Eurozone Sovereign Bond Crisis: Liquidity or Fundamental Contagion

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Preliminary

Abstract

We study how liquidity and credit risks evolve in the eurozone sovereign bond markets since 2006. Through structural break analysis we find that bond spread variations during the early stage of the euro area sovereign debt crisis is mostly due to liquidity concerns, but after the late 2009 it is mostly credit risk driven. Through Structural VAR analyses we find a spillover from aggregate credit risk premium to individual country credit risk premia, from aggregate liquidity to individual country liquidity risk, and a flight-to-liquidity phenomenon associated with domestic liquidity shocks. We do not find, however, a feedback from aggregate or individual country's liquidity risk to a country's credit risk. These findings indicate that even though liquidity risk may be related to credit risk premium of a country, the eurozone sovereign bond crisis is predominately a contagion through the fundamental credit risk channel not through the liquidity risk.

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1 Introduction

In this paper, we investigate how variations in bond yields are affected by credit risk and liquidity risk in the euro area sovereign bond markets since 2006 in order to shed lights on the underlying causes of the European sovereign debt crisis. Is the recent euro area sovereign bond crisis similar to the emerging market crisis ignited by the Russian default in the late 1990s? Does the sovereign debt crisis spread 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 observe any feedback between credit risk and liquidity?

These are important questions as a casual observation of the spillover of the Greek government debt crisis to Spain, Portugal, and Italy indicates that there might be a feedback loop between fundamental credit risk and liquidity. That is, liquidity may dry up when a country is facing fundamental problems – liquidity traders may withdraw their investments in the euro area due to worsening fundamentals. The deterioration of liquidity can further adversely affect the refinancing operations of countries, especially those highly depending on short-term debt and facing rollover risks, which in turn exacerbates the country's likelihood of default, signaled by widening CDS spread. Again the feedback between credit risk and liquidity may have a systematic (or contagious) aspect due to the common currency denomination. The existence of this feedback loop is often considered as one of the main rationales for ECB to intervene as the spread of liquidity crisis across Europe may have real consequence on the fundamentals of the Euro.

In this paper we empirically test for the existence of fundamental and liquidity channels for the yield spread before and during the European sovereign bond crisis. To guide the empirical analysis, we present a simple theory model to capture both effects on the bond prices and show how the existence of the feedback effect, may cause price to overreact to aggregate and idiosyncratic fundamental shocks, and may even overact to liquidity shocks. In our model, fundamental contagion may exist because country fundamentals are correlated. Liquidity contagion could occur since market makers might reduce market-making activities throughout increased adverse selection. Our model also shows the potential feedback from credit risk to the (il)liquidity of the bond and vice versa.

Empirically we test the model by first decomposing the bond yield spread into fundamental-driven credit risk component and liquidity risk component, and analyze how the influence of the two components evolves over time, and how the relation between credit risk and liquidity changes over time. Specifically, we estimate structural breaks in the linear relationship between a country's bond spreads with its liquidity and credit risk components. This allows us to assess the main drivers of the European sovereign bond spreads over time. To test for the spillover and shed lights on the feedback loops, we conduct a Structural VAR (S-VAR) analyses to study the impact of fundamental-related and liquidity-related shocks at both individual country level and euro area aggregated level, and correlate these shocks with the ECB intervention to analyze the role the intervention has played.

Our findings on liquidity to some extent are surprising but intuitive. We find via the structural break analyses that liquidity starts to play a minor role in bond yield determination after the Lehman bankruptcy in 2008, but the role of liquidity is quickly reduced since the late 2009. That is, during the early stage of the European sovereign debt crisis, the Euro sovereign premia are largely characterized by liquidity risk, but at the later stage the fundamental credit risk is the main driver of bond yield spreads.

To delve deeper, our S-VAR analysis studies the interplays of liquidity shocks and fundamental credit shocks that are originated either domestically or in aggregated foreign countries. First, we substantiate a significant contagion effect through the fundamental channel in both directions: (i) domestic credit shocks in Belgium, Greece, Ireland and the Netherlands – that is, sources of fundamental crisis in these countries – tend to have significant effects on the aggregated credit shocks in other European countries; (ii) foreign credit shocks also tend to generate a positive and significant reaction of domestic CDS premia for Ireland, Italy, Portugal and France (marginal), indicating a foreign to domestic contagion channel for fundamental shocks.

Second, we also verify a significant contagion effect through the aggregate liquidity channel. Domestic liquidity seems to react significantly to foreign liquidity shocks in eight out of eleven countries: Austria, Belgium, France, Greece, Ireland, Italy, the Netherlands and Portugal, and for all these countries a reduction in foreign liquidity maps into a domestic liquidity contraction. This also indicates the existence of aggregate liquidity factor in European sovereign bond markets.

Third, our evidence betokens a flight-to-liquidity phenomenon associated with domestic liquidity shocks. Domestic liquidity shocks in Greece, Ireland, Italy, Portugal, Spain, and the Netherlands – that is, the sources of liquidity dry outs – tend to have significant but negative effect on the aggregated liquidity shocks in all other euro area countries.

Lastly, our S-VAR analysis flags the limited role played by liquidity during the European sovereign bond crisis. For example, we do not find that domestic liquidity shocks have any significant effect on domestic or foreign credit risk. In few limited cases, we find that foreign aggregate liquidity shocks have significant but negative effects on domestic credit risk. Overall, we have not found significant feedback from liquidity to fundamental credit risk shocks in the European sovereign markets, which have been used as one of motivations for the ECB interventions.

This set of results, in particular the lack of feedback from liquidity shocks to fundamental credit shocks in the S-VAR analysis and the limited role played by liquidity in our structure break analysis, signify that the European sovereign bond crisis is less a liquidity crisis but rather a crisis fomented by common as well as country-specific fundamentals. However, an alternative interpretation of this result is that the heavy liquidity injection of ECB may have stopped the European sovereign crisis becoming a liquidity crisis but have not stopped the contagion from the fundamental channel. To shed lights on this alternative interpretation, we retrieve the CDS and liquidity innovations from the S-VAR analysis and examine how the ECB intervention co-moved with various types of shocks. We find that the ECB interventions were associated with periods of increased likelihood of sovereign defaults in the euro area as the correlation between the ECB interventions and aggregate foreign credit shocks are statistically significant in nine cases out of ten. By contrast, we find only two significant cases for the correlation between the ECB interventions and aggregate foreign liquidity shocks. Overall, our results indicate that whatever the motivation for the ECB interventions, such action mainly functions through the credit channel by reversing the effects of fundamental shocks to the eurozone countries rather than providing liquidity to the sovereign bond markets.

The structure of the paper is organized as follows. In Section 2, we lay out a simple model to motivate the empirical analysis. In Section 3, we introduce the empirical methodologies on structural breaks and S-VAR. In Section 4, we describe the data and variable constructions. We report our empirical findings in Section 5 and study the role of ECB intervention in Section 6. A summary and conclusion section completes the paper.

2 The Model and Testable Hypotheses

In this section, we provide a stylized model in order to motivate the empirical analysis on the feedback and spillover effects between credit risk and liquidity risk across European sovereign bond markets.

We consider a one-period economy with three assets, a risk-free bond and two risky assets. The risk-free bond can be thought as the numéraire asset with a price of one and the return rate of zero. The risky asset indexed by i is the risky bond issued by sovereign country i. The risky asset indexed by f is the risky sovereign bond index in the euro area. We assume that the payoff of each asset is as follows,

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

$$\tilde{v}_f = \tilde{f} + \alpha_i \tilde{\epsilon}_i + \gamma p_f \tag{2}$$

where $\tilde{v}_i$ and $\tilde{v}_f$ denote the final period payoff of each asset, $\tilde{f}$ is aggregate fundamental credit risk in the euro area, and $\tilde{\epsilon}_i$ is country i's 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. For expositional clarity, we set $\bar{f}$ to zero so that we do not carry a constant in all the price expressions. The coefficient β_i measures sovereign country i's loading on the euro area aggregate risk. The coefficient α_i is the Euro's area's exposure to country i's risk.[1]

We use p_i and p_f to denote the bond prices for sovereign i and the average euro area. Coefficient γ is positive and measures the feedback effect from price to its fundamental value. This is to capture the fact that the lower the bond price, the harder it is for a

[1]The factor structure in the payoff functions follows that in Dittmar and Yuan (2008). In Dittmar and Yuan (2008), the log bond price payoffs are expressed as an exponential affine function and have a standard factor structure, which is common in the fixed income literature. Here, we can interpret prices as the log bond prices.

country to refinance in the bond market for debt rollover or other fiscal budgetary needs. From the above set of equations, we also observe that the two risky assets are exposed to the same fundamental risks. Hence, the equilibrium prices of the two risky assets co-move due to correlated fundamentals. However, the magnitude of this co-movement may exceed the correlation in the underlying fundamentals due to the trading environment, causing the spillover in prices as we will show later.

Now we turn to the trading environment. We assume that there are two types of traders: noise traders and informed traders. Among noise traders, we model the demand from the ones who trade in asset i as $\sigma_y \tilde{y}$ and the demand of noise traders in asset f as $\sigma_z \tilde{z}$. The parameters σ_y and σ_z are positive. The random variables $\tilde{y}$ and $\tilde{z}$ are normally distributed with mean zero and standard deviation of one.

Among informed traders there are ones who are only informed about $\tilde{\epsilon}_i$, the country i specialists, and the ones who are only informed about $\tilde{f}$, the eurozone aggregate specialists. These specialists are risk-neutral. They trade in both asset i and asset f to hedge out the risk they are less informed in order to reduce the adverse selection. That is, the country i specialists submit a market order $x^i(\tilde{\epsilon}_i)$ for a portfolio $\tilde{v}_i - \beta_i \tilde{f}$ which is priced at $p_i - \beta_i p_f$. This portfolio does not contain any exposure to $\tilde{f}$ directly (other than the feedback effect) and allows the country i specialists to (partially) avoid trading against traders who are informed about $\tilde{f}$ and create a trading strategy aligned with their information on $\tilde{\epsilon}$. Similarly, the eurozone aggregate specialists submit a market order $x^f\left(\tilde{f}\right)$ for a portfolio $\tilde{v}_f - \alpha_i \tilde{v}_i$ which is priced at $p_f - \alpha_i p_i$. Yuan (2005) has shown formally that this is optimal trading strategy for heterogeneously informed traders. Here we take this portfolio strategy as given and solve for optimal portfolio size. We denote the demand for asset i and f from the country i specialists as x_i^i $(= x^i)$ and x_f^i $(= -\beta_f x^i)$ and from the eurozone specialists as x_i^f $(= -\alpha_i x^f)$ and x_f^f

$(= x^f)$.

Finally the market makers set prices for both assets based on order flows for asset i, q_i and for asset f, q_f. That is:

$$p_i = E\left[\tilde{v}_i | q_i, q_f\right], \tag{3}$$

$$p_f = E\left[\tilde{v}_f | q_i, q_f\right], \tag{4}$$

where $q_i = x_i^i + x_i^f + \sigma_y \tilde{y} = x^i - \alpha_i x^f + \sigma_y \tilde{y}$ and $q_f = x_f^i + x_f^f + \sigma_y \tilde{y} = x^f - \beta_i x^i + \sigma_y \tilde{y}$. Note that the market makers use the order flows from both markets to set prices. This, and the informed traders' portfolio strategies potentially could cause fundamental and liquidity contagion as we demonstrate later.

We use the following notion of noisy rational expectations equilibrium (henceforth REE).

DEFINITION 1: An equilibrium of our model is consisted of the following strategies $x^i(\tilde{\epsilon}_i)$ and $x^f\left(\tilde{f}\right)$, price functions $p_i(q_i, q_f)$ and $p_f(q_i, q_f)$, such that

- Given the price functions, informed investors solve

$$\max_{x^i} E\left[\left(\tilde{v}_i - \beta_i \tilde{v}_f - (p_i - \beta_i p_f)\right) x^i | \tilde{\epsilon}_i\right] \text{ or } \max_{x^f} E\left[\left(\tilde{v}_f - \alpha_i \tilde{v}_i - (p_f - \alpha_i p_i)\right) x^f | \tilde{f}\right] \tag{5}$$

- Given x^i, x^f, market-makers set the prices based on (3) and (4) to clear the market.

Next we proceed to solve for the REE. A re-organisation of (3) and (4) yields the following:

$$p^i \equiv p_i - \beta_i p_f = E\left[\tilde{\epsilon}_i | q_i, q_f\right] = E\left[\tilde{\epsilon}_i | \frac{q_i + \alpha_i q_f}{1 - \alpha_i \beta_i}\right], \tag{6}$$

$$p^f \equiv p_f - \alpha_i p_i = E\left[\tilde{f} | q_i, q_f\right] = E\left[\tilde{f} | \frac{\beta_i q_i + q_f}{1 - \alpha_i \beta_i}\right], \tag{7}$$

where

$$q^i \equiv \frac{q_i + \alpha_i q_f}{1-\alpha_i\beta_i} \quad = \quad x^i + \frac{\sigma_y \tilde{y} + \alpha_i \sigma_z \tilde{z}}{1-\alpha_i\beta_i} \tag{8}$$

$$q^f \equiv \frac{\beta_i q_i + q_f}{1-\alpha_i\beta_i} \quad = \quad x^f + \frac{\beta_i \sigma_y \tilde{y} + \sigma_z \tilde{z}}{1-\alpha_i\beta_i} \tag{9}$$

Given this new characterization and the above equilibrium notion, we have the following result via the first order conditions of the informed traders' objective function and projection theorem.

Proposition 1: There exists a linear equilibrium with $p^i = \lambda^i q^i$, $p^f = \lambda^f q^f$, $x^i = a\tilde{\epsilon}$ and $x_f = b\tilde{f}$ where

$$\lambda^i \quad = \quad \frac{\sigma_\epsilon \left(1-\alpha_i\beta_i\right)}{2(1-\gamma)\sqrt{\sigma_y^2 + \alpha_i^2\sigma_z^2}}, \quad a = \frac{\sqrt{\sigma_y^2 + \alpha_i^2\sigma_z^2}}{\sigma_\epsilon \left(1-\alpha_i\beta_i\right)}$$

$$\lambda^f \quad = \quad \frac{\sigma_f \left(1-\alpha_i\beta_i\right)}{2(1-\gamma)\sqrt{\beta_i^2\sigma_y^2 + \sigma_z^2}}, \quad b = \frac{\sqrt{\beta_i^2\sigma_y^2 + \alpha_i^2\sigma_z^2}}{\sigma_f \left(1-\alpha_i\beta_i\right)}$$

The above set of results show that fundamentals such as the factor loading α_i and β_i affect the market liquidity as measured by the Kyle λs, indicating fundamentals may affect liquidity. Further, given the equilibrium solution, we can express the exposure of the price functions to various shocks.

$$2\left(1-\gamma\right)\left(1-\alpha_i\beta_i\right)p_i =$$

$$\underbrace{\tilde{\epsilon}+\beta_i\tilde{f}}_{\text{Fundamental Shocks}} + \underbrace{\left(\frac{\sigma_\epsilon}{\sqrt{\sigma_y^2+\alpha_i^2\sigma_z^2}} + \frac{\beta_i^2\sigma_f}{\sqrt{\beta_i^2\sigma_y^2+\sigma_z^2}}\right)\sigma_y\tilde{y}}_{\text{Liquidity Shocks}} + \underbrace{\left(\frac{\alpha_i\sigma_\epsilon}{\sqrt{\sigma_y^2+\alpha_i^2\sigma_z^2}} + \frac{\beta_i\sigma_f}{\sqrt{\beta_i^2\sigma_y^2+\sigma_z^2}}\right)\sigma_z\tilde{z}}_{\text{Foreign Aggregate Liquidity Shocks}}$$

$$2\left(1-\gamma\right)\left(1-\alpha_i\beta_i\right)p_f =$$

$$\underbrace{\tilde{f}+\alpha_i\tilde{\epsilon}}_{\text{Fundamental Shocks}} + \underbrace{\left(\frac{\alpha_i\sigma_\epsilon}{\sqrt{\sigma_y^2+\alpha_i^2\sigma_z^2}} + \frac{\beta_i\sigma_f}{\sqrt{\beta_i^2\sigma_y^2+\sigma_z^2}}\right)\sigma_y\tilde{y}}_{\text{Aggregate Liquidity Shocks}} + \underbrace{\left(\frac{\alpha_i^2\sigma_\epsilon}{\sqrt{\sigma_y^2+\alpha_i^2\sigma_z^2}} + \frac{\sigma_f}{\sqrt{\beta_i^2\sigma_y^2+\sigma_z^2}}\right)\sigma_z\tilde{z}}_{\text{Country Liquidity Shocks}}$$

The above equations show that when $0 < \gamma < 1$, $0 < \alpha_i < 1$, $0 < \beta_i < 1$, it is possible to have both fundamental and liquidity spillover between the two markets since the sensitivities of the prices to the underlying shocks $\tilde{\epsilon}$, $\tilde{f}$, $\tilde{y}$ and $\tilde{z}$ are magnified. The extent of liquidity contagion additionally depends on the parameters of factor loadings α_i and β_i as well as the volatility of the market noise trading σ_y and σ_z. In the empirical part of the paper, we investigate the spillover effects of fundamental and liquidity risk across markets.

3 Methodology

3.1 Bond Yields and Structure Break

We analyze the relationship between bond yield spreads, credit risk, and bond market liquidity, and allow this relationship to vary over time. In particular, for each country, we consider a linear regression of sovereign bond yields in excess of the Euro-denominated swap rate with the same maturity,[2] on (a) the average bid-ask spread across all bonds for a given country in excess of the average bid-ask spread across all bonds for other countries at a given time, and (b) the five-year sovereign CDS for a given country in excess of the average CDS spread across all other countries at a given time.[3] We allow this relationship to change over time by considering structure breaks in the regression.

We identify break dates using country specific linear regressions in which we allow for m break points (where 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

[2] 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. 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 various maturities.

[3] 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.

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 $\theta_i \in \Theta \subset \mathbb{R}^{(m+1)\times \dim \beta_j}$. 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 above 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 departures from stationarity 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 vector autoregression (S-VAR) approach to identify spillover effects of liquidity and credit shocks within and across countries. That is, we ask the data wether credit shocks have a tangible effect on bonds' liquidity, whether liquidity shocks have significant effects on credit risk, and wether these shocks propagate across countries.

In particular, we consider a setting with five types of shocks: *i*) foreign credit shocks, ε^{cf}, *ii*) domestic credit shocks, ε^{c}, *iii*) net order flow shocks (i.e. rebalancing shocks), ε^{nof}, *iv*) foreign liquidity shocks, and *v*) domestic liquidity shocks, ε^{l}. These shocks are assumed to jointly drive the behavior of five quantities:

- x^{cf}: foreign credit risk as the average CDS spread excluding the underlying country;
- x^{c}: domestic credit risk as the CDS spread of the underlying country;
- x^{nof}: net order flow ratio as the percentage of imbalance of trade (buy minus sell orders) to the total outstanding of government bonds issued by the underlying country;
- x^{lf}: foreign liquidity risk as the average bid-ask spread of bond prices excluding the bonds issued by the underlying country;
- x^{l}: domestic liquidity risk as the bid-ask spread of bond price of the underlying country.

For each country, the resulting S-VAR is

$$\Gamma_0 \underbrace{\left[x_t^{cf}, x_t^{c}, x_t^{nof}, x_t^{lf}, x_t^{l}\right]'}_{\equiv X_t} + \Gamma(L) X_{t-1} = \gamma + \underbrace{\left[\varepsilon_t^{cf}, \varepsilon_t^{c}, \varepsilon_t^{nof}, \varepsilon_t^{lf}, \varepsilon_t^{l}\right]'}_{\equiv \varepsilon_t} \sim N(0, I) \tag{12}$$

where Γ_0 is a full rank matrix capturing the contemporaneous interactions among variables, $\Gamma(L)$ is a square matrix of polynomials of order p in the lag operator L (i.e. $\Gamma(L) \equiv \Gamma_1 + \Gamma_2 L^1 + ... + \Gamma_{p+1} L^p$), γ 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 S-VAR system can be rewritten in reduced form as

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

where $B(L) \equiv -\Gamma_0^{-1}\Gamma(L) = B_0 + B_1 L + ... + B_p L^p$ and $c = \Gamma_0^{-1}\gamma$. The reduced form gives in c and $B(L)$ as many parameters as in γ and $\Gamma(L)$. 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 $(n+1)\,n/2$ free elements in $\Gamma_0^{-1}\left(\Gamma_0^{-1}\right)'$ while Γ_0 has n^2 free elements. This means that if we want to identify the structural parameters we need at least $(n-1)\,n/2$ (linearly independent) 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 spreads since, in the long run, the latter should be pinned down only by economic fundamentals, rather than by short run portfolio rebalancing; *ii*) transitory domestic shocks should have no effect in the very long run on foreign variables.

This set of restrictions can be imposed on the S-VAR by rewriting it in its moving average form

$$X_t = k + A(L)\,\varepsilon_t \sim N(0, I) \tag{14}$$

where $k \equiv [\Gamma_0 + \Gamma(L)L]^{-1}\gamma$, $A(L) \equiv [\Gamma_0 + \Gamma(L)L]^{-1} = A_0 + A_1 L + A_2 L^2 + \ldots A_\infty L^\infty$. The above mentioned restrictions imply that $A(1) \equiv A_0 + A_1 + A_2 + \ldots$ is a lower triangular matrix, therefore giving us exactly the $(n-1)\,n/2$ (linearly independent) restrictions needed to recover the S-VAR coefficients from the reduced form VAR in equation (13). To see this note that

$$X_t = [I - LB(L)]^{-1} c + [I - LB(L)]^{-1} v_t = [I - LB(L)]^{-1} c + D\varepsilon_t$$

where $D \equiv [I - B(1)]^{-1}\,\Gamma_0^{-1}$, with $B(1) = B_0 + B_1 + \ldots + B_p$, must be lower triangular given the above identifying restriction. Note also that

$$DD' = [I - B(1)]^{-1}\,\Omega\,[I - B(1)]^{-1\prime} \text{ (since } \Omega = \Gamma_0^{-1}\left(\Gamma_0^{-1}\right)'\text{)}, \tag{15}$$

implying that the $\widehat{DD'}$ matrix can be constructed from the OLS estimates $\hat{B}(L)$ and $\hat{\Omega}$ of the reduced form VAR in equation (13). Therefore, performing a Choleski decomposition of $\widehat{DD'}$

(i.e. imposing the lower triangular structure on D) we can recover $\widehat{D}$ from the reduced form estimates, and recover an estimate of the Γ_0 matrix from $\hat{\Gamma}_0^{-1} = \left[I - \hat{B}(1)\right]\hat{D}$. Finally, given $\hat{\Gamma}_0$, we can recover the other structural coefficients, $\Gamma(L)$ and γ, from $\hat{\Gamma}(L) = -\hat{\Gamma}_0\hat{B}(L)$ and $\hat{\gamma} = \hat{\Gamma}_0\hat{c}$, where $\hat{c}$ denotes the reduced form VAR estimate.

Note also that under our identification restrictions, conditional on knowing $B(L)$ and Ω, we have that Γ_0 and $\Gamma(L)$ are deterministic matrices. This implies that, under a (diffuse) Jeffrey's 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 reduced 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).

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 economy, and the behavior they model implicitly includes dynamics arising from revisions in the forecasting rules and regime changes (as well as other sources of dynamics). As a consequence, a S-VAR 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 Summary Statistics

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, the bid/ask CDS price, and European Central Bank's Securities Market Purchase program (SMP)data are downloaded from Bloomberg. The sample period for our study is from January 2, 2006 to May 31, 2012 in a daily frequency. This time period provides a good platform to study the behavior of European government bond markets before and during 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 2012 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 due to 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, trading volume, order flow, and average bid-ask spread in the daily frequency. The key variable in our study is the government bond yield calculated from 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.

The MTS data is compiled from two different interdealer markets, the EuroMTS and the 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 list 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

Sovereign credit default swap is a financial derivative contract which functions as an insurance against credit events that happen to 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.

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 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. 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 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.

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. Given that 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 the proxy of general liquidity in the sovereign CDS market.

4.3 Descriptive Statistics

Table 1 presents bond characteristics in the European government bond market. There are overall 1612 bonds issued by eleven countries in our sample. In terms of bond number, France has the largest bond market with 408 bonds and Italy is the second for 341 bonds. In terms of trading volume, Italy is the largest European bond market with an average monthly trading volume of €72.69 billions, whereas France is next to Italy, with €15.00 billions trading volume on average per month. The market also observes large trading transactions for countries like Germany, Netherlands, and Belgium. The average remaining time-to-maturity in our bond sample is 6.19 years. The average coupon rate is 4.35 percent, and the average transaction price is 103.65, close to par value. In terms of net order flow ratio on average, Austria, Finland, Greece, Ireland, Portugal, and Spain observe the negative selling pressure.

[Table 1 about here.]

Panels B in Table 1 also show the summary bond characteristics across countries for bonds with time-to-maturity of $(0, 2], (2, 4], (4, 6], (6, 8], (8, 11]$, and $(11, \infty)$ years. There exists a heterogeneity of bond characteristics across countries as well as over various maturities. Here we summarize three interesting findings. First, the very short-term bond with on average (0,2]-year maturity is most traded in the European bond market with a monthly trading volume of €5.51 billions; the next most traded bonds are those with (8,10]-year (€2.12 billions), then with (2,4]-year time-to-maturity (€2.08 billions). Second, the long-term bond category which has time-to-maturity of more than ten years has the widest bid-ask spread, say 0.26, whereas the short-term bond category has the narrowest bid-ask spread, that is 0.01. 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 (4,6]-year bond category, measured by the net order flow (buy minus sell orders), whereas the very short-term bond with maturity less than two years observes a buying pressure with net order flow of €0.31 billion.

[Figure 1 about here.]

Figure 1 provides detailed picture of the time-series trading volume for each country and across bond maturities. Echoing the summary statistics in Table 1, Italy, France, Belgium, Netherlands observe large trading in their government bonds, whereas Austria, Finland, and Ireland see far less trading in their bonds. Moreover, the time-series plots suggest a sharp narrowing in trading position after the Lehman's bankruptcy in the late 2008 for almost all countries, except the Netherlands whose bonds are traded in a continuing increasing pattern. What's most striking, is that the government bond market of Greece and Ireland dried up since 2011, only having sparse trading activities.

[Figure 2 about here.]

To better understand the liquidity of government bonds in European countries, we show liquidity measures further in Figure 2. Figure 2 illustrates the percentage of monthly average trading volume to total outstanding volume of all bonds issued by each country on the right axis, and the average bid-ask spread of all bonds on the left axis. Overall, European countries bond bid-ask spreads have all increased since the subprime crisis in the late 2007. Second, a series of liquidity-easing effort by European Central Bank seems to have different impact on core and peripheral countries. For core European countries such as France, Germany, Netherlands, Austria, Belgium and Finland, their bond bid-ask spreads only narrowed for short periods but rebounded back afterwards and reached the all time high points by the end of 2011. For peripheral countries such as Greece, Ireland, Portugal, and Spain, their bond bid-ask spreads narrowed down to a level even lower than the spreads during the financial crisis of 2008-2009. Meanwhile, these peripheral countries trading volume over total outstanding bond volume also went down to the level lower than the ones before the crisis. Such findings indicate that trading in peripheral government bonds became thin while trading liquidity wasn't affected much. These puzzling findings may result from the ECB's intensive liquidity intervention with a particular target on peripheral countries' government bonds.

[Figure 3 about here.]

Finally, we show the net order flow ratio in Figure 3. NOF ratio is the percentage of imbalance of trade (buy minus sell orders) to the total bond outstanding issued by each country. A negative ratio suggests net selling pressure over the sample period. To minimize the noise in daily order flow data, we aggregate the net order flow information to monthly number and scale them by the total bond outstanding. We then report the quarterly moving average value in Figure 3. Unlike the flight-to-quality expectation that trading flows into countries like Germany and France, we didn't find convincing evidence. Rather we observe a continuing flow-in to the Netherlands' bond market. Also unlike the expectation of outflow from troubled countries such as Greece and Portugal, we neither find consistent negative net order flow in these two countries. One possible explanation is that trading in these two markets already dried up, let alone any outflow.

Beyond these unconditional observations, we will conduct formal statistical tests on the flight-to-liquidity and flight-to-quality effect as well as the credit and liquidity feedback effect in the next section.

In the rest of this paper, the fundamental shocks are synonymous to CDS shocks. That is, instead of using macro fundamental variables which tend to be low-frequency, we choose to use a market price for the fundamental, in this case, CDS spread. In Table 2, we provide some basic macro indicators for the countries in our sample: GDP growth rate, current account, total debt, deficit, as the percentage of GDP.

[Table 2 about here.]

5 Empirical Results

5.1 Bond Yield Spread Decomposition

Using the methodology described in Section 3.1, we study the relative importance of the credit and liquidity risk channels in determining sovereign bond yields. That is, for each country, we regress bond yields in excess of the Euro-denominated swap rate on the average bid-ask spread across all bonds in excess of the average bid-ask spread across all other countries, and the country CDS in excess of the average CDS spread across all other countries. To make the regression coefficients of the liquidity and credit variables comparable, we standardize the regressors so that they have unit variance in each of the subsample identified by the structure breaks.

[Figure 4 about here.]

The time series of the coefficients, together with 95% confidence bands, are reported in Figure 4. In each panel of the Figure we also mark the Bear Stearns's collapse (March 2008), the Lehman Brothers bankruptcy (September 2008), as well as the first (August 2008 to April 2010) and second (May 2010 to May 2011) waves of the sovereign debt crisis. Comparing the results across countries, some clear patterns emerge.

First, in the aftermath of Lehman Brother's bankruptcy (somehow with delay for Italy), the relevance of liquidity in determining sovereign bond yields increases significantly for all countries. Moreover, for nine out of eleven countries, liquidity becomes the main determinant of bond yields (the only exceptions are Greece, for which CDS is always the dominant element, and Ireland for which the relative importance of the two channels is roughly the same in this period), whereas liquidity does not play any significant role before the Lehman event for all countries (Greece again is special, in which liquidity starts to become significant since the Bear Sterns event).

Second, after the last structure break (that, depending on the country, occurs either toward the mid of the first wave of the debt crises or at the beginning of the second wave), the CDS component becomes the main determinant of yield spreads for 9 countries out of 11, while for the countries for which this is not the case, the CDS and liquidity coefficients are statistically indistinguishable in magnitude. Moreover, in this period, for 10 out of 11 countries we observe an increase of the relevance of the CDS channel relative to the liquidity channel.

Overall, these results suggest that the first wave of the sovereign debt crisis was likely triggered by liquidity, while the second wave of the crisis seems to be driven by the fundamental credit risk of sovereign debt. The notable exception to this pattern is Greece, for which the the main driver of the yield spread, before and during the crisis, seems to have always been the country credit risk.

5.2 Spillover Effects of Liquidity and Credit Shocks

From the SVARs impulse-response function (henceforth IRF), and their 90% posterior intervals, we find a rich set of spillovers.

Liquidity Shocks Spillovers. There is a significant spillover of international liquidity shocks to domestic liquidity in eight out of eleven countries, as show in Figure 5. In particular, domestic liquidity seems to react significantly to foreign liquidity shocks in Austria, Belgium, France, Greece, Ireland, Italy, the Netherlands and Portugal, and for all these countries a reduction in foreign liquidity maps into a domestic liquidity contraction. Moreover, this effect tend to be very persistent.

[Figure 5 about here.]

Also, foreign liquidity shocks tend to have a significant effect on domestic credit risk in the SVARs estimates of Austria, Belgium, and the Netherlands, as show in Figure 6.[4] This conditional response is negative, suggesting increasing illiquidity shocks (widening bid-ask spread refers to higher illiquidity risk) outside these countries leads to the decreasing of the CDS spreads in these countries, a flight-to-quality type phenomenon associated with international liquidity shocks.

[4]This effect is only marginal and sparse for Ireland. Judging from the overall performance, we don't think this effect holds for Ireland.

[Figure 6 about here.]

Domestic liquidity shocks also have a significant effect on foreign liquidity in the following six countries: Greece, Ireland, Italy, Portugal, Spain, and the Netherlands, as show in Figure 7. In all of these cases, the impulse-response functions are negative, suggesting a flight-to-liquidity phenomenon associated with domestic liquidity shocks.

[Figure 7 about here.]

We do not find supporting evidence of a spillover of domestic liquidity shocks to foreign CDS premia: only for one country (Ireland), the response of foreign CDS to a domestic liquidity shock is statistically different from zero, and only for limited periods.

Credit Shocks Spillovers. Domestic credit shocks tend to have a significant effect on both foreign liquidity (for Austria, France, Germany, and the Netherlands) as in Figure 8 and foreign CDS premia (for Belgium, Greece, Ireland and the Netherlands) as in Figure 9. All these impulse-response functions are positive, suggesting both a contagion effect of domestic to foreign fundamentals, and a fundamental to liquidity shock spillover (increasing domestic credit shocks leads to higher illiquidity risk). This latter phenomenon is also confirmed by a significant and persistent contraction of domestic liquidity in response to domestic CDS shocks (for Austria, France, Germany and the Netherlands).

[Figure 8 and 9 about here.]

Foreign CDS shocks also tend to generate a positive and significant reaction of domestic CDS premia for Ireland, Italy, Portugal and France (marginal), as shown in Figure 10, indicating a foreign to domestic contagion channel for fundamental shocks. Nevertheless, foreign CDS shocks have a significant effect on domestic liquidity in only one case (Ireland).

[Figure 10 about here.]

6 The ECB Intervention

The reduced form shocks and fundamental shocks (innovations) identified by our S-VAR approach can be used to analyze the nature of the ECB interventions in the European sovereign bond market. In particular, we ask whether the ECB actions tended to be associated with changes in market liquidity conditions, changes in fundamentals, or both.

With the deepening of European sovereign debt crisis, the ECB has conducted a series of interventions in order to boost the liquidity and restore the market confidence. Among those interventions, a direct action in euro area public and private debt securities markets is a large-scale asset purchase program targeted at peripheral European sovereign debt, which is called Securities Market Purchase programme (SMP).[5] The ECB characterized this programme as intended to restore proper market functioning and liquidity in peripheral bond markets, and therefore as part of an effort to re-establish an effective monetary transmission mechanism, rather than direct support for the governments themselves.

The first purchase under SMP started on May 10, 2010. However, the ECB did not announce the targeted countries, nor the country-allocation in the purchase or timeframe.

[5] In addition to the SMP programme, the ECB also introduced other non-standard monetary policy measures during the acute financial market intensions, including the reintroduction of full-allotment 3- and 6-month as well as the new introduction of 3-year long-term refinancing operations (LTROs), covered bond purchase programme I and II, and so on. These measures also helped maintain the financial stability in the European government bond market. However they importantly differs from the SMP programmem, in that they are not directly operated on the government bond market, rather through an indirect channel of supporting the banking sector. It's less possible to trace back such indirect channel to study the impact of the ECB interventions on sovereign bond markets. Therefore we focus on the SMP programme to complement our analysis on the credit and liquidity risk in the European government bond markets.

Anecdotal reports suggested that the early purchases seemed to be focused on debt issued by Greece, Portugal and Ireland, and till August 2011, the purchases started to include debt issued by Italy and Spain. The SMP settled volumes over each week is reported on Friday in ECB's Weekly Financial Statement. The SMP operation was regularly conducted every week throughout 2010, but was withdrawn in most time of the first half of 2011; it continued in August 2008 but again was conducted sparsely in the spring of 2012. As of August 24, 2012, the ECB has purchased €224.4 billion, of which €15.6 billion has matured. Of note, since the program was expanded in August 2011 to include debts issued by Italy and Spain, €146.8 has been purchased.

We retrieve the fundamental innovations (ϵ_t in equation (12))and reduced form shocks (v_t in equation (13)) from the S-VAR analysis reported in the previous section, and examine how the ECB interventions co-moved with the different types of shocks. The reason for analyzing the co-movement with both shocks and innovation is that reduced form shocks are a linear combination of the fundamental innovations. That is, for example, a reduced form shock to CDS could be generated by either a fundamental credit shock, a fundamental liquidity shock, or a combination of two shocks. By looking at the correlation of the ECB interventions and reduced form shocks, we can learn how the ECB interventions tended to co-move with unexpected changes in CDS and liquidity. While from the correlation of the ECB interventions and innovations, we can learn to which fundamental changes in the economy the ECB has been reacting to, or which changes the ECB has, possibly, generated with its own actions.

[Table 3 about here.]

Correlations of the ECB interventions with reduced form shocks are reported in Panel A of Table 3, while the correlations with the innovations are reported in Panel B. We do not report correlations for Ireland since we have insufficient data observations for this country.

The correlations between the ECB interventions and foreign credit shocks are statistically significant in nine cases out of ten, and the significant ones are very large: ranging from 0.46 to 0.61. These correlations are all positive indicating that the ECB interventions were associated with periods of increased likelihood of sovereign defaults in the euro area. We also find positive and statistically significant correlations between domestic CDS shocks and ECB interventions in Greece, 0.80, and Italy, 0.34.

In contrast with the strong correlations between the ECB interventions and credit shocks, we find a statistically significant correlation with foreign liquidity in only two countries. For nine out of ten countries, this correlation is negative, providing (weak, due to the lack of statistical significance in most cases) that the ECB interventions have increased the liquidity of the market. Similarly, the correlations between the ECB interventions and domestic liquidity is significant in only three cases.

These results suggest a strong link between foreign and domestic credit shocks and the ECB interventions, and a relatively weak one between the interventions and the market liquidity. Nevertheless, the strong link with the credit shocks does not necessarily imply that the ECB interventions have been mainly trying to counteract fundamental credit shocks, since reduced form credit shocks could be driven, in principle, by fundamental liquidity innovations. Panel B of Table 3 addresses this issue by reporting the correlations of ECB interventions and fundamental innovations.

The correlations between the ECB interventions and foreign credit innovations are positive in all cases, and statistically significant in seven out of ten cases, and generally very large. Moreover, the correlations with fundamental domestic credit shocks are also all positive, and statistically significant and large for five countries. On the contrary, the correlations between the ECB interventions and fundamental liquidity innovations are mostly not statistically significant and their signs are not stable.

Overall, these findings suggest that the ECB interventions have been blowing against the wind of fundamental shocks to the credit condition of the eurozone countries, rather than simply providing liquidity in the sovereign bond market.

7 Conclusion

In this paper, we examine how credit risk and liquidity risk evolve in the European sovereign bond market, especially during the recent sovereign debt crisis. We show 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. In addition, we cannot identify feedback effect from liquidity shocks to fundamental credit shocks in the structural VAR analysis. These findings signify that the European sovereign debt crisis is less a liquidity crisis.

Alternatively, we verify a significant spillover effect through the fundamental channel in both directions: (i) domestic credit shocks in Belgium, Greece, Ireland, and the Netherlands tend to have significant effects on the aggregated credit shocks in other European countries; (ii)foreign credit shocks also tend to generate a positive and significant reaction of domestic CDS premia for Ireland, Italy, Portugal and France (marginal). Moreover, fundamental credit risk component dominates the bond yield variation for most euro area countries when the sovereign debt crisis deepens. According to these combining results, we dispute the notion that the European sovereign bond crisis mainly propagates through the fundamental credit risk channel.

However, the short-lived liquidity effect might be due to the fact that ECB injected a large amount of liquidity in the Euro sovereign bond markets. Our investigation using the aggregate ECB intervention data argues that this alternative explanation may not stand. Although they are shown to improve the liquidity in the country-specific sovereign bond markets (albeit not statistically significant), the ECB interventions are evidenced to be highly linked with periods of increased likelihood of sovereign defaults in the euro area. Whatever the motivation for the ECB interventions, such actions mainly functions through the credit channel by reversing the effects of fundamental shocks to the eurozone countries rather than providing liquidity to the sovereign bond markets.

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Table 1: Summary Statistics of European Government Bond Market

This table presents summary statistics for European government bond markets. # *Bonds* is the total number of government bonds in each country. *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 mid-price 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. *Vol.* is the monthly-aggregated total trading volume of governments bonds. *TTM* show the average bond time-to-maturity for each country. The sample period is from January 2, 2006 to May 31, 2012. Data source: MTS.

Panel A: All Maturities

Country	# Bonds	Coupon(%)	Coupon Freq	Price	Bid-Ask	NOF(bil)	Vol.(bil)	TTM
Austria	22	4.39	1.00	103.20	0.12	-0.10	1.56	8.49
Belgium	121	4.75	0.66	102.42	0.07	0.64	13.73	4.79
Finland	22	4.53	1.00	103.92	0.08	-0.25	2.08	4.33
France	408	4.17	0.71	105.13	0.12	0.57	15.00	6.55
Germany	218	4.00	0.83	106.27	0.10	0.03	7.79	5.98
Greece	71	4.87	0.93	102.83	0.09	-0.08	4.02	7.39
Ireland	39	4.54	0.83	102.10	0.08	-0.09	0.82	5.56
Italy	341	4.32	1.47	101.91	0.09	0.59	72.69	6.39
Netherlands	180	4.13	0.83	104.02	0.08	2.87	12.45	6.43
Portugal	69	4.51	0.72	100.08	0.06	-0.04	7.03	5.12
Spain	121	4.70	0.70	102.08	0.10	-0.07	6.96	5.76
Total	1612	4.35	0.91	103.65	0.09	0.37	13.10	6.19

Panel B: Other Maturities

TTM	# Bonds	Coupon(%)	Coupon Freq	Price	Bid-Ask	NOF(bil)	Vol.(bil)
(0,2]	1310	4.18	0.51	99.80	0.01	0.31	5.51
(2,4]	306	4.11	1.16	102.74	0.05	0.02	2.08
(4,6]	234	4.18	1.13	103.93	0.07	-0.02	1.49
(6,8]	158	4.25	1.14	104.54	0.09	0.00	0.73
(8,10]	162	4.17	1.18	102.04	0.11	0.03	2.12
$(10,\infty)$	124	5.01	1.21	111.12	0.26	0.01	1.24

Table 2: Economic Outlook of European Countries

	GDP Growth Rate (%)					
	2006	2007	2008	2009	2010	2011
Austria	3.67	3.71	1.44	-3.78	2.05	2.70
Belgium	2.67	2.88	0.99	-2.78	2.42	1.78
Finland	4.41	5.34	0.29	-8.54	3.32	2.74
France	2.47	2.29	-0.08	-3.15	1.66	1.70
Germany	3.70	3.27	1.08	-5.13	4.16	3.03
Greece	5.54	3.00	-0.16	-3.25	-3.52	-6.91
Ireland	5.31	5.18	-2.97	-6.99	-0.43	0.71
Italy	2.20	1.68	-1.16	-5.49	1.80	0.43
Netherlands	3.39	3.92	1.80	-3.67	1.63	0.99
Portugal	1.45	2.37	-0.01	-2.91	1.40	-1.61
Spain	4.08	3.48	0.89	-3.74	-0.07	0.71

	Current Account / GDP (%)					
	2006	2007	2008	2009	2010	2011
Austria	2.79	3.51	4.88	2.72	3.00	1.95
Belgium	1.97	1.69	-1.64	-1.69	1.27	-1.06
Finland	4.09	4.07	2.61	1.81	1.32	-1.28
France	-0.58	-0.99	-1.75	-1.31	-1.57	-1.97
Germany	6.18	7.49	6.21	5.92	5.94	5.66
Greece	-11.26	-14.35	-14.69	-11.02	-9.96	–
Ireland	-3.54	-5.35	-5.67	-2.32	1.14	1.10
Italy	-2.57	-2.43	-2.88	-1.98	-3.48	-3.14
Netherlands	9.29	6.69	4.18	4.10	7.13	8.53
Portugal	-10.75	-9.92	-12.57	-10.73	-10.02	-6.65
Spain	-8.94	-9.98	-9.62	-4.82	-4.51	-3.49

	Total Debt / GDP (%)				
	2006	2007	2008	2009	2010
Austria	60.43	57.83	59.32	64.92	65.75
Belgium	87.57	85.30	90.09	94.89	96.79
Finland	35.56	31.20	29.45	37.55	41.68
France	52.13	52.12	53.41	61.23	67.42
Germany	41.23	39.55	39.55	44.21	44.40
Greece	107.68	105.67	110.62	127.02	147.84
Ireland	20.25	19.83	28.00	47.07	60.70
Italy	97.45	95.63	98.09	106.78	109.02
Netherlands	39.17	37.55	50.07	49.72	51.85
Portugal	67.73	66.62	68.88	78.73	87.96
Spain	32.97	30.02	33.70	46.03	51.69

	Deficit / GDP (%)					
	2006	2007	2008	2009	2010	2011
Austria	-1.67	-0.99	-1.00	-4.15	-4.48	-2.58
Belgium	0.31	-0.10	-1.03	-5.66	-3.93	-3.88
Finland	4.04	5.30	4.25	-2.74	-2.85	-0.86
France	-2.38	-2.75	-3.34	-7.56	-7.09	-5.19
Germany	-1.65	0.23	-0.06	-3.21	-4.28	-0.99
Greece	-6.01	-6.78	-9.93	-15.56	-10.50	-9.16
Ireland	2.92	0.06	-7.34	-14.02	-31.17	-13.03
Italy	-3.41	-1.59	-2.67	-5.37	-4.48	-3.82
Netherlands	0.52	0.16	0.49	-5.55	-5.00	-4.60
Portugal	-4.63	-3.21	-3.70	-10.17	-9.84	-4.24
Spain	2.37	1.92	-4.49	-11.18	-9.34	-8.52

Source: OECD

Table 3: Correlations of Credit and Liquidity Shocks and Innovations with ECB Interventions.

This table reports the correlation results of leading innovations or shocks from the SVAR analysis with the ECB intervention. To avoid overlapping information, we choose innovation or shock as of the current Wednesday while choose SMP data as of last Friday, shown in the below regression:

$$(\text{Innovation or Shock})_{t,3} = \alpha + \beta SMP_{t-1,5} + \varepsilon_t.$$

The result for Ireland is not reported due to insufficient observations in the regression. The sample is at weekly frequency, spanning the period of May 14, 2010 to May 31, 2012.

Panel A: Reduced Form Shocks

	Foreign Credit		Domestic Credit		Net Order Flow		Foreign LIQ		Domestic LIQ	
	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t
Austria	**0.51**	3.78	0.14	0.88	-0.19	-1.25	-0.16	-1.02	**-0.53**	-4.02
Belgium	**0.49**	3.66	0.05	0.30	-0.10	-0.67	-0.05	-0.31	-0.25	-1.70
Finland	**0.51**	3.81	0.25	1.65	**-0.30**	-2.05	-0.13	-0.86	**0.31**	2.08
France	**0.50**	3.77	0.18	1.18	0.15	0.98	-0.20	-1.33	**0.47**	3.44
Germany	**0.54**	4.16	-0.05	-0.29	0.09	0.56	-0.14	-0.91	-0.09	-0.60
Greece	**0.61**	2.30	**0.80**	4.03	-0.16	-0.50	0.49	1.67	0.02	0.07
Ireland	–	–	–	–	–	–	–	–	–	–
Italy	**0.50**	3.74	**0.34**	2.34	-0.05	-0.32	-0.07	-0.46	-0.09	-0.58
Netherlands	**0.53**	4.06	0.14	0.94	-0.07	-0.47	**-0.37**	-2.60	0.22	1.49
Portugal	0.13	0.61	0.11	0.53	0.49	2.62	**-0.40**	-2.06	-0.18	-0.85
Spain	**0.46**	3.37	0.27	1.79	-0.03	-0.17	-0.06	-0.40	-0.29	-1.95

Panel B: Innovations

	Foreign Credit		Domestic Credit		Net Order Flow		Foreign LIQ		Domestic LIQ	
	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t
Austria	**0.53**	4.04	**0.34**	2.31	0.03	0.21	0.11	0.70	**-0.37**	-2.57
Belgium	**0.40**	2.81	**0.38**	2.63	0.24	1.60	0.18	1.16	-0.16	-1.06
Finland	**0.50**	3.75	0.16	1.02	0.25	1.64	0.36	2.50	**0.32**	2.19
France	**0.54**	4.21	0.11	0.72	0.12	0.76	0.23	1.53	**0.35**	2.44
Germany	**0.56**	4.41	0.17	1.12	0.14	0.94	0.29	1.94	0.26	1.78
Greece	0.33	1.04	**0.77**	3.57	**0.56**	2.03	-0.19	-0.58	-0.27	-0.84
Ireland	–	–	–	–	–	–	–	–	–	–
Italy	**0.50**	3.72	0.14	0.93	-0.01	-0.05	0.18	1.17	0.16	1.06
Netherlands	**0.61**	5.05	**0.31**	2.14	0.21	1.41	0.06	0.37	0.23	1.53
Portugal	0.03	0.15	0.04	0.17	**0.41**	2.10	-0.36	-1.78	-0.03	-0.14
Spain	0.24	1.61	**0.46**	3.33	0.01	0.09	-0.07	-0.46	-0.11	-0.73

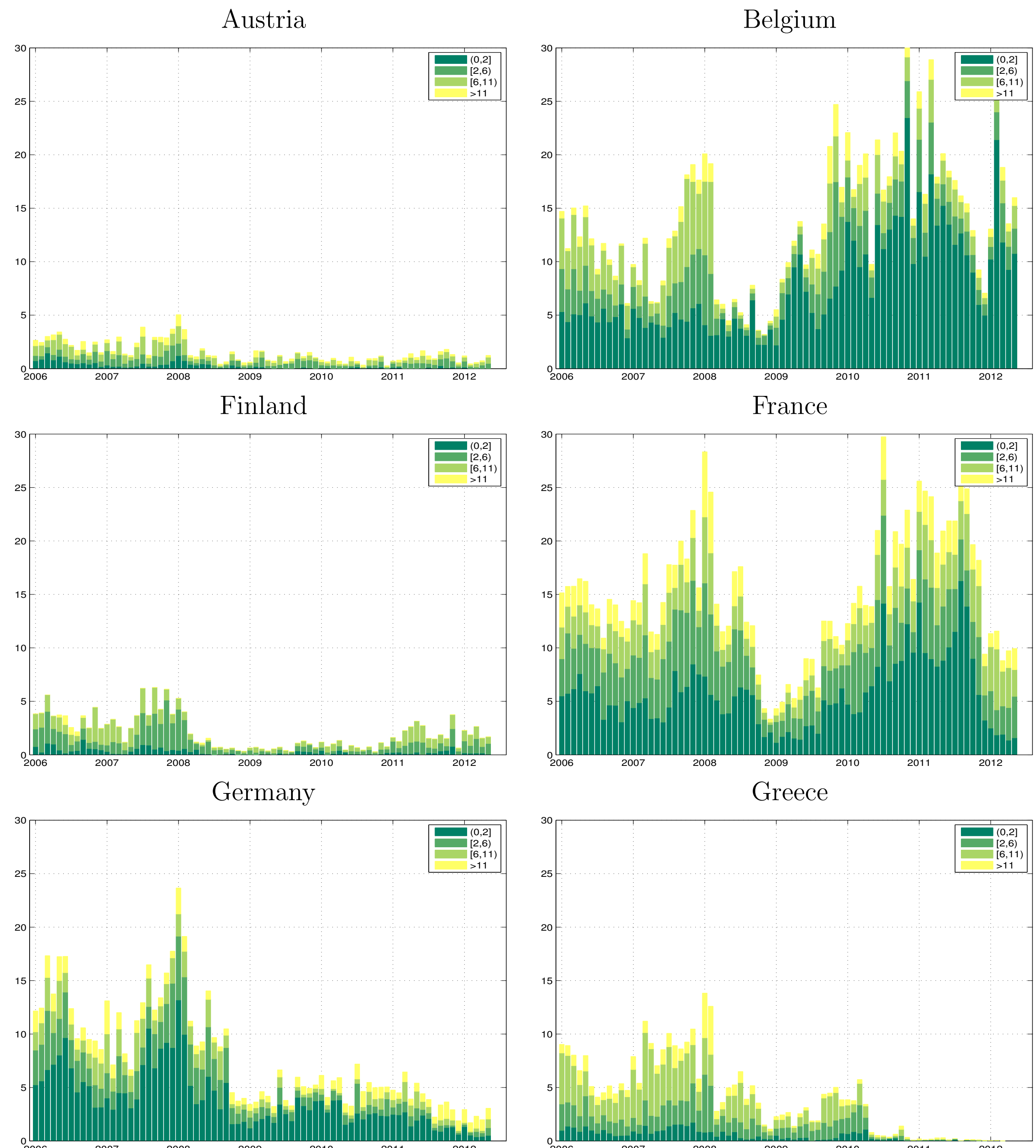


Figure 1: Trading Volume (in Billion Euros) in the European Government Bond Markets. The monthly trading volume is the sum of daily trading volume for all bonds issued by each country within each maturity category.

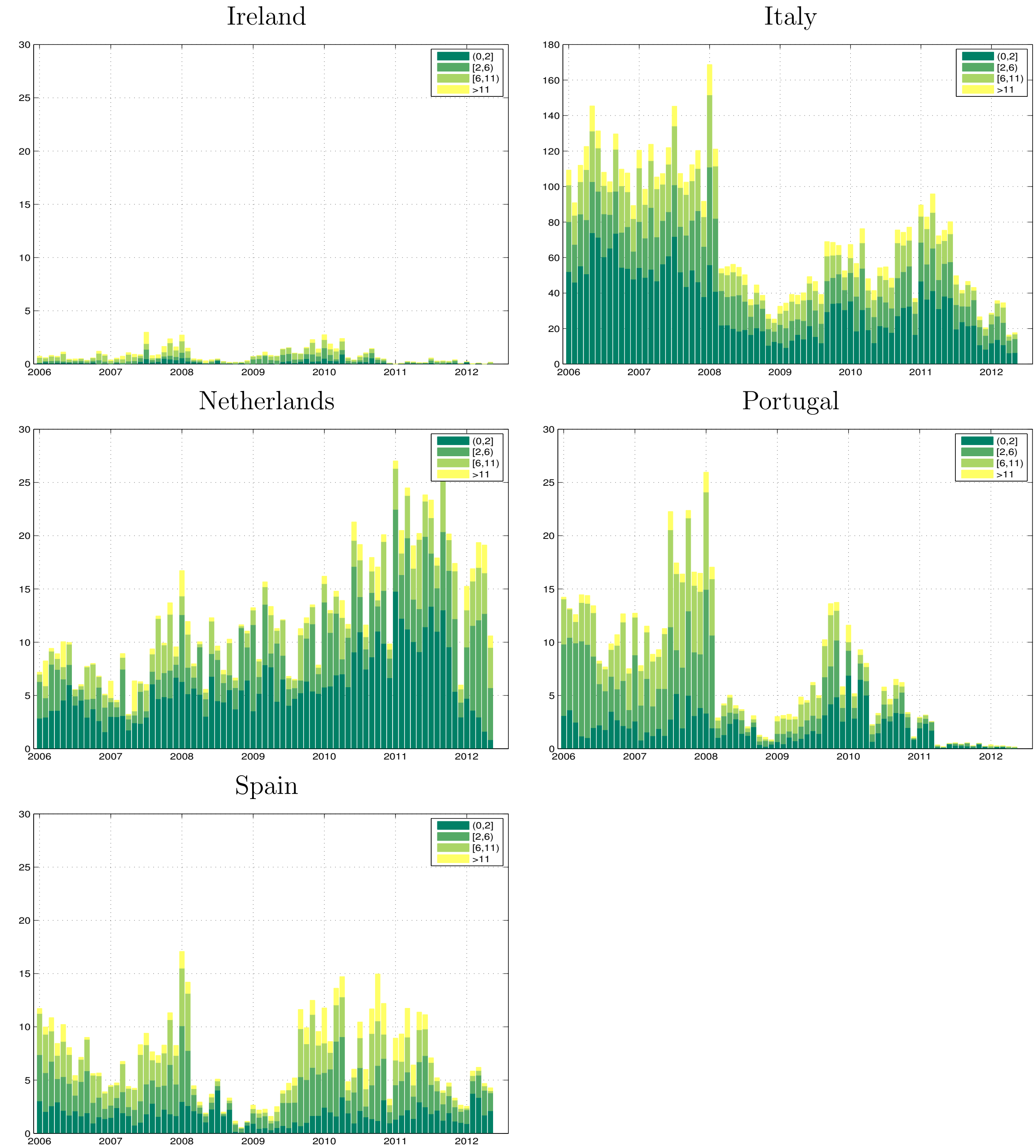


Figure 1 (Cont'd): Trading Volume (in Billion Euros) in the European Government Bond Markets. The monthly trading volume is the sum of daily trading volume for all bonds issued by each country within each maturity category.

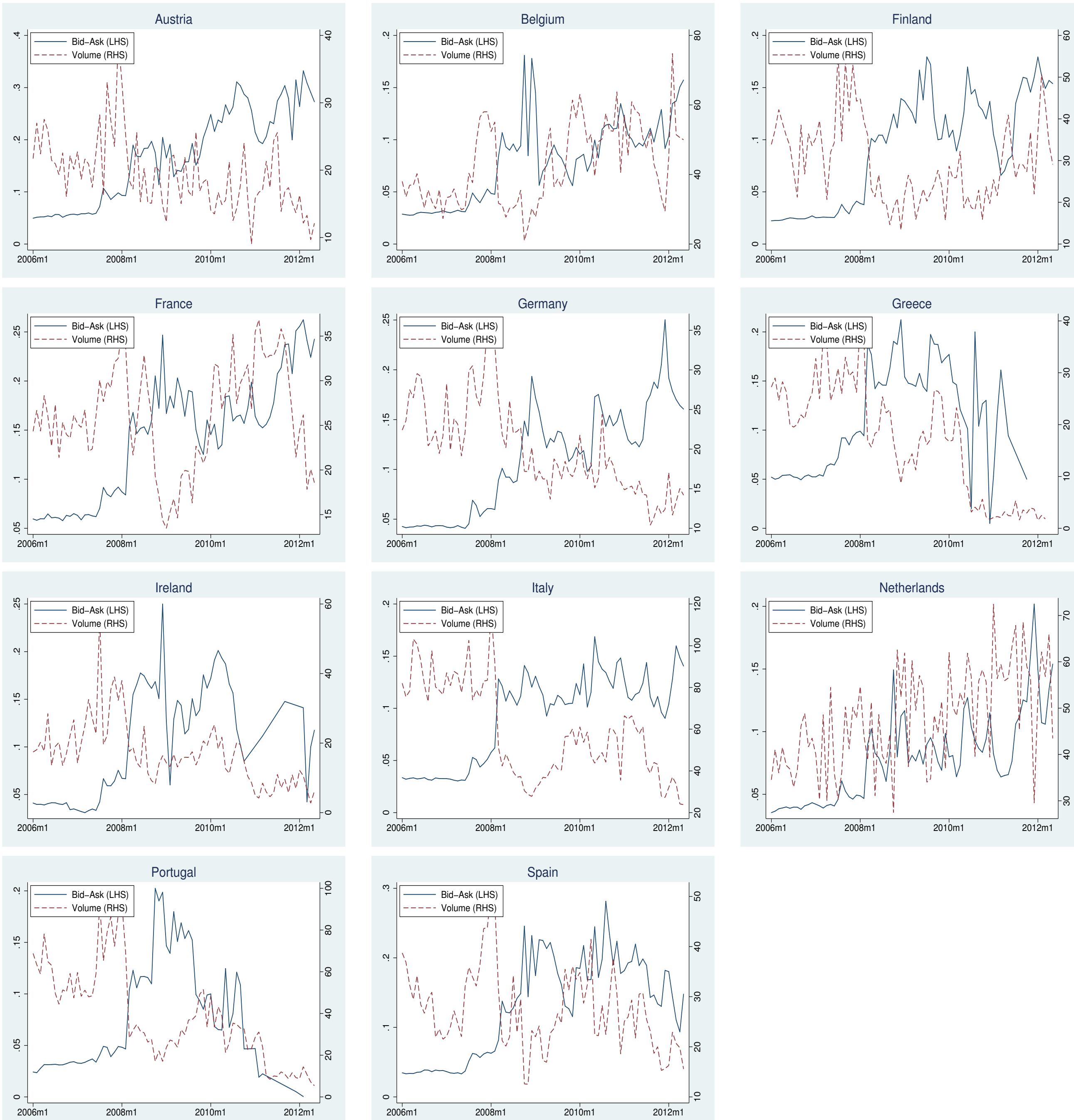


Figure 2: **Liquidity in the Government Bond Market.** *Volume* is the percentage of monthly average trading volume to total outstanding volume of all bonds issued by each country. *Bid-Ask* is the average bid-ask spread of all bonds. The sample period is from January 2006 to May 2012.

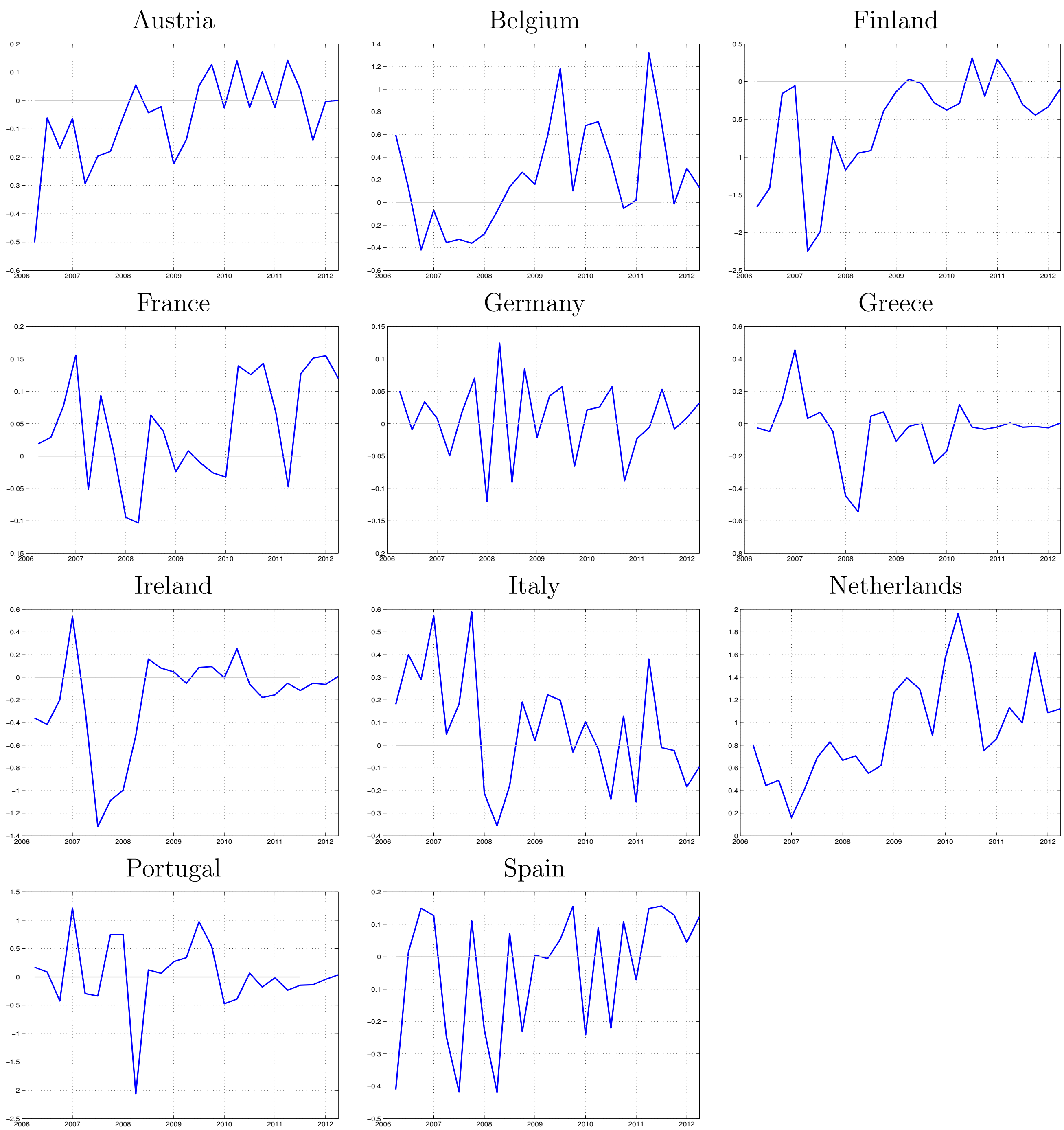


Figure 3: **Net order Flow (NOF) Ratio in the Government Bond Market.** *NOF Ratio* is the percentage of imbalance of trade (buy minus sell orders) to the total bond outstanding issued by each country. A negative ratio indicates net selling pressure over the sample period. The sample period is from January 2006 to May 2012.

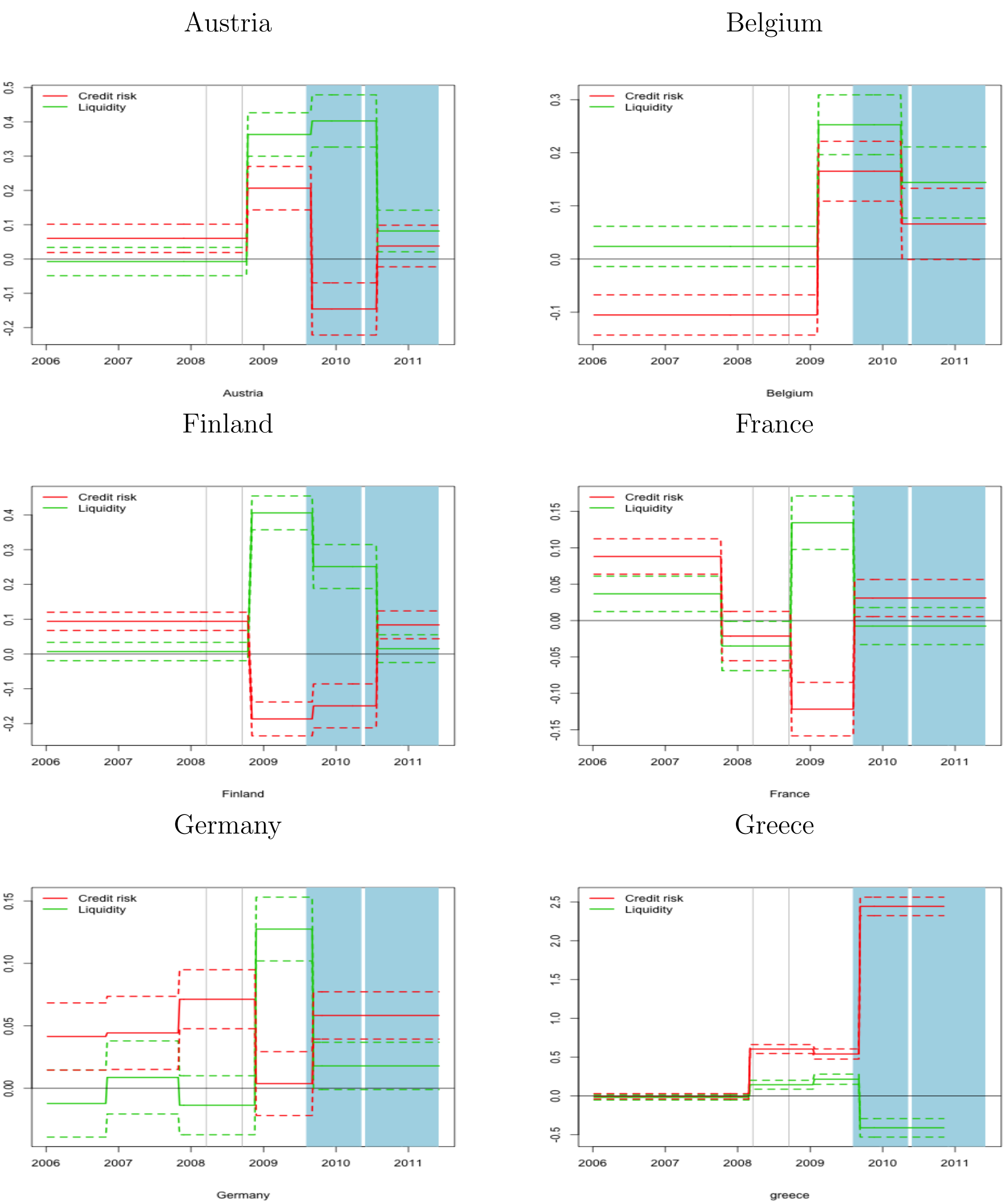
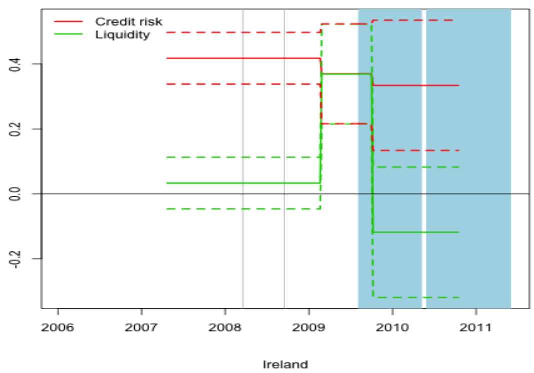
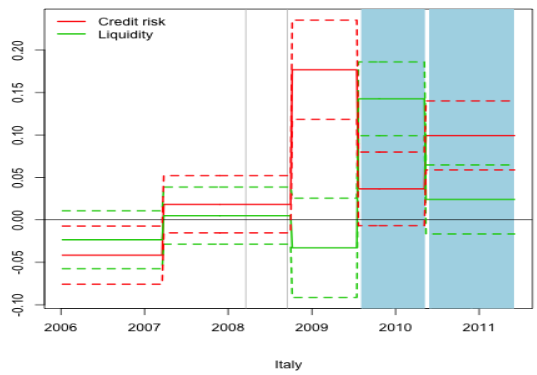


Figure 4: **Time series coefficients in Structural Break Regressions**

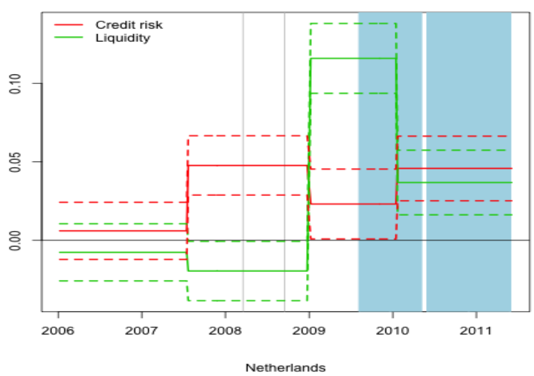
Ireland



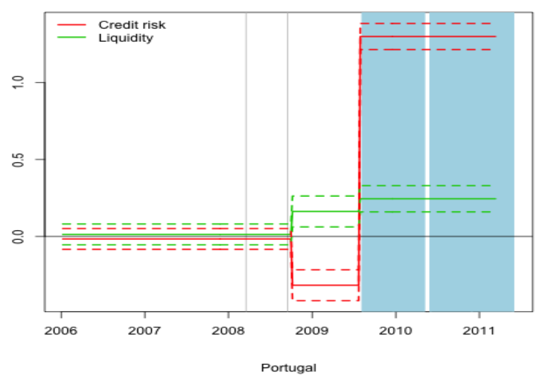
Italy



Netherlands



Portugal



Spain

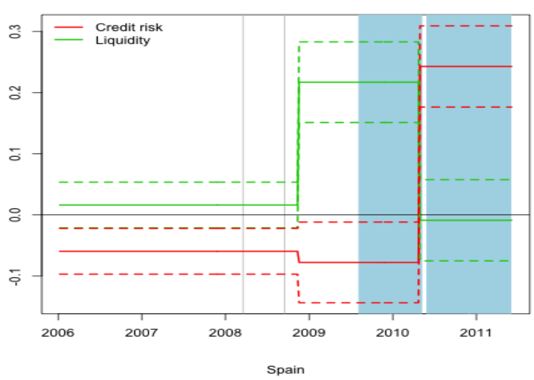


Figure 4 (Cont'd): **Time series coefficients in Structural Break Regressions**

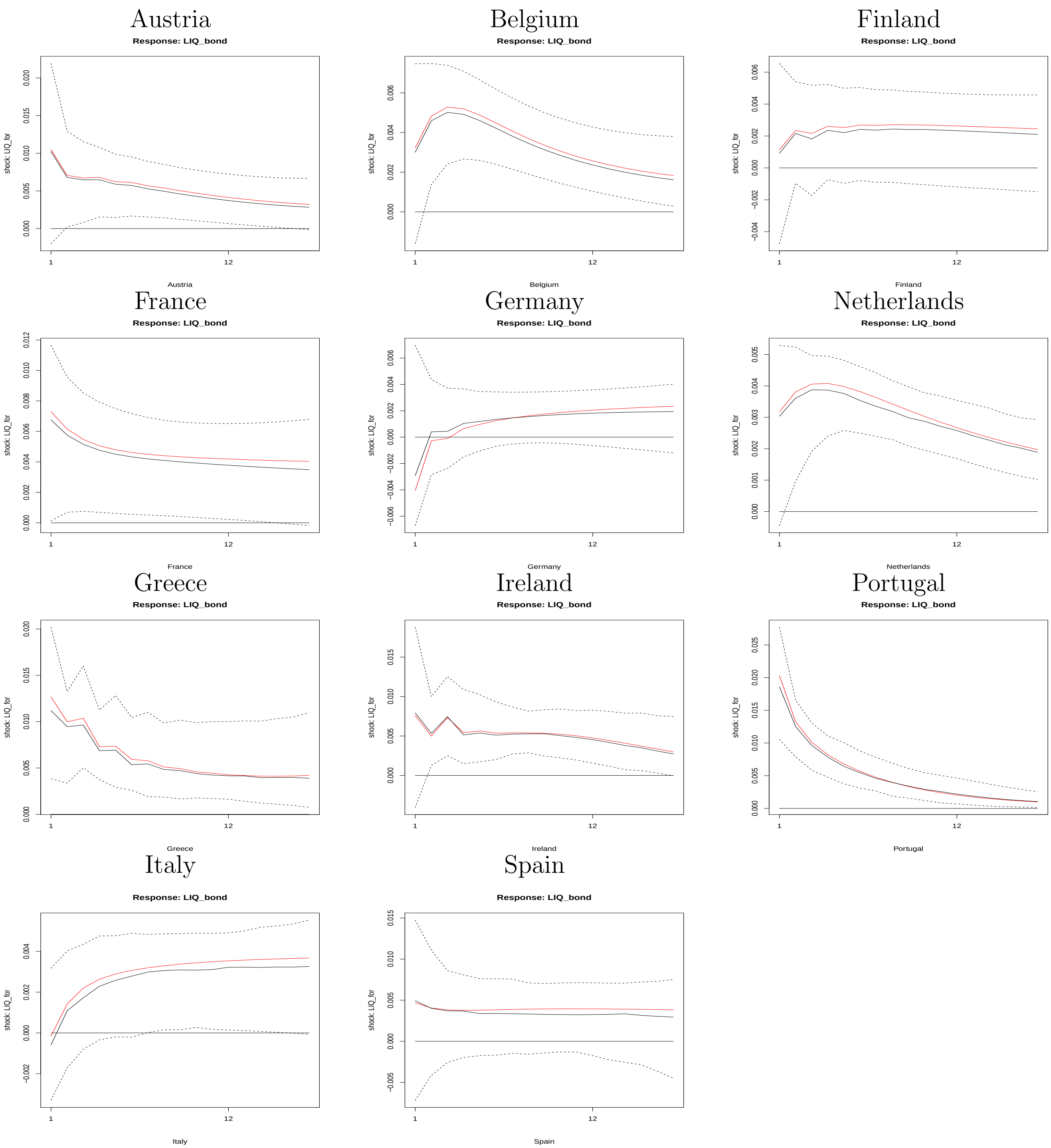


Figure 5: **The Influence of Foreign Liquidity Shock on Domestic Liquidity Risk** The chart illustrates impulse-response functions for the effect of one unit shock in the foreign bond liquidity on the domestic bond liquidity risk. The estimates are based on the SVAR model in Equation (12).

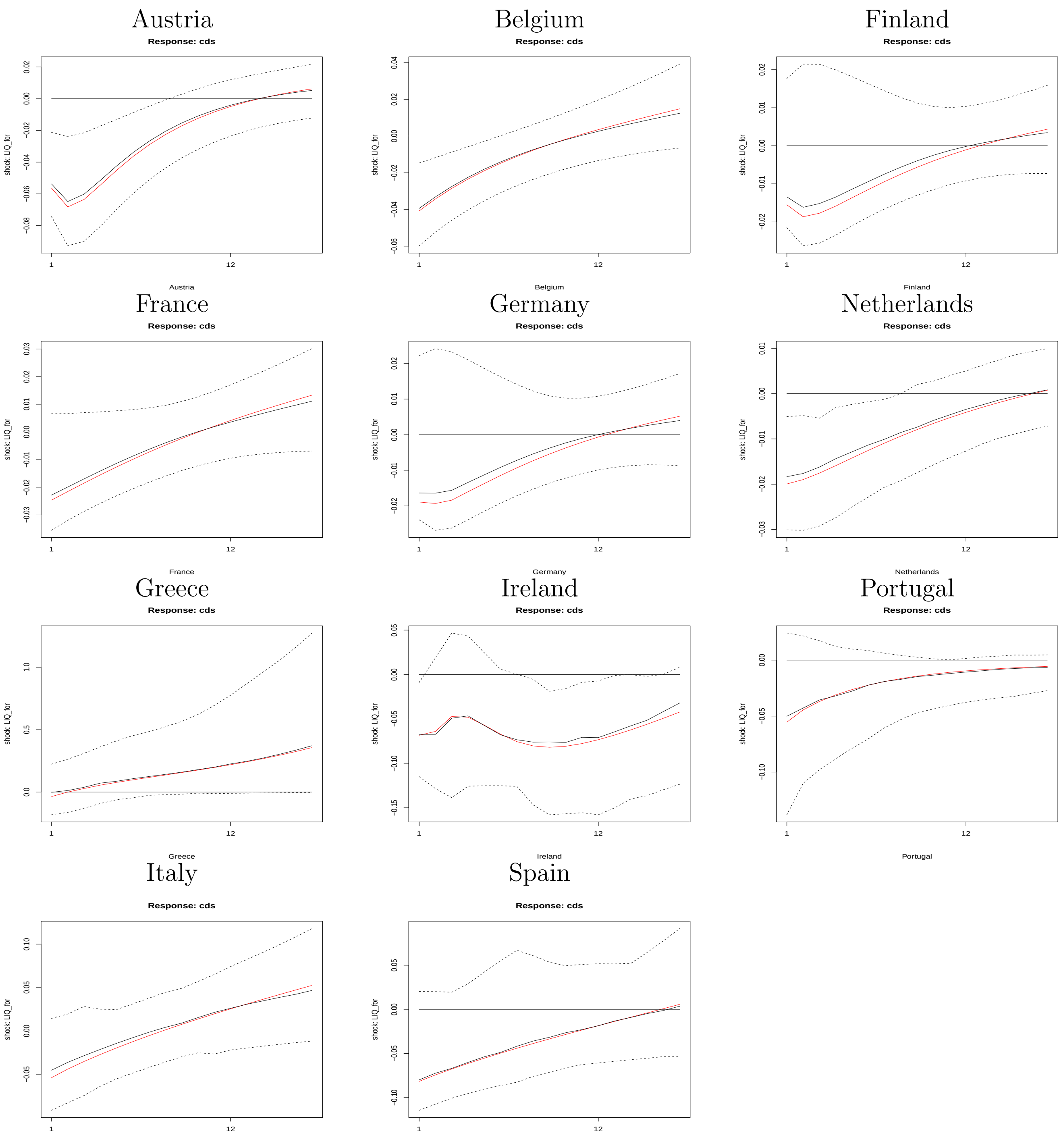


Figure 6: **The Influence of Foreign Liquidity Shock on Domestic Credit Risk** The chart illustrates impulse-response functions for the effect of one unit shock in the foreign bond liquidity on the domestic credit risk. The estimates are based on the SVAR model in Equation (12).

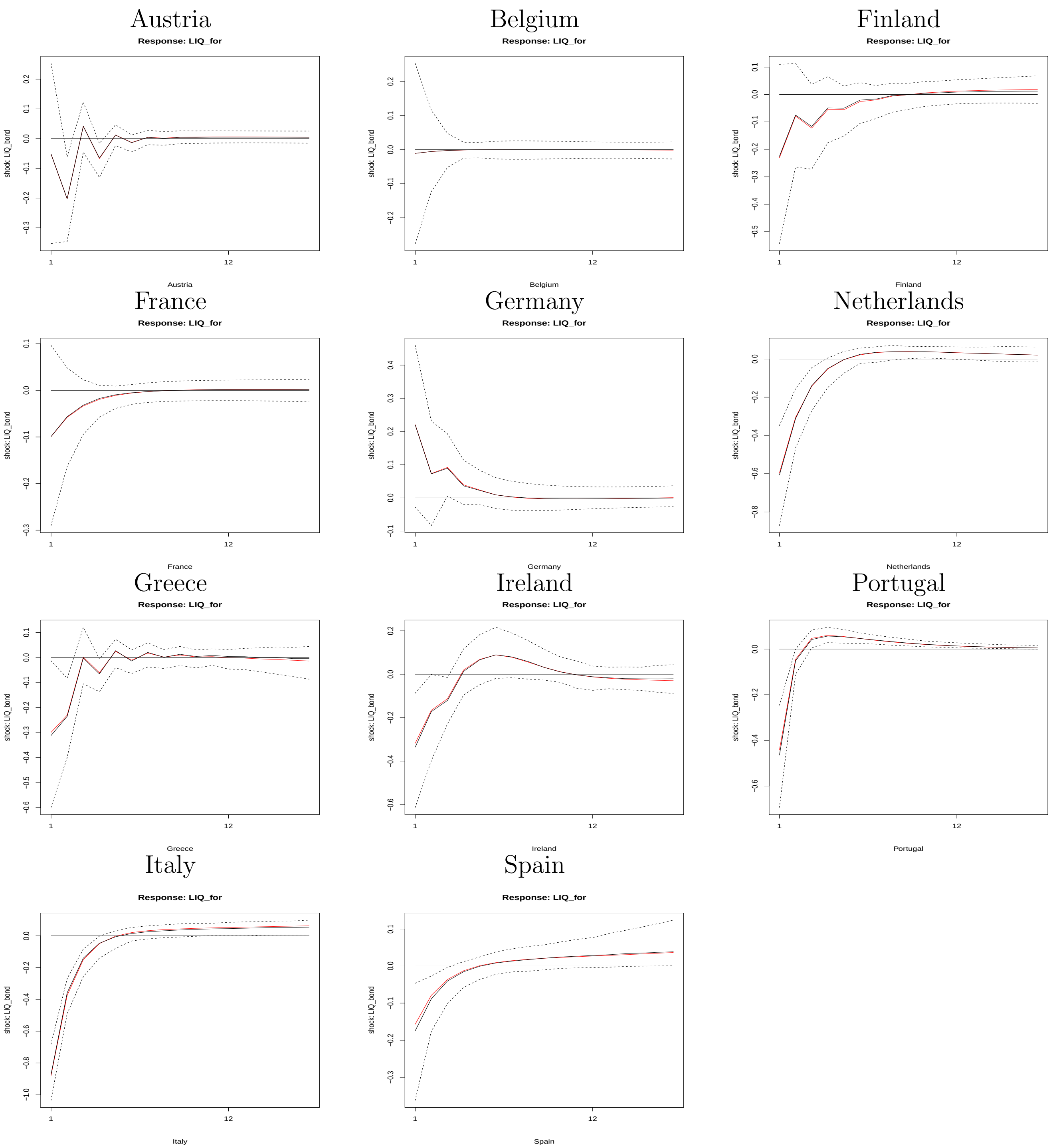


Figure 7: **The Influence of Domestic Liquidity Shock on Foreign Liquidity Risk** The chart illustrates impulse-response functions for the effect of one unit shock in the domestic bond liquidity on the foreign liquidity risk. The estimates are based on the SVAR model in Equation (12).

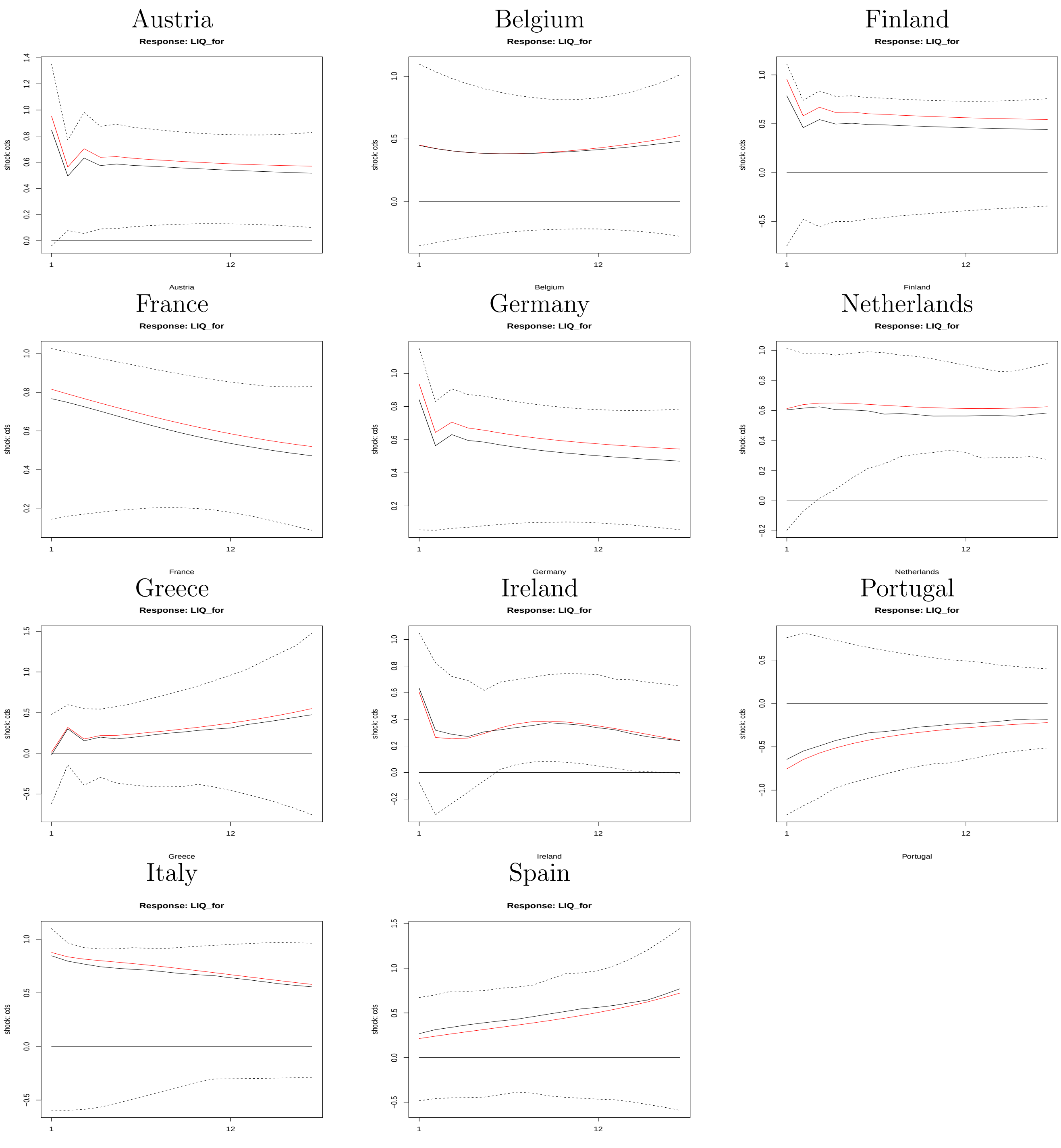


Figure 8: **The Influence of Domestic Credit Shock on Foreign Liquidity Risk** The chart illustrates impulse-response functions for the effect of one unit shock in the domestic CDS on the foreign liquidity risk. The estimates are based on the SVAR model in Equation (12).

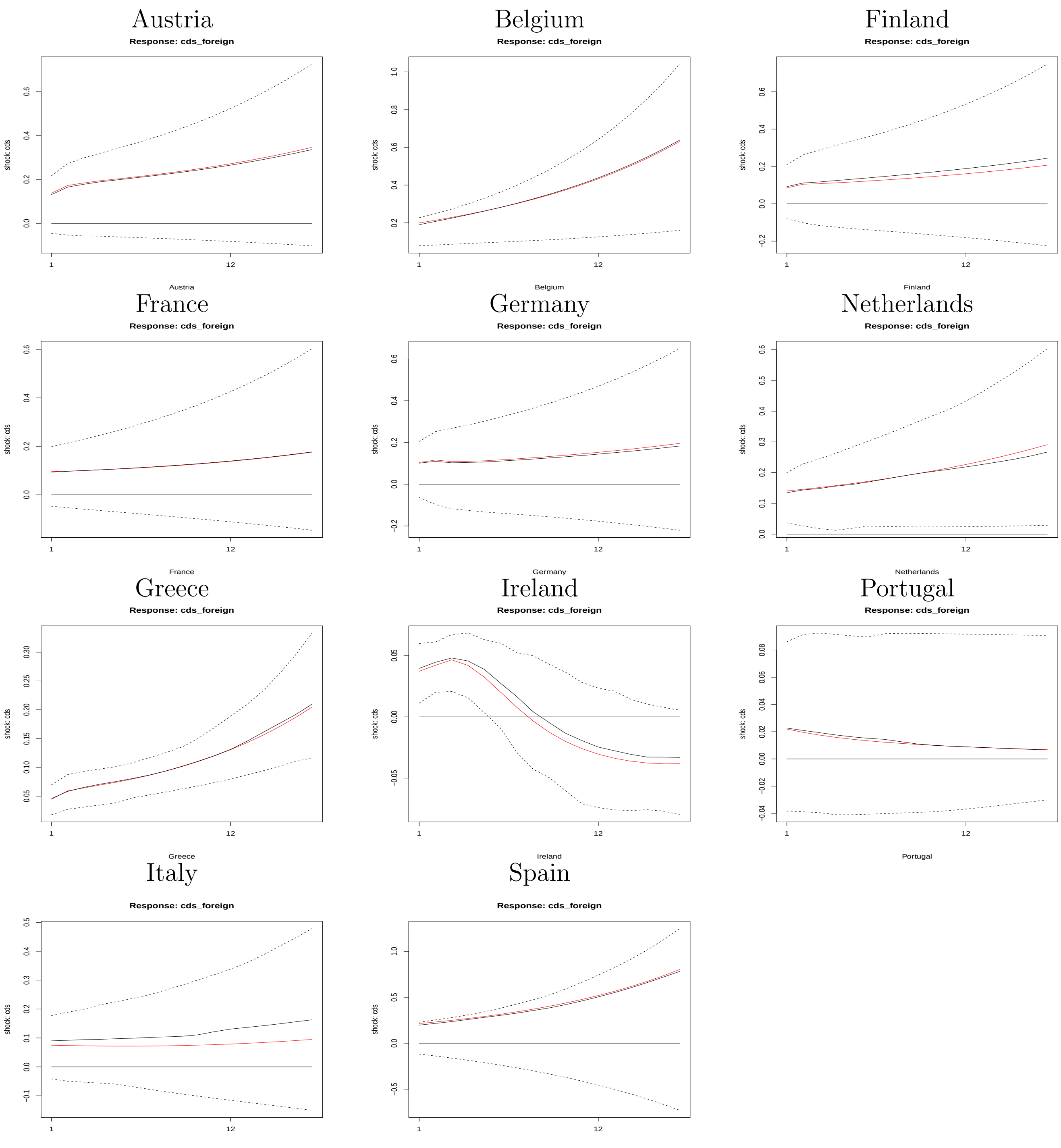


Figure 9: **The Influence of Domestic Credit Shock on Foreign Credit Risk** The chart illustrates impulse-response functions for the effect of one unit shock in the domestic CDS on the foreign CDS spread. The estimates are based on the SVAR model in Equation (12).

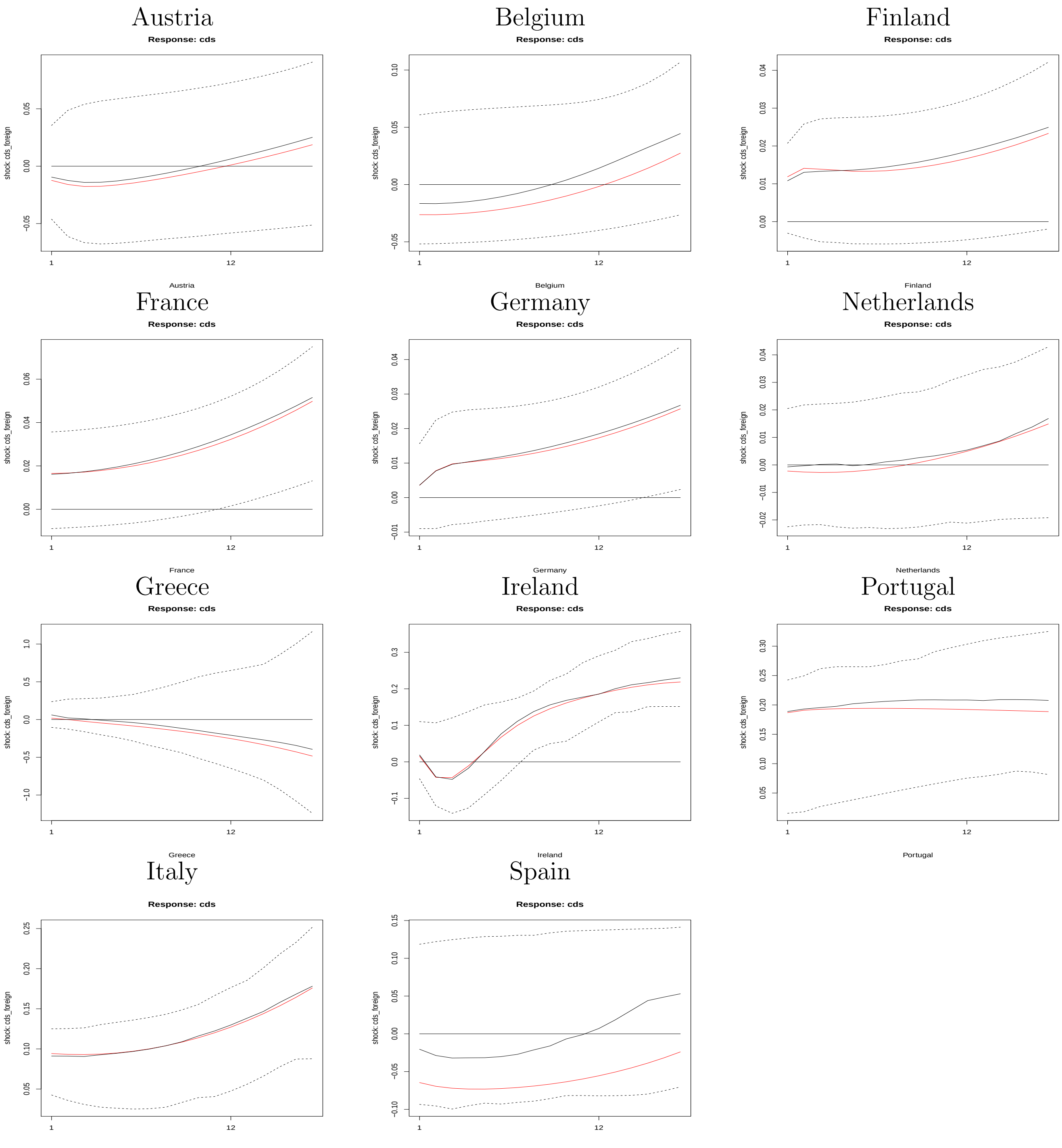


Figure 10: **The Influence of Foreign Credit Shock on Domestic Credit Risk** The chart illustrates impulse-response functions for the effect of one unit shock in the foreign CDS on the domestic CDS spread. The estimates are based on the SVAR model in Equation (12).