Sovereign Markets' Malfunctioning and Observable Indicators

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Abstract

We use a STCC-GARCH model applied to euro area monetary policy rates and sovereign yields of Italy, Spain and Germany at 5-year maturity (i) to estimate the threshold level of the signals above which the sovereign bond market moves to a crisis regime and (ii) to assess whether the signals have leading properties of market malfunctioning. We show that the threshold to a crisis regime for Italy and Spain is reached when (i) their sovereign yield spreads amount to 80-90 basis points; (ii) their CDS spreads amount to 120-130 basis points and (iii) the spread between the Kreditanstalt für Wiederaufbau (KfW) bond and the German Bund amounts to 20 basis points. We also find that the KfW-Bund spread has leading properties, given that a shift to a crisis regime was suggested by this indicator already in August 2007.

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

1. Introduction

We are in the fifth year of the sovereign debt crisis in the euro area, which started in the fourth quarter of 2009 after the disclosure of the severe public finance situation in Greece by the new elected Greek Prime Minister George Papandreou.[3] Since then, the

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[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 the double of the previous estimate.

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 high levels (about 500-650 basis points). The same spreads were about 200 basis points lower only few months earlier in March 2012. The ECB saw the emergence of a tail-risk in the euro area (i.e. the break-up or redenomination risk), which triggered self-perpetuating dynamics in the economy. 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. Therefore, 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 200 basis points. Is the malfunctioning of the euro area sovereign debt market resolved? Clearly, the assessment of the euro area sovereign bond market malfunctioning conditions is a key policy issue, which we aim to address in this paper. Specifically, we ask the following three main questions:

1. Can observable indicators help identifying the malfunctioning of sovereign bond markets?
2. Can we determine the threshold level of such indicators above which the sovereign bond markets move to a malfunctioning-state?
3. Can we rank the indicators on the basis of their leading properties in signalling market malfunctioning?

From a policy-maker perspective, 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, given that sovereign yields are generally used as benchmark reference rates to price key interest rates, such as the lending rates to households and corporations. Therefore, we define a market to be malfunctioning if one of the following two conditions occur: (i) if the value of the indicator is above the threshold for the regime change of the dynamic correlation between the changes in sovereign yield and the changes in the monetary policy rate; (ii) if the value of the indicator is below such threshold, but the dynamic correlation between the sovereign yield and the monetary policy remains below what is typical in normal circumstances. It is uncontroversial that the dynamic correlation between sovereign yields and the monetary policy rates declines sharply if sovereign debt markets are malfunctioning. But obviously, this correlation does not increase when sovereign yield 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 Overnight Indexed Swap (OIS) rate,[4] in some periods rose or remained constant. Moreover, the improvement of the current financial situation requires that the dynamic correlations remain low or turn negative, while what matter is that the identified signal reduces below the threshold for the regime change. Similarly, there could be situations in the near future where the indicators remain below the threshold, but the correlation between the sovereign yield and the monetary policy rate is low. This again is a clear malfunctioning state. All in all, both above conditions signal that the sovereign debt markets are malfunctioning.

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 (Silvennoinen and Teräsvirta (2013), cited as Silvennoinen and Teräsvirta (2005) for years, and Silvennoinen and Teräsvirta (2009)). The two key advantages of Smooth Transition Conditional Correlation GARCH models (STCC-GARCH)[5] are (i) the changes in the conditional correlations are tight 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.

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:

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

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 liquidity premium for sovereigns in country c, $lp^L_{c,t}$; the third component is the credit risk premium for sovereigns in country c, $cp^L_{c,t}$; the fourth

[4]An overnight indexed swap (OIS) is a fixed-floating rate interest rate swap where the floating rate is indexed to an overnight interest rate (normally a cash-collateralised central bank accommodation rate or, in some countries, an interbank rate for the most creditworthy banks).

[5]The STCC-GARCH models have been used to study the correlation between stocks (Aslanidis et al (2009), Silvennoinen and Teräsvirta (2009), Silvennoinen and Teräsvirta (2013) and Chelley-Steeley et al (2013), stocks and bonds (Stein et al (2013)), stocks and exchange rates (Lee et al (2011)) and other asset classes (Silvennoinen and Thorp (2013) and Koch (2011)).

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 noises. 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 potentially indicating a malfunctioning of the sovereign bond markets. Therefore, we employ as signals the following indicators, which can be grouped in three main categories: price indicators partly measuring credit risk, liquidity indicators partly measuring liquidity risk and volatility indicators partly measuring regional and global risk aversion.

Among the price indicators we use the sovereign yield spread and the Credit Default Swap (CDS).

Among the liquidity indicators, we use the bid-ask spread associated to 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, which is used as a proxy for flight to liquidity, because they are both guaranteed by the German government and, therefore, carry the same default risk (Longstaff (2004); Monfort and Renne (2011);Ejsing et al (2012)). Any differences between agency and government bond yields should reflect international investors' preference for assets with the lowest liquidity risk. 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.

Among the volatility indicators we use the the implied volatility of S&P 500 index options (VIX) and of EUROSTOXX 50 index options (VSTOXX). These indicators are generally used to measure risk aversion.

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 mainly used as benchmark. 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 June 2013, except for Spain for which we have a complete database from April 2005. The frequency of the sample is daily business.

We expect that the correlations between the changes in sovereign yields and the changes in monetary policy rates are close to unity at least up to August 2007, before the first signals of the financial crisis were manifested through the interbank market; but below unity after November 2009, when Greece's severe fiscal problems were disclosed.

The analysis for Italy and Spain suggests that the threshold to a crisis regime is reached when (i) the spread between the country's sovereign yield and the OIS rate amounts to 80-90 basis points; (ii) the sovereign CDS spreads amount to 120-130 basis points and (iii) the KfW-Bund spread amount to 20 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.

As for Germany, the dynamic correlation between the German Bund and the OIS rate remain close to unity during the entire 2004-2013 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 for the leading properties of the indicators in signalling market malfunctioning, 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.

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

2. Methodology

In the previous sections we proposed the STCC class of MGARCH models to estimate the time-varying correlation in a volatility framework. Several parameterizations for MGARCH models were developed to cope with estimation problems, after Bollerslev (1986) discussed the multivariate GARCH (MGARCH) process in its most general form, the vech (half-vec) representation.Bollerslev (1990) decomposed the conditional variance-covariance matrix by separating the conditional correlations from the conditional variances, leading to a parameterization of the conditional covariance and proportionality to the conditional standard deviation.

However, this constant conditional correlation (CCC) model does not support time-varying correlation and spillover effects. Engle (2002) then proposed the dynamic conditional correlation (DCC) model, linking the univariate conditional volatility processes to a dynamic conditional correlation.

While the CCC and DCC models among others like the BEKK model (Baba et al (1991) and Kroner and Engle (1995)) have become standard approaches and were successively used and modified, models allowing for regime switches or smooth transition followed. Aslanidis et al (2009) for example use smooth transition volatility models, while Markov-type approaches were used in Ang and Bekaert (2002) and Pelletier

(2006). The STCC model by Silvennoinen and Teräsvirta (2013) shares with the DCC model that to estimate the conditional variance-covariance matrix H_t, the volatility processes are modelled univariately and are linked through conditional correlations that may change over time:

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

As in the univariate specification of a GARCH(p,q) process, the conditional variance h_{it} for any process $y_{it} = E\left[y_{it} \mid \psi_{i,t-1}\right] + \varepsilon_{i,t}$ can be modelled by the q lagged squared residuals and p lagged conditional variances:

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

The errors $z_{i,t}$ are independent random variables with mean zero and unit variance one 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.

To model the conditional correlation, Silvennoinen and Teräsvirta (2013) define a logistic transition function G and two extreme states of correlation represented by 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 of the transition variable s to its threshold c is therefore indicative for the process being in one regime or the other for 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.

Regarding the univariate modelling used in the STCC, a standard choice for the dynamics of the variance is a GARCH(1,1). Along with a standard specification in the mean equation, we obtain the common ARMA(1,1)-GARCH(1,1) for the univariate parts.

A notable difference to the DCC model and many other approaches that separate volatility and correlation parts, is in the way the parameters are obtained: The DCC

[6] Berben and Jansen (2005) independently introduced a time-varying STCC (TV-STCC), where the transition variable s simply is a time trend.

model for example was proposed with a two-step approach in which the univariate volatility processes are modelled first and correlation values are estimated conditioned on these GARCH parameter estimates.Silvennoinen and Teräsvirta (2013) however point out that numerical problems may arise when maximizing the following likelihood with all parameters in the vector θ at once:

$$l_t(\theta) = -\frac{N}{2}log(2\pi) - \frac{1}{2}\sum_{i=1}^{N} log\,(h_{it}) - log \mid R_t \mid - \frac{1}{2} z_t^{\prime} R_{t-1}^{-1} z_t \tag{6}$$

This makes it necessary to estimate the parameters with conditional maximum likelihood. The resulting iterative procedure according to Silvennoinen and Teräsvirta (2013) should be done on three sets of parameters (univariate GARCH parameters, correlation parameters, transition parameters) leading to better convergence and in general smaller standard errors[7]. In addition, this enables feedback effects between volatility and correlation, with Silvennoinen and Teräsvirta (2013) explaining that in general a two-step approach is what one would have done when stopping the conditional maximum likelihood estimation process after one iteration of all three sets. Furthermore, we follow the standard by standardizing the transition parameter γ to get rid of scale effects and fix it at 100, being in line with Silvennoinen and Teräsvirta (2013) who point out that at values above, the likelihood function does not change much. This is found for our estimations as well. In order to avoid obtaining local minima we (i) calculate the likelihood using a very large grid of the two transition parameters with the estimates of the univariate processes being fixed to get starting parameters and (ii) perform the iterative procedure using not only on the single best combination as starting parameter combination but by using several "best" combinations and some random picks. In addition to the GARCH parameters that are used for the grid, one has to define a correlation matrix before searching for combinations of transition parmaeters. As there is no common sense about how this is sensibly done for a regime-switching model, we consider the minimum and maximum of 100-day rolling correlations as initial estimates of the extreme states of correlation R_1 and R_2 a natural choice. Additional random checks where performed to ensure that the found optima represent the true optima and are not results of our approach to estimation. This leads to a highly reliable framework, which is of utmost importance when estimating such models.

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

3. Data Section: Indicators to Monitor Market Malfunctioning

We study the dynamic 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 a tremendous pressure during the euro area sovereign debt crisis. We also consider the case of Germany, which is a key euro area country that has not lost the triple-A rating.

The sovereign bond yield used as a benchmark is at 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 relevant question; second, the market for CDS spreads that are also used in the analysis is much 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 tat 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. sovereign yield-OIS spread and 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).

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), Monfort and Renne (2011), Ejsing et al (2012)), any differences between agency and government bond yields should reflect liquidity premia. At its launch in spring 1998, a jumbo KfW bond offered a 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 rating. 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 bond 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 ares implied stock market volatility (VIX) until end 2009, declined sharply in the course of 2009, fluctuated up to the 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 benefiting 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 clearly described by the developments of the sovereign yields, CDS spreads and bid-ask spreads also obtained from Bloomberg.

All benchmark sovereign yields and OIS rates were tightly comoving up to June 2007. The crisis in the interbank market in August 2007 produced the following results: the correlation between sovereign yields of Spain and Italy versus the German Bund and the OIS rate declined, the KfW-Bund spread rose, the CDS basis become negative for all three sovereigns under consideration. Conversely, sovereign CDS spreads and bid-ask spreads remained invariant. 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 and KfW-Bund spreads 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 Mr. 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. A summary table with descriptive statistics is presented in Table 2.

[Insert Table 2, here]

4. Empirical Results

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

[Insert Table 3, here]

As for the GARCH parameters, the estimated *beta* are much larger relative to the estimated α suggesting an important persistency effect in the volatility of sovereign yields and OIS rates, which is evident in the last two panels of Figure 2-4. This is reflected by the summing up of the GARCH parameters to unity as well. When using exponential or GJR-GARCH (Glosten et al (1993)) both in STCC estimations or on a standalone basis, this was evident as well and might be attributed to breaks in the volatility structure[8].

[Insert Figure 2-4, here]

As for the signals, the analysis for Italy and Spain suggests that the threshold to a crisis regime is reached when the sovereign yield spreads are above 80-90 basis points

[8] Hillebrand and Medeiros (2009) provide an extensive discussion of the topic in a realized volatility framework

and the CDS spreads are above 120-130 basis points. The transition functions and the dynamic correlations are all very similar. 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 95% to 50% for Spain and 40% for Italy. The situation started to improve in the course of the 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. After the disclosure of the Greek severe fiscal problems, 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 around 40% 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 KfW-Bund spread is above 20 basis points. The estimated γ is 7.6 for Spain and 3.2 for Italy implying smooth changes in correlations. The transition functions and the dynamic 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 0.7-0.8 and the correlations between sovereign yields and OIS rates declined to about 60%. Except for the first quarter of 2010, when the KfW-Bund spreads declined to levels before Lehman, the transition functions were always in a crisis regime and the correlations fluctuated around 50%. In this respect, the KfW-Bund spread might lead the signalling of sovereign debt markets' malfunctioning, due to flight to liquidity phenomena that have characterised the euro area sovereign debt market during the financial crisis (De Santis (2014)).

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 30 basis points for the CDS basis, the transition functions and the dynamic correlations change abruptly, except for the bid-ask spread in Spain. Frequent switches are typical of standard regime-switching models and this is not helpful.

Finally, with regard to the stock market implied volatilities, the thresholds for a regime change are estimated at 20-40 basis points for the VIX and 15-20 basis points for the VSTOXX, while 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.

As for Germany, the dynamic correlation between the Bund and the OIS rate remain close to unity during the entire 2004-2013 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.

All the time-varying correlations for Italy and Spain are summarised in Figures 5 and 6, respectively, together with the conditional correlation estimated using a standard DCC model. The bivariate DCC estimates are presented in Table 4. Both the parameters of the univariate GARCH parts and the dynamic correlation parts are highly significant for all three country-OIS pairs. The advantage of the STCC relative to the DCC is that the correlations are more persistent and less volatile, helping the policymaker to make more appropriate decisions.

[Insert Table 4, here]

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. More specifically, the first challenge consists of assessing the threshold level for a specific indicator above which a sovereign debt market moves to a crisis regime. The second more difficult challenge refers to the identification of a sets of indicators that may have leading indicator properties.

Both challenges are addressed in this paper estimating a 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 dynamic correlation between the German Bund and the OIS rate remain close to unity during the entire 2004-2013 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 for Italy and Spain, the STCC-GARCH model suggests that the threshold to a crisis regime is reached when (i) the spread between sovereign yield and monetary policy rates amounts to 80-90 basis points; (ii) the sovereign CDS spread amounts to 120-130 basis points and (iii) the 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 dynamic 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.

As for the leading properties of the indicators in signalling market malfunctioning, 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.

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Table 1: Rating Overview

Notes: Rating overview for bonds of Kreditanstalt für Wiederaufbau (KfW). 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 the study. Data was available from January 8, 2004 until June 30, 2013, except for Spain, where the full data set starts on April 05, 2005. Statistics calculated for shortened sample for the sake of comparison.

Variable	Mean	Minimum	Maximum	Standard Deviation	Skewness	Kurtosis
Overnight Index Swap	256,0595	41,8	480,75	125,3349	-0,0505	1,8282
Spain Interest Rate	379,7869	243,15	749,8	79,6795	0,6195	3,5159
Italy Interest Rate	377,5534	251,5	770,35	85,104	0,9966	4,6128
Germany Interest Rate	246,1631	23,85	476,15	126,6878	-0,1713	1,8762
Overnight Index Swap Change	-0,0944	-22,6	21,45	4,502	-0,148	4,9068
Spain Interest Rate Change	0,0351	-99,3	51,75	9,2719	-1,3892	20,86
Italy Interest Rate Change	0,0274	-95,65	70,2	9,0441	-0,9453	23,2375
Germany Interest Rate Change	-0,0992	-21,6	29,7	5,1209	0,0749	5,0572
Sovereign Spread Spain	123,7274	-28,65	695,4	152,9726	0,9813	2,9144
Sovereign Spread Italy	121,4939	-17,55	637,7	145,0129	1,2552	3,665
Sovereign Spread Germany	-9,8964	-47,15	27,65	12,0237	0,1177	3,4716
Credit Default Swap Spain	150,3597	1,05	636,675	158,9887	0,8888	2,765
Credit Default Swap Italy	145,3014	5,3	595,675	152,2997	1,0962	3,2374
Credit Default Swap Germany	30,8568	0,6	120,585	29,4786	0,8677	2,8849
KfW-Bund Spread	30,9736	4,4904	86,6925	19,1801	0,7245	2,791
Bid-Ask Spread Spain	2,9983	0,4	27,6	3,6435	2,3627	9,8938
Bid-Ask Spread Italy	2,4233	0,3	18,1	1,7421	3,6282	20,5876
Bid-Ask Spread Germany	0,5203	0	1,3	0,4016	0,846	1,9234
CDS Basis Spain	26,6323	-96,55	144,53	36,3359	-0,0914	4,4148
CDS Basis Italy	23,8075	-135,505	158,775	28,7352	0,6331	5,0063
CDS Basis Germany	40,7532	0,9	149,435	34,7177	1,1439	3,4678
VIX	18,9081	8,9433	66,5	9,1279	1,9553	7,8092
VSTOXX	22,6083	9,01	79,28	9,0333	1,7015	7,2796

Table 3, Panel 1: STCC-GARCH Estimates with GARCH(1,1) Specification, Part 1/2

Notes: ω, α and β are the estimates for constant, ARCH and GARCH parameters of the univariate GARCH(1,1) models for the respective countries and the OIS. 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 between which the process is transitioning. Standard errors in parantheses. The speed of transition parameter γ is reported in standardized values as estimated. When no standard error for γ is reported, it was fixed to address numerical standard error calculation issues. Estimation was done from January 8, 2004 until June 30, 2013, except for Spain, where the estimations begin on April 05, 2005.

Transition variable	Country	Country ω	Country α	Country β	OIS ω	OIS α	OIS β	γ	c	$corr_1$	$corr_2$
5-year sovereign yield spread	Spain	0	0,0796	0,9204	0	0,0527	0,9473	7,3251	88,983	0,8446	-0,1489
log likelihood	12535,475	(0,002)	(0,0001)	(0,0002)	(0,001)	(0,0001)	(0,0001)		(34,0864)	(0,0001)	(0,0019)
5-year sovereign yield spread	Italy	0	0,0784	0,9216	0	0,0429	0,9571	9,4519	82,2318	0,8145	-0,1091
log likelihood	14291,2743	(0,0031)	(0,0002)	(0,0002)	(0,0007)	(0)	(0)	(20,2949)	(39,3539)	(0,0002)	(0,0025)
5-year sovereign yield spread	Germany	0	0,0465	0,9535	0	0,0416	0,9584	9,0886	-15,3355	0,7121	0,8607
log likelihood	12888,8685	(0,0007)	(0)	(0)	(0,0005)	(0)	(0)	(143,092)	(2,8728)	(0,0009)	(0,0001)
5-year sovereign CDS spread	Spain	0	0,0808	0,9192	0	0,0533	0,9467	2,6627	127,0224	1	-0,2249
log likelihood	12539,6348	(0,0019)	(0,0001)	(0,0001)	(0,0009)	(0,0001)	(0,0001)		(15,9989)	(0,0001)	(0,0024)
5-year sovereign CDS spread	Italy	0	0,0788	0,9212	0	0,0434	0,9566	3,1988	121,8874	0,9124	-0,2043
log likelihood	14297,5237	(0,0031)	(0,0002)	(0,0003)	(0,0006)	(0,0001)	(0)		(78,4761)	(0,0003)	(0,0031)
5-year sovereign CDS spread	Germany	0	0,05	0,95	0	0,0444	0,9556	0,3232	115,865	0,8301	0,7994
log likelihood	12952,0707	(0,0011)	(0)	(0,0001)	(0,0006)	(0)	(0)		(448556,8126)	(0,0016)	(0,0083)
5-year KfW-Bund spread	Spain	0	0,0681	0,9319	0	0,0421	0,9579	7,5946	18,1591	0,9105	0,1483
log likelihood	12728,253	(0,0017)	(0,0002)	(0,0002)	(0,0007)	(0,0001)	(0,0001)		(0,6249)	(0,0001)	(0,0014)
5-year KfW-Bund spread	Italy	0	0,0735	0,9265	0	0,0363	0,9637	3,241	19,4924	0,9993	0,0473
log likelihood	14422,5834	(0,0026)	(0,0002)	(0,0003)	(0,0006)	(0,0001)	(0)	(0,9881)	(6,621)	(0,0002)	(0,0021)
5-year KfW-Bund spread	Germany	0	0,0462	0,9538	0	0,0405	0,9595	99,9999	10,3544	0,9263	0,8014
log likelihood	12895,8272	(0,0007)	(0)	(0)	(0,0005)	(0)	(0)	(2643,2964)	(0,0505)	(0,0001)	(0,0001)
5-year sovereign bid-ask spread	Spain	0	0,0816	0,9184	0	0,0499	0,9501	37,9303	0,9483	0,8926	0,0918
log likelihood	12702,206	(0,0022)	(0,0002)	(0,0002)	(0,0009)	(0,0001)	(0,0001)	(143,0003)	(0,0024)	(0,0001)	(0,0015)
5-year sovereign bid-ask spread	Italy	0	0,08	0,92	0	0,0377	0,9623	99,9051	2,1313	0,5267	-0,2516
log likelihood	14565,0514	(0,0045)	(0,0004)	(0,0005)	(0,0008)	(0,0001)	(0,0001)	(19803,9703)	(0,0077)	(0,0014)	(0,0068)
5-year sovereign bid-ask spread	Germany	0	0,0515	0,9485	0	0,0447	0,9553	0,3024	0,005	0,5543	0,9994
log likelihood	12961,5123	(0,001)	(0,0001)	(0,0001)	(0,0006)	(0)	(0)	(0,0029)	(0,0555)	(0,0073)	(0,0033)

Table 3, Panel 2: STCC-GARCH Estimates with GARCH(1,1) Specification, Part 2/2

Notes: ω, α and β are the estimates for constant, ARCH and GARCH parameters of the univariate GARCH(1,1) models for the respective countries and the OIS. 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 between which the process is transitioning. Standard errors in parantheses. The speed of transition parameter γ is reported in standardized values as estimated. When no standard error for γ is reported, it was fixed to address numerical standard error calculation issues. Estimation was done from January 8, 2004 until June 30, 2013, except for Spain, where the estimations begin on April 05, 2005.

Transition variable	Country	Country ω	Country α	Country β	OIS ω	OIS α	OIS β	γ	c	$corr_1$	$corr_2$
5-year sovereign CDS basis	Spain	0	0,0726	0,9274	0	0,0338	0,9662	20,1658	32,6212	0,5251	0,1205
log likelihood	12927,2628	(0,0062)	(0,0004)	(0,0005)	(0,0009)	(0,0001)	(0,0001)	(117,4984)	(5,1609)	(0,002)	(0,002)
5-year sovereign CDS basis	Italy	0	0,0787	0,9213	0	0,0301	0,9699	100	27,957	0,5394	0,1069
log likelihood	14609,88	(0,0047)	(0,0004)	(0,0005)	(0,0007)	(0,0001)	(0)	(4300,9681)	(0,0635)	(0,0014)	(0,0025)
5-year sovereign CDS basis	Germany	0	0,0474	0,9526	0	0,0417	0,9583	99,9997	15,8419	0,8736	0,784
log likelihood	12915,4288	(0,0007)	(0)	(0)	(0,0005)	(0)	(0)	(63873,5074)	(0,2447)	(0,0001)	(0,0002)
VSTOXX	Spain	0	0,0744	0,9256	0	0,0396	0,9604	5,8748	14,3588	1	0,2541
log likelihood	12919,1999	(0,0049)	(0,0004)	(0,0005)	(0,0011)	(0,0002)	(0,0001)	(44,7099)	(7,7928)	(0,0002)	(0,0014)
VSTOXX	Italy	0	0,0693	0,9307	0	0,0257	0,9743	3,233	15,7525	1	0,1846
log likelihood	14547,8389	(0,0029)	(0,0003)	(0,0005)	(0,0005)	(0,0001)	(0,0001)	(0,4457)	(0,4835)	(0,0008)	(0,0018)
VSTOXX	Germany	0	0,0484	0,9516	0	0,044	0,956	0,9438	19,1588	1	0,6743
log likelihood	12933,0624	(0,0008)	(0)	(0)	(0,0005)	(0)	(0)		(1,6533)	(0,0009)	(0,001)
VIX	Spain	0	0,0809	0,9191	0	0,0366	0,9634	99,9999	37,5408	0,3372	0,636
log likelihood	12981,2852	(0,0046)	(0,0003)	(0,0004)	(0,0009)	(0,0001)	(0,0001)	(60304,8091)	(0,3638)	(0,0011)	(0,0034)
VIX	Italy	0	0,071	0,929	0	0,0312	0,9688	10,0537	11,8972	0,9463	0,2703
log likelihood	14545,2958	(0,0023)	(0,0003)	(0,0004)	(0,0005)	(0,0001)	(0)	(3,1279)	(0,0749)	(0,0003)	(0,0014)
VIX	Germany	0	0,0467	0,9533	0	0,0411	0,9589	4,4177	11,5827	1	0,7728
log likelihood	12906,7147	(0,0006)	(0)	(0)	(0,0004)	(0)	(0)	(2,5232)	(0,2236)	(0,0002)	(0,0002)

Table 4: DCC-GARCH Estimates

Notes: ω, α and β are the estimates for constant, ARCH and GARCH parameters of the univariate GARCH(1,1) models for the respective countries and the OIS. DDC α and DCC β are the parameter estimates of the dynamic correlation. Standard errors are in parentheses. Estimation was done from January 8, 2004 until June 30, 2013, except for Spain, where the estimations begin on April 05, 2005.

Country	Country ω	Country α	Country β	OIS ω	OIS α	OIS β	DCC α	DCC β
Spain	0	0,1111	0,8889	0	0,0516	0,9468	0,021	0,9772
	(0)	(0,0171)	(0,0168)	(0)	(0,0107)	(0,0122)	(0,0083)	(0,0083)
Italy	0,003	0,0874	0,9126	0	0,0346	0,9598	0,0602	0,9373
	(0)	(0,0214)	(0,0187)	(0)	(0,0082)	(0,0094)	(0,0146)	(0,0153)
Germany	0	0,0324	0,9651	0	0,0346	0,9598	0,0774	0,8909
	(0)	(0,0062)	(0,0065)	(0)	(0,0082)	(0,0094)	(0,0166)	(0,0329)

Figure 1: Variables

The diagrams depict the transition variables that were used in the study, except the upper left panel which does not show the sovereign yield spreads of the three countries but the yields of all those and the OIS. All values in basis points.

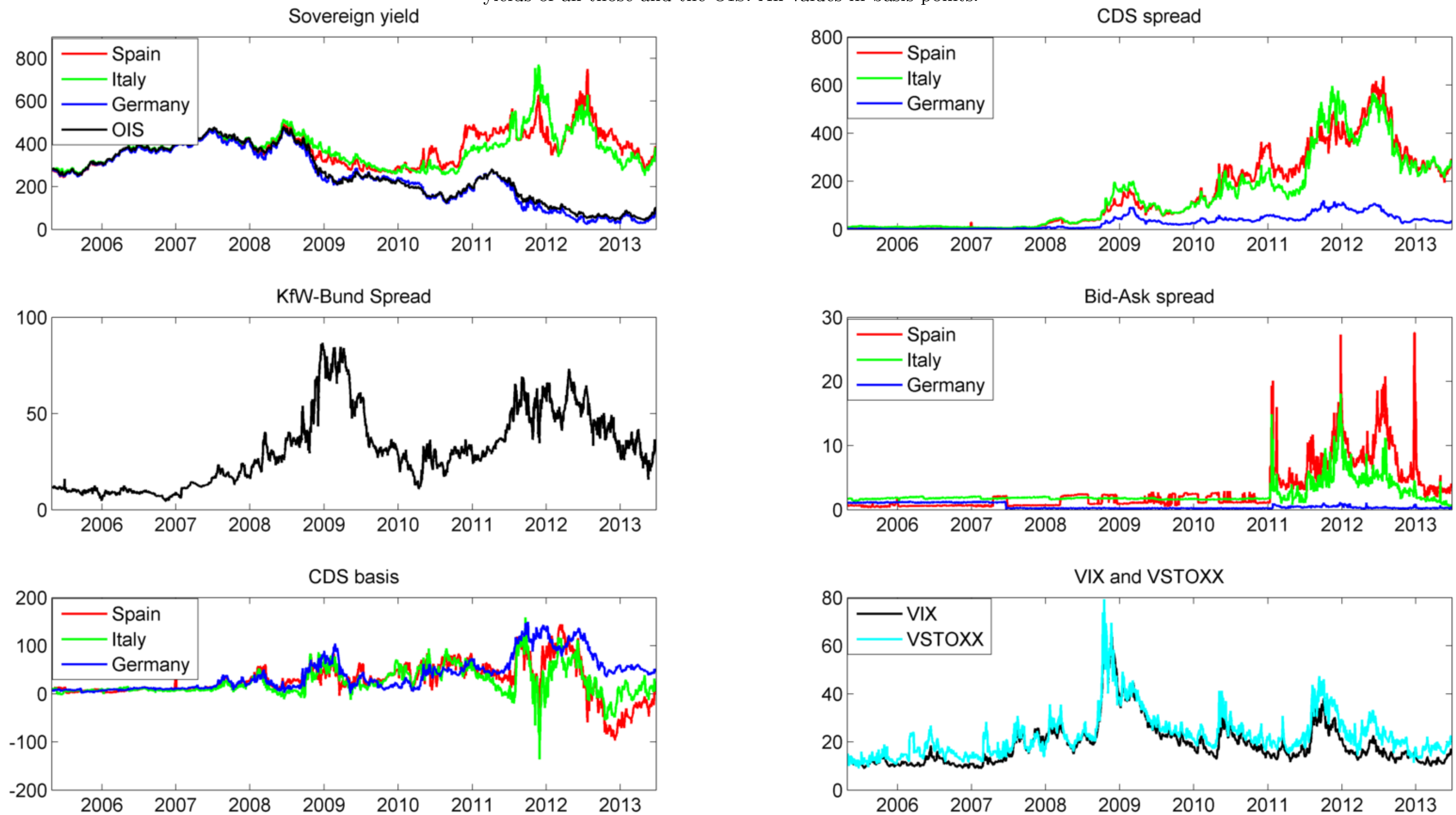

Figure 2: Transition Functions and Conditional Variance for Spain

The diagrams depict the value of the transition function (blue bars, bounded between 0 and 1) and the conditional correlation (red stars, bounded between -1 and 1) and conditional variances, for the respective transition variables.

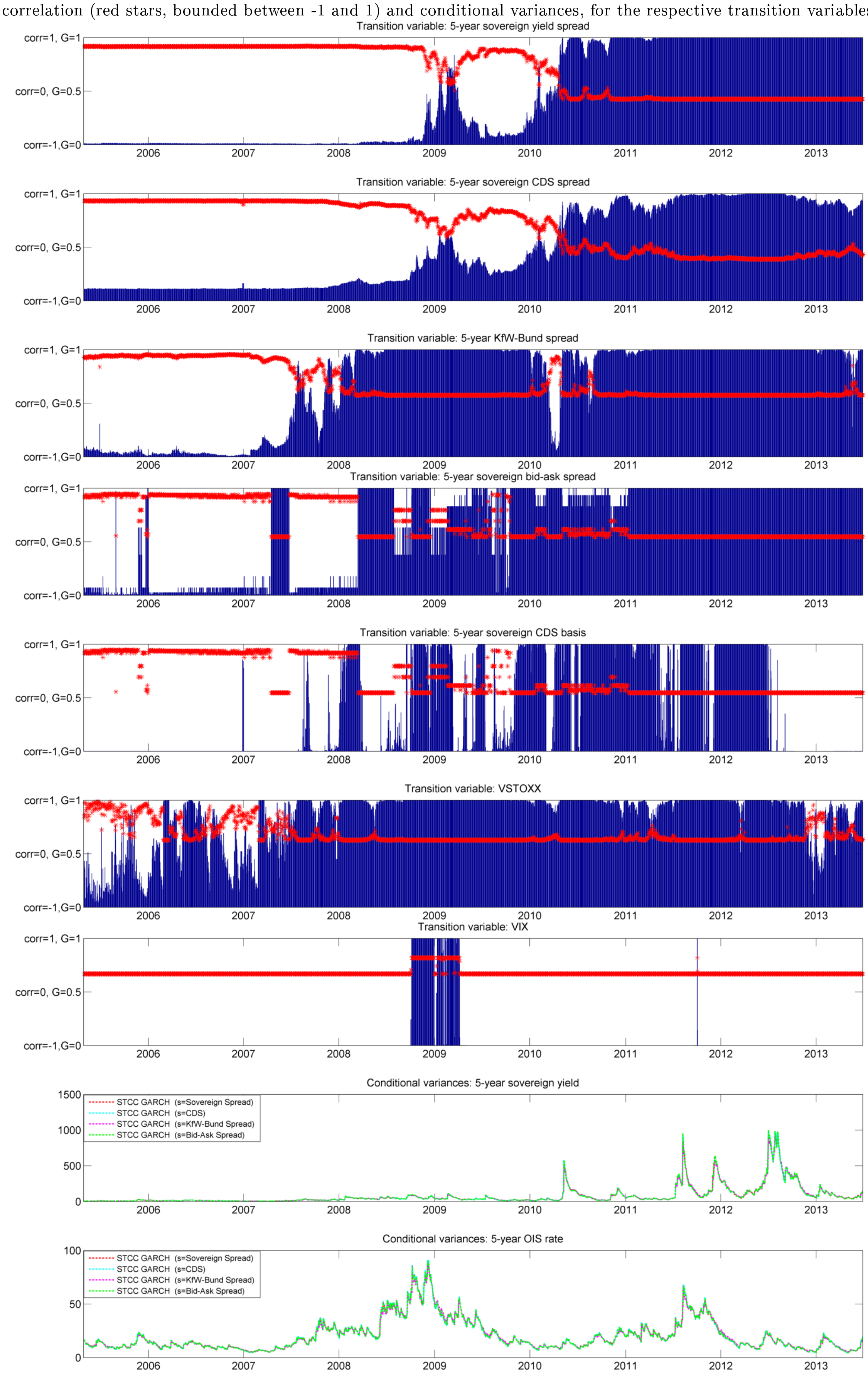

Figure 3: Transition Functions and Conditional Variance for Italy

The diagrams depict the value of the transition function (blue bars, bounded between 0 and 1) and the conditional correlation (red stars, bounded between -1 and 1) and conditional variances, for the respective transition variables.

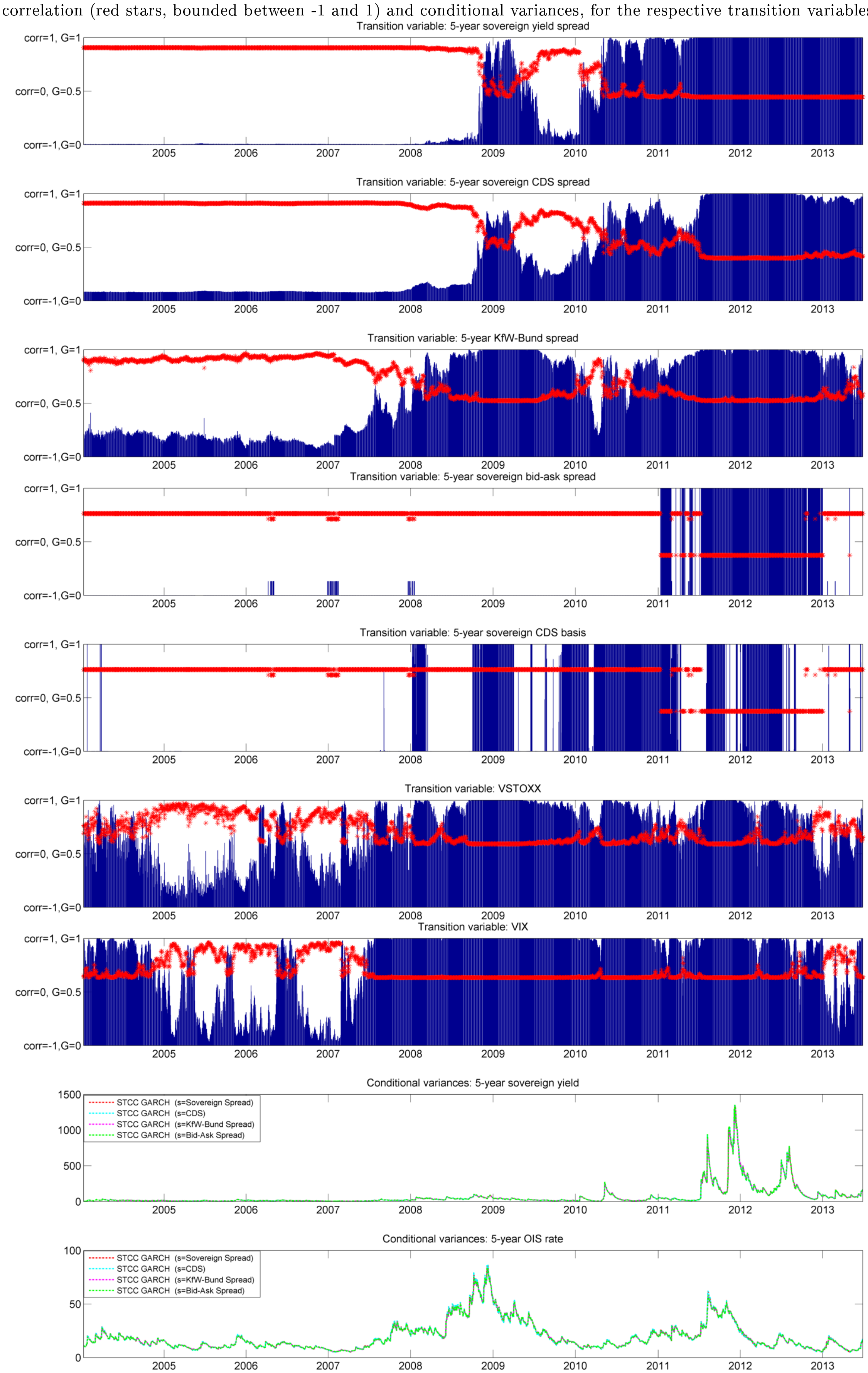

Figure 4: Transition Functions and Conditional Variance for Germany

The diagrams depict the value of the transition function (blue bars, bounded between 0 and 1) and the conditional correlation (red stars, bounded between -1 and 1) and conditional variances, for the respective transition variables.

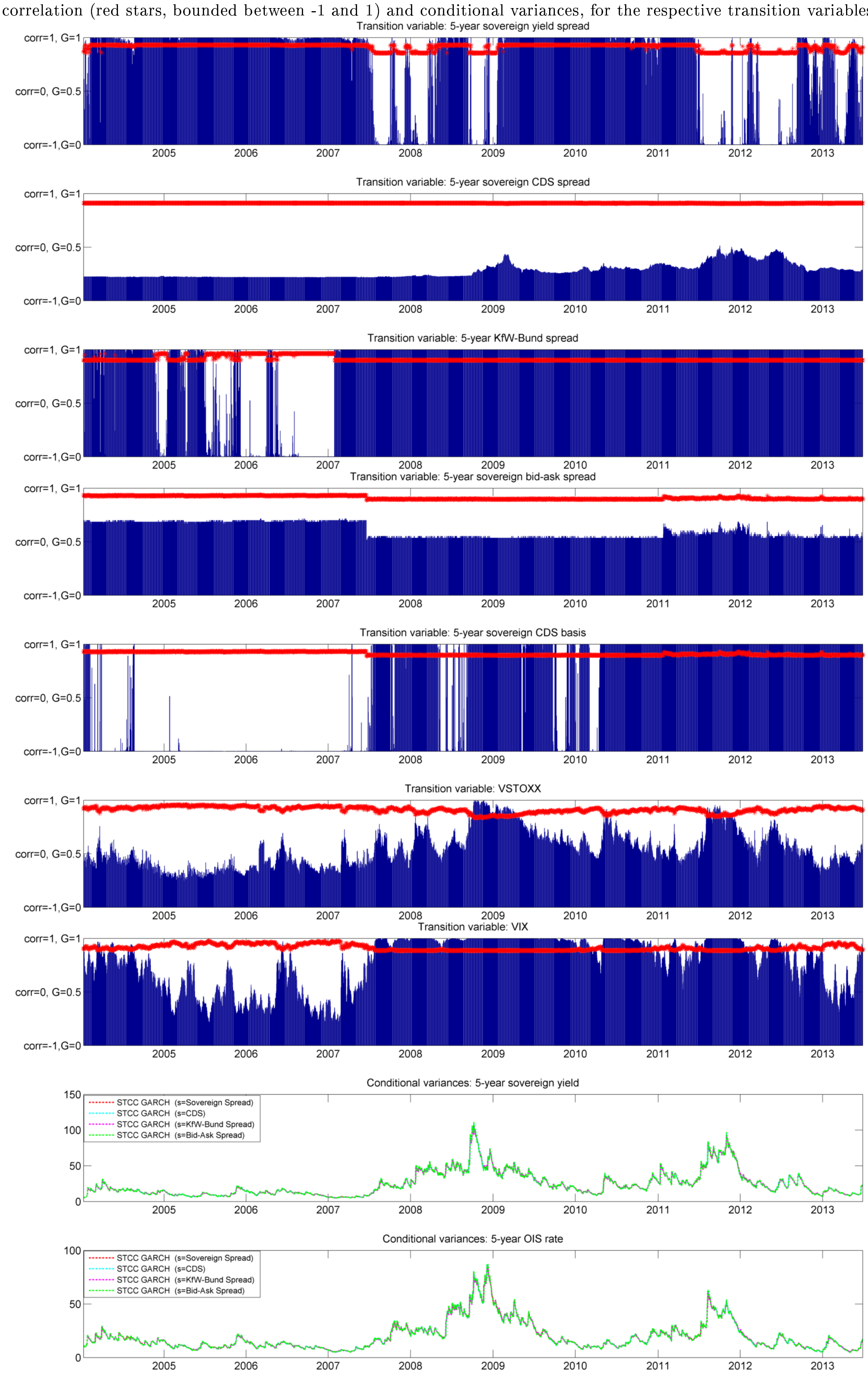

Figure 5: Conditional Correlations Spain

The diagrams depict the correlations of the DCC-GARCH model and the STCC-GARCH models with respective transition variables for Spain

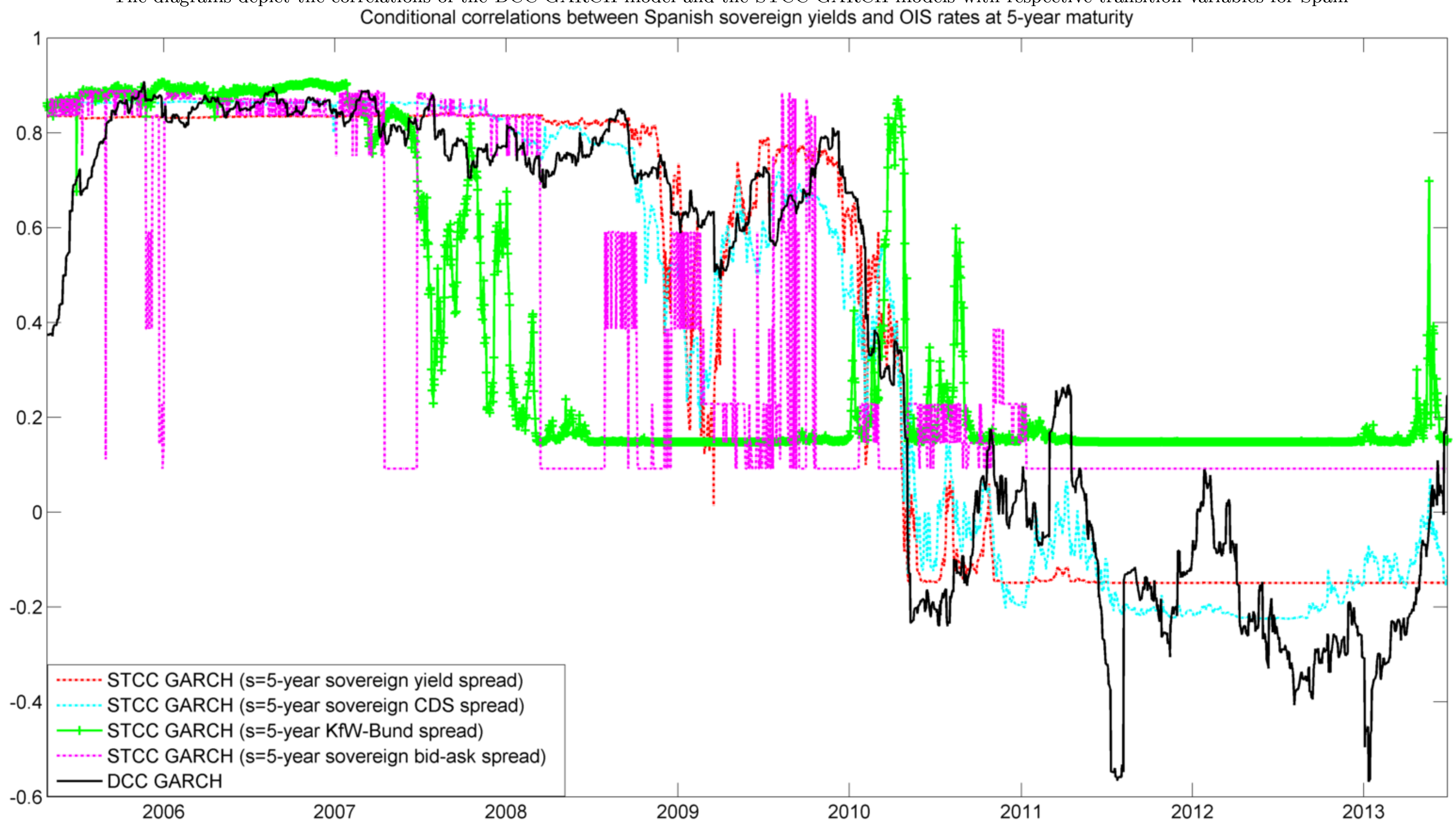

Figure 6: Conditional Correlations Italy

The diagrams depict the correlations of the DCC-GARCH model and the STCC-GARCH models with respective transition variables for Italy