 See: Shah and Khalil (2014)
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

Figure 1: Sovereign-Bank-Corporate Nexus (Source: IMF, 2013)

It can be observed in figure (1) that there exists a feedback loop of uncertainty between the said sectors. In particular, in the sovereign-bank link, the vulnerability potentially transfers from a distressed sovereign to its financial system through decrease in the value of public guarantees and government securities that leads to raise the counter party risk and reduce the collateral value which increases the funding cost. Whereas, the causal effect from the bank-sovereign nexus is principally due to the bail-out packages and the materialization of contingent liabilities (Noyer, 2010). In addition, the bank-corporate network shows the potential risk transfer from a weak financial system to the non-financial corporate sector by reduction in the volume of available credit and a simultaneous increase in the interest rates of corporate loans. While, the adverse feedback effect from a non-financial corporate to the bank is through an increase in the volume of non-performing loans and consequently, higher firm delinquencies (Abildgren et al., 2013; Cornett et al., 2011; Salas and Saurina, 2002). Finally, the potential transmission of distress among a sovereign-corporate nexus is shown through the increase in corporate bond yields (or an increase in the cost of loans) due to the deterioration in a government’s credit rating. Whereas, a reduction in the corporate’s profitability due to weaker economic growth and higher unemployment transmits the negative feedback to the respective sovereign mainly through the reduction in tax revenue and in tandem leads to increase the public expenditure (Borensztein et al., 2013).

Since late 2008, the euro zone started to feel the increase in uncertainty (i.e. the probability of default) in its fiscal, financial and real economic sectors due to the great recession period. This influence can be clearly observed with the onset of divergence in the sovereign yield differentials among the euro area member countries (Mody, 2009). With gradual rise in the fiscal and financial distress, the euro area states felt the heat and started to default on servicing their outstanding public debt (especially the peripheral countries for example, Greece in 2010). These events urged the investors’ in international capital markets to reassess the risk related to the sovereign’s ability to repay its outstanding debt in the context of euro zone. More specifically, the international capital markets started to re-value and reassess the overall solvency of the euro zone’s peripheral states which results in the occurrence of recent euro crisis episode. When this occurs, the respective public debt spread and the level of financial distress increased which led the euro area economy progressively into the recessionary state. Thus, it leads to the emergence of an uncertainty spiral between public, financial and real sectors’ ability to repay the respective outstanding debt.

A number of recent studies engaged in exploring the issue by only focusing on a two-way relationship between sovereign and banking sectors risk or at most concentrate on the empirical investigation of euro crisis regarding the contagion trigger among the EMU countries (see: Arghyrou and Kontonikas, 2012; De Santis, 2012; Missio and

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18 See: BIS (2011b) for details on the potential transmission channels of vulnerability between sovereign-bank nexus.
19 See: BIS (2011a) for details on the potential transmission channels of vulnerability between a bank-corporate nexus.
21 We use the great recession, the Global Financial Crisis (GFC), and the US sub-prime crisis terms interchangeably in this paper.
22 In this work, we use the sovereign debt crisis, the public debt crisis, the euro crisis, and the European debt crisis terms interchangeably for the recent debt crisis in the euro area.
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Watzka, 2011 and Mody and Sandri, 2011 among others). Although, these studies have made valuable contributions, their findings are limited in nature: firstly they lack to quantify the potential transmission channels; secondly, it is presumed that the risk emanating from the non-financial corporate sector (i.e. in this study it represents the real sector) is in fact included in the contagion effect of bank’s credit risk on the sovereign sector; thirdly, there is a lack of consensus regarding the order of credit risk contagion between the sovereign-bank and sovereign-sovereign nexus; and finally, the studies have overlooked this vulnerability contagion across the euro area member states especially from the core countries and mainly focused on the peripheral states.

In order to fill this void, the current work suggests that to evaluate the potential spillover effect and the related intensity of credit risk contagion in the economy, especially during the euro crisis episode, the analysis should take into consideration simultaneously the sovereign-bank-firm nexus. In other words, the inherent interrelatedness of credit risk between these three sectors should be assessed concurrently which varies with the change in respective economic environment (BIS, 2009; Alter and Beyer, 2014). Hence, it aids us to better understand the framework of credit risk contagion and its feedback magnitude, especially in the recent crisis period. Furthermore, the implied hypothesis assumed in the related literature that the credit risk contagion from a non-financial firm (due to the increase in its probability of default) to a sovereign is included in the financial risk contagion, basically ignores to treat any direct effect on the sovereign sector from corresponding real sector which may not be through the banking channel (Borensztein et al., 2013). In addition, even this implied hypothesis is not being empirically tested.

Moreover, in this work we evaluate the contagion risk from a financially and fiscally distressed peripheral member state to the rest of euro zone countries. In this context, we suggest that in addition to analyze the former effect on the rest of euro area countries, it is equally interesting and important to evaluate the effect from the core countries (especially those states that have high public debt stock and weak growth level: like, Belgium, Finland and France) to the rest of member states in the euro zone. Furthermore, the current work additionally conjectures that the contagion effect from the core countries (that are financially strong with sustainable government debt stock and growth level: like, Germany) to the rest of euro area would be higher due to the fact that if a member country on which the euro system principally rests becomes fragile then the existence of a monetary union would be in peril. In this respect, Koop and Korobilis (2016) report that the division of EMU countries into core and peripheral according to the financial contagion effect is questionable, thus, authors’ reject this assumption in the context of recent euro crisis. On the contrary, in the related contagion literature a sovereign-bank nexus is being mainly explored not only in the context of advanced markets but also in the emerging economies (Bolton and Jeanne, 2011). In addition, the current paper attempts to isolate the order of credit risk contagion between the sovereign-bank-firm nexus (especially during a recent crisis episode) as the existing studies lack to come up with a consensus regarding the order of such contagion risk (Reinhart and Rogoff, 2011). So, in this study we are not only analyzing the credit risk transmission but also attempt to evaluate the presence of any contagion effect among respective CDS markets in the euro zone.

Hence, in order to fill this gap: firstly, the current work leans towards the previous empirical literature and attempts to evaluate the dynamics of credit risk contagion between the sovereign-bank nexus and its potential feedback in the euro zone during different crisis periods (i.e. the sub-prime and the sovereign debt crisis episodes). Secondly, by dealing with the issue of credit risk interdependence and contagion among the sovereign, bank and non-financial firm network which becomes a core policy discussion since the onset of recent financial crisis, we incorporate the real sector’s CDS spread into the sovereign-bank nexus by treating it as a continuous loop of credit risk transfer. On the one hand, the identification and the source of vulnerability in this vicious circle not only helps to broaden the existing knowledge on the application of monetary and fiscal policies but, on the other hand, it aids the policy makers to outline proactive crisis management strategies to contain its adverse effect on the economic activity.

Finally, while evaluating the public-to-public and the private-to-public contagion risk from the GIPSI and core countries (for example: Germany) to the rest of euro area, this study indicates that it is more engaging to evaluate the latter effect. This leads us to outline the analytical framework.

3 The analytical framework

As outlined in the previous section, by focusing on the sovereign-bank-corporate nexus especially in the context of euro zone, we attempt to evaluate the order of credit risk contagion between the nexus of said sectors and its potential direct or in-direct feedback effect in the recent euro crisis period. Furthermore, we advance this analysis to cater the excess spillover effect from the individual country’s credit risk premium to the aggregate credit risk premia.
of the rest of euro zone member states and its related causal effect especially for the peripheral (i.e. mainly, Greece) and core countries (i.e. mainly, Germany) during the recent crisis period in respective debt markets.

3.1 Methodology
The recent empirical literature regarding analyzing the excessive spillover effect uses the vector autoregressive (VAR) framework. Following the works of Alter and Beyer (2014) and Koop and Korobilis (2016) on the dynamics of credit risk contagion during the recent euro zone crisis, we use the Panel VAR (PVAR) model to evaluate the presence and order of contagion between the sovereign-bank-corporate default risk variables in the system by incorporating their own lagged effects. As outlined by Canova and Ciccarelli (2009) the PVAR is the most suitable econometric method in order to evaluate the contagion effect of transmission of shocks across the different countries and or the economic sectors because it provides valuable and concrete tool to analyze the dynamics of financial and economic processes. Moreover, the panel VAR, on the one hand, not only increases the efficiency and the power of analysis due to its panel-modeling framework but, on the other hand, efficiently caters the issue of unobserved dynamic heterogeneity (i.e. cross-sectional) by addressing for the fixed effects in the model (Hayashi, 2000).

Let us provide background to introduce the model used in this study to analyze the evidence of credit risk contagion and its order among the sovereign-bank-firm nexus in the euro zone member states especially during the recent crisis period. The model is basically restricted panel vector autoregression (PVAR) in line with the contemporary empirical literature on the default risk spillover (Alter and Beyer, 2014). In this vein, the main endogenous variables considered in the PVAR are the credit risk of sovereigns, banks and non-financial firms, all in natural logarithmic form as advised by Forte and Pena (2009). In addition, all the variations in these variables due to any economy-wide (macroeconomic) effect, the bank-specific effect and the non-financial firm specific effect with the (common) deterministic time trend were removed prior to the analysis.

In this respect, we purge these effects in order to determine the realistic credit risk contagion proxies for the sovereign, bank and non-financial firm sectors that are in excess of the underlying economic fundamentals (and specific risk) present in the state of normal interdependence between the said sectors. In the words of Giordano et al. (2013), our credit risk spillover proxies represent “contagion effect which is not only in excess to changes in fundamental economic factors but also global risk aversion”.

Therefore, the sovereign credit risk after controlling for the macro-economic and global risk aversion factors, as suggested in the related literature, is left with the residual risk that reflects a legitimate variation in the relative sovereign default risk. As put forward by Battistini et al. (2014), this residual in turn may also refer to the fear of break-up of euro zone which is systemic by nature. Along similar pattern, the bank credit risk residual after the control factors presents the variation due to general level of uncertainty prevalent in the corresponding financial system as a consequence to the fear of default in the banking sector. Whereas, the non-financial firm’s credit risk residual after controlling for the firm-specific factors is left with the probability of default that is contagion by nature in the underlying real sector (Heinz and Sun, 2014).

To empirically measure the credit risk contagion effect simultaneously among the sovereign-bank-firm nexus is quite a taxing task. In this regard, we follow Alter and Schüler (2012) and use the credit default swap (CDS) premia as a default risk indicator. As outlined by Aizenman et al. (2013), the CDS spread is quick to respond to market changes and provides timelier market-based pricing than the bond yields (i.e. the interest rate spread of sovereign debt) as they are subject to time to maturity and embed inflation expectations with demand/supply effect for lending conditions as well as a default risk.

3.1.1 VAR framework in panel data
Panel VAR approach enjoys the synthesis of a traditional VAR technique that treats all the variables in a system as endogenous, with the panel data. This technique recently becomes popular among the financial economists who

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23 With global risk aversion measured through VIX
25 See: Cornett et al. (2011) and Tucker (2014) among others.
26 Refer to table (4) in the Appendix, for a list of all the variables used in this study.
27 Berndt and Obeja (2010), Zhang et al. (2011), Ang and Longstaff (2013), Kalbaska and Gatkowski (2012), and Caporin et al. (2013), among others also used the CDS premia as a default risk indicator.
work with the data of many countries. In this context, it is useful to apply P(VAR) technique because we want to jointly model the contagion effect of credit risk among sovereign-bank-firms for the euro zone during recent crisis episodes. Moreover, for the individual country a VAR technique is used that also takes into consideration the linkages of default risk in the respective debt markets between the member states in the euro zone.

Following similar notations in the existing literature, the panel VAR model can be outlined as follows:

$$Z_i = \alpha + \Theta(L)Z_i + \varepsilon_i$$  \hspace{1cm} (1)

Where $\Theta(L)$ is the lag operator and $Z_i$ represents our focused three endogenous variables of the sovereign-bank-firm credit risk (i.e. $Z_i = [SV.rska, BK.rska, and FM.rska]$). Subscripts $i$ and $t$ refer to country and time. $\varepsilon_i$ is a vector of residuals. In addition, to determine the appropriate lag-length, we use the consistent moment and model selection criteria (MMSC) proposed by Andrews and Lu (2001), the results are shown in table (1) in the Appendix. It can be observed in table (1) that the Akaike Information Criteria (AIC), the Bayesian Information Criteria (BIC), and the Hannan-Quinn Information Criteria (HQIC) show minimum value for one-lag length. Therefore, the optimal lag-length in our system of endogenous variables in the PVAR model is one. The PVAR of first order is in fact in line with the CDS literature that outlines its economic significance as a data variable which tends to be sensitive in the short-run due to its high responsiveness to changes in the financial and economic conditions prevalent among the respective debt markets (Koop and Korobilis, 2016). So, a first-order PVAR (1) can be specified as:

$$Z_{ijt} = \alpha_{ij} + \alpha.Z_{ijt-1} + \varepsilon_{ijt}$$  \hspace{1cm} (2)

In equation (2), $Z_{ijt}$ is an $m \times 1$ vector of the three endogenous variables, whereas $\alpha_{ij}$ is an $m \times m$ matrix of the slope coefficients, and $\varepsilon_{ijt}$ is an $m \times 1$ vector of the error terms which is assumed to be independent and identically distributed (i.i.d).

Furthermore, as mentioned above the main variables used in the current study are OLS residuals of the CDS premia from the respective sectors (i.e. sovereign, bank and firm) after accounting for the common and specific control factors that affect the CDS premia of our said sectors including the measure of global investors’ risk aversion. Following the definition of contagion by Constâncio (2012), we consider this two-step approach because it filters out and provides the CDS premia which represents the contagion risk that is a net variation in the default risk of sovereign-bank-firm nexus (Giordano et al., 2013).

Hence, the PVAR (1) model given by equation (2) estimates the credit risk contagion as a systemic shock between the sovereign-bank-firm nexus during the different crises with-in and across the economies in the euro area. For different crises (that is, the global financial crisis and the euro crisis), and the cross-country analysis, we use the dummy variable as a corresponding case indicator. If the respective coefficient $\alpha_{ij}$ in equation (2) is positive and statistically different from zero then there is an evidence of contagion: (i) between sectors in a country, (ii) among sectors across countries, in the euro zone during the recent crisis periods. On the other hand, if the coefficient is negative then the co-movement between sector’s credit risk reduces and we assume no credit risk contagion even if the results are statistically significant.

In the current work, we follow Love and Zicchino (2006) algorithm not only for the panel VAR estimation but also to calculate the orthogonality between these variables (i.e. the transformed and the lagged regressors). Thus, we estimate the system parameters by using the panel generalized methods of moments (GMM) estimator. The System-GMM approach introduced by Blundell and Bond (2000) enables to not only cater the simultaneity problem but also accounts for the heteroscedasticity that may exist due to the presence of heterogeneous errors with different cross-sectional units in the framework of panel data. It is a better estimation method than the GMM in first difference as normally the lagged levels of the time series result in weak instruments (Bond et al. 2001).
As, we know that due to the a-theoretical nature of VAR approach and the presence of large number of estimated parameters it is difficult to interpret the results in economic sense, for instance: some estimated lagged variables may have coefficients that change sign across the lags with the interconnected equations make it unclear to analyze what effect a given estimated variable would have upon the future values of other endogenous variables in the system.32 So, in order to overcome this problem we base our analysis on the results of a set of three test statistics which are normally constructed for an estimated VAR model, that is: Impulse–Responses (IR), Block significance test (or commonly known as Granger causality test) and Variance Decompositions (VD).

In this study, on the basis of estimated P(VAR) output we construct these test statistics to analyze and interpret our results.33 Therefore, we mainly focus on generating the IR’s on the credit risk contagion identified in the estimated P(VAR) output that are significantly different from zero which in fact are subject to the underlying time variations. The explicit P(VAR) model with sovereigns, banks, and firms credit risk variables is presented as equation (5) in the Appendix.

### 3.1.2 Sample data and time period

In line with the recent strand of literature, we use quarterly data of five years senior CDS premia from 2007 till 201234 for sovereigns, banks, and non-financial corporates because these types of CDS are most liquid by nature as they are actively traded in the respective debt markets.35 Our sample consists of eleven euro zone member states (Austria-AT, Belgium-BE, Finland-FI, France-FR, Germany-DE, Greece-GR, Ireland-IE, Italy-IT, The Netherlands-NL, Portugal-PT, and Spain-ES). The quarterly data of CDS contract for the individual sovereigns, banks and non-financial corporates are gathered from the DataStream and Bloomberg.36 The credit default swap contract, in general, shows the market default risk relative to the underlying financial asset. Specifically, it is a financial contract in which lenders pass on the risk of default of borrowers to the third party that provides an insurance against the event if the underlying borrower fails to fulfill its respective debt obligation. In general, the increase in CDS premia indicates growing market expectations of default by the borrower with a peculiar spike in spread at the time of occurrence of the credit event. Furthermore, the CDS spread is normally quoted in basis points (bps).

For analysis, we use time span from 2007-QIV till 2012-QIV37 and divide our sample into two main periods. First, we examine the presence of contagion effect of default risk due to the great recession effect on the sovereign-bank-firm nexus in the euro zone, that is: 2007-QIV till 2009-QIV (Jeff Holt, 2009). Second period constitutes from 2010-QI till 2012-QIV as a sovereign crisis episode when the European Union approves the financial assistance plan for Greece against its vulnerable financial and public debt situation (Alter and Schüler, 2012).38

Furthermore, Finland is excluded from the analysis due to lack of CDS data availability of its banking sector.39 Since, one of the main objectives of this study is to determine the presence and the order of credit risk contagion between the sovereign-bank-firm nexus in the intra and inter euro area countries: we constructed a system-wide risk index for banks stress and non-financial firms’ vulnerability which is specific to an individual country following the methodology outlined by Acharya et al. (2014). The approach is presented as follows:

$$\text{FirmRisk}_{i,t} = \sum_{j=1}^{J} W_{j,i} * \text{FirmCDS}_{i,t}$$  \hspace{1cm} (3)

33 We mainly focus on the results that are significantly different from zero.
34 Specifically, from 2007-quarter IV till 2012-quarter IV
36 For DataStream (DS), we downloaded the CDS data mainly from Thomson Reuters (TR).
37 In DataStream, the CDS data (from Thomson Reuters) is available from December 2007 and not prior to that whereas, the CDS data from CMA is available prior to December 2007 but not with consistent frequency. In addition, I use the Bloomberg terminal to collect any missing CDS quotes regarding the individual entity (i.e. sovereign, bank or non-financial firm). I am thankful to the Library facilities of INSEAD Business School (Fontainebleau, France), specifically for the access to DataStream, Bankscope, Worldscope databases and their research students who allowed me to use the Bloomberg sessions.
38 In fact, the Greek government debt started to surge since autumn 2009; as a consequence, Standard & Poor’s downgrade their sovereign credit ratings (BIS, 2009). But we consider the onset of sovereign debt crisis since quarter 1 of 2010 due to the materialization of these vulnerabilities in the sovereign debt sector in the euro zone (see: Popov and Van Horen, 2013).
39 Detailed list of banks and non-financial firms included in this study with respect to the specific country is outlined in tables (2) & (3) respectively, in the Appendix. For Finland, we only use its sovereign and non-financial firms CDS data.

Syed M. Noaman SHAH

9
In equation (3), the system-wide firm risk index is represented by $FirmRisk_{i,t}$; as the CDS of firm $j$ from country $i$ at time $t$ by $FirmCDS_{i,j,t}$ and the related corresponding weight as $w_{j|i}$. Moreover, to keep the approach simple, the current work uses $W_{j|i} = \frac{1}{J}$. In addition, the non-financial firm weights could be indexed according to the market capitalization or to the value of their total assets. We follow the later to set the weights for the individual firms in a specific country to construct the credit risk index. Similar technique is applied for banks:

$$BankRisk_{i,t} = \sum_{j \in J} w_{j|i} \cdot BankCDS_{j,i,t}.$$  \hfill (4)

In equation (4), $BankRisk_{i,t}$ defines the system-wide measure of bank credit risk constructed as the interaction of CDS of bank $j$ from country $i$ at time $t$ ($BankCDS_{j,i,t}$) with the corresponding weight as $w_{j|i}$. 

Whereas, for the control variables we follow the existing literature that identifies the importance of fundamentals in explaining the variations in CDS spread. A large number of recent studies suggest that the CDS premia is affected by the global risk factors. We use VIX index\(^{40}\) to control for the global risk aversion following Pan and Singleton (2008) that shows strong link between the sovereign credit risk and the global risk aversion. In addition, Hilscher and Nosbusch (2010) suggest the importance of real economic factors as the important determinant of sovereign CDS spread, we control for these factors by using the GDP growth, inflation, real exchange rate, current account balances, and public debt/GDP. In a similar vein, for the financial sector we control for the bank specific factors, such as: return on assets, bank size (net asset value), provision for loss, interbank ratio.\(^{41}\) While, for the non-financial firms we include: firm size (total assets), profitability (net margin ratio), leverage (total debt to EBITDA), and growth ratio (price-earnings ratio). The description and sources of all the variables used in this chapter is outlined in table (4) in the Appendix.\(^{42}\)

On the other hand, since all the variables to be included in the PVAR system are required to be stationary; we tested for the unit root. To test for the stationarity in our panel data, we follow Pesaran (2007) because it runs the t-test for unit roots in the heterogeneous panels with cross-section dependence. Pesaran unit root test is in line with the objectives of the current study because we want to evaluate and identify the credit risk contagion and its related feedback effect in the context of euro zone. Specifically, the euro area constitutes heterogeneous panels with cross-section dependence of the member countries that is, the economic condition of a country is affected by other countries with in the euro zone.

For brevity, the results of the panel unit root test of focused variables are reported in table (5) in the Appendix. The variables are mostly stationary at first difference i.e. I(1), except the banking sector CDS premia which is stationary at I(0). This may be due to the fact that we use the natural log form of the CDS spread for all the three sectors following the contemporary empirical literature on CDS data in the context of credit risk dynamics in the euro zone. Furthermore, for the optimal lag-length we follow the model selection criteria outlined by Andrews and Lu (2001). The authors’ propose a consistent moment and model selection criteria (MMSC) for GMM models based on the J-statistics of over-identifying restrictions (Hansen, 1982). The results of Andrews and Lu (2001) maximum likelihood-based model selection criteria are reported in table (1) in the Appendix. According to the table, the first order PVAR is the preferred model as it has the minimum BIC, AIC and HQIC. These results are in accordance with the economic significance as the CDS data tends to be highly responsive which is mainly short-term in nature due to the changes in underlying economic conditions (Koop and Korobilis, 2016). However, in this context since most of the macro, financial, and firm level variables are stationary at I(1) level and our main variables are also except the bank CDS premia, we check for the cointegration relationship and use Pedroni residual-based test of panel cointegration (Pedroni, 1999).\(^{43}\) We did not find any cointegration effect between the

\(^{40}\) Chicago Board Options Exchange Market Volatility index (VIX)

\(^{41}\) Longstaff et al. (2011)

\(^{42}\) However, an important point to note is that the information regarding fundamentals data relevant for the CDS premia determination is difficult to extract due to its low information frequency and the historical nature. As the CDS market operates on high frequency information with investors’ making decisions on expected future economic trends. To streamline the effect, we focus on quarterly fundamental data which is mainly interpolated (using cubic spline approach) from semi-annual (and annual) accounting information provided by the non-financial firms (Worldscope) and the banks (Bankscope). Furthermore, following equations (3 and 4), we constructed a system-wide fundamentals index to use in the first step to filter out CDS spreads and gather the residuals as a proxy of variation in the default probability for banks and firms.

\(^{43}\) Further, we also use Kao panel cointegration test (Kao, 1999), but results remain unchanged.

Syed M. Noaman SHAH
CDS data of our focused variables mainly outlining a lack of long-term correlation, as also reported by Alter and Schüler (2012). Therefore, we use the panel VAR model to evaluate and identify whether there exists a contagion of credit risk in inter and intra euro zone member states especially during the recent crisis period in the corresponding debt markets (i.e. sovereign-bank-firm).

4 Results
This section presents our main estimation results on two dimensions. First, we show the intra-country credit risk contagion i.e. the interactions and spillovers between the sovereign-bank-firm sectors for peripheral and core member states. Second, we extend the analysis to gauge the credit risk contagion from the peripheral and core countries to the rest of euro zone member states in corresponding debt markets. As mentioned previously: the peripheral countries comprise of Greece, Ireland, Portugal, Spain, and Italy (G-IPSI) whereas, the core countries include Germany and France. In this respect, we mainly focus on the detail analysis of contagion risk from Greece to the rest of euro zone as an example of peripheral country. Whereas, for core countries, our analysis mainly concentrates on the excessive risk spillover from the German sovereign to the rest of EMU member states. In addition, for the aggregate estimation we focus on the full sample of euro zone countries (i.e. 11 states) which enable us to provide evidence regarding the presence of contagion default risk as a determinant in the abrupt increase of public debt yield differential (CDS spread) especially during the euro crisis period.

In this respect, we focus on the impact multipliers (IR functions) derived from the estimation results of the P(VAR) that are statistically different from zero. Whereas, the result tables regarding the P(VAR) estimation, are presented in the Appendix. Before starting reporting and analyzing the intra and inter country default risk contagion in sovereign-bank-firm nexus among the individual and across member states, let us evaluate the dynamics of credit risk contagion in the euro zone, on average, among the said nexus.

4.1 Credit risk contagion in the euro zone
The results of PVAR (1) estimation of credit risk contagion among sovereign, bank and firm in the euro zone is outlined in table (6) in the Appendix. In this respect, SV.rsk, BK.rsk, and FM.rsk represent the credit risk contagion variables for sovereign, bank and non-financial firm, respectively. In addition, panels I, II, and III outline results for the whole period, the sub-prime crisis period and the sovereign debt crisis period. It can be observed that there is a strong presence of credit risk contagion in each sector throughout the three time periods reflecting the evidence of horizontal systemic risk of default in the corresponding debt markets (that is: sovereign, bank, and firm) in the euro zone. Whereas, a dynamic feedback loop of credit risk contagion is present among the sovereign-bank nexus in panel I, with no interaction of the real sector default risk. On the other hand, in panel II, during the sub-prime crisis episode we can see the intricate credit risk contagion dynamics between real, bank and public sectors.

In particular, the results show bi-causal default risk spillover between the sovereign-bank nexus while the feedback effect is stronger in magnitude. Furthermore, the uncertainty in the real sector significantly transmits not only to the financial sector but also to the respective sovereign sector during the Global Financial Crisis (GFC) period. It mainly outlines the differential impact (that is, the direct and indirect) from the non-financial corporates’ probability of default towards the public sector. This result validates our hypothesis that the real sector’s credit risk is not only a part of the financial sector contagion to the public sector but also there is a direct contagion risk from the real sector to the sovereign sector which is consequent to the reduction in economic activity. This led to raise the unemployment level, deteriorate the economic growth and lower the tax revenue (that is: from corporates and households) for the respective governments in the euro zone.

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44 In this context, due to brevity, the PVAR model stability tests, the VD’s, full set of IR functions with Granger causality test results are available on request.
45 For the aggregate estimation we focus on the full sample of euro zone countries (i.e. 11 states).
46 Moreover, table (7) in the Appendix reports the granger causality results for the euro zone, respectively.
47 Horizontal systemic risk refers to the risk generated through the default of one unit in a system that generates the contagion default for other units in the same system (ECB 2009). For instance, in a financial system, the defunct of one bank triggers the increase in probability of default for other banks, same is applied for the non-financial corporates and on macro level to the sovereign sector in any economic system. On the contrary, a vertical perspective of systemic risk focuses on the interaction of units in different sectors to generate contagion risk of default. For instance, the emergence of systemic risk due to defunct of a bank through the increased interconnectedness of the financial sector credit risk with the public and real sectors that generate wave of default in the latter sectors in an economy (ECB, 2009).

Syed M. Noaman SHAH
In addition, the results in panel III advocate the impact of sovereign debt crisis in these debt (CDS) markets. Specifically, we can observe in columns 7, 8 and 9 of table (6) in the Appendix, that there is a strong contagion risk from the sovereign CDS to banks and then a pass-through effect towards the real sector in the euro zone. However, the feedback effect from the non-financial sector CDS premia to bank’s credit risk show either the evidence of disintegration of financial dependence of the real sector on the banking sector or a policy effect of the Stability and Growth Pact (SGP) in the context of EMU that enables to lessen the risk of financial sector meltdown even with persistent recessionary trend in the euro zone. In order to hone the analysis, we turn our attention towards the impact multipliers generated on the PVAR (1) estimation of credit risk contagion during the crisis episodes.

In this context, the results from impulse-responses generated through the statistically significant panel VAR estimation of the sovereign-bank-firm credit risk during sub-prime and public debt crisis episodes in the euro area are depicted in figures (2, 3, 4) and (5, 6, 7), respectively. In all graphs below, the solid line represents the orthogonal impulse response functions of our focused three variables estimated through panel VAR for the euro zone during different crisis episodes and the 5% error bands are generated by Monte Carlo simulation.

Figure (2) reports graph of credit risk contagion from banks to public sector, while figure (3) reports the feedback effect from the sovereign to banking sector in the euro zone, by keeping all other shock effects constant during the great recession period. While, in figure (4) we show the excessive spillover effect of the real sector credit risk towards bank and sovereign sectors. In particular, in figures (2) and (3) we can observe the response of sovereign sector to a one standard deviation shock to banks credit risk and the causal effect from the public sector vulnerability towards the financial sector in the euro zone.

It is engaging to observe that both figures follow similar pattern. During sub-prime crisis in the euro zone, banks credit risk innovation impacts temporarily the government CDS premia and its effect fizzles out approximately in the fifth quarter \( t \leq 5 \), while in the case of causal sovereign credit risk shock towards the banking sector the impact
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

These results are in the cards as we have observed in the related literature that the US mortgage market instigated the crisis to which the banking sector in the euro zone was heavily exposed to (see: Acharya et al., 2014 and Thukral, 2013 among others). Thus, the great recession effect weakens the financial and liquidity conditions of banks in the euro area which leads to increased pressure on the sovereign sector with the investor’s expectation of ultimate bail-outs of these distressed institutions.

Hence, the bank’s credit risk contagion spurs up the uncertainty regarding the sustainability and creditworthiness of the corresponding public sector. Furthermore, it is quite interesting to note that the magnitude of systemic effect of bank credit risk shock to the creditworthiness of public sector is higher than its feedback effect which indicates the time varying and sector-specific nature of the financial crisis episode.

On the other hand, with the onset of the great recession period, the corporate sector in the euro zone also shows difficulty in servicing its outstanding debt obligations which not only spills over to the banking sector but also directly transmits to the sovereign sector (Figure (4)). In addition, we can observe in figure (4) that the innovations from the real sector’s probability of default adversely impacts for about 5 and 9 quarters significantly on sovereign and bank sectors during the sub-prime period, respectively. This, in turn, depicts the onset of long-term recessionary trend in the economies of euro area member countries. Besides, this long lasting influence basically means that the recessionary effect dissipates slowly from the economic system even in the presence of corrective policy measures towards reinventing growth in the euro zone.

As a consequence, in 2008, EU agreed on a € 200bn stimulus package to revitalize the economic growth in the euro zone following the global financial crisis (Baimbridge and Whyman, 2015, pg. xiii). In addition, since the financial aid is also supposed to be borne by respective sovereign sector, this cost in turn is anticipated by the investors’ in international capital markets that leads to invoke the issue of fiscal sustainability. Specifically, it poses question on the government’s ability to service its outstanding debt as a consequence to stagnant economic growth and prevalent high public debt level among the EMU countries.

Furthermore, during sovereign debt crisis period in the euro zone, while keeping all the other innovations invariable: figure (5) depicts the graph of vulnerability contagion from the public sector to the banking sector, where as figure (6) reports the contagion from the bank’s credit risk towards the non-financial firm’s risk of default and figure (7) shows the feedback effect of credit risk contagion from the real sector to the banking sector. Keeping in mind the results of sub-prime crisis, we can observe that in the public debt crisis there is an immediate and a higher magnitude of sovereign credit risk contagion towards the banking sector which in turn show the increased integration of public and financial CDS markets as compared to the real sector. In particular, it is a consequence of the loss of confidence in government’s ability to effectively service its short and long-term obligations. This uncertainty is partially due to the cost of sovereign aid to banks in the form of either the recapitalization or the funding of guarantees (i.e. the implicit and explicit) and partially through the simultaneous reduction in the economic activity with wider output gap resulting in lowering of public revenue (due to the reduction in taxation income for the sovereign) (Battistini et al. 2014).

In addition, it is quite interesting to observe in figure (5) that the innovations effect of sovereign credit risk impacts the banking CDS premia for medium-term (i.e. t ≤ 7) forecast horizon, indicating a somewhat persistent systemic shock during the public debt crisis period. On the other hand, we have seen previously that during the sub-prime period there is only a temporary contagion effect that fades away quickly (that is, t ≤ 4).

Notwithstanding, in figure (6) we can observe the fear of financial sector melt down which is contagious towards the non-financial firms in the euro zone during the recent sovereign debt crisis period. However, the IR function shows that the shock to the banking sector credit risk affects the real sector in short-term (that is, t ≤ 3) and the effect fizzles out quickly and becomes insignificant. That is, the spike is short lived and the peak impact occurs in the second quarter after the shock with a multiplier of 0.06. Hence, the shock from financial sector credit risk in the average pricing of corporate risk eased out significantly after just three quarters of financial shock in the euro zone.

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49 May be through the increase in non-performing loans
50 May be by reduction in the overall tax revenue

Syed M. Noaman SHAH
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Furthermore, figure (7) reports interesting results. In the figure we can discern a negative response of bank’s CDS premia due to innovations in the real sector’s credit risk (that is, no contagion is present, even though the result is statistically significant). Specifically, an unexpected shock to the non-financial firm CDS spread generates an inverse reaction from the banking sector during the public debt crisis period, ideally indicating the EMU efforts for the stabilization of its distressed financial sector. For instance, with a general increase in systemic risk of probability of default in the corporate sector the respective banking sector credit risk goes down mainly due to the safety net stimulus packages approved by the euro zone together with the IMF, to ease out the unrest in its financial system during the euro crisis period (Popov and van Horen, 2013).

In addition, it is engaging to realize in figures (36, 37 and 38) in the Appendix, that the effects of sovereign, bank and firm sectors shock to themselves are significantly different from zero in both the sub-prime and the sovereign debt crisis episodes in the euro zone. Thus, it indicates the presence of horizontal credit risk contagion with-in the respective debt markets and a vertical systemic risk across the corresponding debt markets in the euro area. In particular, this led us to fathom that the credit risk contagion is homogenous with-in sectors and heterogeneous among sectors in the euro zone during the distress periods. Hence, this result shows that our credit risk contagion measures of the sovereign-bank-firm nexus are time independent intra-sector and time dependent inter-sectors which enable us to distinguish the relevant nature of systemic risk in respective debt markets during the recent crisis episodes in the euro zone.

Note: The figures above show the IR functions of sovereign-bank-firm nexus during the sovereign debt crisis period in the euro zone. Specifically: figure (5) shows the sovereign credit risk contagion to banking sector, whereas, figure (6) depicts the contagion from banks credit risk to real sector and, figure (7) presents the feedback effect from shock to the real sector credit risk to the banking sector during the sovereign debt crisis period in the euro zone. The highlighted areas in all of the figures show two-standard error bands. The forecast horizons are in quarters. In addition, BK.rsk, SV.rsk and FM.rsk represent banks, sovereign and firms credit risk, respectively. The sample time period spans from 2010-Q1 till 2012-Q4.

Figure 5: Sovereign credit risk contagion to banking sector in the euro zone

Figure 6: Contagion from Banks credit risk to real sector in the euro zone

Figure 7: Response of banking sector to shock to non-financial firms’ credit risk in the euro zone

51 May be either due to the deterioration in the creditworthiness of sovereign sector or reduction in the economic growth

52 In this context, the European Financial Stability Facility (EFSF) was created in June, 2010 by EU member states to counteract the pernicious financial and fiscal conditions prevalent especially among peripheral countries (http://www.efsf.europa.eu/about/index.htm).
4.2 Is there intra-country credit risk contagion present in the euro zone?

In this section, we try to hone in the findings outlined in the previous section by analyzing the credit risk dynamics among the sovereign-bank-firm nexus in the selected peripheral and core economies.

4.2.1 Peripheral countries (G-IPSI)

In line with the related literature, we mainly report in detail the results for Greece which is fundamentally termed as a main culprit in triggering the recent public debt crisis in the euro zone (see: Missio and Watzka, 2011 and Caceres et al., 2010 among others). Furthermore, the rest of peripheral member states (IPSI) results are also analyzed, succinctly, in the light of different crisis episodes.

4.2.1.1 Greece

Let us analyze the credit risk dynamics between the sovereign, bank and non-financial corporate sectors in Greece. Table (8) in the Appendix, reports the results of VAR estimation regarding the sovereign-bank-firm credit risk measures during the recent crisis episodes in Greece. The panels: I, II and III, outline results for the whole period, the global financial crisis and the euro crisis periods, respectively. In general, we can observe a contagious presence of the horizontal systemic risk with-in the said sectors in Greece regarding their probability of default in all panels.

It is quiet intriguing to observe in panel II, table (8) that Greek banking system in fact withstands the sub-prime crisis effect and was not subject to the credit risk contagion towards its public sector. This finding is in contrast to our results in section (4.1) where, on average, the euro zone analysis showed the build-up of the financial sector’s credit risk towards the sovereign sector that proved to be the partial cause of the recent crisis episode. However, we can see the contagious effect from the Greek banking sector to its real sector that leads to constrict the volume of credit towards the domestic non-financial corporates. It may be due to the consequence of the deepening of GFC episode that result in a credit crunch situation. Therefore, this upshot mainly outlines the fact that Greek financial system was fundamentally comprised of the bank-base credit towards the domestic corporates and households (that is, it principally followed the traditional banking practices and was retail-oriented) (IMF, 2009).

On the other hand, table (8) panel III, shows the results during the sovereign debt crisis period in Greece. It is evident in columns (8) and (9) that there is a presence of credit risk contagion from the Greek public sector towards its bank and real sectors. Notwithstanding, there is a strong contagious effect from the sovereign to banking sector in Greece, whereas only a moderate contagion effect is present towards the non-financial corporates. Keeping in mind the results found in the sub-prime crisis period, it is quite clear that the Greek banking sector was not responsible for the distress in its public sector. On the contrary, already high level of public debt stock and the reduced economic growth with Greek sovereign unable to capitalize and build-up reserves during the times of bonanza (that is, during 2000-2007) leads to the eruption of the crisis situation in the country (IMF, 2010). The evidence regarding contagious effect of credit risk in the Greek economy can be clearly discern by analyzing graphs of the impact multipliers.

In this respect, figure (8) depicts the impulse response function during the great recession period, whereas, figures (9) and (10) show the contagion effects from the public sector to bank and real sectors in Greece during the euro crisis period.\(^3\)

In sub-prime crisis period in figure (8), an unexpected shock to the CDS spread of Greek banking system is moderately contagious towards its real sector and the effect impacted only in short-run \((t \leq 4)\). Whereas during the euro crisis period, the sovereign solvency risk quickly becomes contagious to the Greek banking sector in the first quarter and peaked in the second quarter, which principally evinced the respective public sector’s problem of debt overhang and the underlying difficulty in easing out the distress in banks. In particular, the response of bank’s CDS spread to the innovations in sovereign sector shows the higher integration of these debt markets due to the reduction in value of government securities and guarantees as a consequence of deterioration in the Greek public ratings.

\(^3\) See: Appendix
\(^4\) The respective Granger causality results are reported in table (9) in the Appendix.
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

On the other hand, the real sector probability of default is affected due to the shock from the sovereign credit risk which indicates a prolonged session of recessionary trend in the Greek economy but the estimated impulse responses are mostly insignificant (figure 10). Furthermore, there is an immediate effect from sovereign credit risk to firms indicating a highly responsive real sector against the event of default by the Greek sovereign in May 2010 and its subsequent application for financial aid to the troika (ECB/IMF/EU). It is quite interesting to note that the occurrence of government default event impacted more harshly to the real sector than the banks in Greece mainly showing that the corresponding debt markets penalizes Greeks for their irrational behavior of utilizing erratic level of consumption (that is, economic activity) from the future to the present. On the contrary, this result is somewhat biased due to the fact that firms’ CDS data that we gather and used is subject to direct influence from the Greek sovereign. In addition, the excessive spillover effect from the public to financial sector remained significant till the fourth quarter and then becomes insignificant (figure 9). These results, in turn, provide evidence of high integration and co-movement of sovereign debt market with that of banking sector in Greece especially during the euro crisis period.

Nevertheless, we did not find the presence of private to public transformation of credit risk across the said crisis periods in Greece as reported in section (4.1). Moreover, the results lack to establish the existence of a feedback loop between the default risk contagion measures among the sovereign, bank and real sectors. In turn, these indications confirm the case that the Greek economy fundamentally is plagued with pernicious levels of huge public debt which becomes detrimental when the euro zone receives an external shock in the form of the sub-prime crisis. Hence, the credit risk contagion is from sovereign to banks as far as Greece is concerned during the said turbulent period.

4.2.1.2 IPSI countries

While analyzing the rest of the euro area peripheral member states, the results for Spain most clearly show that the sovereign sector takes the tail risk of its banking sector on the public balance sheet. The fear of materialization of the financial system melt down emerged as a fundamental factor for the transformation of the credit risk from private to public sector in recent crisis period. In addition, our results also support the generation of incessant cycle of the risk of default mainly between the sovereign and banking sector with only a unidirectional contagion from the real sector to banks as proposed in the study by IMF (2013). In this context, we report the impulse response functions of the sovereign-bank-firm credit risk for Spain.

Figures (11), (12), (13) and (14) depict the impulse-response functions generated on the estimated results through VAR (1) for Spain during the great recession and the euro crisis periods, respectively. Here, we mainly focus on the results that are statistically different from zero and provide evidence of the credit risk contagion among the sovereign-bank-firm nexus in Spain. In figure (11), we can observe the indication of default risk contagion from the financial sector towards the sovereign sector during the GFC period mainly reporting the fact that the Spanish

See, table (3) in the Appendix

Syed M. Noaman SHAH
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

Note: The solid lines in figures above show the IR functions of the sovereign-bank-firm nexus during both the crisis episodes in Spain. Figure (11) shows the banking sector contagion effect to the sovereign during the great recession period. Whereas, figure (12) depicts a severe contagion from the sovereign credit risk to banks and, figure (13) presents a causal contagious effect to the public sector from banks during the sovereign debt crisis period. In addition, figure (14) depicts a moderate credit risk effect from the real sector to banks in the euro crisis episode. The highlighted areas in all of the figures show two-standard error bands. The forecast horizons are in quarters. In addition, BK.rsk, SV.rsk and FM.rsk represent banks, sovereign and firms credit risk, respectively. The sample time period for the sub-prime crisis spans from 2007QIV-2009QIV and for the euro crisis from 2010-QI till 2012-QIV.

Nevertheless, the effect dissipates speedily (t ≤ 2) and work its way out of the system. In addition, as a consequence during the euro crisis episode, the build-up of financial uncertainty in the Spanish public sector contagiously transmits the increased sovereign credit risk to the respective banking sector which in turn provides evidence regarding the materialization of private-to-public risk transformation (figures 12 and 13). Furthermore, in figure (13), there is an immediate causal credit risk contagion from banks to the Spanish sovereign sector. Notwithstanding, the responsiveness of the public sector solvency risk to an unexpected shock to the banking sector credit risk is contemporaneous in nature but it becomes insignificant quite rapidly. Hence, these results report the presence of default risk loop which is contagious by nature among the sovereign-bank sectors in Spain (for two quarters) especially during the euro crisis period.

On the contrary, there is also a testament of the real sector’s credit risk spillover to the banks but it fades away very quickly and becomes insignificant (figure 14). That is the spike was very short lived (t ≤ 1) and the shock effect from the real sector’s solvency risk in the pricing of banks risk, on average, eased out significantly in the first quarter in Spain during the euro crisis period. In addition, the corresponding vector autoregression estimation results

56 The respective granger causality results are reported in tables (11), in the Appendix.

Syed M. Noaman SHAH

17
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

Figure 15: Banks credit risk contagion to sovereign sector in Italy during global financial crisis period

Figure 16: Sovereign risk contagion to banking sector during public debt crisis in Italy

Note: The solid lines in figures above show statistically significant IR functions of the sovereign-bank nexus in Italy. Figure (15) depicts the sovereign solvency contagion risk towards the banking sector during the sub-prime crisis period. Whereas, figure (16) shows the sovereign solvency contagion risk towards the banking sector during the euro crisis period. The highlighted areas in above figures represent two-standard error bands and forecast horizons are in quarters. Moreover, BK.rsk and SV.rsk show bank and sovereign credit risk, respectively. The sample time period for the sub-prime crisis spans from 2007QIV-2009QIV and for the euro crisis from 2010-QI till 2012-QIV.

However, the collapse of Lehman brothers in September 2008 leads to the abrupt increase in the counter-party risk in the Italian interbank loan market that spurs-up its cost. As a consequence, the higher illiquidity and uncertainty in the domestic financial market urges the Italian government to provide support in order to ease out the turbulent situation, but this effect was not contagiously transferred to its sovereign sector.

On the other hand, the impulse-response functions estimated on the VAR results for Portugal report mix trends. In contrast to Greece, Spain and Italy, during the great recession period the credit risk contagion in Portugal is from the sovereign to banks (figure 17). In addition, there is also a presence of the default risk spillover from the real sector to banks during the GFC period (figure 18). These results mainly support the findings of Claeys and Vasicek (2014). More specifically, our results validate that the contagion in Portugal during the turbulent periods is due to the high level of public debt and budget deficits with diminishing economic growth which in turn becomes basis for the request of financial assistance from the Portuguese sovereign to troika in May, 2011 (figures, 19 and 20).

Besides, in the figure (18), we can discern that the default contagion risk from the real sector to respective banks dies away quickly (t ≤ 2) and the effect becomes insignificant during the sub-prime period. Whereas, the contagion risk from the sovereign sector is persistent towards banks during the euro crisis period (figure 19). In addition, the deterioration in government’s credit rating and the increased uncertainty among investors’ in capital markets regarding the Portuguese sovereign’s ability to service its public debt leads to the reduction in value of its sovereign debt securities. In this respect, the domestic banking sector that held these securities on their asset side adversely

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58 The result becomes clear after observing the granger causality outcome reported in table (11) in the Appendix.

58 The result becomes clear after observing the granger causality outcome reported in table (11) in the Appendix.

Syed M. Noaman SHAH

18
impacted which in turn deteriorated its liquidity position and hence led to reduce the overall balance sheet strength (Battistini et al., 2014).

Nevertheless, like Greece, in Portugal the main factor of recent distress in economic condition is due to the aggregate fiscal imbalance problem. Particularly, the public debt stock builds up over time to such pernicious levels that when investors’ in international capital markets started to distinguish the sovereign competitiveness among the euro area member states due to the shock from the GFC, the Portuguese government’s (and financial sector) ability to obtain funds from the capital market deteriorates. As a consequence, with the disappearance of fiscal space and the distressed banking sector, the Portuguese sovereign applied for a bail-out program.

Moreover, taking into consideration the figures (17 to 20), our results partially validate the hypotheses outlined in section (2) regarding the presence of the probability of default spillover from the real sector to the sovereign through the financial contagion. In this context, these findings also substantiate that the abrupt increase in the CDS premia among the sovereign-bank-firm nexus is principally due to the presence of contagion risk from the loss of investors’ confidence in Portuguese government ability to cope up with its public debt problem.59

On the other hand, in the case of Ireland our results only provide the evidence of contagion risk from banks to the respective sovereign, irrespective of the different crisis periods. The corresponding impact multipliers in figures (21 and 22) enable us to assess the systemic effect of an unexpected shock to the CDS premia of banking sector on the Irish sovereign during sub-prime and public debt crisis episodes. In both figures, we can observe that the innovations from banking sector’s credit risk immediately impacts the sovereign CDS premium in Ireland. Albeit, the deviations are of contemporaneous nature in the government sector’s solvency risk due to the shock in the banking spread but this effect is clearly stronger in the euro crisis period. This result is quite peculiar to observe because we do not find the private to public transformation of contagion risk from the Irish banking sector towards its sovereign even after

59 In the context of euro area, Giordano et al. (2013) also report similar findings.

Syed M. Noaman SHAH
it rescued the distressed domestic banks (Alter and Schüler, 2012). In other words, the cost of bank’s bail-out on the public balance sheet affected adversely which increases the Irish budget deficit to 32% of GDP in September 2010 (Baimbridge and Whyman, 2015). However, our credit risk contagion measures did not find statistically significant effect from the public sector to other sectors during the euro crisis period in Ireland.

Nevertheless, the deviation in the response of public sector becomes higher due to a shock in banks credit risk during the euro crisis episode which may outlines the indication of increased distress in Irish sovereign sector (i.e. the reduction in its fiscal space) that leads to its request of the rescue package in the month of November 2010.60

4.2.2 Core countries
In this section we analyze the credit risk contagion dynamics among the sovereign-bank-firm nexus during the recent crisis episodes in the core euro area member states. As mentioned in section (3), we mainly focus on Germany and France as selected core countries.

Taking the case of Germany, the impulse-response functions generated on VAR estimates of the focused sector’s default risk that are statistically different from zero are reported in figures (23), (24) and (25) for the GFC and the euro crisis periods. The results of contagion risk of default between sovereign, bank and non-financial firm sectors in German economy are quite intriguing. In fact, we did not find the presence of credit risk contagion among the focused sectors in Germany, mainly indicating the absence of fear regarding its financial, public and real sectors meltdown in the respective debt markets. However, we interpret these results as the disintegration of credit risk among the domestic economic sectors that are subject to time-variations in Germany.

In particular, from figures (23, 24 and 25) we can clearly discern the presence of disintermediation and diversification between the sovereign, bank and non-financial firms credit risk dynamics in the context of Germany, irrespective of the different crisis periods. Specifically, in figures (23) and (25) there is a lucid effect of disintegration among the German banks and corporates during the great recession and the euro crisis periods. In turn, these results enable us to interpret that the firms in Germany to fulfill their financing needs are not dependent only on the respective banking sector but also play an active role in the capital markets (may be through the issuance of bonds) even in the turbulent times.

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60 See: Baimbridge and Whyman (2015), pg xiv

Syed M. Noaman SHAH
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Figure 23: Credit risk interdependencies between banks and firms in Germany during the sub-prime period

Figure 24: Financial sector response to innovation in sovereign risk during the euro crisis period in Germany

Figure 25: Real sector credit risk variations due to shock in banking sector risk of default in Germany during the euro crisis period

Note: The above figures depict presence of credit risk interdependencies among the sovereign, banks and firms in Germany during the recent crises. The solid lines in all figures represent the orthogonal response due to one standard deviation shock in the impulse variable. The highlighted areas in above figures represent two-standard error bands and the forecast horizons are in quarters. Moreover, BK.rsk, SV.rsk and FM.rsk show bank, sovereign and non-financial firms credit risk, respectively. The sample time period for the sub-prime crisis spans from 2007QIV-2009QIV and for the euro crisis from 2010-QI till 2012-QIV.

As a consequence, the increase in funding costs or the reduction in the volume of loans by banks (due to turbulent financial periods) does not perniciously intimidate non-financial firms and simultaneously the potential higher rate of corporate default does not threaten banks liquidity conditions in the context of German economy (Artus, 2013). Furthermore, in figure (24), even though the impulse response function is not significant we interpret this result as the banking sector in Germany concentrates on holding the governments bond portfolio as diversified as possible which results in the disintegration of bank risk and the German sovereign risk (D’Auria et al. 2014). In contrast, the credit risk dynamics among the sovereign-bank-firm nexus in France portrays quite a unique picture more or less related to the results found in the context of GIPSI countries.

In this context, we mainly report the impact multipliers generated on the VAR estimation results that are significantly different from zero during the recent crisis periods in France. Figures (26) and (27) outline the contagion effect from the French financial sector towards its sovereign and real sectors during sub-prime and euro crisis periods, respectively. It is interesting to observe that irrespective pf the crisis period, the contagious effect is from the financial sector. Specifically, there is an immediate shock effect from banks credit risk towards sovereign and real sectors, while the public sector receiving higher magnitude, in particular. Whereas, this excessive spillover effect in the French economy fades out quickly, that is, in the second quarter after the financial sector shock.

On the other hand, in the euro crisis period, the effect lasts a bit longer, that is, till the third quarter but its magnitude is quite on the lower side as compared to the sub-prime crisis period. In fact, these results substantiate that the French financial sector acted as an intermediary between euro area debtors (especially the peripheral ones) and creditors from outside the euro zone. Therefore, during the sub-prime crisis, capital flows into the French economy were diverted towards the peripheral countries in order to receive higher returns. As a consequence, French financial

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Syed M. Noaman SHAH
sector’s exposure towards these Emu member states (especially, Spain, Greece and Italy) increases that led the investors’ in the capital markets to reduce their investment exposure in French government securities.

Consequently, during the euro crisis period, French financial sector reduces its exposure to peripheral states that result in immediate reduction in the magnitude of contagious transfer of credit risk towards its sovereign sector. As, it reduces the higher probability of bail-out of French financial sector from its respective sovereign (Hobza and Zeugner, 2014). Even though, our results clearly outline contagious effect from the financial to sovereign sector in France, the investors’ in international capital markets did not treat French sovereign credit risk at par with G-IPSI countries, may be due to its sustainable fiscal balances and the increased investment from German investors during recent crisis periods. In turn, the core euro area results clearly show divide among countries (in our case between the German and French economies) according to the corresponding debt markets that systemically assess the level of fiscal and current account balances in relation to financial sector distress, especially during the euro crisis period. Hence, this result indicates that for the euro area, the financial markets are able to discern between the diverse set of public borrowers (Caporale and Girardi, 2013).

4.3 Is there evidence of inter-country default risk contagion in the euro zone?
In this section, we mainly evaluate whether a shock to country’s credit risk premium contagiously affects sovereign-bank-firm nexus in the rest of euro zone, especially during the euro crisis period. To represent the peripheral and core regions, we mainly focus on analyzing the presence of credit risk contagion from Greece and Germany to the rest of euro zone during the sovereign debt crisis period in respective debt markets.

4.3.1 Default risk contagion from the Greek sovereign to euro zone’s sovereign-bank-firm nexus
In this respect, table (12) in the Appendix, reports the estimation results regarding the credit risk contagion from the Greek sovereign towards the rest of euro zone’s sovereign-bank-firm nexus in the recent crisis periods. However, for analysis we mainly focus on the impulse-response functions generated on the vector autoregression estimation results during the sovereign debt crisis period.

The graphs below show the IR functions of statistically significant results reported in table (12) in Appendix. In particular, figure (28) depicts that risk from the Greek sovereign’s inability to service its outstanding public debt...
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

Note: The solid lines in above graphs show the IR functions of Greek sovereign towards the rest of euro zone’s sovereign and banks during the public debt crisis period. The highlighted area in figures shows two-standard error bands. The forecast horizons are in quarters. In addition, figure (28) shows default risk contagion from the Greek public sector towards the remaining euro zone member states which is not significant. Figure (29) depicts the presence of increase in uncertainty in the euro zone’s banks due to the innovations to sovereign risk in Greece, whereas; figure (30) portrays the response of Greek sovereign to innovations in the euro zone banking sector. Whereas: SV.rsk.gr, SV.rsk.rst and BK.rsk.rst represent Greek sovereign risk, the rest of euro zone’s sovereign and bank risk, respectively. The sample time period spans from 2010-Q1 to 2012-QIV.

In turn, banks in the euro zone were hard-hit by this sovereign default event which adversely affected their total balance sheet value. Subsequently, the ECB conducted the stress tests on 91 EU financial institutions which revealed that seven banks failed to preserve the adequate capital amount required by the regulators (ECB, 2010). Therefore as a corrective measure, the euro zone finance ministers set-up a bail-out program with € 500bn as the European Stability Mechanism (ESM). Hence, it can be perceived that the contagion risk from the government debt markets to the bank becomes quite significant in the euro zone during the sovereign debt crisis period.

Nevertheless, quite an engaging outcome is reported in figure (30). Particularly, figure (30) shows that as there is an increase in the risk of default in the financial system of euro zone, the sovereign CDS premium of Greece goes down during the euro crisis period. Although, the result is statistically significant after the second quarter till the fifth, it is not considered as a contagion effect as mentioned in section (3.1.1). Despite that fact, we interpret it as an indication

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63 http://www.esm.europa.eu/

Syed M. Noaman SHAH
that with a bail-out package the Greek sovereign was able to turn-over its outstanding public debt through the financial assistance framework of the euro zone banking system operated mainly by the ECB and the bail-in effect of the private investors. On the one hand, in general, it increases the concerns regarding the financial system solvency in the euro area and on the other hand, it starts to ease the fiscal imbalance situation in Greece with its government simultaneously implementing the austerity measures (Featherstone, 2011). Hence, there is a presence of public-to-private transmission of credit risk contagion from the innovations in Greek sovereign towards the rest of euro zone. Furthermore, there is no effect towards the real sectors of EMU countries leading to indicate the close integration of public and financial debt markets especially during the euro crisis period (table (12), Appendix).

Therefore, our results portray more clear and quantified channel of transmission of Greek sovereign credit risk towards the rest of euro zone. In contrast to the existing studies (see: Missio and Watzka, 2011 and Aizenman et al. 2013, among others) that mainly evaluate only sovereign-sovereign nexus report that with the increase in the default risk of Greek sovereign the credit risk increases among the rest of euro zone member states. However, these studies lack to identify the spillover channel. In this respect, our results help to better understand the excessive spillover effect because we manifest that in fact the contagion effect from Greece towards the euro area is through its financial sector that heavily invested in Greek sovereign bonds to satisfy their risk appetite. Consequently, with the Greek default event and subsequent reduction in its sovereign credit rating leads to the lowering of these asset value for the euro zone financial sector. As a result, the distress in euro area’s financial sector increases that generate higher probability of bail-outs from respective sovereigns. This effect, in turn, transfers the increased distress in financial sector to respective sovereigns in the rest of euro zone.

4.3.2 Shock to Germany’s risk premium and relative response of euro area’s sovereign-bank-firm nexus

In this section, we attempt to evaluate our hypothesis regarding to investigate how the monetary union will react if we induce a positive shock to the sovereign risk of default to its strongest and financially secure member state (that is: Germany). In this respect, table (13) in the Appendix, reports the estimation results of credit risk contagion from the German sovereign to the remaining euro area sovereign-bank-firm nexus during the euro crisis period. The presence of contagion risk is evident among the sectors indicating the horizontal systemic risk of default in the respective debt markets in all panels in table (13). On the other hand, in all panels, it is quite interesting to observe the presence of contagion credit risk from the German sovereign to the euro zone’s sovereigns, banks and firms. These engaging scenarios are portrayed in the IR functions generated from a shock (i.e. one standard deviation) originated by the safest EMU economy that is Germany, to the rest of euro zone.

The following graphs depict IR functions of the results reported in table (13) in Appendix that are significantly different from zero. In this respect, figure (31) outlines that a shock to the German sovereign CDS spread contagiously affects the risk premia of the rest of EMU countries and increase a general fear of public default in the euro area debt markets. Specifically, it indicates that in capital markets as investors lose their fascination with German sovereign securities as a safe haven instrument than in turn, it adversely hits the probability of default of other sovereigns in the euro zone. However, in figure (31) we can observe that this response effect is persistent in nature and remains significant till the sixth quarter after the shock among respective debt markets in the euro zone. In addition, the consequent result after the shock peaks in the fourth quarter and takes a while to dissipate from the CDS market of the rest of euro area countries.

On the contrary, figure (32) shows the feedback effect from a shock of other euro area sovereign’s credit risk to the government sector in Germany. Interestingly, the trend here is entirely antithetical in nature indicating the phenomenon of “flight-to-quality” or “flight-to-safety” in corresponding debt markets in the EMU. In particular, with a rise in the general risk premium of the remaining sovereigns in the euro area, investors immediately seek refuge in the German sovereign securities mainly searching for safe returns on their investments. However, the shock to Germany’s risk premium generates a larger and slightly more resolute effect on other member countries sovereign risk of default in the euro region.

64 Along with financial assistance from IMF
65 De Santis (2012) also reports the similar results.
66 Although, we did not find the presence of credit risk contagion among sovereign-bank-firm nexus with-in Germany during the recent crisis period.

Syed M. Noaman SHAH
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Note: The solid lines in above graphs show the IR functions of a shock in the German sovereign towards the remaining euro zone’s sovereign-bank-firm nexus during the recent crisis period. The highlighted area in figures shows two-standard error bands. The forecast horizons are in quarters. Figures (31) and (32) depict the credit risk dynamics between the sovereign sectors of Germany and the rest of euro zone, whereas, figures (33) and (34) portray the default risk contagion among the German sovereign and the euro zone’s financial sector. In addition, figure (35) shows the contagion risk from German sovereign solvency to the euro zone’s non-financial corporate sector. Moreover: SV.rsk.de, SV.rsk.rst, BK.rsk.rst and FM.rsk.rst represent German sovereign risk, the rest of euro zone’s sovereign, bank and firms credit risk, respectively. The sample time period spans from 2010-Q1 to 2012-Q4.

Furthermore, the credit risk dynamics among the sovereign credit risk of Germany and the euro zone’s financial system reports the isomorphic trend with that of sovereign solvency risk. In particular, figure (33) shows the evidence of contagion risk from a decrease in the value of German bunds towards the default risk of banks in the EMU. This result suggests that the financial system in the rest of euro area prefers exposure to the German sovereign debt and is going to be adversely affected (approximately after one year) if Germany loses some of its appeal as a safe haven for investment. On the other hand, figure (34) outlines that as the euro area banking sectors’ CDS premia increases there is a resulting decrease in the sovereign CDS spread of Germany. Basically, this indicates a potential trend of disintegration among banks of the rest of euro zone with the German sovereign solvency risk (Artus, 2013). In other words, the investors in the sovereign CDS market do not consider the general increase in the risk premium of the financial system in the euro zone (other than Germany) as a threat as compared to the ability of German’s sovereign to service its outstanding public debt. In turn, it increases the liquidity towards German government bonds in the respective debt markets. However, both these simulation effects (figures; 33 and 34) take less time to fade away than the potential contagion among sovereign sectors of Germany and the rest of euro zone.

Moreover, it is quite engaging to discern that in figure (35) we have the evidence of contagion risk from German sovereign sector to the rest of EMU corporates. This finding provides a significant testament of the presence of contagion risk that may be through the trade effect. In particular, a shock to the sovereign risk premium of Germany adversely affects the non-financial firm’s bottom line and increases their risk of default in the remaining euro zone during recent crisis period. In other words, it indicates the lower demand for goods and services from German consumers that negatively transmits to the corporates in the rest of euro zone which significantly depend on their exports to Germany. Thus, it shows the higher intensity of trade linkage between Germany and other euro area member states (Elekdag and Muir, 2014).


Syed M. Noaman SHAH
Hence, largely these simulations validate our hypothesis that the contagious effect to other euro area countries would be higher if there is an abrupt increase in the sovereign risk premium of a financially strong country on which a monetary union principally rests. In turn, it leads to engender rise in the general risk perception of break-up of the EMU during the distressed time period that raises the CDS spread in all the corresponding debt markets (i.e. sovereign-bank-firms).

5 Conclusion

The commencement of the recent economic crisis provides a renewed impetus to the forgotten phenomenon of contagion among the financial markets. In this respect, the increased interaction of the credit risk in respective debt markets that generated an adverse feedback loop of default among the sovereign-bank nexus in the context of euro zone comes to the forefront for the regulators and policy makers especially during the recent euro crisis period. In turn, it draws attention of the academics and the researchers that resulted in an abundance of empirical studies on the issue. However, it is not unreasonable to say that the related literature lacks to cater comprehensively the credit risk dynamics and fundamentally focus only on the sovereign-bank nexus in the context of EMU. Taking into consideration the policy recommendations outlined in Alter and Beyer (2014), the current work extends the empirical knowledge by focusing on the cross market credit risk dynamics of sovereign-bank-firm nexus in the euro zone. The study not only contributes to better understand the consequences of the euro crisis to the real sector but also provides the economic application of how the contagion risk plays an important role in the volatility of CDS spread among the corresponding debt markets.

Therefore, in this paper we use the panel vector autoregressive framework to distinguish the importance of credit risk contagion among the sovereign-bank-firm debt markets in the euro zone especially during the public debt crisis. Moreover, we attempt to furnish the harmony to the prevalent empirical debate regarding the order of contagion risk from the peripheral countries to the rest of euro area during recent crisis period. In doing so, our findings provide quite engaging results.

In the context of euro zone as a whole, we report that the contagion is systemic by nature regarding the sovereign-bank-firm credit risk which is time-invariant with-in sector and time-varying among sectors. Consequently, the private-to-public risk transfer is quite evident among the recent crisis periods. Moreover, irrespective of the crisis periods there is a higher integration between the sovereign credit market and banks against the respective non-financial firms in the euro zone, on average. On the other hand, the contagion credit risk from the real sector to the sovereign and banks was found with the euro zone’s financial system ensuing carry-trade behavior in the turbulent times. In this respect, as we make more acute analysis by taking into consideration the individual G-IPSI and the core countries in the euro area, our findings only partially validate these results.

Thus, these results enable us to infer that it is not necessary that the nature of crisis remains time invariant during the turbulent periods in a country or economic region (for instance, it is not imperative that the banking crisis transforms into any other kind of crisis in subsequent periods as assumed in the related literature). On the other hand, it is also not reasonable to assume that the nature of crisis remains sector invariant during a particular time period. As handful of studies reported that since 2010 in the euro area, the distress is mainly related to the fiscal imbalances (see: Popov and van Horen, 2013 and Harjes, 2011 among others). For instance, it basically outlines the fact that during a specific time period there may be emergence and presence of different types of crisis (like financial and or fiscal) at the same time in different member states of the monetary union. Moreover, there is evidence of the real sector credit risk contagion to the sovereign only through the respective financial contagion and no direct influence was found in the individual member states as reported in the context of euro area as whole. Furthermore, no carry-trade behavior by the financial system was validated regarding the individual G-IPSI and core countries. However, only a unidirectional sovereign risk contagion to the real sector is reported directly and through the corresponding financial contagion channel. In addition, a lucid finding of the private-to-public risk transfer is reported only in the context of Spain.

In this respect, while evaluating the presence of contagion risk from the sovereign risk premia of G-IPSI and core countries to the rest of euro area, we find quite interesting results. Specifically, during the euro crisis period, there is an evidence of contagion from the Greek sovereign risk premia to the rest of euro area bank’s risk of default that eventually transforms into the sovereign crisis in the rest of euro zone. Therefore, the order of systemic contagion risk depends upon the underlying fragility in the distressed sector in a euro area country that excessively spillovers to others which is not necessarily time-varying in nature. For instance, our results report the presence of fiscal and
financial crises during the euro crisis period. Consequently, the contagion order depends upon the inherent weakness in the economic structure of the corresponding member states in the euro zone.

In a similar vein, simulating a shock to the German risk premium provides isomorphic results but with an indication of “flight-to-quality” phenomenon. It basically indicates the increased liquidity towards the core countries during turbulent times from the rest of euro area member states. Alternatively, this result outlines that the core country’s credit risk severely affected other countries risk premia in the euro zone without being significantly receiving the same feedback effect in return.

Thus, in the light of above results the tentative policy recommendations can be summarized as follows:

- While formulating a policy-mix for the EMU, it is prudent to take into consideration the heterogeneity that prevails among the credit risk interconnectedness of the sovereign-bank-firm nexus regarding the structural and economic system of the individual member states.

- In taking corrective measures to lessen and contain the contagion risk in the euro area, the credit risk dynamics between the significant economic sectors should be considered and attention should not be limited only to the sovereign-bank nexus.

- Finally, increased efforts should ideally be pursued by the regulators and the EU institutions towards the disintegration and disintermediation of the sovereign-bank-firm nexus to reduce the probability of credit risk contagion during turbulent times in the euro zone. This may be accomplished by encouraging corporates to diversify their funding needs towards the capital markets (as our simulation results report in the case of Germany). On the other hand, among sovereign-bank network, the disintegration may be achieved by adequately pricing the domestic and the euro zone’s sovereign debt securities with the corresponding regulations on the overall exposure of local banks.
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

References

Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Syed M. Noaman SHAH

Appendix

\[
\begin{align*}
\begin{bmatrix}
Z_{AT_{sv,t}} \\
Z_{ES_{sv,t}} \\
Z_{AT_{bk,t}} \\
Z_{ES_{bk,t}} \\
Z_{AT_{fm,t}} \\
Z_{ES_{fm,t}}
\end{bmatrix}
&= 
\begin{bmatrix}
\alpha_{1,0} \\
\alpha_{n,0}
\end{bmatrix}_M
+ \sum_{i=1}^{\mu}
\begin{bmatrix}
ad_{1,i} \\
ad_{n,i}
\end{bmatrix}_M
\begin{bmatrix}
K \\
L
\end{bmatrix}_M
+ \begin{bmatrix}
Z_{AT_{sv,t-1}} \\
Z_{ES_{sv,t-1}} \\
Z_{AT_{bk,t-1}} \\
Z_{ES_{bk,t-1}} \\
Z_{AT_{fm,t-1}} \\
Z_{ES_{fm,t-1}}
\end{bmatrix}_M
\begin{bmatrix}
e_{AT_{sv,t}} \\
e_{ES_{sv,t}} \\
e_{AT_{bk,t}} \\
e_{ES_{bk,t}} \\
e_{AT_{fm,t}} \\
e_{ES_{fm,t}}
\end{bmatrix}_M
\end{align*}
\]

where \(e_{i,t} \sim wn(0, \Sigma_e)\)

Table 1: Model selection criteria

<table>
<thead>
<tr>
<th>Lag</th>
<th>CD</th>
<th>J</th>
<th>Jpvalue</th>
<th>MBIC</th>
<th>MAIC</th>
<th>MQIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.67364</td>
<td>56.7202</td>
<td>0.11296</td>
<td>-199.95</td>
<td>-33.28</td>
<td>-99.981</td>
</tr>
<tr>
<td>2</td>
<td>0.67261</td>
<td>46.527</td>
<td>0.11241</td>
<td>-158.81</td>
<td>-25.473</td>
<td>-78.834</td>
</tr>
<tr>
<td>3</td>
<td>0.69807</td>
<td>35.4829</td>
<td>0.12705</td>
<td>-118.52</td>
<td>-18.517</td>
<td>-58.538</td>
</tr>
<tr>
<td>4</td>
<td>0.75219</td>
<td>25.7701</td>
<td>0.10513</td>
<td>-76.898</td>
<td>-10.23</td>
<td>-36.911</td>
</tr>
</tbody>
</table>

Note: According to Andrews and Lu (2001), panel VAR with lag one shows minimum MBIC, AIC and Hannan QIC, therefore we use PVAR(1) in our GMM System estimation
Table 2: List of banks with respect to the euro zone countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Banks</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Erste Group, Bank für Arbeit und Wirtschaft und Österreichische Postsparkasse AG (BAWAG P.S.K), Raiffeisen Zentralbank Österreich</td>
<td>3</td>
</tr>
<tr>
<td>Belgium</td>
<td>KBC Group</td>
<td>1</td>
</tr>
<tr>
<td>France</td>
<td>Crédit Mutuel, BNP Paribas, Credit Agricole, Credit Lyonnais, Natixis, Calyon Bank</td>
<td>6</td>
</tr>
<tr>
<td>Germany</td>
<td>Bayerische Landesbank, Commerzbank, Deutsche Bank, HSH Nordbank, IKB Deutsche Industriebank AG, Landesbank Berlin, Landesbank Baden-Württemberg, Landesbank Hessen-Thüringen, Norddeutsche Landesbank Girozentrale (NORD/LB), WestLB AG</td>
<td>10</td>
</tr>
<tr>
<td>Greece</td>
<td>Alpha Bank, EFG Eurobank Ergas, National Bank of Greece</td>
<td>3</td>
</tr>
<tr>
<td>Ireland</td>
<td>Allied Irish Bank, Irish Bank Resolution Corporation (IBRC/Anglo Irish Bank)</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>Banca Montepaschi Di Siena, Banco Popolare Italiana, Unicredito, Intesa Sanpaolo, Banca Italease, UBI Banca Group</td>
<td>6</td>
</tr>
<tr>
<td>Netherland</td>
<td>Rabo Bank, ING Banks, SNS Bank</td>
<td>3</td>
</tr>
<tr>
<td>Portugal</td>
<td>Banco Comercial Portugues, Banco BPI, Banco Espirito Santo</td>
<td>3</td>
</tr>
<tr>
<td>Spain</td>
<td>Banco Sabadell, Banco Popular Español, Banco Pastor, Banco Santander, Bankinter SA, La Caixa, Banco Bilbao Vizcaya Argentaria (BBVA)</td>
<td>7</td>
</tr>
</tbody>
</table>

Note: The table reports the list of banks for which the five years CDS spread data is available through the DataStream and Bloomberg for the period 2007-QIV till 2012-QIV. Further, for bank specific control variables, we use Bankscope to collect the data regarding bank fundamentals by manually cross-matching with the CDS data, the bank name and a series of other identification information such as (BIC-Business Identifier Code and SIC-Standard Industrial Classification indicators).
Table 3: List of firms with respect to the euro zone countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Non-financial corporates</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Telekom Austria, OMV</td>
<td>2</td>
</tr>
<tr>
<td>Belgium</td>
<td>Applied Mats Inc, Belgacom, Solvay</td>
<td>3</td>
</tr>
<tr>
<td>Finland</td>
<td>Elisa, Fortum Power &amp; Heat AB, Metsäh Board, Metso, Nokia, Stora Enso, Teliasonera, UPM</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>(The Biofore Company)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accor, Airbus Group, Alcan France, Alcatel Lucent, Alstom, Arcelormittal, Bouygues,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cap Gemini, Carrefour, Groupe Casino, Saint-Gobain, Ciments Français, Danone, Electricité</td>
<td></td>
</tr>
<tr>
<td></td>
<td>de France, GDF Suez, Havas, Kering, Lafarge, Lagardere, L'air liquide, Legrand France,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L'oreal, Michelin, LVMH, Orange, Pernod Ricard, Peugeot, Publicis groupe, Rallye,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Renault, Rexel, Rhodia, Sanofi, Schneider Electric, Securitas, Societe Air, Sodexho</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alliance, Technip, Total, Unibail-Rodamco, Valeo, Veolia, Vinci, Vivendi</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Adidas, BASF, Bertelsmann, Continental, Daimler, Deutsche Bahn, Deutsche Telekom,</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>ENBW, Fresenius, Grohe, Heidelberg cement, Lanxess, Merck, Metro, Pilkington group,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ProSiebensat, RWE group, Siemens, Suedzucker, Thyssenkrupp, TUI, UPC, Voith, Volkswagen</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>Hellenic Telecommunications, Public power corporation</td>
<td>2</td>
</tr>
<tr>
<td>Greece</td>
<td>Cividien, Eaton corporation, Ingersoll-Rand co, Weatherford International Ltd</td>
<td>4</td>
</tr>
<tr>
<td>Ireland</td>
<td>Edison, Enel, ENI, Fiat, Finmeccanica, Gruppo Editoriale L'Espresso, Pirelli &amp; co,</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Seat Pagine Gialle, Telecom Italia</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>Akzo Nobel, Alliander, E.ON, Eneco, Essent, Heineken, Koninklijke Ahold N.V., Koninklijke</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Philips N.V., NXP, PostNL, Reed Elsevier plc, Royal Dutch Shell plc, UniLever, UPC</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>holding, Wolters Kluwer</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>EDP-Energias de Portugal, Portugal Telecom, Petrobras</td>
<td>3</td>
</tr>
<tr>
<td>Spain</td>
<td>Altadis, Endesa, Gas Natural, Iberdrola, Repsol, Telefonica</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: The table reports the list of non-financial firms for which five years CDS spread data is available through the DataStream and Bloomberg for the period 2007-QIV till 2012-QIV. Further, for firm specific control variables, we use Worldscope to collect the data regarding firm’s fundamentals by manually cross-matching with the CDS data, the firm name and a series of other identification information such as (BIC-Business Identifier Code and SIC-Standard Industrial Classification indicators)
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Table 4: Data variables description and source

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit risk-sovereign</td>
<td>Credit Default Swap (CDS) premia of 5 years’ maturity for sovereigns</td>
<td>DataStream/Bloomberg</td>
</tr>
<tr>
<td>Credit risk-bank (1)</td>
<td>Weighted index of CDS premia of 5 years of banks with respect to specific euro zone countries</td>
<td>DataStream/Bloomberg</td>
</tr>
<tr>
<td>Credit risk-firm (2)</td>
<td>Weighted index of CDS premia of 5 years of non-financial firms with respect to specific euro zone countries</td>
<td>DataStream/Bloomberg</td>
</tr>
<tr>
<td>Inflation (PPI)</td>
<td>Inflation ratio indexed by Producer Price (PPI)</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Inflation (CPI)</td>
<td>Inflation ratio indexed by Consumer Price (CPI)</td>
<td>World Development Indicators</td>
</tr>
<tr>
<td>GDP growth</td>
<td>GDP growth rate (%)</td>
<td>World Development Indicators</td>
</tr>
<tr>
<td>Real exchange rate</td>
<td>Natural logarithm of real exchange rate (euro/usd)</td>
<td>Fed. Reserve Bank of St. Louis</td>
</tr>
<tr>
<td>CA</td>
<td>Current account balance as a share of GDP</td>
<td>World Bank</td>
</tr>
<tr>
<td>PD to GDP</td>
<td>Total gross central government debt to GDP</td>
<td>ECB data warehouse</td>
</tr>
<tr>
<td>VIX</td>
<td>S&amp;P 500 volatility index</td>
<td>Fed. Reserve Bank of St. Louis</td>
</tr>
<tr>
<td>Bank-level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return on assets</td>
<td>(Net income/total assets) in %</td>
<td>Bankscope</td>
</tr>
<tr>
<td>Z-score</td>
<td>Sum of the return on assets and capital ratio divided by income volatility</td>
<td>Bankscope</td>
</tr>
<tr>
<td>Provision for loss</td>
<td>provision for loan losses normalized by total loans</td>
<td>Bankscope</td>
</tr>
<tr>
<td>Interbank ratio</td>
<td>due from bank over due to other bank</td>
<td>Bankscope</td>
</tr>
<tr>
<td>Bank size</td>
<td>natural logarithm of total assets</td>
<td>Bankscope</td>
</tr>
<tr>
<td>Firm-level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm size</td>
<td>Natural log of net asset value (mean)</td>
<td>Worldscope (Datastream)</td>
</tr>
<tr>
<td>Leverage ratio</td>
<td>total debt / EBITDA</td>
<td>Worldscope (Datastream)</td>
</tr>
<tr>
<td>Profitability ratio</td>
<td>change in net margin/last year net margin * 100</td>
<td>Worldscope (Datastream)</td>
</tr>
<tr>
<td>Growth multiple</td>
<td>Price earnings ratio</td>
<td>Worldscope (Datastream)</td>
</tr>
<tr>
<td>Liquidity ratio</td>
<td>Current ratio-one-year percentage change</td>
<td>Worldscope (Datastream)</td>
</tr>
</tbody>
</table>

Note:
(1) For the bank credit risk index, refer to equation (4) in section (3.1.2) for the index methodology with respect to the individual country.
(2) For the non-financial firm credit risk index, refer to equation (3) in section (3.1.2) for the index methodology with respect to the individual country. Furthermore, the fundamental bank and firm data is available annually or bi-annually, in order to streamline with the CDS premia, we use cubic spline interpolation to harmonize the frequency of data observations in the sample. In addition, to obtain the residuals of CDS premia, macro-economic factors used interchangeably (for example: inflation through CPI or PPI, and economic output as GDP level or growth) to verify the robustness of default risk proxies for the sovereign-bank-firm sectors of euro zone. Whereas, for the default risk proxies, natural log forms are used.
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Table 5: Panel unit root test (Pesaran, 2007)

<table>
<thead>
<tr>
<th>Variables</th>
<th>t-bar</th>
<th>cv10</th>
<th>cv5</th>
<th>cv1</th>
<th>z[t-bar]</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDS_sovereign</td>
<td>4.39</td>
<td>2.14</td>
<td>2.25</td>
<td>2.44</td>
<td>9.66</td>
<td>0.00</td>
</tr>
<tr>
<td>CDS_bank</td>
<td>4.06</td>
<td>2.14</td>
<td>2.25</td>
<td>2.44</td>
<td>8.45</td>
<td>0.00</td>
</tr>
<tr>
<td>CDS_firm</td>
<td>3.39</td>
<td>2.14</td>
<td>2.25</td>
<td>2.44</td>
<td>5.95</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Note: One-lag is suggested by the model selection criteria (proposed by Andrews and Lu, 2001) results which are outlined in table (C.1). The results of all variables are available upon request. Since, the p-value is less than 1%, we reject the null hypothesis of non-stationarity.

Table 6: Panel VAR (1) estimation for sovereign-bank-firm credit risk in the euro zone

<table>
<thead>
<tr>
<th>Variables</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>SV.rsk(t)</td>
<td>0.599***</td>
<td>0.056*</td>
<td>-0.031</td>
</tr>
<tr>
<td>(0.045)</td>
<td>(0.035)</td>
<td>(0.036)</td>
<td></td>
</tr>
<tr>
<td>BK.rsk(t)</td>
<td>0.163***</td>
<td>0.602***</td>
<td>0.045</td>
</tr>
<tr>
<td>(0.044)</td>
<td>(0.049)</td>
<td>(0.032)</td>
<td></td>
</tr>
<tr>
<td>FM.rsk(t)</td>
<td>0.085</td>
<td>0.018</td>
<td>0.640***</td>
</tr>
<tr>
<td>(0.055)</td>
<td>(0.048)</td>
<td>(0.053)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>SV.rsk(t)</td>
<td>0.550***</td>
<td>0.148**</td>
<td>-0.052</td>
</tr>
<tr>
<td>(0.071)</td>
<td>(0.063)</td>
<td>(0.035)</td>
<td></td>
</tr>
<tr>
<td>BK.rsk(t)</td>
<td>0.182***</td>
<td>0.592***</td>
<td>-0.046</td>
</tr>
<tr>
<td>(0.059)</td>
<td>(0.061)</td>
<td>(0.039)</td>
<td></td>
</tr>
<tr>
<td>FM.rsk(t)</td>
<td>0.109*</td>
<td>0.088**</td>
<td>0.862***</td>
</tr>
<tr>
<td>(0.064)</td>
<td>(0.043)</td>
<td>(0.052)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(8)</td>
<td>(9)</td>
</tr>
<tr>
<td>SV.rsk(t)</td>
<td>0.734***</td>
<td>0.096**</td>
<td>-0.088</td>
</tr>
<tr>
<td>(0.071)</td>
<td>(0.063)</td>
<td>(0.035)</td>
<td></td>
</tr>
<tr>
<td>BK.rsk(t)</td>
<td>0.087</td>
<td>0.681***</td>
<td>0.153***</td>
</tr>
<tr>
<td>(0.066)</td>
<td>(0.073)</td>
<td>(0.051)</td>
<td></td>
</tr>
<tr>
<td>FM.rsk(t)</td>
<td>0.031</td>
<td>-0.174**</td>
<td>0.472***</td>
</tr>
<tr>
<td>(0.090)</td>
<td>(0.077)</td>
<td>(0.082)</td>
<td></td>
</tr>
</tbody>
</table>

The table reports results of P(VAR) system of sovereign, bank and non-financial firm risk in the euro zone. Definitions of variables are outlined in table (4), Appendix. The panel VAR model is estimated by using the GMM system approach whereas; country-time and fixed-effect are removed prior to the estimation (see section 3.1, for details). Panel I outlines the estimation results for the whole sample period (i.e. 2007/QIV-2012/QIV). In addition, panel II shows results of the P(VAR) estimation for the sub-prime period (i.e. 2007/QIV-2012/QIV). Dependent endogenous variables are in columns showing the coefficients of regressing them on row variables, that is, the lag variables. Robust standard errors are in parentheses, whereas *** , **, and * shows 1%, 5% and 10% significance level, respectively.
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Table 7: Panel VAR credit risk granger causality between sovereign-bank-firm nexus in the euro zone

<table>
<thead>
<tr>
<th>Equation/Excluded</th>
<th>SV.rsk</th>
<th>BK.rsk</th>
<th>FM.rsk</th>
<th>SV.rsk</th>
<th>BK.rsk</th>
<th>FM.rsk</th>
<th>SV.rsk</th>
<th>BK.rsk</th>
<th>FM.rsk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>chi2</td>
<td>df</td>
<td>Prob&gt;chi2</td>
<td>chi2</td>
<td>df</td>
<td>Prob&gt;chi2</td>
<td>chi2</td>
<td>df</td>
<td>Prob&gt;chi2</td>
</tr>
<tr>
<td>BK.rsk</td>
<td>13.584</td>
<td>1</td>
<td>0.000***</td>
<td>9.429</td>
<td>1</td>
<td>0.002***</td>
<td>1.722</td>
<td>1</td>
<td>0.189</td>
</tr>
<tr>
<td>FM.rsk</td>
<td>2.361</td>
<td>1</td>
<td>0.124</td>
<td>2.954</td>
<td>1</td>
<td>0.086*</td>
<td>0.115</td>
<td>1</td>
<td>0.735</td>
</tr>
<tr>
<td>SV.rsk</td>
<td>3.832</td>
<td>1</td>
<td>0.05**</td>
<td>5.549</td>
<td>1</td>
<td>0.018**</td>
<td>5.89</td>
<td>1</td>
<td>0.015**</td>
</tr>
<tr>
<td>BK.rsk</td>
<td>0.136</td>
<td>1</td>
<td>0.712</td>
<td>4.092</td>
<td>1</td>
<td>0.043**</td>
<td>5.151</td>
<td>1</td>
<td>0.023**</td>
</tr>
<tr>
<td>FM.rsk</td>
<td>0.732</td>
<td>1</td>
<td>0.392</td>
<td>2.153</td>
<td>1</td>
<td>0.142</td>
<td>2.085</td>
<td>1</td>
<td>0.149</td>
</tr>
</tbody>
</table>

The table shows panel VAR (PVAR-1) granger causality test for the credit risk contagion order between sovereign-bank-firm nexus in the euro zone. Panel I outlines results for the whole sample period (i.e. 2007-QIV to 2012-QIV). Panel II reports the sub-prime crisis period (i.e. 2007-QIV to 2009-QIV), whereas Panel III shows results of the sovereign debt crisis period (i.e. 2010-QI to 2012-QIV). Furthermore, SV.rsk, BK.rsk and FM.rsk represent the sovereign, bank, and firms credit risk premia. Whereas, ***, **, and * shows 1%, 5% and 10% significance level, respectively.

Table 8: VAR (1) estimation results for sovereign, bank and firm credit risk in Greece

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV.rsk(t-1)</td>
<td>0.944***</td>
<td>0.200***</td>
<td>-0.012</td>
<td>0.989***</td>
<td>0.311</td>
<td>-0.049</td>
<td>0.904***</td>
<td>0.220***</td>
<td>0.310*</td>
</tr>
<tr>
<td></td>
<td>(0.104)</td>
<td>(0.07)</td>
<td>(0.071)</td>
<td>(0.144)</td>
<td>(0.227)</td>
<td>(0.127)</td>
<td>(0.235)</td>
<td>(0.084)</td>
<td>(0.173)</td>
</tr>
<tr>
<td>BK.rsk(t-1)</td>
<td>0.121</td>
<td>0.494***</td>
<td>0.364***</td>
<td>0.024</td>
<td>0.458**</td>
<td>0.420***</td>
<td>0.335</td>
<td>0.423*</td>
<td>0.084</td>
</tr>
<tr>
<td></td>
<td>(0.196)</td>
<td>(0.132)</td>
<td>(0.135)</td>
<td>(0.121)</td>
<td>(0.191)</td>
<td>(0.106)</td>
<td>(0.605)</td>
<td>(0.218)</td>
<td>(0.383)</td>
</tr>
<tr>
<td>FM.rsk(t-1)</td>
<td>-0.042</td>
<td>-0.080</td>
<td>0.756***</td>
<td>0.029</td>
<td>0.029</td>
<td>0.814***</td>
<td>0.086</td>
<td>0.136</td>
<td>0.564**</td>
</tr>
<tr>
<td></td>
<td>(0.164)</td>
<td>(0.111)</td>
<td>(0.113)</td>
<td>(0.106)</td>
<td>(0.167)</td>
<td>(0.093)</td>
<td>(0.409)</td>
<td>(0.147)</td>
<td>(0.259)</td>
</tr>
</tbody>
</table>

The table reports results of VAR system of sovereign, bank and non-financial firm credit risk in Greece. Definition of all the variables used is outlined in table (4) in the Appendix. Furthermore, three-variables VAR model is estimated by the GMM-approach, whereas, the country-time and fixed-effect are removed prior to the estimation (see section 3.1, for details). Panel I outlines the results of VAR model for the whole sample period (i.e. 2007-QIV-2012-QIV). Panel II reports the results of period preceding the sovereign debt crisis or time period of the sub-prime effect (i.e. 2007-QIV-2009-QIV), whereas, panel III shows the results of VAR estimation for the sovereign crisis period (i.e. 2010-QI-2012-QIV). Dependent endogenous variables are in columns which show the coefficients of regressing these variables on the row variables that is the lag variables. Robust standard errors are in parentheses, whereas ***, **, and * shows 1%, 5% and 10% significance level, respectively.
Table 9: Credit risk granger causality between sovereign-bank-firm nexus in Greece

<table>
<thead>
<tr>
<th>Equation/Excluded</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>chi2</td>
<td>df</td>
<td>Prob&gt;chi2</td>
</tr>
<tr>
<td>SV.rsk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BK.rsk</td>
<td>0.380</td>
<td>1</td>
<td>0.537</td>
</tr>
<tr>
<td>FM.rsk</td>
<td>0.066</td>
<td>1</td>
<td>0.797</td>
</tr>
<tr>
<td>BK.rsk</td>
<td>8.178</td>
<td>1</td>
<td>0.004***</td>
</tr>
<tr>
<td>FM.rsk</td>
<td>0.527</td>
<td>1</td>
<td>0.468</td>
</tr>
<tr>
<td>SV.rsk</td>
<td>0.029</td>
<td>1</td>
<td>0.863</td>
</tr>
<tr>
<td>BK.rsk</td>
<td>7.292</td>
<td>1</td>
<td>0.007***</td>
</tr>
</tbody>
</table>

The table shows VAR (1) granger causality test for the credit risk contagion order between the sovereign-bank-firm nexus in Greece. Panel I outlines the results for the whole sample period (i.e. 2007-QIV to 2012-QIV). Panel II reports the sub-prime crisis period (i.e. 2007-QIV to 2009-QIV), whereas, Panel III shows results of the sovereign debt crisis period (i.e. 2010-QI to 2012-QIV). Furthermore, SV.rsk, BK.rsk and FM.rsk represent the sovereign, bank, and firms credit risk premia. While, ***, **, and * show 1%, 5% and 10% significance level, respectively.

Table 10: VAR (1) estimation results for sovereign, bank and firm credit risk in Spain

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV.rsk(t-1)</td>
<td>0.478***</td>
<td>0.153*</td>
<td>0.006</td>
<td>0.558***</td>
<td>0.015</td>
<td>0.010</td>
<td>0.228*</td>
<td>0.506***</td>
<td>0.034</td>
</tr>
<tr>
<td></td>
<td>(0.155)</td>
<td>(0.091)</td>
<td>(0.058)</td>
<td>(0.191)</td>
<td>(0.084)</td>
<td>(0.031)</td>
<td>(0.191)</td>
<td>(0.164)</td>
<td>(0.198)</td>
</tr>
<tr>
<td>BK.rsk(t-1)</td>
<td>0.508**</td>
<td>0.529**</td>
<td>-0.108</td>
<td>0.946***</td>
<td>0.321**</td>
<td>0.059</td>
<td>0.521*</td>
<td>0.546***</td>
<td>-0.258</td>
</tr>
<tr>
<td></td>
<td>(0.238)</td>
<td>(0.236)</td>
<td>(0.129)</td>
<td>(0.327)</td>
<td>(0.149)</td>
<td>(0.164)</td>
<td>(0.271)</td>
<td>(0.209)</td>
<td>(0.219)</td>
</tr>
<tr>
<td>FM.rsk(t-1)</td>
<td>0.403</td>
<td>0.155</td>
<td>0.117*</td>
<td>0.410</td>
<td>0.089</td>
<td>0.534**</td>
<td>0.238</td>
<td>0.675***</td>
<td>0.057*</td>
</tr>
<tr>
<td></td>
<td>(0.326)</td>
<td>(0.239)</td>
<td>(0.228)</td>
<td>(0.591)</td>
<td>(0.256)</td>
<td>(0.250)</td>
<td>(0.386)</td>
<td>(0.249)</td>
<td>(0.382)</td>
</tr>
</tbody>
</table>

The table reports results of VAR system of the sovereign, bank and non-financial firm credit risk in Spain. Definition of all the variables used is outlined in table (4). Panel I outlines the results of VAR model for the whole sample period (i.e. 2007/QIV-2012/QIV). Panel II reports results of the sub-prime crisis period (i.e. 2007/QIV-2009/QIV), whereas; panel III shows results of the VAR estimation for the sovereign crisis period (i.e. 2010/QI-2012/QIV). Dependent endogenous variables are in columns which show the coefficients of regressing these variables on the row variables that is their lag variables. Robust standard errors are in parentheses, whereas ***, **, and * shows 1%, 5% and 10% significance level, respectively.
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Table 11: Credit risk granger causality between sovereign-bank-firm nexus in Spain

<table>
<thead>
<tr>
<th>Equation</th>
<th>Excluded</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>chi2</td>
<td>df</td>
<td>Prob&gt;chi2</td>
<td>chi2</td>
<td>df</td>
<td>Prob&gt;chi2</td>
</tr>
<tr>
<td>SV.rsk</td>
<td></td>
<td>4.540</td>
<td>1</td>
<td>0.033**</td>
<td>8.392</td>
<td>1</td>
<td>0.004***</td>
</tr>
<tr>
<td>BK.rsk</td>
<td></td>
<td>1.530</td>
<td>1</td>
<td>0.216</td>
<td>0.482</td>
<td>1</td>
<td>0.488</td>
</tr>
<tr>
<td>FM.rsk</td>
<td></td>
<td>2.821</td>
<td>1</td>
<td>0.093*</td>
<td>0.032</td>
<td>1</td>
<td>0.857</td>
</tr>
<tr>
<td>BK.rsk</td>
<td></td>
<td>0.419</td>
<td>1</td>
<td>0.518</td>
<td>0.121</td>
<td>1</td>
<td>0.728</td>
</tr>
<tr>
<td>FM.rsk</td>
<td></td>
<td>0.013</td>
<td>1</td>
<td>0.91</td>
<td>0.106</td>
<td>1</td>
<td>0.744</td>
</tr>
<tr>
<td>SV.rsk</td>
<td></td>
<td>0.699</td>
<td>1</td>
<td>0.403</td>
<td>0.131</td>
<td>1</td>
<td>0.718</td>
</tr>
</tbody>
</table>

The table shows VAR (1) granger causality test for the credit risk contagion order between sovereign-bank-firm nexus in Spain. Panel I outlines results for the whole sample period (i.e. 2007-QIV to 2012-QIV). Panel II reports the sub-prime crisis period (i.e. 2007-QIV to 2009-QIV), whereas Panel III shows the results of sovereign debt crisis period (i.e. 2010-QI to 2012-QIV). Furthermore, SV.rsk, BK.rsk and FM.rsk represent the sovereign, bank, and firms credit risk premia. Whereas, ***, **, and * show 1%, 5% and 10% significance level, respectively.

Table 12: Greek sovereign risk contagion to the rest of euro zone sovereign, bank and firm credit risk during the sovereign debt crisis period

<table>
<thead>
<tr>
<th>Variables</th>
<th>SV.rsk.rst(t-1)</th>
<th>SV.rsk.gr(t-1)</th>
<th>BK.rsk.rst(t-1)</th>
<th>SV.rsk.gr(t-1)</th>
<th>FM.rsk.rst(t-1)</th>
<th>SV.rsk.gr(t-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV.rsk.rst(t-1)</td>
<td>0.547***</td>
<td>-0.279</td>
<td>0.859***</td>
<td>-0.413***</td>
<td>0.543***</td>
<td>-0.833</td>
</tr>
<tr>
<td></td>
<td>(0.202)</td>
<td>(1.123)</td>
<td>(0.131)</td>
<td>(0.157)</td>
<td>(0.203)</td>
<td>(3.044)</td>
</tr>
<tr>
<td>BK.rsk.rst(t-1)</td>
<td></td>
<td>0.859***</td>
<td>-0.413***</td>
<td></td>
<td>0.543***</td>
<td>-0.833</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.131)</td>
<td>(0.157)</td>
<td></td>
<td>(0.203)</td>
<td>(3.044)</td>
</tr>
<tr>
<td>FM.rsk.rst(t-1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.069*</td>
<td>0.940***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.035)</td>
<td>(0.136)</td>
</tr>
</tbody>
</table>

The table reports results of the Greek sovereign risk contagion to the rest of euro zone's sovereign, bank and non-financial firm credit risk during the recent crisis period (i.e. 2010/QI-2012/QIV). The variables: SV.rsk.gr is the Greek sovereign risk, whereas; SV.rsk.rst, BK.rsk.rst, and FM.rsk.rst are sovereign, bank and non-financial firm risk in the rest of euro zone. Dependent endogenous variables are in columns that show the coefficients of regressing these variables on the row variables that is the lag values. Robust standard errors are in parentheses, whereas ***, **, and * show 1%, 5% and 10% significance level, respectively.
Table 13: Sovereign risk contagion from Germany to the rest of euro zone sovereign, bank and non-financial firm sectors during the public debt crisis

<table>
<thead>
<tr>
<th>Variables</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV.rsk.rst(t-1)</td>
<td>0.914***</td>
<td>-0.202***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.113)</td>
<td>(0.0405)</td>
<td></td>
</tr>
<tr>
<td>BK.rsk.rst(t-1)</td>
<td></td>
<td>0.930***</td>
<td>-0.607***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.134)</td>
<td>(0.157)</td>
</tr>
<tr>
<td>FM.rsk.rst(t-1)</td>
<td></td>
<td></td>
<td>0.176</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.253)</td>
</tr>
<tr>
<td>SV.rsk.de(t-1)</td>
<td>0.622**</td>
<td>0.908***</td>
<td>0.332***</td>
</tr>
<tr>
<td></td>
<td>(0.251)</td>
<td>(0.0904)</td>
<td>(0.102)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.672***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.119)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.409**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.196)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.978***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.174)</td>
</tr>
</tbody>
</table>

The table reports results of VAR system of one standard deviation shock to the sovereign risk of Germany towards the rest of euro zone's sovereign, bank and non-financial firm sectors during the recent crisis period (i.e. 2010/QI-2012/QIV). The variables: SV.rsk.de, is German sovereign risk premia, whereas; SV.rsk.rst, BK.rsk.rst, and FM.rsk.rst are sovereign, bank and non-financial firm credit risk in the rest of euro zone. Dependent endogenous variables are in columns which show the coefficients of regressing these variables on the row variables that is their lag variables. Robust standard errors are in parentheses, whereas ***, **, and * show 1%, 5% and 10% significance level, respectively.

Figure 36: Impulse-response (IR) functions of PVAR (1) estimation for sovereign-bank-firm credit risk in the euro zone

Note: Impulse response functions estimated from focused three-variable panel vector autoregression (PVAR), controlling for country-fixed effects, with identification through Cholesky Decomposition of one-standard deviation. The highlighted area in figure shows two-standard error bands. Forecast horizons are in quarters. Whereas: SV.rsk, BK.rsk, and FM.rsk represents sovereign, bank, and firm credit risk, respectively. The sample period includes full time frame from 2007-QIV to 2012-QIV.
Is there a credit risk contagion present in the euro zone? A panel VAR analysis of CDS premia

Figure 37: Impulse-response (IR) functions of PVAR (1) estimation of sovereign-bank-firm credit risk during sub-prime period in the euro zone

Note: Impulse response functions estimated from focused three-variable panel vector autoregression (PVAR), controlling for country-fixed effects, with identification through Cholesky Decomposition of one-standard deviation. The highlighted area in figure shows two-standard error bands. Forecast horizons are in quarters. Whereas: SV.rsk, BK.rsk, and FM.rsk represents sovereign, bank, and firm credit risk, respectively. The sample period spans from 2007-QIV to 2009-QIV

Figure 38: Impulse-response (IR) functions of PVAR (1) estimation for sovereign-bank-firm credit risk during sovereign debt crisis period in the euro zone

Note: Impulse response functions estimated from focused three-variable panel vector autoregression (PVAR), controlling for country-fixed effects, with identification through Cholesky Decomposition of one-standard deviation. The highlighted area in figure shows two-standard error bands. Forecast horizons are in quarters. Whereas: SV.rsk, BK.rsk, and FM.rsk represents sovereign, bank, and firm credit risk, respectively. The sample period spans from 2010-QI to 2012-QIV