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Spillover Effects in Government Bond Spreads: Evidence from a GVAR Model

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Abstract

This paper analyses the main drivers of sovereign bond spreads in a globalised world. Specifically, we account for international spillovers of bond spreads by adding an additional driver, namely, financial markets, and allowing interactions across countries and markets. We contribute to the VAR literature by taking a global VAR approach, which encompasses international linkages and spillovers and also deals with the issue of identification and the large dimensionality. We find significant spillovers across countries and across markets. Moreover, we reveal that bond spreads are driven by stock markets. Furthermore, highly indebted countries react more strongly to foreign shocks than do stable economies. European bond markets are primarily driven by European shocks, whereas U.S. shocks have a higher impact on European countries that are in crisis and other non-European OECD countries. Our results demonstrate that financial market participants, central bankers, and fiscal policymakers need to be aware of global interdependencies, as bond spread volatility is driven by different factors for each country.

JEL Classification Numbers: C02, C63, E44, E47, E52 F41

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1 Introduction

In April 2010, "The Economist" stated that "the Greek debt crisis was spreading. Europe needed a bolder, broader solution". At that point, government policy-makers began to (again) take notice of sovereign bond spreads. More than four years later, in August 2014, "The Economist" revealed that the sovereign debt crisis was still "taking Europe's pulse". The drivers of these spreads thus continue to be of huge interest to policy-makers, economists, and analysts. Understanding these influences allows policy-makers to better design policy targeted at diminishing risks and improving refinancing conditions. Research has established liquidity, risk aversion, exchange rate, and a country's credit risk as the main driving factors (Codogno, Favero, and Missale 2003; Longstaff et al. 2011). We contribute to this research by considering financial markets as an additional driving factor. In a globalised world, where financial spillovers are not confined to just financial markets, we argue that bond and stock markets are highly interconnected.

Since the run-up to the European Monetary Union (EMU), bond spreads have tended to decline, although they increased tremendously after the outbreak of the global financial crisis. As diminished exchange rate risk has led to the co-moving small European government bond spreads, national risk factors became evident. After the Lehman Brothers disaster, there was a 'flight to safety' that left riskier countries short of capital. The impact of globalisation has become stronger and, especially in bad times, stock market impacts are substantial. This implies that European countries were considered by a similar risk in stable times but by a different risk in times of crisis. This revealed a huge imbalance within the EMU. The increasing sovereign debt in the Eurozone has induced market participants to expect either an exit from the Euro or even the collapse of the common currency.

Bilateral relationships change over time and capturing this time-varying component is difficult by standard means. We therefore employ the global vector autoregressive (GVAR) model of Chudik and Fratzscher (2011) and Chudik and Pesaran (2011) which allows for the time-varying component, as well as for bilateral connections, international linkages, and common factors. Moreover, we do not need the persistent component.

The GVAR approach has several advantages. First, we do not rely on components being persistent processes. Second, foreign variables enter the estimation by a weighted matrix such that the bilateral connections are also captured. Specifically, these weights can alter due to the changed expectations of market participants. This technique is especially appropriate for capturing the recent sovereign debt crisis and it outperforms other approaches (Di Mauro and Pesaran 2013). Third, GVAR allows for interdependencies across individual variables within and across units. Even the reduced-form errors are allowed to be cross-sectionally dependent. If needed, the GVAR approach can also capture non-linearities or thresholds. Furthermore, the introduction of the common variable provides another channel through which influences and linkages enter the bond spread. Therefore, we model bond spreads by domestic, foreign, and common global variables, weighted by their relative fiscal position. Given fiscal problems in one or more Euro-area countries, the interdependence determines the response of each country's spread to those affected by the shocks.

We base our analysis on generalised impulse response functions and variance decomposition. We find that Eurozone Countries are highly interconnected and suffer more from internal shocks. On the other hand, stable Eurozone countries are less vulnerable to shocks from other OECD countries, i.e. U.S. shocks, than other main OECD countries (i.e. Japan). Moreover, our analysis revealed a gap between stable and indebted European countries. Furthermore, we find that the inauguration of the European Monetary Union changed the impact of local shocks: for some 'safer' countries, the impact decreased whereas it increased for the more debt-ridden countries. This leads to a gap within the EMU serious enough to possibly cause the collapse of the common currency.

The remainder of this paper is organised as follows. In Section 2, we provide an overview of the literature on bond spreads, the GVAR approach and international spillovers. In Section 3, we describe the data and perform some pre-analysis of sovereign bond spreads. Section 4 describes the GVAR approach and in Section 5 we present our analysis of the Eurozone bond spreads. Section 6 concludes.

2 Literature Overview

Our paper contributes to the literature in three ways: (1) we contribute to research on international spillovers; (2) we contribute to the analysis of sovereign bond spreads; and (3) we add to work on general vector auto regressive models (GVAR). Spillovers and contagion were already subjects of research before the financial crisis. For example, Rigobon and Sack (2003b), Rigobon and Sack (2004), and Ehrmann, Fratzscher, and Rigobon (2011) use an IV estimator to analyse monetary policy and financial market spillovers. They find strong evidence for spillover effects in both directions. However, Forbes and Rigobon (2002) find no contagion in stock market co-movements. On the other hand, strong evidence of contagious effects of international stock markets after the crisis is provided by Dungey and Martin (2007). More recently, Fratzscher (2009) finds evidence for global transmission of US shocks on foreign exchange markets for both advanced and emerging economies. However, Bekaert, Cho, and Moreno (2010) refutes the presence of cross-border contagion in international equity markets. Regarding the transmission of shocks within markets, Diebold and Yilmaz (2009) develop a spillover index. The authors find evidence that return and volatility spillovers across 19 different countries vary widely. Dungey and Martin (2007) analyses contagion across countries and financial markets.

As mentioned, our paper contributes to the literature on bond spreads. Considering Germany as a 'safe haven', the spread to a German Bund reveals the risk an investor faces by buying a specific government bond. Therefore, knowledge about the drivers of bond spreads is of particular interest to policy-makers. As almost all European bonds are issued in Euros, bond spreads no longer include exchange rate or inflationary determinants. Only three main driving factors are of interest: a general risk factor (risk aversion), a liquidity factor, and a fiscal factor (Codogno, Favero, and Missale 2003; Geyer, Kossmeier, and Pichler 2004; Bernoth, Hagen, and Schuknecht 2006). However, how these determinants are measured is less than uniform in the literature. Understanding sovereign bond spreads became more important after the onset of the sovereign debt crisis. In more recent studies, Manganelli and Wolswijk (2009), Haugh, Ollivaud, and Turner (2009), Attinasi, Checherita, and Nickel (2009), and Barrios et al. (2009) find strong evidence for inter-European co-movements, triggered by the factors mentioned above. Moreover, Borgy et al. (2011), Zoli and Sgherri (2009), and Assmann and Boysen-Hogrefe (2012) prove that European co-movements differ over time. They show that European bond co-movements are less pronounced in bad times such as during the financial debt crisis.

Many studies use the U.S. corporate bond spread as a measure for global risk. Codogno, Favero, and Missale (2003) proves, that it is not liquidity but the common risk factor that drives European bond spreads. His results are supported by Geyer, Kossmeier, and Pichler (2004) and Longstaff et al. (2007). More recently, Zoli and Sgherri (2009) and Manganelli and Wolswijk (2009) find evidence for a common factor of European bond spreads. In times of uncertainty, investors become more risk averse and buy safe bonds.

The second determinant of yield differentials is the liquidity risk factor. Distinguishing between liquidity and fiscal factors is important when analysing financial market integration and a country's fiscal position. The results on liquidity as a driving factor of bond spreads are mixed. Codogno, Favero, and Missale (2003), Bernoth, Hagen, and Schuknecht (2006), and Pagano and Thadden (2004) do not find liquidity to be a significant factor in sovereign bond spreads. On the other hand, a seminal study by Gomez-Puig (2006) proves a positive effect of liquidity on sovereign bond spreads. This finding is supported by Barrios et al. (2009) and Gerlach, Schulz, and Wolff (2010). Favero, Pagano, and Thadden (2010) support the effect of a liquidity factor in sovereign bonds both theoretically and empirically. The authors interact the liquidity factor with a global factor and find evidence that liquidity matters only for a subset of the Euro-area bond markets. On the other hand, Beber, Brandt, and Kavajecz (2009) proves that liquidity especially matters in times of market stress.

The third determinant is the fiscal position of the issuer's country of origin. Bernoth, Hagen, and Schuknecht (2004) analyse European bond spreads and find evidence that debt and deficit are the main driving factors of sovereign bond spreads. Hallerberg and Wolff (2008) confirm the impact of the fiscal position although they find it to be less significant after introduction of the Euro. More recently, Bernoth and Wolff (2008) show that 'creative accounting' triggers the spreads more than the debt or deficit. After intensification of the financial crisis in August 2008, financial markets began penalising fiscal imbalances more before than previously and, at the same time, the impact of global investor risk aversion to yield spreads increased significantly. Zoli and Sgherri (2009), Barrios et al. (2009), and Haugh, Ollivaud, and Turner (2009) show that both the effect of fiscal position and general risk aversion are significantly higher after the financial crisis. However, it might be more plausible to think of coefficients changing gradually over time, rather than having a discrete breakpoint between regimes. The time-varying approach was first undertaken by Assmann and Boysen-Hogrefe (2012) and Pozzi (2008). They find that the debt to GDP ratio is the most important variable in explaining bond spreads. Recently, Bernoth and Erdogan (2012) revealed both the importance of the time-varying approach as well as its results.

We also contribute to the literature on GVAR models. The framework was proposed by Pesaran, Schuermann, and Weiner (2004). In general, it is a framework for capturing international linkages and spillovers by also allowing for common factors and time-varying components. It is enhanced by Pesaran (2006) who analysed credit risk. He also used the GVAR model to analyse whether the United Kingdom and Sweden should have adopted the Euro (Pesaran 2006; Dees et al. 2007). A general overview is given in Di Mauro and Pesaran (2013). Bussiere, Chudik, and Sestieri (2009) extend the GVAR approach by allowing for the United States' global dominance. Chudik and Fratzscher (2011) and Chudik and Pesaran (2011) advance the GVAR model by including dominant units. The GVAR approach can be used for analysing various types of issues. Dees et al. (2007) use a GVAR approach to study macroeconomic spillovers and linkages within Europe. They use standard macroeconomic time series such as inflation, output, and the interest rate to analyse the potential entry to the Eurozone of the United Kingdom and Sweden in 1999. Hiebert and Vansteenkiste (2010) uses the GVAR approach to analyse the connection of trade and technological shocks on the labour market in an international framework. Instead of the standard trade weights, the authors use sectorial data. Sgherri and Galesi (2009) analyse the transmission of financial shocks, using financial flows as a weight matrix. Chudik and Pesaran (2011) analyse international financial market spillovers and the effect of a common shock on the money market rate in Europe. In a recent approach, Favero and Missale (2012) analyses the potential of a Eurobond. This approach was enhanced in Favero (2013) to analyse government bond spreads in particular. We extend the recent literature by incorporating financial markets into the standard approach to account for the interconnectedness of financial markets and bond markets. Furthermore, we account for a country's debt position twice, first by using a weight matrix similar to that of Favero (2013) and, second, by combining different macroeconomic indicators into one debt variable by using a principal component analysis.

3 The GVAR Approach

Given that macroeconomic panels often include many countries, but few observation points, standard VAR models do not estimate country linkages and spillovers properly (Chudik and Pesaran 2014). The GVAR approach overcomes this problem by decomposing the underlying large dimensional VARs into a smaller number of conditional models which are linked together via cross-sectional averages.

The GVAR methodology can be summarised as a two-step approach. In the first step, small-scale, country-specific models are estimated conditionally on the rest of the world. These models feature domestic variables and (weighted) cross-section averages of foreign variables which are treated as weakly exogenous. In the second step, these individual country VAR models (from Step 1), along with exogenous variables (VARX), are stacked and solved simultaneously as one large Global VAR model[1].

[1] A detailed description was recently provided by Chudik and Pesaran (2014).

GVAR in a Nutshell

3.0.1 Step 1

We consider a panel of N countries over time $t \in [1, T]$. Country i is described by k_i variables which are grouped in the $k_i \times 1$ vector x_{it}. $x_t = (x'_{1t}...x'_{Nt})$ is the $k \times 1$ vector of all variables of all countries, with $k = \sum_{i=1}^{N} k_i$. The idea behind GVAR is to estimate the parameters of the small-scale, country-specific variables first. Cross-section averages of foreign variables for country i, denoted by x^*_{it}, are included in the estimation procedure

$$x^*_{it} = \tilde{W_i'} x_t \tag{1}$$

where x^*_{it} is a $k^* \times 1$ vector for $i \in [1, N]$ and $\tilde{W_i}$ is a $k \times k^*$ matrix of country-specific weights[2]. The weights could be used to capture the importance of country j for country ith's economy. This is thus a crucial feature of the GVAR approach, as all foreign variables enter the estimation by the weight matrix. Furthermore, the pooling of the foreign variables by the weight matrix overcomes the above mentioned shortcoming of standard VAR procedures. Each foreign variable is aggregated over all foreign countries by the data shrinkage process given by Equation 1.

Therefore, the variable x_{it} can be described in the context of a $VARX(p_i, q_i)$ model:[3].

$$x_{it} = \delta_{i0} + \delta_{i1,t} + \sum_{l=1}^{p_i} \Psi_{il} x_{i,t-l} + \Lambda_{i0} x^*_{it} + \sum_{l=1}^{q_i} \Lambda_{il} x^*_{i,t-l} + \epsilon_{it} \tag{2}$$

where Ψ_{il} if $l \in [1, p_i]$, and Λ_{il} if $l \in [1, q_i]$, and it represents the $k_i \times k_i$ and $k_i \times k^*$ matrices of unknown parameters. δ_{i0} and $\delta i1, t$ are a trend and a time component. ϵ_{it} is the error term. In total, today's variable x_{it} depends on its previous values as well as foreign influences. The foreign variables are treated as weakly exogenous.

We can rewrite the model in VAR notation by collecting the domestic and foreign variables in one vector $z_{it} = (x'_{it}, x^{*'}_{it})$ and combining

$$A_{i0} = (I_{k_i}, -\Lambda_{i0}) \qquad\qquad A_{il} = (\Psi_{il}, \Lambda_{il}) \tag{3}$$

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[2] The weight matrix contains bilateral information, such as trade. As one country has no trade with itself the matrix takes the value zero in this case. Therefore, the vector x^*_{it} contains only foreign variables, although defined by the entire matrix x_t.

[3] A VARX model is a standard VAR model including exogenous variables

The model given by Equation 2 can then be expressed as

$$A_{i0}z_{it} = \delta_{i0} + \delta_{i1,t} + \sum_{l=1}^{p} A_{il}z_{i,t-l} + \epsilon_{it} \tag{4}$$

where $p = max(p_i, q_i)$ and $\Lambda_{il} = 0$ and $\Psi_{il} = 0$ if $l > q$ and $l > p$, respectively. As we account for only the country-specific models in the first step, variables with an asterisk are treated as weakly exogenous.

Global Variables

In addition to the country-specific variables, this approach allows for the inclusion of global variables such as commodity prices. These variables are equal for all countries (in contrast to the foreign variables). Equation 3 can be augmented by

$$x_{it} = \delta_{i0} + \delta_{i1,t} + \sum_{l=1}^{p_i} \Psi_{il}x_{i,t-l} + \Lambda_{i0}x^*_{it} + \sum_{l=1}^{q_i} \Lambda_{il}x^*_{i,t-l} + D_{i0}\omega_t + \sum_{l=1}^{s_i} D_{il}\omega_{t-l} + \epsilon_{it} \tag{5}$$

where ω_t are the common variables which can be treated as weakly exogenous (similar to the foreign variables). D_{il} is a $k_i \times k_i$ matrix of unknown parameters. ω_t can include lagged variables or influences of the foreign economy; in this case, it is

$$\omega_t = \sum_{l=1}^{p_w} \Psi_{wl}\omega_{t-l} + \sum_{l=1}^{q_w} \Lambda_{\omega l}x^*_{i,t-l} + \eta_{\omega,t}$$

where $\eta_{\omega,t}$ is an error term. The model described in Equation 4 can be estimated individually from the rest of the world if no unobserved common factors are given. However, the model becomes complex if unobserved factors are given, as in Equation 5. Pesaran (2006) and Dees et al. (2007) show that f_t can be proxied by the observed common factors d_t and variables x_{it} if the number of countries is sufficiently large. Conditional on the given domestic parameters, the remaining parameters of the $VARX$ model are consistently estimated by ordinary least squares regressions. By construction, we can then identify a time-varying common component that differs in intensity between countries. We therefore capture the time-varying component of international bond and stock spreads and the international linkages between markets and countries.

3.0.2 Step 2

Once the individual country models are estimated, all the $k = \sum_{i=0}^{N} k_i$ endogenous variables of the global economy, collected in the $k \times 1$ vector $x_t = (x'_{0t}, ..., x'_{Nt})$, need to be solved simultaneously. The weight matrix W_i is defined as $W_i = (E'_i \tilde{W}_i{}')$, where E_i is the $k \times k_i$ dimensional matrix that selects $x_{it} = E'_i x_t$. Given W_i, the matrix of country-specific weights, it is

$$z_{it} = (x_{i_t}, x^*_{it})' = W_i x_t \tag{6}$$

Using the definition of z_{it}, the weight matrix W_i, and the notation from Equation 4, the stacked model can be written as

$$A_{i0} W_i x_t = \delta_{i0} + \delta_{i1,t} + \sum_{l=1}^{p} A_{il} W_{i,t-l} + \epsilon_{it} \tag{7}$$

$$\Leftrightarrow G_0 x_t = \sum_{l=1}^{p} G_l x_{t-l} + \epsilon_t \tag{8}$$

where $\epsilon_t = (\epsilon'_{1,t} ... \epsilon'_{Nt})$ and $G_l = ((A_{1,l} W_1)' ... (A_{N,l} W_N)')$. If G_0 is invertible, this yields into

$$x_t = \sum_{l=1}^{p} F_l x_{t-l} + G_0^{-1} \epsilon_t \tag{9}$$

with $F_l = G_0^{-1} G_l, \ \forall l \in [2, p]$.

Global Variables

Stacking the global variable is quite similar. We include $z_{it} = W_i x_t$ in Equation 5, the country-specific VARX model which includes the common variable ω_t, defined in Equation 6. We define $y_t = (\omega'_t x'_t)$. The GVAR is then similarly stacked into

$$G_{y,0} y_t = \sum_{l=1}^{p} G_{y,l} y_{t-l} + \epsilon_{y,t} \tag{10}$$

where $\epsilon_{y,t} = (\epsilon'_t, \eta'_{wt})$,

$$G_{y,0} := \begin{pmatrix} I_{mw} & 0_{mw \times k} \\ D_0 & G_0 \end{pmatrix}, \ G_{x,l} := \begin{pmatrix} \Psi_{wl} & \Lambda_{wl} \tilde{W}_w \\ D_l & G_l \end{pmatrix}$$

$\forall l \in [2, p]$. Furthermore $D_l = (D'_{1l}, ..., D'_{Nl})'$, $\forall l \in [0, p]$ and $p = max_i\{p_i, q_i, s_i, p_w, q_w\}$ with $D_{il} = 0$ for $l > s_i$, $\Psi_{wl} = 0$ for $l > p_w$, and $\Lambda_{wl} = 0$ for $l > q_i$. If G_0 is invertible then $G_{y,0}$ is invertible (Chudik and Pesaran 2014). The model can then be written as

$$y_t = \sum_{l=1}^{p} F_{y,l} y_{t-l} + G_{y,l}^{-1} \epsilon_{y,t} \quad (11)$$

where $F_{y,l} = G_{x,0}^{-1} G_{y,l}$.

4 Data

Our main goal is to analyse European bond spreads and we thus focus on European countries. We account for over 80 percent of European GDP by including Germany, France, Italy, the Netherlands, and Spain. To account for the effects of the sovereign debt crisis on troubled countries, we also include Greece, Ireland, and Portugal. To account for the open economy, we include the remaining G7 countries which are Canada, the United States, the United Kingdom, and Japan. Our sample starts in 1993:Q1 and ends in 2013:Q4, thus capturing the onset of the Eurozone and its subsequent development. Furthermore, we analyse the time period 1999:Q1 to 2013:Q4 separately to discover the effect of the common currency.

The data on yield spreads were provided by Thomson Financial Datastream. We compare government bonds issued by the nine EU countries and the three remaining G7 countries between 1993 and 2013 which are denominated in Deutsche Marks before 1998 and in Euros thereafter.[4] We normalise all data into a quarterly base. In the case of daily bond spreads, we use the quarterly mean.[5] In the case of annual data, we interpolate the data using cubic splines. One exception is the weight matrix as this accounts only for annual changes. A detailed overview of the data is given in Table 1.

All variables are expressed in differences from the corresponding figures of the benchmark country, Germany. For example, we take the difference in GDP growth with respect to Germany as a proxy for GDP, and we take the difference in fiscal fundamentals with respect to Germany for the weight matrix.

As discussed above, the literature agrees on three driving factors of government bond spreads: a country's default risk, a liquidity risk, and a common risk aversion. We

[4] To compare the variables we converted the bonds into Euros.

[5] As a robustness check we used end of period values, results are similar and will be provided upon request.

contribute a fourth factor: a financial market risk of spillovers. In this section, we describe the factors in detail. A country's risk of default is commonly measured by fiscal variables [6].

Default Risk

We expect that if a country's fiscal position deteriorates relative to the benchmark country, the bond spread increases, as markets will demand a higher default risk premium. Credit risk is estimated by using standard fiscal variables such as the debt to GDP ratio or the deficit to GDP ratio. The list of authors who applied fiscal measures as credit risk indicator is extensive: Favero and Missale (2012), Favero (2013), Manganelli and Wolswijk (2009), Beirne and Fratzscher (2013), Bernoth and Erdogan (2012), Schuknecht, Hagen, and Wolswijk (2010), and Aizenman, Hutchison, and Jinjarak (2013) use the debt to GDP ratio to cover the default risk. Bernoth and Erdogan (2012) and Schuknecht, Hagen, and Wolswijk (2010) also include the deficit to GDP ratio to measure the default risk of a state. Other authors such as Beirne and Fratzscher (2013), Lane (2012), and De Grauwe and Ji (2012), take the current account deficit or the fiscal balance instead. Moreover, Gibson, Hall, and Tavlas (2012) uses expenditure and revenue relative to the GDP to account for fiscal position.

Since inauguration of the Maastricht Treaty, deficit and debt have become of major political interest. Governments tend to engage in 'creative accounting' to reach the Maastricht target. We believe that all fiscal variables have a significant impact on government bond spreads. To use the information provided by all these variables while, at the same time, keeping the number of variables small in order to retain sufficient degrees of freedom, we conduct a principal component analysis of the fiscal variables and extract the dominant patterns. The first component already explains 80% of the variance in the variables. We therefore believe that our fiscal stance variable captures all relevant information. Specifically, we employ government revenues and expenditures, the structural balance, (primary) deficit, the account balance, and net gross debt, all of which are expressed in terms of the national GDP. The explained part is shown in Table 2. To avoid the difficulties inherent in using different data sources, we rely on the AMECO forecast. By using the forecast instead of the actual variable we account for the effect of expectations. Moreover, these variables are less subject to creative accounting.

[6] (i.e. Bernoth, Hagen, and Schuknecht (2004), Codogno, Favero, and Missale (2003), Geyer, Kossmeier, and Pichler (2004), Bernoth, Hagen, and Schuknecht (2006), Manganelli and Wolswijk (2009), Haugh, Ollivaud, and Turner (2009), Attinasi, Checherita, and Nickel (2009), Barrios et al. (2009), Borgy et al. (2011), Zoli and Sgherri (2009), and Assmann and Boysen-Hogrefe (2012).

This procedure is in line with that of Beirne and Fratzscher (2013), Schuknecht, Hagen, and Wolswijk (2010), and Bernoth and Erdogan (2012), among others. However, data are only provided on an annual basis. Therefore, we interpolate the data to quarterly data by using cubic splines.

Market Liquidity

Market liquidity can be measured by direct means, such as the trading volume or bid-ask spreads, or by indirect measures, such as the amount of outstanding debt securities relative to market size. Gomez-Puig (2006) shows that direct and indirect measures are closely related. She compares bid-ask spreads and the amounts of outstanding debt securities and find that both measures are significant drivers of bond spreads. Codogno, Favero, and Missale (2003) compare bid-ask spread, trading volume, and turnover ratio and find that trading volume is the best performing liquidity indicator. Bernoth, Hagen, and Schuknecht (2004) also use the size of government bond markets and find a significant effect of this variable on the yield differentials of Euro-area countries. A drawback of bid-ask spreads as a liquidity measure is that they are not truly exogenous. Dunne, Moore, and Portes (2006) proves that bid-ask spreads depend on their marketplace features. We join those researchers who use market size, measured by the amount of outstanding debt securities relative to overall market size, as a liquidity measure. Data are available on a quarterly basis and are taken from the Bank for International Settlements Database.

Risk-Aversion

Finally, we use the corporate bond yield spread as a proxy for general investors' risk aversion which is a conventional measure in the related literature (Bernoth and Erdogan 2012; Barrios et al. 2009; Attinasi, Checherita, and Nickel 2009; Haugh, Ollivaud, and Turner 2009; Codogno, Favero, and Missale 2003). The corporate bond spread represents the spread between low-grade corporate bonds (Baa) and high-grade bonds (Aaa). In times of greater uncertainty, the corporate bond yield spread widens because of a shift in investor preference from riskier corporate bonds to safer government bonds. Thus, assuming that the benchmark country, Germany, is a 'safe haven' among EMU countries, we expect a positive relationship between the corporate bond yield spread and sovereign bond yield differentials. Data are taken from the Federal Reserve Database. For example, after the shock of Lehman Brothers default, risk aversion increased and high-ranked bonds were bought. This led to higher yields for low-graded bonds and the spread increased. Furthermore, in a similar manner, we include the CBOE VIX index of market volatility. Data are provided by the CBOE website (Favero, Pagano, and Thadden 2010; Beber, Brandt, and Kavajecz 2009).

Financial Markets

Although the interaction of monetary policy and financial markets has been studied thoroughly (i.e., the seminal paper of Rigobon and Sack (2003a)), very little research has been undertaken to analyse stock markets as a driver of sovereign bond spreads. Grammatikos and Vermeulen (2012) and Annaert et al. (2013) show some evidence of the influence of stock markets on sovereign CDS spreads. Looking from an opposite perspective, Kaminsky and Schmukler (2001) find that sovereign ratings affect stock markets. However, we assume highly interacted markets and possible spillovers from stock markets to bond markets and thus include national stock indices in our analysis. In particular, we use the S&P 500 in case of the United States, the TSX in case of Canada, the CAC40 in case of France, the FTSE in case of England, the IBEX in case of Spain, the Nikkei in case of Japan, the AEX in case of the Netherlands, the FTSEMIB in case of Itlaly, the ASE in case of Greece, the ISEQ in case of Ireland, the PSI in case of Portugal and the DAX as German benchmark.

Control Variables

Sovereign risk may also depend on macroeconomic fiscal and monetary policy. Min (1998) argues that inflation can be interpreted as a broad measure of political discipline. Therefore, in line with Aizenman, Hutchison, and Jinjarak (2013) and Antonello and Ehrmann (2012), we control for inflation. Inflation is expressed as the change in the quarterly CPI relative to the same period in the previous year.

The Weighting Scheme

The weighting scheme variables, for each country are fiscal spreads which are the weighted average of other countries' spreads, where weights depend on the distance, measured in terms of differences in fiscal fundamentals, that separates countries. Di Mauro and Pesaran (2013) use bilateral trade as a weighting scheme. Other scholars have extended this idea by using weighting schemes based on financial flows or regional patterns. Galesi and Sgherri (2009) propose a GVAR with weights based on cross-country financial flows, while Vansteenkiste and Hiebert (2011) use weights based on the geographical distance between regions. Hiebert and Vansteenkiste (2010) adopt weights based on sectoral input-output tables across industries. Most recently, Favero (2013) uses the fiscal stance relative to Germany to analyse government bond spreads.

We follow Favero (2013) and contribute to the GVAR literature by using a fiscal variable as the weighting scheme. Specifically, we use each country's deviation from the 60% goal of the Stability and Growth Pact relative to that of the benchmark country. As this ratio is not part of the principal component analysis, there is no direct issue of heterogeneity. As a robustness check, we use the deficit to GDP ratio and the impact of GDP growth on debt as instruments for the excessive deficit procedure. All data are taken from the AMECO database. Our scheme is similar to that of Favero (2013). In an additional test of robustness, we also conduct the analysis using the standard trade weight scheme.

Modelling Bond Spreads

Figures 1 and 3 show evidence of co-movement for major macroeconomic and financial variables, especially for the major international stock indices, the logged industry index, logged GDP, and bond spreads. Bond spreads have co-moved since inauguration of the European Union; however, at the onset of the financial crisis, this changed. More recently, they have tended to co-move again. We also observe co-movements in the fiscal variables; debt to GDP ratios highly co-moved with German debt to GDP ratios until 2007. However, the current account to GDP ratio shows less co-movement. Furthermore, stock markets were strongly linked before and after the financial crisis.

We follow Di Mauro and Pesaran (2013) and Dees et al. (2007) and employ a global vector auto-regressive model (GVAR). The GVAR is designed to treat all country-specific variables x_{it} and observed global factors endogenously. Normally, bond spreads are considered persistent processes with a long-run equilibrium (Favero 2013). However, the static environment does not explain the heterogeneity observed in the bond spreads. The GVAR approach is more flexible and can take into account time-varying co-movements. We compute a vector of variables, consisting of domestic and foreign and common factors, both at the same time and lagged.

5 Estimation

Our first focus is on the overall impulse responses across country groups in order to identify general, overarching trends and differences[7].The first subsection of this section presents findings from the impulse response functions of the GVAR; the second outlines the results of the forecast error variance decomposition.

To arrive at a first impression of the spillover effects in the model, we control the contemporaneous effects of foreign variables on domestic counterparts, given in Table 4. The results suggest that there are significant spillovers between markets. We observe significant spillovers from bond markets to the national bond market for most countries. Similarly, stock market spillovers are significant for Canada, France, Japan, the Netherlands, and Portugal. Liquidity effects spill over for Canada, France, Japan, the Netherlands, and Portugal, and fiscal stance is also important for these countries. All in all, the results support our expectation regarding size and significance. Specifically, we find strong evidence for market and national spillovers. Given the power of estimation for the individual models, shown in Table 5, the model captured fiscal variables very well, and, except in the case of the United States, bonds, stocks, and liquidity are also captured well. Therefore, we are confident that our model captures the major factors driving bond spreads.

5.1 Impulse Response Functions

Figures 2 to 8 show the generalised impulse response function (GIRFs) for the Eurozone countries, European crisis countries, and Greece, and rest of the OECD countries, where impulse responses are unweighted averages of all countries within the group. The first figure shows reactions to a U.S. stock market shock, and makes it obvious that troubled countries react more strongly to this sort of shock than Eurozone countries or the rest of the industrialised countries. A shock on the U.S. stock market causes sovereign bond spreads to first increase and then slowly decrease. The reaction among the industrialised world is more pronounced than within the non-crisis Eurozone countries which might indicate that the 'non-bailout clause' is not reliable, or that within the Eurozone, these countries are considered similarly risky. The stock market reaction

[7] We treat Greece seperately as it is different in several ways from other indebted countries in the Eurozone. First of all, it has defaulted on its debt many times before, therefore a lenders confidence in getting his money back is troubled. Second, it has joined the Eurozone later than the other countries, because it was denied membership in the first place. Third, Greece is relatively higher indebted than other European countries and on the top faces more corruption and cronyism.

is similar. Stock market spreads increase directly due to the shock and then return to 'normal'. However, there is variance in the return process. It is notable that the Greek stock market is considered less risky than the Greek bond market. Therefore, the shock is less pronounced on the stock market than on the bond market. Similar to what occurs in the bond market, reactions of the money market rate are more pronounced in crisis countries and the rest of the world than in the Eurozone. However, interpretation of this finding is difficult as European countries have shared the same money market rate since the introduction of the Euro.

We then compare a U.S. shock on the stock market to a Greek shock on the stock market. We observe a much more pronounced effect in Greece and spillovers to other European crisis countries. However, there is no notable effect on the rest of the Eurozone or other industrialised countries. This is particularly the case for bond prices but also for stock prices and a global volatility shock. Especially in the case of the stock market crisis, Greek stock spreads continue to be deeper than they were at the beginning of the crisis.

A shock on the global volatility index can be interpreted as an increase in risk aversion. As market participants become more cautious, the bond spread in troubled countries increases; therefore, these countries must pay higher interest rates to obtain access to money. There are only minor effects in industrialised countries. Effects on the stock and money markets are similar. Especially on the stock market, there are effects for both industrialised and crisis countries. A shock to volatility causes a reaction in only the troubled bond markets, implying that (negative) spillovers are more pronounced for those countries that are already in debt. However, there are no noticeable spillovers in the rest of the Eurozone and only minor reactions in the rest of the world. The latter are driven by US effects as this was the origin of the shock. In contrast to the bond market, however, there are significant spillovers to all countries on the stock market. As we already found significant contemporaneous effects between the markets, this is in line with our expectations. In this case, the effect on the rest of the world is even stronger than it is in Greece. Except for the Eurozone, we observe similar effects regarding the money market. In the event that the volatility shock originated in Greece, the effects on most markets are less pronounced or even insignificant.

A liquidity crisis is characterised by the inability of traders to sell some of their assets. On the other hand, liquidity shocks can also be manifested as an inflow of market liquidity made with the intent of increasing the number of trading partners. For example, to increase liquidity and diminish investor risk, monetary policy-makers engage in quantitative easing (QE). In this context, a shock in liquidity also represents unconventional monetary policy action. When QE is conducted in the United States, Greek bond markets react strongly; however, other European bonds, as well as bonds from other OECD countries, also react to unconventional US monetary policy. Only European bonds seem to react less strongly. On the other hand, QE has a significant impact on all stock markets and spills over to monetary policy-makers worldwide.

5.2 Variance Decomposition

We now turn to the results of the variance decomposition. Table 6 reports results for the importance of US shocks illustrating selected variables; whereas Table 7 reports similar information for spillovers from Greece. We show the average percentage contribution to the total variance of major shocks across all groups of countries. Table 8 shows an extract of the variance decomposition since formation of the European Monetary Union.

Some of the results are particularly noteworthy. First, as expected, for most variables, U.S. shocks explain more market volatility than Greek shocks. Furthermore, the stable Eurozone bond markets are less vulnerable to US shocks. In contrast, there are contagious effects from U.S. shocks to non-European OECD bond markets. It is striking that U.S. monetary policy, represented by the interbank rate, explains more of the bond market volatility for the European crisis countries than it does for the OECD countries or the stable Eurozone countries. This finding implies that Greece, Spain, and other highly indebted countries are more affected by Fed policy than Germany or the Netherlands.

A U.S. monetary policy shock has a strong impact on highly indebted Eurozone countries, but the effect diminishes rather quickly. Thus, Fed policy appears to have an intense but short effect on the bonds of highly indebted European countries. In total, we observe that stable countries are only affected by US stock markets, but countries in crisis are much more driven by all types of US influence.

Furthermore, US bond market shocks have a stronger impact on non-European bond markets; on the other hand, however, European bond markets are likely to be affected by European bond market shocks. Thus, there are few spillover effects within international bond markets, but strong spillover effects within European bond markets. It is particularly striking that the effect of a Greek bond shock diminishes rather quickly in Greece, but its contagious effects on other European crisis countries increase tremendously over time. In general, there are few spillover effects from Greece to stable European countries and other OECD countries. However, a Greek stock market shock has slightly more impact on European bonds than a US stock market shock.

Comparing results from the sample since 1993 with the one starting in 1999, we find that there was a change in the factors behind stock and bond market shocks in all countries after inauguration of the Euro. We find, in this later period, that stock market volatility is less driven by US stock market shocks, and more by US volatility shocks. Exceptions are the European crisis countries which now react even more strongly to both kinds of shocks. In contrast, it seems that Greek shocks affect European bonds and stocks, particularly those of the more indebted countries, even more strongly after inauguration of the common currency.

6 Conclusion

Since the financial crisis, much research has been undertaken to understand the severe impact of the crisis on the real economy and how it spills over to other countries. We contribute to this literature by analysing the spillovers of financial markets, monetary policy and sovereign bonds. We focus on shocks from the US and Greek financial markets to the bond, stock and money markets. The empirical evidence is derived from a Global VAR approach which allows us to deal with shocks and their transmission, the dimensions of eleven countries and spillover effects. The GVAR models the changing interdependence among spreads by making each country's spread a function of global spreads with a time-varying composition. Specifically, global spreads for each country are defined as the weighted average of spreads for all the other countries. Weights are determined by the distance between countries, measured in terms of differences in the expected debt to GDP ratio. This method captures fluctuations in spreads due to fiscal shocks, financial market shocks or monetary shocks.

Analysis of the impulse response functions suggests that the reactions of troubled countries are stronger than those of the Eurozone or the rest of the industrialised countries. A shock on the US stock market causes sovereign bond spreads to first increase and then slowly decrease. The reaction among the industrialised world is more pronounced than within the non-crisis Eurozone countries which might indicate that the 'non-bailout clause' is not reliable or that within the Eurozone these countries are considered similarly risky. Our findings suggest that stock and money market shocks have a more pronounced effect on the variables whereas the effects of volatility and liquidity shocks are more persistent. We conclude that shocks to the instruments, such as stocks, are more severe, whereas shocks to the driving factors of the instruments, such as liquidity, are more persistent. Furthermore, spillovers from the United States are bigger than those from Greece. More specifically, we find that impulse response functions and the variance decomposition reveal a huge gap within the EMU. On the one hand, the spreads of robust Eurozone countries, such as the Netherlands, react less to shocks from abroad than the rest of the world. However, the troubled countries, such as Greece or Spain, react more strongly than other country groups. This finding implies that markets are not congruent within Europe. Considering that the issuance of Eurobonds is currently under consideration, the results of the paper are highly relevant. The optimal market price would be the average of the prices of sound and indebted European countries. However, this price would not be optimal for either as the yields of these Eurobonds would be too high for sound European countries on the one hand and too low for the highly indebted Eurozone countries on the other.

References

Aizenman, Joshua, Hutchison, Michael, and Jinjarak, Yothin (2013). What is the Risk of European Sovereign Debt Defaults? Fiscal Space, CDS Spreads and Market Pricing of Risk. In: *Journal of International Money and Finance* 34, pp. 37–59.

Annaert, Jan et al. (2013). What Determines Euro Area Bank CDS Spreads?. In: *Journal of International Money and Finance* 32, pp. 444–461.

Antonello, D'Agostino and Ehrmann, Michael (2012). The pricing of G7 Sovereign Bond Spreads–The Times, They are A-Changin. In: *MPRA Discussion Paper* 40604.

Assmann, Christian and Boysen-Hogrefe, Jens (2012). Determinants of Government Bond Spreads in the Euro Area: In Good Times as in Bad. In: *Empirica* 39(3), pp. 341–356.

Attinasi, Maria Grazia, Checherita, Cristina, and Nickel, Christiane (2009). What Explains the Surge in Euro Area Sovereign Spreads During the Financial Crisis of 2007-09?. In: *ECB working paper* 1131.

Barrios, Salvador et al. (2009). Determinants of Intra-Euro Area Government Bond Spreads During the Financial Crisis. In: *Directorate General Economic and Monetary Affairs (DG ECFIN), European Commission* 388.

Beber, Alessandro, Brandt, Michael, and Kavajecz, Kenneth (2009). Flight-to-Quality or Flight-to-Liquidity? Evidence from the Euro-Area Bond Market. In: *Review of Financial Studies* 22(3), pp. 925–957.

Beirne, John and Fratzscher, Marcel (2013). The Pricing of Sovereign Risk and Contagion During the European Sovereign Debt Crisis. In: *Journal of International Money and Finance* 34, pp. 60–82.

Bekaert, Geert, Cho, Seonghoon, and Moreno, Antonio (2010). New Keynesian Macroeconomics and the Term Structure. In: *Journal of Money, Credit and Banking* 42(1), pp. 33–62.

Bernoth, Kerstin and Erdogan, Burcu (2012). Sovereign Bond Yield Spreads: A Time-Varying Coefficient Approach. In: *Journal of International Money and Finance* 31(3), pp. 639–656.

Bernoth, Kerstin, Hagen, Jürgen von, and Schuknecht, Ludger (2004). Sovereign Risk Premiums in the European Government Bond Market. In: *ECB Working paper* 369.

Bernoth, Kerstin, Hagen, Jürgen von von, and Schuknecht, Ludger (2006). Sovereign Risk Premiums in the European Government Bond Market. In: *GESY Discussion Paper* 151.

Bernoth, Kerstin and Wolff, Guntram (2008). Fool the Markets? Creative Accounting, Fiscal Transparency and Sovereign Risk Premia. In: *Scottish Journal of Political Economy* 55(4), pp. 465–487.

Borgy, V. et al. (2011). Fiscal Sustainability,Default Risk and Euro Area Sovereign Bond Spreads Markets. In: *Banque de France Working Paper Series* 350.

Bussiere, Matthieu, Chudik, Alexander, and Sestieri, Giulia (2009). Modelling Global Trade Flows: Results From a GVAR Model. In: *European Central Bank Working Paper Series* 1087.

Chudik, Alexander and Fratzscher, Marcel (2011). Identifying the Global Transmission of the 2007–2009 Ginancial Crisis in a GVAR model. In: *European Economic Review* 55(3), pp. 325–339.

Chudik, Alexander and Pesaran, Hashem (2011). Infinite-Dimensional VARs and Factor Models. In: *Journal of Econometrics* 163(1), pp. 4–22.

Chudik, Alexander and Pesaran, M Hashem (2014). Theory and Practice of GVAR Modeling. In: *University of Southern California, Center for Applied Financial Economics (CAFE) Research Paper Series* 14.04.

Codogno, Lorenzo, Favero, Carlo, and Missale, Alessandro (2003). Yield Spreads on EMU Government Bonds. In: *Economic Policy* 18(37), pp. 503–532.

De Grauwe, Paul and Ji, Yuemei (2012). Mispricing of Sovereign Debt and Multiple Equilibria in the Eurozone. In: *CEPS Working Document No 361*, pp. 1–22.

Dees, Stephane et al. (2007). Exploring the International Linkages of the Euro Area: A Global VAR Analysis. In: *Journal of Applied Econometrics* 22(1), pp. 1–38.

Di Mauro, Filippo and Pesaran, M Hashem (2013). *The GVAR Handbook: Structure and Applications of a Macro Model of the Global Economy for Policy Analysis.* Oxford University Press.

Diebold, Francis and Yilmaz, Kamil (2009). Measuring Financial Asset Return and Volatility Spillovers, with Application to Global Equity Markets*. In: *The Economic Journal* 119(534), pp. 158–171.

Dungey, Mardi and Martin, Vance (2007). Unravelling Financial Market Linkages During Crises. In: *Journal of Applied Econometrics* 22(1), pp. 89–119.

Dunne, Peter, Moore, Michael, and Portes, Richard (2006). European Government Bond Markets: Transparency, Liquidity, Efficiency. In: *CEPR Discussion Paper.*

Ehrmann, Michael, Fratzscher, Marcel, and Rigobon, Roberto (2011). Stocks, Bonds, Money Markets and Exchange Rates. Measuring International Financial Transmission. In: *Journal of Applied Econometrics* 26(6), 948–974.

Favero, Carlo and Missale, Alessandro (2012). Sovereign Spreads in the Eurozone: Which Prospects for a Eurobond?. In: *Economic Policy* 27(70), pp. 231–273.

Favero, Carlo, Pagano, Marco, and Thadden, Ernst-Ludwig von (2010). How Does Liquidity Affect Government Bond Yields?. In: *Journal of Financial and Quantitative Analysis* 45(1), pp. 107–134.

Favero, Carlo A (2013). Modelling and Forecasting Government Bond Spreads in the Euro Area: a GVAR Model. In: *Journal of Econometrics* 177(2), pp. 343–356.

Forbes, Kristin and Rigobon, Roberto (2002). No Contagion, Only Interdependence: Measuring Stock Market Comovements. In: *The Journal of Finance* 57(5), pp. 2223–2261.

Fratzscher, Marcel (2009). What Explains Global Exchange Rate Movements During the Financial Crisis?. In: *Journal of International Money and Finance* 28(8), pp. 1390–1407.

Galesi, Alessandro and Sgherri, Silvia (2009). *Regional Financial Spillovers Across Europe: A Global VAR Analysis.* Vol. 9. International Monetary Fund.

Gerlach, Stefan, Schulz, Alexander, and Wolff, Guntram (2010). Banking and Sovereign Risk in the Euro Area. In: *CEPR Discussion Paper* DP7833.

Geyer, Alois, Kossmeier, Stephan, and Pichler, Stefan (2004). Measuring Systematic Risk in EMU Government Yield Spreads. In: *Review of Finance* 8(2), pp. 171–197.

Gibson, Heather, Hall, Stephen, and Tavlas, George (2012). The Greek Financial Crisis: Growing Imbalances and Sovereign Spreads. In: *Journal of International Money and Finance* 31(3), pp. 498–516.

Gomez-Puig, Marta (2006). Size Matters for liquidity: Evidence from EMU Sovereign Yield Spreads. In: *Economics Letters* 90(2), pp. 156–162.

Grammatikos, Theoharry and Vermeulen, Robert (2012). Transmission of the Financial and Sovereign Debt Crises to the EMU: Stock Prices, CDS Spreads and Exchange Rates. In: *Journal of International Money and Finance* 31(3), pp. 517–533.

Hallerberg, Mark and Wolff, Guntram (2008). Fiscal Institutions, Fiscal Policy and Sovereign Risk Premia in EMU. In: *Public Choice* 136(3-4), pp. 379–396.

Haugh, David, Ollivaud, Patrice, and Turner, David (2009). What Drives Sovereign Risk Premiums. In: *OECD Economics Department Working Papers* 718.

Hiebert, Paul and Vansteenkiste, Isabel (2010). International Trade, Technological Shocks and Spillovers in the Labour Market: A GVAR Analysis of the US Manufacturing sector. In: *Applied Economics* 42(24), pp. 3045–3066.

Jankowitsch, Rainer, Mösenbacher, Hannes, and Pichler, Stefan (2006). Measuring the Liquidity Impact on EMU Government Bond Prices. In: *The European Journal of Finance* 12(2), pp. 153–169.

Kaminsky, Graciela and Schmukler, Sergio (2001). Emerging Markets Instability: Do Sovereign Ratings Affect Country Risk and Stock Returns?. In: *The World Bank Working Paper Series* 2678.

Krishnamurthy, Arvind and Vissing-Jorgensen, Annette (2012). The Aggregate Demand for Treasury Debt. In: *Journal of Political Economy* 120(2), pp. 233–267.

Lane, Philip (2012). The European Sovereign Debt Crisis. In: *The Journal of Economic Perspectives* 26(3), pp. 49–67.

Longstaff, Francis et al. (2007). How Sovereign is Sovereign Credit Risk?. In: *NBER Working Paper Series* 13658.

Longstaff, Francis A. et al. (2011). How Sovereign Is Sovereign Credit Risk?. In: *American Economic Journal: Macroeconomics* 3(2), pp. 75–103.

Manganelli, Simone and Wolswijk, Guido (2009). What Drives Spreads in the Euro Area Government Bond Market?. In: *Economic Policy* 24(58), pp. 191–240.

Min, Hong (1998). *Determinants of Emerging Market Bond Spread: Do Economic Fundamentals MAatter?* Vol. 1899. World Bank Publications.

Pagano, Marco and Thadden, Ernst-Ludwig von (2004). The European Bond Markets Under EMU. In: *Oxford Review of Economic Policy* 20(4), pp. 531–554.

Pesaran, M Hashem (2006). Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure. In: *Econometrica* 74(4), pp. 967–1012.

Pesaran, M Hashem, Schuermann, Til, and Weiner, Scott M (2004). Modeling Regional Interdependencies Using a Global Error-Correcting Macroeconometric Model. In: *Journal of Business and Economic Statistics* 22(2), pp. 129–162.

Pozzi, Lorenzo (2008). Have Euro Area Government Bond Spreads converged to their Common State?. In: *Discussion paper / Tinbergen Institute* TI 08-042/2.

Rigobon, Roberto and Sack, Brian (2003a). Measuring The Reaction of Monetary Policy to the Stock Market*. In: *The Quarterly journal of economics* 118/2).2, pp. 639–669.

— (2003b). Measuring the Reacton of Monetary Policy to the Stock Market. In: *The Quarterly Journal of Economics* 118(2), pp. 639–669.

— (2004). The Impact of Monetary Policy on Asset Prices. In: *Journal of Monetary Economics* 51(8), pp. 1553–1575.

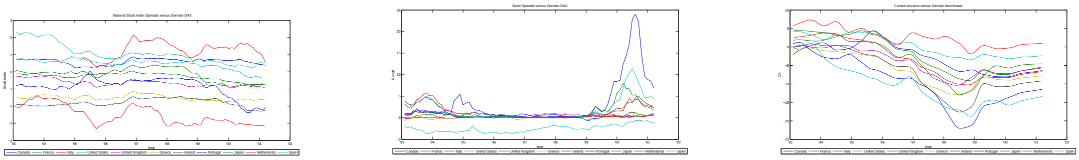
Schuknecht, Ludger, Hagen, Jürgen von von, and Wolswijk, Guido (2010). Government Bond Risk Premiums in the EU Revisited: The Impact of the Financial Crisis. In: *ECB Working Paper* 1152.

Sgherri, Silvia and Galesi, Alessandro (2009). Regional Financial Spillovers across Europe: A Global VAR Analysis. In: *IMF Working Papers*, pp. 1–32.

Vansteenkiste, Isabel and Hiebert, Paul (2011). Do House Price Developments Spillover Across Euro Area Countries? Evidence from a Global VAR. In: *Journal of Housing Economics* 20(4), pp. 299–314.

Zoli, Edda and Sgherri, Silvia (2009). Euro Area Sovereign Risk During the Crisis. In: *International Monetary Fund* 9-222.

7 Figures and Tables



1.1 1.2 1.3

Figure 1: Co-movement of real and financial Euro variables.

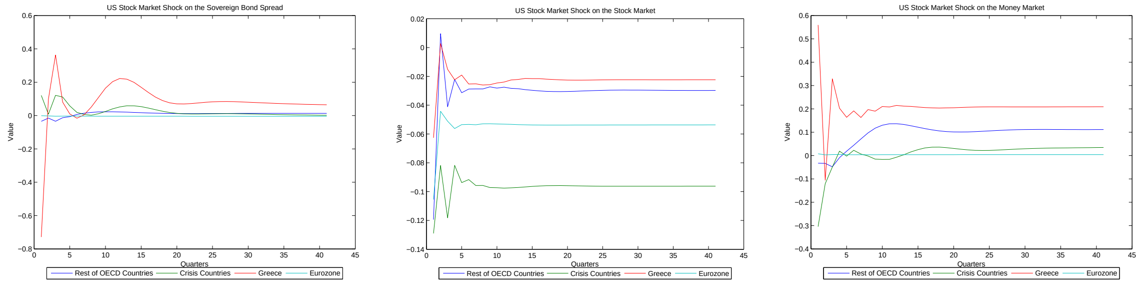


Figure 2: Shock on the US Stock Market

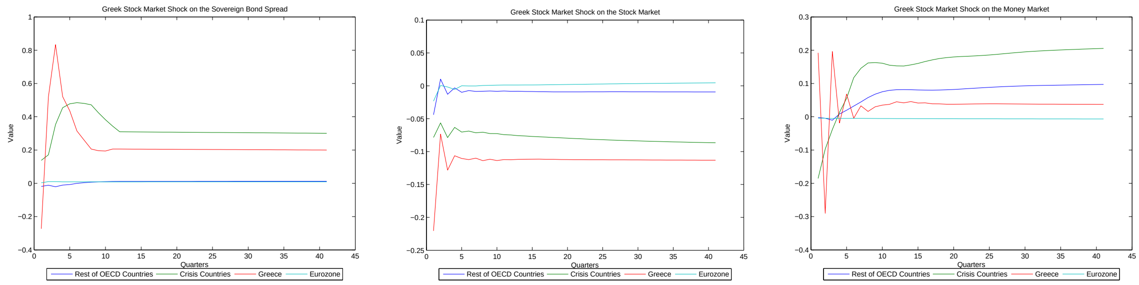


Figure 3: Shock on the Greek Stock Market

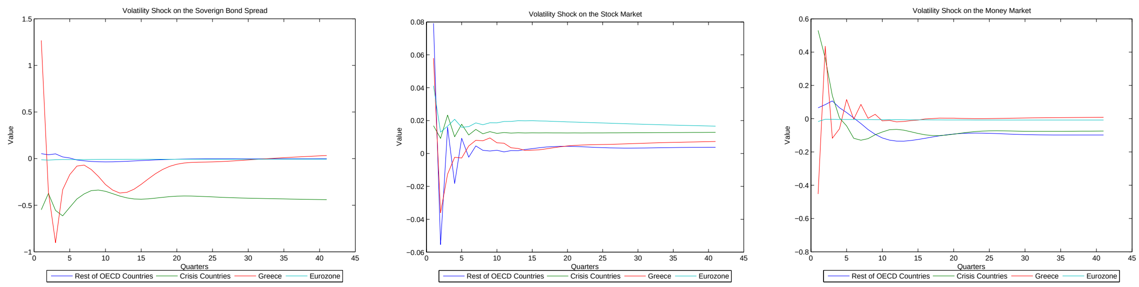


Figure 4: Shock on Volatility, starting in the United States

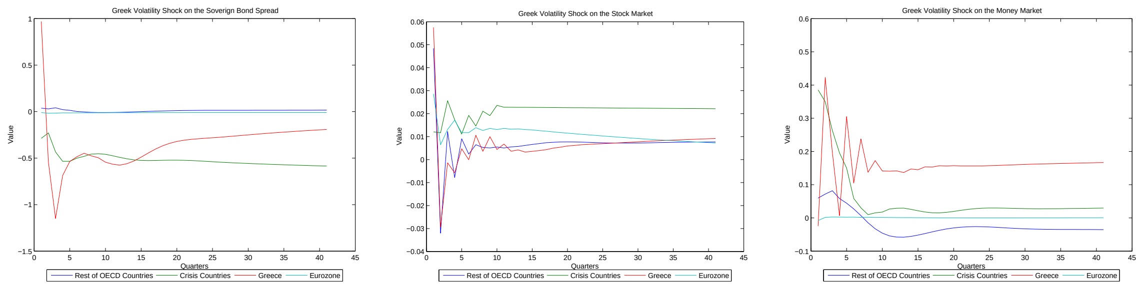


Figure 5: Shock on Volatility, starting in Greece

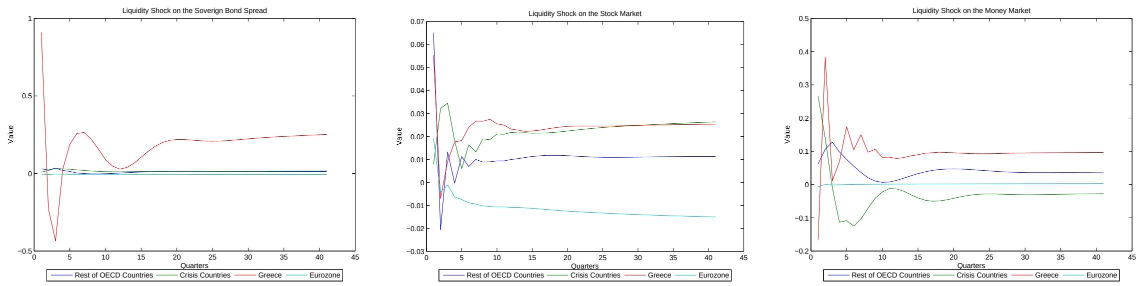


Figure 6: Shock on Liquidity, starting in the United States

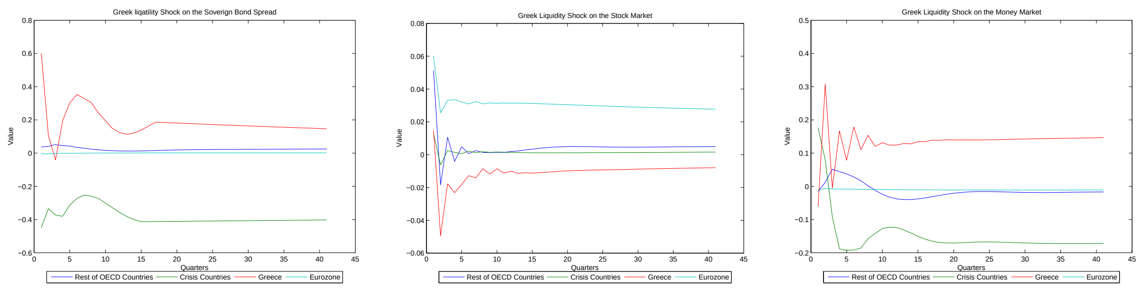


Figure 7: Shock on Liquidity, starting in the Greece

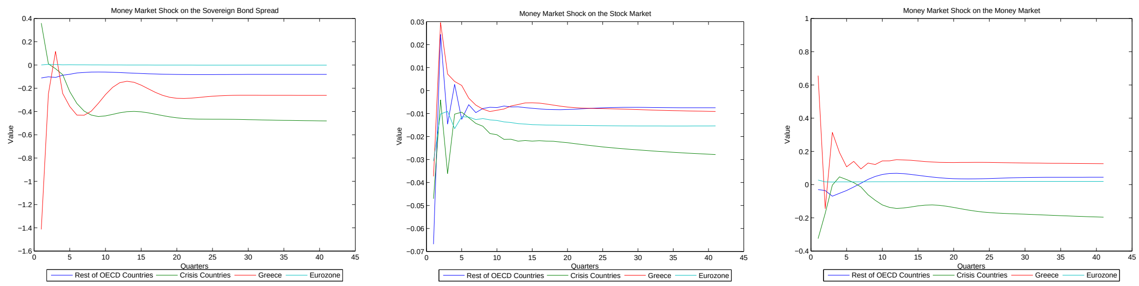


Figure 8: Shock on the Money Market, starting in the United States

Table 1: Data Sources

Variable	Category	Data Source	Frequency
Sovereign Bond Spread	Bond	Reuters	Daily
Stock Index	Financial	Reuters	Daily
Money Market Rate	Monetary Policy	Reuters	Daily
Inflation	Monetary Policy	National Central Banks	Quarterly
Industry Index	Economic Stance	OECD Database	Quarterly
Debt Outstanding	Liquidity	BIS Database	Quarterly
Fiscal Stance	Fiscal Stance	OECD, own calculation	Annual
Baa-Aaa Spread	Risk Aversion	FRED Database	Daily
CBOE VIX Index	Risk Aversion	CBOE	Daily
Bilateral Trade	Weight Matrix	OECD	Annual
FDI	Weight Matrix	OECD	Annual
EDP	Weight Matrix	Eurostat	Annual

Table 2: Principal Component Analysis

Country	Explained	Country	Explained
Canada	87.8	Netherlands	85.9
France	97.6	Portugal	96.8
Greece	93.3	Spain	80.5
Italy	91.1	United Kingdom	95.7
Ireland	85.6	United States	93.0
Japan	99.4		

Table 3: Descriptive Statistics for Sovereign Bond Spreads

	JB	Kurtosis	Skewness	Mean	Min	Max	StDev
Canada	0	3.49	0.17	0.58	-0.64	1.80	0.48
France	1	4.83	1.49	0.25	-0.12	1.23	0.30
Italy	1	2.89	1.11	1.47	0.12	5.80	1.63
Japan	1	2.37	0.54	-2.50	-3.75	-0.62	0.86
United Kingdom	0	2.26	0.36	0.69	-0.06	1.65	0.45
United States	0	2.31	0.07	0.32	-0.75	1.44	0.47
Spain	1	2.54	0.99	1.29	0.01	5.08	1.53
Greece	1	8.50	2.43	3.29	0.15	23.98	5.33
Ireland	1	6.61	2.07	1.23	-0.10	7.97	1.82
Netherlands	1	3.53	0.85	0.13	-0.20	0.67	0.18
Portugal	1	5.37	1.70	1.00	0.00	11.39	2.70

Table 4: Contemporaneous Effects

	bonds	stocks	industry	liquidity	fiscal
Canada	0.05*	0.10*	-0.05*	0.13*	0.01*
	(0.02)	(0.05)	(0.08)	(0.03)	(0.01)
France	0.10*	0.20*	0.05*	0.20*	0.00*
	(0.02)	(0.06)	(0.08)	(0.03)	(0.02)
Italy	-0.05		0.05	-0.19	0.02
	(0.13)	(0.00)	(0.07)	(0.28)	(0.02)
Japan	0.41*	0.76*	0.11*	1.72*	0.41*
	(0.10)	(0.17)	(0.25)	(0.42)	(0.09)
UK	-0.03	0.57	0.50	-1.67	0.00
	(0.02)	(0.09)	(0.19)	(0.16)	(0.03)
US	-0.01	0.34	-0.02	-0.71	0.01
	(0.02)	(0.08)	(0.09)	(0.19)	(0.01)
Spain	-0.03	0.53	0.41	0.77	0.02
	(0.05)	(0.10)	(0.18)	(0.06)	(0.05)
Greece	1.28	0.84	0.96	-1.08	0.14
	(0.99)	(0.17)	(0.17)	(0.45)	(0.15)
Ireland	0.03	0.32	0.23	0.58	-0.01
	(0.04)	(0.07)	(0.19)	(0.10)	(0.02)
Netherlands	0.05*	0.88*	0.77*	-0.24*	0.02*
	(0.02)	(0.24)	(0.26)	(0.07)	(0.05)
Portugal	0.05*	0.06*	-0.15*	0.31*	0.00*
	(0.02)	(0.03)	(0.07)	(0.06)	(0.00)

* 5% significance level, values in brackets are standard errors

Table 5: Power of explanation for the individual estimations

Country	Variable	R^2	$\bar{R}^2$	Country	Variable	R^2	$\bar{R}^2$
Canada	bond	0.57	0.41	US	bond	0.30	0.03
	stock	0.65	0.52		stock	0.63	0.49
	money	0.64	0.51		money	0.71	0.61
	cpi	0.40	0.18		cpi	0.48	0.29
	industry	0.33	0.08		industry	0.47	0.27
	liquidity	0.49	0.29		liquidity	0.35	0.10
	fiscal	0.96	0.94		fiscal	0.93	0.91
	vix	0.56	0.39		vix	0.70	0.59
France	bond	0.48	0.31	Spain	bond	0.77	0.70
	stock	0.67	0.56		stock	0.74	0.65
	cpi	0.35	0.13		cpi	0.33	0.10
	industry	0.61	0.47		industry	0.43	0.23
	liquidity	0.63	0.51		liquidity	0.85	0.80
	fiscal	0.93	0.90		fiscal	0.97	0.96
	vix	0.72	0.62		vix	0.72	0.62
Italy	bond	0.48	0.32	Greece	bond	0.83	0.77
					stock	0.63	0.51
	cpi	0.24	0.01		cpi	0.50	0.33
	industry	0.84	0.79		industry	0.70	0.60
	liquidity	0.22	-0.02		liquidity	0.35	0.13
	fiscal	0.95	0.94		fiscal	0.92	0.89
	vix	0.72	0.63		vix	0.67	0.55
Japan	bond	0.48	0.28	Ireland	bond	0.54	0.39
	stock	0.67	0.55		stock	0.68	0.57
	money	0.76	0.67				
	cpi	0.24	-0.05		cpi	0.22	-0.05
	industry	0.43	0.21		industry	0.41	0.21
	liquidity	0.52	0.33		liquidity	0.61	0.47
	fiscal	0.94	0.92		fiscal	0.95	0.93
	vix	0.70	0.59		vix	0.65	0.53
UK	bond	0.51	0.33	Netherlands	bond	0.56	0.40
	stock	0.78	0.70		stock	0.54	0.37
	money	0.63	0.50		cpi	0.29	0.03
	cpi	0.64	0.51		industry	0.73	0.62
	industry	0.53	0.36		liquidity	0.45	0.24
	liquidity	0.82	0.76		fiscal	0.92	0.88
	fiscal	0.95	0.94		risk	0.52	0.34
	vix	0.61	0.47		vix	0.65	0.51

Table 6: Variance decomposition for the entire dataset
Shocks originated in the United States

		Stocks			VIX			Liquidity			Bonds			Money Market		
Periods after shock		1	4	10	1	4	10	1	4	10	1	4	10	1	4	10
Bonds	World	7.28	5.09	3.42	0.05	0.02	0.01	5.28	3.06	1.99	32.20	25.01	16.48	5.23	5.24	3.59
	Crisis	12.34	8.56	5.58	0.74	0.73	1.13	28.03	20.80	12.11	31.69	23.84	7.62	51.96	46.46	18.16
	Greece	9.34	5.96	3.84	0.75	0.94	1.33	13.28	7.72	3.92	11.07	6.15	2.99	10.12	10.51	6.50
	Eurozone	0.26	0.32	0.23	1.31	1.25	1.24	1.57	1.29	1.21	1.37	3.22	3.01	2.19	5.00	4.65
Stocks	World	55.97	47.11	35.95	0.86	1.94	1.50	11.42	5.72	2.69	1.63	1.07	5.91	6.61	7.01	6.14
	Crisis	50.31	48.22	43.06	1.07	0.17	0.58	3.33	1.08	0.18	0.19	3.63	8.37	0.36	0.23	3.82
	Greece	6.89	5.77	4.08	0.71	0.84	0.74	2.51	1.56	0.81	2.78	1.90	0.78	2.14	2.61	1.32
	Eurozone	11.86	12.48	12.91	1.63	2.17	2.38	0.79	0.60	0.46	0.07	0.93	1.14	0.11	0.71	1.99
Money	World	1.54	1.52	1.12	0.73	0.67	0.64	3.77	4.31	3.51	1.71	0.68	0.33	23.63	14.01	7.29
	Crisis	22.39	15.90	10.23	5.98	6.46	6.14	26.65	17.11	8.95	38.64	26.29	11.43	51.67	52.71	25.89
	Greece	3.01	2.02	1.21	0.61	0.50	0.49	1.12	0.29	0.14	0.31	0.67	1.85	0.41	0.13	0.74
	Eurozone	0.14	0.07	0.01	0.01	0.00	0.00	0.13	0.20	0.04	1.96	2.27	1.75	0.06	0.17	0.10

Table 7: Variance decomposition for the entire dataset

Shocks originated in Greece

		Stocks			VIX			Liquidity			Bonds		
Periods after shock		1	4	10	1	4	10	1	4	10	1	4	10
Bonds	World	1.95	1.80	1.54	4.47	4.96	3.01	4.28	1.63	0.95	16.19	4.56	2.92
	Crisis	4.22	2.21	8.95	24.11	23.22	12.45	20.76	7.79	6.61	20.86	60.76	90.74
	Greece	0.17	3.72	3.65	7.40	28.07	22.96	3.51	1.23	0.58	94.42	26.95	17.27
	Eurozone	3.14	1.38	0.89	5.64	3.84	3.37	0.16	0.22	0.18	0.77	11.07	10.12
Stocks	World	8.70	4.16	3.54	4.19	4.37	2.76	3.44	1.15	0.61	7.49	2.36	1.21
	Crisis	14.55	11.56	11.10	1.08	0.08	0.38	1.79	0.56	-1.05	-1.55	2.53	0.55
	Greece	92.19	70.21	64.74	5.87	3.94	4.48	0.23	1.47	2.13	0.97	3.87	1.90
	Eurozone	0.43	0.43	0.51	0.32	0.12	0.10	0.01	0.01	0.12	0.02	0.16	0.31
Money	World	0.15	0.18	0.06	5.67	3.52	2.43	1.65	0.98	1.32	3.86	1.02	0.62
	Crisis	10.71	6.39	3.37	39.87	32.33	20.04	16.89	5.33	3.17	47.99	11.80	4.39
	Greece	0.13	0.75	0.58	0.02	2.49	1.73	0.01	0.14	0.11	0.61	0.25	0.10
	Eurozone	0.31	0.99	1.07	0.08	0.35	0.21	0.02	0.00	0.19	0.41	0.31	0.69

Table 8: Variance decomposition since the onset of the Eurzone

		Stock			VIX			Liquidity			Bonds		
Periods after shock		1	4	10	1	4	10	1	4	10	1	4	10
		Shocks originated in the United States											
Bonds	World	3.88	2.83	2.39	5.45	6.30	3.84	0.70	0.91	1.36	25.98	22.71	17.86
	Crisis	19.69	0.17	4.89	10.73	9.64	8.26	6.82	15.02	9.52	15.53	7.75	8.40
	Greece	1.24	1.79	1.22	16.42	9.37	5.85	1.99	2.46	1.47	0.94	0.55	1.24
	Eurozone	0.18	0.11	0.10	0.07	2.22	3.12	0.08	0.06	0.13	0.05	0.10	0.06
Stocks	World	21.96	19.27	17.58	6.56	6.51	4.48	2.16	1.48	1.13	10.44	9.25	7.69
	Crisis	0.11	4.90	7.66	0.12	0.87	1.55	6.76	2.78	2.80	6.69	12.36	14.63
	Greece	0.49	0.94	0.55	5.71	5.74	3.63	7.48	6.40	6.60	0.29	1.09	0.66
	Eurozone	0.53	1.06	1.25	0.32	0.45	0.31	0.63	0.26	0.08	2.24	4.23	4.51
		Shocks originated in Greece											
Bonds	World	2.21	1.92	1.69	1.35	1.62	1.24	0.63	0.30	0.51	6.46	1.76	1.46
	Crisis	9.22	11.29	8.20	22.84	10.88	5.59	3.84	6.02	9.17	10.32	75.53	97.16
	Greece	1.19	7.81	7.71	13.34	19.83	13.56	0.04	0.41	0.66	94.58	30.64	21.43
	Eurozone	0.35	0.95	0.73	0.89	0.85	0.55	0.01	0.14	0.90	0.04	1.43	1.04
Stocks	World	7.30	4.74	3.39	0.24	1.31	1.31	0.48	0.54	1.03	4.56	1.30	1.15
	Crisis	12.57	3.51	0.50	7.29	12.89	14.32	3.54	0.50	0.19	3.60	2.81	1.08
	Greece	61.62	43.11	40.49	12.15	11.97	9.42	5.28	8.75	10.60	6.12	1.77	1.57
	Eurozone	0.53	0.42	0.40	2.19	4.58	5.18	-0.06	-0.02	0.22	0.19	0.28	0.79