An investigation into feedback and spatial relationships between banks' share prices and sovereign bond spreads during the euro crisis

Heather D. Gibson[a], Stephen G. Hall[b], Pavlos Petroulas[a], George S. Tavlas [c,*]

[a] Bank of Greece, Greece
[b] University of Leicester, U.K., Bank of Greece, Greece, and University of Pretoria, South Africa
[c] Bank of Greece, Greece, and Hoover Institution, Stanford University, USA

* Corresponding author. Email: gtavlas@bankofgreece.gr

Abstract

We examine (1) spillover effects between euro-area sovereigns and banking systems within national jurisdictions and (2) cross-country spillovers among ten countries during the euro-area crisis. We find that cross-country spillovers substantially amplify the doom loops between the sovereign and banking sectors. We also provide a test that supports the hypothesis that cross-country spillovers among southern-euro-area countries were of a different order from the spillovers among northern-euro-area countries. Our results also imply that, if shocks are idiosyncratic, spillover effects may help in reducing the impact for northern countries.

JEL classification: E3; G01; G21

Keywords: Euro area crisis; doom loops; cross-country spillovers; spatial estimation

1. Motivation

A key characteristic of the euro-area crisis was the macro-financial loops between sovereigns and banks. In Greece, Ireland, Italy, Portugal, and Spain, deteriorations in sovereign creditworthiness, reflected in rises in interest-rate spreads,[1] reduced the market value of banks' holdings of domestic sovereign debt and led to deteriorations in banks' balance sheets (Brunnermeier et al., 2017, Gibson et al., 2017).[2] As a result, banks' capital positions weakened and banks curtailed their lending, contributing to deteriorating economic conditions and worsening governments' fiscal positions. Often, distressed, poorly-capitalized banks reacted to sovereign stress by purchasing still-more public debt, influenced by a search for yields (Altavilla et al., 2017).[3] These various effects -- rises in spreads, deteriorating balance sheets of banks, reductions in banks' lending, deteriorating economic conditions, and worsening fiscal positions, were self-reinforcing, a circumstance referred to as the sovereign-bank "doom loop." The self-reinforcing process was contagious across the crisis countries as a worsening crisis in a single country typically was transmitted to other countries.

There were several reasons for the strong interconnections between banking systems and fiscal positions during the euro area crisis (Shambaugh, 2012, Pisani-Ferry, 2013). The first reason relates to the size of the banking sector in the euro area, which is very large. Therefore, fiscal support for that sector often put large strains on governments' finances. As an example of the relatively-large size of the euro-area banking sector, at the peak of the crisis in 2012, total bank assets as a share of euro area GDP amounted to 360 per cent compared with less than 80 per cent for the United States. Second, banks play a much more important role in the financing of firms in the euro area than is the case for the United States;

about three-quarters of total credit intermediation in the euro area is accounted for by the banking sector, compared with about one-quarter in the United States. Consequently, declines in bank lending have larger effects on economic activity in the euro area than in the United States. Third, although the largest banks in the euro area and the United States are of roughly the same size relative to euro area GDP and US GDP, respectively, the largest euro area banks represent a much larger share of any euro area national economy compared with the situation of US banks. This circumstance implies that the fiscal consequences of euro area bank failures could be large enough to bring state solvency into question (Pisani-Ferry, 2013, p. 9). Fourth, domestic euro area banks typically hold relatively large shares of debt issued by their respective national governments in their portfolios, leaving the banks' balance sheets vulnerable to doubts about sovereign solvency. In contrast, US banks typically hold small amounts of local and state debts on their balance sheets; US banks mainly hold US government debt as their ''safe'' liquid assets. Consequently, defaults by US state and local governments have not involved a systemic risk to the US financial system (O'Rourke and Taylor, 2013, p. 181). In the absence of a euro area safe asset, and, until 2015, a euro area banking union, banks in the crisis countries were exposed to the weaknesses of their sovereigns.

Previous work on the impact of the euro-area crisis on financial markets has focused on (a) the determinants of sovereign bond spreads (or yields) in individual euro-area countries -- see, for example, Annaert et al. (2013), Aizenman et al. (2013), Gibson et al. (2014), Schnabel and Schumer (2017), Böhm and Eichler (2020) and Pamies et al. (2021) -- and (b) the inter-linkages between measures of sovereign distress and measures of banks' performance in individual euro-area counties using either single-equation or simultaneous-equations' specifications -- see for example, Kallestrup et al. (2016), Gibson et al. (2017), and Altavilla et al. (2017). A general result of this latter literature on inter-linkages is that sovereign stress and banks' performance within countries are subject to amplification effects: taking account of the inter-linkages between the sovereign and banking sectors during the euro-area crisis helps account for the large deteriorations observed in both sectors -- over-and-above the effects of other explanatory variables.

Research on the cross-border effects of the crisis, however, is much harder to come-by. Beetsma et al. (2013) used single-equation estimation to examine whether the amount of news on economic, financial, political, and institutional variables in a particular euro-area country affected spreads in other euro-area countries. Those authors found that there were cross-country spillovers between news (that is, developments) in a particular country and spreads in other countries. Altavilla et al. (2017) used single-equation specifications in which the growth of loans by banks in a given country were shown to be affected by the price change of sovereign debt in foreign countries. Bahaj (2020) examined the effects of foreign shocks on euro-area sovereign spreads using a VAR framework. Bahaj found that foreign shocks were an important driver of sovereign spreads during the euro-area crisis. To our knowledge, no previous study has examined the cross-border effects of the doom-loop phenomenon in euro-area sovereign-bond markets and banking sectors.[4]

This paper extends previous work on the euro-area crisis. In addition to examining the spillover effects between sovereigns and banking systems within national jurisdictions, we empirically model the cross-country spillovers in the sovereign-bond and banking sectors among all the countries in the sample. To implement our estimation, we use a spatial autoregressive procedure based on systems of simultaneous equations. The procedure is applicable to both cross-sectional and panel data. As we show, it is a natural way to model spillovers between economic units that are inter-connected across space and time. To anticipate, we find that accounting for inter-linkages between sovereign-bond spreads and banks' share prices amplifies the effects resulting from the treatment of the sovereign-bond markets and banking sectors separately -- that is, we confirm the doom-loop phenomenon.

Additionally, however, we find that cross-country spillovers further amplify the doom loops of national jurisdictions.

The remainder of this paper consists of four sections. Section 2 discusses the spatial procedure that we use. Section 3 describes our data. Section 4 presents the empirical specifications and the results. Section 5 concludes.

2. The spatial model

The measures of sovereigns and banks that are appropriate for the macro-financial loop are for the former: country specific spreads versus U.S. Treasury bonds, while for the latter we utilize an index of bank share prices for each country. We consider this to be an encompassing measure of the banking system which reflects all available information at each point in time.[5]

We consider four models of increasing complexity and realism to explain sovereign spreads and changes in banks' share prices in the ten euro-area countries that comprise our data sample: Germany, France, the Netherlands, Belgium, Austria, Greece, Italy, Spain, Portugal and Ireland. Notice that our sample includes five countries -- Greece, Italy, Ireland, Portugal, and Spain -- that underwent significant stress during the crisis, and five countries – Austria, Belgium, France, Germany, and the Netherlands -- that were less affected. The four models are as follows.

1) We begin with single-equation estimation of the two dependent variables. Specifically, each dependent variable is modeled as a function of variables that might be expected to affect sovereign spreads and changes in banks' share prices in each country separately. These are the economic fundamentals.
2) In light of the feedback effects between the two dependent variables during the euro-area crisis, we allow for simultaneous interactions between those variables. In model (2), the simultaneous interactions take place within a single-country setting. That is, what happens to sovereign spreads in country A affects changes in banks' share prices in that country; likewise, what happens to changes in banks' share prices in country A affects sovereign spreads in that country.
3) We allow for interactions among the countries considered. That is, within the simultaneous equation setting of the second model, we allow, in addition, for cross-border effects -- what happens to spreads and the change in banks' share prices in country A affects all countries other than country A in the sample in an equal way. And what happens in other countries affects spreads and the change in banks' share prices in country A.
4) In recognition of the fact that feedback effects among groups of countries during the euro-area crisis were not symmetric -- the feedback effects among southern euro-area countries appeared to have differed from the feedback effects among the northern euro-area countries -- we allow for the possibility that cross-country interactions differ among the northern and southern euro-area countries. At a minimum, we would like to test the restriction that feedback effects within the southern group of countries were essentially the same as feedback effects within the northern group of countries. We will propose a way of testing that restriction.

Models (3) and (4) employ spatial estimation. In light of the fact that spatial modeling is a recent development, we now provide an overview of spatial estimation.

Spatial autoregressive (SAR) models were introduced by Cliff and Ord, 1973, Cliff and Ord, 1981. These models work in either a cross-section or a panel setting. They differ from more standard models in that they allow for direct interactions among the cross sectional elements of the analysis. For example, in the case of the application investigated in this study, consider the determinants of changes in banks share prices. In a standard model, we would investigate the impact of a range of country specific factors on changes in bank share prices in, say, country A. Indeed, this is precisely what we do in our first (single-equation) and second (simultaneous-equation) models. In a spatial model, we also allow bank share prices in other countries to affect bank share prices in country A. This gives rise to a potentially very complex set of interactions.7 Most of the spatial literature has confined itself to single equation analysis but recent work has extended the spatial framework to the estimation of simultaneous systems of equations.

The application of the simple equation spatial autoregressive model, or SAR, to a simultaneous equations framework is called the SESAR, or simultaneous equations spatial autoregressive model. Work in this area began with Kelejian and Prucha (2004); it was subsequently extended by Baltagi and Pirotte (2011), Yang and Lee (2017) and Liu and Saraiva (2019)[7] The SESAR model has been applied to both cross section and panel data; it is a natural way to model spillovers between economic agents who are interconnected across space.

The general SESAR model for t periods and m cross-section observations may be stated as:

$$Y_{tm}\Gamma_m = W_t Y_{tm}\Lambda_m + X_t\Phi_\mu + u_{tm} \tag{1}$$

where Y_{tm} is a $t * m$ matrix consisting of m endogenous variables over t periods. Γ_m is an m*m matrix which reflects the simultaneous effects in the off-diagonal elements, where the diagonal elements are normalized to unity. W_t is a $t * t$ matrix that summarizes the spatial interactions and is assumed to be known. Λ_m is an $m*m$ matrix of parameters for the spatial effects. X_t is a $t * k$ matrix of k exogenous variables. Φ_m is a $k * m$ matrix of parameters on the exogenous variables. Finally, u_{tm} is a matrix of $t * m$ errors which are assumed IID with zero mean and covariance matrix Σ_{im} for $i = 1 \ldots t$. Notice that the model incorporates simultaneity effects, own-variable spatial effects, and lagged dependent variables as explanatory variables, while allowing for correlation between disturbances across equations (Yang and Lee, 2017, p. 196).

Kelejian and Prucha (2004) developed a two stage least squares (2SLS) estimation approach and a three stage least squares approach (3SLS) for cross section models. Baltagi and Deng (2015) extended this model to a panel data setting with random effects and derived the appropriate 3SLS estimator; Baltagi and Bresson (2011) used a maximum likelihood approach (QML). In an important paper, Yang and Lee (2017) established the conditions for identification of these models and the consistency and asymptotic normality of the QML estimator. Liu and Saraiva (2019) proposed a GMM estimator for this model and also established the identification and conditions for consistency and asymptotic properties. In this study we use a GMM estimation strategy with hetero and auto-correlation corrected standard errors.

3. The data and the results

As mentioned, model (2) -- that is, the model with simultaneous interactions between the dependent variables -- is a two equation system. The dependent variables are the percentage change in banks' share prices and sovereign spreads. Banks' share price is the share price index for banks quoted on the particular country's stock exchange. These data are from Thomson Reuters Datastream. Spreads are defined as the difference between the yield on 10-year government bonds in each country relative to the comparable yield on U.S. Treasury bonds. These data are from the ECB Statistical Data Warehouse.

Fig. A1, Fig. A2 (in the Appendix) show the behaviour of sovereign spreads. Fig. A1 reports spreads of the southern countries. As shown in that table, spreads of Greek sovereigns peaked at over 25% points in late-2011 and early-2012 (right-hand scale in the figure). Movements of spreads in other southern countries mirrored those of Greece, but were of a lesser magnitude (left-hand scale in the figure). Fig. A2 reports spreads in the northern countries; both movements and magnitudes were very similar, and of a smaller order in terms of magnitudes compared to the south. Why do we use the percentage change in banks' share prices instead of the level of that variable? When estimating any panel data model, it is important that the variables are scaled in a common way across the panel. If this is not done, the pooling assumption would be violated and panel data estimation would not be possible. In our sample, sovereign spreads are all measured in a similar metric across all countries. However, there is no reason why the *level* of banks' share prices among countries should be scaled in a similar way. Therefore, we use the change in the log of banks' share prices in order to achieve scaling compatibly.[8] Fig. 1, Fig. 2 below make clear that the percentage change in banks' share prices are of a similar order of magnitude across our sample of countries.

Our sample consists of a balanced panel for the ten euro-area countries mentioned earlier. The data are monthly over the period January 2000 to April 2019. To model bond spreads and the change in banks share prices, we proceeded as follows. For bond spreads, we began by replicating the basic model of Gibson et al. (2017). Those authors estimated a simultaneous-equation model, without spatial effects, of bond spreads and banks' ratings for five euro-area crisis countries.[9] They used monthly data covering the period January 2001 through March 2013. The authors found that the following country-specific variables determined bond spreads in the five countries considered: real GDP growth; the current account-to-GDP ratio; relative (consumer) prices (a measure of competitiveness) between the country concerned and Germany; a variable measuring political uncertainty in the country concerned; and a variable measuring "fiscal news" (essentially whether announced fiscal outcomes were better or worse than expected).

Some studies have found that ECB actions were key elements that reduced spreads during the euro-area crisis – see, for example, Ait-Sahalia et al. (2012), Moessner (2015), and Altavilla et al. (2016), and Gibson et al. (2021). Following Gibson et al. (2021), we examined two intervention variables in our basic specification for sovereign spreads: (1) ECB President Mario Draghi's announcement in July 2012 that the ECB would do whatever it takes to preserve the euro and (2) the announcement in January 2015 that the ECB would conduct asset purchases of sovereign bonds.[10]

Our estimation procedure was as follows. We started with a model with seven possible determinants of bond spreads: the five economic variables in the Gibson et al. (2017) model and the two ECB announcement interventions in Gibson et al. (2021). Each of the seven variables was initially entered into the equations for both sovereign spreads and the change in banks' shares prices. The equations were then pared-down in a general-to-specific exercise. Four of these variables were found to be correctly signed and significant determinants of bond spreads for the ten-country sample over the estimation period used in this study: real GDP growth, the current-account-to-GDP ratio and the two ECB interventions. In summary, the following variables are used in the specifications for sovereign bond spreads:

- *Real GDP growth.* Higher growth helps to keep fiscal imbalances under control and, in particular, improves debt sustainability. Thus, we anticipate that higher real GDP growth will be associated with lower spreads (a negative coefficient). As discussed below, this variable was entered in both the equation for spreads and the equation for the change in banks' share prices. The GDP data are from Thomson Reuters Datastream.

- *The current account balance as a percentage of GDP.* Current account deficits are often a sign of weakening macroeconomic conditions; this was especially the case during the euro-area crisis included in our estimation period. An increase in the current account balance (either a fall in the deficit or a rise in the surplus) is expected to reduce spreads. The current account data are from Thomson Reuters Datastream.
- *Draghi's announcement in July 2012 that the ECB would do whatever it takes to preserve the euro.* This variable was found to be significant as a shift dummy.
- *The announcement in January 2015 that, starting in March 2015, the ECB would conduct purchases in euro-area sovereign bond markets.* This variable was found to be significant.

For the determination of the change in banks' share prices, the variables used were:

- *Banks' returns.* We use pre-tax operating income divided by average total assets. This provides a measure of banking system profitability. Since profits can, if retained, generate internal capital, which covers unexpected losses, a rise in profitability would be expected to have a positive effect on the change in banks' share prices. These data are from Thomson Reuters Datastream.
- *Banks' debts (net issues of long term and short term debt) relative to banks' assets.* This variable is a measure of inter-bank dependence. To generate fundings, banks typically issue deposits and they borrow in the interbank market. This variable measures the use of debt, relative to banks' assets. The more debt that banks' issue relative to their assets, the less their ability to withstand shocks. Thus, the sign of this variable would be expected to be negative. These data are from Thomson Reuters Datastream.

We begin by setting out the basic fully general form of our model. The four stages will then be shown to be restrictions on this general model. The general form is the following.

$$\begin{aligned} bond_{it} &= c_{11} + c_{12} * d(\log\ SP_{it}) + c_{13} * d(\log\ GDP_{it}) \\ &+ c_{14} * CA_{it}/GDP_{it} + c_{15} * Draghi + c_{16} * 2015DUM \\ &+ c_{17} * bond_{it-1} + c_{18} * W_1 * bond_t + c_{19} * W_2 * bond_t + \varepsilon^1{}_{it} \end{aligned} \quad (2)$$

$$\begin{aligned} d(\log\ SP_{it}) &= c_{21} + c_{22} * bond_{it} + c_{23} * (return_{it}/asset_{it}) \\ &+ c_{24} * (debt_{it}/asset_{it}) + c_{25} * d(\lg\ dp_{it}) \\ &+ c_{26} * d(\log\ SP_{it}) + c_{27} * W_1 * d(\log\ SP_t) + c_{28} * W_2 * d(\log\ SP_t) + \varepsilon^2{}_{it} \end{aligned} \quad (3)$$

where bond is the sovereign bond spread in each country, d(log SP) is the change in the log of banks share prices, d(log GDP) is the growth rate of real GDP, CA/GDP is the ratio of the current account to GDP, Draghi is a dummy variable for the July 2012 announcement by the then-President of the ECB for what the markets (correctly) perceived to be unconditional support for the euro, and 2015DUM is a spike dummy for the January 2015 announcement of large scale interventions in the sovereign bond markets by the ECB. W_1 and W_2 are spatial weighting matrices such that, when only W_1 is present, it interacts all 10 countries with equal weights; when both W_1 and W_2 are present, the southern countries interact through W_1 and the northern countries interact through W_2, but there is no spatial interaction between the two groups. Finally, as mentioned, the banks' share price equation includes the variables (1) return/asset, which is the ratio of banks share price returns to total bank assets and (2) the debt/asset ratio which shows the ratio of total bank debts to assets. For the banks' share price equation, we also found that a country's real GDP growth rate was significant and correctly signed.

Given our strategy of moving from separate equations to increasingly complex interactions we move through the following sets of restrictions, corresponding to our four models.

1. $c_{12} = c_{18} = c_{19} = c_{22} = c_{25} = c_{26} = 0,$ so that there are no interactions
2. $c_{18} = c_{19} = c_{25} = c_{26} = 0,$ which allows for simultaneity
3. $c_{18} = c_{25} = 0,$ which allows for one spatial weighting matrix which interacts all countries
4. No restrictions, which means that the north and south interact with different weighting patterns.

3.1. The basic results

Given that the cross section element of our data is relatively small, we approach estimation in a novel way compared with the usual estimation procedure. We set up the system explicitly as a 20 equation simultaneous system and estimate it with standard system estimators.[11] There are a number of advantages to this setup -- for example, the possibility of estimating fixed effects and an increased flexibility in the model specification which allows for the inclusion of dynamics. Additionally, it is also possible to consider standard diagnostics on individual equations. This setup uses a slightly different instrument set than what is common in SESAR models.[12] The empirical results for the models (1) to (4) are reported in the four columns, respectively, of Table 1.

Table 1. The four sets of estimates.

	Separate equations	Simultaneous system, no spatial	Simultaneous system, with spatial	North-South spatial
		Spreads		
GDP growth	-1.1(28.7)	-0.37(12.5)	-0.35(9.4)	-0.2(5.4)
Current account/GDP	-.002(34.9)	-0.004(49.1)	-0.004(44.9)	-0.002(21.1)
Draghi dummy	-0.1(51.5)	-0.09(7.9)	-0.09(37.7)	-0.1(41.0)
2015 dummy	-1.3(7.7)	-0.93(7.9)	-0.91(7.5)	-0.95(8.5)
Lagged spreads	0.98(2204.1)	0.97(2319.1)	0.97(2231.0)	0.96(1307.4)
Spatial effect	–	–	0.004(6.7)	0.03(60.6)
Spatial north	–	–	–	–
Bank share prices	–	-1.9(174.2)	-1.9(177.5)	-2.0(148.4)
		Banks' share price		
Return/asset	0.0003(19.5)	-0.00007(4.4)	0.0002(21.1)	0.0002(20.8)
Debt/assets	-0.25(10.5)	0.003(2.5)	-0.02(18.1)	-0.03(24.1)
GDP growth	0.45(22.5)	0.41(21.3)	0.10(6.6)	0.12(6.8)
Spatial effect	–	–	0.96(309.7)	0.85(192.7)
Spatial north	–	–	–	0.98(278.6)
Lagged banks' share price	0.05(37.0)	0.007(2.0)	-0.02(18.2)	-0.008(8.3)
Spreads	–	-0.0046(51.8)	-0.002(39.3)	-0.001(25.9)

GMM estimation with HAC corrected standard errors. 't' statistics are in parentheses

The first column of Table 1 is the basic specification with no simultaneous effects and no spatial effects. To interpret the coefficients, consider an increase in the GDP growth rate; an increase in a particular country's GDP growth rate of 1% will reduce sovereign spreads by.011 basis point in that country as a direct impact effect. The impact will, of course, grow over time due to the lagged dependent variable. A similar increase in GDP will increase the growth of commercial banks' share prices by.0045% point. Because the dynamic term in the equation for the change in banks' share prices is very small, there would be little further effect on share prices. It is notable that there is a very strong dynamic effect in the spreads equation but not in the equation for banks' share prices. This finding also holds for the other three models.

We next introduce simultaneous interaction between spreads and share prices. The results are shown in column 2. We find that the dependent variables inter-react in a negative way, that is an increase in banks' share prices is positive news and tends to reduce spreads, and an increase in spreads is negative news and tends to reduce banks' share prices. In the equation for banks' share prices the ratio of debt to assets takes the wrong (positive) sign, but apart from this variable, all other coefficients remain correctly signed and are significant. The coefficient on GDP in the spreads equation falls to − 0.37 (from 1.1 in column (1)), which means the impact effect of a 1% increase in GDP on spreads would fall to.0037. In the bank share price equation, the coefficient on GDP falls only a small amount to.41 (from.45 in column (1)) which would give an impact effect of.0041.

The third column introduces a single spatial effect into both equations. The debt-to-asset ratio returns to the correct (negative) sign; all other variables are correctly signed and significant. There are highly-significant spatial effects in each equation. In interpreting the size of the spatial effect it is important to bear in mind the interaction with the dynamic effect; if the sum of the spatial and dynamic effects were greater than 1, the model would be unstable. So, in the spreads equation there is a large dynamic effect (0.97) but a very small spatial effect (0.004), with the sum of the coefficients less than one. As the dynamic effects work through the system, the total impact of the spatial effect will become larger. The sum of the coefficients is below unity in both equations. In the share price equation, there is a very small, and negative dynamic effect. The spatial effect is very large, with a coefficient of.96. Again, the coefficients on GDP growth fall somewhat from the previous case. In the spreads equation the coefficient falls by a small amount, to − 0.35, meaning the direct impact of a 1% rise in GDP would be a fall in spreads of − 0.0035 basis points. It falls somewhat more in the bank share price equation to .1, giving a direct impact effect of .001.

Finally, in the fourth column we allow for the possibility that spatial effects are different in the north and the south. In this case, for sovereign spreads we find no spatial effects in the north but significant spatial effects in the south, with the effect becoming stronger in the long run. That is, we find no cross-country feedback effect in sovereign spreads among the five countries of the north. The coefficient on the spatial term for the south is small -- at .03 -- but its impact has to be interpreted in light of the large coefficient (0.96) on the lagged dependent variable. Our analysis below of the effects of shocking the system will show the implications of the interaction between the spatial term and the lagged dependent variable.

In the case of banks share prices we find strong spatial effects in both the north and the south -- for the short run and for the long run -- with the effect being somewhat stronger in the north than the south (0.98 for the north versus .85 for the south). This finding suggests that there are differences in the degree of integration of the banking systems between the north and the south, with the banking systems in the north being more integrated. Again the coefficient on GDP in the spreads equation falls to − 0.2 giving an impact effect of a rise in GDP of 1% of − 0.002. In the bank share price equation there is very little change from the previous case.

To further investigate the difference in the integration between the banking systems in the north and south, consider Fig. 1, Fig. 2. The figures report changes in banks' share prices in each of the five southern euro area countries relative to italy and each of the five northern euro area countries relative to Germany, respectively. The figures suggest a higher degree of correlation of share-price movements among banks in nothern countries than in southern countries -- but this inference in subjective. In particular, note that the scale of the two figures is different, with the south having a much larger scale than the north.

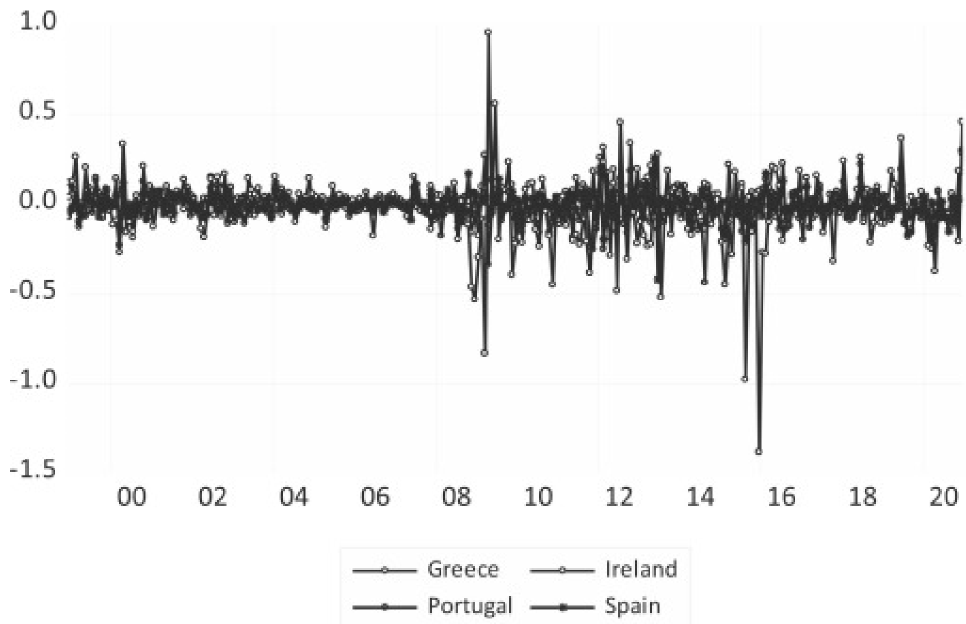

Fig. 1. Movements in the share price of the southern euro area countries relative to Italy.

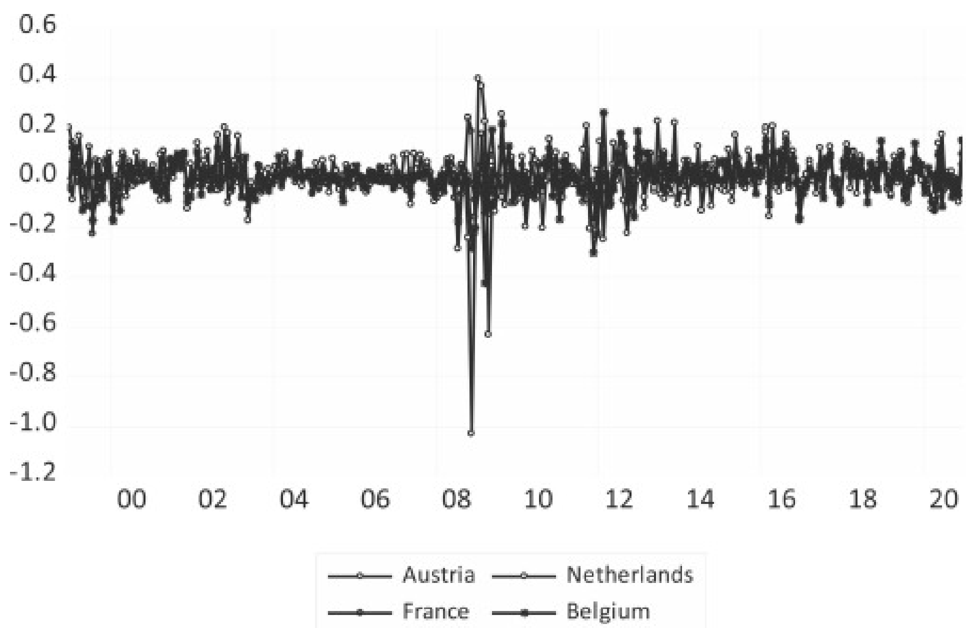

Fig. 2. Movements in the share prices in the northern euro area countries relative to Germany.

To provide an objective measure of the degree of similarity between each group we applied principal components to each group. The degree to which the first principal component explains the variation of banks' share prices in the countries considered can then be taken as a measure of how closely the banks in each country group move together. For the northern banks, the first principal component explains 75.5 per cent of the total variation in each group. For the southern banks, the first principal component explains 66.4 per cent of the variation. These results suggest that the northern banking sectors are more closely integrated than the southern ones. This circumstance is reflected in the larger spatial coefficients in the equaltions for banks' share prices.

Our finding of spillover, or spatial, effects are consistent with the theoretical results that might be expected from a DSGE model. Thus the finding that there are spillovers inside the north would naturally come from input-output relationships inside the north where production is highly integrated. The spillovers inside the south could reasonably come from contagion, as say recession in one country creates fears of euro exit, spurring similar fears in other southern countries. Finally, the weakness of north-south spillovers can be accounted for by the offsetting roles of monetary policy and trade competitiveness, as shown in recent work by Minford et al, (2022). Thus, their estimated DSGE model implies that a positive demand shock in the north raises output directly in the south via trade but this rise is offset by higher euro interest rates reacting to higher euro demand/inflation; the net effect is small. A positive supply shock, e.g. to productivity, in the north, also raises south output via trade, but now the lower inflation in the north combined with the higher inflation in the south lowers north competitiveness vs. south, so reducing south output; again the net effect is small. Similar points apply to the north when the shocks originate in the south.

3.2. Testing the weighting matrices

The above coefficients for the effect of GDP across the four models may give the impression that the effect becomes smaller as we move from the simpler model to the more complex models. This direct effect, however, does not allow for the multiplier effects, which initially stem from the simultaneity and subsequently from the spatial interaction. Our conjecture is that the effects should become larger as the full interactions of the model are taken into account. To examine this conjecture, we performed a set of full-model experiments, which we discuss below. But, first we turn to the issue of the two weighting matrices and an approach to choose between the two cases.

One issue that has, to date, received little attention in the literature concerns the selection between different spatial weighting matrices. In the standard spatial model, the weighting matrix is usually based on either distance (or sometimes inverse distance) or contiguity, that is, whether countries or regions share a border. However, researchers have also used an assortment of other spatial weighting matrices, based on such ideas as institutional similarity (Ahmad and Hall, 2017). This circumstance creates a need for a method to choose between (or among) a set of possible spatial weighting matrices. Dray et al. (2006) propose a method to choose among a range of matrices based on an Akaike information criterion, but this has proved to have poor performance outcomes (Bauman et al., 2018a). Bauman et al. (2018b) propose a method for selecting one optimal weighting matrix based on R^2 but this method only allows for the use of one weighting matrix. That is, we have a range of possible models, each with one spatial weighting matrix. However, previous testing approaches attempt to choose the best model between these options. However, this does not allow for the possibility that there could be more than one weighting matrix in the best model. In this section, we draw on a recent suggestion by Hall and Tavlas (2022), which proposes a new simple test, based on the encompassing principal developed by Hendry and Richard (1982) to test between two or more weighting matrices with the allowing for the possibility that the appropriate model contains more than one weighting matrix.

We now have two possible descriptions of the spatial spillovers within the euro area: one treats all countries in the euro area equally, and the other treats the north and the south separately, so that the north only interacts with the north and the south only interacts with the south. The above results suggest that the spillovers in the two regions are quite different, and we would like to test this hypothesis. We therefore propose a simple way of testing one weighting matrix against another. Consider a general single equation spatial model of the following form.

$$Y = \beta X + \gamma W_i Y + \varepsilon \tag{4}$$

where Y and X are panel data variables involving t observations on n cross sections variables and the W_i are a number of possible weighting matrices. For simplicity of exposition we will consider the case where there are two competing matrices. Thus, the model becomes:

$$Y = \beta X + \gamma_1 W_1 Y + \gamma_2 W_2 Y + \varepsilon \tag{5}$$

We wish to test the hypothesis that only the first weighting matrix is important, that is $H_0: \gamma_1 \neq 0 \; and \; \gamma_2 = 0$ against $H_1: \gamma_1 \neq 0 \; and \; \gamma_2 \neq 0$. We can test this by reparameterising the equation as:

$$Y = \beta X + \gamma_1 W_1 Y + \gamma_3 (W_1 - W_2) Y + \varepsilon \tag{6}$$

If γ_3 is significantly different from zero, we would reject the null hypothesis. This may be thought of a test that W_1 encompasses W_2; it may, of course, be reversed as a test that W_2 encompasses W_1. It could also be possible to find that neither weighting matrix encompasses the other, in which case both are relevant to the general model. In our case, we do not need to be concerned about this possibility, since the entire euro area weighting matrix is a special case of the two separate euro area weighting matrices.

Here, we have a two equation system, but our discussion so far has focused on the case of a single equation. However, this easily generalizes to the case of a number of equations simply by replicating the above process for each equation. In our case, this will give two tests statistics, one for each equation to test whether the single euro area wide matrix is appropriate for each equation. The ‘t’ statistic for the first equation is 11.9 and the ‘t’ statistic for the second equation is 11.8. Both statistics are significant at the one percent level. Thus,the results reject the hypothesis that a single weighting matrix for the whole euro area is adequate in favor of separate matrices for the north and the south.

3.3. Simulating the system

As noted above, a focus on the individual coefficients -- for example, the coefficients on real GDP growth -- of our model suggests that the effect of a change in a variable generally gets smaller as we move from the simpler model to the more complex model. This interpretation, however, is not correct because it does not allow us to consider the full feedback effects stemming from both simultaneity and the spatial effects. Since the system is highly simultaneous, both across countries and within countries, and is dynamic, it is not straightforward to interpret individual coefficients as the effect on the dependent variables of changing one of the exogenous variables. In order to obtain a better understanding of how the entire system adjusts to a shock, the most straightforward approach is to simulate the system. In this connection, we considered the following simulations. First, we applied a country-specific shock to each of the four models. Specifically, for each country, its real GDP growth rate was shocked by one-standard deviation; the shock was applied in the first period. Then, we applied a common shock, comprised of the average of the previous shocks, in all ten countries, to model (4); again, the shock was applied in the first period. The latter simulation with the common shock helps ensure that the magnitude of country specific shocks are not driving the results.

We should point out that we are primarily interested in assessing how differences in the levels of interactions among the four models affect the dynamic responses. Therefore, it is not necessary to shock all the variables in the equations since the relative differences would be the same. In other words, since the shocks are the same in each model, the differences in the effects of the shocks on spreads and banks' share prices are due only to the differences among the models themselves.

The results are reported in Table 2. The table presents results for two countries -- Greece (GR) and Germany (DE) since, as reported in the notes to Table 2, the shock to real GDP growth in Greece is the largest and the shock to Germany is the smallest among the countries in our sample. Hence, the effects for all other countries would lie between those of Greece and Germany. The first four sets of columns in Table 2 show the results of applying the individual country shocks to each of the four models. Each column is comprised of two sub-columns -- one for Greece and another for Germany. Table 2 also presents both short run and long run (defined as 5 years) effects on spreads and banks' share prices.

Table 2. The simulated effects of a shock to GDP.

	Model 1		**Model 2**		**Model 3**		**Model 4 country-specific shocks**		**Model 4 common shocks**	
	GR	**DE**	**GR**	**DE**	**GR**	**DE**	**GR**	**DE**	**GR**	**DE**
Short run change in banks' share price	0.0	0.0	0.00004	0.00001	0.02	0.02	0.01	0.011	0.002	0.02
Long run change in banks' share price	0.0	0.0	0.00003	0.000007	0.06	0.07	0.07	0.0005	0.0001	0.12
Short run change in spreads	-0.008	-0.002	-0.01	-0.002	-0.43	-0.40	-0.010	-0.023	-0.006	-0.4
Long run change in spreads	-0.005	-0.001	-0.007	-0.002	-1.7	-1.7	-0.06	-1.5	-0.015	-2.5

The sizes of the shocks to each country are as follows; Spain, 0.004, Greece .008, Ireland .004, Italy .003, Portugal .004, Austria .003, Belgium .002, France .002, The Netherlands .002, Germany .002. The final column applies an identical shock to all countries of 0.0034.

The main features of the results in the first four columns are the following. First, the differences between model (1) (no simultaneity, no spatial) and model (2) (simultaneity, no spatial) are small. Simultaneity does, however, slightly amplify the effects of shocks. Second, both models with spatial -- that is, models (3) and (4), sharply amplify the effects of the shocks, both in the short run and the long run. For example, consider model (2). In the case of Greece, a one-standard deviation rise in real GDP growth in all countries, raises Greece's banks' share prices by .004 per cent in model (2) in the short run and .003 per cent in the long run. In model (3), in the short run, banks' share prices increase by 2 per cent; in the long run they rise by 6 per cent. Under model (2) for Greece, the positive shock to GDP reduces spreads by 1 basis point in the short run and by 0.7 basis point in the long run. Under model (3), in the short run spreads fall by 43 basis points; in the long run they decline by 170 basis points. A similar picture applies to the results for Germany. Moreover, a similar picture applies in comparing model 4 for models (1) and (2). In sum, the spatial effects are very large. Because the shocks for Greece are significantly larger than those of Germany, the results imply that if the north had experienced similar destibilizating forces as those experienced in the south did during the financial crisis, the final effects would have been significantly larger. We explore this issue in what follows.

The final column of Table 2 shows the results of applying an equal shock to GDP growth to all countries, as opposed to country-specific shocks to each country as in the previous exercise. Specifically, we apply an equal shock to the full model with separate spatial weighting matrices for the north and the south. The shock is an average of the shocks in all the countries. Thus, the size of the shock for the south is smaller than the average in the previous simulation which used country-specific shocks. For the north, the opposite case applies -- that is the size of the shock for the north is larger than in the previous simulation which used country-specific shocks. An equal shock to all countries results in significantly larger effects in Germany and smaller effects in Greece. The short run changes are only a little larger for Germany but the long run changes -- after the dynamic feed-through has taken place after five years -- are considerably larger in Germany than in Greece. The main result that the effects with spatial variables are much larger than without those variables remains.

These results make it clear that the spatial effects have much larger implications for movements in spreads and banks' share prices than the interactions produced by considering simultaneity alone. A main conclusion here is that the normal practice of ignoring spatial effects can seriously underestimate the impact of shocks on an economy. One corollary of above results is, that if negative shocks are idiosynchratic, in particular in the north, spatial spillovers will substantially reduce any negative effects to spreads and banks' share price growth. In the same vein, if a negative shock is euro-area wide, spatial spillovers will substantially amplify it, more so in the north than in the south. The full dynamic path of these simulations is provided in Figs. 3–6. These figures illustrate the full dynamic paths which are discussed in detail above with reference to Table 2.

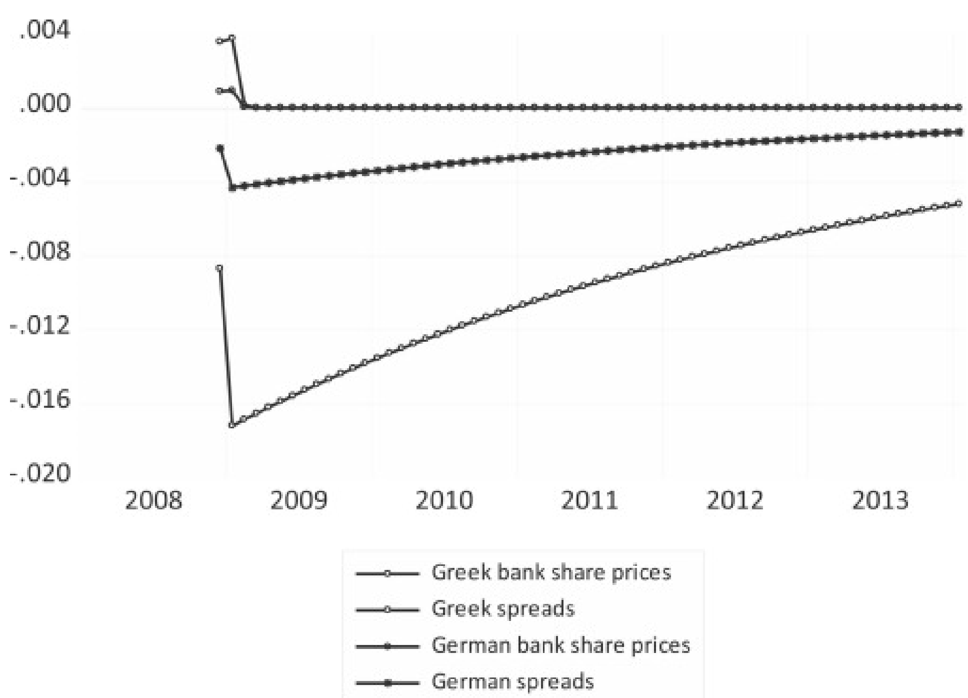

Fig. 3. the GDP simulation for model 1.

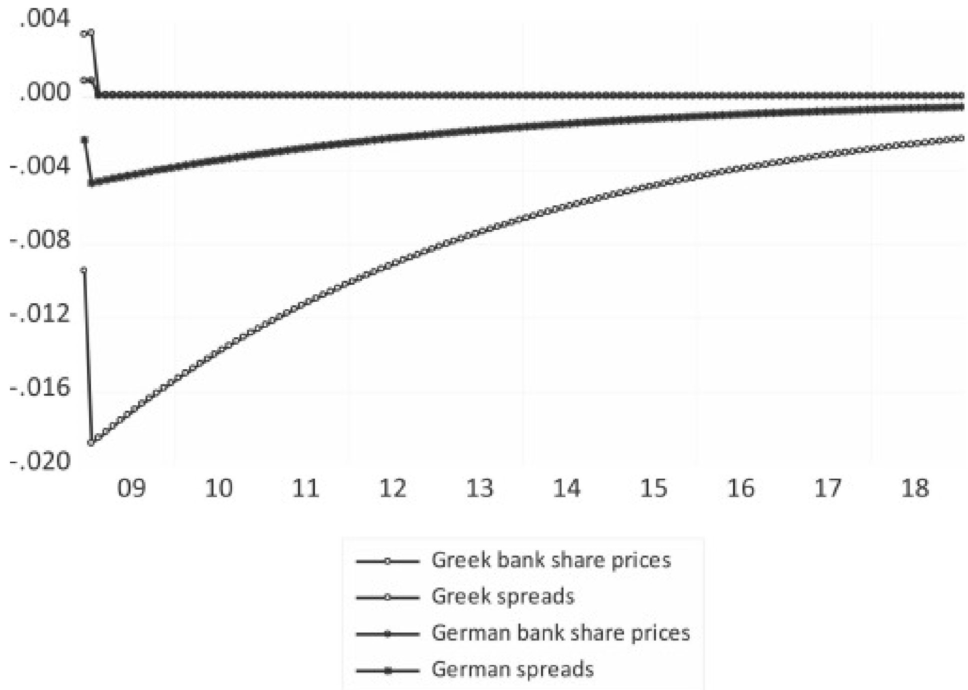

Fig. 4. The GDP simulations for model 2.

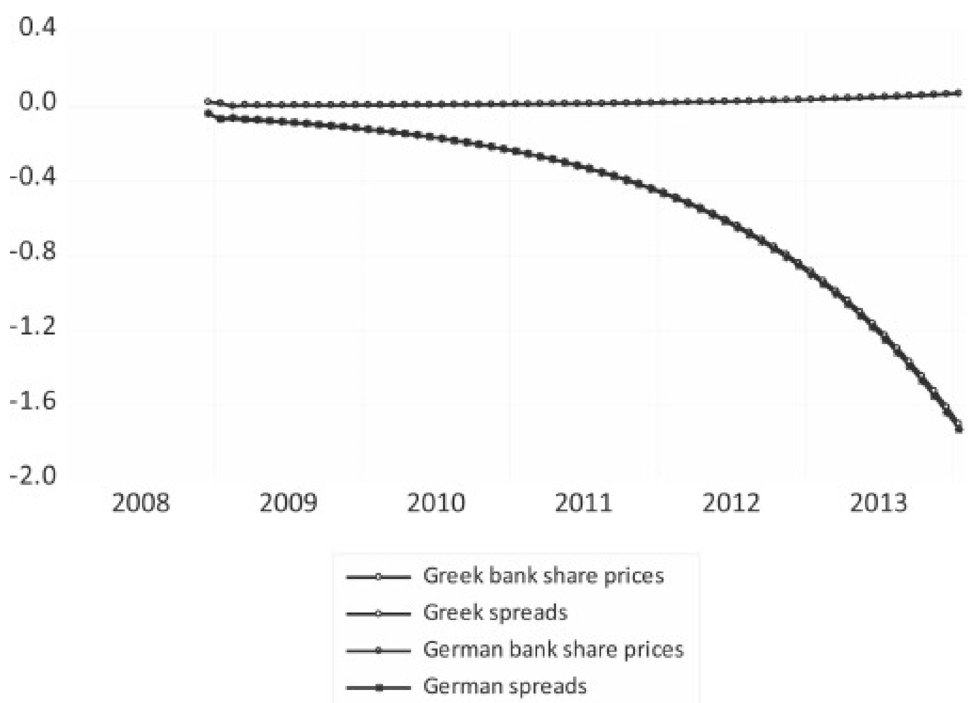

Fig. 5. The GDP simulation for model 3.

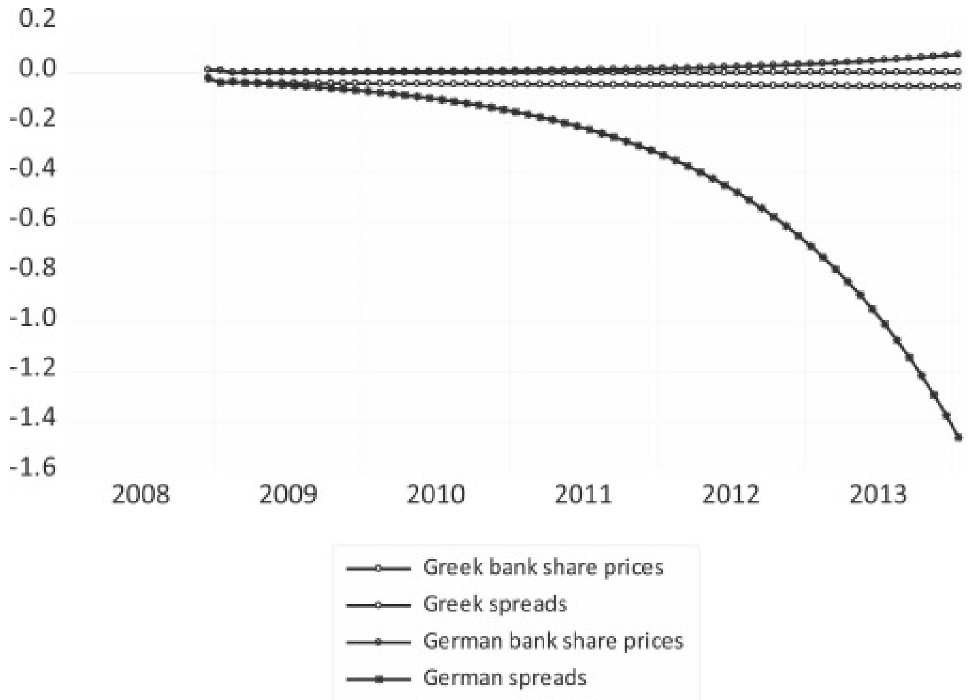

Fig. 6. The GDP simulation for model 4.

4. Conclusion

We have built four models, beginning with a simple standard single equation analysis, extending that to a simultaneous system, and then adding, first, a single spatial matrix with equal weights to all countries, and, finally, introducing a weighting matrix that interacts the northern euro area countries themselves and the southern countries themselves. Along the way we have also proposed a new method for testing between competing spatial matrices.

To fully appreciate the dynamic interactions involved, it is not sufficient to simply look at and interpret single coefficients in the system. We have, therefore, simulated the four systems under three different scenarios that allow us to fully understand the effect of adding increasing complexity and realism. The conclusion here is a very strong one. Ignoring the possible existence of spillover effects can enormously change the dynamic response of a system to a shocks and lead to a serious misinterpretation of the model under consideration.

In our final model we find that spatial interactions in the euro area north are actually stronger between the banks than in the south. This finding reflects the fact, as indicated in the principal components analysis, that changes in banks' share prices in the north have larger comovement than those in the south. Since the euro area crisis was mainly in the south, we might have expected stronger spillovers in that region. It needs to be born in mind, however, that the shocks which occurred in that crisis were mainly to the southern countries. There are still strong spatial effects there which magnify the shocks. However, in the north where there were smaller shocks, the spatial interactions actually helped stabilize the system. Thus, if a shock occurs just in France (as an example), while this will impact other countries, it is also the case that the stability of the banking sectors in the other countries could help stabilise the banking system in France. In other words, and in contrast to the shocks to sovereign spreads in the euro area south, the feedback effects of shocks to the banking sector in the north acted as a stabilizing mechanism. Hence, feedback effects can sometimes work to benefit the system. Conversely, if all northern countries were hit simultaneously by a shock, the effects would have been much larger than those observed in the south.

Appendix.

(See here Appendix Fig. A1, Fig. A2).

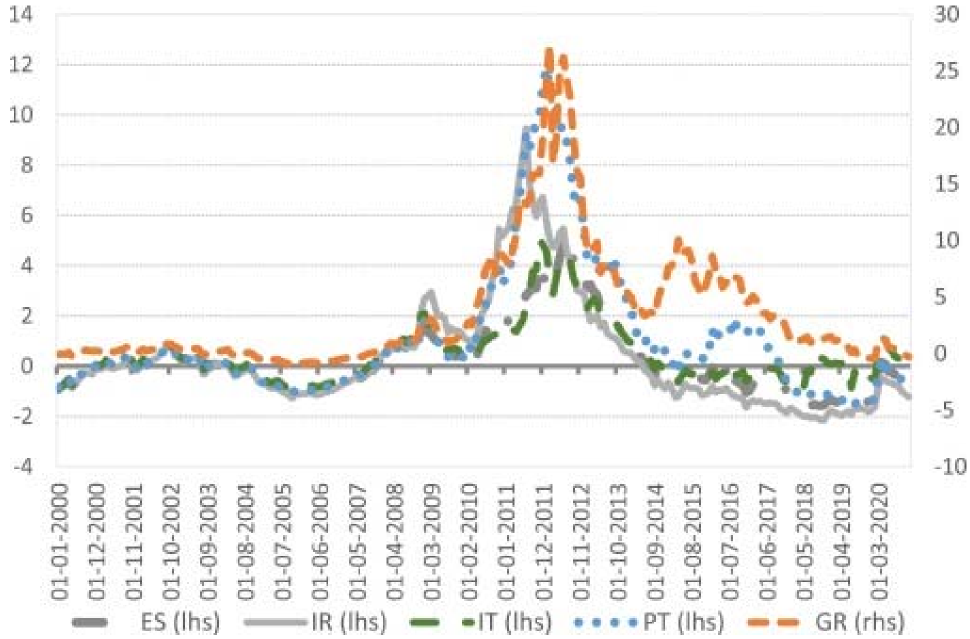

Fig. A1. Spreads vs. US 10 year bond, stressed Southern Euro Area Countries. Source: Eikon and Eikon

Datastream

Fig. A2. Spreads vs. US 10 year bond, non-stressed Northern Euro Area Countries. Source: Eikon and Eikon Datastream

References

Ahmad, M., Hall, S.G., 2017. Economic growth and convergence: do institutional proximity and spillovers matter. J. Policy Model. 39 (6), 1065–1085.

Ait-Sahalia, Y., Andritzky, J., Jobst, A., Nowak, S., Tamirisa, N., 2012. Market response to policy initiatives during the global financial crisis. J. Int. Econ. 87 (1), 162–177.

Aizenman, J., Binici, M., Hutchison, M.M., 2013. Credit ratings and the pricing of sovereign debt during the euro crisis. Oxf. Rev. Econ. Policy 29, 582–609.

Altavilla, C., Giannone, D., Lenza, M., 2016. The financial and macroeconomic effects of OMT announcements. Int. J. Cent. Bank. 12 (3), 29–57.

Altavilla, C., Pagano, M., Simonelli, S., 2017. Bank exposures and sovereign stress transmission. Rev. Financ. 21 (6), 2103–2139.

Annaert, J., De Ceuster, M., Van Roy, P., Vespro, C., 2013. What determines euro area bank CDS spreads? J. Int. Money Financ. 32 (C), 444–461.

Anselin, L., 1988. Spatial Econometrics: Methods and Models. Kluwer Academic Publisher, Boston.

Bahaj, S., 2020. Sovereign spreads in the euro area: cross border transmission and macroeconomic implications. Journal Monet. Econ. 110 (C), 116–135.

Baltagi, B., Pirotte, A., 2011. Seemingly unrelated regressions with spatial error components. Empir. Econ. 40 (1), 5–49.

Baltagi, B., Bresson, G., 2011. Maximum likelihood estimation and lagrange multiplier tests for panel seemingly unrelated regressions with spatial lag and spatial errors: an application to hedonic housing prices in Paris. J. Urban Econ. 69 (1), 24–42.

Baltagi, B., Deng, Y., 2015. EC3SLS estimator for a simultaneous system of spatial autoregressive equations with random effects. Econom. Rev. 34 (6–10), 659–694.

Bauman, D., Drouet, T., Dray, S., Vleminckx, J., 2018a. Disentangling good from bad practices in the selection of spatial or phylogenetic eigenvectors. Ecography 41, 1–12.

Bauman, D., Drouet, T., Fortin, M.-J., Dray, S., 2018b. Optimizing the choice of a spatial weighting matrix in eigenvector-based methods. Ecology 99, 10.

Beetsma, R., Giuliodori, M., de Jong, F., Widijanto, D., 2013. Spread the news: the impact of news on the european sovereign bond markets during the crisis. J. Int. Money Financ. 34, 83–101.

B ̈ohm, H., Eichler, S., 2020. Avoiding the fall into the loop: isolating the transmission of bank-to-sovereign distress in the euro area. J. Financ. Stab. 51.

Brunnermeier, M.K., Langfield, S., Pagano, M., Reis, R., Van Nieuwerburgh, S., Vayanos, D., 2017. ESBies: safety in the tranches. Econ. Policy 32, 175–219.

Cliff, A.D., Ord, J.K., 1973. Spatial Autocorrelation. Pion, London.

Cliff, A.D., Ord, J.K., 1981. Spatial Processes: Models and Applications. Pion, London.

Dray, S., Legendre, P., Peres-Neto, P.R., 2006. Spatial modelling: a comprehensive framework for principal coordinate analysis of neighbour matrices (PCNM). Ecol. Model. 196, 483–493.

European Central Bank, 2021. Monetary-Fiscal Policy Interactions in the Euro Area. ECB Strategy Review, Occasional Paper Series No. 273 (September).

Gibson, H.D., Hall, S.G., Tavlas, G.S., 2014. Fundamentally wrong: market pricing of sovereigns and the greek financial crisis. J. Macroecon. 39, 405–419.

Gibson, H.D., Hall, S.G., Tavlas, G.S., 2017. Self-fulfilling dynamics: the interactions of sovereign spreads, sovereign ratings and bank ratings during the euro area financial crisis. J. Int. Money Financ. 73, 371–33.

Gibson, H.D., Hall, S.G., GeFang, D., Petroulas, P., Tavlas, G.S., 2021. Cross-country spillovers of national financial markets and the effectiveness of ECB policies during the Euro-area Crisis. Oxf. Econ. Pap. 73 (4), 1–17.

Hall, S.G., Tavlas, G.S., 2022. A proposed test to select between two spatial weighting Matrices. Leicester University discussion paper.

Hendry, D.F., Richard, J.-F., 1982. On the formulation of empirical models in dynamic econometrics. J. Econ. 20, 3–33.

Kallestrup, R., Lando, D., Murgoci, A., 2016. Financial sector linkages and the dynamics of bank and sovereign credit spreads. J. Empir. Financ. 33, 374–393.

Kelejian, H.H., Prucha, I.R., 1998. A generalized spatial two-stage least squares procedure for estimating a spatial autoregressive model with autoregressive disturbances. J. Real. Estate Financ. Econ. 17, 99–121.

Kelejian, H.H., Prucha, I.R., 1999. A generalized moments estimator for the autoregressive parameter in a spatial model. Int. Econ. Rev. 40, 509–533.

Kelejian, H.H., Prucha, I.R., 2004. Estimation of simultaneous systems of interrelated cross section equations. J. Econ. 118, 27–50.

Lee, L.-f, 2004. Asymptotic distribution of quasi maximum likelihood estimators for spatial autoregressive models. Econometrica 72 (6), 1899–1925.

Liu, X., Saraiva, P., 2019. GMM Estimation of spatial autoregressive models in a system of simultaneous equations with heteroskedasticity. Econom. Rev. 38 (4), 359–385.

Minford, P., Ou, Z., Wickens, M.R., Zhu, Z., 2022. The Eurozone: What is to Be Done to Maintain Financial Stability? Journal of Financial Stability, forthcoming.

Moessner, R., 2015. Reactions of real yields and inflation expectations to forward guidance in the United States. Appl. Econ. 47 (26), 2671–2682.

O'Rourke, K.H., Taylor, A.M., 2013. Cross of euros. J. Econ. Perspect. 27 (3), 167–192.

Pamies, S., Carnot, N., P˘at˘ar˘au, A., 2021. Do Fundamentals Explain Differences between Euro Area Sovereign Interest Rates? European Economy Discussion Paper No. 141 (June).

Pisani-Ferry, J., 2013. The known unknows and unknown unknowns of European monetary union. J. Int. Money Financ. 34 (C), 6–14.

Schnabel, I., Schumer. U., 2017. What Drives the Sovereign-Bank Nexus? VfS Annual Conference 2017 (Vienna): Alternative Structures for Money and Banking 168259, Verein für Socialpolitik /

German Economic Association.
Shambaugh, J.C., 2012. The Euro's three crises. Brook. Pap. Econ. Acticity 44, 157–231.

Uhlig, H., 2013. Sovereign default risk and banks in a monetary union. Ger. Econ. Rev. 15, 23–41.

Yang, K., Lee, L.-f, 2017. Identification and QML estimation of multivariate and simultaneous equations spatial autoregressive models. J. Econ. 196 (1), 196–214.