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Modelling and Forecasting Yield Differentials in the euro area. A non-linear Global VAR model

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Abstract

Instability in the comovement among bond spreads in the euro area is an important feature for dynamic econometric modelling and forecasting. This paper proposes a non-linear GVAR approach to spreads in the euro area where the changing interdepence among these variables is modelled by making each country spread function of a global variable determined by fiscal fundamentals with a time-varying composition. The model naturally accommodates the possibility of multiple equilibria in the relation between default premia and local fiscal fundamentals. The estimation reveals a significant non-linear relation between spreads and fiscal fundamentals that generates time-varying impulse response of local spreads to shocks in other euro area countries spreads. The GVAR framework is then applied to the analysis of the dynamic effects of fiscal stabilization packages on the cost of government borrowing and to the evaluation of the importance of potential contagion effects determining a significant increase in cross-market linkages after a shock to a group of countries.

Keywords: non-linear Global VAR, Bond Spreads in the euro-area, time-varying interdependence, contagion

JEL Classification: C51, C58

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1 Introduction

Bond spreads in the euro area feature a pattern of co-movement that has important implications for their dynamic econometric modelling and forecasting. Importantly, the nature of co-movement among bond spreads is very different from that of real variables. Figure 1-2 provide some graphical evidence on this issue. Figure 1 reports fluctuations of log real per capita de-meaned GDP[1] of eleven euro area countries and of the spreads of 10-year government bonds on German Bunds with the same maturity. The figure illustrates that instability in the co-movement among spreads is much stronger than that in the co-movement of real variables. Bond spreads comoved very strongly at low level from the inception of euro to the US subprime loans crises. Following the Lehman event in September 2008, a first wave of widening yield spreads of euro area government bonds vis-à-vis German bonds took place. Such a widening was largely synchronous, even though of different magnitude, across most euro area countries. The Greek debt crisis of 2009 brought about different responses in the euro area spreads with some divergence between low-debt countries and high-debt countries. Figure 2 illustrates the heterogeneity in co-movements of real and financial variables in the Euro area by reporting the time series of cross-sectional means and standard deviations of log per capita GDP differentials between euro area countries and Germany and spreads on German Bunds for the same countries. The cross sectional first and second moments of GDP differentials are rather stable over time while the cross-sectional moments of the spreads on bund are much more volatile.

This feature of the data provides a very serious challenge to modelling the common trend of financial spreads within a cointegration framework with a constant number of cointegrating vectors and stable parameters. It also poses a challenge for mapping the volatile time-series behaviour of spreads into slowly evolving and persistent fiscal fundamentals. This paper addresses these issues by extending the framework of a Global VAR introduced by Pesaran and coauthors (see, for example, Pesaran, Schuermann, Weiner (2004), Pesaran and Smith(2006), Pesaran M.H., Schuerman T., B-J. Treutler and S.Wiener (2006) and Dees, di Mauro, Pesaran, Smith (2007)) to propose a non-linear Global VAR model of the spreads on bunds. In the proposed specification the dynamics of each spread on German Bund is determined by a local variable, i.e countries fundamentals relative to the German ones, and a

[1] De-meaning here is to be taken as a simple re-scaling device for graphical purposes. The presence of a unit-root in the log of GDP would prevent the definiton of the undicontional mean.

global European variable that models the exposure of each country's spread to the other spreads in the euro area in terms of the "distance" between their fiscal fundamentals and a global non-European variable, the US Baa-Aaa spread. The global european variable for each country's spreads on Germany is determined by a weighted average of spreads in all other countries in which the weights are constructed to make the factor more dependent on the spreads of those countries that are more similar in terms of fiscal fundamentals. This framework modifies the traditional GVAR approach were global macro variables are constructed for each countries by using trade weights. Using the distance in terms of fiscal fundamentals makes the global variable country specific, as in the traditional GVAR framework, but the weights more volatile than in standard GVAR based on trade weights. The changing weights, related to the changing expectations for fiscal fundamentals, have the potential of explaining the changing correlation among spreads. This specification explicitly allows for a non-linear relationship between spreads and fiscal fundamentals. Fiscal fundamentals are important in the determination of the spreads as they define the distance between countries and therefore select the reference group relevant to determine the global variable that influences different spreads. This framework allows for an important degree of flexibility in modelling the interdependence among long-term interest rates in euro area countries: a time-varying interdependence, dependent on the different evolution of fiscal fundamentals, is explicitly allowed for.

This paper adds to a considerable empirical literature on bond spreads in the euro area. A common finding in this literature, beginning with Codogno et al. (2003), Geyer et al.(2004) and Bernoth et al. (2006) and including more recent studies such as Manganelli and Wolswijk (2009), Haugh et al. (2009) and Schuknecht et al. (2010), is that euro area sovereign yield spreads seem to strongly comove. After the introduction of the Euro and the disappearance of expectations of exchange rate expectations and different fiscal treatment of national and foreign bonds in the euro area, yield differentials in the common monetary policy area can be attributed to credit risk or liquidity risk. The strong co-movements of yields in the presence of a very heterogenous liquidity of bonds issued by the different countries in the euro areas suggest either the dominance of credit risk or a strong co-movement between credit-risk and liquidity risk (Favero, Pagano and von Thadden(2010), Beber, Brandt and K. Kavajecz (2009)). Borgy et al.(2011) illustrates how the strength of co-movement varies substantially over time and has weakened since 2009. Sgherri and Zoli(2009) also argue that since 2008 local fiscal fundamentals have gained strength in explaining the deviation of spreads from a common time-varying factor. Aßmann and

Boysen-Hogrefe (2009) observes a difference in the nature of co-movements in good times and bad. Credit risk should depend on fiscal fundamentals but a linear relation between fiscal fundamentals and yield spreads in the euro area has proven to be elusive and time-varying (Attinasi et al.(2010), Sgherri and Zoli(2009), Laubach(2009, 2011)). In this paper we propose a GVAR framework to model a non-linear relation between fiscal fundamentals and bond spreads in the euro area. In a companion paper, Favero and Missale(2012) apply the model to assess costs and benefits the introduction of a common Eurobond.

The specification of the model is introduced in the next section. We then move to the data and proceed to estimate the relevant parameters and to illustrate the properties of the models via impulse response analysis and out-of-sample forecasting and simulation analysis. Finally, we address the issue of financial contagion among euro area spreads and the relative role of fundamentals and market sentiments in their determination.

2 A non-linear GVAR model for 10-year Bond differentials in the Euro area.

Long-term yields differentials in the euro area co-move but with an unstable pattern of co-movement over time: yields converged significantly with the introduction of the euro, narrowing from highs in excess of 300 basis points in the pre-EMU period to less than 30 basis points about one year after the introduction of the Euro. Yet, bonds issued by euro-area Member States have never been regarded as perfect substitutes by market participants: interest rate differentials co-moved synchronously at the very low-level between the introduction of Emu an the subprime crisis , they became sizeable during the course of 2008 and 2009 with some separation in co-movement between high-debt and low debt countries. The euro debt crisis in 2010 and 2011 brought about differentials of the same, or even greater magnitude, than those of the pre-euro era and more heterogeneity in co-movement.

There are different possible explanations for these interest rate differentials. The first one is credit risk; sovereign issuers that are perceived as having a greater solvency risk, must pay investors a default risk premium. The second explanation is liquidity risk, that is, the risk of having to sell (or buy) a bond in a thin market and, thus, at an unfair price and with higher transaction costs. Before the introduction of the Euro, also expectations of exchange rate fluctuations and different tax treatment of bonds issued by different countries were relevant. Different tax treatments were eliminated or reduced to a negligible level during the course of the 90s. The introduction of the Euro in January 1999 virtually eliminated the expectations on exchange rate fluctuations, at least until the most recent events that might have induced some positive probability on the event of the collapse of the EMU. Of the two remaining explanations credit-risk is the dominant one as liquidity risk has a small role and it strongly co-moves with credit-risk

The availability of Credit Default Swaps (CDS) for the more recent part of the sample allows us to measure the default-risk premium component. A CDS is a swap contract in which the protection buyer of the CDS makes a series of premium payments to the protection seller and, in exchange, receives a payoff if the bond goes into default. The difference between a CDS on a Member State bond and the CDS on the German Bund of the same maturity is a measure of the default risk premium of that State relative to Germany.[2]

Figures 3 and 4 report interest-rate differentials for euro-area Member States (blue line) —i.e. the spreads of 10-year government bond yields on German Bund yields– along with the associated CDS spreads (red line) and the residual non-default component (black line). We group the yield spreads on Bunds and the associated CDS into high yielders (Figure 3) and low yielders (Figure 4).

The data show a clear tendency of all spreads on Bunds in the euro-area to comove, but the nature of the co-movement is not constant over time. The CDS spread, i.e. the default risk component of the yield spread, accounts for virtually the entire differential (and its variability) in the case of high yielders over the whole sample period, with the emergency of some counterparty risk in Greek CDS over the very last part of the sample. The non-default component if the yield spreads is very small for all member countries with only a few exceptions: Finland, the Netherlands, and France during the global financial crisis 2007-09. These components are clearly time-varying and fluctuate between around 10 basis points in calm periods and around 50-60 basis points during crises. They also co-move with default premium. The case of France is particularly interesting in that the co-movement of the spread of OAT on Bunds with other spreads in the euro

[2] Note that, as clearly discussed in Sturzenegger and Zettelmeyer (2006), CDS is direct measure of the default risk but not of the probability of default, as the price of a CDS depends both on the probability of default and on the expected recovery value of the defaulted bond. Moreover, such measure is not perfect; CDS differentials might also reflect the different liquidity of different sovereign CDSs, as well as counterparty risk (i.e. the risk that the protection seller of the CDS is not able to honor her obligation when the bond goes into default).

area seems to be determined primarily by the non-default component during the US subprime crisis and by the default component during the Euro area debt crisis. The commonality of fluctuations in the non default component makes it difficult to relate them to expectations of exchange rate depreciation while it is consistent with time varying models of the liquidity premia as the one proposed by Acharya and Pedersen (2005) and with the empirical evidence on a time-varying liquidity premium in the euro area co-moving with the default risk premium, reported in Beber et al. (2009) and Favero et al. (2010).

The conclusion of the exploratory analysis of the data is that the main driver of yield differentials (spreads of 10-year yields on German Bunds) in the euro area is default risk, that there a strong co-movement among differentials but the nature of this co-movement is time-varying.

The Global VAR (GVAR) approach advanced in Pesaran, Schuermann and Weiner (2004, PSW) provides a flexible reduced-form framework capable of accommodating a time-varying co-movement across domestic variables and their foreign counterpart.

The general specification of a GVAR can be described as follows:

$$\mathbf{x}_{it} = B_{id}\mathbf{d}_t + B_{i1}\mathbf{x}_{it-1} + B_{i0}^*\mathbf{x}_{it}^* + B_{i1}^*\mathbf{x}_{it-1}^* + \mathbf{u}_{it}$$

where $\mathbf{x}_{it}$ is a vector of domestic variables, $\mathbf{d}_t$ is a vector of deterministic elements as well as observed common exogenous variables, $\mathbf{x}_{it}^*$ is a vector of foreign variables specific to country i. In general $\mathbf{x}_{it}^* = \sum_{j \neq i} w_{ji}\mathbf{x}_{jt}$ where w_{ji} is the share of country j in the trade (exports plus imports) of country i. Finally $\mathbf{u}_{it}$ is a vector of country-specific idiosyncratic shocks with $E\left(\mathbf{u}_{it}\mathbf{u}_{jt}'\right) = \Sigma_{ij}, E\left(\mathbf{u}_{it}\mathbf{u}_{jt'}'\right) = 0$, for all i, j and $t \neq t'$. The construction of the foreign variables allows for the identification of a common component that is different across countries and it is computed as a time-varying linear combination the domestic variables. Beside being a parsimonious approach to international co-movement the GVAR has also much more flexibility that a VAR in accommodating varying (both in the cross-sectional and in the time-series dimension) co-variation across variables. The GVAR framework can also accommodate long-run solution and the existence of cointegration between the $\mathbf{x}_{it}$ and the $\mathbf{x}_{it}^*$. A cointegrating GVAR can be written in VECM format as follows:

$$\Delta\mathbf{x}_{it} = B_{id}\mathbf{d}_t - \Pi_i\mathbf{z}_{it-1} + B_{i0}^*\Delta\mathbf{x}_{it}^* + \mathbf{u}_{it}$$

where $\mathbf{z}_{it-1} = \left(\mathbf{x}'_{it-1}, \mathbf{x}^{*\prime}_{it-1}\right)'$, $\Pi_i = (I - B_{i1}, -B^*_{i0} - B^*_{i1})$.

We propose to model spreads in the euro-area via a GVAR specification that allows for a non-linear relation between fiscal fundamentals and government bond spreads. In particular we concentrate on the following specification for a system of ten equations for the 10-year interest-rate spreads on German Bunds for Austria, Belgium, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal and Spain, to be estimated on monthly data:

$$\begin{aligned}
\Delta\left(Y_t^i - Y_t^{bd}\right) &= \beta_{i0} + \beta_{i1}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right) + \beta_{i2}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right)^* + \beta_{i3}\left(Baa_{t-1} - Aaa_{t-1}\right) \\
&\quad + \beta_{i4}E_t\left(b_t^i - b_t^{bd}\right) + \beta_{i5}E_t\left(d_t^i - d_t^{bd}\right) + \\
&\quad + \beta_{i6}\Delta\left(Y_t^i - Y_t^{bd}\right)^* + \beta_{i7}\Delta\left(Baa_t - Aaa_t\right) + \mathbf{u}_{it} \\
\left(Y_t^i - Y_t^{bd}\right)^* &= \sum_{j\neq i} w_{ji}\left(Y_t^j - Y_t^i\right) \\
w_{ji} &= \frac{w_{ji}^*}{\sum_{j\neq i} w_{ji}^*},\ w_{ji}^* = \frac{1}{dist_{ji}}\ if\ dist_{ji} < 1, 0\ otherwise \\
dist_{ji} &= 0.5 * E_t\left(\left|b_t^j - b_t^i\right|\right)/0.6 + 0.5 * E_t\left(\left|d_t^j - d_t^i\right|\right)/3
\end{aligned}$$

The model relates yield spreads on Bunds to local fiscal fundamentals, a non-euro area exogenous variables and foreign euro-area spreads. Following Attinasi et al. (2010), we include the average for a 2-year period of the expected budget balance to GDP ratio (d_t^i) and debt to GDP ratio (b_t^i). The expected variables are the European Commission Forecasts, that are released on a biannual basis. We include in the model the difference between each country's forecast and the forecast of the same variables for Germany. The non-euro area exogenous variables is the US corporate Baa-Aaa spread, computed on the basis of the data made available in the FRED database of the Federal Reserve of St. Louis. This variable is introduced to capture the influence of time-varying risk aversion, which is a world factor commonly believed to influence euro area credit spreads (Codogno et al. (2003), Geyer et al.(2004) and Bernoth et al. (2006)). Finally, we introduce a global variable that delivers country-specific common components designed to capture the impact of other countries' yield spreads on each country's spread on German Bund. In the specification of this variable we innovate with respect to the traditional approach of using trade weights. The spreads of all foreign countries are mapped into a global country-specific factor by taking into account their “distance” from the country considered.This distance is measured in terms of differences in fiscal fundamentals. In particular, an equally weighted average of the distance in expected deficit to GDP ratio and in expected debt to GDP ratio is considered. For aggregation purposes distances in terms of debt and deficit are rescaled by the Maastricht limits (sixty per cent for the debt to GDP ratio and 3 per cent for deficit to GDP ratio). Countries weights are set to zero when the distance between two countries is higher than one. The use of time-varying weights determined by the distance among fiscal fundamentals is a contribution to the existing GVAR literature that already includes weighting schemes alternative to the standard trade weights: Galesi and Sgherri (2009) propose weights based on cross-country financial flows, while Vansteenkiste (2007) uses weights which are based on the geographical distances among regions, whereas Hiebert and Vansteenkiste (2007) adopt weights based on sectorial input-output tables across industries. This construction of the global spread introduces the possibility of a non-linear relation between spreads and fiscal fundamentals and makes the global variable more volatile and thererofre potentially more appropriate to capture fluctuations in domestic spreads than the global variables constructed by using trade weights. Figure 5 clearly illustrates the point by considering the case of Spain, for which a global spreads based on trade weights tracks the observed spreads much worse than a global spread based on weights measuring the distance in terms of fiscal fundamentals. Fiscal fundamentals are important in the determination of the spreads as they define the distance between countries and therefore select the reference group relevant to determine the global variable that influences spreads.

The time-varying weights, related to the changing forecasts for fiscal fundamentals, have the potential of explaining the changing correlation of spreads discussed in the descriptive data analysis. To illustrate the point we report in Figure 6 the global spreads for a typical low-yielder, the Netherlands, and a typical high yielder, Ireland. Note that, in the no-crisis period, the global spread variables for the Netherlands and Ireland are very strongly correlated with a very similar mean, while in the wake of a crisis the two global variables diverge as the higher distance of the Netherlands from the high-yielders generates a lower mean and a lower volatility for its global spread.

2.1 Properties of the model

The specified model consists of twenty equations: ten equations for the spreads and ten identities defining the global variables. No equation is specified for the US (Baa-Aaa) spread and for the forecast of fiscal variables as they are taken as exogenous as the model will be estimated on monthly data and simulated for an horizon of at most six months. The Baa-Aaa is a global non- euro area variable that is considered as strongly exogenous. The (weak) exogeneity of the fiscal forecast can be justified on the basis of the frequency of the data. Forecast for the fiscal variables are provided by the European Commission every six-months while the model is estimated on monthly data for the spread. The assumption of weak exogeneity is therefore justified if the current observation of the spread does not affect the forecast for the fiscal variables over the next six months, and it is also valid for simulation purposes when the model is to be used with an horizon for simulation and forecasting of less than six- months. Given the time necessary to propose and vote budget laws, the absence of a feedback from market conditions to the relevant legislation to determine the dynamics of fiscal variables within a period of six-months seems a tenable assumption. Also the absence of a simultaneous response of real macroeconomic variables, such as GDP growth, to financial variables is a common assumption in the monetary VAR literature. Global spreads are taken as weakly exogenous for estimation purposes as in the tradition of Global VAR (the global variable is an average of spreads in the euro area excluding the country for which the right-hand variable is specified). However, the absence of simultaneous feedback is imposed only contemporaneously, i.e. within the same month, and the global spread are not taken as strongly exogenous as they dynamically depend on each country's spread when the model is simulated. The long-run equilibrium for all spreads depends non-linearly on fiscal fundamentals for all Euro area countries and on the (Baa-Aaa) spread. The model can therefore accommodate multiple equilibria (see, for example, Calvo(1988)) relationships between each country's fiscal fundamentals and the spread on Bunds. For the same level of local fiscal fundamentals a "good equilibrium" or a "bad equilibrium" may emerge depending on the fiscal fundamentals of other euro area countries, close countries in term of fiscal fundamentals matter for each country more than distant countries. As a consequence, the emergence of a "bad equilibrium" might affect only a subset of countries, but the more countries are caught in the bad equilibrium the more likely is that other countries will also fall in the same equilibrium.

The model allows for interaction among different euro area spreads through three separate but interrelated channels:

1. Direct dependence of the each country spreads on their associated global euro area foreign counterparts and their lagged values. Note that the weights adopted to determine the global euro area foreign counterparts

depends on the distance between fiscal fundamentals, therefore the strength of interaction is not constant over time and the time-varying interdependence is determined by the dynamics of fiscal fundamentals ;

2. Dependence of the region-specific variables on a common global exogenous variables: the (Baa-Aaa) spread;

3. Non-zero contemporaneous dependence of shocks in region i on the shocks in region j, measured via the cross-region covariances of the residuals in the behavioural equations of the system.

After model estimation and identification of the relevant shocks, impulse response analysis can be performed. The shape of the impulse responses is determined by the changing fiscal fundamentals and the model will deliver different impulse responses when the same shocks hit the system in different periods. Given the non-linearity of the system, impulse responses can be computed via simulation of the full system of twenty equations through the implementation of the following steps:

1. generation of a baseline simulation for all variables by solving dynamically forward the estimated system of the ten equations and ten identities (in this step all shocks are set to zero and a scenario is available for the fiscal forecasts and the Baa-Aaa spread)

2. generation of an alternative simulation for all variables by setting to one–just for the first period of the simulation–the structural shock of interest, and then solve dynamically forward the model up to the same horizon used in the baseline simulation,

3. computation of impulse responses to the structural shocks as the difference between the simulated values in the two steps above. (Note that these steps, if applied to a standard VAR, would produce standard impulse responses).

4. computation of confidence intervals via bootstrap methods.[3]

   The model can also be used to forecast weekly spreads up to the six-month ahead horizon conditioning on a scenario for fiscal forecasts and the (Baa-Aaa) spread. Finally, the impact of fiscal packages on the

[3]Bootstrapping requires saving the residuals from the estimated model and then iterating the following steps: a) re-sample from the saved residuals and generate a set of observation for all spreads, b) estimate the VAR and identify strucutral shocks, c) compute impulse responses going thorough the steps described in the text, d) go back to step 1. By going thorugh 1,000 iterations we produce bootstrapped distributions for impulse responses and compute confidence intervals.

short-term dynamics of the spreads can be evaluated by generating forecast based on a baseline scenario for fiscal forecast to be compared with the scenario for fiscal forecast modified to take the effect of fiscal stabilization packages into account.

3 Taking the model to the data

The model is taken to the data by considering a sample of monthly observations over the period 2000-2011, the properties of the specification are illustrated via estimation, impulse response analysis and dynamic out-of-sample simulation based on a baseline and on an alternative scenario for the exogenous variables

3.1 Estimation

The results of the estimation, implemented via the SURE method, are reported in Table 1. The model has been estimated over the euro regime for the sample 2000:1-2011:4. We have stopped estimation in April 2004, as this is the last period in which the global variable is different from zero for all countries included in the system. In fact, from May 2004 onwards as a consequence of the increased distance between Greek fiscal fundamentals and all other euro area countries fundamentals, the weight of Greece in the determination of the relevant global trends becomes zero for all countries and no-global variables for Greece can be defined.[4] The definition of global variable that we have adopted prevents from including in the system adopted to generate global variables those countries with fiscal fundamentals "too far", in terms of the Maastricht criteria, from those of the other Euro area countries. The spread on German Bunds for a country that is distant from all other countries in the euro area more that sixty per cent in terms of the debt to GDP ratio and more than three per cent in terms of the deficit to GDP ratio becomes insulated from the general euro area dynamics. The estimation results show that there is evidence for a long-run solution for each spread that depends on the level of the Baa-Aaa spread and

[4] In principle, the estimation of the system over the full-sample up to the end of 2011 could be still performed. From 2011:5 onwards the explosive behaviour of the Greek spread will not affect other spreads as a consequence of the insulation of Greece in the construction of global variables. However, it would be impossible to bootstrap the system using the entire sample because Greece would not be insulated from the rest of Europe before April 2011 and therefore the explosive behaviour of the Greek spread will affect the entire system making it unstable under simulation.

the global variable. This evidence is statistically significant for all countries with milder evidence for Italy and Portugal. Fiscal fundamentals seem to affect spreads only non-linearly through the global variable as there is no evidence for a linear impact of debt to GDP and deficit to GDP forecasts on the spreads. Fluctuations in the global variables and the Baa-Aaa spreads are also in general significant in determining the short-run dynamics of the spreads. However, changes is the Baa-Aaa spread do not impact significantly on the spread of bunds in the case of Ireland, Portugal, and Austria, while changes in the global spread do not affect the Spanish and the Finnish spread. Overall, there is a sizeable heterogeneity of coefficients across countries. This heterogeneity speaks against imposing panel restrictions when the system is estimated. Finally, it is worth noting that the on the top of the interdependence introduced by the global variable and the Baa-Aaa there is an additional channel captured by the variance-covariance matrix of residuals that witnesses the presence of significant cross-correlation among the residuals of the equations for different spreads.

3.2 Impulse Response Analysis

The specification of a non-linear GVAR model for the spreads has interesting implications for the implementation of the standard way of examining economic interaction: i.e. impulse responses. Impulse response analysis examines the effect of a typical shock, usually one-standard deviation, on the time path of the variables in the model. In the non-linear GVAR specification, impulse responses are not constant over time as they depend on the time-varying distance between fiscal fundamentals across different countries. To illustrate the relevance of this point for the econometric modelling of the dynamic properties of our model consider the case of Ireland and Greece. Figure 5 reports the weight of Greece in the determination of the global spread relevant to Ireland. At the beginning of 2005 the fiscal fundamentals in Greece were so different from the Irish one that the weight of Greece in the determination of the global spread for Ireland was zero (the expected debt to GDP ratio over the two following here stood respectively at 32 per cent and 111 per cent, while the expected deficits over GDP ratio were 0.5 per cent and 3.3 per cent). Over time the Irish fiscal fundamentals have converged remarkably to the Greek ones and at the beginning of 2010 the weight of the Greek spread in the determination of the global spread for Ireland has become as high as 0.6, as the Irish debt to GDP ratio has risen to 90 per cent of GDP while the same figure for Greece stood at 130 per cent and the expected deficit to GDP ratio has become very close with the

Irish figure of 14.7 per cent being higher than the Greek figure of 12.5 per cent. Dynamic simulation of our model should reflect these facts through the heterogeneity of impulse response functions in the two periods.

Impulse response functions can be computed by considering innovations to observables, such as the spreads of 10-Y Greek bonds on German Bunds or the US Baa-Aaa spreads, or to unobservables, i.e. the "structural" shocks to some of the variables included in the VAR. Computing impulse responses to unobservables requires some identification assumption and the orthogonality of structural shocks allows to consider the effect of each identified shocks in isolation. The study of the response to the system to an innovation in observable does not require any identification assumption but the contemporaneous linkages between shocks must be modelled. We illustrate the properties of our model by considering the effect of a 50 basis point innovation in the spread of Greek bonds on bunds on the spread of Irish bonds on bunds, using the Generalized Impulse Response Functions, GIRFs, discussed in Garratt et al.(2006), that exploits the estimated error covariances to model the contemporaneous linkages across shocks.[5] This requires no identifying assumptions, although the non-orthogonality of the innovations may pose some difficulties in the structural interpretation of the shocks. GIRF seems to be more appropriate when, as in our case, the primary focus of the analysis is the description of the transmission mechanism rather than the structural interpretation of shocks. The effect of the shock we are studying can be interpreted as the effect on the variables in the model of an intercept adjustment to the particular equation shocked. The second panel of Figure 7 illustrates a significant heterogeneity in the effect of a 50bp innovation in the Greek spread on the Irish Spreads: the effect in 2010 is twice as stronger as in 2005 (with impact multiplier larger than one in 2010 where the response in the Irish spreads stands at 70 basis points against an initial response of 30 basis points in 2005) and the difference is statistically significant.

3.3 Dynamic Simulation

The non-linear relation between fiscal fundamentals and 10-Y government bond spreads embedded in the non-linear GVAR specification could be exploited by using the model to simulate the dynamic effect on spreads of fiscal

[5]Within this framework the simultanoeous response of each country spread to an innovation in the spread of Greek bonds on bunds is estimated as the expectations of the innovation in each country spread conditional on the realization of the innovation in the Greek-German spread.

policy packages. At the end of 2011 the Italian parliament has approved a fiscal stabilization package proposed by the government led by the newly appointed prime minister Mario Monti, that implemented a correction in the deficit to GDP ratio of about 2 per cent and to a stabilization of the debt to GDP dynamics. The non-linear GVAR model allows to evaluate the impact of this stabilization package on the BTP-Bund spread. We do so by simulating the model forward for six-months over the period November 2011-May 2012. Two scenarios for simulations are considered: a baseline scenario in which the projected deficit to GDP ratio and debt to GDP ratio take the values forecasted by the European Commission in October 2011 and stands respectively at 1.75 per cent and 119.6 per cent and an alternative scenario in which the two per cent correction of the Monti stabilization package is used to project the deficit to GDP and debt to GDP ratio for Italy. The European Commission forecasts for all the other countries are left unaltered in the baseline and the alternative scenarios, also the Baa-Aaa spread is kept constant at about one-hundred basis points in the two alternative simulations. Figure 8 reports the simulated spread of Italian BTP on bund under the two scenarios. The dynamic simulation of our model suggests an impact effect of the stabilization package of a reduction in the spread of about 40 basis points (with the spread standing at just below 400 basis points in the baseline scenario and at about 360 bp in the alternative stabilization scenario) that becomes of about 80 basis points after six-months (with the spread standing respectively at 490 and 410 bp). The impact effect is mainly attributable to the modification in the global spread relevant for Italy as a consequence of the change in the distance between Italy and the other Euro area countries caused by the stabilization package, such a modification also affects the relevant dynamics that lead to a further reduction in the spread over time.

4 Interdependence and Contagion

The non-linear GVAR model allows for a time-varying interdependence between spreads in the euro area, where the only source of variation are fiscal fundamentals. The stability of the relation between global spreads and local spreads limits the time variation of the interdependence among country spreads as it only allows fluctuations driven by fiscal fundamentals. In such a framework markets do have a role as a fiscal discipline device as the interdependence among different countries might very well change over time but only in a way related to fundamentals. The structural stability of the coefficients on the global variable it is an issue of some relevance: in fact, instability of the impact on the global variable on local spreads would imply that episodes of contagion might dominate the fundamentals driven interdependence across countries, and market sentiment might become an important driver of spreads in presence of shocks. Following Forbes and Rigobon(2002), a significant increase in cross-market linkages after a shock to a group of countries can be defined as contagion. Contagion here is to be interpreted as a change in the relation between spreads in the Euro area in addition of the "natural" time-varying relation driven by fiscal fundamentals. Note that local spread show a high degree of dependence to global spread during periods of stability. Therefore the evidence that markets continue to be highly correlated after a global shock may not constitute contagion. It is only contagion if cross-market co-movement increases significantly after the shock. The presence of contagion is identified by a time-varying interdependence. If the non-linear GVAR specification captures correctly the fundamentals driving the spreads, then the effect of contagion, can be used to measure the impact of "market sentiment" in driving yield differentials away from the path consistent with fundamentals.

To measure the effect of contagion we propose to estimate a series of Multivariate GARCH model for the spread of each country on Germany and the associated global spread[6]. This specification allows for a time varying conditional variance-covariance between the spread of domestic bonds on Bund and the global spread relevant for each country and it can be used to generate a time-varying estimates of the impact of the global spread on the domestic spread.

In practice, we estimate the following reduced form specifications of our Global VAR:

[6]The specification of the bivariate model allows to parsimoniously parameterise the time varying process for the variance-covariance matrix.

$$
\begin{aligned}
\left[\begin{array}{c} \Delta\left(Y_t^i - Y_t^{bd}\right) \\ \Delta\left(Y_t^i - Y_t^{bd}\right)^* \end{array}\right] &= \boldsymbol{\beta}_{i0} + \boldsymbol{\beta}_{i1}\left[\begin{array}{c} E_t\left(b_t^i - b_t^{bd}\right) \\ E_t\left(b_t^i - b_t^{bd}\right)^* \end{array}\right] + \boldsymbol{\beta}_{i2}\left[\begin{array}{c} E_t\left(d_t^i - d_t^{bd}\right) \\ E_t\left(d_t^i - d_t^{bd}\right)^* \end{array}\right] + \\
&\quad + \boldsymbol{\beta}_{i3}\left[\begin{array}{c} \left(Y_{t-1}^i - Y_{t-1}^{bd}\right) \\ \left(Y_{t-1}^i - Y_{t-1}^{bd}\right)^* \end{array}\right] + \boldsymbol{\beta}_{i4}\left(Baa_{t-1} - Aaa_{t-1}\right) \\
&\quad + \boldsymbol{\beta}_{i5}\Delta\left(Baa_t - Aaa_t\right) + \mathbf{H}_t^{1/2}\left[\begin{array}{c} \overset{i}{u}_t \\ \overset{*}{u}_t \end{array}\right] \\
vech\left(H_t\right) &= M + Avech\left[\begin{array}{c} \overset{i}{u}_{t-1} \\ \overset{*}{u}_{t-1} \end{array}\right]\left[\begin{array}{c} \overset{i}{u}_{t-1} \\ \overset{*}{u}_{t-1} \end{array}\right]' + Bvech\left(H_{t-1}\right) \\
\left(Y_t^i - Y_t^{bd}\right)^* &= \sum_{j \neq i} w_{ji}\left(Y_t^j - Y_t^{bd}\right) \\
E_t\left(b_t^i - b_t^{bd}\right)^* &= \sum_{j \neq i} w_{ji}\left(b_t^j - b_t^{bd}\right) \\
E_t\left(d_t^i - d_t^{bd}\right)^* &= \sum_{j \neq i} w_{ji}\left(d_t^j - d_t^{bd}\right)
\end{aligned}
$$

This specification models the joint process of the yield spread of country i bonds on German Bunds and the global spread variable relevant to country i as a persistent process with a mean determined by the expected fiscal fundamentals and by the US Baa-Aaa spread. The time-varying variance-covariance matrix of residuals, H_t, is modelled as a diagonal BEKK (Engle and Kroner 1995) system. Therefore, the conditional variances, covariances and correlation are allowed to vary over time.

The model provides us with a natural measure of contagion: the dynamic conditional beta in the terminology of Bali and Engle (2010), which is the coefficient determining the effect of a shock in the global spread on the i-th country spread.

$$
\begin{aligned}
E\left(\overset{i}{u}_t \mid \overset{*}{u}_t\right) &= \gamma_t \overset{*}{u}_t \\
\gamma_t &= h_{12,t} h_{22,t}^{-1}
\end{aligned}
$$

Variations in the coefficient γ_t reflect a time varying interdependence between the domestic spread and the global spread and they therefore illustrate how contagion affects the i-th country spread following a shock to the global spread. The estimation of the GARCH system indicates the presence of contagion during financial crisis, we illustrate the point by reporting in

Figure 9 the constant SURE estimates alongwith the time-varying BEKK-GARCH estimates of the impact effect of a change in the global spread for Italy on the BTP-BUND spread. The time varying estimates show that during the US subprime crisis and the Euro-area debt crisis the response of the BTP-BUND spreads to the fluctuations in the other euro-area countries spread was stronger than the one driven by fundamentals in non-crisis periods.

5 Conclusions

Instability in the co-movement among bond spreads in the euro area is an important feature for dynamic econometric modelling and forecasting. This paper has proposed a non-linear GVAR approach to spreads in the euro area where the changing interdependence among these variables is modelled by making each country spread function of a global variable with a time varying composition. In fact, the GVAR model proposed here maps the spreads of all other countries into the factor relevant to determine the dynamics of each country spread by taking into account the "distance" from the country considered. Distance is measured in terms of differences in fiscal fundamentals: the expected deficit to GDP ratio and in expected debt to GDP ratio. The model naturally accommodates the possibility of multiple equilibria in the relation between default premia and fiscal fundamentals. Different spreads might correspond to the same level of domestic fiscal fundamentals as the mapping between spreads and local fiscal fundamentals is affected by other euro area countries fiscal fundamentals. The estimation of the model reveals a significant non-linear relation between spreads and fiscal fundamentals that generates time-varying impulse response function of local spreads to shocks in other euro area countries spreads. The GVAR framework can also be naturally applied to the analysis of the dynamic effects of fiscal stabilization packages on the cost of government borrowing. The simulation of the GVAR model for the evaluation of the fiscal stabilization package introduced by the Monti government in Italy at the end of 2011 estimates its effect on the spread in a reduction of just below one-hundred basis points in the semester following its announcement. Finally, the investigation of the stability in the relation between global spreads and local spreads in the GVAR framework allows to address the importance of potential contagion effects determining a significant increase in cross-market linkages after a shock to a group of countries. The empirical evidence on this issue reveals the existence of important, although non-dramatic, contagion effects during the US subprime mortgage crisis and the Euro area debt crisis.

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Table 1 - Spreads on Bunds, Seemingly Unrelated Regression,
Sample February 2000-April 2011. monthly data

	BG	ESP	FIN	FRA	GRE	IRE	ITA	NL	OE	PT
β_{i0}	**0.078**	0.024	−0.030	−0.01	0.187	**−0.213**	0.066	**−0.021**	**−0.036**	0.085
	(0.020)	(0.024)	(0.021)	(0.006)	(0.236)	(0.054)	(0.050)	(0.007)	(0.0091)	(0.043)
β_{i1}	**−0.182**	**−0.12**	**−0.167**	**−0.177**	**−0.215**	**−0.08**	−0.08	**−0.233**	**−0.107**	−0.069
	(0.048)	(0.037)	(0.036)	(0.036)	(0.058)	(0.029)	(0.05)	(0.045)	(0.035)	(0.056)
β_{i2}	**0.056**	**0.114**	**0.058**	0.098	**0.987**	**0.222**	0.039	**0.031**	−0.0004	**0.365**
	(0.021)	(0.034)	(0.020)	(0.062)	(0.259)	(0.041)	(0.044)	(0.011)	(0.021)	(0.135)
β_{i3}	**0.028**	−0.013	**0.03**	**0.025**	−0.140	**0.108**	0.018	**0.047**	**0.049**	**0.105**
	(0.012)	(0.017)	(0.01)	(0.006)	(0.081)	(0.033)	(0.011)	(0.009)	(0.009)	(0.036)
β_{i4}	−0.017	−0.030	0.011	0.068	−0.262	−0.135	−0.089	**0.066**	0.023	0.366
	(0.013)	(0.039)	(0.042)	(0.051)	(0.312)	(0.080)	(0.085)	(0.026)	(0.057)	(0.282)
β_{i5}	0.007	0.015	−0.006	0.0001	0.014	−0.027	0.002	−0.010	0.0004	−0.017
	(0.011)	(0.011)	(0.008)	(0.005)	(0.039)	(0.016)	(0.010)	(0.006)	(0.007)	(0.039)
β_{i6}	**0.116**	0.017	0.085	**0.073**	**1.700**	**0.510**	**0.404**	**0.360**	**0.442**	**1.199**
	(0.028)	(0.052)	(0.044)	(0.01)	(0.280)	(0.091)	(0.047)	(0.039)	(0.056)	(0.172)
β_{i7}	**0.121**	**0.212**	**0.098**	**0.054**	0.071	0.117	**0.155**	**0.041**	0.030	−0.018
	(0.035)	(0.051)	(0.025)	(0.017)	(0.183)	(0.087)	(0.034)	(0.017)	(0.026)	(0.093)

Residuals Correlation Matrix

	BG	ESP	FIN	FRA	GRE	IRE	ITA	NL	OE	PT
BG	1									
ESP	0.458	1								
FIN	0.226	0.059	1							
FRA	0.603	0.363	0.393	1						
GRE	-0.211	0.261	0.040	-0.193	1					
IRE	0.258	0.360	0.232	0.410	0.175	1				
ITA	0.477	0.434	0.263	0.404	-0.208	0.188	1			
NL	0.094	-0.067	0.072	0.164	-0.240	-0.261	0.028	1		
OE	0.420	0.213	0.403	0.248	-0.010	0.175	0.011	-0.088	1	
PT	-0.278	0.011	-0.049	-0.186	0.249	0.176	-0.240	-0.089	-0.167	1
Adj R^2	0.127	0.196	0.171	0.231	0.318	0.442	0.440	0.475	0.473	0.361

$$\Delta\left(Y_t^i - Y_t^{bd}\right) = \beta_{i0} + \beta_{i1}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right) + \beta_{i2}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right)^* + \beta_{i3}\left(Baa_{t-1} - Aaa_{t-1}\right)$$
$$+\beta_{i4}E_t\left(b_t^i - b_t^{bd}\right) + \beta_{i5}E_t\left(d_t^i - d_t^{bd}\right) + \beta_{i6}\Delta\left(Y_t^i - Y_t^{bd}\right)^* + \beta_{i7}\Delta\left(Baa_t - Aaa_t\right) + \mathbf{u}_{it}$$

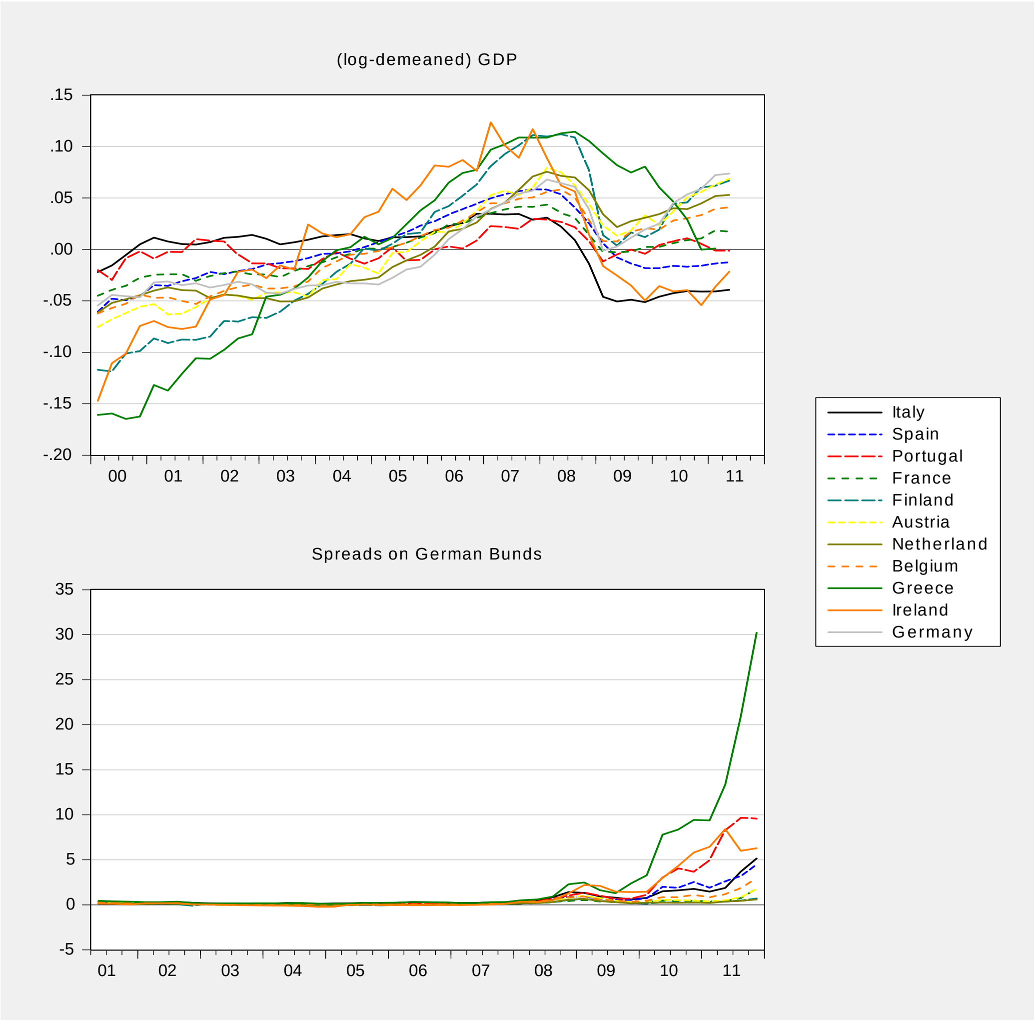

Figure 1: Comovement of real and financial Euro variables

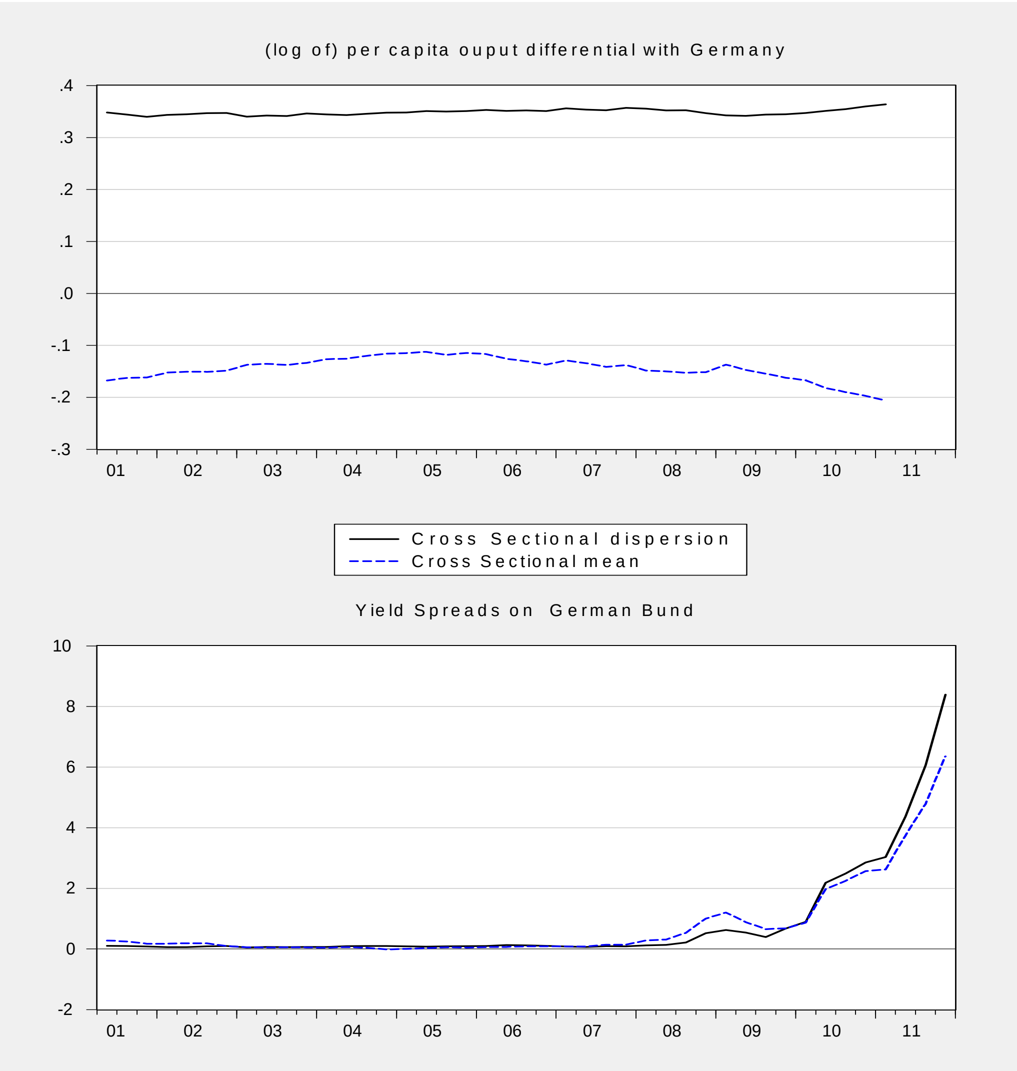

Figure 2: cross-sectional means and standard deviations of Euro area output diffrentials with Germany and 10-year Bond spreads on Bund

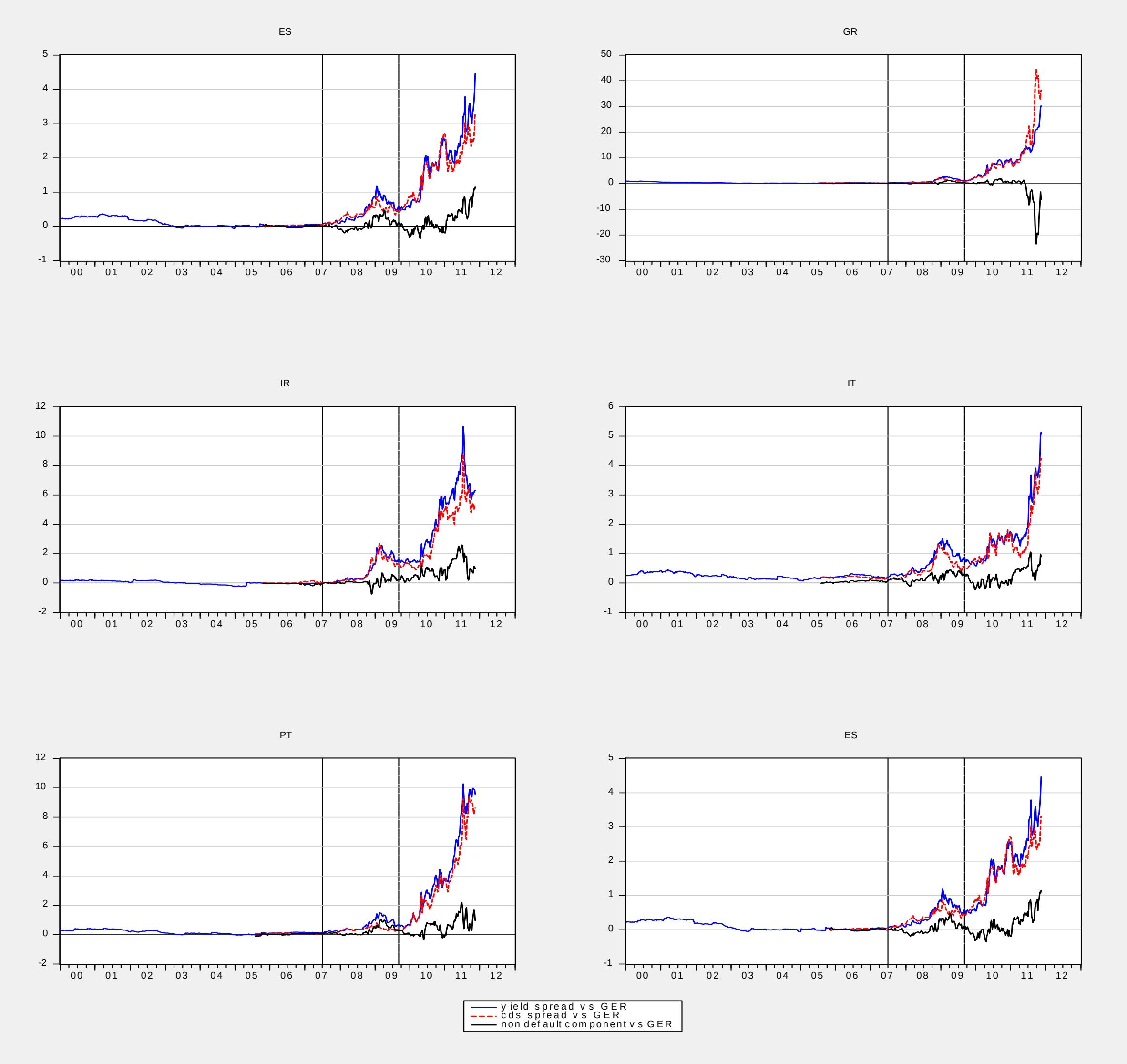

Figure 3: 10-year government bonds spreads on Bund and their components. High yields countries

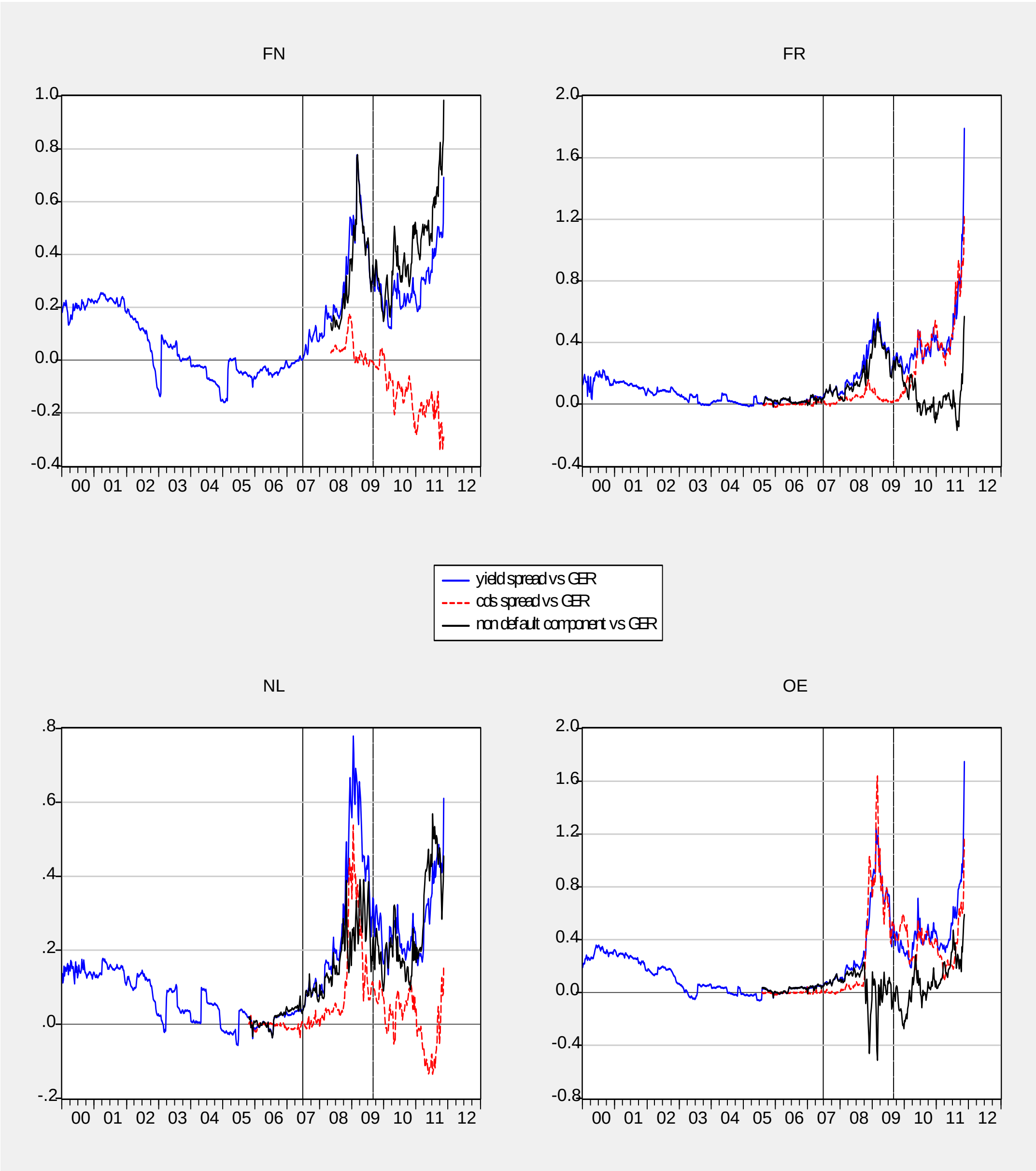

Figure 4: 10-year government bonds spreads on Bund and their components. Low yields countries

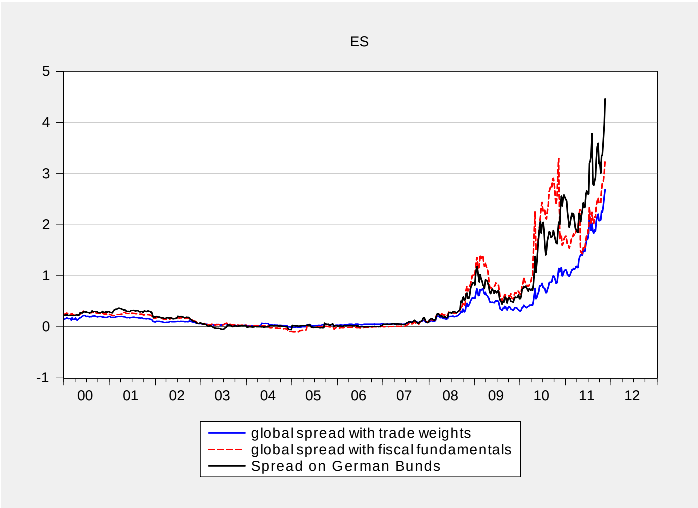

Figure 5. Global variables based on trade weights and on the idstance between fiscal fundamentals. The case of Spain

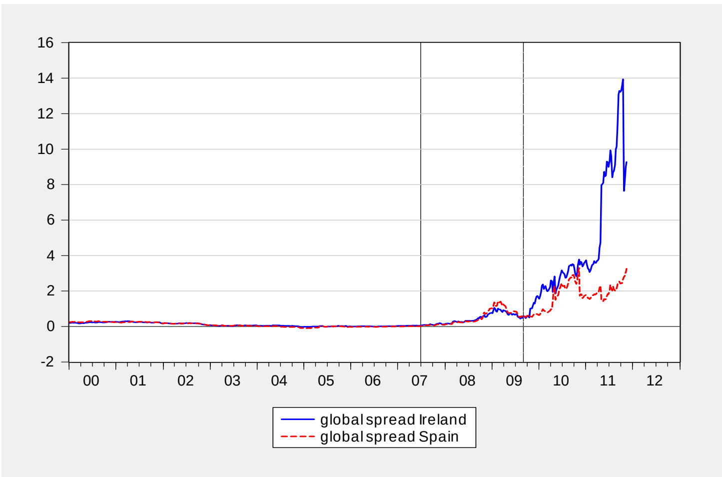

Figure 6: different global variables across different countries. The case of the Netherlands (a low-yielder) and Spain (a high-yielder).

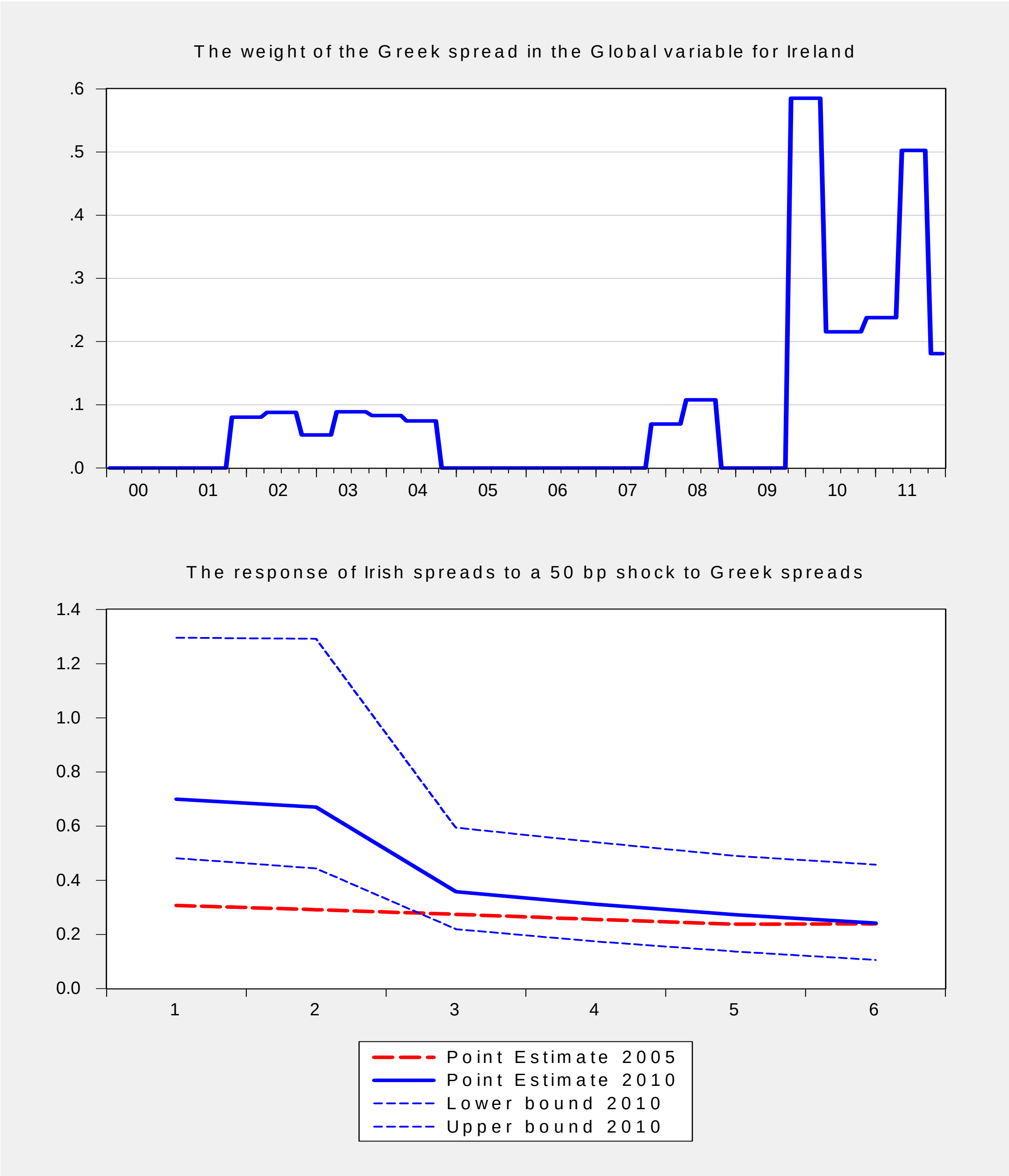

Figure 7: The response of the Irish Spread to the Greek Spread

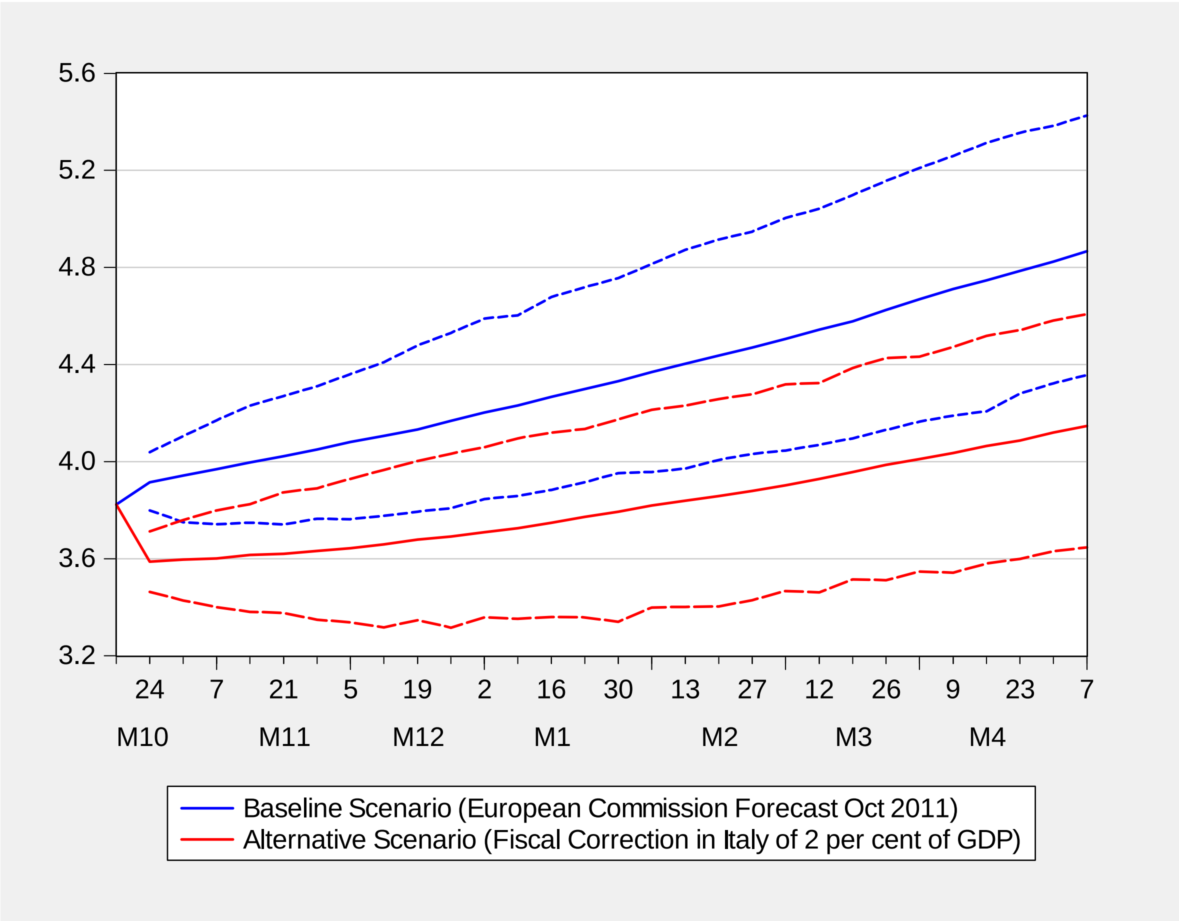

Figure 8: The effect on the 10-Y BTP-Bund spread of a Fiscal Adjustment in Italy

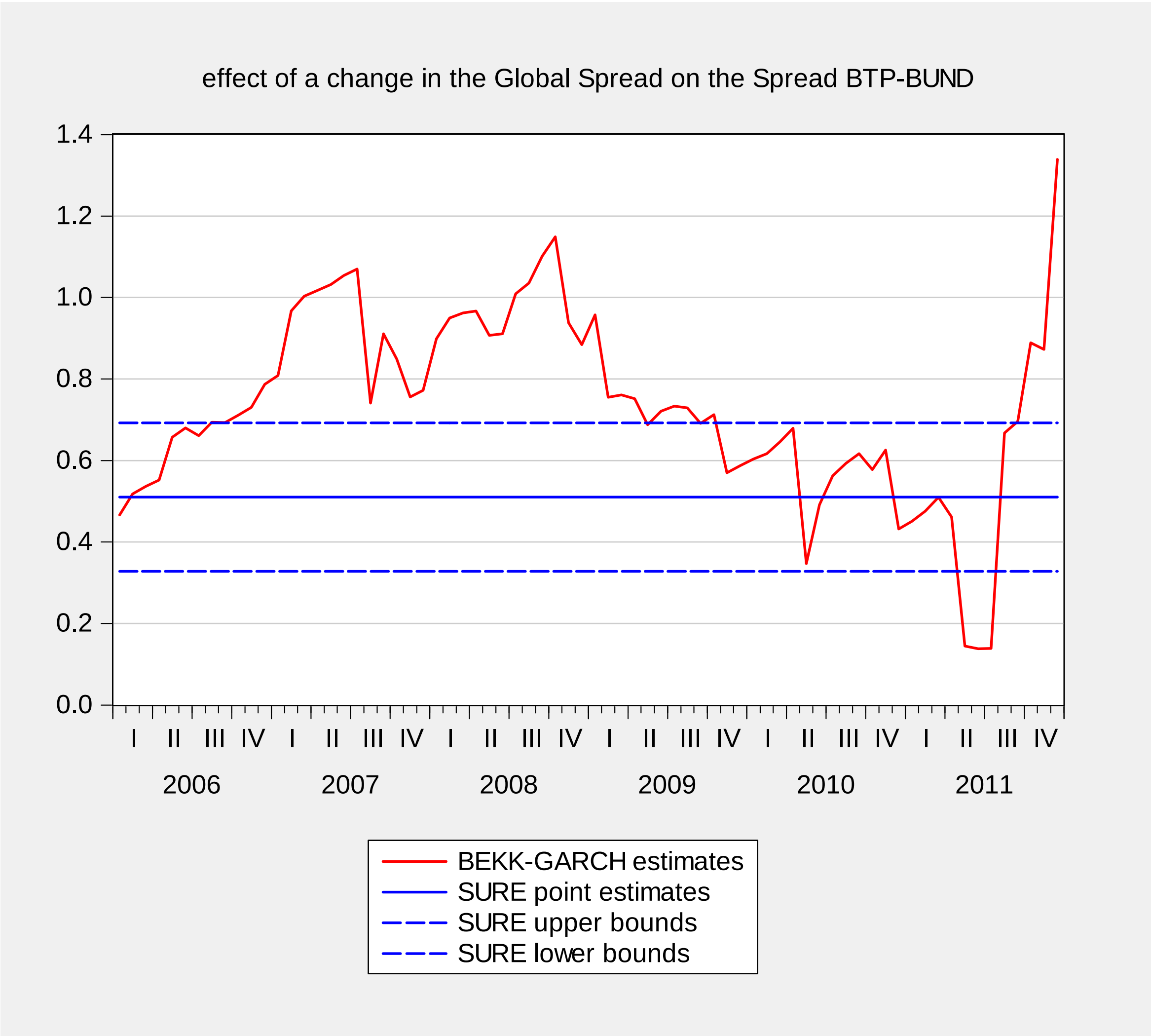

Figure 9: Interdependence and Contagion