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FINANCIAL INDICATORS SIGNALLING CORRELATION CHANGES IN SOVEREIGN BOND MARKETS

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In 2014 all ECB publications feature a motif taken from the €20 banknote.

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Abstract

We use a Smooth Transition Conditional Correlation GARCH (STCC-GARCH) model applied to the euro area monetary policy rates and sovereign yields of Italy, Spain and Germany at 5-year maturity to estimate the threshold level of the signals above which the sovereign bond market moves to a crisis regime. We show that the threshold to a crisis regime for Italy and Spain is reached when (i) their 5-year sovereign yield spreads amount to 80-90 basis points; (ii) their 5-year CDS spreads amount to 120-130 basis points or (iii) the 5-year spread between the Kreditanstalt für Wiederaufbau (KfW) bond and the German Bund amounts to 25 basis points. Using impulse responses, we find that the STCC-GARCH with the KfW-Bund spread has leading properties, a feature corroborated by the fact that this indicator suggested a shift to a crisis regime already in August 2007 and has been signalling an improvement of the situation already in the autumn of 2012. An out-of-sample forecast of the STCC-GARCH model is also provided, which is both a novelty and a further robustness check for the stability of the model.

Keywords: Correlation Breakdowns, Monetary Policy, Regime Changes, Government Bonds, Multivariate GARCH.
JEL Codes: G12, G15, F36.

Non-Executive Summary

Sovereign yields are generally used as benchmark reference rates to price key interest rates. Therefore, the time-varying correlation between changes in the policy rate and the changes in the sovereign yield is of paramount importance for a proper transmission mechanism of the monetary policy. It is uncontroversial that the correlation between sovereign yields and the monetary policy rates declines sharply if shocks affect the sovereign debt markets. But obviously, this correlation can even turn negative when sovereign yields and monetary policy rates do again converge. After the launch of the OMTs in the second half of 2012, for example, the Italian and Spanish sovereign yields fell while the monetary policy stance, measured by the EONIA (Euro Over-Night Index Average) Swap Index or Overnight Indexed Swap (OIS) rate in some periods rose or remained constant. Following the normalization of the financial situation after adverse shocks on sovereign yields, increasingly negative unconditional correlations between sovereign yields and monetary policy rates are a desired outcome, as happened immediately after Mario Draghi's speech in London. However, these mechanisms are very difficult to interpret and to communicate. We need a method which always shows a rise in conditional correlations between sovereign yields and monetary policy rates when the financial situation, summarised by the observable signal, improves. How can we address this dichotomy? We propose to study the problem studying the correlation between benchmark sovereign yields and the monetary policy rate, whose regime depends upon an observable indicator. The two key advantages of such models are the following: (i) the changes in the conditional correlations are tied to an observable variable; and (ii) the conditional correlations change smoothly between "extreme" values on the basis of a transition function.

We focus the analysis on the 5-year sovereign yields of Italy, Spain and Germany, the former two sovereign bonds being under market disruption particularly in the summer of 2011 and 2012, while the German Bund is expected to be tightly linked to the monetary policy rate. As a proxy of the monetary policy stance, we employ the OIS rate with the same maturity. The sample period under investigation is January 2004 to January 2014, except for Spain for which we have a complete database from April 2005. The frequency of the sample is daily business.

The analysis for Italy and Spain suggests that the threshold to a crisis regime is reached when (i) the spread between the country's 5-year sovereign yield and the OIS rate amounts to 80-90 basis points; (ii) the 5-year sovereign CDS spreads amount to 120-130 basis points or (iii) the 5-year spread between the KfW (Kreditanstalt für Wiederaufbau) and the Bund amounts to 25 basis points. The KfW-Bund spread is used as a proxy for flight to liquidity, because both bonds are guaranteed by the German government and, therefore, carry the same default risk. Any differences between agency and government bond yields should reflect international investors' preference for assets with the lowest liquidity risk. The other indicators, such as the sovereign bid-ask spread, the CDS basis and stock market implied volatilities, do not provide a clear consistent signal of regime changes that is in line with market narrative and expectations.

With regard to Germany, the dynamic correlation between the German Bund and the OIS rate fluctuated closely to 80% during the entire 2004-2014 sample period regardless of the developments of the various indicators. This suggests that the Bund yield behaves like a risk free rate anchored to the monetary policy stance. One would expect that the correlations between the changes in sovereign yields and the changes in monetary policy rates were close to unity up to September 2008, before the bankruptcy of Lehman Brothers. However, the KfW-Bund spread suggested a shift to a crisis regime already in August 2007 for both Spanish and Italian sovereign debt markets, when the first signals of the financial crisis were manifested through the interbank market. Moreover, the KfW-Bund spread has been signalling an improvement of the sovereign bond market situation since autumn 2012, when the correlation between sovereign yields and monetary policy rates was negative due to the improvement of the financial conditions and the fall in sovereign yields. Therefore, the KfW-Bund spread can provide a good signal for future correlation changes.

1. Introduction

The euro area sovereign debt crisis started in the fourth quarter of 2009 after the disclosure of the severe public finance situation in Greece by the then newly elected Greek Prime Minister George Papandreou.[3] Subsequently, the sovereign yield spreads rose sharply for most of the euro area countries and the major credit rating agencies reviewed their analysis, downgrading the sovereign debt of all euro area countries, with the exception of Germany, Finland and Luxembourg. The most critical period was reached in July 2012 when the sovereign credit spreads of Italian and Spanish sovereign bonds vis-à-vis the German Bund reached record highs (about 500-650 basis points). The same spreads were about 200 basis points lower only few months earlier in March 2012.

Therefore, on 26 July 2012, Mario Draghi, President of the European Central Bank (ECB), in a speech at an investment conference in London acknowledged that financial markets were pricing the break-up risk and pledged to do "whatever it takes" to protect the euro area from collapse - including fighting unreasonably high government borrowing costs. So the Eurosystem launched the Outright Monetary Transactions (OMTs) in secondary sovereign bond markets. By mid-September 2012, the Italian and Spanish sovereign credit spreads fell by about 250-350 basis points compared to the peak in July, they declined steadily during the course of 2012 and 2013 and by the beginning of 2014 fluctuated around 150-200 basis points.

Sovereign yields are generally used as benchmark reference rates to price key interest rates, such as the lending rates to households and corporations. Therefore, the time-varying correlation between changes in the policy rate and the changes in the sovereign yield is of paramount importance for a proper transmission mechanism of the monetary policy. It is

[3] On 16 October 2009, the Greek Prime Minister George Papandreou in his first parliamentary speech disclosed the country's severe fiscal problems and immediately after, on 5 November 2009, the Greek government revealed a revised budget deficit of 12.7% of GDP for 2009, which was double the previous estimate. Since then euro area sovereign spreads vis-à-vis the German Bund rose with important adverse spillover effects from Greece (De Santis (2014) and Dergiades et al. (2014))

uncontroversial that the correlation between sovereign yields and the monetary policy rates declines sharply if shocks affect the sovereign debt markets. But obviously, this correlation can even turn negative when sovereign yields and monetary policy rates do again converge. After the launch of the OMTs in the second half of 2012, for example, the Italian and Spanish sovereign yields fell while the monetary policy stance, measured by the EONIA (Euro Over-Night Index Average) Swap Index or Overnight Indexed Swap (OIS) rate,[4] in some periods rose or remained constant. Following the normalization of the financial situation after adverse shocks on sovereign yields, increasingly negative unconditional correlations between sovereign yields and monetary policy rates are a desired outcome, as happened immediately after Mario Draghi's speech in London. However, these mechanisms are very difficult to interpret and to communicate. We need a method which always shows a rise in conditional correlations between sovereign yields and monetary policy rates when the financial situation, summarised by the observable signal, improves. How can we address this dichotomy?

We propose to study the problem using regime-dependent models of the correlation between benchmark sovereign yields and the monetary policy rate with smooth transition methods developed by Silvennoinen and Teräsvirta (2005, 2009, 2013). The two key advantages of Smooth Transition Conditional Correlation GARCH models (STCC-GARCH)[5]

[4]The EONIA swap index is an OIS rate for the euro area. It is a fixed-floating rate interest rate swap where the floating rate is indexed to the EONIA rate at which banks provide loans to each other with duration of 1 day. Banks may qualify for the EONIA Swap Index Panel if they meet the following criteria: 1) they are active players in the Euro derivative markets either in the euro area or worldwide and have the ability to transact good volumes in EONIA Swaps, even under turbulent market conditions; 2) panel banks must have a high credit rating and a high ethical behaviour, and enjoy an excellent reputation; 3) panel banks must disclose all relevant information requested by the Steering Committee. The number of panel banks will be sufficient to both represent the diversity of the EONIA swap market and guarantee an efficient manageable panel consisting of only prime banks. At present, 25 prime banks constitute the EONIA Swap Index Panel. These selected banks are obliged to quote the EONIA Swap Index for the complete range of maturities, in a timely manner, every business day with an accuracy of three decimal places. The EONIA Swap Index can point to a strict Code of Conduct which sets out the criteria for inclusion of banks in the panel. The Code of Conduct details the obligations resting on each bank, and outlines the tasks and composition of the Steering Committee which oversees the Index. This independent Steering Committee, which consists of 10 members, closely monitors all market developments and ensures, by reviewing panel banks' contributions on a regular basis, strict compliance with the Code of Conduct. It has the right to request information, remove or appoint panel banks.

[5]The STCC-GARCH models have been used to study the correlation between stocks (Aslanidis et al. (2009), Silvennoinen and Teräsvirta (2005, 2009, 2013) and Chelley-Steeley et al. (2013)), stocks and bonds

are the following: (i) the changes in the conditional correlations are tied to an observable variable; and (ii) the conditional correlations change smoothly between “extreme” values on the basis of a transition function. Once the key drivers of the correlations between sovereign yields and the momentary policy rate are identified, we can (i) study how changes in correlations depend on observable transition variables and (ii) estimate both the threshold for the regime-change and the speed of the smooth transition.

Many authors have developed early warning system models for identifying and predicting financial crises, generally applied to currency crisis and emerging markets. For example, Kaminsky et al. (1998) and Kaminsky and Reinhart (1999) transform vulnerability indicators into binary signals and estimate the critical threshold above which it sends the signal triggering a jump. In the Kaminsky-Reinhart approach, the threshold is chosen after a grid search that minimizes the noise-to-signal ratio, where the "noise" is defined as a situation where the indicator issues the signal but no crisis occurs within 24 months, while the "signal" is defined as a situation where the indicator issues the signal and the crisis occurs within 24 months. Berg and Pattillo (1999a,b) depart from the Kaminsky-Reinhart approach that looks for discrete threshold and propose a probit-based model of predicting currency crises, where the threshold is exogenously specified.

However, a key weakness of these models is the failure of distinguishing tranquil periods, when economic fundamentals are largely sound and sustainable, from post-crisis/recovery periods, when economic variables go through an adjustment process before reaching a more sustainable level or growth path. Bussière and Fratzscher (2006) argue that this problem, the so-called post-crisis bias, can be solved if a three regime model, which can distinguish a tranquil regime, a pre-crisis regime, and post-crisis/recovery regime, is estimated using a logit model.

Our approach overcomes these problems as we estimate a non-linear model where the

(Stein et al. (2013)), stocks and exchange rates (Lee et al. (2011)) and other asset classes (Silvennoinen and Thorp (2013) and Koch (2011)).

function is a smooth continuous function and the threshold is estimated endogenously. In other words, we can estimate both the threshold for the signal and its effect that takes the form of the S-shape curve. Moreover, (i) we make use of impulse response functions to assess whether the correlations obtained with the STCC models lead the correlations obtained with standard dynamic conditional correlation (DCC) models (Engle (2002)); and (ii) we perform out-of-sample forecasts conditional on the transition variable.

Theory can help us in selecting the indicators. Typically, the nominal sovereign long-term rate with maturity L in country c, $i^L_{c,t}$ can be disaggregated in the following main components:

$$i^L_{c,t} = (i^{MP}_t + E^{MP}_t(i_t) + ... + E^{MP}_{t+L-1}(i_t))/L + cp^L_{c,t} + lp^L_{c,t} + rp_t + gp_t + \varepsilon^L_{c,t} \tag{1}$$

where the first component in brackets is the average of the expected monetary policy rates, $(i^{MP}_t + E^{MP}_t(i_t) + ... + E^{MP}_{t+L-1}(i_t))/L$ common to all euro area countries; the second component is the credit risk premium for sovereigns in country c, $cp^L_{c,t}$; the third component is the liquidity premium for sovereigns in country c, $lp^L_{c,t}$; the fourth component is a regional risk premium, $r_{p,t}$; the fifth component is a global risk premium, $g_{p,t}$, and $\varepsilon^L_{c,t}$ denotes country-specific white noise. This implies that the correlation between changes in the policy rate and the changes in the sovereign yields can shift due to changes in $lp^L_{c,t}$, $cp^L_{c,t}$, $r_{p,t}$, and $g_{p,t}$. Abrupt changes in one of these factors would sharply reduce the correlation between the sovereign yields and the expected monetary policy rates.

First, we use the sovereign yield spread - defined as the difference between the sovereign yield and the OIS rate at the same maturity - as a comprehensive sovereign risk measure. Then, we employ the following indicators that reflect the above theoretical considerations:

- As a proxy of credit risk, we use the Credit Default Swap (CDS) spread (Duffie (1999), Pan and Singleton (2008), Beber et al. (2009), Longstaff et al. (2011)).
- As a proxy of liquidity risk, we use the bid-ask spread associated with the sovereign

yield (Beber et al. (2009)), the CDS basis (Bai and Collin-Dufresne (2011)) and the spread between the KfW (Kreditanstalt für Wiederaufbau) bond and the German Bund. The latter is used as a proxy for flight to liquidity, because both bonds are guaranteed by the German government and, therefore, carry the same default risk (Ejsing et al. (2012); De Santis (2014); Monfort and Renne (2014)). Any differences between agency and government bond yields should reflect international investors' preference for assets with the lowest liquidity risk (Longstaff (2004)). De Santis (2014) identifies the KfW-Bund spread to be a euro area common risk factor, which captures the portfolio shift due to a higher appetite for the German Bund, thereby affecting all euro area sovereign yields.

- As a proxy for risk aversion and aggregate uncertainty, we use the implied volatility of S&P 500 index options (VIX) and of EUROSTOXX 50 index options (VSTOXX) (Favero et al. (2010)).

We focus the analysis on the 5-year sovereign yields of Italy, Spain and Germany, the former two sovereign bonds being under market disruption particularly in the summer of 2011 and 2012, while the German Bund is expected to be tightly linked to the monetary policy rate. As a proxy of the monetary policy stance, we employ the OIS rate with the same maturity. The sample period under investigation is January 2004 to January 2014, except for Spain for which we have a complete database from April 2005 on. The frequency of the sample is daily business.

The analysis for Italy and Spain suggests that the threshold to a crisis regime is reached when (i) the spread between the country's 5-year sovereign yield and the OIS rate amounts to 80-90 basis points; (ii) the 5-year sovereign CDS spreads amount to 120-130 basis points or (iii) the 5-year KfW-Bund spread amounts to 25 basis points. The estimated speed of transition is generally relatively moderate. The other indicators, such as the sovereign bid-ask spread, the CDS basis and stock market implied volatilities, do not provide a clear consistent signal of regime changes that is in line with market narrative and expectations.

With regard to Germany, the dynamic correlation between the German Bund and the OIS rate fluctuated closely to 80% during the entire 2004-2014 sample period regardless of the developments of the various indicators. This suggests that the Bund yield behaves like a risk free rate anchored to the monetary policy stance.

As also suggested by the DCC models, one would expect that the correlations between the changes in sovereign yields and the changes in monetary policy rates were close to unity up to 14 September 2008, before the bankruptcy of Lehman Brothers. However, the KfW-Bund spread suggested a shift to a crisis regime already in August 2007 for both Spanish and Italian sovereign debt markets, when the first signals of the financial crisis were manifested through the interbank market. Moreover, the KfW-Bund spread has been signalling an improvement of the sovereign bond market situation since autumn 2012. To evaluate the leading properties of the indicators (i) we make use of impulse responses based on a bivariate Vector Auto Regression (VAR) between the correlations obtained with the DCC and STCC models and (ii) we perform out-of-sample forecasts conditional on the actual developments of the indicators, which is a novelty in the STCC-GARCH literature. The results confirm that the KfW-Bund spread can act as a leading indicator of a change in correlation between sovereign yields and monetary policy rates.

The remaining sections of the paper are structured as follows. Section 2 summarizes the methods. Section 3 describes the data and the indicators. Section 4 discusses the main results. Section 5 concludes.

2. Methodology

To study the conditional correlation between the change in the sovereign yield and the change in the monetary policy rate in a non-linear setting, we construct an STCC-GARCH model à la Silvennoinen and Teräsvirta (2013). As in DCC models (Engle (2002)), the conditional variance-covariance matrix H_t takes the following form:

$$H_t = D_t R_t D_t,\ with\ D_t = diag(h_{i,t}^{1/2}, ..., h_{i,t}^{1/2}), \tag{2}$$

where the conditional variances h_{it} for any process $y_{it} = E\left[y_{it} \mid \psi_{i,t-1}\right] + \varepsilon_{i,t}$ are GARCH(p,q) univariate specifications

$$h_{it} = \omega_{i0} + \sum_{j=1}^{q} \alpha_{ij}\varepsilon_{i,t-j}^2 + \sum_{l=1}^{p} \beta_{il}h_{i,t-l}\ with\ \varepsilon_{it} = h_{it}^{1/2} z_{it}\ and\ \varepsilon_{it} \mid \psi_{i,t-1} \sim N(0, h_{it}). \tag{3}$$

The errors $z_{i,t}$ are independent random variables with mean zero and unit variance, and $\psi_{i,t-1}$ denotes all available information at time $t-1$. In addition, stationarity restrictions for the volatility process and non-negativity of the conditional variance are imposed. Specifically, to estimate the univariate volatility processes we use the common ARMA(1,1)-GARCH(1,1).

To model the conditional correlation, Silvennoinen and Teräsvirta (2013) define a logistic transition function G and two extreme states of correlation represented by the correlation matrices R_1 and R_2:

$$R_t = (1 - G_t) \cdot R_1 + G_t \cdot R_2, \tag{4}$$

$$G_t(\gamma, c, s_t) = (1 + \exp\{-\gamma(s_t - c)\})^{-1}\ with\ \gamma > 0. \tag{5}$$

The difference between the transition variable s_t and its threshold c, which is endogenously determined, is indicative for the process being in one regime or the other at any point in time,[6] with γ defining the speed of transition and G being bounded between 0 and 1. Accordingly, the correlation varies between two extreme states and at any point may be somewhere in between, based on the transition variable and the speed of the adjustment.

The STCC model, the DCC model, and many other approaches that separate the estimation of the volatility process from the correlation, differ in the way parameters are obtained.

[6] Berben and Jansen (2005) independently developed a time-varying STCC (TV-STCC) in the same year when the STCC-GARCH model was first introduced by Silvennoinen and Teräsvirta (2005), with the transition variable s_t being a time trend in the Berben and Jansen (2005) specification.

For example, in the second step of a DCC model, correlation values are estimated conditioned on the GARCH parameter estimates. Silvennoinen and Teräsvirta (2013) point out that in a nonlinear setting numerical problems may arise when maximizing the following likelihood with all parameters in the vector θ:

$$l_t(\theta) = -\frac{N}{2}log(2\pi) - \frac{1}{2}\sum_{i=1}^{N} log\,(h_{it}) - log \mid R_t \mid - \frac{1}{2} z_t' R_{t-1}^{-1} z_t. \tag{6}$$

Thus, parameters need to be estimated with conditional maximum likelihood. The iterative procedure is carried out on three sets of parameter values (univariate GARCH parameters, correlation parameters and transition parameters), ensuring convergence and in general smaller standard errors.[7] All in all, the two-step approach requires only one iteration from the GARCH parameters to correlation and transition parameter values. Conversely, the iterative approach has the advantage of allowing feedback effects between volatility, correlation and transition parameters.

To eliminate scale effects, we follow the common practice of standardizing the transition parameter γ with the transition variable and impose an upper limit of 100, in line with Silvennoinen and Teräsvirta (2005), who point out that the likelihood function is merely insensitive to changes in γ above that value, a result found also in this study.[8] To avoid local minima (i) we carry out a grid search using a very large grid of the two transition parameters together with the estimates of the univariate processes and (ii) we perform the iterative procedure using starting values based not only on the single best starting combination, but also on several well-fitting sets and neighboring random picks.

Before searching for combinations of transition parameters, in addition to the GARCH parameters that are used for the grid, one has to define a correlation matrix. Missing in the

[7]Silvennoinen and Teräsvirta (2013) point out that the estimators using a two-step approach are consistent under regular conditions (see also Engle (2002) and Engle and Sheppard (2001)).

[8]We fix γ at its estimated value to calculate standard errors of all parameters, a procedure similar to Silvennoinen and Teräsvirta (2005), who however exogenously fixed γ to 100.

literature a best-practice recommendation for a regime-switching model, we consider as initial estimates of the extreme states of correlation R_1 and R_2 the minimum and the maximum of 100-day rolling correlations. We argue that the combination of a large grid of initial values, estimations from various rational first guesses and all other routines described above lead to a highly reliable framework.

3. Data Section and Estimation of the KfW-Bund Spread

We study the correlation between the daily change in the monetary policy stance and the daily change in sovereign yields in Italy and Spain, which have been under tremendous pressure during the euro area sovereign debt crisis. We also consider the case of Germany, which is a key euro area benchmark country that has not lost the triple-A rating.

The sovereign bond yield used as a benchmark has a 5-year maturity for two main reasons: first, aggregate demand is typically affected by long-term interest rates and therefore the correlation between long-term sovereign yields and monetary policy rates is a key economic relevant question; second, the market for CDS spreads used to measure credit risk is more liquid at 5-year maturity.

Additional exercises similar to those here described are carried out using bond yields at 2-year maturity. The results are broadly similar and are available upon request.

The time-varying bivariate correlations are regime-dependent and controlled by observable transition variables. Given that we use daily data, we focus primarily on market-determined variables, since they should aggregate expectations of economic agents, which is relevant to investors in the sovereign credit markets.

Credit risk, liquidity risk and aggregate risk aversion are the main risks that can affect the correlation between sovereign yields and monetary policy rates. Therefore, the indicators are grouped in three main types: price indicators partly proxying for credit risk (i.e. CDS spread), liquidity indicators partly proxying for liquidity risk (i.e. sovereign bid-ask spread, KfW-Bund spread and CDS basis) and volatility indicators partly proxying for risk aversion (i.e. VIX and VSTOXX). We also use the sovereign yield-OIS spread as a comprehensive measure of sovereign risk.

These measures are all well-known in the literature except for the KfW bond yield. The KfW banking group is Germany's largest public development bank and is instrumental in executing numerous government policies of the Federal Republic of Germany. The credit ratings are chiefly based on the unconditional guarantee provided by the German state since April 1998 (Moody's (2011)). Since the credit risk component of agency yields is assumed to be the same as that of bonds issued directly by the guaranteeing government (Longstaff (2004), Ejsing et al. (2012), De Santis (2014), Monfort and Renne (2014)), any differences between agency and government bond yields should reflect liquidity premia. At its launch in spring 1998, a jumbo KfW bond offered 10-15 basis points in addition to the benchmark German government bond (McCauley (1999)) and fluctuated around that range for about a decade before the financial crisis started. This positive spread is due to the fact that the portfolio composition of mutual funds with low risk profile includes the German Bund and not the KfW bond. A second explanation is associated to the depth of the Bund market. Important international investors often prefer to hold very liquid assets, such as the Bund, which can be easily dismissed in large quantities, if required. Also anecdotal evidence can proof that the KfW bonds and the Bund are characterised by the same credit risk. On 4 December 2012, the three main rating agencies have assigned a triple-A rating to KfW as is the case for the Bund and a more adverse credit rating to KfW-IPEX, which is a 100%-held subsidiary of KfW, whose debt however is not covered by the guarantee of the German state (see Table 1).

[Insert Table 1, here]

Moody's decisions in July 2012 are additional important evidence in support of the view that the Bund and the KfW debt carry the same default risk. On 23 July 2012, Moody's announced to have changed the outlook from stable to negative on the German sovereign debt ratings. On 24 July 2012, Moody's announced to have changed the outlook from stable to negative on six German region's sub-sovereign debt rating. On 25 July 2012, Moody's announced to have changed the outlook from stable to negative on KfW long-term debt rating, indicating in the press release that this action followed the previous actions on the German sovereign and sub-sovereign debt ratings.

As proposed by Vasicek and Fong (1982) and following Ejsing et al. (2012), zero-coupon yield curves for bonds issued by KfW and the German government are estimated using the so-called Merrill Lynch exponential spline (MLES) model. The various KfW yields needed to construct the yield curve are available in Bloomberg and are collected at the end of the day. The 5-year spread between the German KfW and the Bund is estimated to have increased steadily from 10-15 basis points before the financial crisis started, to 90 basis points in the first quarter of 2009 (see Figure 1). The estimated spread comoves with the US and euro area implied stock market volatility (VIX) until end 2009, declined sharply in the course of 2009, fluctuated up to autumn 2010, but then they decoupled. The KfW-Bund rose again as the euro area's sovereign debt crisis unfolded in 2010, 2011 and 2012 with risk aversion and aggregate uncertainty benefitting liquid, safe haven assets, such as the Bund.

[Insert Figure 1, here]

The various stages of the sovereign debt crisis in the euro area are also clearly described by the developments of the sovereign yields, CDS spreads and bid-ask spreads, which are also obtained from Bloomberg.

All benchmark sovereign yields and OIS rates were tightly comoving up to 14 September 2008. With the intensification of the financial crisis in September 2008 after the collapse of Lehman, Italian and Spanish government bond yields relative to the Bund and the OIS rates rose. CDS spreads, KfW-Bund spreads and the CDS basis followed similar developments. Italian and Spanish bid-ask spreads started to rise only by end-2010.

The developments in 2010 and 2011 were remarkable with the Italian and Spanish 5-year sovereign spreads hitting respectively 380 and 390 basis points in July 2011 and 600 and 740 basis points in July 2012. After the "whatever it takes speech" by Mario Draghi, the sovereign credit spreads and bid-ask spreads as well as the KfW-Bund spread started a steady decline. The VIX and VSTOXX also reverted their trend, although they were already fluctuating much below their developments recorded previously. Conversely, the CDS bases fluctuated with an upward trend and then reverted back towards zero.

However, the only variable which showed a clear upward trend since the crisis in the interbank market in August 2007, is the KfW-Bund spread. We will show in the next section that the STCC-GARCH with the KfW-Bund spread as transition variable can lead the change in dynamic correlation between sovereign yields and monetary policy rates. A summary table with descriptive statistics is presented in Table 2.

[Insert Table 2, here]

4. Empirical Results

4.1. Transition Functions and Conditional Correlations

The results for the key STCC-GARCH(1,1) parameters are summarised in Table 3. The transition functions and the conditional correlations are plotted against time in Figure 2 for Spain, Figure 3 for Italy and Figure 4 for Germany.

[Insert Table 3, here]

The GARCH parameters and their sum point to important persistency effect in the volatility of sovereign yields and OIS rates.[9] This is also evident in the last two panels of Figures 2-4, where the conditional variances are plotted. In general, the volatility parameters, the correlations and most of the threshold parameters are highly significant (see Table 3).

[9]Hillebrand and Medeiros (2009) provide an extensive discussion of the long-range dependence and structural change topic in a realized volatility framework. Amado and Teräsvirta (2014) examine long-run and short-run properties with a non-stationary component in variance equations for a conditional correlation multivariate GARCH framework.

Regarding γ, the estimated speed of transition is generally relatively moderate, except for the bid-ask spread of Italy and Spain, the CDS basis of Germany and the VIX for Spain.

[Insert Figures 2-4, here]

Given the similar developments in Italian and Spanish sovereign yields, the estimated parameters for both markets are in general similar. This is the case despite the two different sample periods and, most importantly, despite applying the suggested routines to avoid local minima separately. Therefore, we can safely argue that the iterated conditional maximum likelihood procedure for the three sets of parameters (volatilities, correlations and transition parameters) is robust.

The analysis for Italy and Spain suggests that the threshold to a crisis regime is reached when the 5-year sovereign yield spreads are above 80-90 basis points and the 5-year CDS spreads are above 120-130 basis points. The transition functions and the conditional correlations are all very similar for both countries and both indicators. After Lehman, the transition functions rose from zero (the no-crisis regime), to 0.5-0.6 for Spain and 0.8-1 for Italy. Similarly, the conditional correlations declined from 80% to 40% for Spain and from 80% to zero for Italy. The situation started to improve in the course of spring 2009 after the announcement of stringent fiscal stabilization measures by the Irish government on 22 February 2009. It could be argued that the improvement was rather the result of global uncertainty receding. However, the STCC-GARCH with VIX and VSTOXX as transition variable does not support this argument, given that the correlations fluctuated around 20-30% over this period. After the disclosure of the Greek severe fiscal problems in October 2009, the transition functions computed using both the sovereign yield and CDS spreads started to rise again and the correlations started to decline, stabilizing since May 2010 in negative territory around -10% in a full crisis regime mode.

With regard to the KfW-Bund spread, the analysis for Italy and Spain suggests that the threshold to a crisis regime is reached when the 5-year KfW-Bund spread is above 25 basis points. The transition functions and the conditional correlations are all very similar across countries. Compared to the signal provided by the sovereign credit spreads, the transition functions started to move out of the no-crisis regime already in August 2007 when they reached 0.2-0.3 and the correlations between sovereign yields and OIS rates declined to about 50-60%. After Lehman, the transition functions rose above 0.5 and the correlations declined further reaching negative territory. The correlations have slightly increased in the course of 2009 despite the sharp decline of the KfW-Bund spread, but then the correlations have fluctuated around zero since the speech of Mario Draghi in London. After the launch of OMTs in September 2012, the transition functions have been declining and the correlations have been improving signalling a gradual improvement of the situation. In this respect, the KfW-Bund spread might lead the signalling of a breakdown or improvement in the conditional correlations between sovereign yields and policy rates, as a result of flight-to-liquidity phenomena that have characterized the euro area sovereign debt market during the financial crisis and that are captured by this indicator.

With regard to the sovereign bid-ask spreads and the cash basis, while the thresholds for a regime change are well estimated at 1-2 basis points for the bid-ask spreads and 10-20 basis points for the CDS basis, the transition functions and the conditional correlations change abruptly. Frequent switches are typical of standard regime-switching models and this is not helpful to make key decisions.

Finally, with regard to the stock market implied volatilities, the transition functions and the dynamic correlations do not provide a clear consistent signal of regime changes that is in line with market narrative and expectations.

Contrary to the findings for Spain and Italy, the conditional correlation between the Bund and the OIS rate remained close to 80% during the entire 2004-2014 sample period, regardless of the developments of the various indicators. This suggests that the Bund yield behaves like a risk-free rate anchored to the monetary policy stance. Note also that the threshold for the German sovereign spreads is negative amounting to -17 basis points. This is due to flight-to-liquidity and flight-to-safety phenomena, which induced investors to transfer large sums of money into the German Bund to hedge against the worst outcomes of the euro area sovereign debt crisis.

The relationships between transition functions and the key signals are plotted in Figure 5 for Spain and Figure 6 for Italy. The signal has an effect that takes the form of the S-shape curve, which is generally smoother for Italy relative to Spain and for CDS spreads relative to the other indicators. The bid-ask spreads as well as the other indicators (here not reported), such as volatility measures and the CDS basis, shift from one regime to the other almost instantaneously; a characteristic which is not helpful for policymaking decisions.

[Insert Figures 5-6, here]

These results are robust to alternative univariate volatility specifications, such as an asymmetric GARCH of the Glosten-Jagannathan-Runkle type (Glosten et al. (1993)) used by Silvennoinen and Teräsvirta (2013).

Furthermore, we also consider a specification with two transition variables and four regimes of correlation between which the process may vary, using the double STCC (DSTCC) model of Silvennoinen and Teräsvirta (2009). Except for changes in the transition speeds, the conditional variances and the correlation patterns remain similar to those already presented in Figures 2-6. This is because the threshold of one transition variable and the correlation of at least one of the additional regimes are insignificant. In other words, the combination of transition variables does not strengthen the estimation of the correlations obtained using the STCC models.

4.2. Predicting Correlations

Can we use the STCC results to predict correlations? We evaluate the results of our model against standard correlations obtained with the DCC model, which typically are very similar to unconditional rolling correlations. The bivariate DCC estimates are presented in Table 4. All GARCH and correlation parameters are highly significant for all three country sovereign-OIS pairs.

[Insert Table 4, here]

The smooth transition conditional correlations together with the conditional correlation estimated using the DCC model are summarized in Figures 7 and 8 for Italy and Spain, respectively. The advantage of the STCC relative to the DCC models is that the correlations are more persistent and less volatile. Moreover, the STCC allows the endogenous computation of signals useful to assess a crisis.

The results suggest that the correlations between the sovereign yields and the OIS rate obtained with the DCC model comove with that obtained with the STCC model and CDS spreads as transition variable. Conversely, the correlations obtained using the KfW-Bund spread as transition variable lead the DCC results, as this indicator suggested a shift to a crisis regime for both Italian and Spanish sovereign yields already in August 2007 and has been signalling an improvement of the situation already in the autumn of 2012.

[Insert Figures 7-8, here]

To address these results formally, we make use of impulse response functions (IRFs) generated by a bivariate VAR, which takes the following form:

$$\mathbf{A}_0\mathbf{Y}_t = \phi + \sum_{j=1}^{p} \mathbf{A}_j\mathbf{Y}_{t-j} + \eta_t, \tag{7}$$

where $\mathbf{Y}_t$ is the 2×1 vector of variables observed at time t, namely the correlations generated by the DCC and the STCC-GARCH models, p is the lag length set equal to 11 according to the Akaike information criterion (AIC) and η_t is a 2×1 vector of innovations, defined as being uncorrelated with one another. $\mathbf{A}_0$ is the impact matrix. Restrictions must be imposed on $\mathbf{A}_0$ to uniquely recover the structural form. The identification restrictions imposed on $\mathbf{A}_0$ is recursive, which is equivalent to a Cholesky factor of the variance-covariance matrix of the reduced form white noise innovations with the innovations of the STCC correlations ordered last. This assumption is very conservative, as we assume that all common contemporaneous innovations are generated by the DCC model.

The structural VAR associated with this equation can be represented by its vector moving average form,

$$\mathbf{Y}_t = \mu + \mathbf{C}(L)\,\eta_t, \tag{8}$$

where L is the lag operator, $\mathbf{C}(L) = \left(\mathbf{A}_0 - \sum_{j=1}^{\infty} \mathbf{A}_j L^j\right)^{-1}$ provide the key dynamic multipliers and the constant 2-vector $\mu = \left(\mathbf{A}_0 - \sum_{j=1}^{\infty} \mathbf{A}_j L^j\right)^{-1} \phi$. As suggested by equation (8), the variations of the endogenous variables can only be explained by variations in current and an infinite number of past innovations.

The IRFs are reported in Figure 9 and 10 for Spain and Italy, respectively. They indicate that the correlations obtained with the DCC do respond to STCC innovations. Specifically, the responses reach the peak after 150-200 days when using the KfW-Bund spread as transition variable, whereas they reach the peak after less than 100-150 days when using other variables. The results also suggest that the correlations obtained with the STCC model do not all respond to DCC innovations. While the STCC with CDS spreads and bid-ask spreads do respond suggesting that these variables cannot be used as leading indicators, the STCC with KfW-Bund spread do not repond to DCC innovations confirming the usefulness of this variable as a leading indicator of correlations among sovereign yields and OIS rates.

[Insert Figures 9-10, here]

Finally, given the estimated parameters, the model allows to compute projections. Silvennoinen and Teräsvirta (2013) indicated that the research agenda on out-of-sample forecasts for STCC models is feasible. To the best of our knowledge, our is the first study to assess future correlations using STCC parameters. First, we re-estimate the parameters of the STCC-GARCH models up to 30 June 2012. Then, we run out-of-sample forecasts conditional on actual developments in the transition variable. The results are reported in blue after the vertical bar in Figures 11 and 12. Focusing on the STCC with the KfW-Bund spread, the correlations between the sovereign yields of Italy and Spain and the OIS rate were expected to increase reaching 60-70%. Conversely, the correlations obtained with the DCC model were negative and further declined in the second half of 2012. Only in the course of 2013, their trend reverted back reaching the level indicated by the STCC-GARCH. This suggests that the financial conditions in the sovereign debt market, as summarised by the KfW-Bund spread indicator, improved after the speech of Mario Draghi in July 2012 and this was clearly reflected in the correlations generated by the STCC model.

[Insert Figures 11-12, here]

A comparison between the results reported in Figures 7 and 11 for Spain and in Figures 8 and 12 for Italy indicates that the STCC models, except for that using the bid-ask spread of Italian sovereign yields, produce very similar correlations in sample and out of sample, suggesting that the models are very stable. Therefore, the STCC model with the KfW-Bund spread is very useful for forecast analysis.

5. Conclusions

Policymakers face the challenge of identifying the key indicators that can be used to uncover risks for the euro area sovereign debt market. The key challenge consists of assessing the threshold level for a specific indicator above which a sovereign debt market moves to a crisis regime.

We address this issue by estimating an STCC-GARCH model for the daily changes in sovereign yields and the daily changes in OIS rates for Italy, Spain and Germany at 5-year maturity.

The conditional correlation between the German Bund and the OIS rate remains close to 80% during the entire 2004-2014 sample period, regardless of the developments of the various indicators. This suggests that the Bund yield behaves like a risk-free rate anchored to the monetary policy stance.

For Italy and Spain, the STCC-GARCH model suggests that the threshold to a crisis regime is reached when (i) the 5-year spread between sovereign yield and monetary policy rates amounts to 80-90 basis points; (ii) the 5-year sovereign CDS spread amounts to 120-130 basis points and (iii) the 5-year KfW-Bund spread amounts to 20 basis points. The estimated speed of transition is generally relatively moderate, which permits the policymakers to make a proper assessment.

The transition functions and the conditional correlations estimated using other indicators, such as the sovereign bid-ask spread, the CDS basis and US and euro area stock market implied volatilities, change abruptly and do not provide a clear consistent signal of regime changes that is in line with market narrative and expectations.

Regarding the leading properties of the indicators in signalling correlation breakdowns, it seems that the KfW-Bund spread can play such a role given that a shift to a crisis regime was suggested already in August 2007 for both Spanish and Italian sovereign debt markets. Moreover, the KfW-Bund spread seems also useful to signal when the sovereign bond market situation is improving, as this indicator has been suggesting a gradual shift away from the crisis regime already in the autumn of 2012.

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Table 1: Rating Overview

Notes: Rating overview for bonds of Kreditanstalt für Wiederaufbau (KfW) on 25 July 2012. KfW-IPEX, is a 100%-held subsidiary of KfW, whose debt is not covered by the guarantee of the German state.

	Bund Rating	Bund Outlook	KfW Rating	KfW Outlook	KfW-Ipex Rating	KfW-Ipex Outlook
Fitch	AAA	Stable	AAA	Stable	–	–
Moody's	Aaa	Negative	Aaa	Negative	Aa3	Negative
SP	AAA	Stable	AAA	Stable	AA	Stable

Table 2: Descriptive Statistics

Notes: Descriptive statistics are reported for all data used in this study computed over the common sample period 5 April 2005 - 14 January 2014.

Variables in basis points	Mean	Minimum	Maximum	Standard Deviation	Skewness	Kurtosis
Overnight Index Swap	245,4805	41,8	480,75	128,1279	0,0578	1,7432
Spain Interest Rate	375,0409	228,85	749,8	79,8061	0,666	3,5416
Italy Interest Rate	372,4671	243,05	770,35	85,0176	1,0421	4,6628
Germany Interest Rate	235,6435	23,85	476,15	129,3093	-0,0471	1,7521
Overnight Index Swap Change	-0,0899	-22,6	21,45	4,4407	-0,1415	4,9371
Spain Interest Rate Change	-0,0229	-99,3	51,75	9,1009	-1,3582	21,0979
Italy Interest Rate Change	-0,0199	-95,65	70,2	8,8881	-0,9184	23,4101
Germany Interest Rate Change	-0,0899	-21,6	29,7	5,0405	0,0775	5,1164
Sovereign Spread Spain	129,5604	-28,65	695,4	150,0409	0,8784	2,8223
Sovereign Spread Italy	126,9866	-17,55	637,7	142,1506	1,1516	3,5479
Sovereign Spread Germany	-9,837	-47,15	27,65	11,8098	0,1098	3,52
Credit Default Swap Spain	153,544	1,05	636,675	154,8169	0,8479	2,8156
Credit Default Swap Italy	149,6989	5,3	595,675	148,7343	1,0267	3,2186
Credit Default Swap Germany	30,5108	0,6	120,585	28,5856	0,9276	3,1031
KfW-Bund Spread	35,4881	0,6682	94,0467	24,3333	0,4402	2,3339
Bid-Ask Spread Spain	2,9098	0,4	27,6	3,5576	2,4458	10,4509
Bid-Ask Spread Italy	2,3091	0,3	18,1	1,7468	3,4919	20,071
Bid-Ask Spread Germany	0,5076	0	1,3	0,3937	0,9279	2,0816
CDS Basis Spain	23,9836	-96,55	144,53	36,8786	-0,0023	4,075
CDS Basis Italy	22,7123	-135,505	158,775	28,4101	0,6791	5,0731
CDS Basis Germany	40,3478	0,9	149,435	33,7436	1,2011	3,7016
VIX	18,4964	8,9433	66,5	8,9878	2,0301	8,1704
VSTOXX	22,1891	9,01	79,28	8,9085	1,7721	7,5642

Table 3: STCC-GARCH Estimates (Panel 1)

Notes: α and β are the estimates for the ARCH and GARCH parameters of the univariate GARCH(1,1) models for the respective interest rates. Parameter estimates γ and c are the speed of transition and the threshold of the transition variable, respectively, $corr_1$ and $corr_2$ are the estimated correlation parameters of the correlation matrices. Standard errors in parantheses. The speed of transition parameter γ is reported in standardized values as estimated, and γ is fixed for standard error calculation to accomodate numerical issues. Sample period: 8 January 2004 - 14 January 2014 for Italy and Germany; 5 April 2005 - 14 January 2014 for Spain

Transition variable	Country	Country α	Country β	OIS α	OIS β	γ	c	$corr_1$	$corr_2$
5-year sovereign yield spread	Spain	0,0752	0,9248	0,049	0,951	7,4997	86,3988	0,843	-0,1044
log likelihood	-13371,6181	(0,0001)	(0,0001)	(0,0001)	(0,0001)		(34,8478)	(0,0001)	(0,0016)
5-year sovereign yield spread	Italy	0,0769	0,9231	0,0391	0,9609	10,7196	78,6673	0,8119	-0,0573
log likelihood	-15123,7373	(0,0002)	(0,0002)	(0)	(0)		(52,0729)	(0,0002)	(0,0021)
5-year sovereign yield spread	Germany	0,0436	0,9564	0,0397	0,9603	5,9197	-17,4357	0,7016	0,855
log likelihood	-13566,7838	(0)	(0)	(0)	(0)		(19,226)	(0,001)	(0,0001)
5-year sovereign CDS spread	Spain	0,0768	0,9232	0,0502	0,9498	2,5276	129,3172	1	-0,2209
log likelihood	-13368,4852	(0,0001)	(0,0001)	(0,0001)	(0,0001)		(16,6813)	(0,0001)	(0,0023)
5-year sovereign CDS spread	Italy	0,0774	0,9226	0,0396	0,9604	2,3355	121,2164	0,9987	-0,2325
log likelihood	-15128,2587	(0,0002)	(0,0002)	(0)	(0)		(39,7803)	(0,0004)	(0,0032)
5-year sovereign CDS spread	Germany	0,0462	0,9538	0,0416	0,9584	0,1303	117,1398	0,8463	0,7822
log likelihood	-13614,9687	(0)	(0)	(0)	(0)		(29021,5162)	(0,0126)	(0,0268)
5-year KfW-Bund spread	Spain	0,0688	0,9312	0,0425	0,9575	3,6761	27,6938	0,9156	0,0211
log likelihood	-13494,2992	(0,0002)	(0,0002)	(0,0001)	(0,0001)		(1,7118)	(0,0001)	(0,0016)
5-year KfW-Bund spread	Italy	0,0724	0,9276	0,0359	0,9641	2,3009	26,5931	1	-0,0591
log likelihood	-15167,0004	(0,0002)	(0,0002)	(0)	(0)		(1,0717)	(0,0002)	(0,0022)
5-year KfW-Bund spread	Germany	0,0426	0,9574	0,0385	0,9615	100	11,4746	0,919	0,7815
log likelihood	-13523,222	(0)	(0)	(0)	(0)		(0,0312)	(0)	(0,0002)
5-year sovereign bid-ask spread	Spain	0,0744	0,9256	0,0438	0,9562	38,3116	0,9343	0,8818	0,0933
log likelihood	-13536,5864	(0,0002)	(0,0002)	(0,0001)	(0,0001)		(0,0007)	(0,0001)	(0,0014)
5-year sovereign bid-ask spread	Italy	0,0771	0,9229	0,0372	0,9628	99,6966	2,1342	0,5125	-0,2522
log likelihood	-15402,2262	(0,0004)	(0,0004)	(0,0001)	(0,0001)		(0,0022)	(0,0013)	(0,007)
5-year sovereign bid-ask spread	Germany	0,0466	0,9534	0,0407	0,9593	0,2925	0,0068	0,5574	0,9994
log likelihood	-13618,0777	(0)	(0)	(0)	(0)		(0,025)	(0,0074)	(0,0035)

Table 3: STCC-GARCH Estimates (Panel 2)

Notes: α and β are the estimates for the ARCH and GARCH parameters of the univariate GARCH(1,1) models for the respective interest rates. Parameter estimates γ and c are the speed of transition and the threshold of the transition variable, respectively, $corr_1$ and $corr_2$ are the estimated correlation parameters of the correlation matrices. Standard errors in parantheses. The speed of transition parameter γ is reported in standardized values as estimated, and γ is fixed for standard error calculation to accomodate numerical issues. Sample period: 8 January 2004 - 14 January 2014 for Italy and Germany; 5 April 2005 - 14 January 2014 for Spain.

Transition variable	Country	Country α	Country β	OIS α	OIS β	γ	c	$corr_1$	$corr_2$
5-year sovereign CDS basis	Spain	0,0673	0,9327	0,033	0,967	22,8329	33,1136	0,4988	0,1176
log likelihood	-13762,1137	(0,0003)	(0,0004)	(0,0001)	(0,0001)		(6,6391)	(0,0017)	(0,002)
5-year sovereign CDS basis	Italy	0,075	0,925	0,0303	0,9697	10,6369	27,1465	0,5309	0,1023
log likelihood	-15451,1051	(0,0004)	(0,0005)	(0)	(0)		(10,6721)	(0,0015)	(0,0029)
5-year sovereign CDS basis	Germany	0,0441	0,9559	0,0391	0,9609	99,9939	15,8179	0,873	0,7863
log likelihood	-13581,1265	(0)	(0)	(0)	(0)		(0,1053)	(0,0001)	(0,0002)
VSTOXX	Spain	0,0696	0,9304	0,0362	0,9638	6,8083	14,0657	0,9941	0,2564
log likelihood	-13750,4866	(0,0003)	(0,0004)	(0,0001)	(0,0001)		(0,1266)	(0,0002)	(0,0012)
VSTOXX	Italy	0,0662	0,9338	0,027	0,973	3,5223	15,1458	1	0,2011
log likelihood	-15385,4779	(0,0004)	(0,0005)	(0,0001)	(0,0001)		(0,1558)	(0,0008)	(0,0016)
VSTOXX	Germany	0,0439	0,9561	0,0402	0,9598	0,9695	18,1895	1	0,6826
log likelihood	-13587,8416	(0)	(0)	(0)	(0)		(1,4166)	(0,0009)	(0,0009)
VIX	Spain	0,0754	0,9246	0,0353	0,9647	99,9999	37,5351	0,3325	0,634
log likelihood	-13811,2641	(0,0003)	(0,0003)	(0,0001)	(0,0001)		(0,0156)	(0,001)	(0,0035)
VIX	Italy	0,0687	0,9313	0,0301	0,9699	10,8041	11,592	0,9556	0,2726
log likelihood	-15384,5558	(0,0003)	(0,0003)	(0)	(0)		(0,0209)	(0,0003)	(0,0013)
VIX	Germany	0,0461	0,9549	0,0388	0,9612	14,7396	12,2118	0,9268	0,7864
log likelihood	-13552,8911	(0)	(0)	(0)	(0)		(0,0843)	(0,0001)	(0,0002)

Table 4: DCC-GARCH Estimates

Notes: α and β are the estimates for the ARCH and GARCH parameters of the univariate GARCH(1,1) models for the respective interest rates. DCC α and DCC β are the parameter estimates of the dynamic correlation. Standard errors are in parentheses. Sample period: 8 January 2004 - 14 January 2014 for Italy and Germany; 5 April 2005 - 14 January 2014 for Spain.

Country	Country α	Country β	OIS α	OIS β	DCC a	DCC b
Spain	0,0952	0,9048	0,0406	0,9526	0,0233	0,976
	0,0175	0,0175	0,0091	0,0113	0,0112	0,0116
Italy	0,0894	0,9106	0,0347	0,9589	0,0475	0,9501
	0,0225	0,0192	0,0079	0,0102	0,018	0,0188
Germany	0,0317	0,9653	0,0347	0,9589	0,1043	0,8231
	0,0061	0,0066	0,0079	0,0102	0,0187	0,037

Figure 1: Variables

The diagrams depict the variables in basis points used in this study. Sample period: 8 January 2004 - 14 January 2014 for Italy and Germany; 5 April 2005 - 14 January 2014 for Spain.

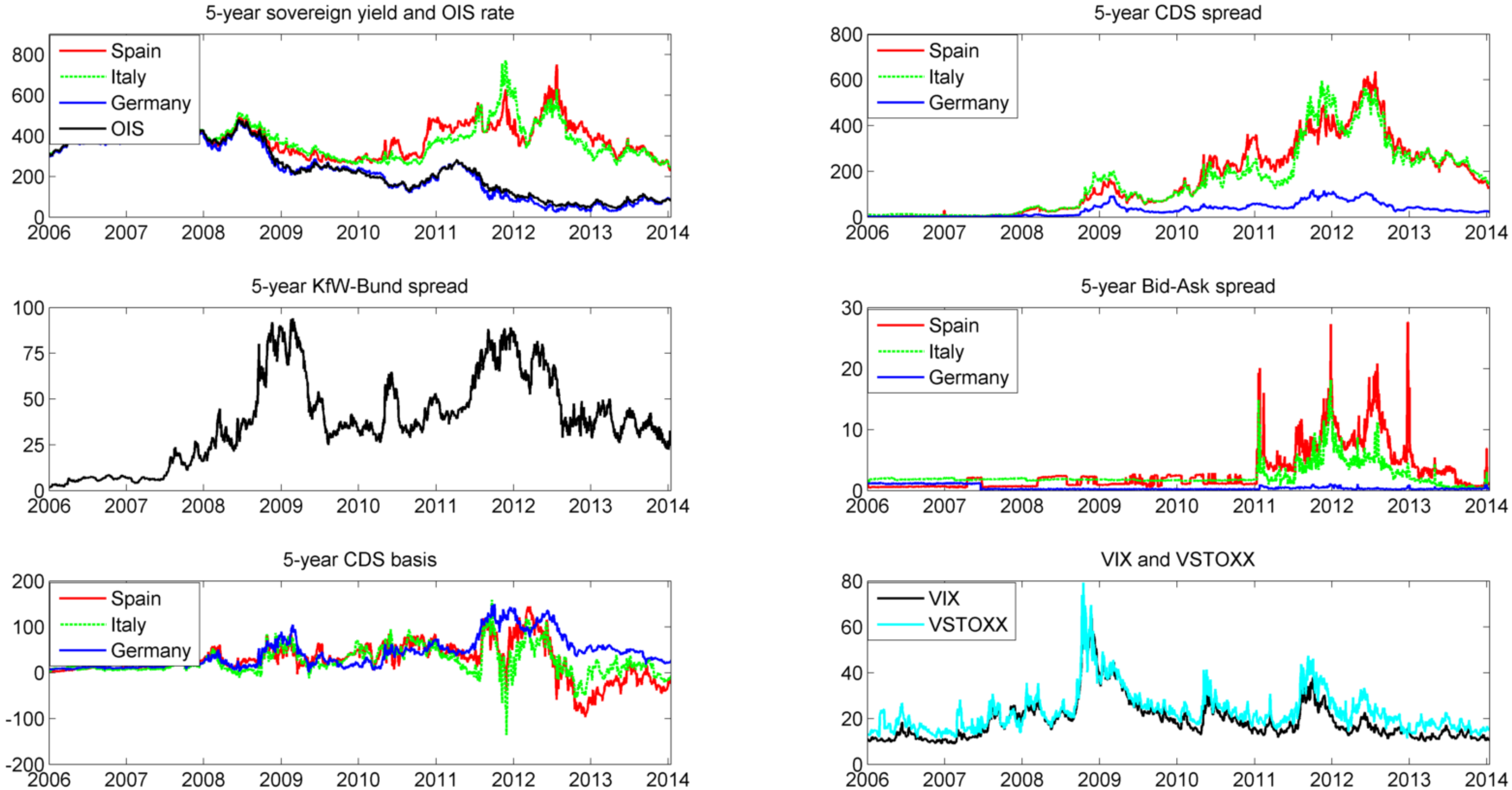

Figure 2: Transition Functions, Conditional Correlations and Conditional Variances for Spain

The diagrams depict the value of the transition functions (blue bars, bounded between 0 and 1), conditional correlations (red stars, bounded between -1 and 1) and conditional variances for the respective transition variables. Sample period: 5 April 2005 - 14 January 2014.

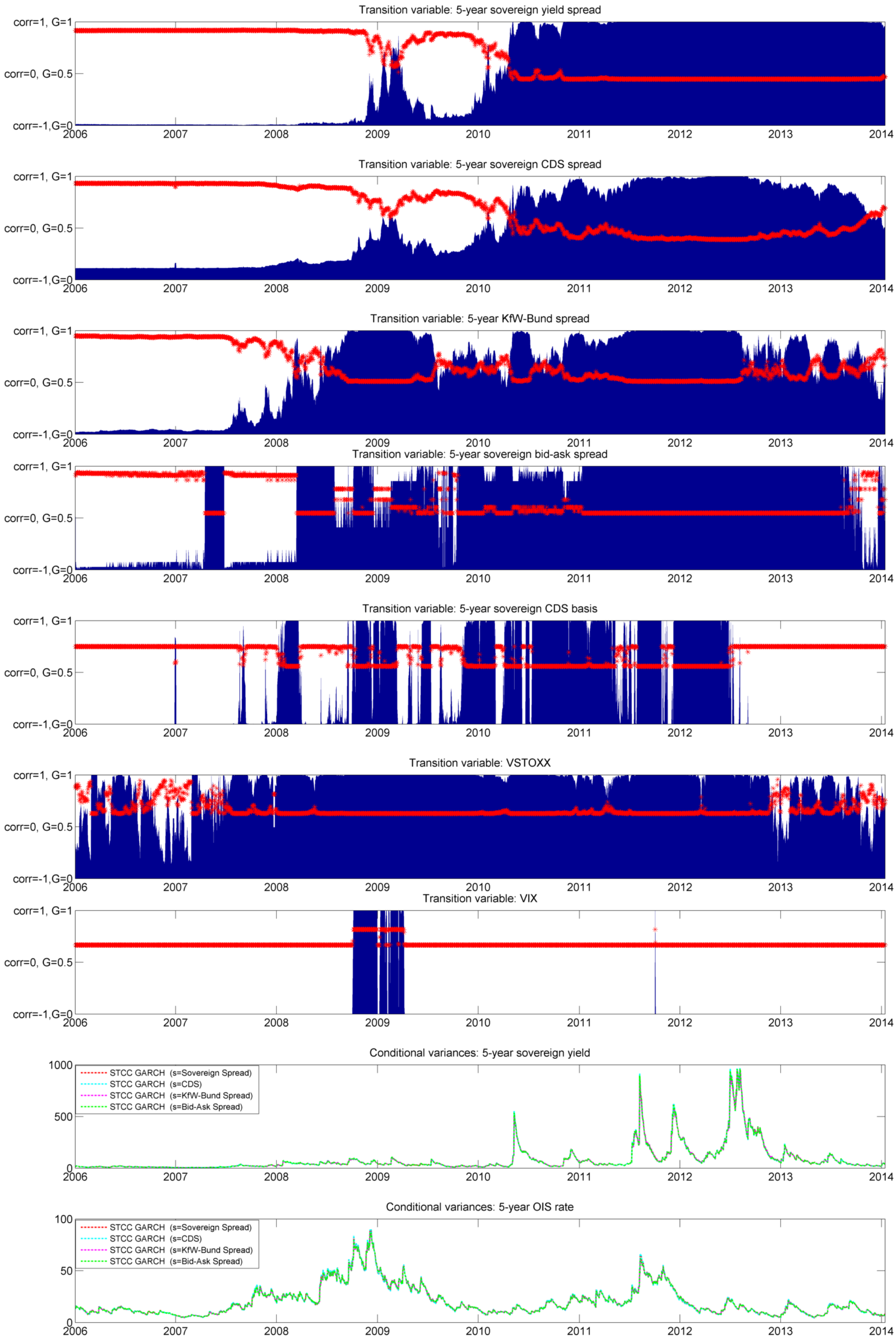

Figure 3: Transition Functions, Conditional Correlations and Conditional Variances for Italy

The diagrams depict the value of the transition functions (blue bars, bounded between 0 and 1), conditional correlations (red stars, bounded between -1 and 1) and conditional variances for the respective transition variables. Sample period: 8 January 2004 - 14 January 2014.

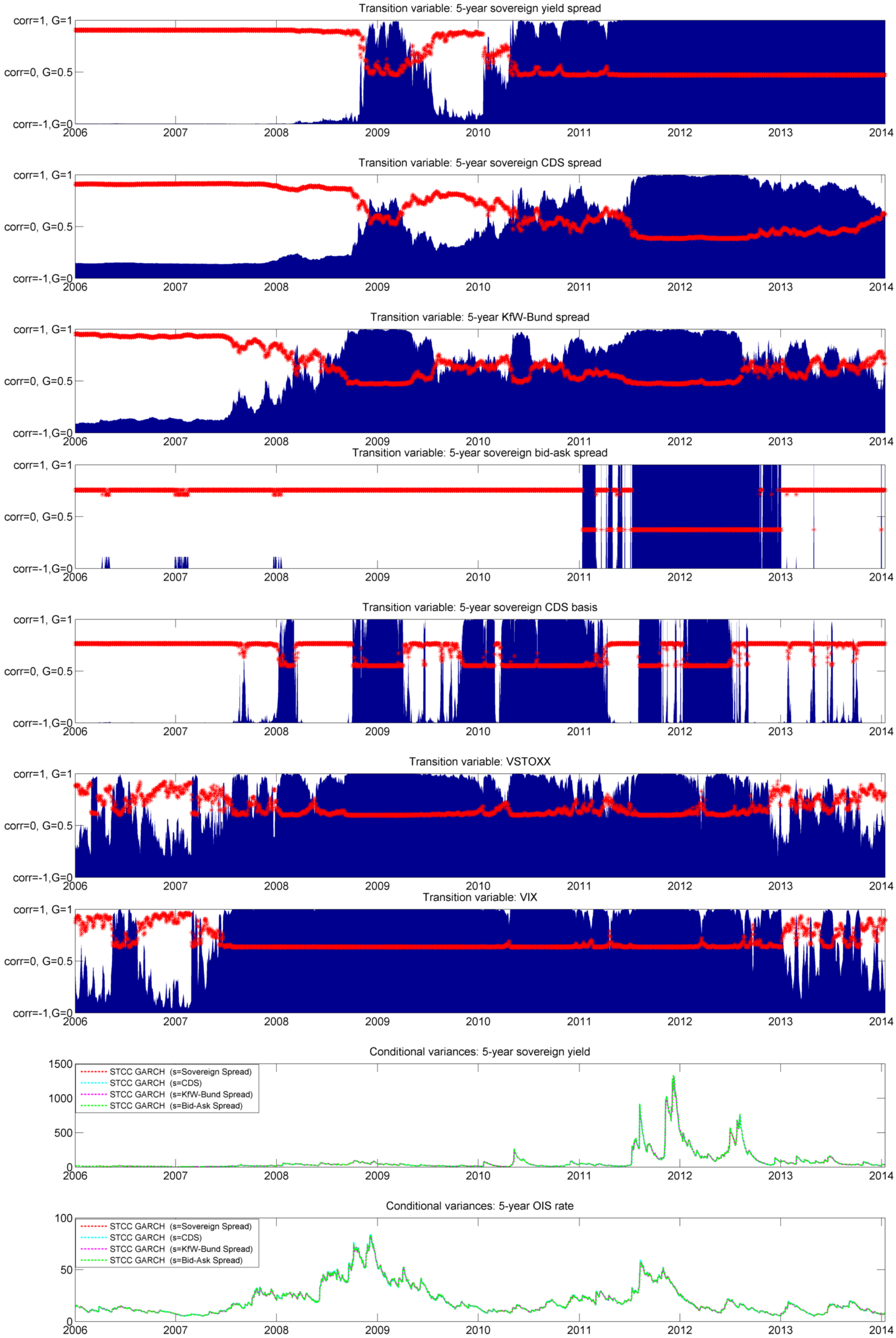

Figure 4: Transition Functions, Conditional Correlations and Conditional Variances for Germany

The diagrams depict the value of the transition functions (blue bars, bounded between 0 and 1), conditional correlations (red stars, bounded between -1 and 1) and conditional variances for the respective transition variables. Sample period: 8 January 2004 - 14 January 2014.

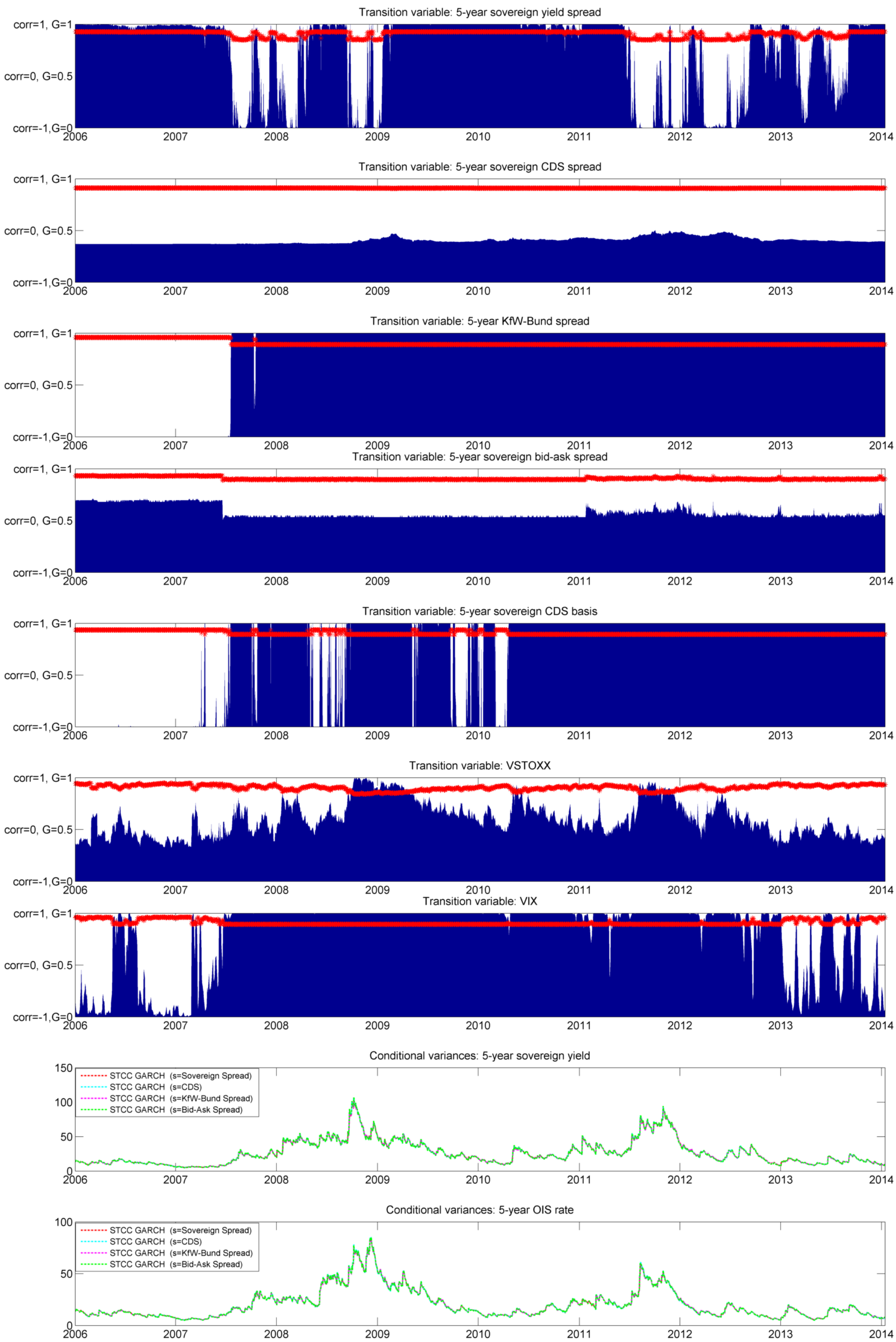

Figure 5: Transition Variables and Transition Functions for Spain

The diagrams depict the value of the transition functions based on the respective transition variable values. Sample period: 5 April 2005 - 14 January 2014.

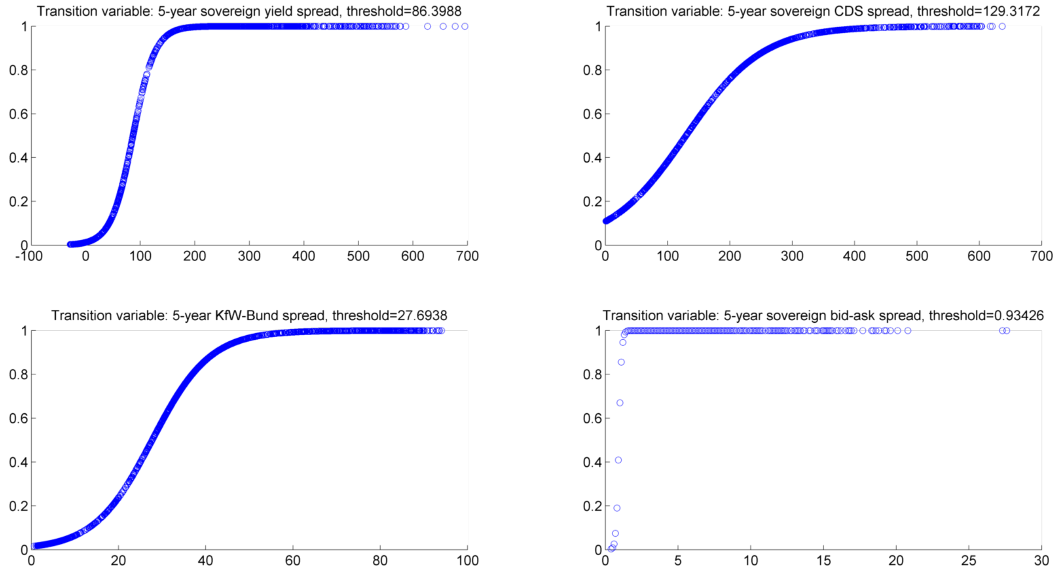

Figure 6: Transition Variables and Transition Functions for Italy

The diagrams depict the value of the transition functions based on the respective transition variable values. Sample period: 8 January 2004 - 14 January 2014.

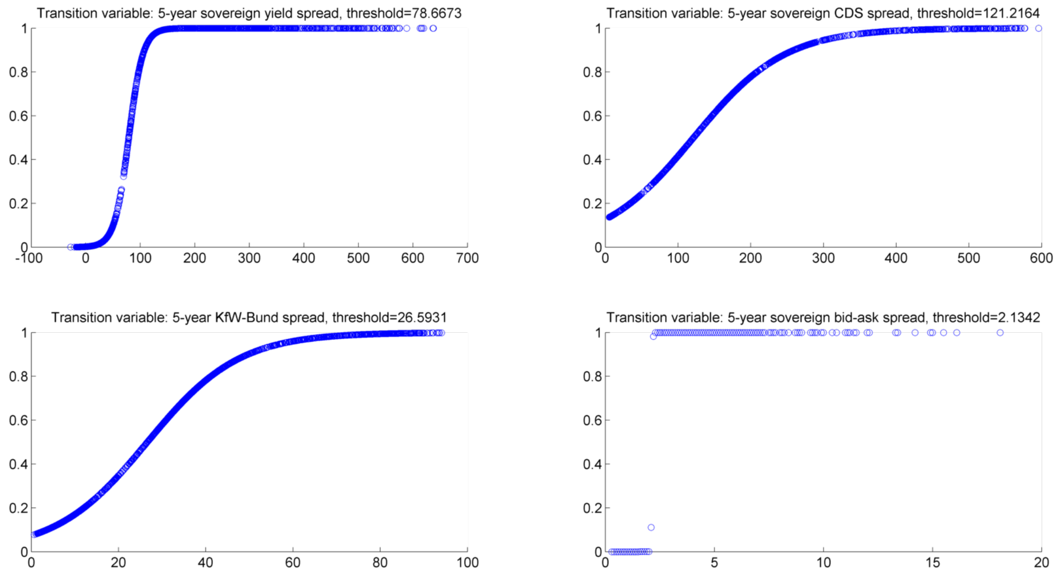

Figure 7: Conditional Correlations between Spanish Sovereign Yields and OIS Rates at 5-year Maturity

The diagrams depict the value of the transition functions based on the respective transition variable values. Sample period: 5 April 2005 - 14 January 2014.

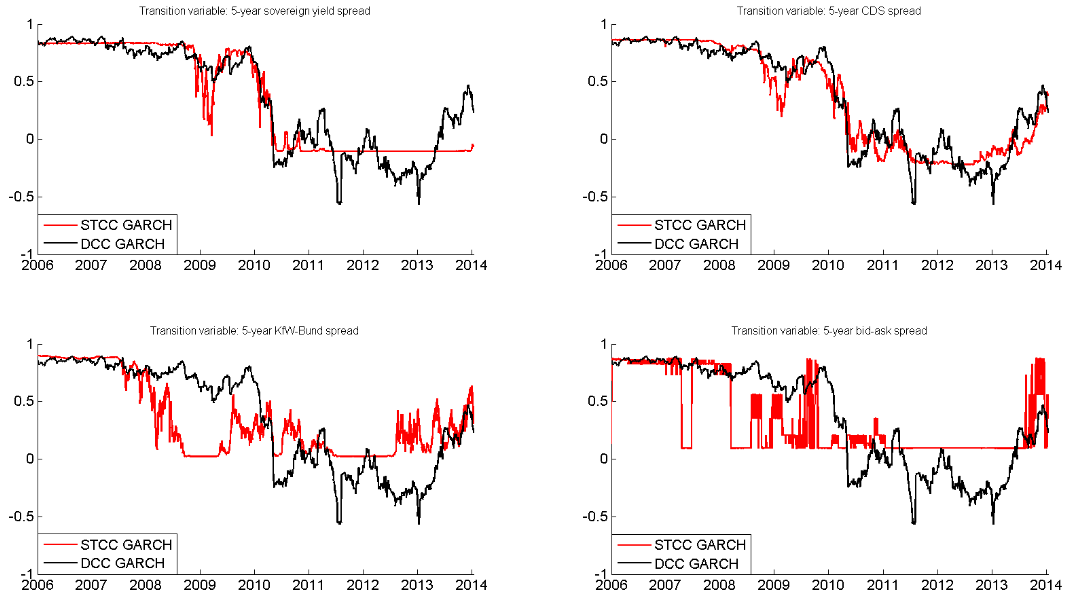

Figure 8: Conditional Correlations between Italian Sovereign Yields and OIS Rates at 5-year Maturity

The diagrams depict the value of the transition functions based on the respective transition variable values. Sample period: 8 January 2004 - 14 January 2014.

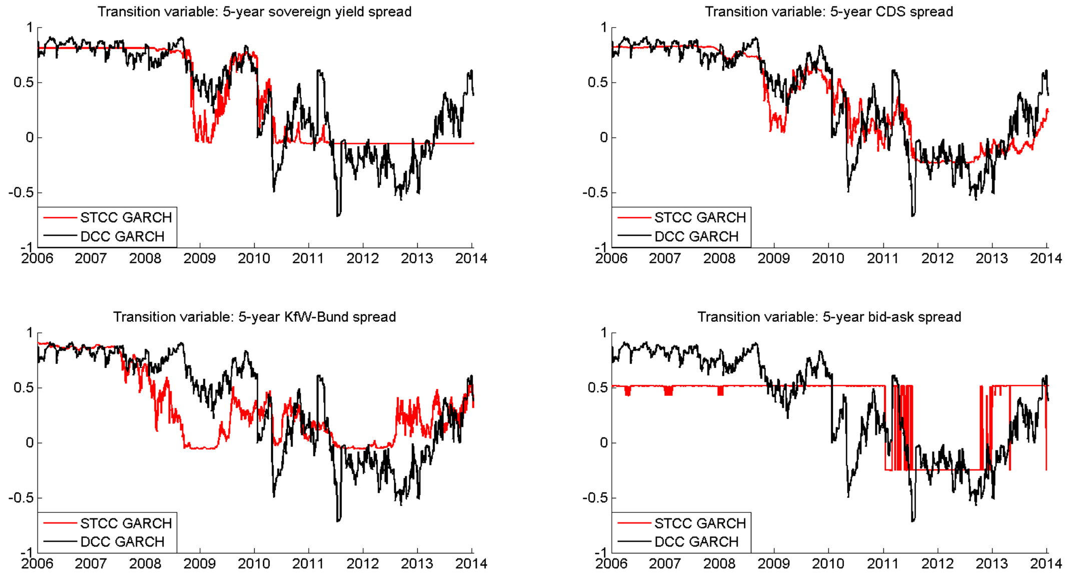

Figure 9: Impulse Responses

The diagrams depict the impulse response functions for Spain of the DCC and STCC correlations based on different transition variables. Upper Panel: Responses of DCC to STCC innovations. Lower Panel: Responses of STCC to DCC innovations. Sample period: 5 April 2005 - 14 January 2014.

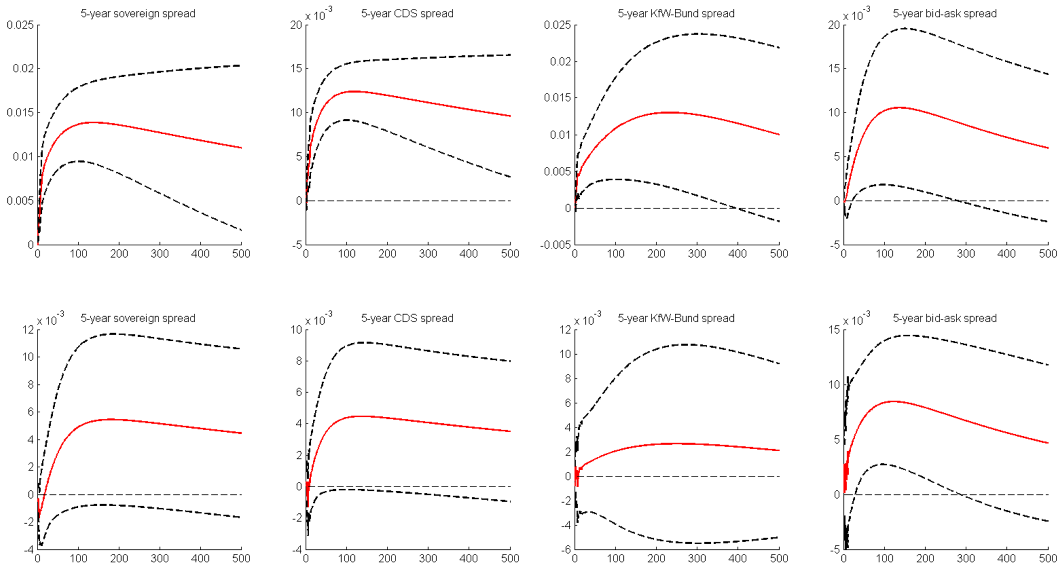

Figure 10: Impulse Responses

The diagrams depict the impulse response functions for Italy of the DCC and STCC correlations based on different transition variables. Upper Panel: Responses of DCC to STCC innovations. Lower Panel: Responses of STCC to DCC innovations. Sample period: 8 January 2004 - 14 January 2014.

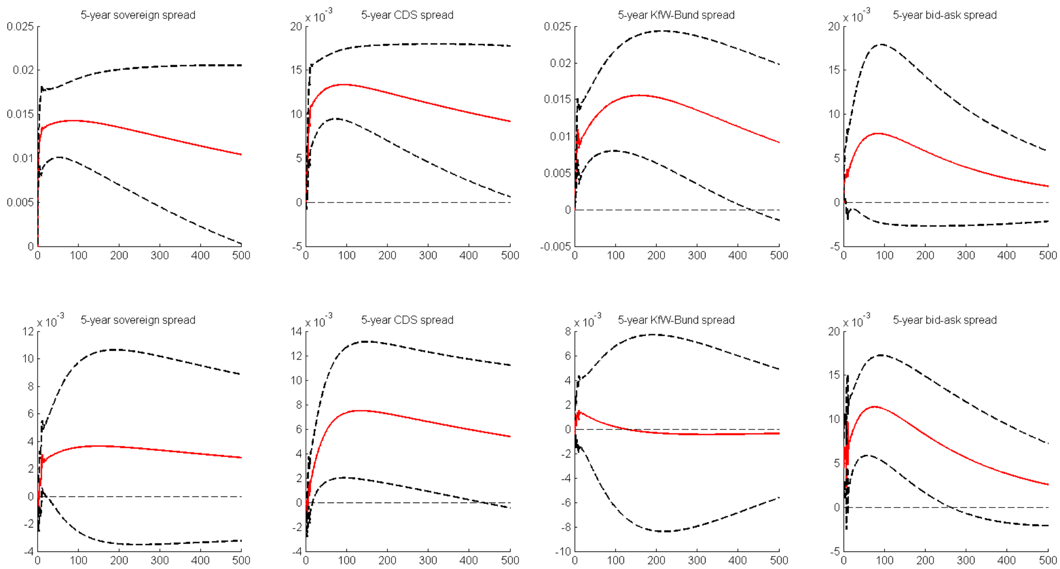

Figure 11: Out-of-sample forecasts of conditional correlations between Spanish Sovereign Yields and OIS Rates at 5-year Maturity

The diagrams depict the value of the transition functions conditional to the transition variable. In-Sample period: 5 April 2005 - 30 June 2012, out-of-sample forecast until 14 January 2014

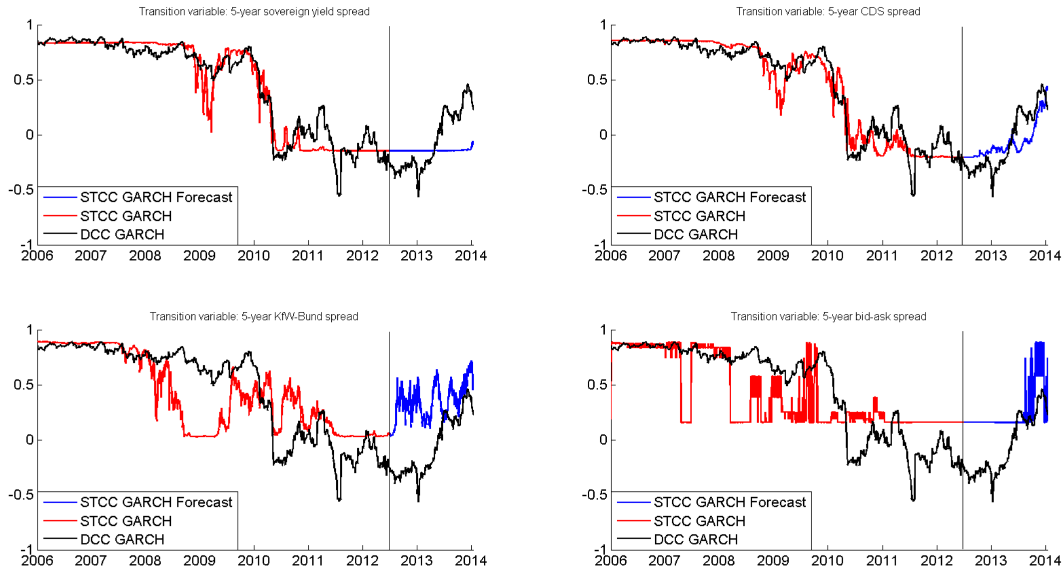

Figure 12: Out-of-sample forecasts of conditional correlations between Italian Sovereign Yields and OIS Rates at 5-year Maturity

The diagrams depict the value of the transition functions conditional to the transition variable. Sample period: 8 January 2004 - 30 June 2012, out-of-sample forecast until 14 January 2014.