A Forensic Analysis of Liquidity and Credit Risk in European Sovereign Bond Markets

Jennie Bai, Christian Julliard and Kathy Yuan*

May 9, 2012

Very Preliminary

Abstract

We study how liquidity and credit risks evolve in European sovereign bond markets since 2006. We have three sets of findings. First, we find by structural break analysis that liquidity started to affect sovereign bond yields significantly after the credit crisis of 2008 but has a much smaller effect after the late 2009. That is, the bond spread variation during the early stage of the Euro area sovereign bond crisis is mostly due to liquidity concerns (i.e., flight to liquidity), but during the second stage it is mostly credit risk driven (flight to quality). Second, we find CDS markets lead bond markets in price discovery normally but this lead is substantially reduced/reversed during the crisis stage, indicating that a potential spillover from credit risk to liquidity. Finally, we find through VAR analyses a spillover from the aggregate credit risk premium to each individual country credit risk premium, a spillover effect from the credit risk premium of each country to its liquidity risk. We do not find, however, a feedback from the aggregate or individual country's liquidity risk to a country's liquidity risk. These findings indicate that even though liquidity risk may be related to the credit risk premium of a country, the European sovereign bond crisis is a contagion through the credit (fundamental) risk channel not through the liquidity risk.

JEL Codes: G02

Keywords: Sovereign Debt Crisis, Liquidity, Flight-to-Quality, Credit Risk, Structural Break, Contagion

*We thank; e-mail: Bai is from Federal Reserve Bank of New York; e-mail:jennie.bai@ny.frb.org. Julliard is from the London School of Economics; e-mail: C.Julliard@lse.ac.uk. Yuan is from the London School of Economics and CEPR; e-mail: K.Yuan@lse.ac.uk.

1 Introduction

In this paper, we investigate how variations in bond yield are affected by credit risk and liquidity risk in the Euro sovereign bond markets since 2006 to shed lights on the underlying causes of the European sovereign debt crisis. Is the recent European sovereign bond crisis similar to the emerging market crisis ignited by the Russian default in late 1990s? Is the Euro sovereign crisis spreading through the fundamental or the liquidity channel? Since new sovereign debts are mostly issued to rollover old debts, a worsening liquidity may exacerbate a worsening fundamental? Do we see any feedbacks between the credit risk and the liquidity? These are the questions we aim to answer in this paper.

The bond liquidity is typically measured by the market microstructure characteristics such as bid-ask spread, net order flows price elasticity etc. The credit risk relates to the fundamental risk of the bond issuer. Both affect the cost of financing faced by the issuers. We present a simple theory model to capture both effects on the bond prices and show how the existence of traders who follow the price trend, may cause price to over-react to the aggregate and idiosyncratic fundamental shocks, and may even overact to liquidity shocks. These traders can be interpreted as institutional bond investors. Our model also shows the potential feedback from credit risk to the (il)liquidity of the bond.

Empirical we test the model by first decomposing the bond spread into the fundamental driven credit risk premium component and the liquidity risk component and see how the two components evolve over time and how the relation between the credit risk and liquidity changes over time. Second, the spillover of the Greek government debt crisis to Spain, Portugal, and Italy, indicate that there might be a feedback loop between credit risk and liquidity. That is, the liquidity may dry up when the country facing funding problems –

liquidity traders may withdraw their investments in the Euro area due to worsening fundamentals. The deterioration of the liquidity can further adversely affect the refinancing operations of countries, especially those depending on high level of short-term debt and facing rollover risks, which in turn exacerbates the country's likelihood of default. Again the feedback between the credit and liquidity may have a systematic (or contagious) aspect due to the common currency denomination.

Our empirical analyses rely on the following methodologies. First, we employ vector error-correction model (VECM) to test whether the information is discovered in the CDS market or in the bond market. This helps us understand the information discovery in the bond market and hence the liquidity formation process. Second, we estimate structural breaks in the bond spread determination over time. That is, whether the linear relationship between a country's bond spreads with its liquidity and credit risks changes over time. Third, we conduct VAR analyses to analyze the impact of country-, euro-area-, credit risk-related, liquidity-related shocks and hence shed lights on the feedback loops. Finally, we use regression analyses to investigate the co-movement of credit risks and liquidity over this period.

Our price discovery analysis shows that CDS leads bond market in the normal time but during the crisis a significant amount of price discovery starts to occur in the bond market. Our structural break analyses find that liquidity was a bigger component of bond spread before the crisis worsens, and then the credit component starts to dominate. The literature on delegated portfolio management has pointed out that the agency issue may cause institutional investors to be trend chasers; buying when prices are high and selling when prices are low in order to attract/retain fund flows. Our findings are consistent with this interpretation: prior to the crisis of 2007 institutional bond investors are less informed about the difference in fundamentals in the Euro area, and most price discovery was conducted in the CDS market where hedge funds and other types of arbitrageurs are active players . However, when the crisis of 2007 struck, institutional investors over-react, initially they flee to liquidity, that is, the bond market with a lot of liquidity such as Italy and France; as the fundamental worsens, they flee to quality such as Germany.

Our findings on liquidity to some extent are surprising but intuitive. We find via the structural break analyses that liquidity plays a minor role in bond yield determination until 2008, after the Lehman crisis and this role is quickly reduced after late 2009. That is, during the early stage of the Euro sovereign crisis, the market is characterized by flight to liquidity, but the later stage, the credit risk is the main driver of bond yields and the market is characterized by flight to quality. Further, our VAR analysis find that credit shocks are very persistent while the liquidity shocks tend instead to die off very quickly; there is also a feedback from country-specific credit risk to country-specific liquidity but not vice versa; and finally there is a contagion from the Euro-area aggregate credit risk to the country-specific credit risk, but not from aggregate liquidity to the country-specific credit risk. This set of results indicate that the Euro sovereign bond crisis is less a liquidity crisis but a crisis induced by common fundamentals. However, an alternative interoperation of this result is that the heavy liquidity injection of ECB may have stopped the Euro sovereign crisis becoming a liquidity crisis but have not stopped the contagion from the fundamental channel.

2 The Model and Testable Hypotheses

In this section, to guide the empirical analysis, we provide a stylized model to analyze the feedback effect between the credit risk and the liquidity risk in sovereign bond market. The model is a reduced form of the feedback model in Ozdenoren and Yuan (2008).

We consider a one-period economy with two types of assets, a riskless bond and many risky assets. The riskless bond can be thought as the numeraire asset with a price of one and the rate of return of zero. A risky asset indexed by i can be thought as the risky bond from sovereign country i. We assume it has a supply of M_i and its payoff is as follows,

$$\tilde{v}_i = \beta_i \tilde{f} + \gamma P_i + \tilde{\epsilon}_i \tag{1}$$

where $\tilde{v}_i$ denotes its final period payoff, $\tilde{f}$ the Euro area aggregate fundamental credit risk, $\tilde{\epsilon}_i$ sovereign-specific credit risk. The random variables $\tilde{f}$ and $\tilde{\epsilon}_i$ are independently and normally distributed with mean $\bar{f}$ and zero, standard deviation σ_f and σ_ϵ respectively. The coefficient β_i sovereign country i's loading on the Euro area aggregate risk. Finally P_i is sovereign i's bond price and γ measures the feedback effect from price to its fundamental value. This is to capture the fact that lower the bond price, the hard it is for a country to come to the bond market to raise funding for debt rollover or other fiscal budgetary needs.

There are three types of traders in this market. One is fundamental-driven traders who trade on signals related to the fundamental worthiness of the risky assets. The signals they receive are of two types: country-specific $\tilde{s}_i$ and aggregate $\tilde{s}_f$. They are specified as follows

$$\tilde{s}_f = \tilde{f} + \tilde{\eta}_f, \quad \tilde{s}_i = \tilde{\epsilon}_i + \tilde{\eta}_i, \tag{2}$$

where $\tilde{\eta}_f$ and $\tilde{\eta}_i$ are normally distributed with mean zero and standard deviation of σ_{η_f} and σ_{η_i} respectively. We assume that these fundamental-driven traders receive identical signals and have CARA preferences so that $u(w) = -exp(-rw)$.

The second type of the traders are typical bond fund investors. They trade based on past performance of the asset class. We model this trading behavior as follows:

$$L(P_i) = \delta P_i + \lambda \sigma_y \tilde{y}. \tag{3}$$

That is, they increase their investment in sovereign country i's bond when its price is high and reduce it otherwise. Their investment has a noise component $\tilde{y}$ which is normally distributed with zero mean and standard deviation of one.

The third type of traders are noise traders and their demand is denoted as $\sigma_z \tilde{z}$ which is also normally distributed with zero mean and standard deviation of one.

With this simple setup, we solve for the optimal demand by the the fundamental-driven traders and then solve for the equilibrium bond price through the market clearing condition. The equilibrium price is given by,

$$P_i = a_0 + a_f s_f + a_e s_i + a_y \lambda(\sigma_y \tilde{y} + \sigma_z \tilde{z}) \tag{4}$$

where

$$a_0 = \frac{1}{\frac{r}{\frac{\beta_i^2}{\tau_f+\tau_{\eta_f}}+\frac{1}{\tau_\epsilon+\tau_{\eta_i}}}(1-\gamma)-\delta} \left(\frac{1}{\frac{\beta_i^2}{\tau_f+\tau_{\eta_f}}+\frac{1}{\tau_\epsilon+\tau_{\eta_i}}} \frac{\tau_f \bar{f}}{\tau_f+\tau_{\eta_f}} \beta_i - M \right) \tag{5}$$

$$a_f = \frac{1}{\frac{r}{\frac{\beta_i^2}{\tau_f+\tau_{\eta_f}}+\frac{1}{\tau_\epsilon+\tau_{\eta_i}}}(1-\gamma)-\delta} \times \frac{1}{\frac{\beta_i^2}{\tau_f+\tau_{\eta_f}}+\frac{1}{\tau_\epsilon+\tau_{\eta_i}}} \frac{\tau_{\eta_f}}{\tau_f+\tau_{\eta_f}} \beta_i \tag{6}$$

$$a_e = \frac{1}{\frac{r}{\frac{\beta_i^2}{\tau_f+\tau_{\eta_f}}+\frac{1}{\tau_\epsilon+\tau_{\eta_i}}}(1-\gamma)-\delta} \times \frac{1}{\frac{\beta_i^2}{\tau_f+\tau_{\eta_f}}+\frac{1}{\tau_\epsilon+\tau_{\eta_i}}} \frac{\tau_{\eta_i}}{\tau_f+\tau_{\eta_i}} \tag{7}$$

$$a_y = \frac{1}{\frac{r}{\frac{\beta_i^2}{\tau_f+\tau_{\eta_f}}+\frac{1}{\tau_\epsilon+\tau_{\eta_i}}}(1-\gamma)-\delta} \tag{8}$$

A few comments on this price function are in order. First, prices would over-react to the shocks in the aggregate fundamental credit risk, country-specific fundamental credit risk, and liquidity risk if there is a feedback from price to the country's fundamental, that is, when δ or γ is non-zero. This over-reaction may show up as contagion from the aggregate credit risk ($\tilde{f}$). Second, the over-reaction may be different with respect to the aggregate credit risk shock, country-specific credit risk shock, and liquidity risk depending on the perceived risk of the fundamentals (i.e., precision of the signals) and the magnitude of the liquidity risk. For example, when the signal about the aggregate fundamental is relatively precise, that is, τ_{η_f} is relatively large, compared with the liquidity risk (σ_y), prices over react more to the liquidity shock relatively. In the empirical part of the paper, we test for the structural breaks in the coefficients on $\tilde{f}$, $\tilde{\epsilon}$ and $\tilde{y}$ to gauge how changes in the information environment affects the bond prices.

We can substitute the above price function to (1) to decompose various shocks to country i' fundamentals.

$$\tilde{v}_i = \gamma a_0 + \underbrace{(\beta_i + \gamma a_f)\,\tilde{f}}_{\text{Aggregate Credit Risk}} + \underbrace{(\gamma a_e + 1)\,\tilde{\epsilon}_i}_{\text{Country-Specific Credit Risk}} + \underbrace{\gamma\,(a_f \tilde{\eta}_f + a_e \tilde{\eta}_i)}_{\text{Noisy Information}} + \underbrace{\gamma(\sigma_y \tilde{y} + \sigma_z \tilde{z})}_{\text{Liquidity Risk}} \quad (9)$$

This equation shows that the country's fundamental is more sensitive to the aggregate fundamental shock than to the liquidity shock as $a_f < 1$. By substituting the above equation to (3), we find that the institutional investors' demand is heavily influenced by the fundamental shocks to $L(P)$. That is there is a potential spillover from the aggregate as well as the idiosyncratic fundamentals to the liquidity. In the empirical part of the paper, we test for the existence of such feedbacks from credit risk to liquidity and vice versa.

3 Methodology

3.1 Bond Yields and Structure Break

We identify break dates using country specific linear regressions in which we allow for m break points (were the optimal m is endogenously determined as described below). That is, we allow the regression coefficients to shift from one stable regression relationship to a different one. Thus, there are $m+1$ segments in which the regression coefficients are constant, and the econometric model can be written as

$$y_t = x_t' \beta_j + u_t, \quad j = 1, 2, ..., m+1, \quad t = 1, ..., T$$

where j denotes the segment index.

The foundation for estimating breaks in time series regression models was given by Bai (1994), and was extended to multiple breaks by (Bai, 1997a, 1997b) and Bai and Perron (1998). Our approach is similar in spirit to the algorithm of Bai and Perron (2003) for the simultaneous estimation of multiple breakpoints. We choose the optimal number of breaks for each country as the one that minimizes the Bayesian Information Criterion (BIC) but, differently from the previous literature, we modify the BIC statistics to be robust to potential non-stationarity in the data.

Given an integer m denoting the number of break points, for any vector of break dates $\tau_i(m)$ (of length m), we denote the extended parameter set with $\theta_i \in \Theta \subset \mathbb{R}^{m \times \dim \beta_j}$. The associated likelihood of the data is given by $f(Z_T | \theta_i, \tau_i(m))$, where Z_T denotes the history of available data. From the Bayes Theorem we have that, under a flat prior over both the parameter space and the space of possible models, the posterior probability of a specification with $\tau_i(m)$ as break dates is proportional to the Bayes Factor, that is

$$\Pr(\tau_i(m)|Z_T) \propto \int_\Theta f(Z_T|\theta_i, \tau_i(m))\, d\theta_i \simeq (2\pi)^{d_\theta/2} \left|\hat{\Sigma}_{\theta_i}\right|^{\frac{1}{2}} f\left(Z_T|\hat{\theta}_i, \tau_i(m)\right)$$

where $\hat{\theta}_i$ is the vector of MLE estimate, $\hat{\Sigma}_\theta^{-1}$ is the the observed information matrix (i.e. the negative Hessian evaluated at $\hat{\theta}_i$), d_{θ_i} is the dimension of θ_i, and the last equality comes from a second order approximation of the log likelihood at the MLE. Taking logs of the last expression we have

$$\frac{d_\theta}{2}\ln 2\pi + \ln f\left(Z_T|\hat{\theta}_i, \tau_i(m)\right) - \ln\left|\hat{\Sigma}_{\theta_i}\right|^{-\frac{1}{2}}. \tag{10}$$

For stationary time series, under mild regularity conditions, $T\hat{\Sigma}_{\theta_i} \xrightarrow[T\to\infty]{p} \Omega_{\theta_i}$ for some constant Ω_{θ_i}, and $\frac{1}{T}f\left(Z_T|\hat{\theta}_i, \tau_i(m)\right) \xrightarrow[T\to\infty]{p} \bar{f}_i$ for some constant $\bar{f}_i$. Therefore, as $T \to \infty$ the behavior of the log Bayes factor will be dominated by

$$\ln f\left(Z_T|\hat{\theta}_i, \tau_i(m)\right) - \frac{d_\theta}{2}\ln T.$$

But minus twice the last expression is exactly the Bayesian Information Criterion (BIC) of the specification with break dates given by $\tau_i(m)$

$$BIC(\tau_i(m)) = -2\ln f\left(Z_T|\hat{\theta}_i, \tau_i(m)\right) + d_\theta \ln T. \tag{11}$$

That is, using the BIC as selection criterion for the break dates, as suggested in the previous literature, is asymptotically equivalent to choosing the model with the highest posterior probability. Nevertheless, this equivalence does not hold if the data show non-stationary behavior. This is an issue for our empirical application since the time series under analysis often show departure from stationary in subsamples. Moreover, departures from stationarity do not allow us to use standard F-test based break identification approaches.

To circumvent this issue we use as BIC statistic (minus twice) the expression in Equation 10 rather than the standard one in Equation (11). We compute this statistic for any $\tau_i(m)$, and (due to sample size considerations) we consider up to a maximum number of breaks, m, equal to 8. The optimal break dates are then identified as the ones that deliver the smallest (modified) BIC statistic.

3.2 S-VAR Identification of Credit and Liquidity Spillovers

We use a structural VAR (S-VAR) approach to identify spillover effect of liquidity and credit shocks. That is, we ask the data wether credit shocks have a tangible effect on bonds' liquidity and whether liquidity shocks have significant effects on the credit risk of a country.

In particular, we consider a setting with four types of shocks: *i*) domestic credit shocks, ε^c, *ii*) foreign credit shocks, ε^{cf} *iii*) net order flows shocks i.e. rebalancing shocks ε^{nof}, *iv*) domestic liquidity shocks, ε^l. These shocks are assumed to jointly drive the behaviour of four quantities *i*) domestic CDS rates, x^c; *ii*) foreign CDS rates, x^{cf} (measured as an averaged of foreign CDS); *iii*) net order flow for the country, x^{nof}; *iv*) domestic bonds liquidity (percentage bid-ask spread), x^l. For each country, the resulting S-VAR is

$$\Gamma_0 \underbrace{\begin{bmatrix} x_t^c \\ x_t^{cf} \\ x_t^{nof} \\ x_t^l \end{bmatrix}}_{\equiv X_t} + \Gamma(L) X_{t-1} = c + \underbrace{\begin{bmatrix} \varepsilon_t^c \\ \varepsilon_t^{cf} \\ \varepsilon_t^{nof} \\ \varepsilon_t^l \end{bmatrix}}_{\equiv \varepsilon_t} \sim N(0, I) \tag{12}$$

where Γ_0 is a full rank matrix capturing the contemporaneous interactions among variables, and $\Gamma(L)$ is a square matrix of polynomials of order p in the lag operator L (i.e. $\Gamma(L) \equiv \Gamma_1 + \Gamma_2 L^1 + ... + \Gamma_{p+1} L^p$), c is a vector of constants, and ε_t contains the structural shocks that are normalized to have unit variance (this normalization is innocuous – alternatively, we could have normalized the diagonal elements of the Γ_0 matrix).

Not imposing zero restrictions on elements of Γ_0 implies that all the variables can potentially respond contemporaneously to all the shocks considered – that is, we don't make any slow reaction assumption about the variables in the S-VAR.

The above system can be rewritten in reduced form as

$$X_t = \gamma + B(L) X_{t-1} + v_t \sim N(0, \Omega) \tag{13}$$

where $B(L) \equiv -\Gamma_0^{-1}\Gamma(L) = B_0 + B_1 L + ... + B_p L^p$ and $\gamma = \Gamma_0^{-1} c$. The reduced form gives in γ and $B(L)$ as many parameters as in c and $\Gamma_1, ...\Gamma_p$. Moreover, we have that by construction $\Gamma_0^{-1}\left(\Gamma_0^{-1}\right)' = \Omega$ since $v_t = \Gamma_0^{-1}\varepsilon_t$. So we could hope to recover Γ_0 from the covariance matrix of v_t. The problem is that there are there are $(n+1)\, n/2$ free elements in $\Gamma_0^{-1}\left(\Gamma_0^{-1}\right)'$ while Γ_0 has $n^2 = 4$. This means that if we want to identify the structural parameters we need at least $(n-1)\,n/2$ restrictions.

The most common way of achieving identification in S-VARs is to impose some zero restrictions on the elements of Γ_0, but this would be unappealing in our setting since it would imply that some of the financial variables considered react with delay to some of the shocks considered. The alternative approach that we use is based instead on imposing restrictions on the long run effect of the different types of shocks (see e.g. Blanchard and Quah (1989)).

A natural restriction is that transitory liquidity shocks should have no effect on the credit spreads, nor on portfolio rebalancing, in the infinite future. The idea is that a reduction of liquidity implies a reduction of the likelihood of matching with a counterparty willing to take the other side in an economic transaction. This implies that, when liquidity is reduced, to be able to complete an economic transaction a premium has to be paid to complete the transaction without delay. Therefore, a liquidity shock can potentially have a short run effect on the credit spread. Similarly, liquidity shocks can have a short run effect on net order flows if they generate a flight to liquidity. Nevertheless, looking in the infinite future, the probability of matching a counterparty is one (unless there is a market shut down i.e. a permanent liquidity shock), therefore transitory liquidity shocks should not have any effects on the credit spread in the infinite future. Similarly, transitory liquidity shocks should not affect net order flows in the infinite future. This long run neutrality assumption allows us to identify the liquidity shocks. To be able to identify the other shocks we make two further assumptions: *i*) transitory net order flows shocks should have no long run effects on CDS rates since, in the long run, the latter should be pinned down only by economic fundamentals; *ii*) foreign CDS shocks should not have a long run effect on domestic CDS since the former, in the long run, should be pinned down by the country specific fundamentals that determine the likelihood of default.

Rewriting the S-VAR in it's moving average form we have

$$\underbrace{\begin{bmatrix} x_t^c \\ x_t^{cf} \\ x_t^{nof} \\ x_t^l \end{bmatrix}}_{\equiv X_t} = k + A(L) \underbrace{\begin{bmatrix} \varepsilon_t^c \\ \varepsilon_t^{cf} \\ \varepsilon_t^{nof} \\ \varepsilon_t^l \end{bmatrix}}_{\equiv \varepsilon_t} \sim N(0, I) \tag{14}$$

where $A(L) \equiv [\Gamma_0 + L\Gamma(L)]^{-1} = A_0 + A_1 L + A_2 L^2 + ...A_\infty L^\infty$. The long run restrictions outlined above can be simply written as

$$\sum_{j=0}^{\infty} \{A_j\}_{1,2} = \sum_{j=0}^{\infty} \{A_j\}_{1,3} = \sum_{j=0}^{\infty} \{A_j\}_{1,4} = \sum_{j=0}^{\infty} \{A_j\}_{2,3} = \sum_{j=0}^{\infty} \{A_j\}_{2,4} = \sum_{j=0}^{\infty} \{A_j\}_{3,4} = 0 \tag{15}$$

where the $\{.\}_{i,l}$ operator returns the (i, l) element of the matrix. The above restrictions imply that $A(1) \equiv A_0 + A_1 + A_2 + ...$ should be a lower triangular matrix, therefore this gives us exactly the $(n-1)\,n/2$ restrictions needed to recover the S-VAR coefficients from the reduced form VAR in equation (13).

Note also that under these restrictions, conditional on knowing $B(L)$ and Ω, Γ_0 and $\Gamma(L)$ are deterministic matrices. This implies that, under a diffuse prior, we can construct posterior confidence intervals for Γ_0, and for the resulting impulse-response functions, by taking draws from the Normal-inverse-Wishart posterior of the reduce form VAR – that is, we can construct Bayesian confidence intervals that are robust to close to unit root behavior of the variables in the samples considered. Similarly, to avoid issues with close to unit root behavior, the optimal number of lags is chosen using the modified BIC in Equation 10.

Note that, due to data limitations, we do not allow for structural breaks in the S-VAR specification. Nevertheless, as pointed out in Sims (1987) and Leeper and Zha (2003) VARs are best thought of as a linear approximations to the behavior of the private sector, and the behavior they model implicitly includes dynamics arising from revisions in the forecasting rules (as well as other sources of dynamics). As a consequence, a SVAR is likely to do a good job in projecting the impact of credit and liquidity shocks as long as the model's nonlinearities generated by regime shifts are not too severe.

4 Data and Variable Construction

We use three main sources of data. First, the European government bond transaction data is from the MTS (*Mercato dei Titoli de Stato*) system. Second, the credit default swap spread data is from the Markit. Inc. Third, the Euro-denominated interest rate swaps and the bid/ask CDS price is from Bloomberg. The sample period for our study is from January 2, 2006 to May 31, 2011 in a daily frequency. This time period provides a good platform to study the behavior of European government bonds markets before/during/after the European sovereign debt crisis. Specifically, this time period includes a number of significant credit events that directly affect the credit risk and liquidity risk in the government bond yields, for example, the Lehman Brothers bankruptcy, the banking crisis in Ireland, and a series of downgrading events on Greece, Ireland, Italy, Portugal and Spain.

4.1 European Bond Market

The MTS system is the largest interdealer market for Euro-denominated government bonds. MTS Time Series data is based on the MTS interdealer markets including EuroMTS, EuroCredit MTS and the various domestic MTS markets. The database as of May 2011 includes government bond trade data for twelve countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Slovenia and Spain. We exclude Slovenia from our sample for the sparsity of the data.

The MTS data contains both bond reference information (issuer, coupon rate, coupon frequency, maturity) and detailed transaction information including trading market indicator, trading price and size, order flow, and average bid/ask spread in the daily frequency. The key variable in our study is the government bond yield which is based on the midprice, a flat price quote based on the average of the best bid/offer prices at or before 5pm Central European Time. To be qualified in our sample, all bonds need to meet the following criteria: 1) issued by a government (excluding quasi-government securities or structured securities); 2) traded in Euros; 3) having valid records on midprice and bid/ask spread. To minimize the impact of confounding effects related to special bond features, we exclude securities with floating rate coupons, inflation- or index-linked securities. To check the heterogeneity across maturities, we split the bonds into four categories based on their remaining time-to-maturity: 2-4 years, 4-6 years, 6-8 years, 9-11 years. The rationale for these four maturity categories is that we can match the bond data with corresponding sovereign CDS data (3-, 5-, 7-, and 10-year).

The MTS data is compiled from two different interdealer markets, the EuroMTS and the various domestic MTS markets. According to Dufour and Skinner (2010) and the MTS data manual, “EuroMTS is the reference electronic market for Euro benchmark bonds, or bonds with an outstanding value of at least €5 billion.” The MTS domestic markets lists the whole yield curve of the government securities for each country. The majority of dealers are members of both markets, and are therefore allowed to parallel quote, namely they post their quotes on both markets simultaneously. Parallel quotes will have the same prices although may specify different sizes on the domestic and benchmark markets. Additionally, whenever a proposal is aggressed in one market, the dealer's position is immediately updated on both markets. Due to the transparency of these two systems, any differences in price or liquidity are eliminated by arbitrageurs.

Beber, Brandt, and Kavajecz (2009) also use the MTS data but for a different sample period, April 2003 to December 2004. They report the summary statistics uniquely based on the benchmark market given the reason that the benchmark market lists newly issued bonds and hence are effectively on-the-run securities. However, Dufour and Skinner (2010) make no indication that only newly issued bonds are listed in the benchmark market. In our sample, we use the data from the benchmark as well as the domestic market. Therefore a single bond may have multiple entries at a given day, however all entries share the same price (may have different trading volume). Such an arrangement allows us to construct open interest and order flow variables from both markets in order to capture complete information.

4.2 Sovereign CDS Market

Credit-Default Swap (CDS) is a financial derivative contract which functions as an insurance against credit events that happen to a reference entity such as a corporate company. One special type of reference entity is the sovereign government. The reference obligation for sovereign credit-default swap contract is designated as senior external debt or international debt. According to the ISDA 2004 Sovereign Master Credit Derivatives Confirmation agreement, credit events that trigger a sovereign CDS contract include failure to pay, repudiation/moratorium and restructuring.

To illustrate how a sovereign CDS works, consider the case of Greece. The spread for a 5-year CDS contract on Hellenic Republic rose to 1420.43 basis points on May 31, 2011. This means a trader would have to pay USD 1,420,430 a year to insure a notional USD 10 million of the Greek debt for a pre-contracted credit event. If no such credit event happens, the protection buyer would pay this annuity for the full five-year horizon of the contract. If a credit event happens, however, the protection buyer could sell the sovereign bond to the protection seller at a par value (or obtain the cash equivalent of the net gain), and terminate the contract. In addition to physical settlement, one can opt for cash settlement, where the protection buyer does not deliver any obligations and instead the protection seller pays the difference between par and the recovery rate.[1]

Sovereign CDS has several unique features. The first aspect is that the currency of the CDS differs from the currency of the sovereign entity. The currency of euro-area sovereign CDS is generally in U.S. dollars. This convention was chosen in order to protect the protection buyer against inflation risk and foreign exchange risk. Secondly, the reference obligation does not have to be of the same maturity as the CDS contract because all sovereign bonds issued by one issuer rank *pari passu* with each other. In sovereign CDS, the reference debt instruments have the same seniority, while in the corporate bond world there are different levels of seniority and subordination of obligations.

Market participants in the sovereign CDS market often are macro hedge funds which use sovereign CDS to express directional views on sovereign debt markets particularly since the considerable rise in LIBOR rates made funding in the cash market more expensive. Nonetheless, the use of sovereign CDS has grown much broader over the recent years. Credit funds, real money managers, structured credit investors and proprietary trading desks became active

[1] Similar to the physical settlement case, the protection buyer retaining the underlying deliverable obligation bond will be able to sell the bond at the distressed prices in the market and thereby obtain the "recovery rate", thus restoring total proceeds back to par. An explicit recovery rate is typically determined by a poll of market quotations for a deliverable obligation or the reference obligation.

in the sovereign CDS market to take directional bets on the credit risk of European countries. In particular, anecdotal evidence suggests that these investors were using sovereign CDS also for counterparty risk management purposes, and hedging systemic 'tail' risk. For example, banks have used sovereign CDS to reduce exposure to either sovereign exposure or bank loans to corporate within a country over recent months.

We obtain the time-series CDS price from Markit.Inc for the 3-, 5- 7- and 10-year maturities for each country. They are denominated in US dollars and have the cumulative restructuring clause. We download the bid-ask spread for CDS with five-year maturity from Bloomberg.[2] We supplement the CDS pricing data with CDS transaction information from the Depository Trust and Clearing Corporation (DTCC), including net notional outstanding, the number of CDS contract, new trades. The CDS transaction data spans the period of September 2008 (corresponding to the beginning of the DTCC data set) to May 2011 at a weekly frequency.

4.3 Variable Construction

In this paper we study the role of flight-to-liquidity and flight-to-safety in explaining the European government bond yield spreads. First, we construct the bond yield spreads by subtracting the Euro-denominated interest rate swap from the bond yield with the same maturity. As noted by Dunne, Moore, and Portes (2003) and Beber, Brandt, and Kavajecz (2009), the Euro-swap rate serving as the benchmark is preferred by market participants and academic researchers, since the government bonds are less than an ideal proxy for the unobserved risk-free rate due to taxation treatment, repo specials, and scarcity premia.

[2]For many countries, the bid/ask price is missing for non-five year maturity. We use the bid/ask spread for CDS with five-year maturity as proxy of general liquidity in the sovereign CDS market.

Moreover, the use of interest rate swaps provides a homogeneous benchmark across the euro-zone area (Fontana and Scheicher (2010)) and provides explicit quotes for the 3-, 5-, 7-, 10-year maturities.

We use the sovereign credit default swap spreads as the proxy of the credit risk embedded in the government bond yield spreads. Sovereign CDS offers a direct measure of the credit quality on sovereign government. . The CDS data is available in the daily frequency, which can timely capture the overall credit risk perceived by the market, as opposed to an indirect estimate by using low frequency national account variables.

4.4 Descriptive Statistics

Table 1 presents important bond characteristics in the European government bond market. There are overall 702 bonds issued by 11 countries in our sample. Italy has the largest bond market with 145 bonds and an average monthly trading volume of €45.46 billions. France is next to Italy, with 142 bonds and €6.65 billions trading volume on average per month. The market also observes large trading transactions for countries like Belgium, Netherlands, Spain, and Portugal. The average remaining time-to-maturity in our bond sample is 5.53 years. The average coupon rate is 4.22 percent, and the average transaction price is 100.78, close to par value. In terms of bid-ask spread, Greece and Spain have the wider spread.

Panels B to F in Table 1 also show the bond characteristics for 3-, 5-, 7-, 10-year maturity categories. There exists a heterogeneity of bond characteristics across countries and over various maturities. Here we summarize three interesting findings. First, the short-term bond with on average 3-year maturity is most traded in the European bond market with a monthly trading volume of €2.65 billions; the next most traded bonds are those with 5-year

(€1.95 billions), then with 10-year time-to-maturity (€1.80 billions). Second, the 10-year bond category has the widest bid-ask spread, say 0.118, whereas the 3-year bond category has the narrowest bid-ask spread, that is 0.069. In general bonds with longer maturity tend to have wider bid-ask spreads on average across countries. Third, the market witnesses a selling pressure on the 5-year bond category, measured by the net order flow (buy minus sell orders).

4.5 Preliminary Look: Price Discovery

Financial engineers suggest that a sovereign CDS contract can replicate a position in a cash bond as the protection seller assumes the credit risk of the reference entity. In theory, under some conditions, an arbitrage relation exists which implies that the CDS spread should equal the credit spread on the deliverable bond.[3] Empirically, in the emerging-market countries Ammer and Cai (2011) found that sovereign CDS premia and bond spreads are linked by a stable linear long-run equilibrium relationship. However, the two prices of credit risk often diverge in the short-term, with the more liquid market tending to lead the other. They argue that price leadership in the more liquid market is consistent with the sovereign credit risk pricing being driven mostly by public information. In developed countries however, Fontana and Scheicher (2010), Alper, Forni, and Gerard (2011) find mixing evidence of co-movements between sovereign CDS spreads and bond credit spreads, where the CDS market may or may not lead the bond market and some countries even do not observe a cointegration between CDS and bond spreads.

Figure 5 plots the time-series evolution of five-year CDS spreads and five-year govern-

[3]Duffie (1999) discusses the specific conditions and show why the arbitrage relation might not exactly hold in practice.

ment bond credit spreads for eleven countries during the period of 2006 to 2011. The first impression is a significant divergence of CDS premia and bond spreads, which is defined as the "basis". Across countries the bases were small and stable till the summer of 2007, then they widened and became volatile during the financial crisis and the sovereign debt crisis. The basis is positive for most countries, indicating that CDS spread exceeds the bond spread. However, Ireland, Greece, and Portugal observe some negative basis when their solvency becomes a serious concern. Overall, we observe that both CDS and bond spreads go widening significantly but at different pace. Yet we need formal tests to answer which market leads the other in the pricing process.

[Figure 5 about here.]

As noted in Blanco, Brennan, and Marsh (2005), the appropriate method to investigate the mechanics of price discovery is not clear. We follow the literature and use the following vector error-correction model (VECM) to test whether information of credit risk is discovered mainly in the sovereign CDS market or in the government bond market:

$$\begin{aligned}
\Delta CDS_t &= \alpha_1 + \lambda_1(CDS_{t-1} - Bond_{t-1}) + \sum_{i=1}^{p} \beta_{1i}\Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{1i}\Delta Bond_{t-i} + \varepsilon_{1,t} \\
\Delta Bond_t &= \alpha_2 + \lambda_2(CDS_{t-1} - Bond_{t-1}) + \sum_{i=1}^{p} \beta_{2i}\Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{2i}\Delta Bond_{t-i} + \varepsilon_{2,t}
\end{aligned}$$

where λ_i stands for the speed of adjustment in corresponding market to the long-run relationship, *Bond* is the government bond yield subtracting the interest rate swap.

Before the formal test, we first apply the augmented Dickey-Fuller test to identify the non-stationarity of the CDS spread and bond spreads for each country. As expected, the test does not reject the null hypothesis of a unit root for all testing series in their levels, but it does for all series in their first difference.[4] Then we conduct cointegration analysis on CDS spreads and bond spreads within the above VECM framework. Table 2 presents the contribution to the price discovery by the CDS market, measured by the mid value of Hasbrouck information share (HAS mid) as well as permanent factor (noted as GG) in Gonzalo and Granger (1995).

[Table 2 about here.]

Overall, the sovereign CDS market leads the bond market.

5 Empirical Results

5.1 Bond Yield Spread Decomposition

6 Conclusion

In this paper, we examine how the credit risk and liquidity evolve over the Euro sovereign bond crisis. We find that a significant spillover from aggregate credit risk to the individual country's credit risk and increased in the effect of credit on bond yield determination as sovereign debt crisis deepens. This all indicates that the Euro sovereign bond crisis speeds through the fundamental.

We dispute the notion that the Euro sovereign bond crisis is a liquidity one as we find through structural break analyses and VAR analysis that the liquidity effect on the sovereign bond yield is a short-lived one. However, the short-lived liquidity effect might be due to the fact that ECB injected a large amount of liquidity in the Euro sovereign bonds. This is open

[4]We do not report the results for brevity but can provide them upon request.

to further research.

7 Appendix

7.1 Structural Breaks Identification

References

Alper, Emre, Lorenzo Forni, and Marc Gerard, 2011, Pricing of sovereign credit risk: Evidence from advanced economies during the recent financial crisis, working paper, IMF.

Ammer, John, and Fang Cai, 2011, Sovereign cds and bond pricing dynamics in emerging markets: does the cheapest-to-deliver option matter?, *Journal of International Financial Markets, Institutions and Money* 21, 369–387.

Bai, J., 1994, Least squares estimation of a shift in linear processes, *Journal of Time Series Analysis* 15, 453–472.

——— , 1997a, Estimating multiple breaks one at a time, *Econometric Theory* 13, 315–352.

——— , 1997b, Estimation of a change point in multiple regression models, *Review of Economics and Statistics* 79, 551–563.

——— , and P. Perron, 1998, Estimating and testing linear models with multiple structural changes, *Econometrica* 66, 47–78.

——— , 2003, Computation and analysis of multiple structural change models, *Journal of Applied Econometrics* 18, 1–22.

Beber, Alessandro, Michael W. Brandt, and Kenneth A. Kavajecz, 2009, Flight-to-quality or flight-to-liquidity? evidence from the euro-area bond market, *Review of Financial Studies* 22, 925–957.

Blanchard, Olivier Jean, and Danny Quah, 1989, The dynamic effects of aggregate demand and supply disturbances, *American Economic Review* 79, 655–73.

Dufour, Alfonso, and Frank S. Skinner, 2010, MTS time series market and data description for the european bond and repo database, Icma centre discussion papers in finance Henley Business School, Reading University Version 5.0.

Dunne, Peter, Michael Moore, and Richard Portes, 2003, Defining benchmark status: An application using euro-area bonds, working paper, NBER.

Fontana, Alessandro, and Martin Scheicher, 2010, An analysis of euro area sovereign cds and their relation with government bonds, working paper, ECB.

Leeper, Eric M., and Tao Zha, 2003, Modest policy interventions, *Journal of Monetary Economics* 50, 1673–1700.

Sims, Christopher A., 1987, A rational expectations framework for short run policy analysis, in W. Barnett, and K. Singleton, ed.: *New Approaches to Monetary Economics* . pp. 293–310 (Cambridge University Press).

Table 1: Summary Statistics of European Government Bond Market

This table presents summary statistics for Euro-area countries' bond markets. *# Bonds* is the total number of government bonds in each maturity category. *Coupon(%)* is the average coupon rate the bonds of each country pay out. *Coupon freq* is the average frequency of coupon payments per year. *Price* is the average midprice of all bonds for each country. *Bid - Ask* is the average spread of bond transaction. *NOF* is the monthly-aggregated net order flow (buy minus sell orders) across all bonds issued by each country. *Total Vol.* is the monthly-aggregated total trading volume of governments bonds. In Panel A we also show the average bond maturity for each country. The sample period is from January 2, 2006 to May 31, 2011.

Panel A: All Maturities

Country	# Bonds	Coupon(%)	Coupon freq	Price	Bid - Ask	NOF(bil)	Total Vol.(bil)	Maturity
Austria	22	4.41	1.00	102.91	0.12	-0.11	1.62	6.97
Belgium	121	4.79	0.65	102.32	0.06	0.65	13.62	4.07
Finland	22	4.64	1.00	103.45	0.07	-0.27	2.09	4.44
France	408	4.19	0.70	104.92	0.12	0.47	15.30	4.67
Germany	218	4.07	0.82	105.22	0.09	0.03	8.39	4.37
Greece	71	4.85	0.93	102.84	0.09	-0.08	4.36	5.60
Ireland	39	4.51	0.81	102.11	0.08	-0.09	0.90	5.55
Italy	338	4.32	1.44	102.08	0.08	0.85	77.88	4.83
Netherlands	180	4.20	0.82	103.28	0.07	2.85	12.08	4.97
Portugal	69	4.51	0.71	100.08	0.06	-0.05	7.81	4.39
Spain	121	4.74	0.70	102.12	0.10	-0.14	7.27	4.28
Total	1609	4.38	0.89	103.33	0.09	0.37	13.76	4.75

Table 2: Price Discovery between Government Bond and Sovereign CDS Markets

In this table we show the contribution to price discovery generated by the CDS market. The contributions are measured by Hasbrouck information share (HAS mid) and Gonzalo-Granger permanent factor noted as GG, calculated from the vector error-correction model as below:

$$\begin{aligned}
\Delta CDS_t &= \alpha_1 + \lambda_1(CDS_{t-1} - Bond_{t-1}) + \beta_1 \sum_{i=1}^{p} \Delta CDS_{t-i} + \gamma_1 \sum_{i=1}^{p} \Delta Bond_{t-i} + \varepsilon_{1,t} \\
\Delta Bond_t &= \alpha_2 + \lambda_2(CDS_{t-1} - Bond_{t-1}) + \beta_2 \sum_{i=1}^{p} \Delta CDS_{t-i} + \gamma_2 \sum_{i=1}^{p} \Delta Bond_{t-i} + \varepsilon_{2,t}
\end{aligned}$$

We report the results for the whole sample and four subsample periods: *Period 1: Before the crisis* is from January 2006 to August 2008, *Period 2: Hedge fund crisis* ranges from September 2008 to July 2009, *Period 3: Sovereign debt crisis (Phase I)* is from August 2009 to May 2010, and *Period 4: Sovereign debt crisis (Phase II)* ranges from June 2010 to May 2011.

Country	Hasbrouck Middle					Gonzalo-Granger				
	Total	1	2	3	4	Total	1	2	3	4
Austria	0.96	0.57	0.90	0.57	0.68	0.87	1.07	0.74	0.54	1.81
Belgium	0.96	0.50	0.97	0.55	0.86	1.08	1.17	1.17	0.61	1.00
Finland	0.94	0.86	0.97	0.51	0.82	1.09	1.03	1.09	0.75	1.18
France	1.00	0.59	0.94	0.05	0.84	0.99	1.09	1.12	-0.30	0.77
Germany	1.00	0.77	0.94	0.07	0.93	0.97	1.05	0.88	-0.48	0.86
Greece	0.64	0.81	0.91	0.56	0.43	0.91	1.15	1.46	1.00	0.37
Ireland	0.97	0.98	0.96	0.73	1.00	1.12	1.01	1.02	0.50	0.98
Italy	0.83	0.86	0.89	0.80	0.56	0.91	1.10	0.84	0.18	0.55
Netherlands	0.99	0.65	0.95	0.23	0.74	0.96	1.08	0.91	0.49	0.77
Portugal	0.65	0.50	0.99	0.73	0.19	0.73	1.29	1.07	1.04	-1.82
Spain	0.90	0.55	0.98	0.82	0.77	1.23	1.26	0.96	0.51	1.06
Mean	0.89	0.70	0.94	0.51	0.71	0.99	1.12	1.02	0.62	0.68
Median	0.96	0.65	0.95	0.56	0.77	0.97	1.09	1.02	0.61	0.86

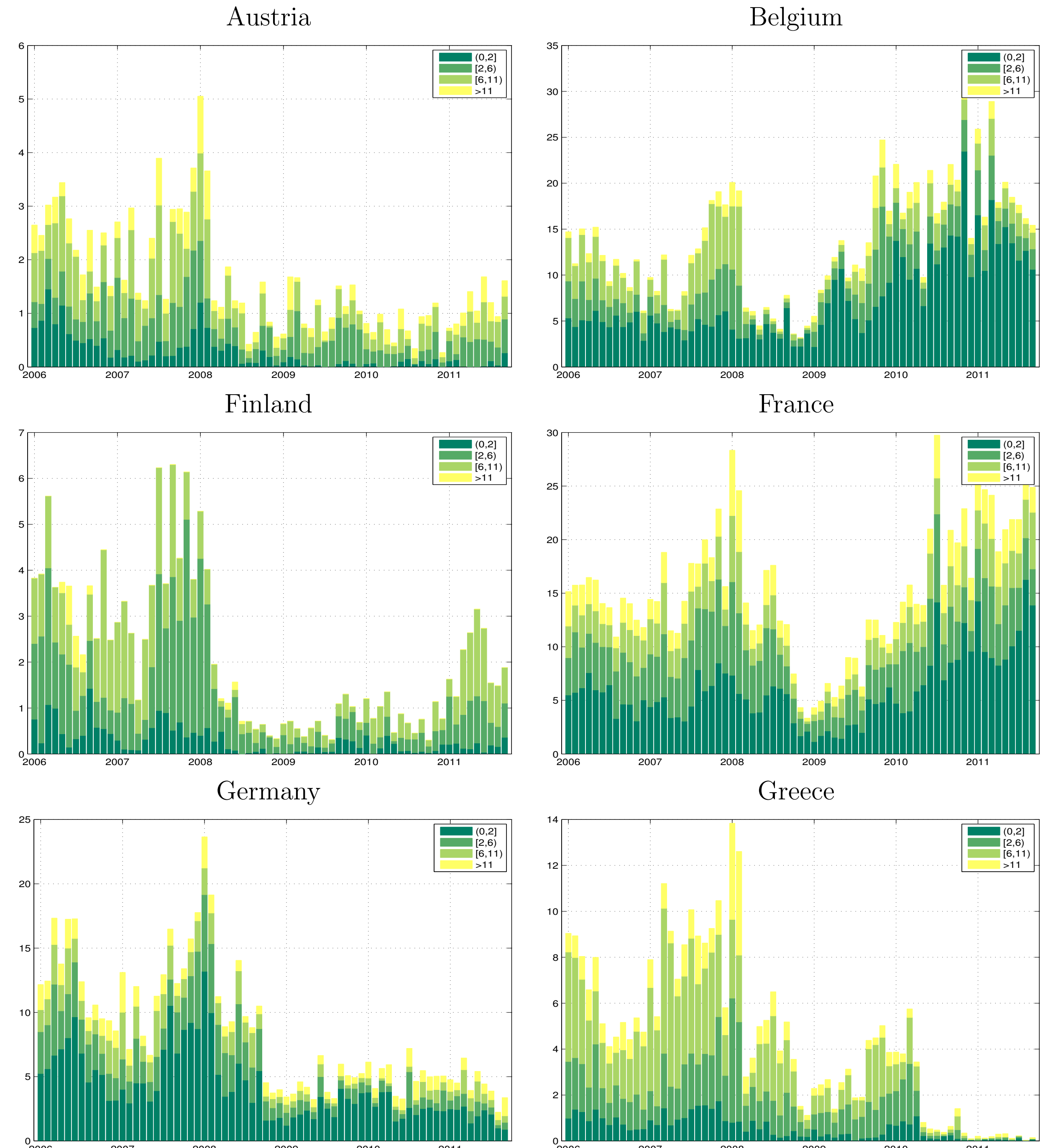


Figure 1: Trading Volume (in Billion Euros) in the European Government Bond Markets. The monthly trading volume is the sum of daily trading volume for all bonds issued by each country within each maturity category.

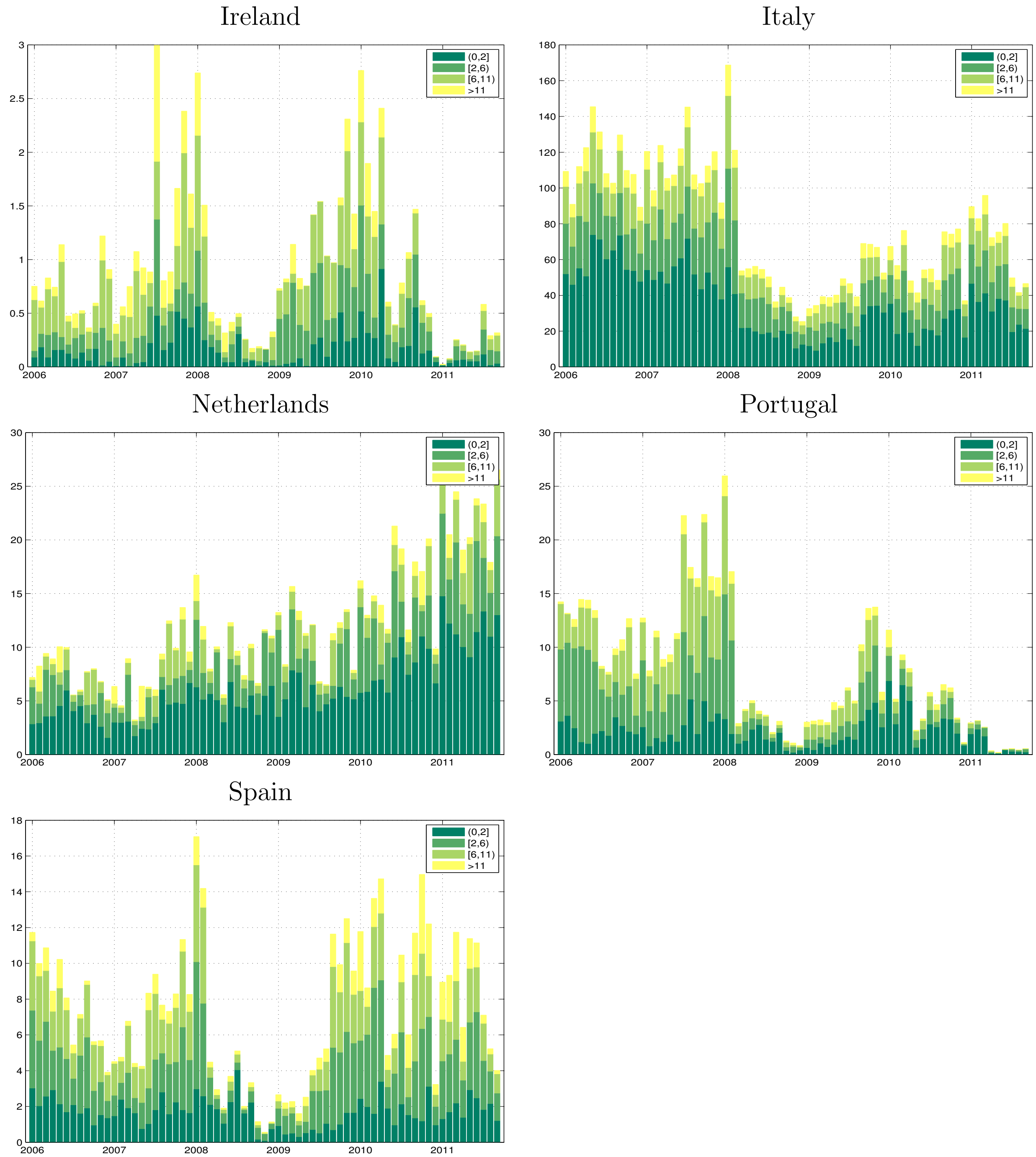


Figure 1 (Cont'd): Trading Volume (in Billion Euros) in the European Government Bond Markets. The monthly trading volume is the sum of daily trading volume for all bonds issued by each country within each maturity category.

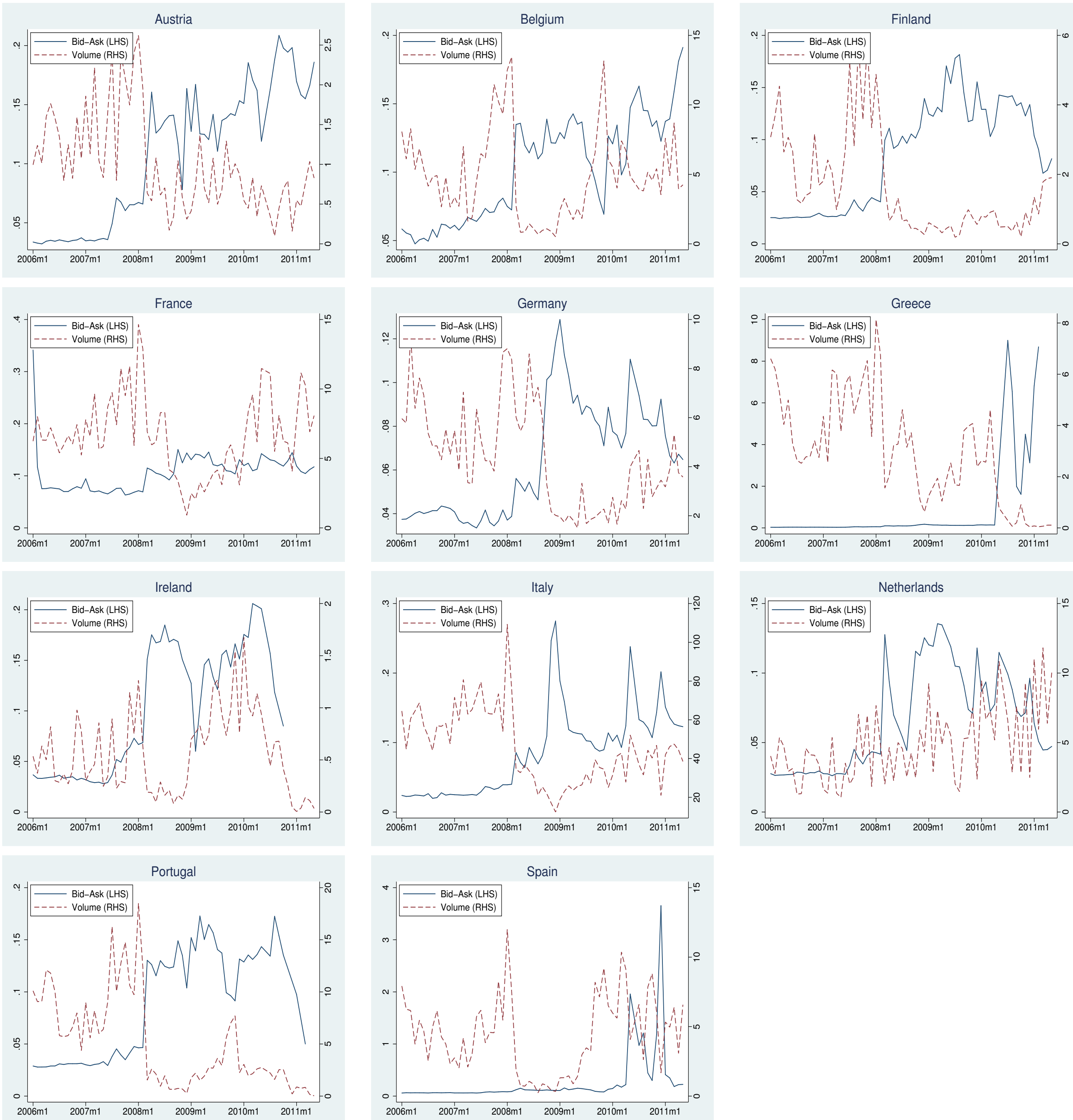


Figure 2: **Liquidity in the Government Bond Market.** *Volume* is the percentage of monthly average trading volume to total outstanding volume of all bonds issued by each country. *Bid-Ask* is the average bid-ask spread of all bonds. The sample period is from January 2006 to September 2011.

Figure 3: **Liquidity in the Government Bond and CDS Markets.** Liquidity in each market is measured by the percentage bid-ask spread, which is the average bid-ask spread divided by mid-price. Both bond and CDS have a maturity of five years. For a smooth illustration, we present the monthly average of liquidity from daily observations. The sample period is from January 2006 to September 2011.

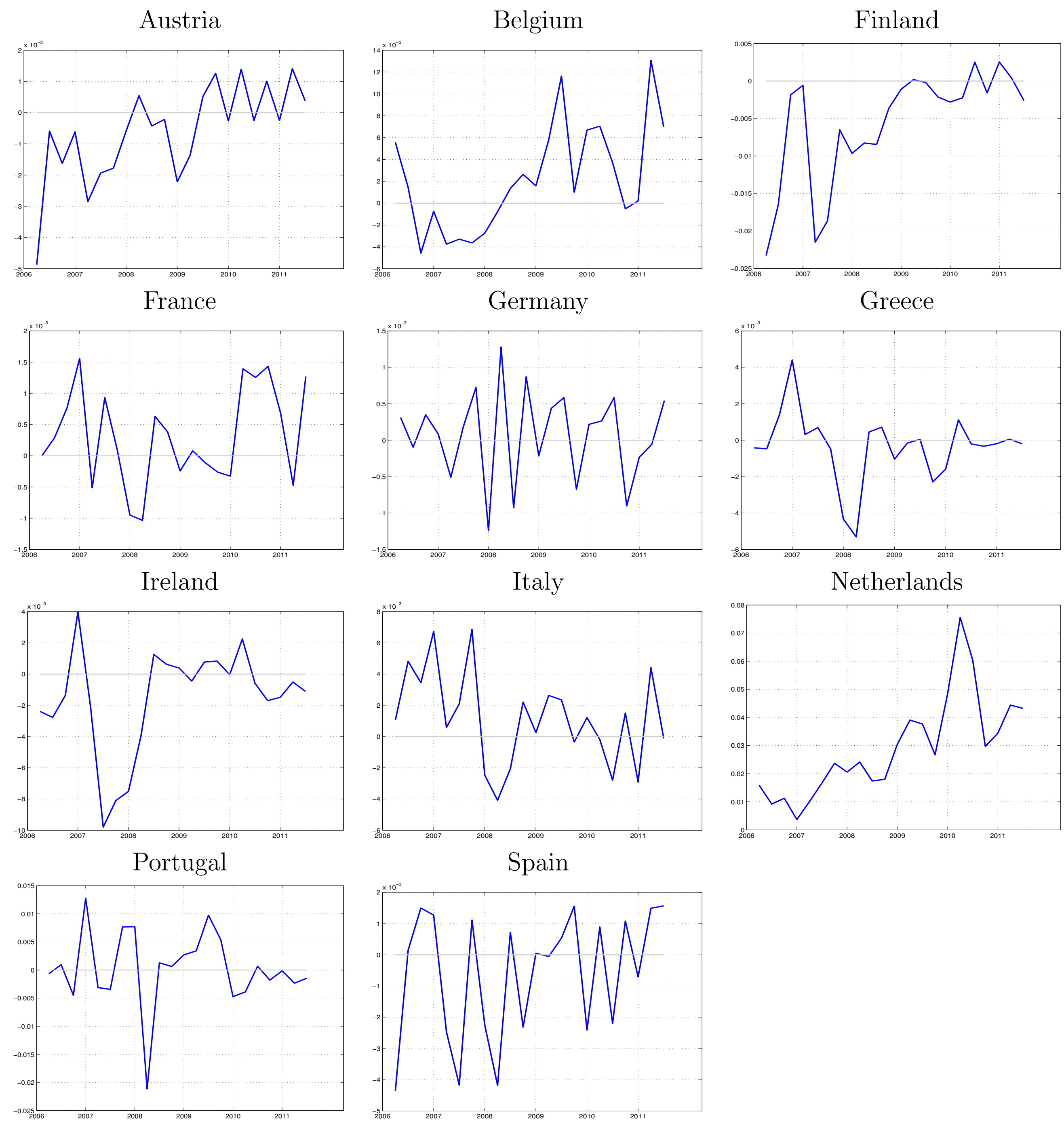


Figure 4: **Net order Flow (NOF) Ratio in the Government Bond Market.** *NOF Ratio* is the the percentage of imbalance of trade (buy minus sell orders) to the total bond outstanding issued by each country. A negative ratio indicates net selling pressure over the sample period. The sample period is from January 2006 to September 2011.

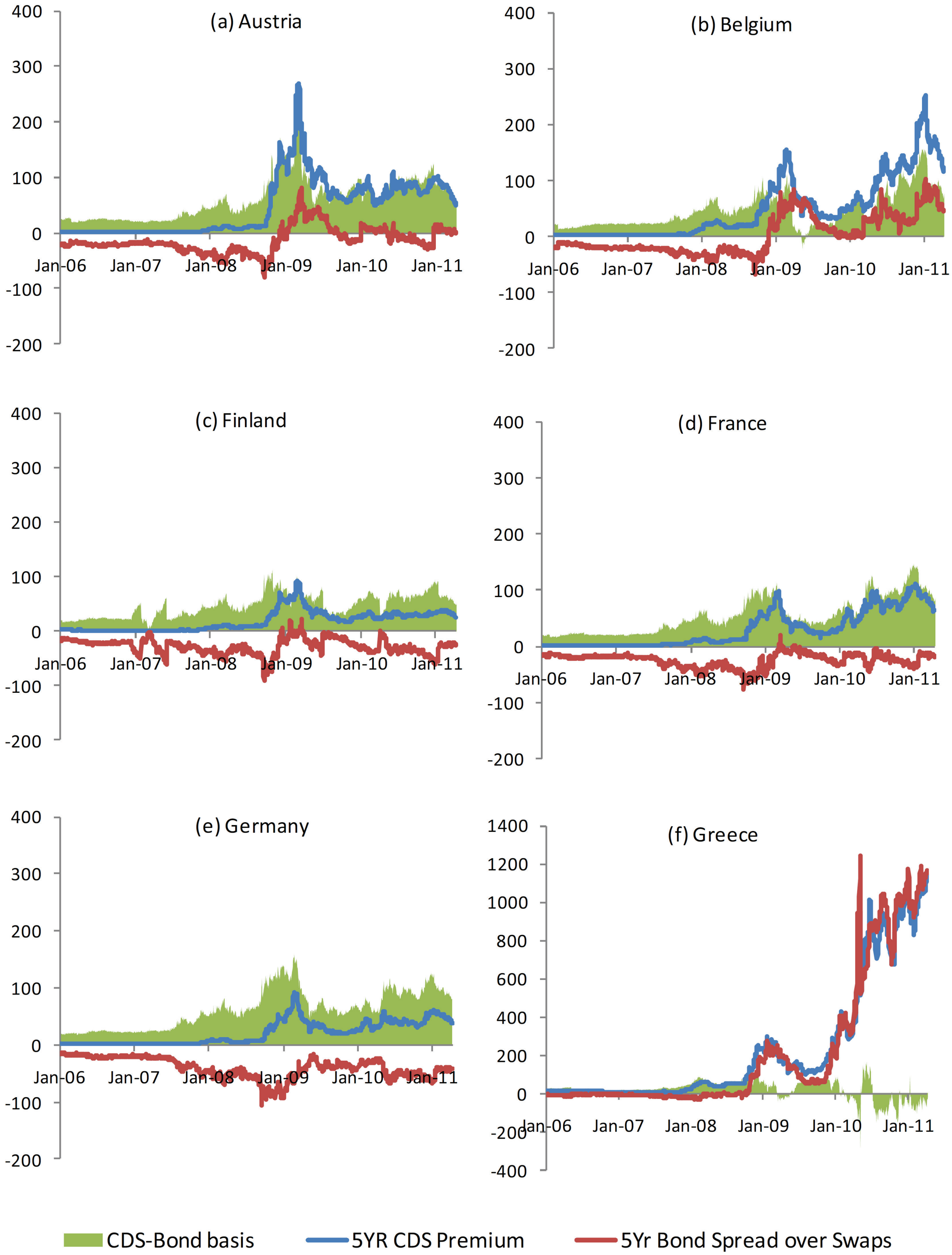


Figure 5: **The Sovereign CDS-Bond Basis** .

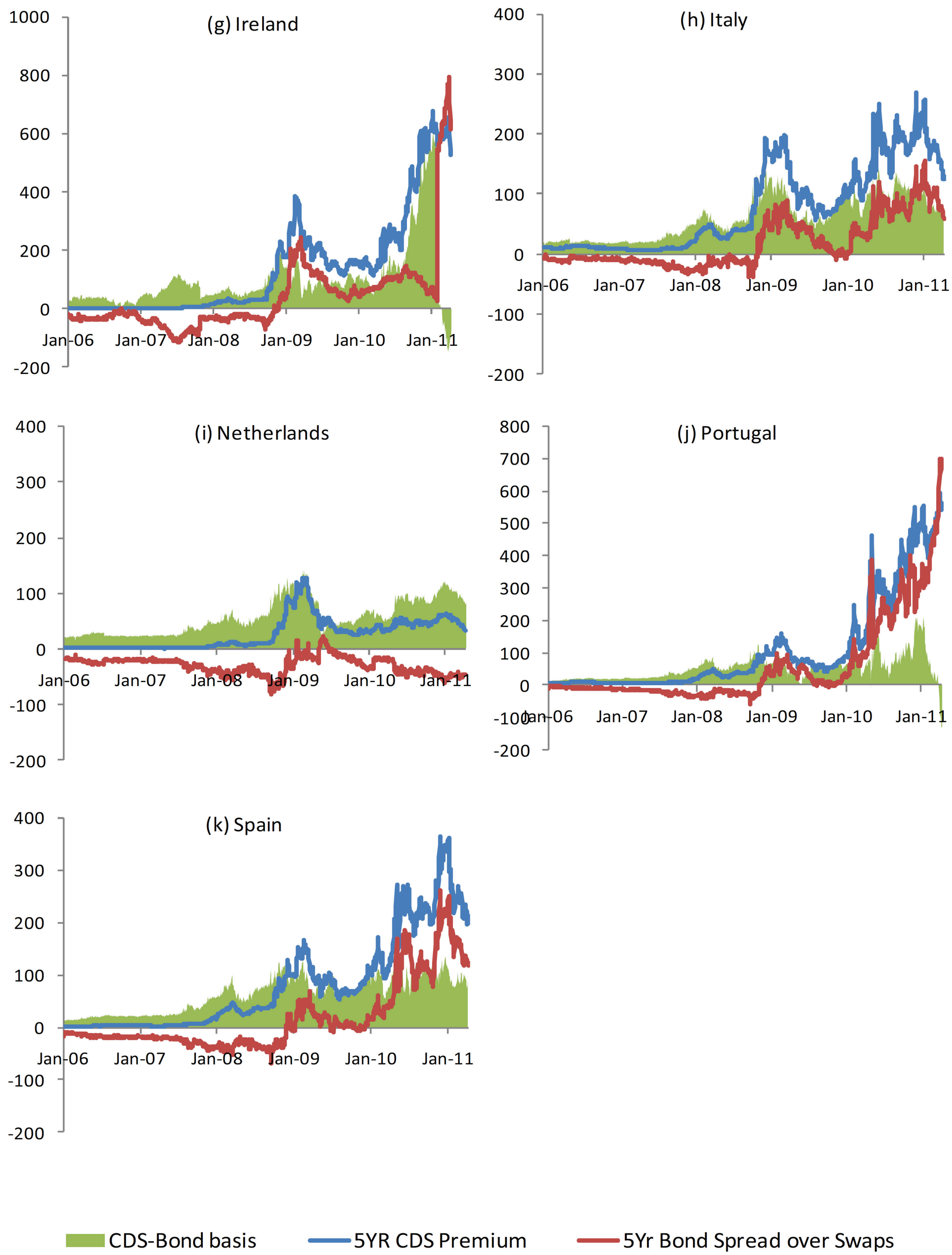
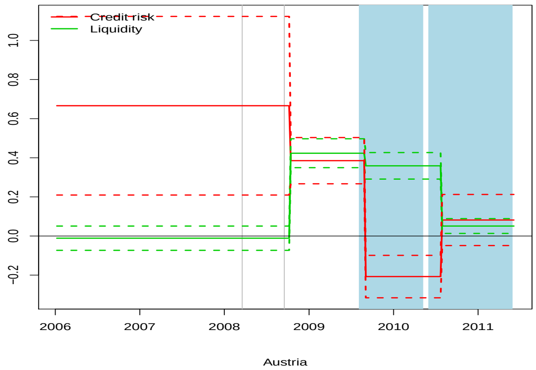
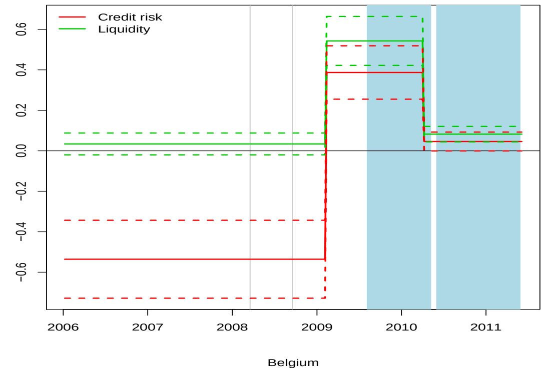


Figure 5 (Cont'd): **The Sovereign CDS-Bond Basis.**

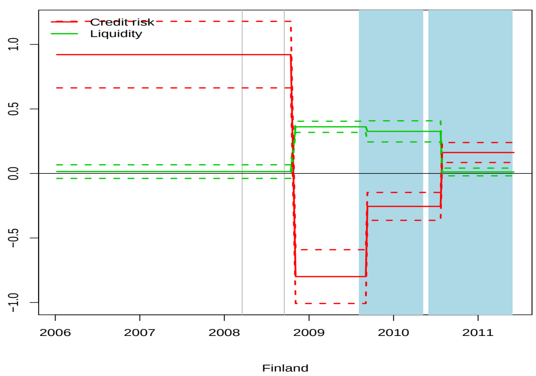
Austria



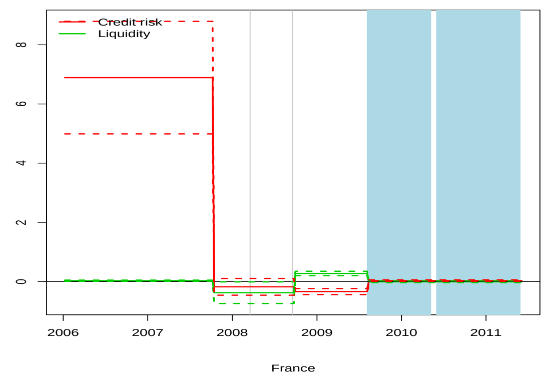
Belgium



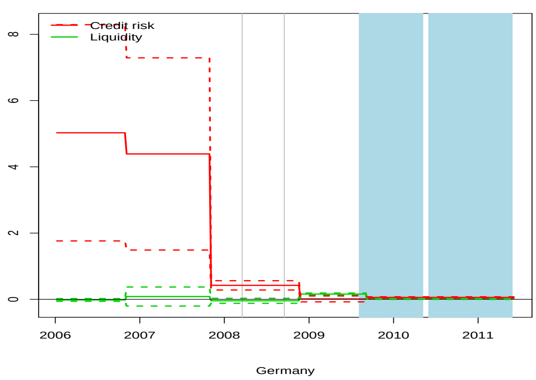
Finland



France



Germany



Greece

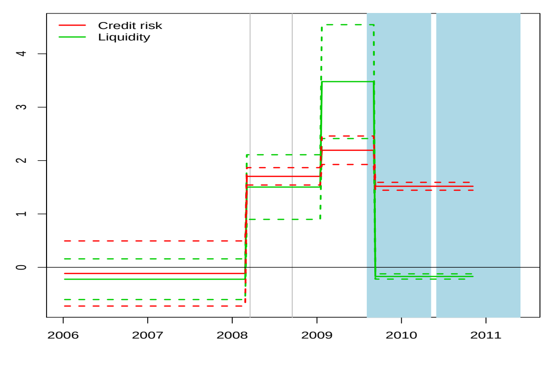


Figure 6: **Time series coefficients in Structural Break Regressions**

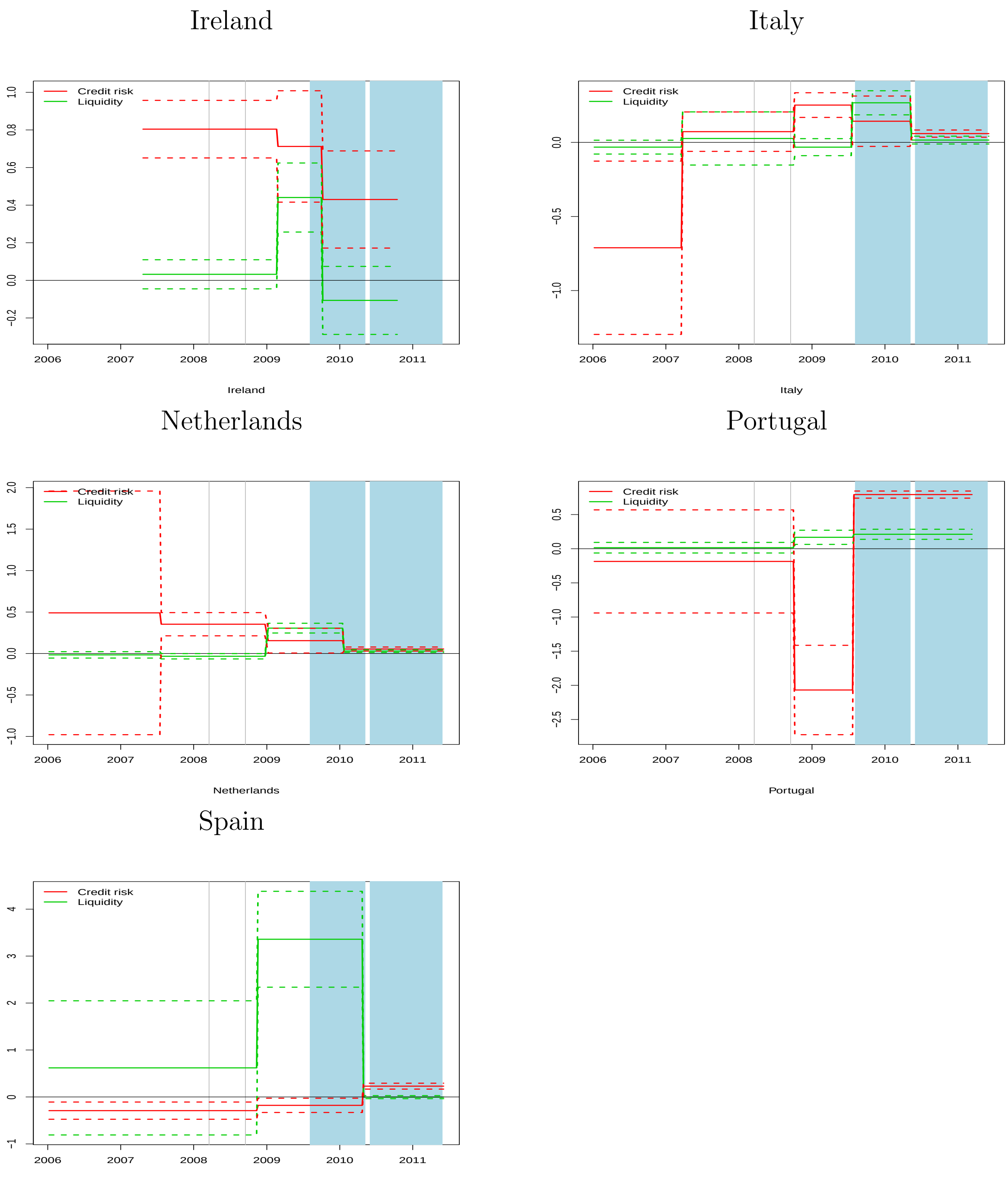


Figure 6 (Cont'd): **Time series coefficients in Structural Break Regressions**

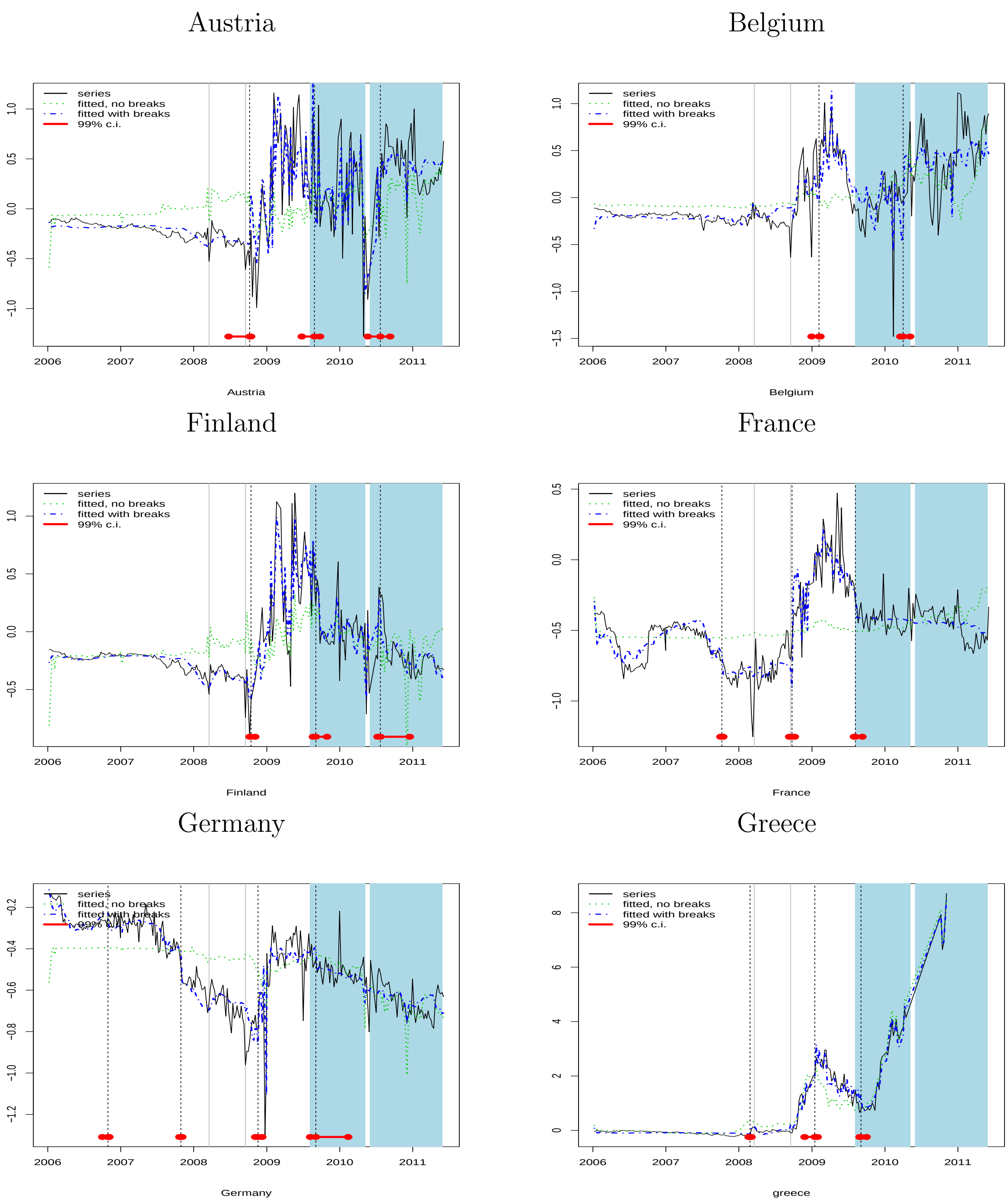


Figure 7: Structural Break Points Identification

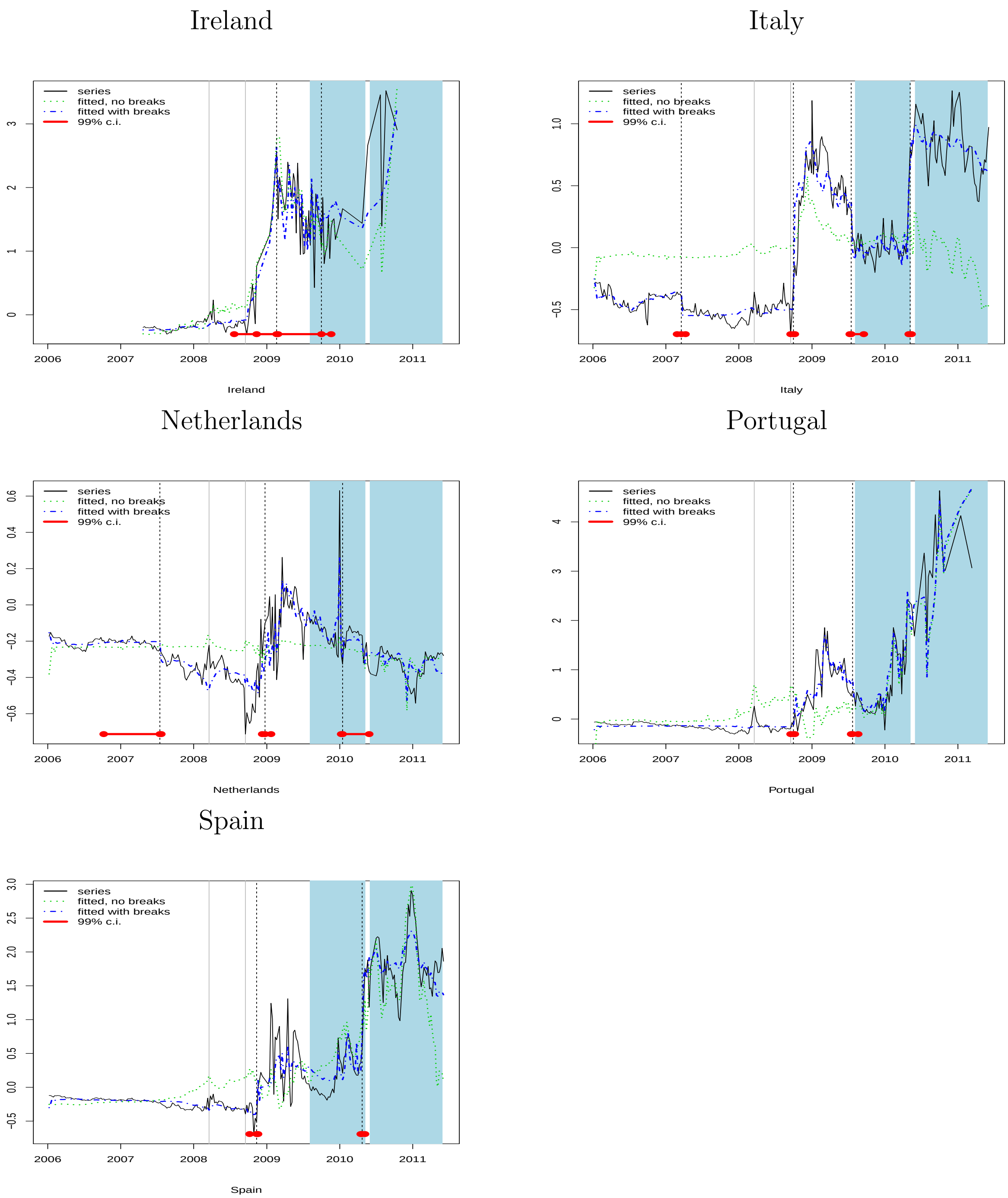


Figure 7 (Cont'd): Structural Break Points Identification