Modelling and forecasting government bond spreads in the euro area: a GVAR model.

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Abstract

This paper proposes an extension to Global Vector Autoregressive (GVAR) models to capture time-varying interdependence among financial variables. Government bond spreads in the euro area feature a time-varying pattern of co-movement that poses a serious challenge for econometric modelling and forecasting. This pattern of the data is not captured by the standard specification that model spreads as persistent processes reverting to a time-varying mean determined by two factors : a local factor, driven by fiscal fundamentals and growth, and a global world factor, driven by the market's appetite for risk. This paper argues that a third factor, expectations of exchange rate devaluation, gained traction during the crises. This factor is well captured via a GVAR that models the interdependence among spreads by making each country's spread function of global European spreads. Global spreads capture the exposure of each country's spread to other spreads in the euro area in terms of the time-varying "distance" between their fiscal fundamentals. This new specification dominates the standard one in modelling the time-varying pattern of comovements among spreads and the response of euro area spreads to the Greek debt crisis.

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1 Introduction

Government bond spreads in the euro area have reached, during the 2010-2012 crisis, levels that cannot be predicted by standard models. The identification of the relative importance of model mispecification and deviation of market prices from fundamentals in explaining this evidence carries important policy implications[1].

This paper proposes a new model for government bond spreads in the euro area that outperforms standard models and interprets their failure during the debt crisis in terms of the omission of one pricing factor that has been silent before 2007 but has become sizeable in the course of the crisis. The new pricing factor, related to the resurgence of expectations of exchange rate depreciation, can explain a sizeable part of the difference between actual spreads and those predicted by the standard specification.

Long-term yields differentials between euro area government bonds and German government bonds co-move with an unstable pattern of co-movement over time. Yield spreads on the safe benchmark in the area 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 loans 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 from the end of 2009 onwards brought about differentials of the same, or even greater magnitude, than those of the pre-euro era and more heterogeneity in co-movement.

The standard approach to model government bond spreads in the euro area is based on the view that credit risk is the dominant component in their fluctuations. Credit risk is modelled as a persistent process that reverts to a time-varying mean determined by two factors : a local factor, driven by

[1] If markets can stay irrational longer than a country can stay solvent, then the role of yield spreads on national bonds as a fiscal discipline device is considerably weakened, and some form of ECB intervention or the issuance of Eurobonds can be economically justified (see, for a discussion, Favero and Missale(2012)).

fiscal fundamentals and growth, and a global world factor, driven by markets' appetite for risk.

In fact, the main drivers of fluctuations in government bond spreads in the euro area have been traditionally credit risk and expectations of exchange rate fluctuations[2]. We argue that the introduction of the euro in January 1999 initially eliminated the expectations on exchange rate fluctuations, but the subprime loan crisis first and then the generalized surge in the debt to GDP and deficit to GDP ratios for all euro area countries that has been observed after 2009, has induced markets to reconsider the possibility of the exit from the euro for some of the countries and even of a collapse of the common currency.

The standard approach to model spreads in the euro area provided a congruent statistical model of the data up to 2009, in the absence of expectations of exchange rate fluctuations and in the presence of a comovement between the dominant credit risk factor and the secondary liquidity risk factor. However, the onset of the euro debt crisis and the emergence of a probability of exit of some countries caused a generalized predictive failure. We propose to model fluctuations in the expectations of exchange rate devaluations via the dependence of each country's spread on all the other countries' spreads and fiscal fundamentals, as the probability of a euro break-up depends on the level of the spreads and the divergence of fiscal fundamentals of the whole currency area.

In particular, we consider an extension of the framework of a Global VAR (GVAR) 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 GVAR model of the spreads on bunds.

The dynamics of each spread on German bund is determined by three factors: a local variable, i.e. countries fundamentals relative to the German ones, a global non-European variable, the US Baa-Aaa spread, and global European variables. Global European variables model the dynamics of each country's spread in terms of weighted averages of all other euro are countries' spread with weights determined by the distance between countries measured in term of their relative position in fiscal fundamentals.

This framework modifies the standard GVAR approach were global macro variables are constructed for each countries by using trade weights. Using

[2] A third driver, liquidity risk, i.e. 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, has been shown to be less relevant and not independent from the other two factors (see, for example, Favero, Pagano and Von Thadden(2010)).

the distance in terms of fiscal fundamentals makes the global variables country specific, as in the standard GVAR framework, but the weights are more volatile than in standard GVAR based on trade weights.

Changing weights, related to the changing expectations for fiscal fundamentals, have the potential of explaining the changing correlation among spreads. In our framework changing correlations are related to expected fluctuations of exchange rate fluctuations.

The emergence of fiscal problems in any given country or in a subset of countries affects spreads on German bunds of all other countries when it generates expectations of exchange rate fluctuations. The possibility of a some euro exits or a euro break-up is the source of interdependence between spreads in the euro area. Proximity of fiscal fundamentals determines the strength of interdependence.

This specification, that is linear for estimation, explicitly allows for a non-linear relationship between spreads and fiscal fundamentals that determines the properties of the model under dynamic simulation.

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. 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)). Models projecting spreads on fiscal fundamentals and proxies for global risk aversion have been subjected to parameters instability after 2009 (see, for example, Di Cesare et al.(2012), Pericoli et al.(2012)).

We also add to the literature on market spillovers (Diebold and Yilmaz(2009,2011)). Note that there are important difference between our proposed approach and the approach proposed by Diebold and Yilmaz(2009, 2011). Diebold and Yilmaz(2009, 2011) measure spillovers in terms of the proportion of the (conditional) variance of the returns to an asset that is explained by the (conditional) variance of returns to other assets and it is based on the variance decompositions of VARs. This approach requires the identification of structural shocks orthogonal to each other and it does not allow spillovers to affect first moments of returns. Orthogonality of shocks is required to decompose the total forecasting variance in the sum of variances of shocks (with no-covariance terms), spillovers do not affect first moments as the considered source of spillovers are unpredictable shocks that have no effect on expected values of returns. In our specification spillovers, that reflect expectations of exchange rate devaluation, affect the conditional mean of spreads. Moreover, the measurement of the effect of spillovers via the GVAR model does not require the identification of structural shocks.

The rest of this paper is organized as follows. In the next section we perform exploratory data analysis to highlight some relevant features of the time series and cross sectional properties of euro area spreads. The third section introduces the specification of the GVAR and compares it to the standard approach to model spreads in the euro area. Section four contains a discussion of the properties of the model based on estimation, on simulation, and on impulse response analysis. The standard specification for euro area spreads is used as a benchmark to assess estimation and simulation performances. The last section concludes.

2 Exploratory data analysis

Exploratory data analysis reveals immediately that 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[3] 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 the euro to the US subprime loans crises. Following the Lehman event in

[3] 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.

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 a strong 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 and correlated.

These features of the data provide a very serious challenge to modelling the common factor(s) of financial spreads within a constant weights framework. They also pose a challenge for mapping the volatile time-series behaviour of spreads into slowly evolving and persistent fiscal fundamentals.

The decomposition of spreads in default-risk and non-default risk components might help interpreting the observed heterogeneity in their comovement. The availability of Credit Default Swaps (CDS) for the more recent part of the sample allows to measure the default-risk premium component and to separate fluctuations of the spread into fluctuations of the default-risk component and of the non-default risk component which, as we shall see, is to be mainly attributed to the expectations of exchange rate devaluation.

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.[4]

Figures 3 and 4 report 10-year interest-rate spreads for euro-area Member States along with the associated CDS spreads and the residual non-default

[4] 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). Counterparty risk has become particularly relevant for Greece CDS differentials over the most recent part of the sample, for this reason we exclude them from the analysis.

component. 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 over the initial period of the euro before the US subprime loans crisis.

With the US subprime loan crisis and the following euro area debt crisis some common fluctuations in the non-default risk component become visible in the data and they become more sizeable in the euro crisis.

Commonality of these fluctuations makes it more natural to relate them to expectations of currency devaluation rather than to liquidity factors, although they might be also 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 main conclusion of the exploratory analysis of the data is that the time varying co-movement of government bond spreads in the euro area might depend on the fact that default risk was the main driver before 2007 but after 2007 a new pricing factor emerged as the increase in default risk was also accompanied by the inception of some probability of a euro exit by some country or of an even more dramatic euro-break-up.

3 Modelling 10-year bond differentials in the euro area.

The exploratory data analysis shows that time-varying co-movement of bond spreads and fluctuations related to the emergence of exchange rate devaluation factor in EMU after 2007 are the most prominent features in the dynamics of 10-year bond spreads in the euro area.

The standard specifications adopted for sovereign spreads in EMU (Favero et al., 2010; Beber et al., 2010; Schuknecht et al., 2009; Attinasi et al., 2009; Sgherri and Zoli, 2009; Laubach(2009,2011) models them as persistent processes reverting toward a time-varying mean determined by country-specific factors, namely fiscal fundamentals and a common world factor, measuring market appetite for risk.

A representative model of this line of research is the following:

$$\begin{aligned}
\Delta\left(Y_t^i - Y_t^{bd}\right) &= \beta_{i0} + \beta_{i1}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right) + \beta_{i2}\left(Baa_{t-1} - Aaa_{t-1}\right) \qquad (1)\\
&+\beta_{i3}E_t\left(b_t^i - b_t^{bd}\right) + \beta_{i4}E_t\left(d_t^i - d_t^{bd}\right) + \\
&+\beta_{i5}\Delta\left(Baa_t - Aaa_t\right) + \mathbf{u}_{it}\\
\mathbf{u}_{it} &\sim i.i.d.\left(\mathbf{0}, \sum\right).
\end{aligned}$$

The dynamics of the system of spreads of 10-year yields to maturity of government bonds of country i,Y_t^i, on 10-year yields to maturity on bunds, Y_t^{bd}, is modelled as a partial adjustment around a long run equilibrium level determined by fiscal fundamentals, growth and risk aversion. Fiscal fundamentals and growth are proxied by 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) (see, for example, Attinasi et. al.(2010)). The expected variables are the European Commission Forecasts, that are released every six-months. These variables enter the specification in terms of the difference between each country's forecast and the forecast of the same variables for Germany. Global risk aversion is proxied by the US corporate long-term 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 exogenous factor commonly believed to influence euro area credit spreads (Codogno et al. (2003), Geyer et al.(2004) and Bernoth et al. (2006)).

Specification (1) models spreads as persistent processes reverting towards a time-varying long-run equilibrium determined as follows:

$$\begin{aligned}
\left(Y_t^i - Y_t^{bd}\right)^{eq,SM} &= -\frac{\beta_{i0}}{\beta_{i1}} - \frac{\beta_{i2}}{\beta_{i1}}\left(Baa_{t-1} - Aaa_{t-1}\right) - \qquad (2)\\
&-\frac{\beta_{i3}}{\beta_{i1}}E_t\left(b_t^i - b_t^{bd}\right) - \frac{\beta_{i4}}{\beta_{i1}}E_t\left(d_t^i - d_t^{bd}\right)
\end{aligned}$$

The persistency and the mean-reversion of the credit risk factor generate predictability in the spreads. In fact, predictability patterns in financial returns are commonly interpreted as capturing time-varying risk premia (see, for example,Elliott and Timmermann(2008)).

Note that (2) can be interpreted as a cointegrating relationship in the case spreads, fundamentals and risk appetite can be characterized as unit-root process but this need not to be the case and the equilibrium relationship can be also interpreted as a long-run equilibrium between persistent, but stationary, variables. In any case the dynamic model (1) is preferable for the estimation of the parameters of interest.

However, model (1) has very little potential to explain the observed heterogeneity in co-movements of spreads determined by the emergence of a new pricing factor related to non-local euro-area variables: the long-run equilibrium spreads in (1) are determined in a constant parameterization by local macroeconomic and fiscal fundamentals and by a common world risk aversion factor.

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 (in our case euro area) 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 $\mathbf{z}_{it-1} = \left(\mathbf{x}_{it-1}', \mathbf{x}_{it-1}^{*\prime}\right)'$, $\Pi_i = \left(I - B_{i1}, -B_{i0}^{*} - B_{i1}^{*}\right)$.

We propose to model spreads in the euro-area via a GVAR specification that allows for a time-varying relation between fiscal fundamentals and government bond spreads. In particular, we consider the following model :

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

In (3) the standard specification is augmented by two global euro area variables designed to capture a time-varying interdependence among spreads in the euro area.

These two variables define for each country global spreads which are weighted average of other countries spreads where weights depend on the distance, measured in terms of differences in fiscal fundamentals, that separates countries.

Note that the distance in terms of debt and deficit is rescaled by the respective reference values of 60 per cent of GDP and 3 per cent of GDP specified in the Maastricht criteria. This rescaling allows to measure the two distances in the same metric of percentage deviation from the Maastricht reference point, and it makes them comparable.

Mapping distances into weights ensures that the parameters determining the spill-over effect from foreign spreads on Bunds to local spread on bunds is bounded between zero and one, even when fiscal fundamentals have a very persistent nature. The two global spreads are entered in the specification separately and therefore the regression selects the relative weights of the two global spreads.

This strategy is more flexible than an alternative one in which the two measures of distance are combined in an "arc distance" and a single global spread is constructed. This approach, followed by Hondroyiannis et al.(2010), restricts the debt and the deficit distance to have equal weights in the determination of a global distance. 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 a GVAR with 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.

The introduction of the global variables makes the equilibrium spread of each country dependent on fiscal and macroeconomic fundamentals of the whole monetary area and introduces a time-varying interdependence among spreads determined by the evolution of the relative position of countries in terms of their fiscal fundamentals.

Equilibrium spreads from the GVAR model can be written as follows:

$$\begin{aligned}\left(Y_t^i - Y_t^{bd}\right)^{eq,GV} = & -\frac{\beta_{i0}}{\beta_{i1}} - \frac{\beta_{i2}}{\beta_{i1}}\left(Baa_{t-1} - Aaa_{t-1}\right) - \\ & -\frac{\beta_{i3}}{\beta_{i1}} E_t\left(b_t^i - b_t^{bd}\right) - \frac{\beta_{i4}}{\beta_{i1}} E_t\left(d_t^i - d_t^{bd}\right) - \\ & -\frac{\beta_{i6}}{\beta_{i1}}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right)^{*,b} - \frac{\beta_{i7}}{\beta_{i1}}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right)^{*,d}\end{aligned} \quad (4)$$

Dependence of local spreads from global fiscal and macroeconomic fundamentals in the euro area is the channel through which fluctuations in the probability of a euro exit or a more dramatic euro break-up (captured by the worsening of fundamentals in one or more euro area countries) affect local spreads.

The model determines the strength of interdependence between euro area countries as a function of their distance, measured in terms of fiscal fundamentals. Spreads are now modelled as a mean reverting process toward a time varying mean determined by three factors: local fundamentals, global appetite for risk, and expectations of exchange rate fluctuations. The likelihood of some form of break-up depends on euro-area fiscal fundamentals and euro area spreads, the exposure of any country to the emergence of problems in any other country depends on their distances in terms of fiscal fundamentals. Given the emergence of fiscal problems in one or more countries in the area, the interdependence determines the response of each country's spread to those affected by the negative shocks. Time-varying weights in the determination of global spreads, 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, Figure 5 reports global spreads for a typical low-yielder, the Netherlands, and a typical high yielder, Ireland. Note that, in the no-crisis period, 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 higher distance of the Netherlands from high-yielders generates a lower mean and a lower volatility for its global spread.

Interestingly, if global variables in the GVAR capture exchange rate risk then the difference between the equilibrium spreads from the GVAR and equilibrium spreads from the traditional model $\left[\left(Y_t^i - Y_t^{bd}\right)^{eq,GVAR} - \left(Y_t^i - Y_t^{bd}\right)^{eq,SM}\right]$ should be closely related to the non-default component of the spreads reported previously in Figure 3. We shall empirical evaluate this prediction in the next section.

It is important to note that, unlike in standard GVAR, global variables enter (3) only through their lags: contemporaneous global spreads are not included in the specification.

The estimated model is to be interpreted as a reduced form specification in which the long-run equilibria of local spreads depend on global euro area fundamentals. Including contemporaneous global variables in (3) is problematic because these variables are unlikely to be exogenous for the estimation of the parameters of interest. Pesaran et al. (2003) show that exogeneity in GVAR requires that the sum of the squares of the weights used to determine the global variable is approximately zero. This is true when the cross-section dimension is sufficiently large and all weights decrease with the sample size. In our model for the euro area spreads there are only ten cross–section units, and some of them will attract a very high weight on some occasions, therefore conditions for exogeneity are likely to be violated, and contemporaneous global spreads will be endogenous for the estimation of parameters of interest.

The reduced form specification can be adopted directly for forecasting purposes but some identification choice must be made if the model is to be used for structural analysis, such as impulse response functions. This point will be explicitly addressed in the discussion of impulse response analysis.

To sum up, 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 behavioral equations of the system.

As noted in the introduction, the specification adds to the literature on market spillovers by explicitly inserting them into the forecasts. This is very different from the approach to spillovers adopted in the literature (see, for example,Diebold and Yilmaz(2009,2011)).

In our suggested approach spillovers are included in the specification by extending the standard model (1) to (3).

In this specification spillovers, that reflects expectations of exchange rate devaluation, affect the conditional mean of all spreads and they are therefore relevant in forecasting the future path of the variables of interest. Spillovers also vary over time even if the parameters in (3) are constant, as the relative position of countries in terms of fiscal fundamentals is time-varying.

Diebold and Yilmaz(2009,2011) would measure spillovers by concentrating on (1), to consider some orthogonalization of the residuals that allows to derive variance decompositions and to assess the proportion of conditional variance of each country's spread that is explained by the conditional variance of other countries' spreads. In this approach spillovers cannot be used in forecasting, as the considered source of spillovers are unpredictable shocks, and they can vary over time in a constant parameter model such as (1) only if rolling or recursive estimation is adopted.

In fact, no heteroscedasticity is explicitly allowed for when the variance-covariance matrix of the structural shocks is estimated.

Finally, note that (3) can be estimated with linear estimation techniques but it delivers responses of each country spreads to shock in other countries that are non-linear as they depend on the distance between countries measured in terms of fiscal fundamentals. 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 time-varying relationships between each country's fiscal fundamentals and the spread on Bunds.

For the same level of local fiscal fundamentals a "low spread equilibrium" or an "high spread 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 "high spread 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 determinant of the high spread equilibrium is the emergence of a pricing factor that was previously silent: the expectations of exchange depreciation.

Expectations of exchange rate depreciations are irrelevant if all countries are virtuous but they become more relevant the higher the number of countries that deviate from the Maastricht criteria for fiscal variables. Given important deviations of fiscal fundamentals of some countries from the Maastricht criteria and the possible separation of EMU countries in "ins" and "outs", then groupings of countries is naturally determined by their fiscal position and hence by their distance in terms of fiscal fundamentals from the problematic countries.

After model estimation and identification of the relevant shocks, impulse response analysis can be performed. The shape of the impulse responses is determined by changing fiscal fundamentals and the model will deliver different impulse responses when the same shocks hit the system in different periods.

This point is promptly illustrated by the following representation of the GVAR system (3)

$$S_t = AS_{t-1} + BF_t + C_1 S_t^{US} + C_2 S_{t-1}^{US} + \tag{5}$$

$$\left(D_1 W_t^b (F_t) + D_2 W_t^d (F_t)\right) S_{t-1} + \mathbf{u}_t \tag{6}$$

$$S_t = \begin{bmatrix} Y_t^{bg} - Y_t^{bd} \\ ... \\ Y_t^{pt} - Y_t^{bd} \end{bmatrix}, F_t = \begin{bmatrix} b_t^{bg} - b_t^{bd} & d_t^{bg} - d_t^{bd} \\ ... & ... \\ b_t^{pt} - b_t^{bd} & d_t^{pt} - d_t^{bd} \end{bmatrix}$$

$$S_t^{US} = (Baa_t - Aaa_t)$$

The GVAR can be estimated by linear methods, as distances in term of debt and deficits that determine $W_t^b(F_t)$ and $W_t^d(F_t)$ do not contain any unknown parameter, but it implies a non-linear dynamic effect of shocks.

Impulse responses can be computed via simulation of the full system consisting of n equations for the spreads and of $2n$ identities defining the global variables in terms of the debt/GDP and the deficit/GDP distance 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 twenty 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.

4 Taking the model to the data

The model is taken to the data by considering a sample of monthly observations over the period 2000-2012. The pre-euro area debt crisis period (2000-2009) is used for estimation, out-of-sample simulation is then conducted over the period 2010-2012. We compare first the properties of a standard model and a GVAR model for the 10-year interest-rate spreads on German Bunds for Austria, Belgium, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal and Spain, via estimation and out-of-sample forecasting. We then assess the properties of the GVAR model using impulse response functions with different initial conditions.

4.1 Estimation

The results of the estimation of the standard model (1) and of the GVAR (3), implemented via the SURE method, are reported in Tables 1-2.

The models have been estimated over the euro regime for the sample 2000:1-2009:12, that includes the subprime lending crises but leaves about three years of euro debt crisis for out-of-sample simulation. Table 1 reports the results of the estimation of the standard model (1)

Insert Table 1 about here

The evidence in Table 1 shows that all spreads are mean reverting towards a time varying mean determined by the local fiscal fundamentals and the Baa-Aaa spread.

The effect of fiscal fundamentals is rather heterogenous with the projected deviations of local government debt from German government debt being significant in the cases of Belgium and Greece, while the projected deviations of local government deficits from German deficits are significant in the cases of Belgium, Spain, France, Greece, Italy, Austria and Portugal. The effect of the US Baa-Aaa is more homogenous in size and magnitude, being significant in all countries with a more heterogenous short-run impact and a more homogenous long-run impact. All coefficients but the one on the debt are significant when the panel restrictions are imposed. However, the impositions of these restrictions causes a generalized worsening of the goodness of fit of the estimated equations and their validity is statistically rejected.

Table 2 reports the results of the estimation of the GVAR model obtained by augmenting the standard specification with the two global spreads generated by the two weighting schemes based respectively on the distance measured in the space of debt to GDP ratio and on that based on deficit to GDP ratio.

Insert Table 2 about here

The results show that the inclusion of the global variables improves the goodness of fit for all equations in the system and their effect is also heterogenous, with the debt based global spread being significant in the cases of France, Greece, Austria and Portugal, while the deficit based global spread is significant in the cases of Ireland, Italy and, marginally, the Netherlands.

All coefficients but the one on debt-based global spread are significant when panel restrictions are imposed, but, again, these restrictions cause a generalized worsening in the goodness of fit and they are statistically rejected. Finally, it is worth noting the variance-covariance matrix of residuals witnesses for both model (1) and (3) the presence of significant positive cross-correlation among the residuals of all the equations for different spreads.

The standard model and the GVAR feature different long-run equilibria as the GVAR uses three-factor to determine the long-run mean of spreads while the standard model includes only two. Figure 6.1 and 6.2 show that the standard specification does well before 2010 and it is fully capable of explaining the yield spreads observed in Europe during the subprime loan crisis period, however after 2010,during the euro area debt crisis period, a pattern of very strong systematic downward bias emerges for all Italy, Spain, Portugal, Ireland and Belgium with observed spreads being much higher than the model implied long-run equilibria. The long-run equilibria implied by the GVAR model are much closer to realized spreads during the euro debt crisis. The only notable exception is Greece in the case of which the local shock (abrupt revisions in fiscal fundamentals due to previous misreporting) that caused the spread of Greek government bonds on German bunds to skyrocket is not captured by both specifications.

Figure 6.3 provides further evidence on the different performance of the two modelling strategies by reporting, for high-yielders countries, the co-movement between the difference in projected spreads from the GVAR model and the standard model alongwith non-default components of spreads, as measured by the difference between 10-year bond spreads and 10-year CDS spreads.

The clear association between $\left[\left(Y_t^i - Y_t^{bd}\right)^{eq,GVAR} - \left(Y_t^i - Y_t^{bd}\right)^{eq,SM}\right]$ and the non-default component of the spreads is consistent with our interpretation of the significance of the global euro area factors in terms of their relation to expectations of exchange rate depreciations.

4.2 Simulation

To further assess the relative performance of the GVAR and the standard model we consider dynamic simulation of the two models during the euro debt crisis period.

Given estimation of the two models up to 2009:12 we proceed to their dynamic stochastic simulation over the period 2010:1 2012:12. The two alternative simulations are conditioned to the same information set consisting of the behaviour of the Greek spread, fiscal fundamentals in all euro area countries and the BAA-AAA spread.

This exercise allows to evaluate capability of the two models to replicate the response of euro area bond spreads to the Greek crisis. Importantly, as the simulations are conditioned to the same information set, the differences in simulated spreads simulated are to be attributed to the way in which the same information is processed by the two different models.

Figures 7.1 and 7.2 illustrate the properties of the standard model for the projections of spreads of European high yielders and low-yielders. The

Figures show a very strong systematic downward bias emerges for all Italy, Spain, Portugal, Ireland and Belgium with observed spreads being much higher than the 95 per confidence intervals projected by the model. The downward bias problem affects also all the low yielders countries, although mis-predictions are more contained in these cases. Finland is the only case in which small violations of the 95 confidence intervals associated to forecasts are observed. In the case of this country the worsening of fiscal fundamentals after 2009 (with projected debt/GDP ratio increasing from a level close to 30 per cent in 2009 to a level around 50 per cent in 2012 and the projected deficit/GDP ratio moving from a surplus of 4 per cent at the end of 2008 to an average deficit of 3 per cent over the period 2009-2012) had a moderate impact on the fluctuations of the spread of Finnish government bonds on German bunds.

Overall figure 7.1 and 7.2 illustrate that the two factors determining the long-run equilibrium spreads in the standard model move very little over the simulation period and the dynamic simulation, that starts from an initial point not far from the long-run equilibrium, generates mean reversion towards levels of the spreads that are much lower than those observed in the data.

The forecasting performance of the GVAR model reported over Figure 7.3 and 7.4 strongly dominates that of the standard model. In the case of high-yielders countries predicted spreads from the GVAR are on average 150 basis points higher than those based on the traditional model, witnessing the importance of interdependence in determining the dynamics of spreads in these countries over the simulation period.

Such an observed interdependence reflects the emerging probability of exchange rate devaluation.

Clearly the GVAR model with interdependence is not capable of explaining the size of spreads observed at the peak of the crisis, this could be interpreted as evidence for contagion over the forecasting sample. Interestingly, observed spreads for all high-yielders feature an hump-shape pattern with respect to the GVAR forecast with a general tendency to converge back towards the model based predictions in the last part of the forecasting sample. Figure 7.4 concentrates on low-yielders to show that, with the only exception of Finland, the over-performance of the GVAR specification with respect to the standard model is generally confirmed.

4.3 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 GVAR specification, impulse responses are not constant over time as they depend on the time-varying distance between fiscal fundamentals across different countries.

Given that our GVAR specification is linear for estimation it is interesting to evaluate to what extent a model estimated with linear methods can be non-linear under simulation. Non-linearity is a consequence of the effect of global spreads and the way they are constructed.

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 the imposition of some identification assumptions and the orthogonality of structural shocks is a necessary condition to consider the effect of each identified shocks in isolation. The study of the response to the system to an innovation in observables does not require any identification assumption but the contemporaneous linkages between shocks must be modelled.

In our case it seems natural to concentrate on impulse responses to innovations in observables. In fact, the GVAR specification is a reduced form model where only lagged values of the global spreads are entered to avoid endogeneity problems related to the sizeable size of some of the weights used to compute the global spreads. In particular, the properties of the GVAR will be illustrated by considering the effect of a 200 basis point innovation in the spread of Greek bonds on Bunds on the spread of Portuguese bonds on bunds in two different periods, featuring respectively low distance and high distance between Greek fiscal fundamentals and Portuguese fiscal fundamentals.

Of course, observable innovations in the equations for spreads of different countries included in the GVAR system are not orthogonal to each other, as there is a general strong pattern of positive correlation. In cases like this the Generalized Impulse Response Functions, GIRFs, discussed in Garratt et al.(2006) can appropriately take care of a non-diagonal structure in the variance-covariance matrix of innovations by exploiting the estimated error covariances to model the contemporaneous linkages across innovations.[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 first panel of Figure 9 reports the weight of Greece in the determination of the global spreads for Portugal and allows the identification of 2002 and 2005 as periods of respectively low and high interdependence for the determination of the global spreads for these two countries. At the beginning of 2002 the fiscal fundamentals in Greece were so different from the Portuguese ones that the weight of Greece in the determination of the global spreads for Ireland was negligible (the expected debt to GDP ratio over the two following years stood respectively at 53.4 per cent and 96.8 per cent, while the expected deficits over GDP ratio were -0.55 per cent and 1.5 per cent). In the following years the Portuguese fiscal fundamentals have converged remarkably towards the Greek ones and at the beginning of 2005 the weight of the Greek spread in the determination of the global spread based on the deficit to GDP ratio for Portugal has become as high as 0.45, as the Portuguese deficit to GDP ratio has risen to 4.45 per cent to a level very close to the Greek 4.8 per cent of GDP (at the same time the debt to GDP ratio have become respectively of 63.5 per cent and 109.7 per cent).

Our model should reflect these facts through the heterogeneity of impulse response functions in the two periods.

The second panel of Figure 9 reports of the simulation of impulses responses of the Portuguese spread to a 200bp innovation in the Greek spread. These impulse responses are computed on the basis of the estimation of the GVAR model over the sample 2000-2009. Therefore, they are based on the same estimated parameters but on different initial conditions for the fiscal fundamentals and for the global spreads that determine the importance of fluctuations in the Greek spread for the Portuguese spread. The Figure reports a significant heterogeneity in the responses: the effect in 2005 is almost twice stronger as that in 2002, with the same (by construction) impact

[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.

multiplier of 0.7 that becomes 0.6 after six months in 2005 and decreases much more rapidly to about 0.3 in 2002. Note that the point estimate of the impulse response for a shock given in 2002 falls outside the 95 per cent confidence interval for the same impulse responses simulated in 2005.

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 pattern in the data is not captured by the standard model that relates government bond spreads on Bunds for euro area countries to two factors: local fiscal fundamentals and a global market appetite for risk.

This paper has proposed to extend the standard specification to a GVAR approach that includes a third factor, expected exchange rate devaluations as captured by the global euro area spreads and the global euro area fiscal fundamentals.

The GVAR models the changing interdependence among spreads by making each country's spread function of global spreads with a time varying composition. In particular, global spreads for each country are defined as weighted average of spreads for all the other countries. Weights are determined by the distance between countries measured in terms of differences in their fiscal fundamentals: the expected deficit to GDP ratio and the expected debt to GDP ratio.

The presence in the GVAR of the global fiscal fundamentals of the euro area allows to capture fluctuations in spreads related to emergence of expectations of exchange rate fluctuations (related to some non negligible probability associated to the event of one or more countries exit from the euro area) and generates out-of-sample forecasts for the period 2010-2012 that dominate those of the standard specification for euro area spreads.

The interdependence built into the GVAR model is not however capable of predicting the highest level of spreads observed during the euro debt crisis, hinting at the empirical relevance of contagion.

Finally the model, despite being linear for estimation, shows some important nonlinearity in simulation that make impulse response function to shocks to spreads sensitive to the relative position in term of fiscal fundamental between the country where the shock occurs initially and the countries to which the shock is transmitted.

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Table 1 - Spreads on Bunds, Seemingly Unrelated Regression,
Sample February 2000-December 2009. Monthly data
standard specification

	β_{i0}	β_{i1}	β_{i2}	β_{i3}	β_{i4}	β_{i5}	$\bar{R}^2$	$\bar{R}^2 (pan.)$
BG	−0.038	−0.248	0.074	0.036	0.025	0.101	0.03	0.10
	(0.0165)	(0.030)	(0.012)	(0.017)	(0.007)	(0.028)		
	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]		
ESP	−0.019	−0.157	0.053	0.017	0.099	0.122	0.09	0.10
	(0.0131)	(0.031)	(0.012)	(0.017)	(0.006)	(0.028)		
	[0.16]	[0.00]	[0.00]	[0.38]	[0.09]	[0.00]		
FIN	−0.009	−0.153	0.040	0.021	0.007	0.106	0.11	0.12
	(0.0219)	(0.030)	(0.010)	(0.040)	(0.008)	(0.026)		
	[0.69]	[0.00]	[0.00]	[0.59]	[0.34]	[0.00]		
FRA	−0.022	−0.222	0.038	0.029	0.009	0.052	0.09	0.08
	(0.007)	(0.031)	(0.006)	(0.051)	(0.004)	(0.016)		
	[0.00]	[0.00]	[0.00]	[0.56]	[0.03]	[0.00]		
GRE	−0.276	−0.159	0.182	0.251	0.058	0.285	0.25	0.006
	(0.071)	(0.025)	(0.026)	(0.093)	(0.011)	(0.065)		
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]		
IRE	−0.105	−0.176	0.147	−0.005	0.035	0.072	0.23	0.003
	(0.027)	(0.028)	(0.021)	(0.041)	(0.008)	(0.056)		
	[0.00]	[0.00]	[0.00]	[0.90]	[0.00]	[0.20]		
ITA	−0.03	−0.188	0.088	−0.010	0.027	0.189	0.20	0.16
	(0.031)	(0.026)	(0.014)	(0.04)	(0.007)	(0.031)		
	[0.34]	[0.00]	[0.00]	[0.79]	[0.00]	[0.00]		
NL	−0.04	−0.255	0.068	0.040	−0.001	0.104	0.26	0.18
	(0.007)	(0.034)	(0.010)	(0.025)	(0.005)	(0.018)		
	[0.00]	[0.00]	[0.00]	[0.11]	[0.72]	[0.00]		
OE	−0.05	−0.219	0.086	0.077	0.014	0.068	0.17	0.12
	(0.010)	(0.025)	(0.011)	(0.04)	(0.005)	(0.029)		
	[0.00]	[0.00]	[0.00]	[0.09]	[0.01]	[0.02]		
PT	−0.051	−0.168	0.080	0.014	0.020	0.136	0.11	0.08
	(0.015)	(0.027)	(0.015)	(0.08)	(0.010)	(0.037)		
	[0.00]	[0.00]	[0.00]	[0.86]	[0.05]	[0.00]		
Panel		−0.089	0.022	0.013	0.013	0.089		
		(0.012)	(0.005)	(0.008)	(0.002)	(0.017)		
		[0.00]	[0.00]	[0.13]	[0.00]	[0.00]		

$$\begin{aligned}
\Delta\left(Y_t^i - Y_t^{bd}\right) &= \beta_{i0} + \beta_{i1}\left(Y_{t-1}^i - Y_{t-1}^{bd}\right) + \beta_{i2}\left(Baa_{t-1} - Aaa_{t-1}\right) \\
&\quad + \beta_{i3}E_t\left(b_t^i - b_t^{bd}\right) + \beta_{i4}E_t\left(d_t^i - d_t^{bd}\right) + \\
&\quad + \beta_{i5}\Delta\left(Baa_t - Aaa_t\right) + \mathbf{u}_{it} \\
\mathbf{u}_{it} &\sim i.i.d.\left(\mathbf{0}, \sum\right).
\end{aligned}$$

Y_t^i : 10-year yields to maturity of government bonds of country i

Y_t^{bd} : 10-year yields on German governmanet bonds

d_t^i :, average for a 2-year ahead period of the expected budget balance to GDP ratio (European Commission)

b_t^i :, average for a 2-year ahead period of the expected debt to GDP ratio (European Commission)

$(Baa_t - Aaa_t)$: spread between long-term yields on US corporate graded Baa and Aaa (Moody's)

Table 2 - Spreads on Bunds, Seemingly Unrelated Regression,
Sample February 2000-December 2009. Monthly data
GVAR model

	β_{i0}	β_{i1}	β_{i2}	β_{i3}	β_{i4}	β_{i5}	β_{i6}	β_{i7}	$\bar{R}^2$	$\bar{R}^2\,(pan.)$
BG	−0.016	−0.161	0.047	0.015	0.022	0.103	0.020	−0.019	0.08	0.09
	(0.0180)	(0.062)	(0.014)	(0.019)	(0.007)	(0.031)	(0.032)	(0.053)		
	[0.38]	[0.00]	[0.00]	[0.44]	[0.00]	[0.00]	[0.53]	[0.71]		
ESP	−0.019	−0.156	0.039	0.007	0.005	0.129	0.080	−0.028	0.12	0.07
	(0.0158)	(0.031)	(0.014)	(0.020)	(0.007)	(0.028)	(0.07)	(0.027)		
	[0.22]	[0.00]	[0.00]	[0.71]	[0.48]	[0.00]	[0.26]	[0.31]		
FIN	0.004	−0.295	0.007	0.049	−0.001	0.125	0.140	0.035	0.19	0.09
	(0.022)	(0.061)	(0.012)	(0.042)	(0.008)	(0.025)	(0.151)	(0.129)		
	[0.84]	[0.00]	[0.58]	[0.25]	[0.88]	[0.00]	[0.36]	[0.27]		
FRA	−0.017	−0.415	0.019	−0.008	0.01	0.060	0.068	0.057	0.14	0.09
	(0.007)	(0.073)	(0.007)	(0.057)	(0.004)	(0.016)	(0.032)	(0.034)		
	[0.01]	[0.00]	[0.00]	[0.89]	[0.02]	[0.00]	[0.03]	[0.09]		
GRE	−0.167	−0.100	0.123	0.139	0.052	0.278	0.261	−0.246	0.31	0.03
	(0.080)	(0.052)	(0.031)	(0.102)	(0.011)	(0.065)	(0.148)	(0.183)		
	[0.03]	[0.05]	[0.00]	[0.18]	[0.00]	[0.00]	[0.08]	[0.18]		
IRE	−0.128	−0.239	0.064	−0.124	0.041	0.072	−0.044	0.486	0.36	0.004
	(0.027)	(0.040)	(0.028)	(0.050)	(0.01)	(0.053)	(0.099)	(0.133)		
	[0.00]	[0.00]	[0.02]	[0.02]	[0.00]	[0.18]	[0.66]	[0.00]		
ITA	−0.01	−0.279	0.069	−0.025	0.029	0.226	−0.059	0.185	0.20	0.15
	(0.038)	(0.072)	(0.016)	(0.04)	(0.008)	(0.033)	(0.034)	(0.063)		
	[0.78]	[0.00]	[0.00]	[0.59]	[0.00]	[0.00]	[0.09]	[0.00]		
NL	−0.03	−0.405	0.056	0.027	−0.001	0.110	0.020	0.09	0.27	0.19
	(0.008)	(0.072)	(0.010)	(0.030)	(0.005)	(0.019)	(0.067)	(0.05)		
	[0.00]	[0.00]	[0.00]	[0.38]	[0.73]	[0.00]	[0.76]	[0.08]		
OE	−0.04	−0.380	0.048	0.024	0.005	0.025	0.216	0.033	0.37	0.16
	(0.009)	(0.071)	(0.011)	(0.05)	(0.006)	(0.026)	(0.045)	(0.034)		
	[0.00]	[0.00]	[0.00]	[0.63]	[0.80]	[0.35]	[0.00]	[0.32]		
PT	−0.045	−0.280	0.059	0.091	0.003	0.126	0.235	0.011	0.30	0.09
	(0.015)	(0.054)	(0.014)	(0.09)	(0.010)	(0.034)	(0.057)	(0.048)		
	[0.00]	[0.00]	[0.00]	[0.32]	[0.74]	[0.00]	[0.00]	[0.81]		
Panel		−0.080	0.031	0.014	0.010	0.080	0.017	0.044		
		(0.012)	(0.006)	(0.009)	(0.002)	(0.016)	(0.012)	(0.011)		
		[0.00]	[0.00]	[0.11]	[0.00]	[0.00]	[0.14]	[0.00]		

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

Y_t^i : 10-year yields to maturity of government bonds of country i

Y_t^{bd} : 10-year yields on German governmanet bonds

d_t^i :, average for a 2-year ahead period of the expected budget balance to GDP ratio (European Commission)

b_t^i :, average for a 2-year ahead period of the expected debt to GDP ratio (European Commission)

$(Baa_t - Aaa_t)$: spread between long-term yields on US corporate graded Baa and Aaa (Moody's)

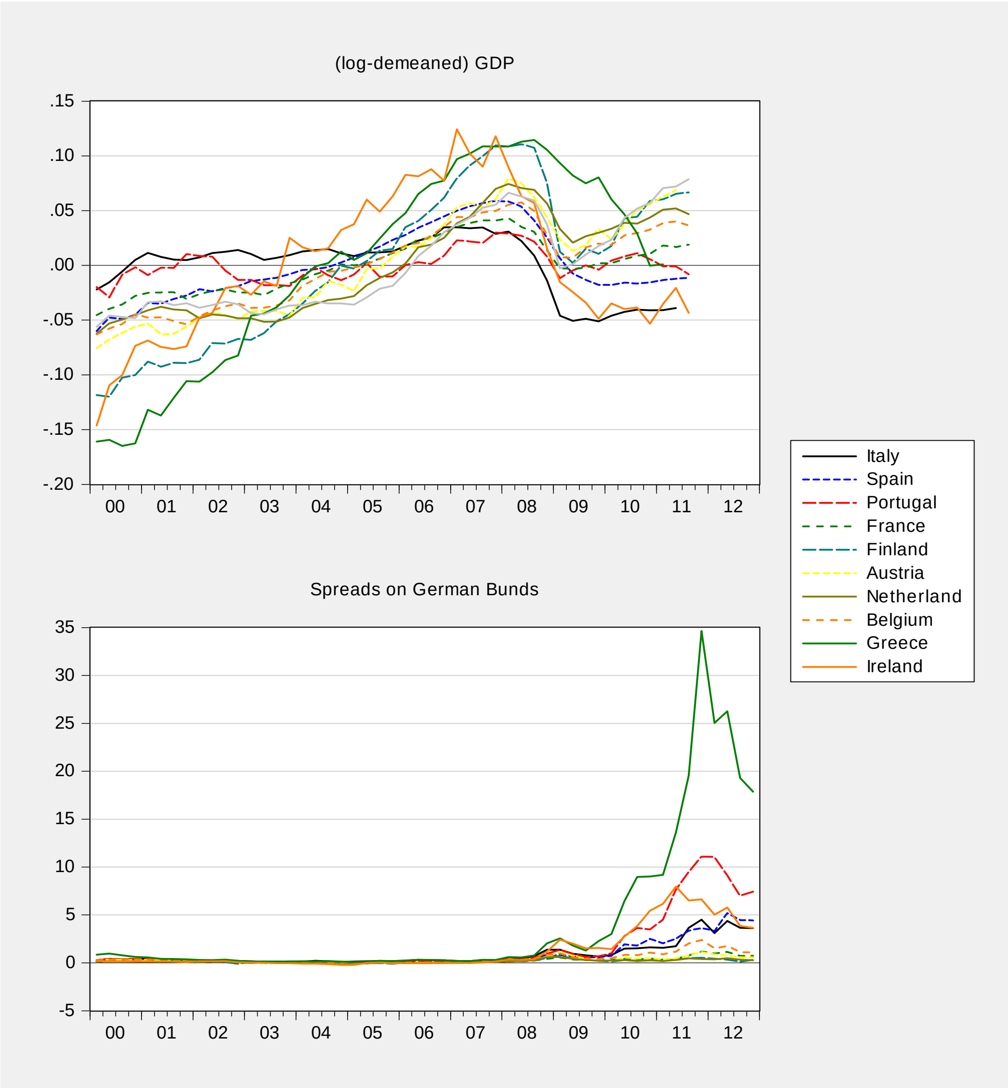

Figure 1: Comovement of real and financial Euro variables

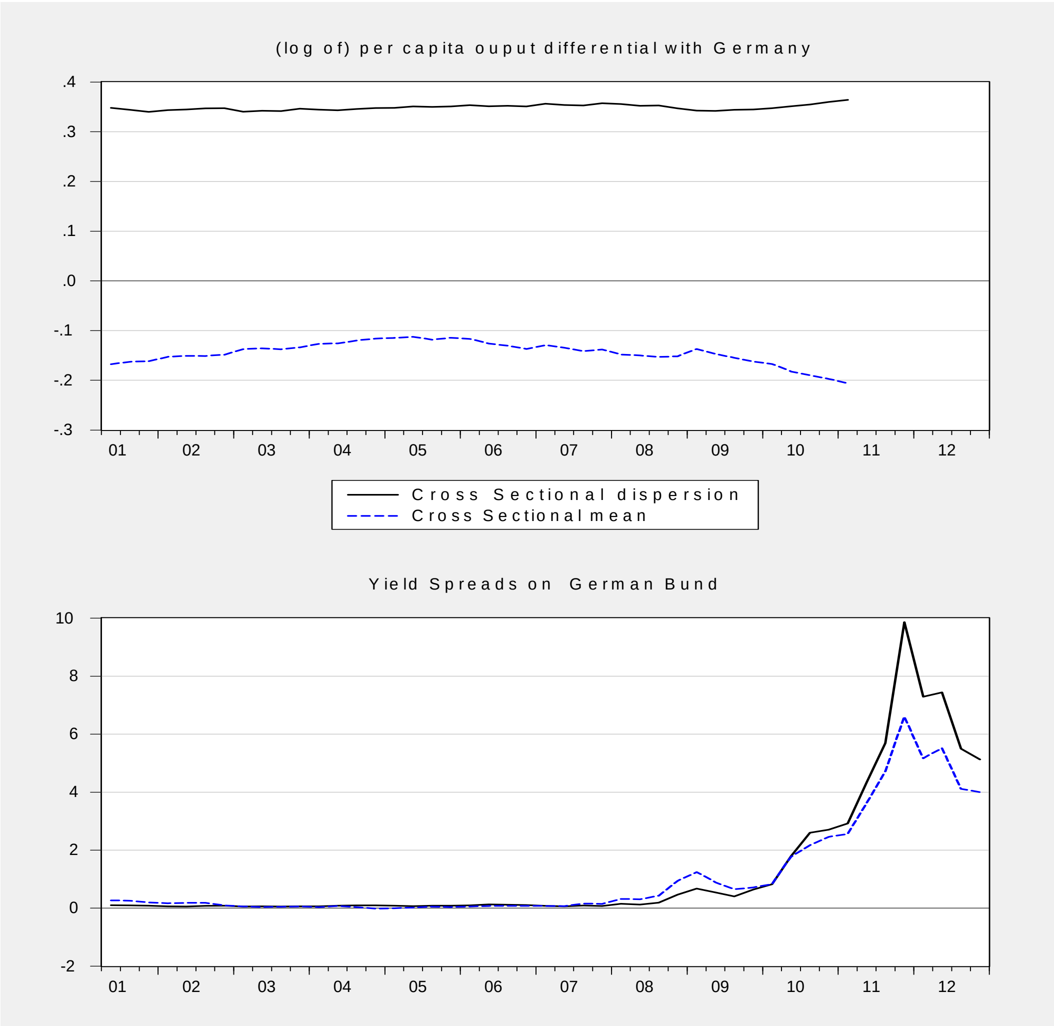

Figure 2: cross-sectional means and standard deviations of Euro area output diffrentials with Germany and 10-year Bond spreads on Bund

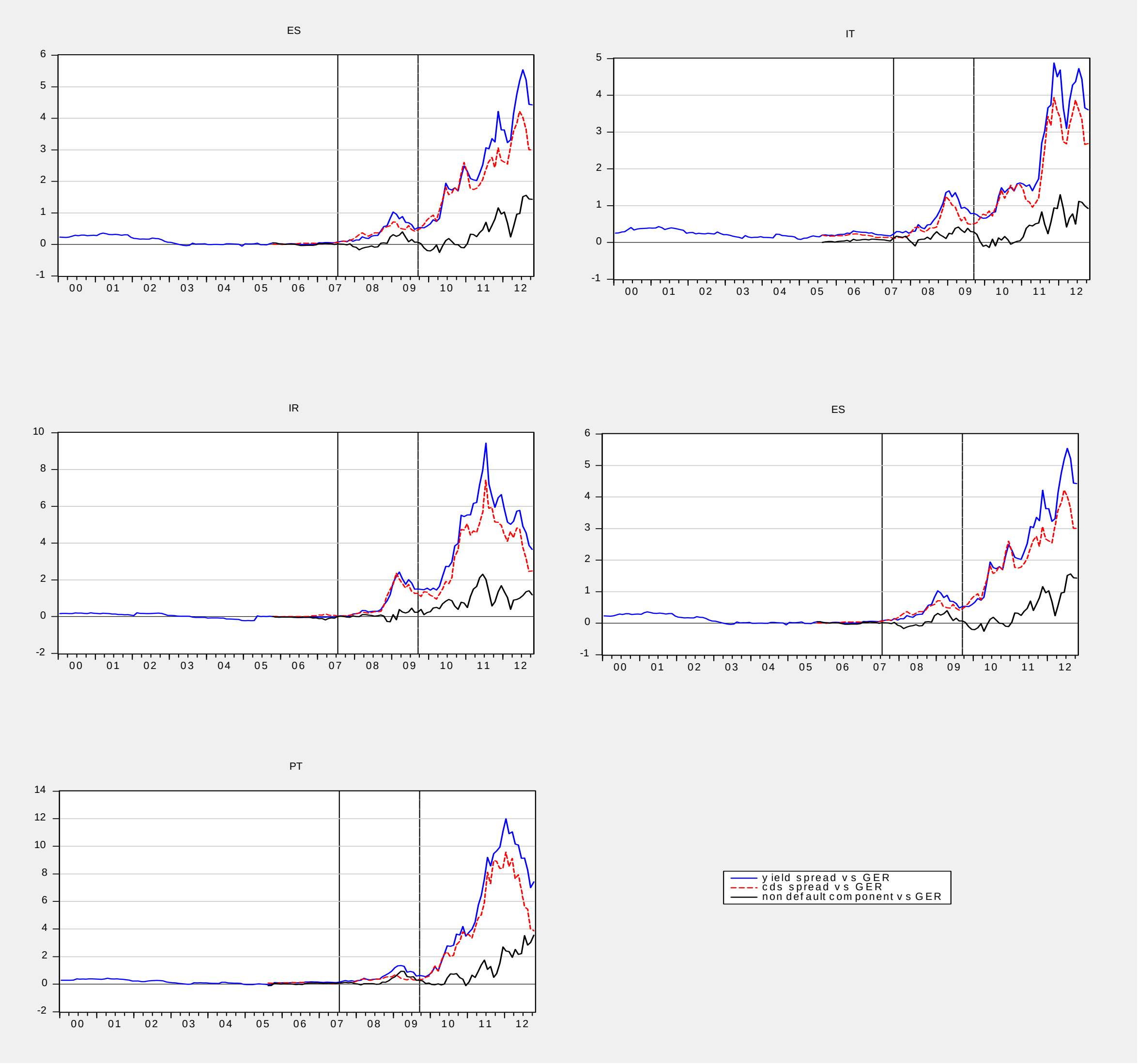

Figure 3: 10-year government bonds spreads on Bund and their components. High yields countries

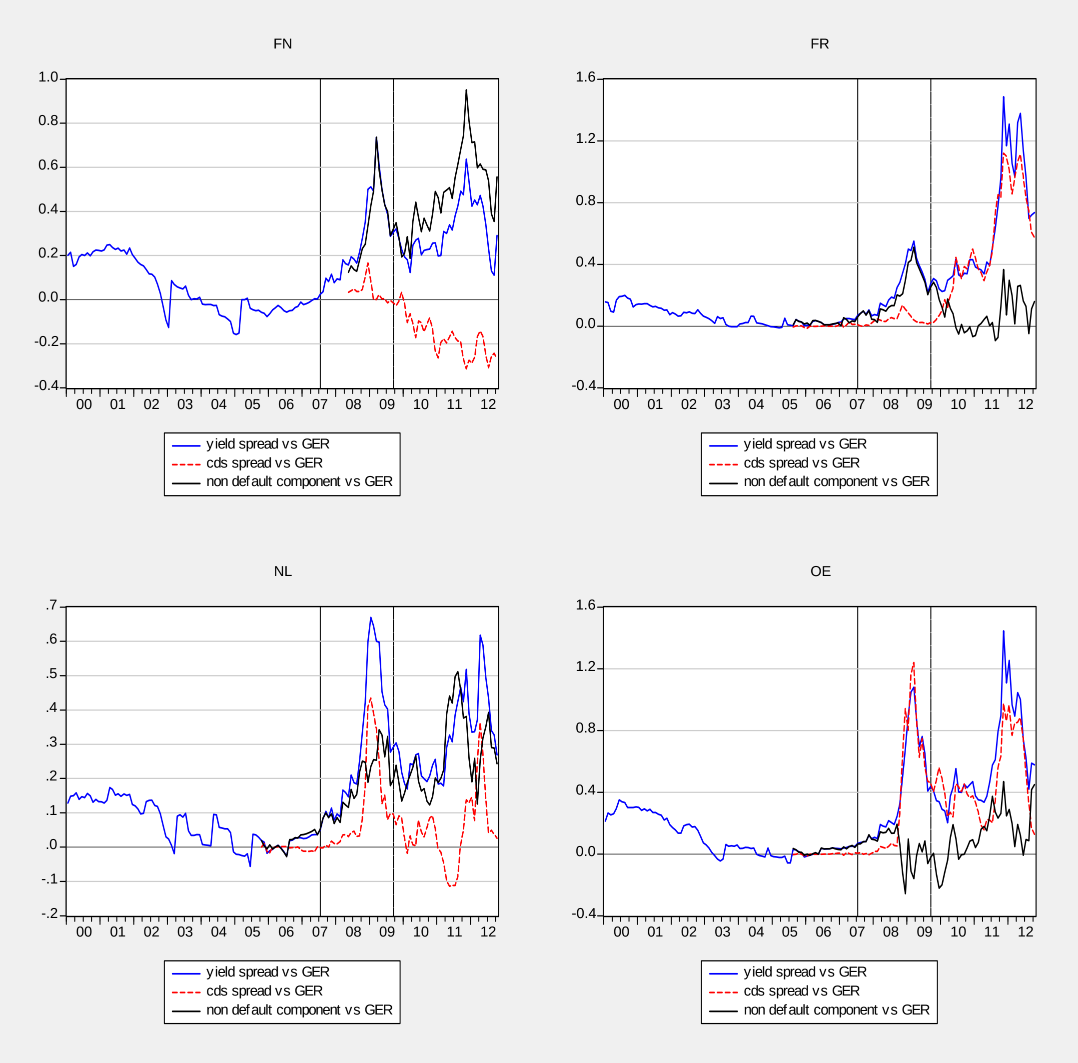

Figure 4: 10-year government bonds spreads on Bund and their components. Low yields countries

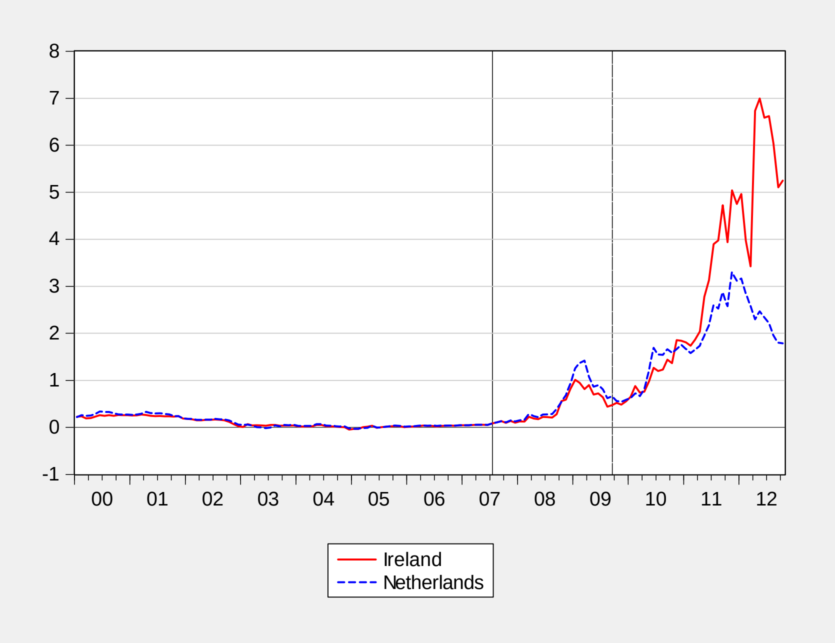

Figure 5: Global spreads based on the debt/GDP distance

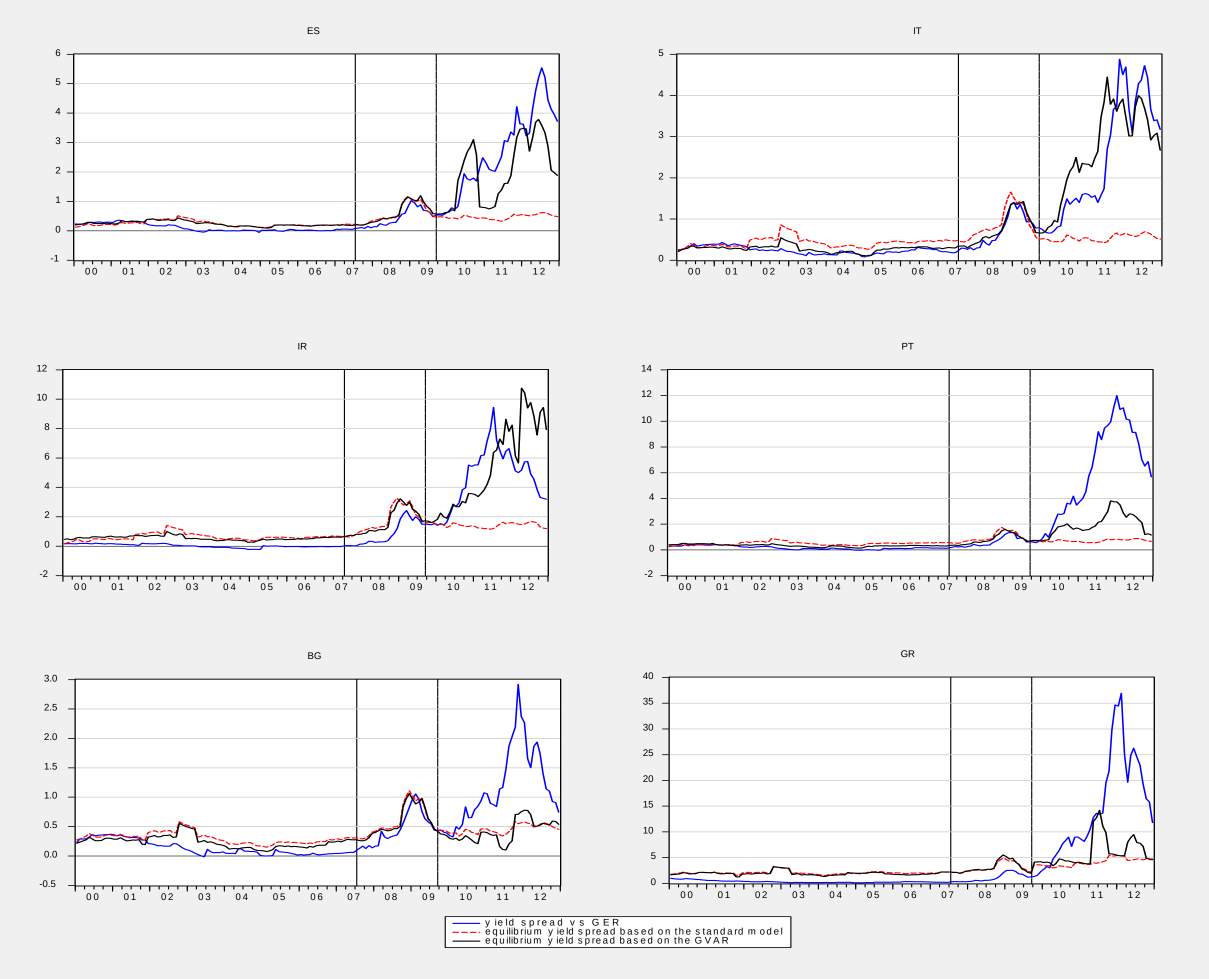

Figure 6.1: Equilibrium spreads in the standard model and in the GVAR.
High Yielders

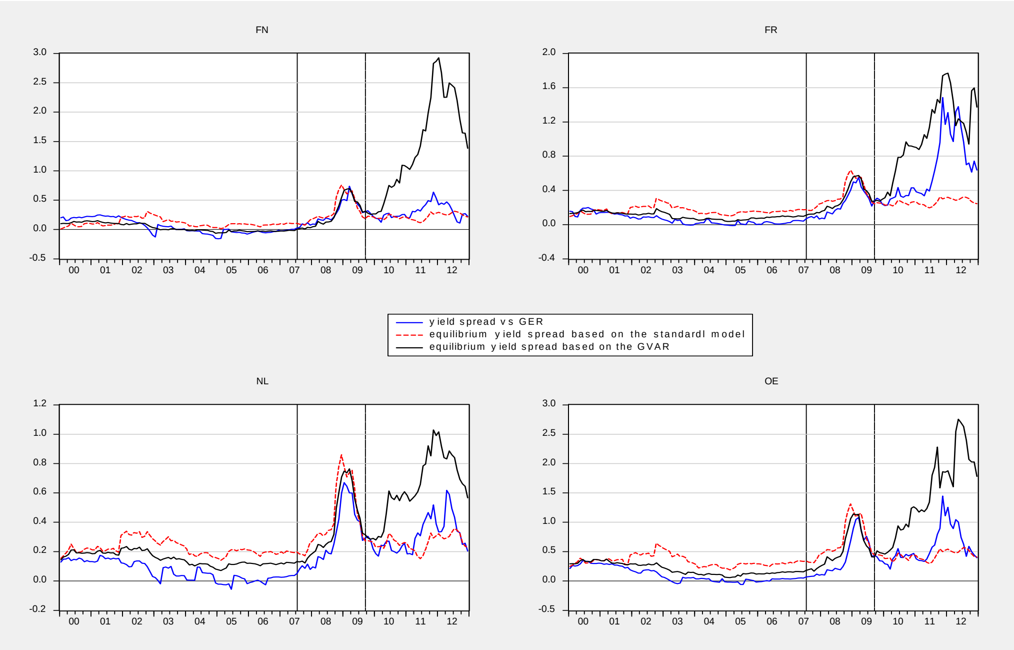

Figure 6.2: Equilibrium spreads in the standard model and in the GVAR. Low Yielders

Figure 6.3: The non-default component of spreads and the difference between GVAR equilibrium spreads and TM equilibrium spreads

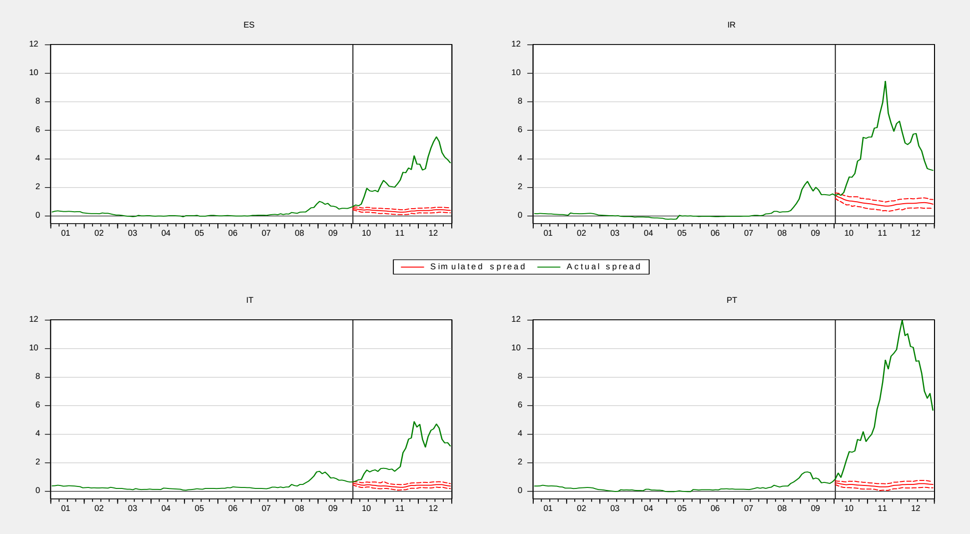

Figure 7.1: Simulation Performance. Standard Model High Yielders

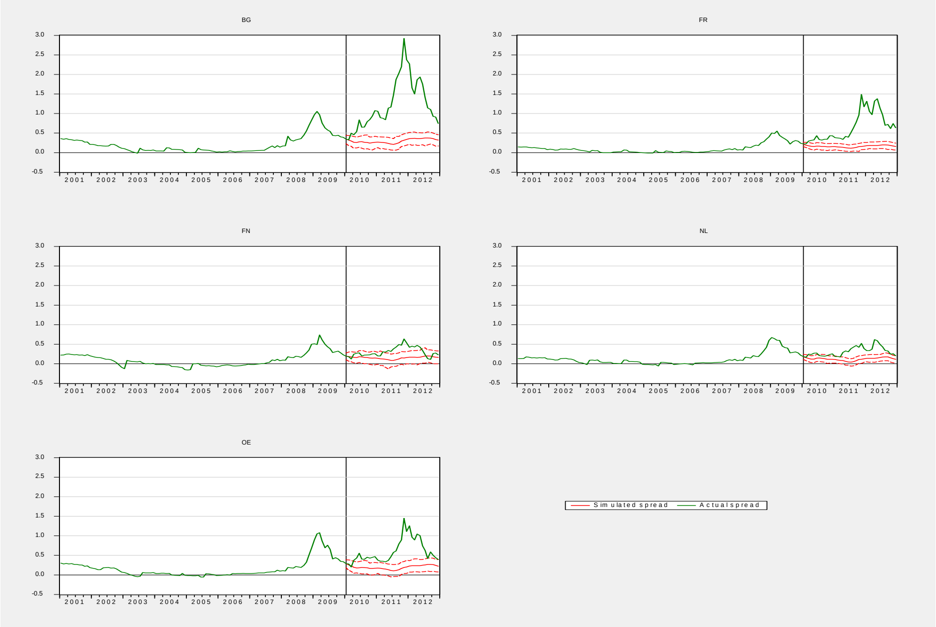

Figure 7.2: Simulation Performance. Standard Model Low Yielders

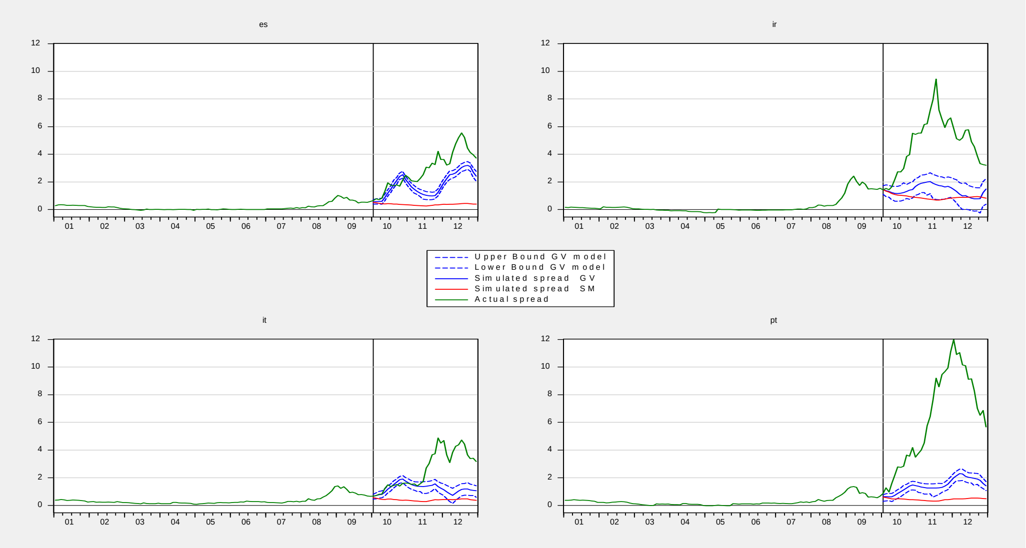

Figure 7.3: Simulation Performance. GVAR Model High Yielders

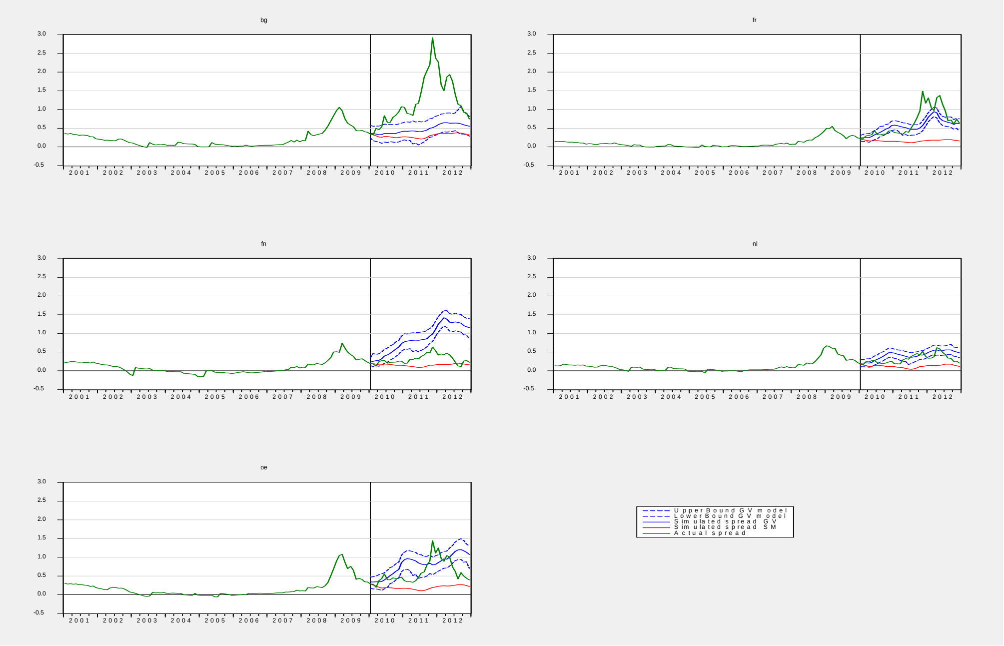

Figure 7.4: Simulation Performance. GVAR Model Low Yielders

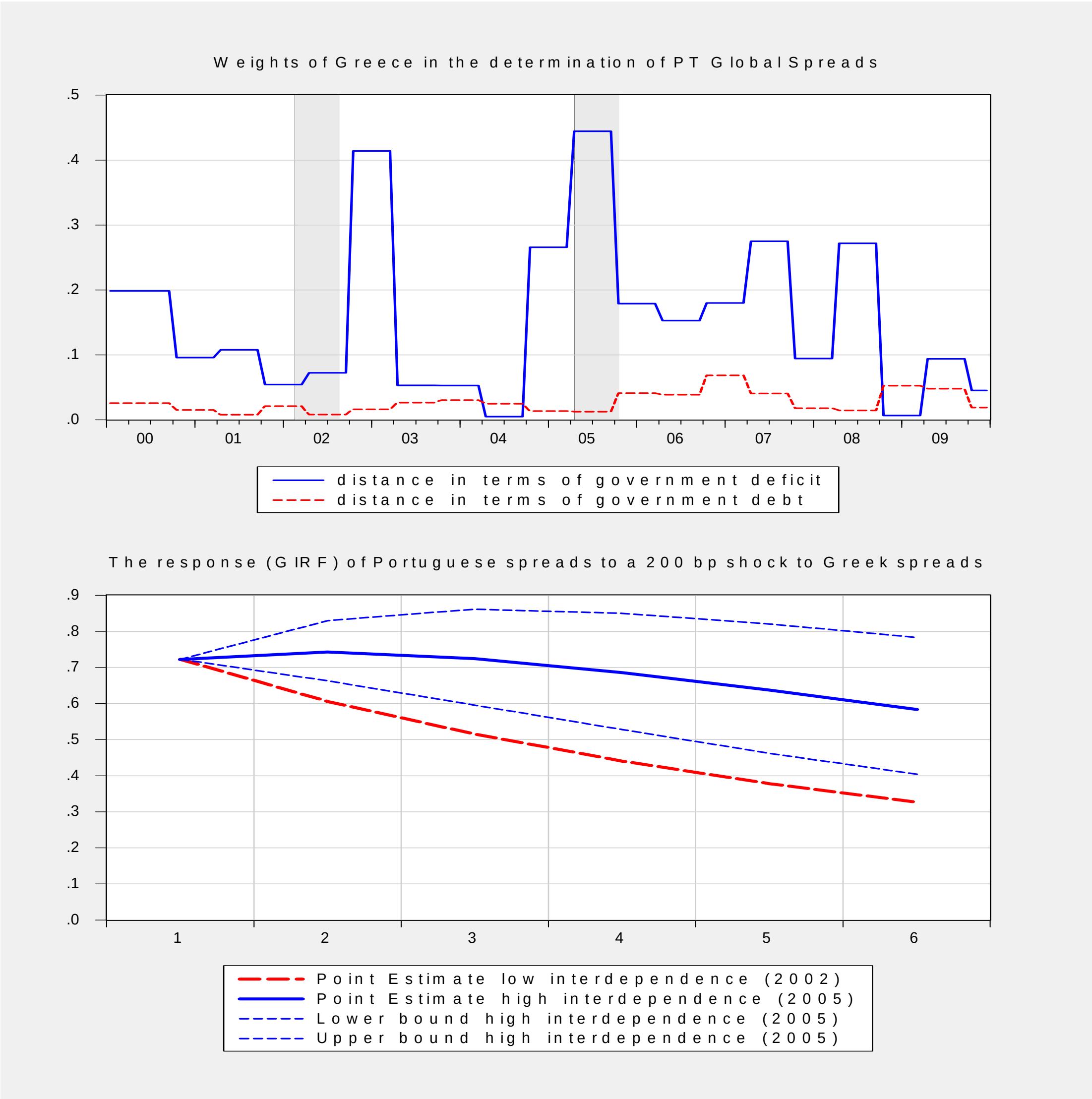

Figure 8: Responses of the portuguese spread on bunds to a shock in the greek spread on bunds in times of high and low interdependence