



Spillovers from one country's sovereign debt to CDS (credit default swap) spreads of others during the European crisis: a spatial approach

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Abstract

This paper examines the interactions among CDS spreads across 13 European countries using spatial econometrics techniques. Our model allows for the estimation of direct and indirect transmission of sovereign risk and feedback effects across the network of these countries. The novelty of this paper is to link macroeconomic variables and CDS spreads in a new context of analysis to uncover new channels affecting sovereign risk across countries during the European debt crisis. We show that the key channel in driving sovereign risk spillovers is trade linkages between the countries. Our results also reveal that a country's CDS spread is approximately 7 basis points (bps) higher for a 1% increase in public debt-to-GDP levels while that increase in indebtedness is associated with roughly 2 bps higher spreads in all other countries.

Keywords CDS spreads · European debt crisis · Spatial econometrics · Sovereign risk · Government debt

JEL classification C23 · E44 · F30 · H63

Introduction

The debt crisis in Europe tested the fiscal fragility of the currency union for the first time in its more than a decade long history. During the discussions on the second rescue package for Greece of €130 billion, *The Telegraph* reported the German Chancellor's warning that "the risks of turning away from Greece now are incalculable. No one can assess what consequences would arise for the German economy, on Italy, Spain, and the Eurozone as a whole and finally for the whole world," [while] "...protestors gathered outside the Bundestag... [and]... while Germany's best-selling newspaper, *Bild*, a populist tabloid, splashed with the headline: 'Billions for Greece—Stop'" and called for politicians not to

"go any further down this crazy path."¹ If there were spillovers from Greek debt to German sovereign risk however the German Chancellor, Angela Merkel, would be justified in her comments.

This study aims to examine the impact of the level of government debt in a European country on the CDS spreads of other European countries. We investigate 13 European countries from 2008-Q1 to 2012-Q1 for this purpose. This period comprises the subprime crisis in the United States that triggered the crisis in Europe which escalated to several countries and culminated in 2012 with Greece's default on its sovereign debt. The European crisis focused attention on the heterogeneity of the European economies, especially those in the Eurozone and outside. For example, Sweden, the United Kingdom (UK), and Denmark are not in the Eurozone but are in the European Union (EU). These countries have stable economies that are similar to core Eurozone countries such as Germany, France, Austria, Belgium, and the Netherlands. The periphery countries in the Eurozone such as Greece, Ireland, Portugal, Spain, and Italy (GIPSI) all faced unique challenges during the crisis in adjusting their indebtedness and economic fundamentals. Beside the

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¹ *The Telegraph*, 27th February 2012 by Louise Armitstead: <http://www.telegraph.co.uk/finance/financialcrisis/9109722/Germany-approves-Greek-bail-out-but-warns-Angela-Merkel-against-further-help.html>.



country specific policies, the European Central Bank (ECB) also played an important role in stabilizing the financial imbalances from the beginning of the crisis. In response to the sovereign debt crisis, ECB implemented a series of conventional monetary policy measures, such as cuts in policy interest rate and minimum reserve requirements and unconventional policy measures, such as Securities Market Programme (SMP) and Outright Monetary Transactions (OMT) (Korus 2019).²

We knew that real economy variables have an impact on sovereign CDS spreads (Augustin and Tédongap 2016; Chernov et al. 2020; Dieckman and Plank 2012; Stamatoopoulos et al. 2017). Some studies also investigate the impact of financial contagion on sovereign risk across European countries during the European debt crises (see, Broto and Perez-Quiros 2015, for example). However, we use such well-known links in a new context of analysis by using spatial econometric techniques. This paper shows that the indebtedness of trading partners provides additional information about a country's sovereign risk. The spatial econometric analysis allows us to learn the role of indirect effects in transmitting sovereign risk across the countries. We can identify that the source of sovereign risk in one country includes the debt-to-GDP level of others and we can ascertain the transmission channel as the trade links between the two countries.

Relative to existing literature, this paper has four major contributions. First, instead of looking at cross-country risk spillovers through the lens of CDS spreads for all countries, we examine the impact of macroeconomic fundamentals on other countries' CDS spreads. Second, we use spatial econometric analysis that allows us to estimate direct and indirect contagion effects across the network of 13 European countries for this purpose. Third, we contribute to the existing literature by bringing an underlying economic source that drives the contagion channel directly and indirectly. Countries with more trade with each other are more prone to contagion. Fourth, we perform counterfactual analysis identifying the spillovers from the government debt in one country to CDS spreads of others.

In the literature, there is no generally accepted definition of contagion. We use contagion in a broader sense as the cross country transmission of shock or general cross-country spillover (Pritsker 2001; Kalbaska and Gatkowski 2012). Some studies use narrower definitions like a significant increase in comovements of prices (Pericoli and Sbracia 2003; Phylaktis and Xia 2009). We prefer to use the broader definition of contagion to concentrate on the transmission channels that lead to cross-country contagion

(Kaminsky and Reinhart 2000; Masson 1998; Pritsker 2001; Eichengreen et al. 1996). Equity literature provides various examples of contagion through stock exchanges (Bekaert et al. 2014; Forbes and Rigobon 2001). Several studies have documented the presence of contagion effects in sovereign risk across the countries (Arellano et al. 2017; Brutti and Saure 2015; Claeys and Vašíček 2014; Gevorkyan and Semmler 2016; Gomez-Puig and Sosvilla-Rivero 2016; Wu et al. 2016).

Understanding the transmission channels that lead to cross-country contagion is important. Most attention so far has been dedicated to cross-country risk transmission through financial linkages (see for example Kallestrup et al. 2016; De Bruyckere et al. 2013; Dungey and Renoult 2018) and a limited number of studies are on the real channel (Gorea and Radev 2014; Gu 2021). We show that a real channel, trade linkage, is important. We provide strong and direct empirical evidence for the trade channel.

Most of these former studies that measure contagion use mainly various econometric methods (Kallestrup et al. 2016; Caporin et al. 2018; Benzoni et al. 2015). Ait Sahalia et al. (2014) uses an econometric approach to estimate asymmetric mutual and self-reinforcing dependencies across sovereign CDS spreads of European countries. Lucas et al. (2014) use Copula techniques to study changes in default probabilities in the Eurozone. Gross and Siklos (2020) use a network model where they place financial institutions in the center and group non-financial entities and sovereigns around them. We use spatial econometric methods that contribute to this literature to differentiate between direct and indirect transmissions and feedback effects from sovereign debt in one country to CDS spreads in others. There exists some literature on the use of spatial methods for financial or sovereign CDS spreads (Eder and Keiler 2015; Mili 2018; Blasques et al. 2016).³ Eder and Keiler (2015) investigated the contagion risks among financial institutions. Mili (2018) focused on the systematic risk spillovers in Europe. Blasques et al. (2016) presented a model for time-varying spatial dependence in panel data. They estimate CDS spreads of the eight EU countries with their proposed model. Nevertheless, our study differs from these studies since we have focused on sovereign CDS spreads and we have examined the impact of macroeconomic fundamentals on CDS spreads via direct and indirect effects.

² ECB announced SMP in May 2010 and OMT program in August 2012.

³ Debarsy et al. (2018) used spatial regressions for 41 advanced and emerging countries by using bond spreads. However, because of being more liquid and allowing more accurate estimates of credit/sovereign risk, CDS spreads as an indicator of sovereign risk have received much attention in recent studies; see Longstaff et al. (2011), Augustin and Tedongap (2016) for details on the main advantages of using CDS spreads instead of interest rate/bond spreads.



The rest of the paper is organised as follows. Section 2 reviews the empirical literature on CDS spreads; in Sect. 3 we describe our method; in Sect. 4 we discuss the data and the stylised facts in Europe during the crisis; Sect. 5 presents the empirical results, followed by the robustness analysis in Sect. 6 and lastly conclusion part is presented.

The empirical literature on CDS spreads

The main drivers of sovereign risk are important to understand in financial turmoil periods. Since the seminal work of Edwards (1984), various studies have examined the determinants of sovereign risk. In his study, Edwards (1984) finds that domestic macroeconomic fundamentals such as the debt to output ratio, reserves to GDP ratio, current account to GDP ratio, and inflation are significant drivers of the government bond spread. The literature on sovereign risk and financial crises that focus on CDS spreads are more recent and many studies link macroeconomic variables and CDS spreads. For example, Chernov et al. (2020) develop a macro-based theoretical framework to explain high sovereign CDS spreads during financial crisis in US. In their model monetary and fiscal policies jointly endogenously determine the dynamics of debt, taxes, growth and inflation. Their result implies that the CDS premiums reflect the endogenous risk-adjusted probabilities of fiscal default. Similarly, Augustin and Tedongap (2016) uses an equilibrium model connecting a country's default risk to expected growth and macroeconomic uncertainty. They empirically show that US expected growth and macroeconomic uncertainty explain a large fraction of co-movement in sovereign CDS spreads.

We identify government debt as the major driver in the pricing of sovereign risk during the European crisis. The value of a country's debts affects its ability to repay its liabilities and also reduces the share of revenues for more productive uses. Specifically, if a country struggles to fulfil its debt obligations over time, then the sovereign risk will increase because of the higher probability of default. For this reason, an increase in public debt can lead to an increase in CDS spreads. In this respect Stamatopoulos et al. (2017) investigate the impact of fiscal space and downgrade announcement on CDS spreads during the sample period of 2008–2013 for the 16 Eurozone countries. They find significant effect of public debt on the CDS spreads during this period. However, the current account balance and the inflation rate are not found to be effective on the CDS spreads. Dieckmann and Plank (2012) examine the role of state of the country's financial system and the world financial system on the CDS spreads. In their analysis they find positive and significant relation between CDS spreads and public debt for the Western European countries considering the period of

2007–2010. Within several estimation results, the relationship between the government debt and the CDS spreads is found to be stronger in the post crisis period (after September 2008). However, these researches have not studied the effect of government debt in one country on the sovereign risk of other countries.

During the Eurozone crisis, European Central Bank (ECB) debated what effect the higher sovereign debt of the periphery countries might have on the systemic risk of EU countries as a whole. The links between the European economies are mainly trade and finance. If government debt in country A increases, then its interest rate becomes higher to reflect the higher risk. The high interest rate then reduces investments due to the higher cost of capital that leads to lower levels of output. The contraction in aggregate demand lowers the output in country A and has an adverse effect on the economies of its trading partners through reductions in the imports and exports of goods and services. In this case, trade works as an active contagion channel that increases the sovereign risk of trade partners.⁴

Besides government debt, the studies find that other macroeconomic variables such as inflation, the current account balance (CAB), growth rates or international reserves (Longstaff et al. 2011; Ho 2016) are significant, common variables in explaining the CDS spread. We use the following variables to control for the determinants of CDS spreads.

Inflation indicates how well a country is conducting its monetary and fiscal policy. Rising inflation rates can cause economic instability and higher CDS spreads because higher rates can represent a sovereign borrower's imposition of imprudent policies (i.e., excessive spending and borrowing) that lead to higher sovereign risk. From the investors' perspective, macroeconomic stability also affects risk attitudes; for example, high inflation can discourage investors' in their investment decisions (Afonso et al. 2011).

High growth rates are always desired by policymakers, investors, and households. It is known that higher growth rates strengthen the government's ability to repay its obligations. Therefore, we expect a negative relation between the growth rates and the CDS spreads (Fender et al. 2012; Fu et al. 2021).

Dieckmann and Plank (2012) find that the market often presumes that a country's foreign reserves indicate the

⁴ Households, banks, or corporations might hold assets of another country. When the government debt of country A increases, the value of the assets declines due to the increase in its interest rate. The decline in the value of the assets of country A effects the foreign investors that hold these assets in their portfolios. Hence the sovereign risk of country B increases due to the financial link. Furthermore, countries that are geographically close have stronger economic and interactions (see, e.g., gravity models based on Tinbergen (1963)). Thus, the government debt in one country could affect the CDS spreads of its neighbours.



ability-to-pay. Reserves measure a country's liquidity and its ability to repay its foreign debt with hard currency. With high levels of foreign reserves, countries strengthen their economies and enhance their ability to pay their debts conveniently and hence, give confidence to the global markets. Therefore, the higher the foreign reserves, the lower the CDS spreads.

Another determinant of sovereign risk is the CAB. If there is a current account deficit, then external sources finance private domestic investment. On the other hand, an increase in the CAB means an improvement in the economy overall. Therefore, we expect a negative relation between the CAB and CDS spreads. In addition, Afonso et al. (2011) mention that the CAB can reflect the rapid accumulation of fixed capital which leads to higher growth rates and lower CDS spreads.

In this study, we try to bring novelty to the literature mentioned above by presenting a spatial model. In our model, sovereign CDS spreads are explained by the macroeconomic variables. In contrast to the studies listed above we emphasize the possible linkages between the countries via spatial methods which allow the feedbacks that arise as a result of impacts passing through neighbouring countries and back to the country itself (Seldadyo et al. 2010). Because of this feedback effect, we can measure the direct and indirect effects of the macroeconomic variables. In this way we uncover new channels affecting sovereign risk across European countries.

Econometric approach

This section describes the econometric approach we apply to analyse the determinants of CDS spreads. The traditional fixed effects model has the following form:

$$y_{it} = \alpha_i + \mathbf{x}_{it}\boldsymbol{\beta} + \varepsilon_{it} \quad (1)$$

where y_{it} is the CDS spread for country i ($i = 1, \dots, N$) at time t ($t = 1, \dots, T$); α_i is a country-specific fixed effect; \mathbf{x}_{it} is a $(1 \times K)$ vector of control variables which include inflation, real growth, the growth rate of reserves, current account to GDP, government debt to GDP, and an associated vector of coefficients $\boldsymbol{\beta}$; ε_{it} is an independently and identically distributed error term.

We could adopt several spatial regression structures when specifying a spatial dependence amongst the observations for Eq. (1). As Anselin et al. (2008) point out; the spatial autoregressive process could be in the dependent variable or the error term.

We use the spatial lag model (or spatial autoregressive model, SAR) for the main model specification in our analysis. The SAR model is:

$$y_{it} = \alpha_i + \rho \sum_{j=1}^N w_{ij}y_{jt} + \mathbf{x}_{it}\boldsymbol{\beta} + \varepsilon_{it}, \quad (2)$$

where w_{ij} is the element of the spatial weight matrix \mathbf{W} , which represents the degree of interaction (proximity) between countries i and j , and ρ is the coefficient for the spatial autocorrelation. The \mathbf{W} is a nonnegative $N \times N$ matrix specified, a priori, according to the connectivity across countries. Its diagonal elements are zero by assumption because no country can be its own neighbour. The \mathbf{W} is commonly used as a row which is standardized such that the elements of each row sum to one. Hence, the spatially lagged variable $\sum_{j=1}^N w_{ij}y_{jt}$ is interpreted as the weighted average of the CDS spreads of the neighbouring countries.

When the SAR model performs the true data generating process, the fixed effects model in Eq. (1) suffers from omitted variable bias because it does not include the spatially lagged dependent variable. In the SAR model, $\boldsymbol{\beta}$ parameters associated with independent variables do not show the marginal effects of changes in the fundamentals. For each explanatory variable, we can calculate the marginal effect by reformulating Eq. (2) as

$$\begin{aligned} y_t &= (\mathbf{I}_N - \rho\mathbf{W})^{-1}\boldsymbol{\alpha} + (\mathbf{I}_N - \rho\mathbf{W})^{-1}\mathbf{X}_t\boldsymbol{\beta} + (\mathbf{I}_N - \rho\mathbf{W})^{-1}\boldsymbol{\varepsilon}_t \\ &= \sum_{r=1}^k \mathbf{S}_r \mathbf{x}_{rt} + \mathbf{V}\boldsymbol{\alpha} + \mathbf{V}\boldsymbol{\varepsilon}_t \end{aligned} \quad (3)$$

where \mathbf{I}_N is an identity matrix of dimension N , $\mathbf{V} = (\mathbf{I}_N - \rho\mathbf{W})^{-1}$, and $\mathbf{S}_r = \mathbf{V}\boldsymbol{\beta}_r\mathbf{I}_N$.

Thus, the direct effect is a change in the CDSs of a particular country because of a change in an explanatory variable of that country. The effect is the average of the diagonal of the matrix \mathbf{S}_r . The difference between the direct effect and the point estimate of $\boldsymbol{\beta}_k$ is called the feedback effect (see Seldadyo et al. 2010, for details).

The indirect effect or spillover effects from neighbouring units is the average of the row sums (or column sums) of the non-diagonal terms of the matrix \mathbf{S}_r . Lesage and Pace (2009, pp. 33–42) show that the numerical values of the two measures are the same. Hence, the indirect effect is either the change in the CDSs of a particular country because of a change in an explanatory variable for all other countries or the effect of a change in an explanatory variable of a particular county on the CDSs of all other countries.

In the SAR model, shocks to the error term at one location are also transmitted to all other locations within the spatial system. The average marginal effect of a CDS shock on a particular country's CDSs is calculated through the average of the diagonal matrix \mathbf{V} . Similarly, the average marginal effect of a CDS shock to a particular country on



Table 1 Data sources

Variables	Description	Source
CDS Spreads	Five-year sovereign CDSs, denominated in US\$	Thomson Reuters Datastream
GovDebt/GDP	Government consolidated gross debt as of GDP	Eurostat
CAB/GDP	Net current account as of GDP	Eurostat
GDPGrowth	Real GDP growth rate- volume, year on year (not seasonally adjusted)	Eurostat
ReserveGrowth	Growth rates of total reserves minus gold, quarter on quarter	IMF-IFS
Inflation	Percentage change in the Consumer Price Index (CPI) year on year	IMF-IFS
Weight matrices	Description	Source
W1: Trade linkage	Sum of exports and imports between country <i>i</i> and <i>j</i> as a proportion of the total exports and imports of country <i>i</i> with all other countries	IMF-Direction of Trade Statistics (DOTS)
W2: Financial linkage	Stock market return correlations.	Thomson Reuters Datastream
W3: Geographical linkage	Inverse of the Euclid distance calculated using the latitude and the longitude values of the countries	CEPII (Centre d'Etudes Prospectives et d'Informations Internationales)

This table shows the description and the sources for the data used in the estimations and weight matrices

the CDSs in all other countries is given by the average of the column sum of the non-diagonal terms of the matrix V .

Alternatively, in the spatial error model (SEM), the spatial correlation occurs only through the error term, or formally as;

$$y_{it} = \alpha_i + \mathbf{x}_{it}\boldsymbol{\beta} + u_{it}$$

where

$$u_{it} = \lambda \sum_{j=1}^N w_{ij}u_{jt} + \varepsilon_{it}. \quad (4)$$

In the SEM model, shocks to the error term in one country are transmitted to all neighbouring countries within the spatial system.

To decide on an appropriate model that describes the data, we conduct the Lagrange multiplier (LM) tests and robust LM tests that are based on the residuals of the fixed effects model in Eq. (1). In the robust LM tests, the existence of one type of spatial dependence does not bias the test for other types of spatial dependence (Seldadyo et al. 2010). If the LM tests are in favour of one or both of the spatial models, Lesage and Pace (2009) recommend also considering the more general spatial Durbin model (SDM). The Likelihood ratio (LR) tests can be used to test whether it can be reduced to the spatial lag or spatial error model.

In the SAR model, due to the existence of the spatial lagged dependent variable as the independent variable, the feedback effects exist. The feedback effect induces an endogeneity problem. Therefore, ordinary least square (OLS) estimates of the model parameters are inconsistent. Maximum likelihood estimation can be performed to obtain consistent parameter estimates. The log-likelihood function that is to be maximized is:

$$\ln L = -\frac{NT}{2} \ln(2\pi\sigma^2) + T \ln |\mathbf{I}_N - \rho \mathbf{W}| - \frac{1}{2\sigma^2} \sum_{i=1}^N \sum_{t=1}^T \left(y_{it} - \rho \sum_{j=1}^N w_{ij}y_{jt} - \mathbf{x}_{it}\boldsymbol{\beta} - \alpha_i \right)^2 \quad (5)$$

Data

Our data set covers 13 EU countries: three non-Eurozone countries (Sweden, the UK, and Denmark), five core Eurozone countries (Germany, France, Austria, Belgium, and the Netherlands), and five periphery countries (Greece, Ireland, Portugal, Spain, and Italy). The data span from 2008-Q1 to 2012-Q1. We use quarterly data due to frequency of the macroeconomic variables. The time period ranges from the subprime crisis in the United States that triggered the crisis in Europe to the 2012 Greek default on its sovereign debt. The choice of our data period ensures the inclusion of Greece, whose indebtedness has been a major issue during the crisis.⁵ We use a balanced panel due to the statistical properties of our method (see Lesage and Pace 2009). Therefore, the start date of our sample period is due to availability of CDS data for all of the 13 countries.⁶ Table 1 provides the information and sources about the data.

⁵ After February 2012, the 5-year Greek CDS was fixed at 37,030 bps until 2014. The reasoning being that Greek debts were subject to a restructuring process and an auction for these debts was held on March 19th. In this auction, most of the old bonds had already been exchanged and those remaining were insufficient for the purposes of the auction (Zettelmeyer et al. 2013).

⁶ The start date of CDS data for UK is 2008-Q1.



We use weight matrices to measure the spillover effects amongst the CDS markets in the EU countries under consideration. Because the EU is economically integrated, the countries in our analysis have strong connections not only geographically but also through trade and financial linkages. In this respect, distance or closeness between countries through financial and economic linkages can transmit the effect of government debt in one country to the CDS spreads in others and via feedback effects back to the original country.

In the construction of the SAR model, we use bilateral trade as a measure of spatial distances to construct weight matrices. The weight matrix represents trade linkages (Asgharian et al. 2013). We define this weight as the importance of country j 's trade for country i by taking the trade between these two countries as a share of the total trade of country i :

$$w_{ijt} = \frac{ex_{ijt} + im_{ijt}}{\sum_{k=1}^N ex_{ikt} + \sum_{k=1}^N im_{ikt}}$$

where x_{ijt} is the annual exports of country i to country j at time t ; im_{ijt} is the annual imports of country i from country j at time t ; and w_{ij} is obtained by taking the average of w_{ijt} in the time domain.⁷

We use two additional weight matrices for robustness. As the second weight matrix, we use the correlations of the stock returns between countries. This weight matrix represents financial linkages. Most of the applied studies that use spatial econometrics implicitly assume that geographically close countries have stronger interactions. Also, geographical distances are strictly exogenous. By following the same arguments, the third weight matrix we construct depends on the geographical distances between countries. We define the weight as:

$$w_{ij} = 1/d_{ij},$$

where d_{ij} denotes the Euclid distance between countries i and j .

Table 2 reports the summary statistics of the CDS spreads, sovereign debt, and other macroeconomics fundamentals. The table shows, by comparing minimum and maximum values, that the largest increase in the CDS spreads is in the GIPSI countries. The largest CDS spread belongs to Greece at 7780.8 bps, whereas the minimum spread is

34.3 bps for this country. Portugal, with a maximum spread of 1318.37, Ireland with 832.52, and Spain with 408.9 bps follow Greece. Their minimum CDS spreads are 19.5, 24.5, and 23.8 bps, respectively. Large deteriorations in macroeconomic fundamentals accompanying large increases in CDS spreads are another characteristic of this time period.

Accelerating debt levels were striking for the EU countries during the debt crisis. For example, the government debt to GDP ratio of the largest debtor country, Greece, increased from 107.9 to 170.3% during the crisis. A similar change can be observed for Ireland (from 27.5 to 106.8), Portugal (from 67.6 to 111.9%), Spain (from 35.5 to 74.4%), and Italy (from 104.7 to 123.6%). The large increase in government debt ratios also occurred in the core EU countries such as Germany (from 65.5 to 82.5%), France (from 66.8 to 90.2%), and the UK (from 42.8 to 85%) and also for other EU countries such as Denmark (from 23.9 to 49%) and Sweden (from 36 to 42.6%).

We observe sharp decreases in GDP levels. The largest average decline is in Greece (− 4.07%). Ireland follows this country with a value of − 1.44% for the period under consideration. For the EU countries in our sample, there is a heterogeneous picture in the current account to GDP values. The GIPSI countries have high deficit values with average values as much as − 11.55% for Greece, − 9.95% for Portugal, − 5.65% for Spain, and − 2.85% for Italy. For this period, we also observe current account surpluses mainly for the core EU countries, such as 6.39% in Germany, 6.72% in the Netherlands, and 3.25% in Austria. Further, large fluctuations exist in the quarterly growth rates of the reserves in the countries that ranges between the minimum and maximum values (e.g., − 22.52% and 117.62% for Ireland). However, the inflation rates remain stable and low for all countries relative to the other macroeconomic indicators in this period. The highest inflation rate is in the UK, followed by Greece and Belgium (3.38%, 3.27% and 2.59% on average, respectively).

Empirical results

This section presents our empirical results using the method laid out in Sect. 3. It starts with a discussion on model specifications, followed by an analysis based on the SAR model. Then we compare the different weight matrices and analyse the effect of a 1-unit shock in a particular country on other European countries through trade linkages. The last part of this section discusses feedback effects and the extent of the indirect effect of the neighbours' government debt on CDS spreads in every European country.

⁷ It might be argued that the time variant weights that depend on trade and financial distances could be endogenous. To deal with this problem we used averages across time for the weight matrix. Then we also used weight matrices constructed by using only the beginning and end of the sample. The results are similar and available on request. Conclusions do not change.



Table 2 Descriptive statistics

Countries	CDS spreads				Reserves growth (%)				Current balance/GDP(%)			
	Average	Minimum	Maximum	Standard deviation	Average	Minimum	Maximum	Standard deviation	Average	Minimum	Maximum	Standard deviation
Austria	79.44	6.5	159.1	45.48	1.26	-27.14	40.03	13.68	3.25	-0.7	9	2.49
Belgium	104.63	16.6	279.83	79.59	4.32	-11.53	64.28	16.19	-0.42	-8.3	9	4.75
Denmark	52.64	6.2	113.85	32.51	6.57	-12.12	37.30	14.68	4.37	-0.5	7.6	2.15
France	66.68	6.8	173.76	50.80	1.75	-25.14	55.51	17.86	-1.56	-2.9	-0.1	0.91
Germany	40.56	4.7	85.37	25.24	2.87	-6.76	36.73	9.26	6.39	4.6	8.5	1.27
Greece	1247.30	34.3	7780.80	2110.02	14.27	-38.92	281.19	70.65	-11.55	-17.6	-3.6	4.47
Ireland	321.61	19.5	832.52	269.35	6.17	-22.52	117.62	30.09	-1.36	-8.3	3.8	3.65
Italy	168.76	24.8	487.34	133.04	3.54	-4.92	26.14	7.19	-2.85	-5.9	-0.9	1.41
Netherlands	46.83	7	100	28.15	5.30	-8.54	66.51	16.92	6.72	1.9	10.8	2.52
Portugal	369.66	24.5	1318.37	412.80	6.09	-23.10	110.30	30.89	-9.95	-14.1	-3.5	3.32
Spain	174.15	23.8	408.06	125.23	7.10	-3.67	46.16	13.56	-5.65	-11.8	-2.7	2.71
Sweden	42.16	6.5	98	23.25	4.217	-23.84	52.71	16.86	6.92	4	11.5	1.80
UK	63.02	11.3	128	30.60	3.48	-12.62	27.59	9.17	-1.66	-3.7	0.5	1.18
					Inflation (%)				GDP growth (%)			
					Average	Minimum	Maximum	Standard deviation	Average	Minimum	Maximum	Standard deviation
Austria	69.27	61.4	74.2	4.43	2.22	0.03	3.72	1.21	0.66	-6.3	5.2	3.31
Belgium	96.06	86.3	103.1	5.33	2.59	-1.21	5.58	1.88	0.57	-4.4	3	2.39
Denmark	39.45	23.9	49	7.617	2.45	0.98	4.15	0.82	-0.92	-7.8	2.6	3.27
France	79.35	66.8	90.2	7.86	1.67	-0.42	3.3	1.09	0.36	-4	3.1	2.27
Germany	74.49	65.5	82.5	5.97	1.56	-0.23	3.08	0.97	0.89	-7.5	5.7	3.99
Greece	134.69	107.9	170.3	19.70	3.27	0.66	5.53	1.58	-4.07	-9.2	0.4	3.31
Ireland	71.90	27.5	106.8	26.73	0.42	-6.1	4.7	3.57	-1.44	-10	4.6	4.29
Italy	115.62	104.7	123.6	6.39	2.16	0.13	3.97	1.12	-1.11	-7.3	2	2.94
Netherlands	59.93	46.3	66.7	6.73	1.85	0.28	3.16	0.76	0.08	-5	3.5	2.55
Portugal	87.51	67.6	111.9	15.15	1.80	-1.51	3.91	1.81	-0.55	-4.1	2.7	2.00
Spain	54.32	35.5	74.4	12.74	2.18	-1.06	4.9	1.77	-0.78	-4.5	2	2.00
Sweden	38.45	36	42.6	1.65	1.76	-1.41	4.28	1.66	1.02	-6.8	8.2	4.84
UK	67.48	42.8	85	14.89	3.38	1.45	4.81	0.98	-0.58	-6.3	2.7	3.16

This table shows the descriptive statistics for the dependent variable and independent variables for the period of 2008–2012



Table 3 Estimations results, 2008Q1-2012Q1, trade linkage

Variables	Fixed effect (1)	IV (2)	SAR (3)	SAR direct effects (3a)	SAR indirect effects (3b)
CAB/GDP	10.77**	6.22	11.00**	11.15**	2.96
GDPGrowth	- 11.68***	- 19.47**	- 11.54***	- 11.64**	- 3.06
GovDebt/GDP	8.24***	11.54***	7.44***	7.47***	1.91*
Inflation	28.87***	23.69	27.59***	27.77***	7.30
ReserveGrowth	- 1.60***	- 3.63**	- 1.58***	- 1.58**	- 0.41
(CAB/GDP) ²	- 1.87***	- 2.15*	- 1.87***	- 1.89***	- 0.49
Dummy	5672.33***	5764.22***	5659.91***	5704.80***	1509.26*
ρ	-	-	0.20***		
R^2	0.91	0.91	0.93		
Log likelihood	-	-	1453.12		
LM spatial lag	3.00*		-		
LM spatial error	0.52		-		
Robust LM spatial lag	2.60*		-		
Robust LM spatial error	0.12		-		
Ho: spatial lag	-		LR: 7.11		
H ₁ : spatial Durbin					
Ho: spatial error	-		LR: 8.79		
H ₁ : Spatial Durbin					

This table represents the estimation results for the period of 2008–2012. The dependent variable is sovereign CDS spreads. On the other hand, current account balance as of GDP, GDP growth rate, government debt as of GDP, inflation rate, international reserves growth rate are used as the explanatory variables. Estimation results for the fixed effect model and instrumental variable model are shown in the first and second column. Third column indicates the results for the Spatial Autoregressive (SAR) model. Direct and indirect effects for the SAR model are shown in the last two columns respectively. Dummy is for the last two quarters of Greece. The ***, **, and * represent significance at the 1%, 5%, and 10% levels

Determinants of CDS spreads and sovereign debt spillovers via trade linkage

Table 3 presents the estimation results of the effect of sovereign debt and other macroeconomic determinants on CDS spreads.⁸ The squared term of CAB/GDP is added to the model to account for the nonlinear relation for this variable.⁹ We use a time dummy variable for Greece for the last two quarters because its CDS spreads diverged strongly from the remaining European countries and reached as high as 7880 bps in 2012:Q1. The CDS spreads are estimated in levels.¹⁰

The literature defines a pooled regression as a restricted form of a fixed-effects model. To test the validity of this

restriction, we perform an LR test. The LR statistic is 131.5 and significant at the 1% level. Hence, we find empirical support for the validity of the fixed-effects model. The results of the fixed effects model are presented in column 1 of Table 3. The table shows that all of the coefficients are significant and their signs are as expected.

To extend the model to SAR or SEM specifications, we use LM tests and robust LM tests that are based on residuals of the model. In these tests, the weight matrix reflects the trade linkage. Both tests provide evidence in favour of the SAR model because they reject the hypothesis of no spatial lagged dependent variable. The LM tests for the SEM specifications do not reject the hypothesis of no spatial auto-correlated error term. No rejection indicates that the SAR specification is more appropriate.

A more general SDM specification adds spatial lagged independent variables to the SAR model. According to the LR test results, we cannot reject the null hypothesis; thus, we do not reject the SAR model in favour of the SDM.¹¹ Accordingly, we adopt the SAR model with fixed effects as our benchmark model.

⁸ According to the panel unit root tests, we found that all of the variables are stationary. The results are available upon request.

⁹ To measure the possible nonlinear effects of the macro variables, we add the squared term of the variables to the models and find only a significant relationship for the CAB/GDP variable. Therefore, our models also include the squared term of this variable.

¹⁰ In the robustness part, we also include alternative estimations by using the first difference of CDS spreads, the natural logarithm of CDS spreads as the dependent variable. Additionally, we conduct our estimations without Greece in order to see the robustness of the coefficients.

¹¹ We also do not reject the null hypothesis that the SDM can be simplified to a SEM.



The spatial autoregressive coefficient ρ in the SAR model is 0.20 and is significant. The significance of this coefficient implies the presence of financial contagion between sovereign CDS spreads in Europe. The relatively low value for the coefficient could be related to the period under consideration. In downturns, the global correlation increases, while the impact of neighbours might become smaller (Asgharian et al. 2013, p. 4749).

As with the fixed effects model (column 1), the coefficients for the SAR model (column 3) are also as expected and significant. While an increase in GovDebt/GDP and Inflation leads to an increase in the CDS spreads, an increase in GDPGrowth and ReserveGrowth decreases the CDS spreads. Because our model specification tests show that the SAR model is more appropriate than the fixed effects model, the coefficients from the fixed effects model might be biased. The coefficients for GovDebt/GDP, Inflation, and the dummy for Greece are 7.44, 27.59, and 5659.91, respectively. The fixed-effects model overestimates these coefficients. The coefficients for CAB/GDP and GDPGrowth are 11.00 and -11.54 , respectively. The fixed-effects model underestimates these coefficients. The coefficients for ReserveGrowth and the squared term of CAB/GDP are -1.58 and -1.87 and are quite similar in the two models. This result indicates that besides sovereign debt, other economic fundamentals have also mattered during the EU debt crisis. Since CDS spreads tend to respond quickly to changes in credit conditions, changes in macro variables are expected to have immediate effects on CDS spreads. On the other hand, changes in CDS spreads may affect macro variables in the longer term. Since our data set is quarterly, we do not expect to confront with the endogeneity problem in estimations. Still, we conduct instrumental variable (IV) estimation as a robustness check in column 2 and obtain a similar result.

Column 3a of Table 3 presents the direct effect estimates. These estimates are different from the coefficient estimates in column 3. The differences are due to the feedback effects. However, these feedback effects are not significantly high. For example, the direct effect of GovDebt/GDP is 7.47, while the coefficient estimate is 7.44. The difference of about 0.03 is the feedback effect. Similarly, the feedback effects are 0.15 for CAB/GDP, 0.10 for GDPGrowth, 0.18 for Inflation, 0.02 for the squared term of CAB/GDP, and 47.89 for the dummy variables, respectively. Furthermore, when we compare the results of the direct effects to the fixed-effects model, we see differences in the marginal effects, especially for the GovDebt/GDP and Inflation variables. While the marginal effect for the GovDebt/GDP variable is 8.24 in the fixed-effect model, the same effect is 7.44 in the SAR model. Similarly, the marginal effect of Inflation is 28.87 in the fixed effects model, while it is 27.77 in the SAR model.

According to the estimates of the direct effects, the estimated coefficient for GovDebt/GDP is positive and

significant as in the study of Dieckmann and Plank (2012). We find that a 1% increase in GovDebt/GDP leads to a 7.47 bp increase in CDS spreads. This result indicates that higher debtor countries have a higher risk premium. At the end of 2012, the Greek public debt to GDP ratio reached as high as 157%. The Troika imposed a package on Greece that included a reduction in the public debt to GDP ratio to 124% as of 2020, or an approximately 30% decrease. According to our estimations, a reduction of 30% in the public debt to GDP ratio leads to a 224 bps decrease in CDS spreads.

The sign of the coefficient on GDPGrowth is negative, in accordance with the study of Afonso et al. (2011). When the growth rate increases by 1%, the CDS spread declines by 11.64 basis points. This value is similar to the values usually found in the literature.

The estimated coefficient for Inflation is positive. This coefficient supports the view that a higher inflation rate leads to higher sovereign risk. Specifically, when the inflation rate increases 1%, the CDS spread increases by 27.77 bps. This effect is the highest amongst the other macro variables.

In our estimations, both the CAB/GDP and its squared term have significant coefficients that indicate a nonlinear relation with the CDS spreads. Similar to the fixed-effect model, the coefficients for the CAB/GDP variables indicate an inverted U-shaped effect for this variable. From the estimated coefficients, we find a turning point of approximately 3%. This turning point means that an increase in the current account balance leads to a decrease in CDS spreads but only after a 3% threshold value in the variable CAB.¹²

The coefficient for the growth in reserves is negative, which is consistent with our expectation. The effect of this coefficient is smaller than the other explanatory variables used in the analyses. A 1% increase in the growth in reserves decreases the CDS spread by 1.58 bps. Finally, the coefficient for the dummy variable for Greece is positive and significant and indicates that the CDS spreads for Greece were 5,704 basis points higher than other countries for the last two quarters (2011: Q4–2012: Q1) in the sample.

Column 3b of Table 3 shows the indirect effect estimates obtained from the SAR model. As far as these are concerned, amongst the macro variables only the GovDebt/GDP variable has significant spatial spillover effects amongst the macro variables. This is in line with the public debate that stressed the role of sovereign debt in the crisis's transmission across European countries. When government debt increases by 1% in one country, the CDS spreads in the other countries

¹² The nonlinear effect of CAB/GDP might be due to the structure of EU countries during the debt crisis. Some countries such as Greece, Ireland, Portugal, and Spain had higher current account deficits in the beginning of 2008 and realised a recovery for this variable. This recovery can be partly explained by the negative growth rates they experienced during this period.



increase by 1.91 bps in total. Specifically, when the government debt of a country increases, it affects not only its own CDS spreads but also other countries' CDS spreads due to the spatial linkages across Europe. Thus, Merkel's warning that "the risks of turning away from Greece now are incalculable. No one can assess what consequences would arise for the German economy, on Italy, Spain, the Eurozone as a whole and finally for the whole world" is important for European debt policy. Our results also indicate that helping Greece might in fact have been the only solution for preventing the Eurozone from an overall financial crisis that might have had a domino effect. The main policy imposed on the GIPSI countries by the Troika was in cutting down the government spending and excessive borrowing.

Related to the other variables that have an effect on one country's CDS spreads, we do not observe any indirect effects on the CDS spreads of other countries. The effects of changes in inflation, growth, growth of reserves, or CAB/GDP on the CDS spreads are mainly through the policy action of the country in question and are limited to that country. This result shows that government debt is a very important policy variable for the EU. The effect of an increase in government debt in one country leads to an increase in the sovereign risk of the other countries. Hence, EU countries cannot be unresponsive to an increase in the government debt levels of their neighbours.

Further, the indirect effect estimate for the dummy variable for Greece is also positive and significant. The sharp increase in Greek spreads for the last two quarters leads to a 1509 bps increase in the CDS spreads of all other countries in total. This sudden sharp increase in sovereign risks cannot be explained by the fundamentals of any country but by the spillover of the risk to other countries within the EU.

Comparison of different linkages

We now extend our model to include two spatial weight matrices (see, Le Sage and Pace 2009, for a similar model). This model enables us to show to what extent the trade linkages capture the spatial dependencies between sovereign CDS spreads. The first weight matrix (W1) will represent the trade and the second one (W2) represents financial or geographical matrices. Now, the SAR model we estimate is:

$$y_{it} = \alpha_i + \rho_1 \sum_{j=1}^N w1_{ij} y_{jt} + \rho_2 \sum_{j=1}^N w2_{ij} y_{jt} + x_{it} \beta + \varepsilon_{it}. \quad (6)$$

The results are presented in Table 4.

According to the second column of the table, the spatial autoregressive coefficient ρ_1 in the model is 0.433 and is significant. This means that the trade channel is active even we include financial linkages. However, the spatial autoregressive coefficient ρ_2 in the model is close to zero (-0.064) and is insignificant. Hence financial linkages are not effective

Table 4 Comparison of different linkages

Variables	Trade-financial	Trade-geographical
ρ_1	0.433**	0.486**
ρ_2	-0.064	-0.111
CAB/GDP	1.02	0.97
GDPGrowth	-9.967***	-9.965***
GovDebt/GDP	8.013***	8.027***
Inflation	25.739***	25.792***
ReserveGrowth	-0.799***	-0.798***
(CAB/GDP) ²	-0.643***	-0.647***
R^2	0.7818	0.7819
Log likelihood	-962.92	-962.90

This table shows the comparison of trade linkages with the financial linkages and geographical linkages. Data limited to period where CDS spreads were under 1000 bps. The ***, **, and * represent significance at the 1%, 5%, and 10% levels

in spillover besides trade linkages. Except for CAB/GDP the coefficients of the remaining macro variables have all similar values to the ones in Table 3 and are significant. In the third column of the table, we replicate the analysis with a geographical weight matrix. Again, the spatial autoregressive coefficient ρ_1 is significant and has a value of 0.486. But the coefficient of the second weight matrix representing the geographical linkages is -0.111 and insignificant. This result provides strong supporting evidence for the use of trade channel.

Spatial transmission of shocks via trade linkages

During our research period, the EU markets witnessed many events with a domino effect. For example, in January 2010, the surprising news about the falsification of the public debt in Greece¹³ led to rapid increases in the CDS values of EU countries at that time. These types of events are unit shocks to the CDS values of the countries through the error term. In this subsection, we show how the effect of an exogenous shock to a country is magnified due to spatial linkages. If an EU country receives a 1-unit shock that increases the error term by one unit, then the CDS value of that country would, by definition, increase by 1 bps with the conventional fixed-effects model. However, with a SAR model, we can analyse how the feedback effects magnify the effect of a shock. Table 5 shows that a 1-unit shock to the CDS spreads

¹³ On 12 January 2010, a report published by the European Commission condemned Greece for falsifying data on public finances. The Commission said the budget deficit and public debt of Greece might be even higher than the government had claimed (<http://www.ft.com/intl/cms/s/0/33b0a48c-ff7e-11de-8f53-00144feabdc0.html#axzz3eRIGYkps>).



Table 5 Average effect of a unit shock to a country

	Trade linkage
Own effect with feedback	1.0054
Average effect on all other countries	0.2492
Total effect	1.2546

This table shows the average effect of a unit shock to a country for the trade weight matrix. In the first row, own effect with feedback is represented and in the second row, average effect on all other countries is shown

in one country increases the CDS spread of that country by more than 1 bps. The increase is 1.0054 bps.

The average indirect effect on all other countries is 0.2492. Further, the sum of the average country effect and the average effect on all other countries gives the total effect. The total effect of a 1-unit shock to the CDS of a particular country leads to a 1.2546 bps increase in the CDS spreads of the other countries through the trade linkages.

To extend the analysis, we present the effect of a 1-unit shock on the CDS spread of a specific country on the CDS spreads of the other countries. Figure 1 illustrates the values obtained from the V_{ij} element of the V matrix given in Eq. (3), where j denotes the country under consideration. With this matrix, we show the important transmission channels for each EU country under consideration. We observe that through trade linkages the effect of a unit shock on core EU countries (the UK, Germany, France, the Netherlands, and Belgium), has relatively more severe effects on other countries. For example, when there is a 1-unit shock to Belgium, the shock affects the CDS spreads of France, Ireland, and the Netherlands mostly around 0.04 bps, respectively. On the other hand, a 1-unit shock to the CDS spreads in France affects the CDS spreads in Belgium, Italy, and Spain by nearly 0.05 bps. As the main creditor country of the EU, Germany affects the other EU countries' CDS spreads by 0.05 to 0.1 bps. The Netherlands affects the CDS spreads of Belgium, Germany, and the UK mostly through the trade linkages with 0.03 and 0.05 bps. Lastly, when there is a 1-unit shock to the UK, the CDS spread of Ireland increases by 0.08 bps. Also, the CDS spreads of Greece are affected by 0.02 bps and the CDS spreads of Sweden increase by 0.03 bps.

When it comes to GIPSI countries, we observe much lower impacts. When there is a 1-unit shock to Greece, the CDS spread of Austria increases by 0.02 bps and that of Italy increases by 0.01 bps. A 1-unit shock to Ireland results in an increase in the CDS spreads of the UK, Belgium with a range of 0.02 to 0.01 bps. A 1-unit shock to Italy increases

the CDS spreads in Greece, France, Austria and Spain by between 0.05 and 0.03bps. A 1-unit shock to Portugal increases the CDS spreads of Spain by 0.02 bps. On the other hand, a 1-unit shock to Spain affects Portugal's CDS spreads the most about 0.08 bps. When there is a unit shock to Austria, then the CDS spreads of Germany increase by 0.02 bps. Further, a 1-unit shock to Denmark leads to a 0.032 bps increase in the CDS spreads of Germany. Lastly, a 1-unit shock to Sweden increases the CDS spreads of Denmark of around 0.046 bps via the trade linkages.

Spatial effects of changes in government debt

This subsection shows how the CDS values of each country changed due to the changes in the government debt to GDP ratio of the EU countries during the crisis. Thus, we measure the role of change in the government debt of the i country, and the other countries in the increases in sovereign risk in the i th country. Table 6 presents the results. The first column of the table gives the change in the government debt to GDP ratio for each country.¹⁴ For the i th country, we multiply these values by the i th row values of the S_{debt} matrix given in Eq. (3). Specifically, we calculate the direct effect of a change in government debt to GDP on the CDS spread for the i th country as:

$$\Delta CDS(Direct)_i = S_{debt,ii} \times \Delta \left(\frac{GovDebt}{GDP} \right)_i$$

and the indirect effect for the i th country as:

$$\Delta CDS(Indirect)_i = \sum_{j \neq i}^N S_{debt,ij} \times \Delta \left(\frac{GovDebt}{GDP} \right)_{ij}$$

We begin by interpreting the results from Ireland, which realised the highest increase in the government debt to GDP ratio (79.3%) during the EU debt crisis. The direct effect of this change on the CDS spread of Ireland is an increase of 591.68 bps via the trade linkages. As the table shows, the increase in government debt of the other countries (the indirect effect) causes a 52 bps increase in the CDS spreads of Ireland. A similar tendency can be observed for Greece as the 62.4% change in the government debt of this country lead to a 464.68 bps increase in its CDSs. On the other hand, the increase in the government debts of the other EU countries is responsible for the 44.01 bps increase in the CDS spread of Greece. A similar evaluation applies to Spain and Portugal, where the direct effect of a 38.9 and 44.3% increase in government debt increase their CDS spreads by 290.16 and 332.33 bps and the indirect effects of 47.90 and

¹⁴ These changes are obtained from maximum-minimum values of GovDebt/GDP in Table 2.



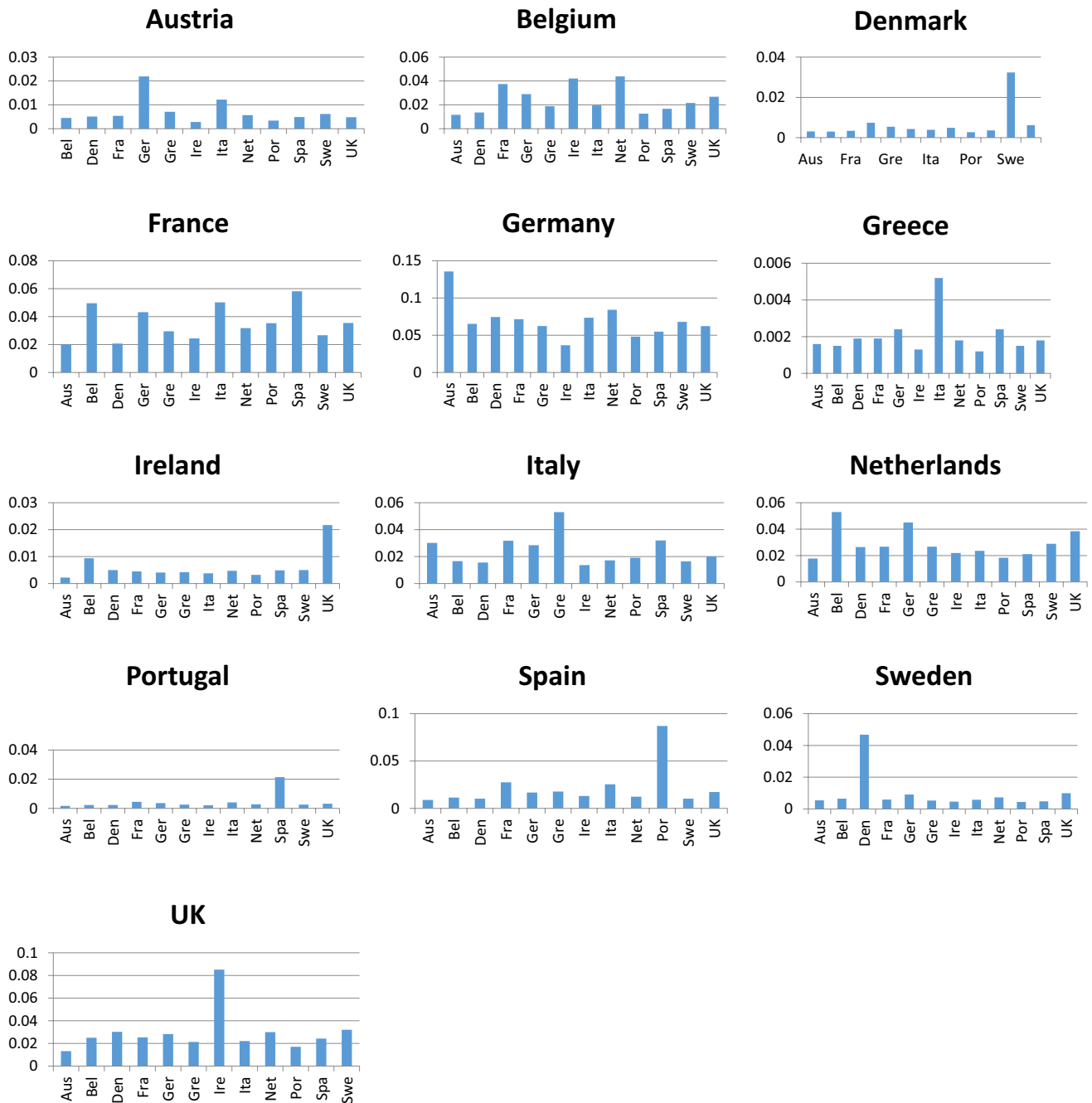


Fig. 1 Spatial effect of a unit shock to a country on CDS spreads of other countries. Figure 1 illustrates the spatial effect of a unit shock to a country on CDS spreads of other countries with trade weight

matrix. For the j th country these values correspond to j th column values of the V matrix given in Eq. (3) for $i \neq j$

51.43 bps also increase in the CDS spreads for these countries, respectively.

For Italy, the contagion effect is much more important. The direct effect of an 18.6% change in the Italian government’s debt is a 141 bps increase in Italian CDS spreads, while the effect from the change in other countries’ sovereign debt is about 46 bps, approximately 30% of the direct effect for this country. The UK also experiences a high increase in

the government debt ratio (42.2%). The direct effect of this change is a 314.96 bps increase in CDS spreads, while only a 49.11 bps increase is due to the increase in the debt ratio of the other countries.

On the other hand, Germany has a relatively low (17%) increase in the government debt to GDP ratio that causes a 128.50 bps increase in the CDS spreads during the crisis. For Germany, we find relatively important indirect effects



Table 6 The effect of change in government debt to GDP ratio on CDS spreads during 2008-2012

	Δ GovDebt/GDP (Direct) (max-min)	Δ CDS (Direct) Trade	Δ CDS (Indirect) Trade
Austria	12.8	95.58	39.17
Belgium	16.8	125.87	46.73
Denmark	25.1	187.25	40.75
France	23.4	175.70	44.64
Germany	17	128.50	44.30
Greece	62.4	464.68	44.01
Ireland	79.3	591.68	52.57
Italy	18.9	141.43	46.49
Netherlands	20.4	153.04	43.45
Portugal	44.3	332.33	51.43
Spain	38.9	290.16	47.90
Sweden	6.6	49.390	46.75
UK	42.2	314.96	49.11

In Table 6, the effect of a change in the government debt to GDP ratio is represented for the trade weight matrix considering the direct and indirect effects. First column shows the the max-min values for the government debt to GDP ratio. The other columns show the possible effects of max-min difference on the CDS spreads including the direct and indirect effects with trade weight matrix. Maximum and Minimum values are obtained from Table 1

from the increase in government debt of other countries (44 bps), which amounts approximately to 34% of the direct effect. Like Germany, the other core Eurozone countries of Austria, Belgium, the Netherlands, and France, and the non-Eurozone countries Sweden and Denmark, experience relatively low increases in the government debt ratio of between 6.6 and 25.1%. The indirect effects of the government debt increases are relatively more responsible for the increases in the CDS spreads of these countries. The indirect effects of the government debt increases on the CDS spreads of these countries are between 39.17 and 51.43 bps, which amounts to between 21 and 94% of the direct effect. For example, in Sweden, the 6.6% increase in government debt has a 49.39 bps direct effect and a 46.75 bps in indirect effect. For Denmark, a 25.1% change in government debt has a direct effect of about 187.25 bps while the indirect effect is about 40.75 bps.

In Sect. 5.1, we find that government debt is the single significant macroeconomic variable through an indirect effect. To evaluate the spillover mechanisms to other countries in more detail, we evaluate the possible effects that might be the result of a 10% increase in the government debt to GDP ratio of a specific country on other countries. In this respect, we calculate the effects of trade linkages on 13 European countries. The results are in Fig. 2.

The values plotted for the j th country correspond to the j th column values of the $10 * S_{debt}$ matrix. For example, when there is a 10% increase in the GovDebt/GDP ratio for Austria, the effect is between 0.5 and 1.6 bps for Germany, Greece, and Italy. One of the core countries, Belgium, affects France, Germany, Ireland and the Netherlands mostly. The effect on the CDS spreads of these countries is between 2.6 and 3.8 bps. For Denmark, the strongest impact is on Sweden CDS spreads. When there is a 10% increase in Denmark's GovDebt/GDP ratio, Sweden's CDS spreads increase by 2.4 bps.

Further, the core EU countries such as France and Germany affect the other countries more strongly. For instance, when there is a 10% increase in the French GovDebt/GDP ratio, the CDS spreads of most of the EU countries increase by as much as 3 bps. Germany also has a big effect on the other EU countries' CDS spreads. In the case of a 10% increase in the German GovDebt/GDP ratio, the CDS spreads of the other EU countries increase between 4 and 6 bps. There is an exception for Austria, whereby the CDS spreads are higher by about 10 bps. When we consider the most struggling countries in terms of public debt, Greece comes first. When there is a 10% increase in the Greek GovDebt/GDP ratio, the effect is less than the other GIPSI countries (under 1 bp except Italy). On the other hand, Ireland affects the CDS spreads of UK and Belgium mostly as much as 1.5 and 0.7 bps respectively. A change in Italian government debts affects the Greek CDS spreads by as much as 4 bps via trade linkages. When we continue with the GIPSI countries, the government debt of Portugal affects the CDS spreads of Spain with a maximum level of 1.5 bps. When there is a 10% increase in Spanish debt, the largest effect is on the CDS spreads of Portugal by about 6 bps. A 10% increase in GovDebt/GDP ratio in the Netherlands leads to an increase in the CDSs of other EU countries by as much as 2-4 bps. Sweden has the largest effect on Denmark (about 3 bps). Lastly, when there is a 10% increase in the GovDebt/GDP of the UK, the strongest effect is on Ireland (6.3 bps)

Robustness analysis

Determinants of CDS spreads and sovereign debt spillovers through financial and geographical linkages

We now examine whether our conclusions are sensitive to financial and geographical linkages. Table 7 presents the results obtained from the SAR model for the financial and geographical weight matrices.

The LR test statistics again point towards the SAR model for the model specification for these weight matrices. In all



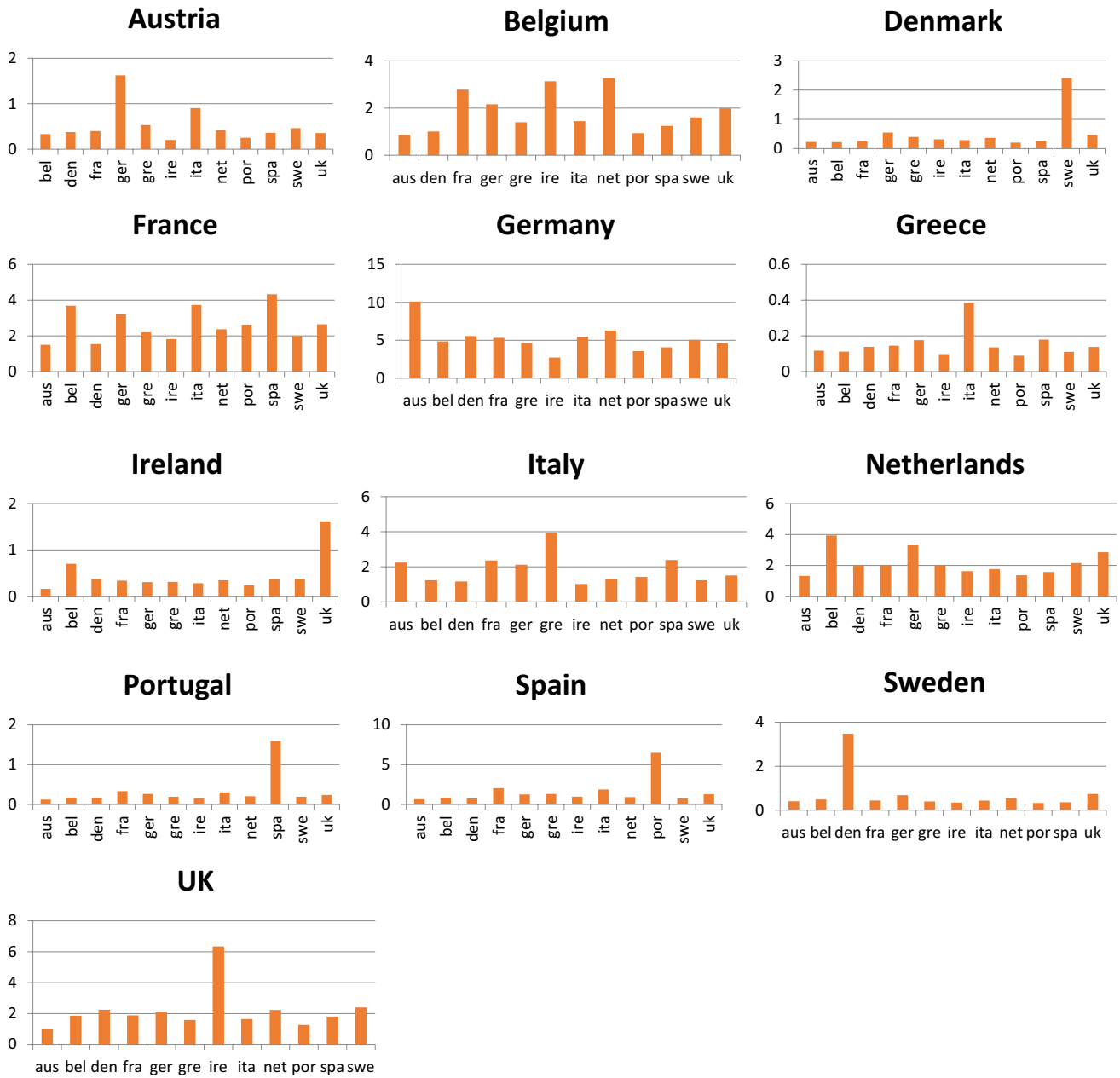


Fig. 2 The impact of a 10% increase on government debt to GDP ratio on CDS of other countries. This figure illustrates the impact of a 10% increase in the government debt to GDP ratio on CDS of other

countries with trade weight matrix. For the j th country these values correspond to j th column values of the $10 * S_{debt}$ given in Eq. 3 for $i \neq j$

of the estimations, the value of the spatial autoregressive coefficient ρ is positive and significant. The largest ρ value is 0.14 for the geographical linkage. This number is lower than ρ value for the trade linkages found as 0.20. These values further indicate that trade linkage is the most important linkage between the 13 EU countries.

Table 7 further shows that the coefficient estimates are quite robust to the type of spatial weight matrix that we use. The direct effect estimates for all of the models are close to the estimates of the model with the trade linkages, and they

are all significant. Also, the significance of these coefficients does not change and similar interpretations are valid for the direct effects of the macro-variables on the CDS spreads.

Further, as before, the only macro-variable that has a significant indirect effect is GovDebt/GDP in all models with different weight matrices. The largest effect of government debt on other countries is through geographical linkages, where the indirect effect is 1.19 which is much lower than 1.91 obtained through trade linkages. This result confirms the importance of the sovereign debt in one country on the



Table 7 Estimation results with different weight matrices, 2008Q1-2012Q1

Variables		Financial	Geographical
CAB/GDP	Direct effect	11.49**	11.12*
	Indirect effect	1.76	1.97
GDPGrowth	Direct effect	- 11.97**	- 11.75**
	Indirect effect	- 1.81	- 2.05
GovDebt/GDP	Direct effect	7.06***	7.17***
	Indirect effect	1.01*	1.19*
Inflation	Direct effect	25.46**	26.10**
	Indirect effect	3.70	4.42
ReserveGrowth	Direct effect	- 1.63**	- 1.62***
	Indirect effect	- 0.24	- 0.28
(CAB/GDP) ²	Direct effect	- 1.89***	- 1.87***
	Indirect effect	- 0.28	- 0.32
Dummy	Direct effect	5676.41***	5689.42***
	Indirect effect	862.14	1,000.13*
ρ		0.12*	0.14*
R^2		0.93	0.93
Log likelihood		- 1452.69	- 1452.58
H ₀ : spatial lag		LR: 7.44	LR: 7.03
H ₁ : spatial Durbin			
H ₀ : spatial error		LR: 9.40	LR: 9.45
H ₁ : spatial Durbin			

This table represents the estimation results for the different weight matrices. Weight matrices show the interaction between the countries and two weight matrices are constructed in accordance with the literature. Dummy is for the last two quarters of Greece. The ***, **, and * represent significance at the 1%, 5%, and 10% levels.

rest of Europe along with the trade linkages. The indirect effect is 1.19 for the geographical linkages which shows that the geographical proximity is also an important channel to transmit the effect of a change in government debt to other countries. Financial linkages have the smallest indirect effect (1.01) in this respect. These results further support our hypothesis that government debt not only affects the movements in one country's CDS spreads but also affects the ups and downs in the sovereign risks of other countries in Europe as well.

Prediction errors

As a robustness analysis, we investigate the prediction errors of our spatial models. We calculate prediction errors as a ratio of the actual CDS spreads to the predicted CDS spreads (Prediction error = y_{it}/y_{it}^p). A prediction error above one is evidence of under prediction. Specifically, the CDS spreads are overpriced if the prediction error is bigger than one. In this respect, we present the prediction errors of our models with trade weight matrices. As can be seen from Table 8, the

Table 8 Prediction errors of sovereign CDS spreads (in-sample)

	2008	2009	2010	2011	2012
Austria	0.27	- 4.57	1.32	0.90	1.15
Belgium	1.96	0.30	0.83	1.33	0.90
Denmark	1.71	1.18	1.69	0.66	0.87
France	0.20	1.15	0.99	0.89	0.89
Germany	0.24	- 0.47	10.95	0.92	0.76
Greece	1.85	0.41	1.24	1.30	1.21
Ireland	0.25	0.18	0.70	1.10	0.87
Italy	0.66	0.54	1.34	1.36	1.25
Netherlands	- 0.17	0.06	2.25	- 1.47	1.14
Portugal	0.55	0.38	1.86	1.03	1.53
Spain	1.20	1.15	0.93	0.85	0.89
Sweden	0.19	0.14	44.46	1.53	0.79
UK	- 3.63	- 7.88	1.08	0.34	0.44

This table shows the prediction errors of sovereign CDS spreads for all the 13 EU countries considering the trade weight matrices. Prediction error = y_{it}/y_{it}^p

CDS spreads of Belgium, Denmark, Greece, and Spain are overpriced in 2008. The errors range from 1.20 to 1.96. In 2009, the CDS spreads of Denmark, France and Spain are overpriced, but the errors are slightly above one. The CDS spreads of Austria, Denmark, Germany, France, Greece, Italy, the Netherlands, Portugal, Sweden, and the UK are overpriced in 2010. The prediction errors range from 1.08 (UK) to 44.46 (Sweden) for this year. For the GIPSI countries in 2011, the CDS spreads are slightly overpriced except for Spain. The prediction errors are between 1.03 and 1.36. For the same year, the prediction errors are 1.33 for Belgium and 1.53 for Sweden. Finally, the actual CDS spreads of Austria, Greece, Italy, Netherlands and Portugal exceed the predicted spreads in 2012 in the models with trade linkages. As summary, we do not systematically observe large prediction errors for the EU countries in our analysis.

Comparison of the alternative models

To provide robustness check, we conduct alternative estimations. Table 9 presents the estimation results. Firstly, we consider the possible effect of the ECB intervention through SMP during sovereign crisis. We add dummy variable for the periods where intensive SMP bond purchases are realised by the ECB.¹⁵ According to the estimation results, dummy

¹⁵ We use time dummy variable for the second quarter of 2010, the third and the fourth quarter of 2011 for this purpose. The effect of the ECB interventions during the EU debt crisis are also investigated in several studies (see, Eser and Schwaab 2016; Roman and Bilan 2012; Saka et al. 2015, for example)



Table 9 Estimation results for different model specifications

Variables	y = CDS in levels			y = CDS in levels (without Greece)			y = Log(CDS)			y = first difference in CDS			y = CDS in levels		
	SAR	SAR direct effects	SAR indirect effects	SAR	SAR direct effects	SAR indirect effects	SAR	SAR direct effects	SAR indirect effects	SAR	SAR direct effects	SAR indirect effects	SAR	SAR direct effects	SAR indirect effects
CAB/GDP	10.91**	11.02*	2.64	8.19***	8.25***	3.46*	0.003	0.004	0.01	0.93	0.87	0.93	11.97**	12.10**	3.27
GDPGrowth	-11.70***	-11.68**	-2.77	-8.75***	-8.92***	-3.71**	-0.04***	-0.05***	-0.12***	-3.28	-3.53	-3.65	-9.93**	-9.91**	-2.66
GovDebt/GDP	7.40***	7.48***	1.75	7.16***	7.31***	2.99***	0.02***	0.02***	0.07***	1.92***	2.05***	2.10**	8.30***	8.40***	2.23*
Inflation	27.49***	27.70***	6.62	28.61***	29.05***	12.06**	0.03**	0.04**	0.11*	2.67	2.76	2.80	11.11	11.15	2.87
Reserve-Growth	-1.57***	-1.55**	-0.37	-0.93**	-0.95**	-0.39*	-0.002***	-0.003**	-0.008**	-0.74***	-0.79**	-0.82**	-1.67***	-1.65***	-0.44
(CAB/GDP) ²	-1.86***	-1.87***	-0.45	-1.49***	1.51***	-0.62**	-0.001***	-0.002**	-0.005**	-0.08	-0.07	-0.08	-1.76***	-1.77***	-0.48
Dummy	5658.56***	5687.55***	1374.60				1.46***	1.77**	4.32***	2748.51***	2916.32***	3027.74***	5558.61***	5593.30***	1525.50*
Dummycecb	9.58	9.14	1.47										13.71***	13.90**	3.81
PrimaryBal/GDP															
ρ	0.19**			0.29***			0.75***			0.52***			0.21**		
R ²	0.93			0.79			0.94			0.91			0.93		
Log likelihood	-1453.0892			-1194.31			-62.5481			-1228.5231			-1449.1457		

This table shows the estimation results considering the ECB policies (SMP interventions), without Greece, with CDS spreads in different forms and with primary balance to GDP variable. In all estimations, trade weight matrices are used. "Dummy" is for the last two-quarters of Greece and "dummeceb" is used for the second quarter (Q2) of 2010, third and fourth quarter (Q3, Q4) of 2011. The ***, **, and * represent significance at the 1%, 5%, and 10% levels



Table 10 Estimation results for different time periods

Variables	The post-crisis period (2012Q2-2019Q3) ^a			The Covid-19 period (2019Q4-2021Q2)		
	SAR	SAR direct effects	SAR indirect effects	SAR	SAR direct effects	SAR indirect effects
CAB/GDP	- 0.53	- 0.61	- 1.37	- 0.31	- 0.33	- 0.28
GDPGrowth	- 6.35***	- 7.43***	- 16.28***	- 0.44	- 0.45	- 0.39
GovDebt/GDP	6.15***	7.02***	15.28***	- 0.88	- 0.89	- 0.79
Inflation	10.62**	12.10*	26.38*	- 6.09	- 6.61	- 6.33
ReserveGrowth	- 0.009	- 0.01	- 0.02	0.26	0.27	0.26
(CAB/GDP) ²	- 0.02	0.03	- 0.07	- 0.006	- 0.007	- 0.006
ρ	0.72***			0.50***		
R ²	0.72			0.76		
Log likelihood	- 1984.0262			- 402.69059		

This table shows the estimation results considering different time periods with trade linkages. The ***, **, and * represent significance at the 1%, 5%, and 10% levels

^aExcluding Greece due to missing observations for the CDS spreads

variable for ECB intervention is not found to be significant. Our results remain robust to inclusion of this variable. Second, we estimate our benchmark model without Greece. As can be seen from the table using data set without Greece we obtain very similar results. The coefficient of GovDebt/GDP is significant and found as 7.17 which is a very close number (7.44) to our result where we used the whole data set.

As an alternative exercise, we use the logarithm of the CDS spreads as the dependent variable. We again obtain very similar estimation results. The sign of the coefficient of variables are the same and found as significant except for the current account balance. When we use the first difference of CDS spreads in our estimations, the coefficient of GovDebt/GDP is still found as positive and significant.

Finally, we include primary balance to GDP variable into regression.¹⁶ As Table 9 reveals, direct effect is found as positive and significant. One can say that fiscal efforts to reduce fiscal deficit may lead to contraction in economic activity in the short run and may lead to an increase in sovereign risk for the European countries during the debt crisis (see, Yuan and Pongsiri 2015, for a similar argument). However, the coefficient of indirect effect is found as positive but insignificant.

Comparison of different time periods

Although the aim of the study is to investigate the impact of macroeconomic fundamentals on CDS spreads via direct and indirect effects during the European debt crisis, we also

¹⁶ Primary balance (surplus), sovereign risk and public debt relations has been investigated in some studies (see, among others, Jiang et al. 2019; Yuan and Pongsiri 2015).

examine validity of our results for different time periods. Table 10 illustrates the estimation results. Firstly, we obtain the estimation results for a period where the sovereign risk was perceived relatively low for the EU countries (between 2012: Q2-2019: Q3). As can be seen from the table, there are still spillovers from government debt to other countries CDS spreads. It is also interesting to note that besides government debt, inflation and GDP growth have also significant indirect effects on CDS spreads after European debt crisis.

Finally, we conduct estimations related to COVID-19 period (between 2019:4-2021: Q2) Limited number of studies examine sovereign risk during the pandemic (see, Augustin et al. 2021 and Cevik and Ozturkkal 2021). The spatial autoregressive coefficient ρ in the SAR model is found as positive and significant implying the presence of financial contagion between sovereign CDS spreads. However, the results reveal no significant direct and indirect effects of macroeconomic variables for this time period. This implies negative shocks like COVID-19 pandemic have a spillover effect among CDS spreads in Europe. However, we could not find empirical support for existence of spillover from one country's government debt to CDS spreads of others for this relatively short time period.

Conclusions

In this study, we estimate a pricing model of sovereign risk based on not only the direct effect of sovereign debt of the country in question but also the indirect effect on its neighbours' sovereign debt. We investigate the indirect spillovers from government debt to CDS spreads for 13 European countries during the European crisis. We use spatial panel econometric techniques for this purpose. We find



trade linkages as an important transmission mechanism of sovereign debt in one country to the CDS spreads of others. We test for other channels of contagion and provide strong empirical evidence for the trade channel.

Our results reveal that government debt has a significant indirect effect. When government debt in a European country increases, the CDS spreads in other countries increase. We show that the effects of our control variables, inflation, growth, growth of reserves, or CAB/GDP on CDS spreads are mainly through the policy action of the country in question, and they do not have an indirect effect on other countries CDS spreads. This result is robust to the specification of different transmission channels.

We further investigate how shocks to the CDS spreads in one country affect the CDS spreads in other countries. We determine the extent of the indirect effect from neighbours' government debt on own CDS spreads in every European country. Our analysis shows that the indirect effects of government debt increases are relatively more responsible for the increase in CDS spreads, especially for the core Eurozone countries. This result indicates that important creditor countries such as Germany cannot isolate themselves from the transmission of a country's risk due to the increase in its government debt. Therefore, they have a vested interest in helping out other countries with sovereign debt problems.

We also find that measuring the indirect effect of the neighbours' government debt via trade linkages helps to reduce the systematically large mispricing of CDS spreads, especially for the periphery countries in Europe. Reducing the mispricing in CDS spreads is important for meaningful policy action to be taken. Our empirical analysis has important policy implications. The EU countries cannot be unresponsive to an increase in government debt levels of their geographical neighbours, trade partners, or countries with close financial ties. An increase in government debt in neighbours has an effect on their own CDS spreads. Enforceable and binding rules on government debt levels and more centralized mechanism of the bailout decisions across Europe are suggested in many studies (see, Beetsma and Mavromatis 2014, among others). Our empirical results support these views through implying that austerity measures for the high debtor countries are required not only to reduce the sovereign risk of those countries, but also the whole of the EU countries.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Code availability Paul Elhorst's Matlab codes are used in this study.

Declarations

Conflict of interests None of the authors has any conflicts of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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