檢視歐洲主權債務國家金融蔓延

***丁千容[1]、林湘閔[2]**

[1]南臺科技大學休閒事業管理系、[2]樹德科技大學國際企業與貿易系

*cjting@stust.edu.tw

摘要

本文探討於歐洲主權債務危機時期，核心國家與邊緣國家的主權債務違約風險與不同區域共同因素之關係，並透過邊緣國家主權債務違約共同因素與此12個國家的相互關係，以檢視2009年邊緣國家的主權債務違約是否造成各國金融蔓延。本文依據Stock and Watson（1998, 2002）的主成分分析法（principle component analysis），找出影響市場變動的擴散指標（diffusion index），透過向量自我迴歸模型（VAR）以檢視歐洲國家間主權信用違約交換溢差共移與相互因果關係。實證結果顯示邊緣國家的共同因素確實對於不同國家的主權債務違約風險具顯著的預測力，且義大利、葡萄牙、希臘、西班牙的債務違約風險也可顯著地預測邊緣國家與核心國家的共同因素。此相互因果關係顯示邊緣國家債務違約造成區域國家的金融蔓延效果，且區域國家之金融不穩定也更進一步影響歐洲債務違約之源頭國家。本文有二主要貢獻。第一，本文實證結果呼應事實，歐洲債務危機由歐陸邊緣國家延燒到核心國家。本文發現希臘、葡萄牙和愛爾蘭此3國的債務違約進一步擴大邊緣國家的主權債務違約風險，符合此3國主權債務問題最嚴重的事實。我們也發現比利時、法國等核心國家受到邊緣國家債務違約之顯著影響，此實證結果符合法國銀行業被調降信用評等、比利時與法國合資的跨國銀行接受政府紓困之事實。第二，本文運用可代表國家風險之主權信用違約交換溢差（sovereign CDS spreads）資料，實證結果確實描述出不同國家的主權債務違約風險與不同區域共同因素之顯著提前、落後與相互因果關係，成功地說明了國家間風險蔓延之相互關係。目前，運用信用違約交換溢差（CDS spreads）探討蔓延效果的相關文獻中，較欠缺專注於蔓延效果傳遞管道的文獻，本文補足此類文獻之不足。

關鍵詞：主權債務違約、金融蔓延、擴散指標、向量自我迴歸模型（VAR）

Examining the Financial Contagion Effects in European Countries

***Chien-Jung Ting[1], Hsiang-Min Lin[2]**

[1]Department of Business Administration, Southern Taiwan University of Science and Technology

[2]Department of International Business & Trade, Shu-Te University

Abstract

The sovereign debt default of periphery countries depressed the economies of Eurozone and flooded to others outside the Eurozone. Through the relationship between sovereign debt default risks and the common factors of different regions, we inspected the financial contagion effects of several European countries during and in the aftermath of debt default era, especially the interactions of sovereign debt default in core countries with those in periphery countries. Based on the principal component analysis (PCA) of Stock and Watson (1998, 2002), we used the sovereign debt default swaps (CDS) spreads of European countries to construct the diffusion indexes. Our empirical results showed that the common factors in periphery countries significantly predicted the sovereign debt default risks of several countries, and the sovereign debt default risks in Italy, Portugal, Greece, and Spain also significantly predicted the common factors in periphery countries and core countries. This granger causality showed the financial contagion effects which spread from periphery countries to regional countries, and the

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Corresponding author: C.H. Chen, Department of Industrial Management and Information, Southern Taiwan University of Science and Technology, Tainan 710301, Taiwan.

financial instability of regional countries also speeded up the sovereign debt default in those originating countries in the peripheral area. We had two major contributions. First, corresponding to the facts, our empirical results showed that the sovereign debt default crisis spread from periphery countries to core countries. Our empirical results also concluded that the debt default in Greece, Portugal, and Ireland, had further expanded the sovereign debt default risks of periphery countries, which met the actual circs, of those countries facing the most serious risks of debt distress. At the same time, our empirical results concluded that the core countries, Belgium, and France, were significantly affected by the sovereign debt default in periphery countries, which also met the actual circs that the banking industry in France had credit falling and the multinational banks, the joint ventures established by Belgium and France, received the government bailout funds. Second, we used the CDS spreads data to proxy the sovereign debt default risks, which exactly showed the significant lead, lag, and causality relationship between the sovereign debt default risks and the common causes of several countries, and which successfully represented the interactions between financial crisis contagion effects of several countries. Until now, a shortage of literature applied the CDS spreads to discuss the passing through channels of contagion effects, and this paper made up for the deficiency.

Keywords: Sovereign debt default risks, Financial contagion effects, Diffusion indexes, VAR

JEL Classification Code: F30, F34, F36, F41

I. Motivation

In August 2007, the US subprime mortgage crisis erupted, and following with global financial crises and economic downturn over 20 months till September 2009. On 20 October 2009, the global economic recovery just started, however, the Greece government announced its fiscal deficit-to-GDP ratio approaching to 12%, which exceeded the upper limit of 3% set by the European union (EU). Then, the top three credit rating agencies in the world cut Greece’s credit rating to the lowest in Eurozone, and the European sovereign debt default started in Greece. Reinhart and Rogoff (2009) said that the sovereign debt default crisis always occurred after the financial crisis. The Greece sovereign debt crisis brought about the following European sovereign debt crises, banking liquidity crises and economic crises. Since the upsurge of Greece fiscal deficit in the end of 2009, the effects were being felt throughout the high-debt and low economic growth countries, such as Ireland, Portugal, Spain, and Italy, and triggered the European sovereign debt crises. In addition, the European banking system exposed risks to government debts in GIIPS (Greece, Ireland, Italy, Portugal, and Spain), and thus the depositors lost faith and withdrew money, which brought about the liquidity problems in banking systems, and hereafter the banking crises occurred. The banks were uncapable of operating loans and credit business with insufficient funds, which restricted the economic recovery and further resulted in the difficulties of repaying debts, and thus the consequences of the economic crisis. While the member countries in EU took coordinated action in accordance with the contingency plan, the banks in EU had also been asked to raise capital to fulfil the Basel III requirements. The derivative impacts of European sovereign debt crises were separately, (1) The vicious circle of sovereign debt crises, credit rating falling, and banking crises. (2) This crisis underlined the inconsistency of monetary policy and fiscal policy. The exchange rate policy and interest rate policy were unified, but the member countries had their own fiscal policy with varied inflation rate and labor market conditions in periphery countries and core countries, which induced the sovereign debt problems in periphery countries to get worse. (3) The banks in EU should follow the new rules for capital buffer in Basel III. The Basel III aimed at correcting the market failure occurred in financial crises in 2008 and extending the monitoring points from the individual financial institution to a framework for macroprudential analysis (BIS, 2011).

Stylized facts pointed out that the correlation between periphery countries and core countries in Europe differed before and in the aftermath of sovereign debt default era. Since 2000 to 2007, bond spreads in periphery countries and core countries were almost completely correlated, and the correlation between government bond spreads of Germany and Greece approached to 0.99. But the correlation between bond spreads in periphery countries decreased since 2007 to 2013, the relationship of bond spreads between periphery countries and Germany turned to be negative. The decreasing correlation showed both the banks' carry trade behaviors and the moral suasion behaviors of authorities in periphery country after the debt crisis in 2009[1] (Acharya and Steffen, 2015). Those expressed higher correlation of bond spreads between periphery countries and core countries before the debt crisis eruptions, and the correlation was lower in the aftermath of the debt crisis eruptions.

Aiming at verifying the stylized facts, we examined the financial contagion effects of several European countries during and in the aftermath of debt default era, especially the interactions of sovereign debt default in core countries with which in periphery countries. We argued that the financial contagion effects may come from some common causes. Belonged to different regions, those common factors could help us to differentiate the origins of sovereign debt defaults through the empirical results. Following the existing studies, we used the sovereign debt default swaps (CDS) spreads to proxy the sovereign debt default risks.

CDS spread is the price of CDS, an important indicator of measuring credit risks, and a substantial literature suggest that the CDS spreads reflect market information quickly. For example, the credit ratings of Greece and Italy had been downgraded because of the aggravating fiscal deficit in those European countries since January 2009, and their CDS spreads started to go upward. The CDS spreads rose from 200bps to 800bps during January 2010 to July 2010. At the same time, the 10-year government bond yield spreads between Greece and Germany increased from 2% to 10%, reflecting the remarkable predictability of the CDS spreads. The European Central Bank (ECB) had measured the sovereign credit risks via the CDS spreads, and their results in the 2008 annual report showed that the prominent effects of the CDS spreads on credit risks, representing that it's one of the best references of hedging asset credit risks.

The variation of the CDS spreads reflected the probability of debt default. As aforementioned, Greece was unable to repay their matured outstanding bonds at the beginning of 2010, which induced the Greece 5-year government bond CDS premium to rise rapidly from 309bps (3.09%) to 893bps (8.93%) during the end of March 2010 to April 2010. In December 2011, Greece again experienced the sovereign debt default, and the market expected that the Greece government's announcement was imminent, which pushing up the CDS premium to 9,962bps. Hence, if the continued presence of the debt problems, the CDS premium would increase rapidly with uprising credit risks, and vice versa.

Lots of research had used the CDS spreads to proxy the sovereign debt default risks, and they applied the CDS spreads data to get the significant results (Bampinas et al., 2020; Caporin et al., 2018; Kalbaska and Gatkowski, 2010; Sabkha et al., 2019). Following existing literature, we also used the CDS spreads to proxy the sovereign credit risk and examined the financial crisis contagion effects.

Centered on the periphery countries, the European sovereign debt default in 2009 enhanced the financial interactions between countries in Eurozone. The CDS spreads spillover changes and co-movements, so-called the contagion effects, which originated from the specific sovereign debt default. This contagion effects were impacted by both domestic information and the financial markets shocks outside this country. Since the end of 2009, the points of studies on this issue lay on which proportion of contagion effects induced from the sovereign debt

[1] Under the hypothesis of moral suasion, the authorities of periphery countries expect the local banks to implement more domestic sovereign debts absorption, which would further reduce the sovereign bond spreads. This hypothesis also implies that the home bias of domestic investment uprise over time.

defaults in periphery countries was? What's its influence on the core countries? How about those contagion effects on countries outside the Eurozone? Where's the channel those impacts passing through by? What is more, the common factor highlighted in existing literature in the past, which could not give a complete description of the sovereign debt default in 2009. Therefore, the importance of the distinguishing characteristics in the third country was pointed out in the existing studies. Broto and Perez-Quiros (2015) mentioned that since the financial aids had been requested by Greece in April 2010, the sovereign debt default spreads just increased in the European developed countries. However, it's not proper to treat Greece as the third originating country, for the financial aids had also been requested by Ireland and Portugal in November 2010 and April 2011, which also affected other countries.

Our empirical results were consistent with Broto and Perez-Quiros (2015) and the facts. Our results figured out the sovereign debt default of Greece, Ireland, and Portugal, which further reinforced the sovereign debt default risks in periphery countries. Corresponding to the facts, our empirical results showed that the sovereign debt default in periphery countries had affected the credit risks in developed countries. Besides, the sovereign debt default risks in Italy, Portugal, Greece, and Spain also significantly predicted the common factors in periphery countries and core countries, and this granger causality showed up the financial contagion effects in regional countries from the periphery countries, and the financial instability of regional countries also speeded up the sovereign debt default in those source countries in periphery area.

The sovereign debt default of periphery countries depressed the economies of Eurozone and flooded to others outside the Eurozone. We want to examine the existence of contagion effects between European core countries and periphery countries. Mainly focusing on figuring out where do the changes in sovereign debt default spreads come from, we try to answer the questions as follows. Could the originating countries be the periphery countries or other highly financially-linked countries? Further, we want to discover which common factor do the specific sovereign debt default risk originate from?

According to the principal component analysis (PCA) of Stock and Watson (1998), we constructed those diffusion indexes and applied the VAR model to examine the co-movements of common factors in 5 regions, separately middle-income countries, high-income countries, periphery countries, core countries and overall sample countries. There are two major contributions in this paper. First, our empirical results corresponded to the facts, which expressed the European sovereign debt default crisis from periphery countries to core countries. That is, our empirical results pointed out that the sovereign debt default in Greece, Ireland, and Portugal, further amplifying the default risks in periphery countries, also met the actual circs, those countries facing most serious risks of debt distress. Moreover, our empirical results concluded that the core countries, such as Belgium and France, had significantly been affected by the sovereign debt default in periphery countries, corresponding to the facts, the banks in France had credit rating falling and the multinational banks, the joint ventures established by Belgium and France, received the government bailout funds. Second, we used the CDS spreads data to proxy the sovereign debt default risks, which exactly described the lead, lag, and granger causality between the sovereign debt default risks and the common causes in several regions, and successfully represented the interactions of financial crisis contagion effects between several countries.

By now, much literature applied the CDS spreads to discuss the contagion effects with divergency of conclusions, but a shortage of literature focused on the passing through channels of contagion effects. This paper made up for the deficiency, and we stressed on the financial contagion effects transmission between countries in the European debt default era.

II. Literature review

How to tell those definitions of financial markets co-movement, contagion effects, and inter-dependence apart? Ayuso and Blanco (2001) described straight that higher integration and larger stock price co-movements between markets induced the higher correlation in those markets. Further, through the correlation coefficients between two markets in different periods, the transitions of integration level in markets could be judged. However, the size of correlation coefficient was not a necessary and sufficient condition of market integration, for their heterogeneous bias. Forbes and Rigobon (2002) modified the correlation coefficients according to the market volatility movements, which was applied to confirm the performance of stock markets before and in the aftermath of three shocks, separately the US stock market depressions in 1987, the tequila crisis of Mexico in 1994, and the Asia financial crisis in 1997. They concluded that no apparent difference occurs between stock markets in several main economies after three shocks, for the close linkage between economies in various respect aspects. Caporale et al. (2005) extended the method in Forbes and Rigobon (2002), further identifying and adjusting sample limitations, and they inspected whether the interactions between global asset returns are positive or not to confirm the contagion effects.

The co-movement of CDS spreads between countries had been emphasized in studies, especially its interactions with global common factors and financial markets (Kamin and von Kleist, 1999; Eichengreen and Mody, 2000; Mauro et al., 2002; Pan and Singleton, 2008; Longstaff et al., 2011; Ang and Longstaff, 2013). Since the sovereign debt defaults in 2009 and financial deepening, the CDS spreads were generally treated as the proxy of sovereign debt default risks in the empirical analyses. The literature focusing on CDS spreads in Eurozone recently had increased lately (Broto and Perez-Quiros ,2015; Fontana and Scheicher, 2010; Arce et al., 2013; Carboni, 2011; Palladini and Portes, 2011; Alberola et al., 2012). Those literature focusing on CDS spreads concluded, (1) The strong commonality between those CDS spreads, which represented the high correlation between those common factors. (2) The sovereign credit risks were seemingly dominated by the global common factors, but not the fundamentals of a specific country. Furthermore, the changes in common factors of CDS spreads were closely related to the global risk aversion. Longstaff et al. (2011) and Pan and Singleton (2008) indicated that the main sources of cross-border CDS spreads variance were related to the returns and volatility of US stock markets.

Applying the CDS spreads, lots of crisis-warning related papers had inconsistent consequences. For detecting the Granger-causality test of European bank credit defaults and sovereign debt defaults, Alter and Schuler (2012) used sovereign debt default risks data and local bank risks data in European countries during 2007 to 2010. They concluded that the country was flooded with risks from banks in the early sovereign debt default era, and the shocks of financial department played a role in the aftermath of sovereign debt default. Applying the event study method, Dooley and Hutchison (2009) observed the impacts of 5-year CDS spreads on sovereign debt default and discussed the US subprime mortgage crisis passing through to emerging markets. They deduced that the US financial events intensively transmitted to emerging markets during the entire subprime mortgage period. Eichengreen et al. (2012) observed the influence of US subprime mortgage in 2008 on global banking system and figured out the common factors of bank credit default exchange spreading through the PCA. Longstaff (2010) verified the subprime asset backed CDOs to explore how the contagion effects of US subprime mortgage crisis in 2008 flooded into other financial markets. They got the strong evidence of financial contagion effects mainly through the liquidity and risk premium channel, but not the related information channel. Sabkha et al. (2019) used the CDS spreads in 35 worldwide countries to examine the contagion effects during recent crises over a period ranging from 2006 until 2014. Their analysis of each county solely represented the contagion effects were obviously during the Eurozone crisis, comparing with other crises. Caporin et al. (2018) suggested that the negative shock of contagion emerges in times of crisis affected countries with higher debt, that is, GIIPS.

Bampinas et al. (2020) examined the nonlinear nature of the cross-market linkages of EMU sovereign bond and CDS markets during 2006-2018, and they highlighted the importance of credit risk over liquidity risks.

III. Empirical model

Following Stock and Watson (1998), we adopt the PCA to construct the diffusion indexes impacting markets. The prominent advantages of diffusion indexes are extracting useful information from plenty of market data. Through the PCA, we could get the orthogonal diffusion indexes without interruptions of linear relation between variables, and the diffusion indexes could be applied to execute approximating data in concluding the main factors. Applying those diffusion indexes to constitute a simple linear model, we verify the co-movement and integration between specific CDS spreads with common factors[2]. The main questions are separately, examining the contagion effect and causality of specific country in the aftermath of European crisis, whether the specific country affected by the common factors in periphery countries or other regions? The empirical steps are as follows.

1. Step 1 Index construct reduction-construct the diffusion indexes

Diffusion indexes come from the PCA in statistical application, which are several arrays having strongest correlation in variables, and the estimated arrays from X are called diffusion indexes or market common factors. The method is described as follows, and X is assumed to be a $T \times N$ matrix with time series data, N variables and T sample points. F is assumed to be another $T \times k$ matrix, which represents the estimated k diffusion indices from X. Let the relationship between X and F to be,

$$X = F\beta + \varepsilon \tag{1}$$

β is called the factor loading matrix, which is a $k \times N$ coefficient matrix, resulting from regressing F on X. ε is a vector of residuals, whose distribution has white noise. In other words, the distribution of ε in each period satisfies with $E(\varepsilon) = 0$ and $V[vec(\varepsilon)] = \Omega$, and the diagonal elements of Ω are positive, which also a positive and definite matrix. ε is independent and identically distributed (i.i.d) in different period.

Equation (1) describes the linear correlation between X and F, and its error terms satisfy the basic statistical assumptions, which could be the basis of forecasting the single series through diffusion indexes. All the column vectors in X should be I (0) series without unit root, for a certainty of the asymmetric distribution in estimation. F and β in Equation (1) should be both estimated variables, however they couldn't be identified in the same way. Hence, the two-step approach is adopted. In other words, F is estimated in the first step, then we get the best parameter estimator $\hat{\beta}$ through regressions, which is the second step. As mentioned above, in the estimation of first step, F could be treated as a set of series, k diffusion indexes, which has the strongest correlation in common with X column vectors. That's to say, the vector which satisfies this condition, is the solution of minimizing objective functions,

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[2] The prominent advantage of the PCA lies on its techniques for reducing the dimensionality of a dataset, so-called "dimension reduction." When people try to analyze large datasets containing a high number of dimensions per observation, it's suggested to use the PCA to prevent from the curse of dimensionality, to preserve the maximum amount of information, and to keep the characteristics of data being indifferent, even more efficient.

PCA could extract the important components from variables and construct the diffusion indices. Those diffusion indices are several arrays having strongest correlation in variables, and the estimated arrays from those enormous variables are called diffusion indexes or market common factors. In this paper, we use the PCA to extract those diffusion indices to cover the common information of several countries. Comparing with the existing literature, which had applied the correlation coefficients between two variables (or two countries) to discuss the contagion effects between two variables (or two countries), we use the PCA to cover more abundant information from more variables (or countries), not limited to only two variables (or two countries).

Lately, lots of studies had applied the PCA in examining the financial contagion issues and had concluded better statistical results than before. For it's good at analyzing large datasets and having better performance, the remarkable feature and advantage of the PCA, that's why we adopted the PCA to extract the common factors of enormous variables to examine the financial contagion effects in this paper.

$$\min_F \sum_{i=1}^{N}(X_i - F\beta_i)'(X_i - F\beta_i) \tag{2}$$

X_i and β_i are separately the i element of X column vectors and β vector. To find the solutions of F and β, F in equation (1) is temporarily assumed to be known, and the least sum of square estimator β is $\hat{\beta}_i = (F'F)^{-1}(F'X_i)$. $\hat{\beta}_i$ is to substitute the β_i in equation (2), then the objective function could turn to be $\min_F \sum_{i=1}^{N} X'[I - F(F'F)^{-1}F']X_i$. Or go further to show in matrix form,

$$\min_F \{trace[X'X - X'F(F'F)^{-1}F'X]\} \tag{3}$$

Trace (・) represents the function of diagonal element summation in square matrix. Because the $X'X$ comes from the sample series not the estimating parameter, the solution of minimizing equation (3) actually is equal to which in maximizing equation (4),

$$\max_F \{\mathrm{trace}[X'F(F'F)^{-1}F'X]\} \tag{4}$$

Stock and Watson (1998) adopted the proof of Connor and Korajczyk (1986, 1993), demonstrating the eigenvector, the largest k eigenvalues in $X'X$ corresponding to, which was the solutions of F in equation (4). The estimated matrix $\hat{F}$, composed of k eigenvectors in $T \times 1$, which was called the estimating diffusion indexes. Put $\hat{F}$ into equation (1), it was concluded that the least square estimator of element loading matrix β would be as follows,

$$\hat{\beta}_{OLS} = (F'F)^{-1}(F'X) \tag{5}$$

In this paper, the steps of constructing the diffusion indexes of CDS spreads in 48 countries are as follows.

(1) First, to execute the unit root test for each time series, we identify each variable to be satisfied with the transform pattern without unit root. If the original series should be differenced to be I (0), the natural log difference will be adopted, and the matrix X is composed[3]. The largest k eigenvalues of $X'X$ will be got through program calculating, and also the corresponding eigenvector, which is the estimating diffusion indexes.

(2) Second, to analyze the relationship between CDS spreads and diffusion indexes, we separate those CDS spreads into different categories. The purpose lies in detecting the co-movement of the specific country's CDS spreads through those diffusion indexes.

We construct the diffusion indexes based on Stock and Watson (1998, 2002). According to 5 regions, the data are separated into 5 categories, and there're specific 3 diffusion indexes in each region. We construct the specific 3 diffusion indexes of 5 regions in global 48 countries.

At first, we figure out the common factors in total CDS spreads of all sample countries. To clearly capture the influence of common factors in different regions, we further classify countries into another 4 regions, and estimate the common factors in those 4 regions.[4] Then, our demonstration stresses on the correlation between those diffusion indexes with the CDS spreads of 12 countries in Eurozone.

2. Step 2 The Vector Autoregression model (VAR) model for diffusion indexes

The estimated diffusion indexes represent the k series which has the strongest correlation with original series in X, and the individual diffusion indexes of 5 separate regions are estimated for analysis. Although the diffusion

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[3] In this paper, the natural log is adopted for all CDS spreads. And all variables are I (0) without unit root.

[4] There are 3 diffusion indexes in "all sample countries," which are separately represented as DF1, DF2 and DF3. Accordingly, there're also specific 3 diffusion indexes in "middle income countries,"" high income countries,"" periphery countries," and "core countries." For simplification, the specific 3 diffusion indexes of each region all represented as DF1, DF2 and DF3.

indexes estimation is only the statistical analysis method without any theoretical background of economics, we still could discuss the association between the diffusion indexes with CDS spreads through variation and quantitative analysis of the diffusion indexes.

We use those diffusion indexes to construct the VAR model, which predicts the object variable y in future periods. X_{it} is the observation of the ith variable in t period, N is the total number of variables. γ is the estimated parameter from maximizing the variation of DF, and it satisfies with $\sum_{i=1}^{N}\gamma^2 = 1$ under the restrictions of all normalized variables. $DF_t = \gamma_1 x_{1t} + \gamma_2 x_{2t} + \ldots + \gamma_N x_{Nt}$ is the first component of DF_t.

In this step, we estimate the relationship between diffusion indexes and objective variables through the VAR model. Let the VAR (p) model in the AR (1) form represented as follows,

$$Z_t = AZ_{t-1} + \varepsilon_t \tag{6}$$

Let $\begin{pmatrix} x_t \\ y_t \end{pmatrix} \in R^2$, and $(x_t \quad y_t)'$ is assumed to be VAR (p) model. Hence, $E_t(Z_{t+j}) = A^j Z_t$ and

$E_t(y_{t+j}) = [010 \ldots\ldots 0]A^j Z_t = e_2{}' A^j Z_t$, especially, $e_2 = \underbrace{\begin{bmatrix} 0 \\ 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix}}_{2p\times 1}$,

In addition, $x_t = [010 \ldots \ldots 0]Z_t = e_2{}' Z_t$. In combination of all, we could get

$$e_2{}' Z_t = x_t = \sum_{j=1}^{\infty} \beta^j E_t(y_{t+j}) = \sum_{j=1}^{\infty} \beta^j e_2{}' A^j Z_t \tag{7}$$

, then $e_2' Z_t = e_2'\left(\sum_{j=1}^{\infty} \beta^j A^j\right) Z_t$. And $e_1' = e_2' \beta A (I - \beta A)^{-1}$, which means $e_1'(I - \beta A) = e_2' \beta A$. We do the test of coefficient matrix A in VAR(P) model through the Wald test,

$$\begin{aligned} x_t &= \Phi_{11} x_{t-1} + \Phi_{12} y_{t-1} + \varepsilon_{xt} \\ y_t &= \Phi_{21} x_{t-1} + \Phi_{22} y_{t-1} + \varepsilon_{yt} \end{aligned} \tag{8}$$

then

$$\underbrace{\begin{bmatrix} x_t \\ y_t \end{bmatrix}}_{Z_t} = \underbrace{\begin{bmatrix} \Phi_{11} & \Phi_{12} \\ \Phi_{21} & \Phi_{22} \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix}}_{Z_{t-1}} + \underbrace{\begin{bmatrix} \varepsilon_{xt} \\ \varepsilon_{yt} \end{bmatrix}}_{\varepsilon_t}$$

Hence,

$$\underbrace{e_1'(I - \beta A)}_{1\times 2} = [1 \quad 0](I - \beta A) = [1 - \beta\Phi_{11} \quad -\beta\Phi_{12}]$$

$$\underbrace{e_2' \beta A}_{1\times 2} = [0 \quad 1]\beta A = [\beta\Phi_{21} \quad \beta\Phi_{22}]$$

then the null hypothesis is

$$\begin{cases} 1 - \beta\Phi_{11} = \beta\Phi_{21} \\ -\beta\Phi_{12} = \beta\Phi_{22} \end{cases} \quad \text{or} \quad \begin{cases} \Phi_{11} + \Phi_{21} = \frac{1}{\beta} \\ \Phi_{12} + \Phi_{22} = 0 \end{cases}$$

if we don’t accept this null hypothesis, that’s the model not be accepted.

We want to understand the interrelationship between CDS spreads in Eurozone and specific diffusion indexes of 5 specific regions, and through the VAR model to examine the lead, lag and feedback responses of those diffusion indexes. We also proceed the Granger causality test[5]. In this paper, the model is as follows[6,7],

$$\text{Model1: } y_t = \alpha_1 + \beta_1 y_{t-1} + \beta_2 DF1_{t-1} + \beta_3 DF2_{t-1} + \beta_4 DF3_{t-1} \quad (9)$$
$$\text{Model2: } DF1_t = \alpha_2 + \beta_5 y_{t-1} + \beta_6 DF1_{t-1} + \beta_7 DF2_{t-1} + \beta_8 DF3_{t-1}$$
$$\text{Model3: } DF2_t = \alpha_3 + \beta_9 y_{t-1} + \beta_{10} DF1_{t-1} + \beta_{11} DF2_{t-1} + \beta_{12} DF3_{t-1}$$
$$\text{Model4: } DF3_t = \alpha_4 + \beta_{13} y_{t-1} + \beta_{14} DF1_{t-1} + \beta_{15} DF2_{t-1} + \beta_{16} DF3_{t-1}$$

y_t is the specific CDS spreads of each country, and $DF1_t$,$DF2_t$,$DF3_t$ are the specific 3 diffusion indexes of each region.

IV. Data and Empirical results

1.Data

In this paper, we adopted the monthly data of CDS spreads in 48 countries of different regions to construct those diffusion indexes. According to 5 regions as follows, separately middle-income countries, high-income countries, periphery countries, core countries and all sample countries, shown in Table 1 to 2, we separated our sample data into 5 categories[8,9]. The data spanned from January 2008 to December 2016[10]. We adopted the 3-year CDS spreads[11], which was the difference of 3-year sovereign credit default swaps (CDS) in each country and the

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5 We also do the Granger causality tests for robust check. Those results are corresponding to the conclusions of the Vector Autoregression model (VAR). In this paper, we abbreviate the results of Granger causality test for space limitation.

6 We use the AIC and SBC criterions to evaluate the model fitness, and the VAR (1) model is chosen. That's the lag term is 1 period, and $P = 1$ in VAR (p) model.

7 The model can also be represented as a matrix form. That's $\begin{bmatrix} y_t \\ DF1_t \\ DF2_t \\ DF3_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} + \begin{bmatrix} \beta_1 & \beta_2 & \beta_3 & \beta_4 \\ \beta_5 & \beta_6 & \beta_7 & \beta_8 \\ \beta_9 & \beta_{10} & \beta_{11} & \beta_{12} \\ \beta_{13} & \beta_{14} & \beta_{15} & \beta_{16} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ DF1_{t-1} \\ DF2_{t-1} \\ DF3_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{DF1_t} \\ \varepsilon_{DF2_t} \\ \varepsilon_{DF3_t} \end{bmatrix}$.

8 We classify the sample countries into middle-income countries and high-income countries based on the classification of World Bank, which using "income levels" to classify the whole countries in the world. Following with the definitions from World Bank,

> *"low-income economies are defined as those with a GNI per capita, calculated using the World Bank Atlas method, of $1,085 or less in 2021; lower middle-income economies are those with a GNI per capita between $1,086 and $4,255; upper middle-income economies are those with a GNI per capita between $4,256 and $13,205; high-income economies are those with a GNI per capita of $13,205 or more." (Sourced: The World Bank, 2022)*

Owing to the data limitation, our sample countries don't cover low-income countries, and for simplicity, we combine both "lower-middle income countries" and "upper middle-income countries" into "middle-income countries." We aimed at inspecting the financial contagion effects between core countries and periphery countries with many other regions. And the definitions of World Bank are adopted to classify those sample countries into several regions.

9 Our research focused on examining the financial contagion effects between the Eurozone countries with many other regions. We paid attention to the Eurozone countries because those countries all used the common currency, euro. Existing studies had concluded that the underlying causes of sovereign debt default in GIIPS were their fragile economies, however, those countries were incorporated into the Eurozone. Since the sovereign debt default erupted, following with the aggravation of financial crises, and the leading cause of financial crises was using the common currency in those countries, without individual monetary policy to insulate negative impacts from other countries, inducing the financial contagion spread rapidly.

In this paper, we further separate those countries into core countries, periphery countries and many other regions. That's why we ignore UK and Swiss, which do not belong to the Eurozone. In addition, due to the data shortage, all the CDS data in this paper come from the Thomson Reuters Datastream database, however, this database covers the CDS data about 60 countries without Swiss. In the future, we have some extensions of this research, and the advisor's suggestions deserve serious consideration.

10 Constrained by the data limitation, we adopted the sample data spanned from January 2008 to December 2016. In most of sample countries, the initial CDS spreads data started from January 2008. Considering the early sovereign debt default era and the impacts of global financial crises in 2008, our sample data started from January 2008, and following the existing literature, we also paid attention to the subsequent years, the closely related 5 years after the sovereign debt default.

11 In our paper, we use the 3-year CDS spreads to proxy the sovereign debt default risks. For robust check, we also try both the 5-year CDS spreads and 10-year CDS spreads, but get almost the approximate results with the 3-year CDS spreads. Because of the space limitation, only the result of 3-year credit default spreads is shown in the context. All CDS spreads are taken log for the empirical tests' implementation.

base sovereign CDS. US was treated as the base country, and the US sovereign CDS was treated as the base sovereign CDS.

2. Empirical results

In this paper, we applied the PCA of Stock and Watson (1998, 2002) to construct the common factors. For observing how the sovereign debt default in periphery countries affect the worldwide CDS spreads, we constructed the specific 3 diffusion indexes of 5 regions. Focusing on the 12 countries in Eurozone, we aimed at exploring the interrelationship between the specific diffusion indexes of 5 regions and CDS spreads in 12 countries in Eurozone. We separated 48 countries into 5 categories, which were separately middle-income countries, high-income countries, periphery countries, core countries and all sample countries. Then, we constructed the 3 specific diffusion indexes in each region. For detecting the reciprocal reactions, we took both those 3 specific diffusion indexes of 5 different regions and CDS spreads of 12 countries in Eurozone to execute the VAR model test.

(1)Results of the periphery countries

The outcomes of VAR model test in periphery countries were shown on Table 3. In Part1 of Table 3, we saw that the Greece sovereign debt default risks could be predicted by lag DF1 and lag DF2 of "middle-income countries, periphery countries, and core countries." Also, the diffusion indexes of "middle-income countries, periphery countries, and core countries" could be predicted by the lag Greece sovereign debt default risks, which had its own feedback effects. In Part2 of Table 3, we saw that the Ireland sovereign debt default risks could be predicted by lag DF1 of "middle-income countries, periphery countries, and core countries." However, there's no feedback effect of the Ireland sovereign debt default risks. In Part3 of Table 3, we saw that the Italy sovereign debt default risks couldn't be predicted by any lag diffusion indexes. But the lag Italy sovereign debt default risks could predict the diffusion indexes of "middle-income countries, high-income countries, periphery countries, core countries, and all countries." The Italy sovereign debt default risks had its own feedback effects. In Part4 of Table 3, we saw that the Portugal sovereign debt default risks could be predicted by the lag DF3 of "middle-income countries, periphery countries, and core countries." The lag Portugal sovereign debt default risks also could predict the diffusion indexes of "high-income countries, and all countries." The Portugal sovereign debt default risks had its own feedback effects. In Part5 of Table 3, we saw that the Spain sovereign debt default risks could be predicted by the lag DF3 of "middle-income countries, periphery countries, and core countries."

Table 1

Countries

Group	Number	Countries
Middle-income countries	21	Argentina, Brazil, Bulgaria, China, Colombia, Indonesia, Kazakhstan, Lebanon, Lithuania, Malaysia, Morocco, Panama, Peru, Philippines, Romania, Russia, South Africa, Thailand, Tunisia, Ukraine, Vietnam
High-income countries	15	Australia, Chile, Czech, Denmark, Hungary, Iceland, Israel, Japan, Korea, Norway, Poland, Sweden, Turkey, Croatia, Qatar
Peripherals countries	5	Greece, Ireland, Italy, Portugal, Spain
Core countries	7	Austria, Belgium, France, Germany, Netherlands, Slovak, Slovenia
Total	48	Total sample countries

Source: The authors.

Table 2

Variables and data source

	Variables	Definitions	Periods	Source
Object variables	Sovereign credit default swaps (CDS)	3-year dollar denominated CDS	2008M1-2016M12	Thomson Reuters Datastream
	Sovereign credit default swaps (CDS)（Based country-United States）	3-year benchmark CDS (United States)	2008M1-2016M12	Thomson Reuters Datastream

Source: The authors.

The lag Spain sovereign debt default risks also could predict the diffusion indexes of "middle-income countries, high-income countries, periphery countries, core countries, and all countries." The Spain sovereign debt default risks had its own feedback effects.

In summary, the sovereign debt default risks in Greece, Ireland, Portugal, and Spain could be predicted by the common factors of periphery countries. And the sovereign debt default risks in Greece, Italy, and Spain could predict the common factors of periphery countries. From the results in Table 3, we could conclude that the existence of contagion effects between periphery countries with their highly financially-linkage countries.

Based on the history, several financial institutions were eager to deleverage in global financial crises in 2008, and the easy fiscal policy and money policy aiming at stimulating economic recovery, which were pursued by several countries in Eurozone, had pulled the trigger for the breakdown of sovereign debt default. The main causes of sovereign debt default in PIIGS were as follows,

a. Greece: long-term fiscal deficit and external deficit

In October 2009, the sovereign debt default erupted in Greece, which was the first country seeking the project financing plans aids from other countries and IMF. The Greece sovereign debt default crisis originated from the global financial crisis and huge fiscal deficit. The Greece government highly relied on raising funds from international capital market to pay off external deficit, while the investors didn't trust the Greece government anymore, they would stop lending money to the Greece government. Finally, the Greece government suffered the dilemma of paying off old debts without refunding.

b. Ireland: banking crisis led to sovereign debt default crisis

The burst of real estate bubble triggered the banking crisis, and the government provided a relief package to help those banks, reversing the fiscal surpluses to deficit. From 1990 to 2007, the average economic growth rate reached up to 6.5% in Ireland, but the banking industry overinvested the real estate with huge bad debts inducing market credit illiquidity. Since the global financial crisis erupted, the Ireland government finance had deteriorated sharply in 2008 and 2009, and the Ireland government tried to take over the banking industry in September 2010 but aggravated the nation's fiscal deficit.

c. Portugal: A surge of fiscal deficit

Adopting the euro induced Portugal's economy booming, but also raised up the crisis contagion effects in Portugal's banking system from other member countries in Eurozone. In 2009, the fiscal deficit in Portugal surged from 3.6% to 10.1%, and the sovereign credit rating falling in March 2011, which sent 10-year bond yield soaring to 8%. However, compared with Greece and Ireland, Portugal had lower sovereign debt and more stable banking system.

Table 3

VAR results (periphery countries)

Dependent variables		Part1: Greece					Part2: Ireland					Part3: Italy				
Model	Countries Coefficients	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries
1	$\widehat{\alpha_1}$	0.72†	0.72†	0.61**	0.72†	0.61**	0.24	0.24	0.11	0.24	0.20	0.58**	0.58**	0.50*	0.58**	0.50*
		(0.23)	(0.23)	(0.26)	(0.23)	(0.26)	(0.24)	(0.24)	(0.25)	(0.24)	(0.25)	(0.24)	(0.24)	(0.26)	(0.24)	(0.26)
	$\widehat{\beta_1}$	0.97†	0.97†	0.97†	0.97†	0.97†	0.97***	0.97†	0.98†	0.97†	0.97†	0.90†	0.90†	0.91†	0.90†	0.91†
		(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
	$\widehat{\beta_2}$	0.68**	0.68**	-0.32	0.68**	-0.32	0.81**	0.81**	-0.29	0.81**	-0.25	0.63	0.63*	-0.34	0.63*	-0.34
		(0.33)	(0.33)	(0.36)	(0.33)	(0.36)	(0.37)	(0.37)	(0.39)	(0.37)	(0.39)	(0.35)	(0.35)	(0.37)	(0.35)	(0.37)
	$\widehat{\beta_3}$	0.61*	0.61*	-0.12	0.61*	-0.12	0.35	0.35	-0.06	0.35	0.26	0.14	0.14	0.06	0.14	0.06
		(0.32)	(0.32)	(0.33)	(0.32)	(0.33)	(0.36)	(0.36)	(0.37)	(0.36)	(0.38)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)
	$\widehat{\beta_4}$	0.42	0.42	-0.48	0.42	-0.48	0.31	0.31	-0.33	0.31	0.74	0.31	0.31	0.13	0.31	0.13
		(0.32)	(0.32)	(0.33)	(0.32)	(0.33)	(0.37)	(0.37)	(0.38)	(0.37)	(0.38)	(0.34)	(0.34)	(0.35)	(0.34)	(0.35)
2	$\widehat{\alpha_2}$	-0.14**	-0.14**	-0.19**	-0.14**	-0.19**	0.01	0.01	-0.06	0.01	-0.05	-0.07	-0.07	-0.19†	-0.07	-0.19†
		(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
	$\widehat{\beta_5}$	0.01**	0.01**	0.01	0.01**	0.01	-0.005	-0.005	0.004	-0.005	0.003	0.01	0.01	0.03†	0.01	0.03†
		(0.005)	(0.005)	(0.01)	(0.005)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_6}$	0.20*	0.20*	0.21*	0.20*	0.21*	0.25**	0.25**	0.28†	0.25**	0.28†	0.23**	0.23**	0.23**	0.23**	0.23**
		(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.10)	(0.11)	(0.10)
	$\widehat{\beta_7}$	0.001	0.004	-0.02	0.004	-0.02	-0.02	-0.02	-0.04	-0.02	-0.04	0.001	0.001	-0.04	0.001	-0.04
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.10)	(0.09)
	$\widehat{\beta_8}$	-0.01	-0.01	-0.10	-0.01	-0.10	-0.001	-0.001	-0.09	-0.001	0.01	-0.01	-0.01	-0.10	-0.01	-0.10
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
3	$\widehat{\alpha_3}$	-0.01	-0.01	0.02	-0.01	0.02	0.03	0.03	-0.08	0.03	0.002	0.08	0.08	-0.02	0.08	-0.02
		(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.07)	(0.08)
	$\widehat{\beta_9}$	-0.001	-0.001	-0.004	-0.001	-0.004	-0.01	-0.01	0.01	-0.01	-0.01	-0.02**	-0.02**	-0.002	-0.02**	-0.002
		(0.005)	(0.005)	(0.01)	(0.005)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{10}}$	-0.08	-0.08	0.05	-0.08	0.05	-0.08	-0.08	0.02	-0.08	-0.04	-0.04	-0.04	0.03	-0.04	0.03
		(0.11)	(0.11)	(0.12)	(0.11)	(0.12)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
	$\widehat{\beta_{11}}$	0.09	0.09	0.002	0.09	0.002	0.08	0.08	-0.0002	0.08	0.08	0.05	0.05	0.01	0.05	0.01
		(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
	$\widehat{\beta_{12}}$	-0.03	-0.03	-0.13	-0.03	-0.13	-0.02	-0.02	-0.13	-0.02	-0.15	-0.02	-0.02	-0.13	-0.02	-0.13
		(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
4	$\widehat{\alpha_4}$	-0.02	-0.02	0.0004	-0.02	0.0004	-0.10	-0.10	0.02	-0.10	-0.18**	-0.03	-0.03	0.03	-0.03	0.03
		(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.07)	(0.08)
	$\widehat{\beta_{13}}$	-0.001	-0.001	0.0001	-0.001	0.0001	0.01	0.01	-0.002	0.01	0.01	-0.002	-0.002	-0.005	-0.002	-0.005
		(0.010)	(0.005)	(0.01)	(0.005)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{14}}$	0.14	0.14	0.06	0.14	0.06	0.13	0.13	0.07	0.13	-0.20**	0.13	0.13	0.07	0.13	0.07
		(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
	$\widehat{\beta_{15}}$	0.01	0.01	0.02	0.01	0.02	0.0	0.03	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.02
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	3(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_{16}}$	-0.17	-0.17	-0.15	-0.17	-0.15	-0.18	-0.18	-0.15	-0.18	-0.20**	-0.17	-0.17	-0.15	-0.17	-0.15
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	det(SSE)	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0005	0.0004	0.0004	0.0003	0.0003	0.0004	0.0003	0.0004
	AIC	-7.67	-7.67	-7.65	-7.67	-7.65	-7.43	-7.43	-7.32	-7.43	-7.48	-7.64	-7.64	-7.55	-7.64	-7.55
	BIC	-7.25	-7.25	-7.21	-7.25	-7.21	-7.01	-7.01	-6.89	-7.01	-7.05	-7.22	-7.22	-7.11	-7.22	-7.11
	HQ	-7.50	-7.50	-7.47	-7.50	-7.47	-7.26	-7.26	-7.15	-7.26	-7.31	-7.47	-7.47	-7.37	-7.47	-7.37

Source: The authors. Robust t statistics in brackets. * significant at 10%; ** significant at 5%; † significant at 1%. We adopt the VAR(1) model as equation (9).

Table 3 (continue)

Dependent variables		Part4: Portugal					Part5: Spain				
Model	Countries Coefficients	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries
1	$\widehat{\alpha_1}$	**0.59***	**0.59***	**0.71****	**0.59***	**0.71****	**0.53†**	**0.53****	0.31	**0.53****	0.31
		(0.30)	(0.30)	(0.33)	(0.30)	(0.33)	(0.26)	(0.26)	(0.25)	(0.26)	(0.25)
	$\widehat{\beta_1}$	**0.94†**	**0.94†**	**0.92†**	**0.94†**	**0.92†**	**0.92†**	**0.92†**	**0.93†**	**0.92†**	**0.93†**
		(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
	$\widehat{\beta_2}$	0.20	0.20	0.03	0.20	0.03	0.51	0.51	-0.57	0.51	-0.57
		(0.45)	(0.45)	(0.47)	(0.45)	(0.47)	(0.39)	(0.39)	(0.41)	(0.39)	(0.41)
	$\widehat{\beta_3}$	-0.12	-0.12	0.16	-0.12	0.16	0.23	0.23	-0.04	0.23	-0.04
		(0.42)	(0.42)	(0.43)	(0.42)	(0.43)	(0.38)	(0.38)	(0.38)	(0.38)	(0.38)
	$\widehat{\beta_4}$	**0.91****	**0.91****	0.07	**0.91****	0.07	**0.75***	**0.75***	-0.33	**0.75***	-0.33
		(0.42)	(0.42)	(0.43)	(0.42)	(0.43)	(0.38)	(0.38)	(0.38)	(0.38)	(0.38)
2	$\widehat{\alpha_2}$	**-0.14****	**-0.14****	**-0.18****	**-0.14****	**-0.18****	-0.07	-0.07	**-0.13****	-0.07	**-0.13****
		(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.07)	(0.06)
	$\widehat{\beta_5}$	0.01	0.01	**0.02****	0.01	**0.02****	0.01	0.01	**0.02****	0.01	**0.02****
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_6}$	0.19*	**0.19***	**0.21***	**0.19***	**0.21***	**0.23****	**0.23****	**0.24****	**0.23****	**0.24****
		(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.11)	(0.10)
	$\widehat{\beta_7}$	0.01	0.01	-0.03	0.01	-0.03	0.004	0.004	-0.05	0.004	-0.05
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_8}$	-0.02	-0.02	-0.09	-0.02	-0.09	-0.01	-0.01	-0.09	-0.01	-0.09
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
3	$\widehat{\alpha_3}$	0.03	0.03	-0.03	0.03	-0.03	**0.13***	**0.13***	-0.04	**0.13***	-0.04
		(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
	$\widehat{\beta_9}$	-0.01	-0.01	0.0002	-0.01	0.0002	**-0.03†**	**-0.03†**	0.001	**-0.03†**	0.001
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{10}}$	-0.05	-0.05	0.03	-0.05	0.03	-0.02	-0.02	0.03	-0.02	0.03
		(0.11)	(0.11)	(0.12)	(0.11)	(0.12)	(0.11)	(0.11)	(0.12)	(0.11)	(0.12)
	$\widehat{\beta_{11}}$	0.08	0.08	0.01	0.08	0.01	0.02	0.02	0.01	0.02	0.01
		(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
	$\widehat{\beta_{12}}$	-0.02	-0.02	-0.13	-0.02	-0.13	0.01	0.01	-0.13	0.01	-0.13
		(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
4	$\widehat{\alpha_4}$	-0.03	-0.03	0.03	-0.03	0.03	-0.10	-0.10	0.03	-0.10	0.03
		(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
	$\widehat{\beta_{13}}$	0.0001	0.0001	-0.003	0.0001	-0.003	0.01	0.01	-0.01	0.01	-0.01
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{14}}$	0.13	0.13	0.08	0.13	0.08	0.10	0.10	0.08	0.10	0.08
		(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
	$\widehat{\beta_{15}}$	0.02	0.02	0.02	0.02	0.02	0.05	0.05	0.02	0.05	0.02
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_{16}}$	-0.17	-0.17	-0.15	-0.17	-0.15	-0.19	-0.19	-0.15	-0.19	-0.15
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	det(SSE)	0.001	0.001	0.001	0.001	0.001	0.0004	0.0004	0.001	0.0004	0.001
	AIC	-7.20	-7.20	-7.11	-7.20	-7.11	-7.53	-7.53	-7.35	-7.53	-7.35
	BIC	-6.78	-6.78	-6.68	-6.78	-6.68	-7.11	-7.11	-6.92	-7.11	-6.92
	HQ	-7.03	-7.03	-6.94	-7.03	-6.94	-7.35	-7.36	-7.18	-7.36	-7.18

Source: The authors. Robust t statistics in brackets. * significant at 10%; ** significant at 5%; † significant at 1%. We adopt the VAR(1) model as equation (9).

d. Spain: housing bubble burst and economic depression

The lively housing market induced Spain to boost economic development for 15 years, but huge private loans drove a housing bubble, and the housing bubble burst in the aftermath of contagion effects of global financial crisis and European sovereign debt default. In the past three years, the housing price had plummeted, inducing the depreciation of collateral which eroded the bank capital.

e. Italy: high level of public debt

Italy was up against the wall when facing the big public-debt burden, and its public debt-to-GDP ratio was 118.4%, only next to the debt-to-GDP ratio of 144.9% in Greece. The public debt prices started to fall in July 2011, with a surge of bond yield, which underlined the threat of European sovereign debt default crisis. The ECB helped Italy in August 2011.

Corresponding to the results in Broto and Perez-Quiros (2015), which concluded that the sovereign debt default in periphery countries had affected the credit risks in core countries, and our empirical results also showed that the financial contagion spread from periphery countries to core countries. Our empirical results further figured out the significant predictability of the common causes in periphery countries for the sovereign debt default risks in several countries, and the sovereign debt default risks in Italy, Portugal, Greece, and Spain could also predict the common causes in periphery countries and core countries. This granger causality showed the financial contagion effects from periphery countries to regional countries, and the financial instability of regional countries further affected the originating countries of European sovereign debt default.

(2)Results of the core countries

The outcomes of VAR model test in core countries were shown on Table 4. In Part1 of Table 4, we saw that the Austria sovereign debt default risks couldn't be predicted by any lag diffusion index. Neither do the Austria sovereign debt default risks have its own feedback effect. In Part2 of Table 4, we saw that the Belgium sovereign debt default risks could be predicted by the lag DF1 and the lag DF2 of "middle-income countries, periphery countries, and core countries." The Belgium sovereign debt default risks could be predicted by the lag DF1 of "high-income countries, and all countries." The lag Belgium sovereign debt default risks also could predict the diffusion indexes of "all countries." The Belgium sovereign debt default risks had its own feedback effects. In Part3 of Table 4, we saw that the France sovereign debt default risks could be predicted by the lag DF1 and the lag DF3 of "middle-income countries, periphery countries, and core countries." The France sovereign debt default risks could be predicted by the lag DF1 of "high-income countries, and all countries." The lag France sovereign debt default risks also could predict the diffusion indexes of "high-income countries, and all countries." The France sovereign debt default risks had its own feedback effects.

In Part4 of Table 4, we saw that the Germany sovereign debt default risks could be predicted by the lag DF3 of "all countries." However, there's no feedback effect of the Germany sovereign debt default risks. In Part5 of Table 4, we saw that the Netherlands sovereign debt default risks could be predicted by the lag DF1 of "middle-income countries, periphery countries, and core countries." The lag Netherlands sovereign debt default risks also could predict the diffusion indexes of "middle-income countries, periphery countries, and core countries." The Netherlands sovereign debt default risks had its own feedback effect. In Part6 of Table 4, we saw that the Slovak sovereign debt default risks could be predicted by the lag DF3 of "middle-income countries, periphery countries, and core countries." The lag Slovak sovereign debt default risks also could predict the diffusion indexes of "middle-income countries, periphery countries, and core countries." The Slovak sovereign debt default risks had its own feedback effects. In Part7 of Table 4, the Slovenia sovereign debt default risks couldn't be predicted by any lag diffusion indexes. The lag Slovenia sovereign debt default risks also could predict the diffusion indexes of "high-income countries, middle-income countries, periphery countries, and core countries." The Slovenia sovereign debt default risks have its own feedback effects.

To sum up, the sovereign debt default risks in Belgium, France, Netherlands, and Slovak could be predicted by the common factors of periphery countries. And the sovereign debt default risks in Netherlands, and Slovak could predict the common factors of periphery countries. From the results in Table 4, we could conclude that the existence of contagion effects between periphery countries and core countries.

Those outcomes in Table 3 and Table 4 suggest that the sovereign debt defaults of periphery countries bring about the worldwide contagion effects. Our empirical results corresponded to the facts, representing that the European sovereign debt default spread from periphery countries to core countries. We concluded the two main possible explanations as follows,

a. Complicated relation between debtors with creditors in the member countries of EU and a domino effect

The main causes of European sovereign debt default spread were reciprocal lending relationships between Europe governments and banks, inducing a domino effect. Since July 2011, the financial instability was not only limited to Greece, but also the bigger economies, that is, Spain and Italy. The overall GDP of those countries in crisis amounted to one third of the total GDP in Eurozone. Obviously, the Europe financial crisis was not only limited to those periphery countries, but also financial contagion spread to large countries in Eurozone.

b. Europe' s banking industry and serious sovereign debt exposures

With the expanding threat from European sovereign debt default, the credit rating institution, the Moody's, had downgraded the credit rating of 21 financial institutions in British and Portugal (IMF, 2011). Besides, the extensions of threat on banking industries were as follows.

(a) The credit risks of GIIPS continued to rise and credit rating falling. Since the eruption of European sovereign debt default in 2009, the CDS spreads spiked continue.

(b) The banking industry crisis. The real crisis of European sovereign debt default laid on the enormous sovereign debt default risk exposure up to 300 billion euros, and in case of the debt default eruption, the liquidity crisis would occur in the European banking industries. America's funds accounted for a large proportion of total funds in the European banking industries, and a ripple effect through the whole banking industries showed that the debt default was not only a specific country's problem, but also the liquidity problems overall Europe and America. ***(i)Several banks' credit ratings had been downgraded.*** The credit ratings of the banking industries in France and Switzerland were warned, and the eight banks in Greece had credit rating falling. ***(ii)Large European banks had asked for the economic relief packages provided by the governments.*** The multinational bank, Dexia SA, a joint venture of Belgium, France, and Luxembourg, had therefore weaken their ability to access funds for the huge Greece public debt in the early October 2011. Dexia SA was the first large bank receiving the economic relief packages provided by the governments, which represented that the crisis had extended from periphery countries to core countries and thus caused the public's anxiety for the France's banking industry.

Our empirical results represented that the core countries, such as Belgium and France, both were affected by the common causes in periphery countries. Corresponding to the facts, the bank industries in France, and Belgium had received the economic relief packages provided by governments.

V. Conclusions

In conclusion, the empirical results showed that 4 out of 5 periphery countries, except Italy, were significantly affected by the diffusion indexes of "middle-income countries, periphery countries, and core countries." Besides, the sovereign debt default risks of 4 out of 5 periphery countries, except Ireland, could significantly predict the diffusion indexes of many regions. It implied that the debt default risks of many regions were affected by Italy, Portugal, Greece and Spain.

Our empirical results showed that the diffusion indexes of different regions could significantly predict the sovereign debt default risks in Eurozone, especially the diffusion indexes of "middle-income countries, periphery countries, and core countries." The sovereign debt default risks of periphery countries were affected by which of those regions. And the sovereign debt default risks in Italy, Portugal, Greece and Spain could significantly predict the diffusion indexes of many regions, which implied that the sovereign debt default risks of periphery countries were the origins of global financial contagion.

The derivatives of Greece sovereign debt default were banking crisis and economic recession. Since late 2009, the huge fiscal deficit problem in Greece had spread to Ireland, Portugal, Spain, and Italy, resulting in the European sovereign debt default crisis. Further, the banking crisis occurred since the serious sovereign debt risks exposure to PIIGS, which also induced the financial systems illiquidity. Insufficient bank funds would restrict the economic growth, which induced the debt repayment difficulties and gradually formed an economic crisis. Once a country's sovereign debt default triggered, the chain reactions flooded in the global financial market.

The multifaceted crisis facing the Europe had resulted in the sovereign debt default. In this paper, we used the CDS spreads to proxy the sovereign debt default risks, and corresponding to facts, our empirical results concluded that the sovereign debt default risks in Greece, Ireland, and Portugal had further spread to the periphery countries, and those countries could be treated as the originating countries of sovereign debt default.

Our empirical results showed that the common factors in periphery countries indeed significantly predicted the sovereign debt default risks of several countries, and the debt default risks in Italy, Portugal, Greece, and Spain also can significantly predicted the common factors in periphery countries and core countries. The reciprocal interactions represented the financial crisis contagion spread from the periphery countries to regional countries, and the financial instability in regional countries further impacted the originating countries of European sovereign debt default.

We have two major contributions. First, corresponding to the facts, the empirical results in this paper showed that the sovereign debt default crisis spread from periphery countries to core countries. It is concluded that the debt default in Greece, Portugal, and Ireland, had broadened the sovereign debt default risks of periphery countries, also met the actual circs, that is, these 3 countries facing most serious risks of debt distress. It is also concluded that the core countries, Belgium, and France, were significantly affected by the sovereign debt default in periphery countries, also met the actual circs, that is, the banking industry in France had credit falling and the multinational banks, the joint ventures established by Belgium and France, received the government bailout funds. Second, we use the CDS spreads to proxy the sovereign debt default risks, which exactly show the significant lead, lag and causality relationship between the sovereign debt default risks and the common causes in several regions, and successfully representing the interactions between financial crisis contagion effects of several countries.

Table 4

VAR results (core countries)

Dependent variables		Part1: Austria					Part2: Belgium					Part3: France				
Model	Countries Coefficients	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries
1	$\widehat{\alpha_1}$	1.90†	1.90†	0.52	1.90†	0.61	0.89†	0.89**	0.51	0.89**	0.71*	0.91†	0.91†	0.58*	0.91†	0.65*
		(0.62)	(0.62)	(0.32)	(0.62)	(0.32)	(0.38)	(0.38)	(0.40)	(0.38)	(0.41)	(0.31)	(0.31)	(0.33)	(0.31)	(0.34)
	$\widehat{\beta_1}$	0.84†	0.84†	0.91†	0.84†	0.90†	0.88†	0.88†	0.92†	0.88†	0.90†	0.85†	0.85†	0.89†	0.85†	0.88†
		(0.05)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
	$\widehat{\beta_2}$	0.32	0.32	-0.47	0.32	-0.57	0.95*	0.95*	-1.00*	0.95*	-1.02*	1.07†	1.07†	-0.80*	1.07†	-0.87*
		(0.64)	(0.64)	(0.43)	(0.64)	(0.43)	(0.53)	(0.53)	(0.57)	(0.53)	(0.59)	(0.40)	(0.40)	(0.43)	(0.40)	(0.44)
	$\widehat{\beta_3}$	0.30	0.30	-0.07	0.30	0.49	1.07**	1.07**	-0.83	1.07**	0.57	0.48	0.48	-0.49	0.48	0.33
		(0.63)	(0.63)	(0.41)	(0.63)	(0.42)	(0.52)	(0.52)	(0.54)	(0.52)	(0.58)	(0.39)	(0.39)	(0.41)	(0.39)	(0.43)
	$\widehat{\beta_4}$	0.91	0.91	-0.12	0.91	-0.42	-0.05	-0.05	-0.81	-0.05	0.01	0.69*	0.69*	-0.001	0.69*	-0.22
		(0.64)	(0.64)	(0.42)	(0.64)	(0.41)	(0.53)	(0.53)	(0.54)	(0.53)	(0.56)	(0.39)	(0.39)	(0.42)	(0.39)	(0.42)
2	$\widehat{\alpha_2}$	-0.06	-0.06	-0.01	-0.06	-0.01	-0.01	-0.01	-0.10	-0.01	-0.10	-0.03	-0.03	-0.16**	-0.03	-0.16**
		(0.10)	(0.10)	(0.08)	(0.10)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
	$\widehat{\beta_5}$	0.002	0.002	-0.003	0.002	-0.002	-0.002	-0.002	0.01	-0.002	0.01	0.0001(0.	0.0001(	0.02**	0.0001	0.02**
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	01)	0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_6}$	0.24**	0.24**	0.28†	0.24**	0.28**	0.25†	0.25**	0.26†	0.25**	0.27*	0.24**	0.24**	0.26**	0.24**	0.26**
		(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_7}$	-0.02	-0.02	-0.03	-0.02	-0.01	-0.01	-0.01	-0.05	-0.01	-0.04	-0.01	-0.01	-0.05	-0.01	-0.04
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_8}$	-0.01	-0.01	-0.10	-0.01	-0.02	-0.003	-0.003	-0.09	-0.003	-0.02	-0.01	-0.01	-0.07	-0.01	-0.02
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
3	$\widehat{\alpha_3}$	-0.09	-0.09	-0.06	-0.09	-0.12	0.002	0.002	-0.13	0.002	-0.19*	0.05	0.05	-0.09	0.05	-0.11
		(0.10)	(0.10)	(0.08)	(0.10)	(0.08)	(0.07)	(0.07)	(0.08)	(0.07)	*(0.08)	(0.08)	(0.08)	(0.09)	(0.08)	(0.08)
	$\widehat{\beta_9}$	0.01	0.01	0.004	0.005	0.01	-0.004	-0.004	0.01	-0.004	0.02**	-0.01	-0.01	0.01	-0.01	0.01
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{10}}$	-0.09	-0.09	0.03	-0.09	-0.05	-0.08	-0.08	-0.0004	-0.08	-0.10	-0.07	-0.07	0.02	-0.07	-0.07
		(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
	$\widehat{\beta_{11}}$	0.08	0.08	0.003	0.08	0.05	0.09	0.09	-0.01	0.09	0.02	0.08	0.08	0.06	0.08	0.06
		(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
	$\widehat{\beta_{12}}$	-0.04	-0.04	-0.13	-0.04	0.02	-0.03	-0.03	-0.13	-0.03	0.01	-0.02	-0.02	-0.13	-0.02	0.01
		(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
4	$\widehat{\alpha_4}$	-0.18	-0.18	0.04	-0.18	-0.03	-0.09	-0.09	0.02	-0.09	-0.09	-0.10	-0.10	0.06	-0.10	-0.10
		(0.10)	(0.10)	(0.08)	(0.10)	(0.08)	(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
	$\widehat{\beta_{13}}$	0.01	0.01	-0.01	0.01	0.003	0.01	0.01	-0.002	0.01	0.01	0.01	0.01	-0.01	0.01	0.01
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{14}}$	0.12	0.12	0.06	0.12	0.15	0.12	0.12	0.07	0.12	0.13	0.12	0.12	0.08	0.12	0.13
		(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
	$\widehat{\beta_{15}}$	-0.01	-0.01	0.02	-0.01	0.02	0.02	0.02	0.02	0.02	0.003	0.02	0.02	0.02	0.02	0.01
		(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)
	$\widehat{\beta_{16}}$	-0.19	-0.19	-0.15	-0.19	-0.24	-0.18	-0.18	-0.15	-0.18	-0.24**	-0.18	-0.18	-0.15	-0.18	-0.24**
		(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	det(SSE)	0.001	0.001	0.0006	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0004
	AIC	-6.38	-6.38	-7.15	-6.38	-7.35	-6.66	-6.66	-6.62	-6.66	-6.82	-7.29	-7.29	-7.18	-7.29	-7.38
	BIC	-5.96	-5.96	-6.71	-5.96	-6.91	-6.24	-6.24	-6.19	-6.24	-6.38	-6.87	-6.87	-6.75	-6.87	-6.94
	HQ	-6.21	-6.21	-6.97	-6.21	-7.17	-6.49	-6.49	-6.45	-6.49	-6.64	-7.12	-7.12	-7.01	-7.12	-7.20

Source: The authors. Robust t statistics in brackets. * significant at 10%; ** significant at 5%; † significant at 1%. We adopt the VAR(1) model as equation (9).

Table 4 (continue)

Dependent variables		Part4: Germany					Part5: Netherlands					Part6: Slovak				
Model	Countries Coefficients	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries
1	$\widehat{\alpha_1}$	**1.10†**	**1.10†**	**1.11†**	1.10†	**1.28†**	**0.87****	**0.87****	**0.80****	**0.87****	**0.80****	**0.40***	0.40*	0.30	0.40*	0.28
		(0.41)	(0.41)	(0.42)	(0.41)	(0.41)	(0.35)	(0.35)	(0.36)	(0.35)	(0.36)	(0.24)	(0.24)	(0.24)	(0.24)	(0.24)
	$\widehat{\beta_1}$	**0.84†**	**0.84†**	**0.83†**	**0.84†**	**0.83†**	**0.87†**	**0.87†**	**0.86†**	**0.87†**	**0.86†**	**0.91†**	**0.91†**	**0.93†**	**0.91†**	**0.93†**
		(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
	$\widehat{\beta_2}$	0.11	0.11	-0.42	0.11	-0.19	**0.74***	**0.74***	-0.50	**0.74***	-0.55	0.57	0.57	-0.60	0.57	-0.63
		(0.43)	(0.43)	(0.47)	(0.43)	(0.43)	(0.42)	(0.42)	(0.45)	(0.42)	(0.45)	(0.38)	(0.38)	(0.40)	(0.38)	(0.40)
	$\widehat{\beta_3}$	0.04	0.04	-0.17	0.04	-0.01	-0.003	0.00	-0.26	-0.003	-0.01	0.37	0.37	0.40	0.37	0.17
		(0.42)	(0.42)	(0.44)	(0.42)	(0.42)	(0.42)	(0.42)	(0.43)	(0.42)	(0.44)	(0.37)	(0.37)	(0.38)	(0.37)	(0.39)
	$\widehat{\beta_4}$	0.49	0.49	-0.03	0.49	**0.94****	0.30	0.30	0.02	0.30	-0.38	**0.64***	**0.64***	-0.002	**0.64***	-0.35
		(0.43)	(0.43)	(0.45)	(0.43)	(0.43)	(0.42)	(0.42)	(0.44)	(0.42)	(0.44)	(0.37)	(0.37)	(0.39)	(0.37)	(0.39)
2	$\widehat{\alpha_2}$	0.05	0.05	-0.02	0.05	0.002	0.06	0.06	-0.11	0.06	-0.12	0.02	0.02	-0.07	0.02	-0.07
		(0.10)	(0.10)	(0.09)	(0.10)	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
	$\widehat{\beta_5}$	-0.01	-0.01	-0.001	-0.01	-0.003	-0.01	-0.01	0.01	-0.01	0.01	-0.01	-0.01	0.01	-0.01	0.01
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_6}$	**0.24****	**0.24****	**0.28†**	**0.24****	**0.27†**	**0.24****	**0.24†**	**0.28†**	**0.24†**	**0.28†**	**0.24****	**0.24****	**0.28†**	**0.24****	**0.28†**
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_7}$	-0.01	-0.01	-0.03	-0.01	-0.02	-0.02	-0.02	-0.03	-0.02	-0.01	-0.02	-0.02	-0.03	-0.02	-0.02
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_8}$	0.0001	0.0001	-0.10	0.0001	0.05	-0.01	-0.01	-0.09	-0.01	-0.01	-0.001	-0.001	-0.09	0.001	-0.02
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
3	$\widehat{\alpha_3}$	-0.01	-0.01	-0.09	-0.01	0.002	0.09	0.09	0.02	0.09	-0.02	0.09	0.09	-0.04	0.09	-0.07
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.06)	(0.06)	(0.07)	(0.06)	(0.07)
	$\widehat{\beta_9}$	-0.002	-0.002	0.01	-0.002	-0.01	**-0.02****	**-0.02****	-0.01	**-0.02****	-0.003	**-0.02****	**-0.02****	0.002	**-0.02****	0.01
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{10}}$	-0.08	-0.08	0.04	-0.08	-0.05	-0.09	-0.09	0.03	-0.09	-0.06	-0.10	-0.10	0.03	-0.10	-0.06
		(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
	$\widehat{\beta_{11}}$	0.09	0.09	0.004	0.09	0.12	0.08	0.08	0.004	0.08	0.07	0.07	0.07	0.01	0.07	0.07
		(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
	$\widehat{\beta_{12}}$	-0.03	-0.03	-0.13	-0.03	-0.14	-0.03	-0.03	-0.13	-0.03	0.01	-0.02	-0.02	-0.13	-0.02	0.01
		(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
4	$\widehat{\alpha_4}$	-0.08	-0.08	0.04	-0.08	-0.17	-0.02	-0.02	0.07	-0.02	-0.03	-0.08	-0.08	0.04	-0.08	-0.06
		(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
	$\widehat{\beta_{13}}$	0.01	0.01	-0.01	0.01	0.01	-0.003	-0.003	-0.01	-0.003	0.002	0.01	0.01	-0.01	0.01	0.01
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$\widehat{\beta_{14}}$	0.13	0.13	0.06	0.13	-0.17	0.13	0.13	0.07	0.13	0.15	0.13	0.13	0.07	0.13	0.14
		(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
	$\widehat{\beta_{15}}$	0.01	0.01	0.02	0.01	0.05	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
		(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	$\widehat{\beta_{16}}$	-0.18	-0.18	-0.15	-0.18	-0.17	-0.17	-0.17	-0.15	-0.17	-0.24	-0.18	-0.18	-0.15	-0.18	-0.24
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
	det(SSE)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0004	0.0004	0.001	0.0004	0.0004
	AIC	-7.08	-7.08	-7.03	-7.08	-7.24	-7.15	-7.15	-7.05	-7.15	-7.18	-7.40	-7.40	-7.28	-7.40	-7.41
	BIC	-6.66	-6.66	-6.59	-6.66	-6.82	-6.73	-6.73	-6.61	-6.73	-6.75	-6.98	-6.98	-6.84	-6.98	-6.98
	HQ	-6.91	-6.91	-6.85	-6.91	-7.07	-6.98	-6.98	-6.87	-6.98	-7.01	-7.23	-7.23	-7.10	-7.23	-7.24

Source: The authors. Robust t statistics in brackets. * significant at 10%; ** significant at 5%; † significant at 1%. We adopt the VAR(1) model as equation (9).

Table 4 (continue)

Dependent variables		Part7: Slovenia				
Model	Countries Coefficients	Middle-income countries	Periphery countries	High-income countries	Core countries	All countries
1	$\widehat{\alpha_1}$	**0.41*** (0.24)	**0.41*** (0.24)	0.30 (0.27)	**0.41*** (0.24)	0.32 (0.27)
	$\widehat{\beta_1}$	**0.94**† (0.03)	**0.94**† (0.03)	**0.96**† (0.04)	**0.94**† (0.03)	**0.95**† (0.04)
	$\widehat{\beta_2}$	0.53 (0.36)	0.53 (0.36)	-0.38 (0.40)	0.53 (0.36)	-0.34 (0.40)
	$\widehat{\beta_3}$	-0.03 (0.36)	-0.03 (0.36)	0.05 (0.37)	-0.03 (0.36)	-0.34 (0.39)
	$\widehat{\beta_4}$	0.57 (0.36)	0.57 (0.36)	0.14 (0.38)	0.57 (0.36)	-0.07 (0.38)
2	$\widehat{\alpha_2}$	-0.04 (0.07)	-0.04 (0.07)	**-0.12*** (0.07)	-0.04 (0.07)	**-0.12*** (0.07)
	$\widehat{\beta_5}$	0.001 (0.01)	0.001 (0.01)	0.01 (0.01)	0.001 (0.01)	0.01 (0.01)
	$\widehat{\beta_6}$	**0.24**** (0.10)	**0.24**** (0.10)	**0.25**** (0.10)	**0.24**** (0.10)	**0.25**** (0.11)
	$\widehat{\beta_7}$	-0.01 (0.10)	-0.01 (0.10)	-0.02 (0.10)	-0.01 (0.10)	0.01 (0.10)
	$\widehat{\beta_8}$	-0.01 (0.10)	-0.01 (0.10)	-0.09 (0.10)	-0.01 (0.10)	-0.02 (0.10)
3	$\widehat{\alpha_3}$	0.10 (0.07)	0.10 (0.07)	0.08 (0.08)	0.10 (0.07)	0.03 (0.08)
	$\widehat{\beta_9}$	**-0.02**** (0.01)	-0.02 (0.01)	**-0.02**** (0.01)	-0.02 (0.01)	-0.01 (0.01)
	$\widehat{\beta_{10}}$	-0.06 (0.10)	-0.06 (0.10)	0.07 (0.11)	-0.06 (0.10)	-0.03 (0.11)
	$\widehat{\beta_{11}}$	0.04 (0.10)	0.04 (0.10)	-0.01 (0.11)	0.04 (0.10)	0.06 (0.11)
	$\widehat{\beta_{12}}$	-0.02 (0.10)	-0.02 (0.10)	-0.13 (0.11)	-0.02 (0.10)	0.02 (0.11)
4	$\widehat{\alpha_4}$	-0.05 (0.07)	-0.05 (0.07)	0.03 (0.07)	-0.05 (0.07)	-0.08 (0.07)
	$\widehat{\beta_{13}}$	0.003 (0.01)	**0.003**** (0.01)	-0.004 (0.01)	**0.003**** (0.01)	0.01 (0.01)
	$\widehat{\beta_{14}}$	0.12 (0.10)	0.12 (0.10)	0.07 (0.11)	0.12 (0.10)	0.12 (0.11)
	$\widehat{\beta_{15}}$	0.02 (0.10)	0.02 (0.10)	0.01 (0.10)	0.02 (0.10)	0.04 (0.11)
	$\widehat{\beta_{16}}$	-0.17 (0.10)	-0.17 (0.10)	-0.15 (0.10)	-0.17 (0.10)	-0.24 (0.10)
	det(SSE)	0.0004	0.0004	0.0004	0.0004	0.0004
	AIC	-7.46	-7.46	-7.38	-7.46	-7.51
	BIC	-7.04	-7.04	-6.94	-7.04	-7.07
	HQ	-7.29	-7.29	-7.20	-7.29	-7.33

Source: The authors. Robust t statistics in brackets. * significant at 10%; ** significant at 5%; † significant at 1%. We adopt the VAR(1) model as equation (9).

References

Acharya, V.V. & Steffen, S. (2015). The “greatest” carry trade ever? Understanding eurozone bank risks. *Journal of Financial Economics, 115*(2), 215–236.

Alberola, E., Rio, P. del & Molina, L. (2012). Boom-bust cycles, imbalances and disciplines in Europe. *Moneday Credito, 234,* 169–205.

Alter, A. & Schuler, Y.S. (2012). Credit spread interdependencies of European states and banks during the financial crisis. *Journal of Banking & Finance, 36,* 3444–3468.

Ang, A. & Longstaff, F. (2013). Systemic sovereign credit risk: lessons from the U.S. and Europe. *Journal of Monetary Economics*, *60*(5), 493–510.

Arce, O., Mayordomo, S. & Pena, J.I. (2013). Credit-valuation in the sovereign CDS and bonds markets: evidence from the euro area crisis. *Journal of International Money Finance, 35*, 124–145.

Ayuso, J. & Blanco, R. (2001). Has financial market integration increased during the nineties? *Journal of International Financial Markets, Institutions and Money*, *11*(3–4), September–December, 265–287.

Bampinas, G., Panagiotidis, T. & Politsidis, P. (2020). *Sovereign bond and CDS market contagion: A story from the Eurozone crisis.* MPRA Paper 102846, University Library of Munich, Germany.

BIS. (2011). *Basel III: A global regulatory framework for more resilient banks and banking systems.* Basel Committee on Banking Supervision, Bank for International Settlements.

Broto, C. & Perez-Quiros, G. (2015). Disentangling contagion among sovereign CDS spreads during the European debt crisis. *Journal of Empirical Finance*, *32*, 165–179.

Caporale, G.M., Cipollini, A. & Spagnolo. N. (2005). Testing for contagion: A conditional coorelation analysis. *Journal of Empirical Finance*, *12*(3), 476–489.

Caporin, M., Pelizzon, L., Ravazzolo, F. & Rigobon, R. (2018). Measuring sovereign contagion in Europe. *Journal of Financial Stability, 34*, 150–181.

Carboni, A. (2011). *The sovereign credit default swap market: price discovery, volumes and links with banks risk premia*. Banca d’Italia Working Paper 821.

Connor, G. & Korajczyk, R. (1986). Performance measurement with the arbitrage pricing theory: A new framework for analysis. *Journal of Financial Economics, 15*, 373–394.

Connor, G. & Korajczyk. R. (1993). A test for the number of factors in an approximate factor model. *Journal of Finance, 48*, 1263–1291.

Dooley, M. & Hutchison, M. (2009). Transmission of the U.S. subprime crisis to emerging markets: Evidence on the decoupling–recoupling hypothesis. *Journal of International Money and Finance*, *28*, 1331–1349.

Eichengreen, B. & Mody, A. (2000). What explains changing spreads on emerging-market debt? In Sebastian Edwards (Ed). *The Economics of International Capital Flows.* University of Chicago Press.

Eichengreen, B., Mody, A., Nedeljkovic, M. & Sarno, L. (2012). How the subprime crisis went global: Evidence from bank credit default swap spreads. *Journal of International Money and Finance, Elsevier, 31*(5), 1299–1318.

Fontana, A. & Scheicher, M. (2010). *An analysis of euro area sovereign CDS and their relation with government bonds.* ECB Working Paper 1271.

Forbes, K.J. & Rigobon, R. (2002). No contagion, only interdependence: Measuring stock market co-movements. *Journal of Finance, 57*, 2223–2261.

International Monetary Fund (2011). *World economic and financial surveys, global financial stability report, grappling with crisis legacies.* International Monetary Fund, Publication Services.

Kalbaska, A. & Gatkowski, M. (2010). Eurozone sovereign contagion: Evidence from the CDS market (2005–2010). *Journal of Economic Behavior & Organization*, special issue.

Kamin, S. & von Kleist, K. (1999). *The evolution and determinants of emerging market credit spreads in the 1990s.* Working paper No. 68, Bank for International Settlements.

Longstaff, F.A. (2010). The subprime credit crisis and contagion in financial markets. *Journal of Financial Economics, 97*, 436–450.

Longstaff, F.A., Pan, J., Pedersen, L.H. & Singleton, K.J. (2011). How sovereign is sovereign credit risk? *American Economic Journal: Macroeconomics, 3*(2), 75–103.

Mauro, P., Sussman, N. & Yafeh, Y. (2002). Emerging market spreads: Then versus now. *Quarterly Journal of Economics, 117*, 695–733.

Pan, J. & Singleton, K.J. (2008). Default and recovery implicit in the term structure of sovereign CDS spreads. *Journal of Finance, 63*, 2345–2384.

Palladini, G. & Portes, R. (2011). *Sovereign CDS and bond pricing dynamics in the euro area.* NBER Working Paper 175856.

Reinhart, C.M. & Rogoff, K.S. (2009). *This time is different: Eight centuries of financial folly*. Princeton University Press.

Sabkha, S., de Peretti, C. & Hmaied, D. (2019). The credit default swap market contagion during recent crises: International evidence. *Rev Quant Finan Acc, 53*, 1–46. https://doi.org/10.1007/s11156-018-0741-6

Stock, J.H., & Watson, M.W. (1998). *Diffusion indexes.* NBER Working Paper No.6702.

Stock, J.H., & Watson, M.W. (2002). Macroeconomic forecasting using diffusion indexes. *Journal of Business and Economic Statistics, 20*(2), 147–162.

The World Bank (2022). Countries and economies, income levels. Retrieved from https://data.worldbank.org/country