Working Paper Series

No 9 / May 2016

Regime-dependent sovereign risk pricing during the euro crisis

by
Anne-Laure Delatte
Julien Fouquau
Richard Portes

ESRB
European Systemic Risk Board
European System of Financial Supervision

Abstract

Previous work has documented a greater sensitivity of long-term government bond yields to fundamentals in Euro area stress countries during the euro crisis, but we know little about the driver(s) of regime-switches. Our estimates based on a panel smooth threshold regression model quantify and explain them: 1) investors have penalized a deterioration of fundamentals more strongly from 2010 to 2012; 2) a key indicator of regime switch is the premium of the financial credit default swap index: the higher the bank credit risk, the higher the extra premium on fundamentals; 3) after ECB President Draghi's speech in July 2012, it took one year to restore the non-crisis regime and suppress the extra premium. *Key Words* : European sovereign crisis, Panel Smooth Threshold Regression Models, CDS indices.

J.E.L Classification: E44, F34, G12, H63, C23.

1 Introduction

Financial market participants have a particular taste for locutions that describe the dynamics of asset prices. In 2011, when sovereign spreads for European peripheral countries successively soared, bond market participants asserted the presence of a *cliff risk*, the point at which a small shift in a bond's value can have a big impact on its price.[1] A similar pattern was emphasized by policymakers (with different terminology) when they complained about growing mistrust on the part of investors, a fact that drove *self-reinforcing* dynamics.[2] A way to picture these comments is to say that sovereign risk pricing is regime-dependent and subject to threshold effects. It is clear from Fig. 1, which plots spreads between 10-year peripheral and German sovereign bonds, that the trend breaks after 2010, a break that is hard to reconcile with the gradual deterioration of economic conditions.[3]

There is an extensive body of research examining sovereign bond prices in the context of the euro crisis, and we have learned several important lessons. First, the massive holding of peripheral sovereign bonds by the Eu-

[1] See for example "Bond investors fear cliff risks.", Financial Times, November 7, 2011.

[2] "The Greek financial crisis: From Grexit to Grecovery", Speech by Mr George A Provopoulos, Governor of the Bank of Greece, for the Golden Series lecture at the Official Monetary and Financial Institutions Forum (OMFIF), London, 7 February 2014.

[3] In Spain, for example, the public debt amounted to less than 60% of GDP even by end-2009. The Italian primary budget surplus implied that if interest rates had stayed low, only modest fiscal adjustment would have been necessary to service the debt. Unemployment and the trade deficit had been increasing gradually. And Ireland's trade balance had been improving at the time of the crisis.

ropean banking sector created a dangerous nexus between sovereigns and banks. It made banks' balance sheets sensitive to sovereign shocks, and this in turn increased pressures on sovereigns, because they were expected to bail out the banks. These feedback loops have been put forward by Gennaioli *et al.* (2010), Huizinga and Demirguc-Kunt (2010), Acharya and Steffen (2013), Acharya *et al.* (2014) and Coimbra (2014). Second, there have been liquidity spirals such as the sell-off in Irish bonds in November 2010, driven by an attempt by market participants to regain liquidity after being unable to meet collateral requirements.[4] Liquidity conditions in the euro-area did not recover after the sub-prime crisis, with a clear drop in liquidity after 2011. But so far, however, we do not know the details: it is unclear by how much these two effects, the sovereign-bank nexus and the liquidity spirals, have affected the peripheral sovereign bond markets and if one effect has dominated.

The last lesson we have learned: previous empirical work documents a regime switch in the spread determination model for euro-area peripheral sovereigns during the crisis. Two different regimes have been described, a crisis and a non-crisis regime, with a higher sensitivity of yields to fundamentals in the crisis regime (Costantini *et al.* (2014), Aizenman *et al.* (2014), Afonso *et al.* (2015)). But this work does not tell us what drove the change in regime.

In this paper, we integrate these different pieces by exploring the possibility that the switch to the crisis regime was triggered by the deterioration of the banks' risk, the liquidity spirals, or both: two endogenous mechanisms potentially implying self-amplifying dynamics. We also control for alternative

[4]"Irish bond yields leap after selling wave", Financial Times, 10 November 2010.

mechanisms, such as the rise of systemic risk in the market and the rise of volatility on several market segments.[5]

These questions require testing for regime-switching dynamics in bond spread determination and investigating the triggers. To do so, we use the smooth transition regression model developed by Terasvirta (1996), extended in panel by González *et al.* (2005). Contrary to the alternative family of nonlinear models employed in previous works, the STR model offers a parametric solution to account for nonlinearity by allowing the parameters to change smoothly as a function of an observable variable. We exploit this advantage by taking an off-the-shelf model estimating the impact of economic fundamentals on the spread of sovereign bonds, and we consider potential threshold variables to account for the time variability of the estimated coefficients. We compute an original set of domestic and aggregate indicators for banking and liquidity risk. Our linearity tests establish a ranking among hypothetical drivers of self-reinforcing effects, and we identify the prominent driver of regime switch following Gonzalez *et al.*, (2005) and Fouquau *et al.* 2008.

In order to work on a homogeneous sample of countries, we focus on the five European stress countries: Spain, Ireland, Italy, Portugal and Greece. We start the estimation in 2006 to examine the transition from the non-crisis to the crisis regime and stop right before the spreads decline drastically in July 2012 to document the dynamics specific to the crisis period. We then investigate the reversion mechanisms by extending our period of estimation

[5]We thank an anonymous referee for this valuable suggestion.

until March 2014.[6]

A preview of our results is the following. First, sovereign yield spreads became more sensitive to fundamentals between 2010 and 2012; interestingly we do not confirm the finding of Aizenman *et al.* (2014) and Afonso *et al.* (2015) of an extra premium on fiscal imbalances for Italy, Spain and Portugal. In these countries, we find that an extra premium was instead attached to a deterioration of competitiveness and of international risk. Second, the bank-sovereign nexus is the leading driver of nonlinearities, well beyond liquidity spirals and systemic risk. The deterioration of banks' credit risk changed the way investors price risk of the sovereigns. It exacerbated the effect of initial shocks to the fundamentals. We find that the threshold value of bank credit risk that triggers amplification effects is relatively low. Last, we find that the spreads switched back to the non-crisis determination regime during the year following ECB President Mario Draghi's speech in July 2012. In that speech, he asserted the lender-of-last-resort role of the ECB, saying it would do "whatever it takes" to safeguard the monetary union.

Our work complements earlier research on sovereign credit risk during the euro crisis (Attinasi *et al.* (2009), Dieckman and Planck (2012), Ang and Longstaff (2013), Acharya *et al.* (2014), Avino and Cotter (2014)). Technically our work imposes fewer constraints than previous work on the functional form of nonlinearities and allows parameters to change smoothly as a function of an observable variable. The innovations here are therefore

[6] Again, we thank the referee for this suggestion.

the identification of the amplification mechanisms; pinpointing the bank-sovereign nexus working through aggregate credit risk for financial names; quantifying the resulting change in the relative weight of the determinants; and documenting the reversion process after the crisis. More generally, documenting nonlinear dynamics in asset pricing during a crisis episode should contribute to a better understanding of drivers of financial instability.

The remainder of this paper is organized as follows. Section 2 reviews the abundant literature on sovereign bond pricing during the euro-crisis in order to specify our contribution. Section 3 introduces the PSTR specification methodology and the test procedure. Section 4 summarizes our data-set, and Section 5 discusses the estimation results. Section 6 concludes.

2 Sovereign risk pricing: what have we learned?

Substantial research has examined the sovereign bond price in the context of the euro crisis. On the one hand, there is a consensus that a sovereign-bank nexus generated feedback loops in the dynamics of government bond spreads during the crisis: the deterioration of the sovereign's creditworthiness fed back onto the financial sector, reducing the value of its guarantees and existing bond holdings and increasing its sensitivity to future sovereign shocks. On the other hand, bank risk affects the sovereigns, which are expected to bail out systemically important institutions. That represents a significant risk given the size of banks compared to the size of the public backstop (Acharya *et al.*, 2014). A theoretical paper suggesting for our empirical investigation is by Coimbra (2014), who shows how the initial shock is exacerbated and feeds back to credit conditions. After a rise in sovereign risk, the banks' VaR constraint binds, which reduces their demand for sovereign bonds, thereby raising the sovereign risk premium. This in turn leads to adverse sovereign debt dynamics, which raise sovereign risk.

Attinasi et al. (2009) empirically confirm the effect of the bank-sovereign nexus in a model of government bond yield spreads (over Germany) of 10 European countries. They find that government bond yield spreads are significantly affected by the announcements of bank rescue packages in addition to standard measures of government creditworthiness. Acharya *et al.*(2013) find that credit default swap (CDS) spreads of banks and those of governments tend to move more closely together after the announcement of financial sector bailouts.[7] But these papers assume a linear relationship between bank credit risk and government yield. We find it more realistic to relax the linearity assumption to account for self-reinforcing dynamics in the feedback loop.

Liquidity spirals during the euro crisis may have amplified the effect of initial shocks. More precisely, liquidity spirals occur when an initial shock

[7] Several papers have focused on the opposite direction of the feedback loop: Acharya and Steffen (2013) find that the Eurozone banks actively engaged in a 'carry trade' in the crisis period, increasing their exposure to risky sovereign debt. Gennaioli *et al.* (2010) argue that the sovereign risk affects the banks through their exposure to sovereign bonds. Huizinga and Demirguc-Kunt (2010) provide evidence in a large cross-country sample that bank CDS spreads responded negatively to the deterioration of government finances in 2007-08.

on sovereign bonds degrades the quality of collateral. This forces banks to sell off bonds to regain liquidity or restore their capital ratio, reinforcing the initial downgrading. In addition to the example of the Irish bond sell-off mentioned in introduction, we have the spiral on the Italian sovereign bond market documented by Pelizzon *et al.* (2015). They find threshold effects in the dynamic relationship between changes in Italian sovereign credit risk and liquidity: there is a structural change in this relationship above 500 basis points (bp) in the sovereign Italian CDS spread, because of changes in collateral and margins for Italian bonds. Brunnermeier and Pedersen (2009) have theoretically modeled the liquidity spirals: [8] the pricing of debt becomes more "information sensitive", and safe assets become less safe, so investors are more selective about the quality of assets they accept as collateral. Their demand for the sovereign bonds that are perceived to be more risky declines, thereby raising the sovereign risk premium. So there is a liquidity spiral: a falling sovereign bond market leads financial intermediaries to fly to liquidity, and this amplifies the effects of the initial price reduction. Relatively small shocks can cause liquidity suddenly to dry up, leading to a major correction of asset prices.

We have learned, therefore, that banking credit risk and liquidity deterioration affected sovereign credit risk during the euro crisis. In addition, theoretical models point to endogenous amplification effects. Consequently, handling these variables as extra regressors in the sovereign risk-pricing model

[8] Stiglitz (1982) and Geanakoplos and Polemarchakis (1986) initially pointed out this externality.

is misleading. Our work tests the hypotheses that the deterioration of banking risk and liquidity shocks have had self-reinforcing effects on sovereign pricing. Before proceeding, we conclude the review of the literature by examining existing evidence of nonlinearities in the Euro-area sovereign bond spread.

Several empirical papers find a regime-switch in the spread determination model for euro-area peripheral sovereigns during the crisis. Yet none offers a satisfying framework to explain regime-shifts. [9] For example, Costantini *et al.* (2014) find evidence for a level break in the cointegrating relationship of sovereign bond yield spreads in nine economies of the European Monetary Union. They also find significant differences in the coefficient weight of fiscal space in determining sovereign risk in peripherals versus core EMU members. They attribute this difference to the fact that international investors perceive which EMU members legitimately qualify as Optimal Currency Area members. This is intellectually appealing, but the interpretation cannot be tested in their empirical framework because it does not allow them to test the potential drivers of observed nonlinearities. Our objective here is to relax linearity and allow the spread determination model to change according to an *observable signal* that sets off amplifying spirals. We now describe our empirical strategy.

[9] The authors finding regime-switch include among others Aizenman *et al.* (2014), Gerlach *et al.* (2010), Montfort and Renne (2012), Borgy *et al.* (2011), Favero and Missale (2011), Alfonso *et al.* (2015).

3 Empirical strategy: specification and estimation

Previous work neither explains nor quantifies the mechanism driving the regime change in the sovereign bond pricing. We use a smooth transition regression model (STR), whose advantage over a structural break model is that it can explain the transition with an observable variable. We compare the effect of different potential channels of amplification. With linearity tests we identify the predominant shift-regime driver. Last, we quantify this shift by estimating the coefficients in both extreme regimes.

To do so, we employ a panel smooth threshold regression (PSTR) model developed by Gonzáles *et al.* (2005). The choice of panel data is motivated by the low time dimension of macroeconomic data. The PSTR model allows us to characterize nonlinearity as a function of an observable variable. The sovereign spread can be estimated as follows:

$$S_{it} = \mu_i + \beta_1' X_{it} + \beta_2' X_{it} g(q_{it}; \gamma, c) + u_{it} \tag{1}$$

for countries $i = 1, \dots, N$ and $t = 1, \dots, T$. Here μ_i represents individual fixed effects, X_{it} is a set of variables that capture credit risk, liquidity risk and international risk aversion and u_{it} are i.i.d. errors. $g(.)$ is a continuous transition function bounded between 0 and 1. We use a logistic function of order 1 that has an S shape:

$$g(q_{it}; \gamma, c) = \frac{1}{1 + \exp\left[-\gamma(q_{it} - c)\right]} \quad, \gamma > 0. \tag{2}$$

where q is the observable threshold variable. The gamma parameter determines the smoothness, *i.e.,* the speed at which the vector of coefficients goes from β_1' to $\beta_1' + \beta_2'$; the higher the value of the parameter, the faster (*i.e.*, sharper) the transition. The location parameter c shows the inflection point of the transition, *i.e.* the threshold value at which the regime shifts. In order to get an accurate grasp of the pricing evolution during the crisis period, we will plot $g(.)$, the combination of q_{it}, γ and c to show for every date in which regime the model is, this regime being potentially an intermediate regime.

The estimation of the PSTR model consists of several stages. In the first step, a null hypothesis of linearity is tested against the alternative hypothesis of a threshold specification. Then, if the linear specification is rejected, the estimation of the parameters of the PSTR model requires eliminating the individual effects, μ_i, by removing individual-specific means and then applying nonlinear least squares to the transformed model.
In the González *et al.* (2005) procedure, testing linearity in a PSTR model (equation 1) can be done by testing $H_0 : \gamma = 0$ or $H_0 : \beta_0 = \beta_1$. In both cases, the test is non-standard, since the PSTR model contains unidentified nuisance parameters under H_0 (Davies, 1987). The solution is to replace the transition function, $g(q_{it}; \gamma, c)$, with its first-order Taylor expansion around $\gamma = 0$ and to test an equivalent hypothesis in an auxiliary regression. We then obtain:

$$S_{it} = \mu_i + \theta_0 \ X_{it} + \theta_1 \ X_{it} q_{it} + \epsilon_{it}^{*}. \tag{3}$$

In these auxiliary regressions, parameter θ_1 is proportional to the slope parameter γ of the transition function. Thus, testing linearity against the PSTR simply consists of testing $H_0 : \theta_1 = 0$ in (3) for a logistic function with the usual LM test. The corresponding LM statistic has an asymptotic $\chi^2(p)$ distribution under H_0.

Before proceeding to the estimation, we present our data.

4 Data description

The estimation of the model of Eq.(1) is subject to two major data constraints. On the one hand, macroeconomic fundamentals have a low frequency (annual, quarterly or monthly), while our financial data are daily. Therefore we transform all series to monthly data. We calculate the monthly average of the daily series and we transform quarterly to monthly using a local quadratic transformation with the average matched to the source data.[10] On the other hand, the sovereign crisis started in late 2009, and the Outright Monetary Transactions (OMT) program implemented in September 2012 successfully narrowed the spreads when it was announced in July 2012. So we have only three years during which the hypothesized transition might have occurred. Therefore, to obtain a sufficient number of observations, our estimation is based on a balanced panel of the five peripheral European countries in which the sovereign yield has been most under pressure (Greece, Ireland, Italy, Spain and Portugal) between January 2006 and July 2012. Subsequently, in order to test the robustness of our findings, we extend our estimates up until March 2014.

[10] We used Eviews software for this transformation.

4.1 Determinants of the sovereign bond spread

Our dependent variable is the long-term government bond spread, which prices the country risk. It is defined as the difference between country i's government bond yield and the risk-free rate of the same maturity. For each country in the sample, we use the long-term German yield, which is the benchmark risk-free rate for the Euro area (Dunne *et al.*, 2007), and the government yield of this country at the same maturity. We rely on daily observations of 10-year bond yields provided by Bloomberg, from which we compute a monthly average.[11] The descriptive statistics of our variables are presented in Table 1.

A key choice is the set of explanatory variables included in X_t in Eq (1). The government bond yield spread represents the risk premium paid by governments relative to the benchmark government bond[12]. From a theoretical perspective, these instruments can be priced by decomposing the risk premium into credit risk and liquidity risk.[13] Credit risk is influenced by variables that affect the sustainability of the debt and the ability and willingness of repayment. For a sovereign entity, these are macroeconomic variables determining internal and external balances, *i.e.* the budget deficit and the

[11]For Ireland only 8-year bond yields are available, so we computed the spread using the 8-year German yield.

[12]Early and influential empirical papers include Edwards (1986), Eichengreen and Portes (1989), Cantor and Packer (1995).

[13]For countries in the euro area, most of government bonds are held by euro-area investors, we can ignore foreign exchange risk. Recall also that our spread variable is the spread over the euro-denominated Bund.

current account. The empirical evidence in the euro area context suggests that significant determinants include fiscal variables, activity-related and competitiveness-related variables (see Attinasi *et al.* (2009), Haugh *et al.* 2009, De Grauwe and Ji, 2013). Liquidity risk is related to the size of the issuer, with an expected negative relationship due to larger transaction costs in small markets. In contrast with findings on credit risk, empirical evidence is mixed about the pricing of a liquidity premium in the sovereign bond spread.[14] Beyond these two theoretical risk premia, Longstaff *et al* (2011) find that a large component of sovereign credit risk is linked to global factors, while Ang and Longstaff (2013) find that the systemic default risk of European countries is highly correlated with financial market variables. In total, we draw on the previous works mentioned above to test a large range of macroeconomic and financial determinants.

To capture the fiscal space, we include the debt-to-GDP ratio and fiscal balance from Eurostat. The expected signs are positive for debt-to GDP and negative for fiscal balance because a deterioration of fiscal sustainability increases the sovereign risk; we add the squared value of the debt-to-GDP ratio to capture non-linear dynamics that might be due to threshold effects of sovereign debt on real growth. The fiscal data are revised data, necessary because of the presence of Greece in the sample, although these are not the data initially observed by market participants. Other relevant vari-

[14] For example, Geyer *et al.* (2004) find that liquidity plays a minor role for the pricing of EMU government yield spreads. Favero *et al.* (2009) find that investors value liquidity, but they value it less when risk increases.

ables are economic activity and the country's competitiveness. We proxy economic activity with four alternative variables: unemployment has an expected positive sign, the manufacturing production index, the new housing permits (from Eurostat) and the industrial production index (IMF) have all the expected effect to reduce the spread when they increase (negative coefficient). The country's competitiveness is proxied with the real effective exchange rate defined as the relative price of domestic to foreign consumer price index (source: IFS). An increase is an appreciation, so a deterioration of competitiveness implying that the expected coefficient is positive. In addition we use the trade balance, which is expected to have a negative coefficient (Eurostat).[15] Second, we include a variable for liquidity risk, proxied by the bid-ask spread of the dependent variable; it is expected to have a positive coefficient, because an increase of the bid-ask spread is a deterioration of liquidity. Because the liquidity effects were mixed in previous studies, we also use the country's share of total outstanding Euro-denominated long-term government securities issued in the Euro zone. The sign of the coefficient is ambiguous: it is expected to be negative because a higher ratio means a higher liquidity, but it may turn positive because it also means a higher relative stock of debt. Data are available on a monthly basis from the European Central Bank (ECB), while the bid-ask spread is taken from Bloomberg. We include the CBOE Volatility Index (VIX) as a measure of international risk aversion, because it is often considered to be the world's premier barometer of investor sentiment and market volatility (*e.g.*, Rey,

[15]All data are available at a quarterly frequency, except for unemployment and real exchange rate (monthly) and fiscal deficit (annual).

2013). The coefficient is expected to be positive.

Last, we control for the effect of non-standard monetary measures adopted by the ECB during the crisis. In May 2010, the ECB decided to start the Securities Markets Programme (SMP) with large securities purchases in order to address tensions in certain market segments.[16] We use the amount of securities held for monetary purposes (divided by 100), as shown in the ECB's weekly financial statements, and including Securities Market Program, 1st and 2nd Covered Bond Purchase Programs (available in ECB Statistical Data Warehouse).[17]

4.2 Endogenous drivers of nonlinearities, two hypotheses

We present the set of financial data used to capture our two hypotheses, bank-sovereign nexus and liquidity spirals. They represent the set of threshold variables that we will include alternatively in our nonlinear estimations in the next Section. They are composed of indicators of uncertainty and stress in the banking sector and liquidity risk. In addition to including usual well-known measures of such risk, we decompose the indicator of systemic risk designed by the Kansas City Fed which aggregates risk of different market segments, and we re-calculate the individual components measuring

[16] The SMP was terminated in September 2012 in favor of Outright Monetary Transactions (OMTs) in sovereign secondary bond markets.

[17] On the other hand, the ECB provided in December 2011 and March 2012 more than 1 trillion Euros of additional liquidity to the financial system with the very long-term refinancing operations (LTRO). Unfortunately publicly available data are not broken down by country so they are not relevant in our panel estimates.

banking and liquidity risk with European data (Hakkio and Keeton, 2009). This allows us to obtain a fair number of measures tested in alternative specifications to obtain robust findings.

1. *Banking-sovereign nexus*

    - We take the price of credit default swaps (CDS) because it is the premium an investor must pay to hedge the risk or express a credit view of a reference entity. More specifically, we take the price of *SenFin* CDS index which is a basket of 25 single CDS covering 25 investment-grade European banks. As an alternative, we include the equivalent index in subordinated debt, *subfin CDS* (riskier).[18]
    - *IVolbank* denotes the idiosyncratic volatility of bank stock prices. It serves as an equivalent of the VIX for the banking industry. It is computed as the standard deviation of residual returns from a CAPM regression using an aggregate European banking sector

[18] *SenFin* CDS index is in the family of the i-Traxx Europe, a broad tradable credit default swap family of indices. The main advantages of these new classes of credit derivatives are standardization and liquidity, which explain their growth at the expense of trading in single name CDS. CDS indices accounted for 43% of gross notional amount of the CDS market in December 2012, up from 20% in 2004 (Vause, 2011). CDS trading has continued to grow after 2007 (IOSCO, 2012). At the end of 2012, the gross notional value of outstanding CDS contracts amounted to approximately 25 trillion US dollars, and the corresponding net notional value to approximately 2.5 trillion US dollars. The fact that the gross notional value of the CDS contracts has more than halved since the peak of 2007 (with 60 trillion US dollars) is mostly attributed to the development of compression mechanisms that eliminate legally redundant contracts (Vause 2011).

price index and the S&P Europe 350 taken from Datastream.

- *CMAXFin* is an indicator of stress that identifies periods of extreme price declines. We take the five domestic banking stock indices from Datastream and calculate the maximum cumulated index losses over a moving two-year window with $Cmax_t = 1 - \frac{P_t}{max[P_{t-24}...P_t]}$. The more bearish the market, the closer to 1 the indicator.
- *Euribor-OIS spread* is calculated as the difference between the Euro Interbank Offered rate and the overnight indexed swap rate. This indicator must be taken with some caution because of the alleged manipulation of the Euribor rate.

2. *Liquidity spirals*

- *Aaa/10-year Bund spread* denotes the spread between European corporate bonds rated Aaa and the 10-year German Bund. It is a standard measure of liquidity premium, because even the highest-rated corporate bonds tend to be less liquid than Treasury securities. All corporate bond indices are Markit i-boxx European corporate bonds, taken from Datastream.
- *High-yield bond/Baa spread* denotes the spread between "junk bonds", *i.e.* bonds with too low a rating to be considered investment-grade, and Baa-rated corporate bonds, the lowest-rated bonds considered as investment-grade. High-yield bonds are issued in smaller quantities and traded by a limited set of investors (institutional investors are banned from the market) in comparison

with Baa-rated bonds, implying a liquidity premium to compensate investors for holding the less liquid asset.

- *10-year swap spread.* The fixed-rate payment leg of a swap is expressed as the Treasury yield plus a spread that compensates investors for the fact that claims on fixed-rate payments are considerably less liquid than Treasury securities.

  During a liquidity run, investors fly to quality because of asymmetry of information, so we complement our set with the following:

- *StockbondsCorr* measures the correlation between domestic stock total return indices and the total return German Bund index. The correlation between stock and government bond returns is usually significantly negative during financial crises, because investors consider government bonds safer. We compute the correlation over rolling three-month periods using the domestic stock index of each country of our panel and the 10-year Bund index taken from Datastream. We use the negative values of the correlations, so that an increase in the measure corresponds to higher *flight-to-quality.*

- *Cross-section dispersion bank* computes the cross-section dispersion of bank stock returns to capture uncertainty about the relative quality of banks and to proxy *asymmetry of information.* The intuition is that the larger the cross-section dispersion, the larger proportion of returns is unexpected, so the larger the information asymmetry. It is calculated using daily data on the S&P

Europe 350 and the stock prices of the 82 largest commercial banks in terms of market value.[19]

3. *Control Variables*

We control for alternative mechanisms, such as the rise of systemic risk in the market and the rise of volatility on several market segments

- The Composite Indicator of Systemic Stress (CISS) of the ECB which aggregates five market-specific subindices (Hollo *et al.* 2012)
- *i-Traxx Europe* comprises the most liquid 125 CDS referencing European investment grade credits
- *X-over* comprises the most risky 40 constituents
- *HiVol* is a subset of the main Europe index consisting of what are seen as the most risky 30 constituents
- *Vstoxx* is the European equivalent of the VIX, considered by many to be the leading measure of market volatility.[20]
- *FTSE300* and *S&P350* denote the returns of the European aggregate stock market indices

[19] More precisely we estimate a CAPM regression of the daily return on each bank's stock index against the daily return on the S&P Europe 350 index, using data for the previous 12 months. The estimated coefficients are then used to calculate the forecast errors of the current month. Last we calculate the interquartile range for these residuals in order to keep the central 50%. The lower the interquartile value, the smaller the dispersion across banks.

[20] We use Vstoxx to proxy the European market volatility, while we use VIX to capture international risk aversion.

- *DomsticIndex* is the matrix of the domestic stock returns indices of the five countries in our panel (PSI, IBEX, ATHEX, FTSEMIB, ISEQ).
- *RvolBonds* captures bond market volatility using the 10-year German government bond index. It is the realized volatility computed as the monthly average of absolute daily rate changes.
- *Rvol Nonfi* is the realized volatility of domestic non-financial sector stock market indices taken from Datastream.
- *Rvoldoll*, *Rvolyen* and *Rvolpound* are the realized volatility of three bilateral euro exchange rates for the US dollar, the Japanese yen and the British pound respectively.

5 Estimation results: Nonlinear dynamics in the European sovereign market

We recall that the PSTR specification of the spread is as follows:

$$S_{it} = \mu_i + \beta_1' X_{it} + \beta_2' X_{it} g(q_{it}; \gamma, c) + u_{it}$$

for $i = 1, ..., n$ and $t = 1, ..., T$, X represents the vector of determinants, μ_i the country fixed effects, $g(.)$ the threshold function, q_{it} the threshold variable, γ the smooth parameter, c the location parameter.

5.1 The changing composition of the yield spreads over time

In order to test the linearity assumption and select the optimal threshold variable, we need a single specification for the whole set of threshold variables. Selecting explanatory variables by linear models might not be appropriate, since some variables could be important in a nonlinear way.[21] So we select the common specification using a time-varying PSTR (TV-PSTR) which allows the coefficients to vary with time. It has both advantages of allowing non-linearity and not imposing a particular observable threshold variable. To proceed, we estimate a TV-PSTR on alternative specifications and select the optimal specification according to information criteria.[22]

The linearity test results reported at the bottom of Table 2 clearly reject the null hypothesis of a linear relationship. The remarkably high level of rejection makes the presence of nonlinear dynamics unambiguous (the LM test goes from 207 to 227 across the different specifications). It is, therefore, clear that linear models of sovereign spreads are misspecified during this period of estimation. Our specifications look robust with similar slope parameters (γ is estimated between 0.07 to 0.22), the same inflection date ($c = 72$ corresponds to December 2011 when the LTRO operation was launched) and consistent estimated values and signs across different specifications.

Figure 3 which plots the estimated transition function indicates that in-

[21] We thank the anonymous referee for this comment.

[22] We test the largest possible vector of determinants by simultaneously including several proxies of the same effect (for example we include the real exchange rate and the trade balance together). The only exception is the four alternative proxies for economic activity because of their strong correlation.

vestors have priced sovereign risk differently during the crisis, and the transition from the non-crisis to the crisis regime has taken two years. The information criterion suggests that the second specification including the manufacturing production index is optimal (Schwarz = -0.65). In the following we focus on this specification to comment on the changing composition of the spread determinants over time.

First, investors price fiscal risk, throughout the period under examination, through the debt-to-GDP ratio and the fiscal balance. In the crisis regime, however, they penalize fiscal imbalances more strongly, attaching an extra premium on the stock of debt ($\hat{\beta}_1 + \hat{\beta}_2 = 0.7$ versus $\hat{\beta}_1 = 0.03$) and the fiscal balance ($\hat{\beta}_1 + \hat{\beta}_2 = -1.5$ versus $\hat{\beta}_1 = 0.09$).[23] Note that we find that yield spreads are positively associated with a larger issue of long-term bonds during the crisis, thereby reinforcing the extra premium on fiscal imbalances ($\hat{\beta}_1 + \hat{\beta}_2 = 18.9$ versus $\hat{\beta}_1 = 0$. Before the crisis the effect of competitiveness was ambiguous, as an improvement of the trade balance was associated with higher yield spreads. Since the crisis however, the relationship has become unambiguous: the deterioration of the trade balance is now associated with a higher yield ($\hat{\beta}_1 + \hat{\beta}_2 = -23.4$ versus $\hat{\beta}_1 = 24$). Since the crisis, yield spreads increase as a response to a slowdown in economic activity, proxied by the manufacturing production index ($\hat{\beta}_1 + \hat{\beta}_2 = -0.38$ versus $\hat{\beta}_1$ not significantly different of 0). The international risk is statistically significant in explaining spreads before the crisis, but its role becomes critical during the

[23] The increase is attenuated by the negative coefficient of squared debt $\hat{\beta}_1 + \hat{\beta}_2 = -0.002$. The aggregate sign is, however positive.

crisis when the relationship between the two variables is multiplied by 10 ($\hat{\beta}_1 + \hat{\beta}_2 = 0.1$ versus $\hat{\beta}_1 = 0.01$). Liquidity becomes significant only during the crisis, as a higher bid-ask spread is associated with a higher yield spread only during the crisis ($\hat{\beta}_1 + \hat{\beta}_2 = 5.5$ versus $\hat{\beta}_1 = 0$).[24] Last, as expected, the yield spreads decrease as a response to the OMT program during the crisis.

Overall, we confirm a key finding of previous work: the change of the fundamentals are not sufficient to explain yields over the crisis period, and an *increase in the sensitivity to fundamentals* and the pricing of new risks are also relevant (Aizenman *et al.* (2014) and Afonso *et al.* (2015)). So far we have allowed the coefficients to vary over time, but we argue that the regime shift may be endogenous due to self-reinforcing dynamics. What are the drivers of regime shift? In the following, we answer by relaxing the linearity assumption again and we allow the coefficients to vary with the different observable variables that capture the bank-sovereign nexus, liquidity risk, and the controls.

5.2 Linearity tests: the prominent role of the bank-sovereign nexus

We now run linearity test on the optimal specification (3 in Table 2) using observable threshold variables instead of time. The linearity test results reported in Table 3 clearly reject the null hypothesis of a linear relationship, regardless of which threshold variable is included in the specification. To

[24]This effect is confirmed in two out of four specifications reported in Table 2

identify the prominent determinants of bond pricing shifts, we select the best threshold variables, which as suggested by González *et al.* (2005), are those which leads to the strongest rejection of the linearity hypothesis.

The ranking of the test statistics reveals that four out of the five proxies of the bank-sovereign nexus rank in the top five highest rejection statistics: *CDSSnrFin*, *CDS SubFin*, *IVolBank* and *CmaxiFi* reject linearity with 210.8, 177.2, 144.8 and 140.6 respectively. Only one indicator of liquidity risk ranks in the top five : *Aaa/10-year Bund* spread gets a rejection statistic of 147.3, while the five alternatives get a significant lower statistics mostly below 100. We cannot reject the hypothesis of adverse effects due to fire-sale liquidation. Nevertheless, the bank-sovereign nexus gets stronger empirical support, suggesting that it was prominent in driving nonlinearities.

In fact, the tests reveal that neither the rise in systemic risk nor the volatility of other market segments performs as well. For example, CISS, the indicator of systemic risk, gets a rejection statistics of 79.7, almost three times lower than the banking CDS index. Alternative controls of aggregate risk such as the volatility of FTSE and S&P as well as Vstoxx get similar rejection statistics (70.4, 69.6 and 63.2 respectively). Similarly, the indicators of uncertainty in the *non*-banking sector, *rvol NonFin* and *rvol Bond* and of the foreign exchange market get lower statistics. We find, therefore, that investors are sensitive to the risk in the banking sector, and this triggers nonlinear dynamics. While the bank-sovereign loop has been documented before, we are the first to give a functional form to the subsequent amplification effects in the government bond pricing. More precisely, *the pricing model is a nonlinear function of fundamentals, where the weight of these fundamentals varies with the risk of banks.* The deterioration of market conditions for banks changes the way investors price risk of the sovereigns. We examine the evolution of the estimated coefficient below.

Given the high rejection statistics obtained in every model, we check the robustness of our selection choice using BIC information criteria. While the model with the banking CDS index rejects linearity with the highest statistics, the BIC criterion indicates that the model with the banking stress indicator *CmaxFi* is more efficient (Table 4). So in the last step of our empirical investigation, we estimate the two specifications to examine the variation of coefficient loads.

5.3 Heteroegeneity in the sample

The threshold variable *CmaxFi* has an individual dimension (*i.e.* it takes different values across countries, see Fig. 2) contrary to the homogeneous *CDSFin*, a feature allowing us to spot heterogeneity in our sample and suggesting two different dynamics. Indeed, the threshold value of *CmaxFi* that triggers the regime shift, $c = 0.86$, was never crossed in Italy, Spain and Portugal, while Ireland and Greece went from the first to the second regime (Fig. 2). Therefore, while the five peripheral countries are usually gathered in the same bundle, our estimates suggest that their spreads have a different dynamics. González-Hermosillo and Johnson (2014) point out similar heterogeneous dynamics in the sovereign CDS of the five stressed countries. This finding leads us to split our sample into two sub-samples, one including Italy, Spain and Portugal, the other Greece and Ireland. The smaller sub-sample still has 162 observations, which is sufficient for reasonably precise and stable estimates.

We re-estimate the model in each sub-sample (Tables 5 and 6). We obtain a parsimonious specification by adopting a general-to-specific modeling approach, where we eliminate variables based on their statistical significance and the Schwartz information criterion.

5.3.1 Italy, Portugal and Spain

Results in Table 5 report the transition speed, γ, the location parameter c and the estimated coefficients in regime 1 and regime 2 ($\hat{\beta}_1$ and $\hat{\beta}_1 + \hat{\beta}_2$) in two estimations, one using the optimal threshold variable, *CDSFin* and the other using *CmaxFi* for robustness check. Below we comment only the first estimate. The transition from the first to the second regime is sharp ($\gamma = 95.4$) and the threshold value, c is 130.7 bp. Our model predicts that investors price the sovereign risk differently when the banking CDS index is over 130.7 bp, a value which was crossed in autumn 2010 shortly after the Greek crisis broke. When we focus on the crisis period, the transition is sharp, which may illustrate the sudden contagion effects. The plot of a sharp transition function does not carry much information, so we focus instead on the numerical evolution of the coefficients.

Estimates confirm the time-varying PSTR result of an increase in the sensitivity to fundamentals. Investors apply an extra premium to competitiveness (the coefficient of the real exchange rate in hte second regime is $\hat{\beta}_1 + \hat{\beta}_2 = 0.078$ versus $\hat{\beta}_1 = 0.044$ in the first regime) and international risk (for VIX, $\hat{\beta}_1 + \hat{\beta}_2 = 0.04$ versus $\hat{\beta}_1 = 0.01$). In turn, the extra premium on fiscal imbalances uncovered in the large sample is much less pronounced in this sub-sample: when we plot the evolution of the weight, we observe that the increase is very limited.[25] In sum, the market discipline effect works through a higher sensitivity to the countries' perceived competitiveness rather than the fiscal situation. Last, the SMP program does not have the expected negative effect on the yield spread.

5.3.2 Greece and Ireland

The results of the second sub-sample including Greece and Ireland reported Table 6 also indicate that the yield spreads have become more sensitive to fundamentals since 2010. Figure 4 plots the smooth transition to the crisis regime. The fact that the transition is smooth and not sharp in this sample may be due to the presence of Greece, the epicenter of the crisis from which contagion effects then spread.

Contrary to the previous sample, we find that an extra premium is applied to fiscal imbalances: the coefficient of debt-to-GDP increases dramatically in the second regime ($\hat{\beta}_1 + \hat{\beta}_2 = 0.868$ versus $\hat{\beta}_1 = -0.22$) as well as the absolute value of the coefficient of fiscal balance ($\hat{\beta}_1 + \hat{\beta}_2 = -0.56$, negative

[25] The graph is available upon request.

as expected, versus $\hat{\beta}_1 = 0.34$). So the higher sensitivity to fiscal imbalances seen in the larger sample was driven by the presence of Greece and Ireland, two counties that have faced fiscal deterioration to a much larger extent than Italy, Spain and Portugal. In addition, a higher sensitivity is detected for competitiveness (the real effective exchange rate and trade balance have both a higher absolute coefficient in the second regime) and economic activity (manufacturing production index). We do not detect a significant effect of the SMP program in this sub-sample either.

In total, splitting the sample highlights that an extra premium on fiscal deterioration is applied in Greece and Ireland only.

Robustness

To check the robustness of our results, we proceed to alternative estimates:

- In the first sub-sample (including Italy, Spain and Portugal), overall amplification effects are confirmed when *Cmax Fin* is used as a threshold variable in an alternative specification reported in Table 5. In particular, these estimates confirm that fiscal imbalances are not priced more severely in the crisis.

- Banking CDS and sovereign bonds may price the same information, which would raise an endogeneity bias due to simultaneity. To address this, we re-estimate our optimal model by lagging the threshold variable. Linearity is strongly rejected ($LM = 179.9$), and amplification effects are confirmed.

- Last, we check that our nonlinearity finding does not result from omitting the financial CDS index as an explanatory variable so that a linear regression would be enough.[26] Our results are not affected by the introduction of the financial CDS index in the vector of determinants (X_{it} in Eq. 1), and its coefficient is not significant. That indicates that this variable drives nonlinear effects in the sovereign bond pricing (LM= 216.8).

5.4 Dynamics after Draghi's speech and macro-prudential implications

Our objective in this paper was to shed light on the regime shift during the crisis. We start the estimation in 2006 to examine the transition towards the crisis regime and stop right before the spreads decline drastically in July 2012. It is interesting, however, to examine whether our model captures the drastic decline afterwards, a sudden decline that cannot be due to the evolution of fundamentals. It may be that the ECB President's commitment to do "whatever it takes" blurred market signals, so that "spreads no longer show us what investors think about debt sustainability" (Paris and Wyplosz, 2013). In our analysis, that would introduce a third regime in government yield pricing after Draghi's speech, where the vector of determinants and their sensitivity change again. Alternatively, one may argue that Draghi's speech tamed market tensions and restored the pricing regime prevailing before the crisis, in that case, we would find that the same endogenous mechanisms operated in reverse. To check, we extend the estimates

[26] We thank the referee for this comment.

of our optimal specification in both sub-samples up until March 2014, the maximum date with available data.[27]

The takeaway is that the evolution of the coefficient load is very similar to the previous estimation period and the same regime-shifting mechanism operate in reverse. Indeed, Figure 5 of the new transition functions indicates that the model shifts back progressively to the first regime after July 2012. By the end of 2013, the shift was complete with the coefficients back to their pre-crisis level. The financial CDS index is still a key driver of regime shift (LM statistics is 155 and 137 in each sub-sample respectively). The fact that it gets progressively back to its pre-crisis value drives the shift back to the first regime of coefficients. Our estimates, therefore, show that the *reversion to the non crisis regime was driven by a break of the vicious feedback loop between the sovereign and the banks.* It is interesting to observe that it occurred well before macro-prudential measures were enforced to address the fragility of the banking sector's balance sheet, including the banking union and the stress tests in Fall 2014. The ECB broke the sovereign-bank nexus and interrupted the feedback loop. This bought time while macro-prudential measures were being implemented.

[27] There are missing data for the Irish yield after 2012 because liquidity was scarce during the assistance program. In order to bridge the missing data, we mix three different maturities, the 7, 8 and 9 year maturity (the longer maturity yield data include all bonds with lower maturity).

6 Concluding remarks

We estimated the sovereign spread of five peripheral members of the euro area using panel non-linear estimation methods. Our objectives were threefold: 1) test for nonlinear sovereign bond pricing 2) discriminate between two potential drivers of non-linearity, the sovereign-bank nexus and liquidity spirals and 3) quantify the threshold effects and coefficient regime shifts in order to draw lessons for economic policy.

Our PSTR estimations confirm the previous finding that the changing sensitivity of bond yields to fundamentals is necessary to explain yields during the crisis period (Aizenman *et al.* (2014) and Afonso *et al.* (2015)). We find that investors then attached an extra premium to competitiveness, international risk, and to a lesser extent liquidity. Contrary to previous studies, we find an extra premium on fiscal imbalances only in Greece and Ireland, not in Italy, Spain and Portugal. We show that the increasing risk in the banking sector was not only a significant determinant of sovereign risk, but it also amplified the effects of movements in fundamentals. This was a key link in the bank-sovereign nexus. Finally, we find that bond yields returned to their pre-crisis spread determination regime during the year after Draghi's speech, demonstrating the power of the lender of last resort to stabilize markets. These findings of regime switch and switch back are new, revealed by our estimation method.

There are significant lessons for European regulators and policymakers here: 1) Domestic fiscal discipline and structural reforms could not bring yields down as long as the bank-sovereign feedback loop was not fully addressed. 2) Regime shift was better explained by risk in the banking sector than a general systemic risk indicator. So tracking the financial CDS index would effectively complement the macroprudential toolkit of policymakers. 3) The individual dynamics were driven by the aggregate banking risk, a risk that the ECB intervention has successfully tamed. So, a more speculative conclusion: 4) Limiting the risk-sharing of the ECB operations in the sovereign bond markets as in the asset purchase program announced in January 2015 carries the risk of re-igniting tensions.

Beyond the specific Eurozone crisis event, our findings may contribute to a better understanding of financial instability, with macroprudential lessons. The financial price determination models prevailing in normal times may be invalid during crises; the risk pricing of financial assets is *fundamentally state-dependent*. Our empirical framework gives a simply implementable method to track regime changes and identify the trigger. It is key to act on it quickly. When the risk trigger is systemic, the central bank can change the state to restore the pricing dynamics, by virtue of its unique role as lender of last resort.

References

1. Acharya, V., and Steffen, S. "The greatest carry trade ever? Understanding Eurozone bank risks", CEPR Discussion Paper 9432 (2013).

2. Acharya, V., Drechsler, I., and Schnabl, P. "A Pyrrhic victory? Bank bailouts and sovereign credit risk", Journal of Finance,69, 2689-2739

(2014).

3. Afonso, A., Arghyrou, M. G and Kontonikas, A. "The determinants of sovereign bond yield spreads in the EMU", European Central Bank Working Paper (2015).

4. Aizenman J, M. M. Hutchison and Y. Jinjarak, "What is the risk of European sovereign debt default? Fiscal space, CDS spread, and market pricing of risk", *Journal of International Money and Finance*, 34, 37-59 (2013).

5. Allen, W. A. and Moessner, R. "The liquidity consequences of the euro area sovereign debt crisis". BIS Working Paper (2013).

6. Ang, A., and F. A. Longstaff. "Systemic sovereign credit risk: Lessons from the US and Europe." *Journal of Monetary Economics* 60.5 (2013): 493-510.

7. Attinasi, M. G., Checherita, C. and Nickel, C., "What explains the surge in euro area sovereign spreads during the financial crisis of 2007-09?", ECB Working Paper (2009).

8. Avino, D., and J. Cotter. "Sovereign and bank CDS spreads: two sides of the same coin?." *Journal of International Financial Markets, Institutions and Money* (2014).

9. Borgy, V., Laubach, T., Mesonnier J.-S. and Renne, J.-P., "Fiscal Sustainability, Default Risk and Euro Area Sovereign Bond Spreads Markets", Document de travail n.350, Banque de France (2011).

10. Brunnermeier, M., and Oehmke, M., "Complexity in financial markets", Technical report, Princeton Working Paper 2009/2, 4 (2009).

11. Brunnermeier, M., and Pedersen, L.H., "Market liquidity and funding liquidity", R*eview of Financial Studies*, 22, 2201-2238 (2009).

12. Cantor, R., and Packer, F., "Determinants and impact of sovereign credit ratings", FRB NY*Economic Policy Review*, 2(2) (1996).

13. Coimbra, N., "Sovereigns at risk: a dynamic model of sovereign debt and banking leverage", London Business School (January 2014).

14. Costantini, M., M. Fragetta and Melina, G."Determinants of sovereign bond yield spreads in the EMU: An optimal currency area perspective," *European Economic Review*, 70(C), 337-349 (2014).

15. Davies R.B. "Hypothesis testing when a nuisance parameter is present only under the alternative", *Biometrika* 74, 33-43 (1987).

16. De Grauwe, P., and Ji, Y. " Self-fulfilling crises in the Eurozone: an empirical test", *Journal of International Money and Finance*, 34, 15-36 (2013).

17. De Grauwe, P.,"A fragile eurozone in search of a better governance", *CESIFO Working Paper*, n.3456 (2011).

18. Duffie, D., and Singleton, K., "Modeling term structures of defaultable bonds", *Review of Financial Studies*, 12(4), 687-720 (1999).

19. Edwards, S., "The pricing of bonds and bank loans in international

markets: An empirical analysis of developing countries' foreign borrowing", *European Economic Review*, 30 (3), 565-589 (1986).

20. Eichengreen, B., and Portes, R., "After the Deluge: Default, Negotiation and Readjustment in the Interwar Years", in B. Eichengreen and P. Lindert (eds.), *The International Debt Crisis in Historical Perspective* pp. 12-47(MIT Press, 1989).

21. Favero, C., Pagano, M. and von Thadden, E.L. "How Does Liquidity Affect Government Bond Yields?", *Journal of Financial and Quantitative Analysis*, 45, 107-134 (2010).

22. Favero, C. and A. Missale, “"Sovereign Spreads in the Euro Area. Which Prospects for a Eurobond?" *Economic Policy*, 27(70), 231-273 (2012).

23. Fouquau J., Hurlin C., Rabaud I., "The Feldstein-Horioka Puzzle: a Panel Smooth Transition Regression Approach." *Economic Modelling*, 20, 284-299 (2008).

24. Geanakoplos, J. and Polemarchakis, H. "Existence, regularity and constrained suboptimality of competitive allocations when markets are incomplete", in W. Heller, R. Starr and D. Starrett (eds), *Essays in Honor of K. Arrow*, Cambridge: Cambridge University Press (1986).

25. Gennaioli, N., Martin, A. and Rossi, S., "Sovereign default, domestic banks and financial institutions", CEPR Discussion Paper 7955 (2010).

26. Gerlach, S., A. Schulz and G.B. Wolff, "Banking and sovereign risk

in the euro area", Deutsche Bundesbank Discussion Paper n.09/2010 (2010).

27. Geyer, A. Kossmeier, S and Pichler, S., "Measuring systematic risk in EMU government yield spreads", *Review of Finance*, 8(2), (171-197) (2004).

28. González A., Terasvirta T. and D. van Dijk "Panel smooth transition regression models", SEE/EFI Working Paper Series in Economics and Finance No. 604 (2005).

29. Gonzalez-Hermosillo, B., and C. A. Johnson. "Transmission of Financial Stress in Europe: The pivotal role of Italy and Spain, but not Greece." (2014).

30. Hakkio C.S and Keeton, W., "Financial Stress: What is it? How can it be measured?", Federal Reserve Bank of Kansas City, *Economic Review* (2009).

31. Haugh, D., P. Ollivaud and D. Turner, "What Drives Sovereign Risk Premiums?: An Analysis of Recent Evidence from the Euro Area" , OECD Economics Department Working Papers, No. 718, OECD Publishing (2009).

32. Hollo, D., Kremer, M. and Lo Duca, M., "CISS-a composite indicator of systemic stress in the financial system", ECB Working Paper (2012).

33. Huizinga, H., and Demirguc-Kunt, A., "Are banks too big to fail or too big to save? International evidence from equity prices and CDS

spreads", European Banking Center Discussion Paper 2010-15 (2010).

34. IMF, "World Economic Outlook. Coping with High Debt and Sluggish Growth", World Economic and Financial Surveys, International Monetary Fund, Washington (2012).

35. IOSCO, "The credit default swap", Technical Report, International Organization of Securities Commissions (2012)

36. Longstaff, F.A., Pan Jun, Pedersen, L.H. and Singleton K.J. , "How Sovereign Is Sovereign Credit Risk?," *American Economic Journal: Macroeconomics,* 3(2), 75-103 (2011).

37. Montfort A., and J.P. Renne, "Decomposing Euro-Area Sovereign Spreads: Credit and Liquidity Risks", *Review of Finance* (2013)

38. Pelizzon, L., Subrahmanyam, M. G., Tomio, D., and Uno, J., "Sovereign Credit Risk, Liquidity and ECB Intervention: Deus ex Machina?." (March 2015). SAFE Working Paper No. 95. (2015).

39. Paris P., and Wyplosz C. , "To end the Eurozone crisis, bury the debt forever", voxEU, 6 August (2013).

40. Patel, S. and A. Sarkar, "Stock Market Crises in Developed and Emerging Markets", *Financial Analysts Journal*, 54(6) 50-59 (1998).

41. Rey, H., "Dilemma not Trilemma: The global financial cycle and monetary policy independence." Jackson Hole Economic Symposium. (2013).

42. Stiglitz, J., "The Inefficiency of the Stock Market Equilibrium", *Review of Economic Studies*, 49(2), 241-261 (1982)

43. Vause, N., "Enhanced BIS statistics on credit risk transfer", *BIS Quarterly Review*, December (2011).

44. Wyplosz, C., "Eurozone Crisis: It's About Demand, not Competitiveness." The Graduate Institute, Geneva (2013).

Table 1: Descriptive statistics of the sovereign spreads and explanatory variables

	Spread	Debt	Deficit	R. Eff. Exch rate	VIX	Bis-ask
Mean	2.678	85.591	-6.780	100.98	23.086	0.143
Median	0.870	94.626	-5.518	100.59	20.723	0.013
Maximum	29.886	174.882	3.134	115.22	62.254	5.886
Minimum	-0.801	23.159	-34.081	92.95	10.787	0.001
Std. Dev.	4.686	35.237	6.477	3.456	10.624	0.539
Skewness	3.364	-0.042	-1.779	1.277	1.708	7.273
Kurtosis	16.384	2.235	8.495	6.436	6.346	64.823

	Out. Issues	UMP	Manufacturing	Housing	Industry	Unemployment
Mean	0.082	64.051	105.46	205.72	105.08	11.141
Median	0.047	2.571	100.80	138.43	103.24	9.200
Maximum	0.262	283.61	132.47	907.47	140.99	25.300
Minimum	0.007	0.000	81.110	25.294	51.500	4.300
Std. Dev.	0.089	93.716	11.788	179.72	14.714	4.864
Skewness	1.244	1.275	0.588	2.028	0.060	1.024
Kurtosis	2.893	3.290	2.285	7.231	3.192	3.357

Notes: Out. Issues: Outstanding Euro-denomneated long-term government securities issued in the Euro-zone.UMP: Unconventional Monetary Policy. Manufacturing: Manufacturing production index. Industry: Industrial production index. Housing: new housing permits.

Table 2: Selection of the optimal specification with a TVPSTR model

	Specification 1		Specification 2		Specification 3		Specification 4	
	β_1	β_2	β_1	β_2	β_1	β_2	β_1	β_2
$Debt-to-GDP$	0.137*** (7.78)	0.353*** (2.61)	0.034** (2.21)	0.666*** (5.29)	0.030** (2.04)	0.645*** (4.78)	0.021 (1.32)	0.686*** (5.09)
$Debt-to-GDP^2$	−0.001*** (−6.16)	0.000 (−0.52)	0.000 (1.44)	−0.002*** (−3.80)	0.000*** (2.89)	−0.002*** (−3.48)	0.000*** (3.24)	−0.002*** (−3.71)
Fiscal balance	0.162*** (4.69)	−0.845*** (−5.10)	0.096*** (7.13)	−1.649*** (−9.80)	0.094*** (6.69)	−1.992*** (−10.3)	0.073*** (4.26)	−2.059*** (−10.21)
R Effect. Exch Rate	0.230*** (9.28)	−0.395*** (−4.22)	0.127*** (8.46)	−0.156 (−1.19)	0.121*** (8.65)	−0.573*** (−6.40)	0.126*** (8.34)	−0.615*** (−6.02)
Trade balance	28.39*** (6.54)	−46.93*** (−9.84)	24.05*** (7.94)	−47.51*** (−8.34)	25.49*** (7.98)	−64.05*** (−17.05)	26.58*** (7.73)	−60.03*** (−13.36)
VIX	0.022*** (5.87)	0.034 (0.98)	0.019*** (7.17)	0.087** (2.11)	0.018*** (7.09)	0.079 (1.61)	0.019*** (6.93)	0.055 (1.06)
Bid-Ask	4.059* (1.76)	−2.491 (−0.53)	−0.505 (−0.56)	5.561*** (2.99)	−0.106 (−0.13)	5.075*** (2.89)	0.083 (0.1)	4.584*** (2.62)
Outstanding issues of LT govt sec	−75.76*** (−3.49)	−12.52*** (−2.84)	0.333 (0.02)	10.78*** (2.46)	−8.300 (−0.58)	18.88*** (3.63)	−2.082 (−0.15)	14.93** (2.42)
Unconventional Monetary Policy	0.017*** (4.72)	−0.033*** (−3.97)	0.013*** (7.00)	−0.031*** (−3.66)	0.012*** (6.32)	−0.021** (−2.51)	0.012*** (5.41)	−0.024*** (−2.81)
Unemployement	0.054 (1.02)	0.541*** (3.42)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Manufacturing production index	– (–)	– (–)	0.005 (1.1)	−0.393*** (−3.17)	– (–)	– (–)	– (–)	– (–)
Industry production index	– (–)	– (–)	– (–)	– (–)	0.004* (1.67)	−0.006 (−0.21)	– (–)	– (–)
New housing permits	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	0.001*** (2.67)	0.031 (0.8)
Smooth Parameter γ	0.072		0.179		0.211		0.221	
Loc Parameter c	72.0		72.0		72.0		72.0	
Linearity Stat.	222.7***		227.4***		207.7***		208.2***	
RSS	153.9		139.1		149.7		148.0	
Schwarz Crit.	-0.549		-0.651		-0.577		-0.588	

Notes: The T-statistics in parentheses are corrected for heteroskedasticity. (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level.β_1 and β_2 correspond to the coefficient in Eq (11). β_1 is the coefficients in the first extreme regime . The coefficients in the second extreme regime is $\beta_1 + \beta_2$.

Table 3: Linearity Tests with a PSTR model (specification 2)

	H1: Fire-sale liquidation			H2: Bank-sovereign loop	Control
	Flight to liquidity	Flight to quality	Asymetry information		
AAA/ 10-year Bund spread	147.3***				
10-year Swap spread	110.2***	110.2***			
A/ 10-year Treasury spread	92.10***	92.10***			
High-Yield bund/ Baa spread	77.6***	77.6***	77.6***		
StockbondsCorr		80.4***			
Cross-Section dispersion banks			63.2***		
IVOL bank				144.8***	
CmaxFin				140.6***	
Euribor-OIS				123.2***	
CDS Snr-Fin				210.8***	
CDS Sub-Fin				177.2***	
I-traxx Europe					120.4***
X-over					84.10***
Hivol					79.3***
Vstoxx					63.2***
RVOL Germ					24.1***
RVOL Nonfin					78.7***
RVOL Pound					54.6***
RVOL Doll					20.3**
RVOL Yen					45.2***
FTSE 300					70.4***
S& P 350					69.6***
Domestic indices returns					26.8***
CISS					79.7***

Notes: The corresponding LM statistic has an asymptotic $\chi^2(p)$ distribution under H_0. (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. We have used the specification 2 of the table 1.

Table 4: Comparison of test statistics and parameters with two different threshold variables, SnrFin and CmaxFin.

Threshold	Snr Fin	Cmax Fi
Linearity Stat	201.7***	140.6***
Smooth Parameter	0.928	549.9
Loc Parameter	259.1	0.859
RSS	238.9	145.92
Schwarz Crit.	-0.110	-0.603

We have used the specification 2 of the table 1. Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level.

Table 5: Estimates of the sovereign bond model with a PSTR model for Italy, Spain and Portugal

	CDS Snr Fin		CMax Fi	
	β_1	β_2	β_1	β_2
$Debt-to-GDP$	0.064^{***} (2.56)	-0.068^{**} (-2.48)	0.097^{***} (12.26)	-0.015^{***} (-4.27)
$Debt-to-GDP^2$	0.000 (-1.14)	0.001^{***} (3.17)	$-$ $(-)$	$-$ $(-)$
Fiscal balance	0.035^{***} (3.72)	0.011 (0.16)	-0.042^{***} (-2.84)	0.130^{***} (4.50)
Real Exchange Rate	0.044^{***} (2.82)	0.034^{*} (1.82)	0.050^{***} (3.69)	0.060^{***} (4.20)
Trade balance	$-$ $(-)$	$-$ $(-)$	-7.444^{***} (-3.57)	10.03^{***} (4.19)
VIX	0.014^{***} (6.73)	0.028^{***} (3.67)	0.022^{***} (7.52)	0.006 (0.96)
Bid-Ask	17.72^{***} (3.62)	-13.19^{***} (-2.68)	4.872^{***} (7.29)	-0.119 (-0.2)
Outstanding stock	-7.045 (-0.59)	-9.766^{***} (-5.38)	$-$ $(-)$	$-$ $(-)$
Unconventional Monetary Policy	-0.003 (-1.27)	0.014^{***} (6.29)	0.004^{***} (6.25)	0.007^{***} (6.61)
Manufacturing prod. index	-0.008^{**} (-1.97)	-0.015 (-1.00)	0.042^{***} (7.85)	-0.036^{***} (-3.05)
Smooth Parameter γ	95.4		42.2	
Loc Parameter c	130.7		0.530	
Linearity Stat.	94.6^{***}		79.7^{***}	
RSS	21.6		18.5	
Schwarz Crit.	-1.843		-2.053	

Notes: The T-stat in parentheses are corrected for heteroskedasticity. (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. β_1 and β_2 correspond to the coefficient in Eq (11). β_1 is the coefficient in the first extreme regime . The coefficient in the second extreme regime is $\beta_1 + \beta_2$.

Table 6: Estimates of the sovereign bond model with a PSTR model for Greece and Ireland

	CDS Snr Fin		CMax Fi	
	β_1	β_2	β_1	β_2
$Debt-to-GDP$	-0.222^{**} (-2.39)	1.08^{***} (4.02)	-0.123^{***} (-4.47)	0.376^{***} (5.52)
$Debt-to-GDP^2$	0.000 (0.90)	-0.004^{***} (-2.75)	0.001^{***} (6.86)	-0.001^{***} (-3.49)
Fiscal balance	0.336^{***} (3.74)	-0.895^{***} (-4.32)	-0.088^{***} (-2.13)	0.108^{*} (1.8)
R Effect. Exch Rate	-0.179^{**} (-2.14)	1.304^{***} (7.88)	0.060^{**} (2.06)	-0.021 (-0.81)
Trade balance	44.63^{***} (4.53)	-67.13^{***} (-3.79)	28.51^{***} (5.13)	-43.48^{***} (-6.04)
VIX	0.104 (1.50)	-0.356^{**} (-2.00)	0.016^{***} (2.66)	-0.032 (-1.49)
Bid-Ask	$-$ $(-)$	$-$ $(-)$	4.054^{***} (10.63)	-0.657 (-1.17)
Outstanding stock	$-$ $(-)$	$-$ $(-)$	-11.696 (-0.31)	-416.2^{***} (-4.59)
Unconventional Monetary Policy	$-$ $(-)$	$-$ $(-)$	0.029^{***} (6.41)	-0.048^{***} (-6.51)
Manufacturing prod. index	0.473^{***} (6.12)	-1.693^{***} (-6.8)	$-$ $(-)$	$-$ $(-)$
Smooth Parameter γ	0.007		438.4	
Loc Parameter c	176.5		0.861	
Linearity Stat.	132.6^{***}		59.7^{***}	
RSS	241.2		86.9	
Schwarz Crit.	1.049		0.186	

Notes: The T-stat in parentheses are corrected for heteroskedasticity. (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. β_1 and β_2 correspond to the coefficient in Eq (11). β_1 is the coefficient in the first extreme regime . The coefficient in the second extreme regime is $\beta_1 + \beta_2$.

Figure 1: Sovereign spreads

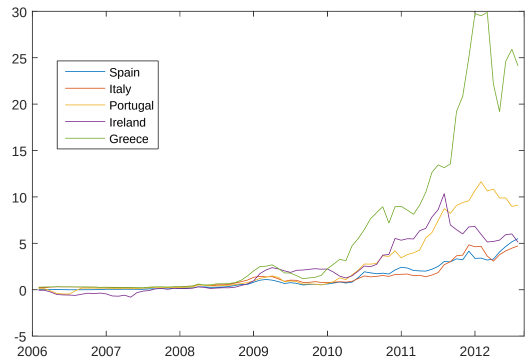
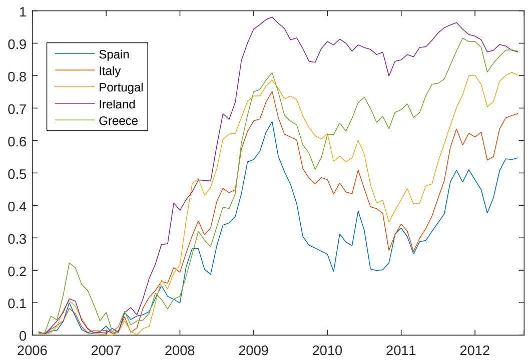


Figure 2: Threshold variable CmaxFin



Note: $Cmax_t = 1 - \frac{P_t}{max[P_{t-24} \ldots P_t]}$ with P_t, the domestic banking stock index. The more bearish the market, the closer to 1 the indicator.

Figure 3: Transition function in the TVPSTR model

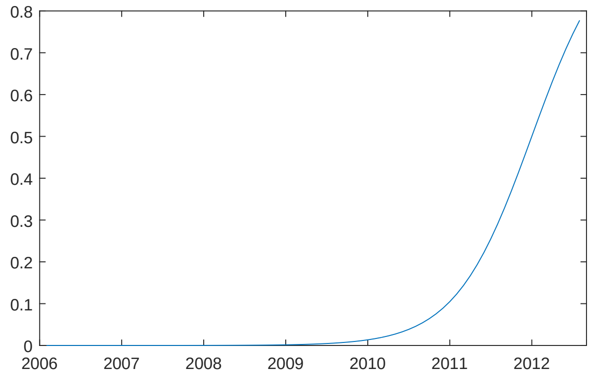


Figure 4: Transition function in Greece and Ireland from 2006 to 2012

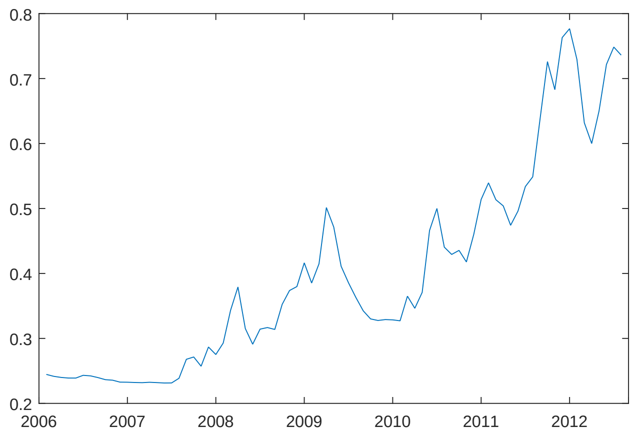
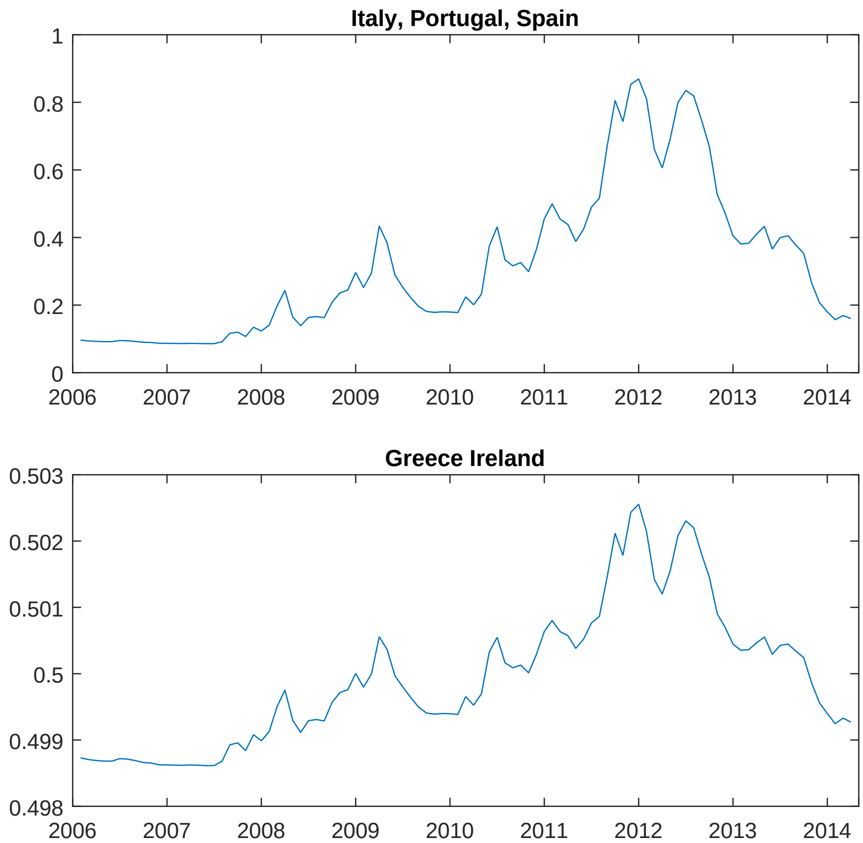


Figure 5: Transition functions from 2006 to 2014



Acknowledgements

We are grateful for comments from seminar participants.We would like to acknowledge helpful discussions with Vincent Bouvatier, Markus Brunnermeier, Isabelle Couet, J´erˆome Creel, Darrell Duffie, Linda Goldberg, Fr´ed´eric Malherbe, Mathiew Plosser, Lisa Pollack, H´el`ene Rey, Giovanni Ricco, Or Shachar and Paolo Surico. This research was partly supported by a grant from the London Business School RAMD fund and from the EU 7th Framework Program (FP7/ 2007-2013) under grant agreement 266800 (FESSUD). We are very grateful to Alessandro Giorgione for very meticulous research assistance. We thank an anonymous referee for helpful comments and suggestions.

Anne-Laure Delatte
CNRS, OFCE, CEPR

Julien Fouquau
ESCP EUROPE

Richard Portes
London Business School, European University Institute, CEPR and NBER, **rportes@london.edu**

Postal address	60640 Frankfurt am Main, Germany
Telephone	+49 69 1344 0
Website	**www.esrb.europa.eu**

ISSN	2467-0677 (online)
ISBN	978-92-95081-36-9 (online)
DOI	10.2849/801247 (online)
EU catalogue No	DT-AD-16-009-EN-N (online)