

REM WORKING PAPER SERIES

“Whatever it takes” to resolve the European sovereign debt crisis?
Bond pricing regime switches and monetary policy effects

António Afonso, Michael G. Arghyrou, María Dolores Gadea,
Alexandros Kontonikas

REM Working Paper 002-2017
September 2017

REM – Research in Economics and Mathematics

Rua Miguel Lúpi 20,
1249-078 Lisboa,
Portugal

ISSN 2184-108X

Any opinions expressed are those of the authors and not those of REM. Short, up to two paragraphs can be cited provided that full credit is given to the authors.



“Whatever it takes” to resolve the European sovereign debt crisis? Bond pricing regime switches and monetary policy effects

António Afonso[§], Michael G. Arghyrou[#], María Dolores Gadea⁺,
Alexandros Kontonikas[±]

September 2017

Abstract

This paper investigates the role of unconventional monetary policy as a source of time-variation in the relationship between sovereign bond yield spreads and their fundamental determinants. We use a two-step empirical approach. First, we apply a time-varying parameter panel modelling framework to determine shifts in the pricing regime characterising sovereign bond markets in the euro area over the period January 1999 to July 2016. Second, we estimate the impact of ECB policy interventions on the time-varying risk factor sensitivities of spreads. Our results provide evidence of a new bond-pricing regime following the announcement of the Outright Monetary Transactions (OMT) programme in August 2012. This regime is characterised by a weakened link between spreads and fundamentals, but with higher spreads relative to the pre-crisis period and residual redenomination risk. We also find that unconventional monetary policy measures affect the pricing of sovereign risk not only directly, but also indirectly through changes in banking risk. Overall, the actions of the ECB have operated as catalysts for reversing the dynamics of the European sovereign debt crisis.

JEL: E43, E44, F30, G01, G12

Keywords: euro area, spreads, crisis, time-varying relationship, unconventional monetary policy

Acknowledgements: We thankfully acknowledge financial support by FCT (Fundação para a Ciência e a Tecnologia, Portugal). FCT had no involvement in the study design, collection, analysis and interpretation of data, writing and submission of this research paper. M. Dolores Gadea acknowledges financial support from the Ministerio de Ciencia y Tecnología, Spain, under grant ECO2011-30260-C03-02. We thank participants at the 6th UECE Conference on Economic and Financial Adjustments, 2017 (Lisbon) for very useful comments, and we are grateful to Mina Kazemi for valuable research assistance.

[§] ISEG-UL – Universidade de Lisboa; REM – Research in Economics and Mathematics, UECE – Research Unit on Complexity and Economics. email: aafonso@iseg.utl.pt

[#] Cardiff Business School, Cardiff University, Colum Drive, Cardiff, CF10 3EU, UK, email: arghyroum@cardiff.ac.uk

⁺ Department of Applied Economics, University of Zaragoza, Gran Via, 4, 50005 Zaragoza, Spain, email: lgadea@unizar.es

[±] Essex Business School, University of Essex, Colchester Campus, Wivenhoe Park, Colchester, CO4 3SQ, email: a.kontonikas@essex.ac.uk

1. Introduction

The European sovereign debt crisis has dominated the international economic debate in recent years. It has posed an existential threat for the European Economic and Monetary Union (EMU), largely monopolised the agenda of policy makers and triggered a vast academic literature on the subject. Within the latter, one may distinguish four related but distinct branches. First, theoretical models of the EMU crisis highlighting the role of changes in market expectations as a key driver of the crisis' evolution (Arghyrou and Tsoukalas, 2011; De Grauwe and Ji, 2013). Second, empirical studies investigating the fundamental determinants of EMU long-term government bond yield spreads against Germany. These document significant time-variation in the relationship, specifically a shift from a pre-crisis to a crisis-related bond pricing regime (Arghyrou and Kontonikas, 2012; Bernoth and Erdogan, 2012, Afonso et al. 2014, 2015). Third, the role of banking risk in transforming the global financial crisis of 2008/09 into the sovereign debt crisis, and the nexus between banking risk and sovereign risk (Alter and Schüller, 2012; De Bruyckere et al., 2013; Acharya et al., 2014). Finally, a fourth branch investigates the effectiveness of non-conventional monetary policy actions by the European Central Bank (ECB) to stabilise sovereign bond markets. Most of these studies analyse the Security Markets Programme (SMP) and the effect of the Outright Monetary Transactions (OMT) announcement, while a few more recent papers consider the ECB's Quantitative Easing (QE) programme.¹ They typically find that the ECB policy interventions are associated with lower spreads without, however, identifying the channels via which they affect spreads.²

This paper brings together multiple branches of the literature on the European debt crisis by investigating the hypothesis that the relationship linking spreads with fundamentals is affected by the behaviour of the ECB. In other words, we posit that policy interventions may alter the underlying bond pricing regime. This hypothesis reflects notably the insights from

¹ The SMP commenced on May 2010 and involved the purchase of sovereign bonds from euro area periphery countries (Greece, Ireland, Italy, Portugal and Spain) during 2010-2011. For studies on the impact of SMP on spreads see, among others, Eser and Schwaab (2013), Ghysels et al. (2014) and Trebesch and Zettelmeyer (2014). The OMT was announced on 2 August 2012, following the statement by President Draghi on 26 July 2012 that the "ECB is ready to do whatever it takes to preserve the euro". The technical framework for the OMT was revealed on 6 September 2012 and on the same date the SMP was terminated. Altavilla et al. (2014) evaluate the reaction of spreads to the OMT announcement, while Krishnamurthy et al. (2015), Szczerbowicz (2015) and Gibson et al. (2016) examine both the SMP and the OMT. The QE programme was announced in January 2015 and is effective since March 2015. It involves the monthly purchase of euro area sovereign bonds, as well as other assets. The impact of QE on spreads is analysed in Altavilla et al. (2015) and De Santis (2016).

² An exception is the study of Krishnamurthy et al. (2015), who decompose the policy impact on sovereign yields into effects via default risk, market segmentation and redenomination risk. They find that default risk and market segmentation are the dominant channels through which the SMP and OMT worked in Italy and Spain, while redenomination risk may have been a policy channel in Spain and Portugal.

the theoretical models of the European sovereign debt crisis quoted above. The key prediction of these models relates to the possibility of multiple equilibria in the relationship between spreads and fundamentals. Drawing on models of currency crises (e.g. Obstfeld, 1996), they predict that the variable determining which of the possible multiple equilibria will eventually prevail is the status of redenomination/default expectations held by the private sector. Under favourable expectations, markets impose small penalties on risk factors, determining spreads at relatively low levels. An adverse shift in expectations results into higher penalties on risk factors and relatively high spread values. The ECB, through its actions and guarantees that it is ready to operate as a lender of last resort, can improve expectations and thereby generate a shift in bond pricing behaviour.³

To explore this hypothesis, we adopt a two-step empirical approach. First, we employ a time-varying parameter (TVP) panel econometric methodology to capture changes in the relationship between 10-year sovereign bond yield spreads against Germany and their fundamental determinants (global financial risk, liquidity risk and credit risk). We present results for a panel of ten EMU countries over the period January 1999 to July 2016, as well as its core and periphery countries constituent sub-panels. This part of our analysis extends previous research on the time-varying relationship between spreads and fundamentals, whose samples typically end in 2010/11, into the period following the announcement of the OMT and Quantitative Easing (QE) programmes. Second, we model the series of TVP coefficients estimated for each of the spreads' determinants on a dummy variable capturing the effects of the OMT announcement and empirical measures of ECB monetary policy (conventional and unconventional). To our knowledge, this work is entirely novel in the literature. Moreover, we control for the effects of bank credit risk in the euro area.

With regards the determinants of spreads, we confirm the main finding of previous studies and extend them with a significant new one. Specifically, we document a change in the EMU bond-pricing regime from risk under-pricing before the global financial crisis, where the sensitivity of spreads to fundamentals is zero or near zero, to a regime involving increasingly larger penalties on risk factors and very high spreads.⁴ In addition to these two

³ See also the discussion in Appendix B of Paniagua et al. (2016) where they refer to monetary policy shifts as an example of factors that may affect expectations.

⁴ Earlier studies typically document the switch from a pre-crisis to a crisis-related bond pricing regime using fixed-parameter models and imposing exogenous break points on the data. These include Barrios et al. (2009), Arghyrou and Kontonikas (2012), Caggiano and Greco (2012). Another strand of the literature identifies the regime shift using time-varying coefficients models and endogenously determined structural breaks. Such studies include work by Aßmann and Boysen-Hogrefe (2012), Bernoth and Erdogan (2012), Constantini et al. (2014), D'Agostino and Ehrmann (2014), Afonso et al. (2015), Paniagua et al. (2016) and Delatte et al. (2017).

regimes, however, we identify a third pricing regime, triggered by the announcement of the OMT in August 2012 and characterised by a weakening of the link between spreads and their underlying fundamentals. This regime-shift has not been reported in previous studies, except from Delatte et al. (2017) who conclude that it represents a restoration of the first (pre-crisis/non-crisis) regime, driven by a decline in bank credit risk. We argue, however, that the third regime is new and different from the first one, with the main distinguishing factors being higher spreads relative to the pre-crisis era and a residual redenomination risk in periphery countries, carried over from the second (crisis) regime.

The second part of our analysis provides evidence that the transition from the second regime to the third is determined by factors relating to monetary policy, especially non-conventional interventions. Specifically, we find that the OMT announcement reduced the responsiveness of spreads to their fundamental determinants. Expansions in the ECB balance sheet due to the SMP and QE programmes, also had a similar effect. Finally, we show that the impact of monetary policy on the relationship between spreads and fundamentals can materialise not only directly but also indirectly through reductions in bank credit risk. This is because banking risk affects the sensitivity of spreads to fundamentals, but at the same time is highly driven by non-conventional monetary policy actions.

Our findings are in line with the predictions of theoretical models of the European debt crisis and are intuitively appealing. They suggest that by providing markets with a guarantee that it stands ready to act as a lender of last resort, the ECB managed to improve expectations causing a shift away from the “bad” equilibrium prevailing during the crisis. The direct effect suggests that the OMT and purchases of sovereign bonds in the secondary market reassured investors that the ECB stands ready to prevent the collapse of sovereign bond markets due to existing fiscal liabilities. The indirect effect hints that the ECB reassured markets that sovereigns will not be called upon to finance unsustainable contingent fiscal liabilities originating from extensive bank losses.

Overall, our work is related to several strands of the literature on the European debt crisis and contributes in numerous ways. First, it validates the predictions of multiple-equilibria models of the EMU debt crisis. Second, it presents evidence of a new bond-pricing regime following the announcement of OMT, which is different both to the pre-crisis as well as the crisis pricing regimes reported in previous literature. Third, it identifies a two-fold channel, direct and indirect, via which the ECB has stabilised euro area sovereign bond markets. Our paper’s main take-home message is that President Draghi’s speech on 26 July 2012 announcing the introduction of OMT was a game-changer for the resolution of the

crisis. The expansion of the ECB's balance sheet provided extra stimulus towards that direction.

The remainder of this paper is structured as follows: Sections 2 and 3 respectively discuss our econometric methodology and data. Section 4 presents our empirical findings. Specifically, section 4.1 estimates TVP panel models capturing the changing relationship between spreads and fundamentals, while section 4.2 investigates the factors that affect the TVP coefficients. Finally, section 5 summarises the paper and offers concluding remarks.

2. Methodology

In the first stage of our analysis, we model the euro area 10-year government bond yield spreads against Germany using a TVP panel specification. Given Greece's idiosyncratic characteristics, in the baseline estimates, we present results excluding and including this country.⁵ Following Li et al. (2011) and Bernoth and Erdogan (2012), we estimate the following TVP specification:

$$y_{it} = x'_{it}\beta_t + \alpha_i + f_t + v_{it}. \quad (1)$$

In equation (1), y_{it} denotes 10-year government bond yield spreads, where $i = 1 \dots N$; $t = 1 \dots T$; $x_{it} = [x_{it,1}, \dots, x_{it,k}]'$ is a vector of k regressors; and $\beta_t = [\beta_{t,1}, \dots, \beta_{t,k}]'$ is a vector of k time-varying coefficients. In line with previous studies (Manganelli and Wolswijk, 2009; Afonso et al., 2014), x_{it} includes variables measuring global financial risk, liquidity risk and credit risk. α_i captures country fixed effects and v_{it} a random error term. Fixed effects account for unobserved time-invariant country-specific factors that can affect spreads.⁶ The trend function f_t denotes time-specific effects. These control for omitted variables that do not vary across countries but evolve over time. The model of Li et al. (2011) is a non-parametric time-varying coefficient panel data model based on previous contributions by Robinson (1989) and Cai (2007), estimated using the local linear dummy variable (LLDV) approach

⁵ Unlike the rest of our sample countries, Greece joined the euro in 2001 rather than 1999. Furthermore, since July 2015 Greece has in place capital controls, designed to stabilise the Greek banking system following large deposits withdrawals during the period January – June 2015. In addition, Greece is the only country among our sample countries whose sovereign bonds are not part of the QE programme. Finally, as Greece has been the country at the epicentre of the EMU sovereign debt crisis, its spreads and fiscal imbalances are a clear outlier, even when compared with the figures of other EMU periphery countries (see the descriptive statistics in Table 1).

⁶ For identification, it is assumed that $\sum_{i=1}^N \alpha_j = 0$ (Su and Ullah, 2006) and the fixed effects are eliminated in the procedure.

which improves the rate of convergence of $\hat{\beta}$ and outperforms the averaged local linear estimate.

As in all non-parametric estimates based on a kernel function, the estimation involves the choice of a bandwidth parameter (denoted by h^*), to which the results are typically sensitive. A lower value for h^* reduces the bias involved in the TVP estimates but increases their variance. We set $h^* = 0.15$ using the cross-validation selection method,⁷ which is based on the principle of selecting the bandwidth that minimizes the mean squared error of the resulting estimates.⁸ Our estimations also account for the “boundary effect” according to which the estimated coefficients are biased at the beginning and end of the estimation sample. To address this bias, we follow Dai and Sperlich (2010) who propose reducing the bandwidth value at the beginning and end of the sample. We do so using a bandwidth correction parameter value, denoted by ε , equal to 0.08, satisfying the restriction $0 < \varepsilon < h^*$. Finally, for each estimated TVP coefficient we calculate a 95% confidence interval by applying the wild bootstrap method on the estimated residuals of the non-parametric estimated regression, based on 1000 replications. The same bandwidth and boundary effect correction are used, as in the source regression.

In the second stage of our analysis we model each TVP coefficient on an intercept dummy variable capturing the effects of the OMT announcement in August 2012, measures of conventional and unconventional monetary policy, as well as banking risk. Our econometric specification for this part of the analysis is given by equation (2) below:

$$\widehat{\beta}_t^j = \gamma + z_t' \delta + u_t. \quad (2)$$

In equation (2), the dependent variable $\widehat{\beta}_t^j$ is the time-series estimated for the TVP coefficient of each of the spreads’ determinants $j = (1 \dots k)$, and u_t is a random error term. We estimate equation (2) using Ordinary Least Squares (OLS) and three definitions of z_t .⁹ The first includes only the OMT dummy. The second extends z_t to include the proxies for the ECB’s conventional and unconventional monetary policy, while the third adds an empirical measure of aggregate credit risk for European banks.

⁷ Instead of the conventional leave-one-out cross validation method, we use the leave-one-unit-out approach, which is proposed by Sun et al (2009) and it is more adequate for the local linear dummy approach.

⁸ An alternative approach, the so-called “rule-of-thumb” method, suggested $h^* = 0.04$. This approach is computationally less demanding but can lead to non-robust results, especially when the data series present high volatility, as it is the case with our variables. The TVP coefficients that we obtain using $h^* = 0.04$ are broadly consistent with those using $h^* = 0.15$, but more volatile. These results are available upon request. An extensive survey of bandwidth selection methods can be found in Racine (2008).

⁹ The variables entering equation (2) are stationary series (see section 4.2 below).

3. Data

We have obtained data on euro area government bond yield spreads and the underlying fundamentals over the period January 1999 to July 2016 (monthly frequency). Our sample includes ten EMU member states, covering core (Austria, Belgium, Finland, France and the Netherlands) and periphery (Greece, Ireland, Italy, Portugal and Spain) economies¹⁰(see the Appendix for data descriptions and sources).

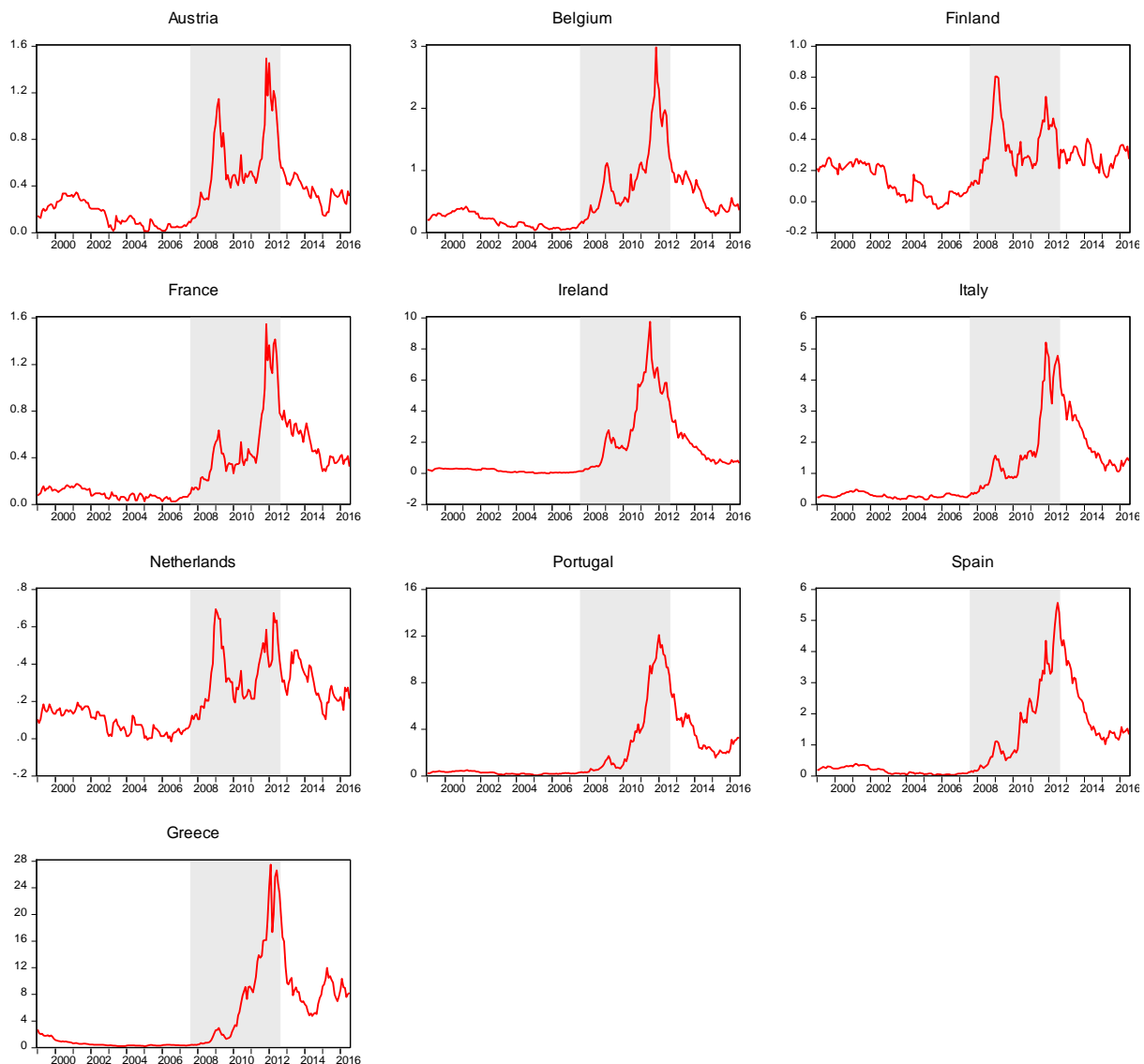
Figure 1 plots 10-year spreads versus Germany, while Panel A of Table 1 presents the corresponding descriptive statistics. They highlight the existence of three distinct periods. The first covers 1999 to summer 2007, and is characterised by near-zero spread values. The second covers summer 2007 to the peak of the crisis in late 2011-early 2012, and involves substantial increases in spreads, particularly in Greece but also in other periphery EMU countries. Finally, following the OMT announcement, we observe a gradual reduction in spread values to levels significantly lower than those in 2012 but higher (and typically more volatile) than the pre-crisis period. Furthermore, compared to the latter, mean spread values during the third period present higher variation across countries, and are clearly higher in EMU periphery countries.

We approximate global risk conditions using the logarithm of the Chicago Board Options Exchange Volatility Index (*vix*), a variable used by several previous studies (Beber et al., 2009; Afonso et al., 2015) to gauge the international risk factor. The data is obtained from Bloomberg. An increase in *vix* is expected to result in higher spread values. Developments in global risk involve low pre-crisis values, followed by significant increases between 2007 and 2012 and a gradual return towards pre-crisis values thereafter (see Figure A1 in the Appendix).

BA denotes the 10-year government bond bid-ask spread, sourced from Bloomberg, used to capture liquidity effects (Favero et al., 2010; Gerlach et al., 2010). A higher value of *BA* indicates a fall in bond market liquidity, and is expected to lead to an increase in government bond yield spreads. The almost zero bid-ask spreads between 1999 and 2007 reflect the ample liquidity of the pre-crisis period. A significant deterioration in liquidity conditions ensued, associated with the global financial crisis and European sovereign debt crisis, which affected more strongly the periphery group. Since mid-2012, periphery bid-ask spreads declined significantly but, on average, still exceed their pre-crisis level.

¹⁰ The distinction between these two groups is common in the literature. See, among others, Afonso et al. (2014), Paniagua et al. (2016) and Garcia and Werner (2016).

Figure 1: 10-year government bond yield spreads



Note: This figure plots the 10-year government bond yield spreads versus Germany over the period January 1999 - July 2016 for ten-euro area countries. Vertical axis: percentage points. The shaded area denotes the period July 2007 - July 2012. Source: European Central Bank.

Finally, we measure credit risk using two forward-looking variables: First, the logarithm of the Economic Sentiment Index relative to Germany (*esi*), available from Eurostat. The sentiment index is a weighted average of five sectoral indexes, whose scores are gathered from surveys stating agents' assessment of the current economic situation and their expectations about future developments. As such, the sentiment index is used in the literature as a forward-looking variable capturing growth expectations (Monfort and Renne, 2013; Dewachter et al., 2015). Higher *esi* values signal lower credit risk and are therefore expected to result into lower spread levels. Second, the one-year ahead expected general government gross debt-to-GDP ratio relative to Germany (*ED*), provided by the European

Commission's Economic Forecasts. The use of expected, as opposed to historical fiscal data, is in line with previous studies on the determinants of spreads (Attinasi et al., 2009; Arghyrou and Kontonikas, 2012). Fiscal conditions are related to credit quality, with fiscal deterioration implying higher credit risk. Hence, increased values for *ED* are expected to result in higher spread levels.

Both measures of credit risk indicate significant increases during the crisis period (see Panels C and D of Table 1). Unlike *vix* and *ba*, however, credit risk variables do not signal improvements following the summer of 2012. By contrast, economic sentiment relative to Germany deteriorates further in all core countries and Italy, while the improvement observed in the cases of Greece, Portugal and Spain falls short of restoring the average pre-crisis relative *esi* levels. Moreover, except from Finland and the Netherlands, average expected debt values relative to Germany increase further since summer 2012. All in all, the summary statistics reported in Table 1 suggest that the substantial reductions in spreads observed since the OMT announcement do not coincide with a similar improvement in national macro/fiscal fundamentals. This is a prima-facie evidence supporting the multiple equilibria theoretical models of the European sovereign debt crisis discussed in the introduction.

For the second part of our econometric analysis, i.e. the modelling of the spread's time-varying responses to the factors described above, we require measures of conventional and unconventional monetary policy, as well as banking risk. Conventional monetary policy is approximated using the change in the main policy rate of the ECB, namely the main refinancing operations rate (ΔMRO). Unconventional monetary policy is captured by the growth (logarithmic difference) in the amount of securities held by the ECB for monetary policy purposes ($\Delta shmp$), as reported in the ECB's weekly financial statements. The ECB's securities holdings, data for which is available since July 2009 only, have also been used by Gibson et al. (2016) and Delatte et al. (2017), among others, to capture the effect of non-standard monetary measures adopted by the ECB during the crisis. To construct a monthly series for securities holdings, we use the relevant figure quoted in each month's last weekly consolidated financial statement of the Eurosystem, published by the ECB (assets side, item 7.1). The resulting series is presented in Figure 2 and depicts the significant expansion of the ECB's balance sheet effected in the context of the SMP and, much more so, the QE programme. At the same time, Figure 2 shows the gradual relaxation of the ECB's conventional monetary policy stance, captured by the reduction in the *MRO* towards zero since the end of 2011. Both the change in the *MRO* and the growth of the ECB's securities holdings are included at lagged form (1-month lag) when estimating equation (2).

Table 1: Descriptive statistics

Panel A: 10-year government bond yield spreads versus Germany

	AT	BE	FI	FR	IE	IT	NL	PT	ES	EL	All+EL	All	Core	Per+EL	Per
1999.01-2016.07															
Mean	0.320	0.486	0.228	0.300	1.297	1.064	0.202	1.915	1.007	4.353	1.117	0.758	0.307	1.927	1.321
St. Dev.	0.279	0.498	0.160	0.300	1.949	1.158	0.160	2.761	1.270	5.896	1.443	0.948	0.279	2.607	1.784
1999.01-2007.07															
Mean	0.142	0.177	0.126	0.083	0.118	0.258	0.084	0.204	0.141	0.535	0.187	0.148	0.123	0.251	0.180
St. Dev.	0.102	0.111	0.101	0.041	0.110	0.073	0.058	0.109	0.111	0.518	0.133	0.091	0.083	0.184	0.101
2007.08-2012.07															
Mean	0.596	0.922	0.360	0.509	3.150	1.698	0.337	3.606	1.606	7.233	2.002	1.421	0.545	3.459	2.515
St. Dev.	0.339	0.661	0.179	0.372	2.601	1.382	0.170	3.860	1.439	7.869	1.887	1.223	0.344	3.430	2.320
2012.08-2016.07															
Mean	0.355	0.603	0.280	0.505	1.512	2.001	0.286	3.473	2.116	8.945	2.008	1.237	0.406	3.609	2.276
St. Dev.	0.112	0.257	0.064	0.154	0.994	0.863	0.097	1.672	1.104	3.595	0.891	0.591	0.137	1.645	1.158

Panel B: Bid-ask spread of 10-year government bonds

	AT	BE	FI	FR	IE	IT	NL	PT	ES	EL	All+EL	All	Core	Per+EL	Per
1999.01-2016.07															
Mean	0.204	0.199	0.092	0.110	0.412	0.113	0.083	0.474	0.188	0.567	0.244	0.208	0.138	0.351	0.297
St. Dev.	0.183	0.218	0.122	0.092	0.837	0.157	0.070	0.908	0.251	1.064	0.390	0.315	0.137	0.643	0.538
1999.01-2007.07															
Mean	0.076	0.062	0.009	0.057	0.019	0.052	0.058	0.064	0.054	0.068	0.048	0.046	0.053	0.044	0.038
St. Dev.	0.036	0.023	0.083	0.043	0.098	0.022	0.055	0.032	0.029	0.046	0.047	0.047	0.048	0.045	0.045
2007.08-2012.07															
Mean	0.306	0.237	0.142	0.173	1.182	0.238	0.143	1.205	0.359	1.262	0.525	0.443	0.200	0.849	0.746
St. Dev.	0.197	0.214	0.107	0.106	1.157	0.244	0.080	1.386	0.348	1.731	0.557	0.427	0.141	0.973	0.784
2012.08-2016.07															
Mean	0.353	0.445	0.208	0.144	0.374	0.089	0.060	0.439	0.263	0.771	0.315	0.264	0.242	0.387	0.291
St. Dev.	0.163	0.219	0.072	0.086	0.513	0.075	0.025	0.470	0.214	0.294	0.213	0.204	0.113	0.313	0.318

Panel C: Log of economic sentiment index relative to Germany

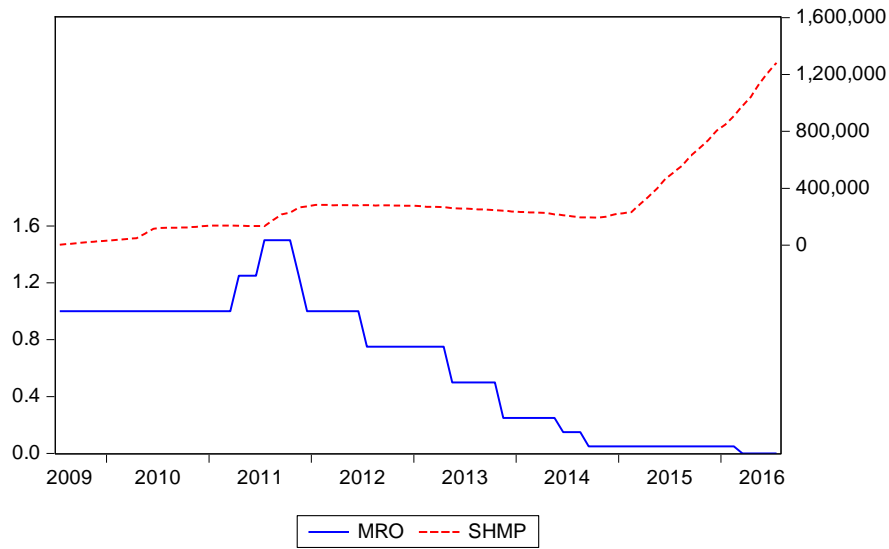
	AT	BE	FI	FR	IE	IT	NL	PT	ES	EL	All+EL	All	Core	Per+EL	Per
1999.01-2016.07															
Mean	0.003	0.006	0.005	0.009	0.000	0.004	-0.001	-0.005	0.005	-0.009	0.002	0.003	0.005	-0.001	0.001
St. Dev.	0.029	0.026	0.034	0.034	0.012	0.040	0.031	0.044	0.046	0.063	0.036	0.033	0.031	0.041	0.036
1999.01-2007.07															
Mean	0.025	0.025	0.026	0.036	0.006	0.030	0.020	0.018	0.039	0.036	0.026	0.025	0.026	0.026	0.023
St. Dev.	0.022	0.019	0.028	0.021	0.008	0.028	0.020	0.024	0.032	0.028	0.023	0.022	0.022	0.024	0.023
2007.08-2012.07															
Mean	-0.008	-0.006	0.004	-0.003	-0.014	-0.017	-0.019	-0.029	-0.040	-0.053	-0.019	-0.015	-0.007	-0.031	-0.025
St. Dev.	0.019	0.020	0.022	0.023	0.007	0.040	0.030	0.057	0.035	0.072	0.033	0.028	0.023	0.042	0.035
2012.08-2016.07															
Mean	-0.028	-0.018	-0.037	-0.031	0.006	-0.024	-0.022	-0.023	-0.013	-0.051	-0.024	-0.021	-0.027	-0.021	-0.014
St. Dev.	0.011	0.012	0.015	0.013	0.009	0.029	0.021	0.034	0.024	0.030	0.020	0.019	0.014	0.025	0.024

Panel D: 1-year ahead expected gross government debt to GDP ratio relative to Germany

	AT	BE	FI	FR	IE	IT	NL	PT	ES	EL	All+EL	All	Core	Per+EL	Per
1999.01-2016.07															
Mean	-0.529	29.700	-22.161	5.945	-6.035	45.668	-9.361	13.320	-4.493	57.609	10.966	5.784	0.719	21.214	12.115
St. Dev.	6.842	10.694	8.231	10.393	32.506	8.285	6.975	22.404	19.720	30.327	15.638	14.006	8.627	22.649	20.729
1999.01-2007.07															
Mean	-0.824	34.903	-22.351	-1.983	-31.850	43.451	-9.523	-3.149	-12.969	38.023	3.373	-0.477	0.044	6.701	-1.129
St. Dev.	3.864	11.339	4.565	1.043	7.245	5.100	6.441	2.970	12.129	3.872	5.857	6.077	5.450	6.263	6.861
2007.08-2012.07															
Mean	-5.372	20.490	-29.622	6.070	3.133	39.933	-14.975	11.652	-14.413	55.600	7.250	1.877	-4.682	19.181	10.076
St. Dev.	1.881	2.740	2.591	3.129	28.362	1.988	4.043	11.247	9.358	29.546	9.489	7.260	2.877	16.100	12.739
2012.08-2016.07															
Mean	6.156	30.050	-12.425	22.800	37.900	57.594	-1.994	50.744	26.094	102.150	31.907	24.102	8.918	54.896	43.083
St. Dev.	9.825	7.404	9.008	6.328	7.635	6.878	3.325	6.045	8.359	10.446	7.525	7.201	7.178	7.873	7.229

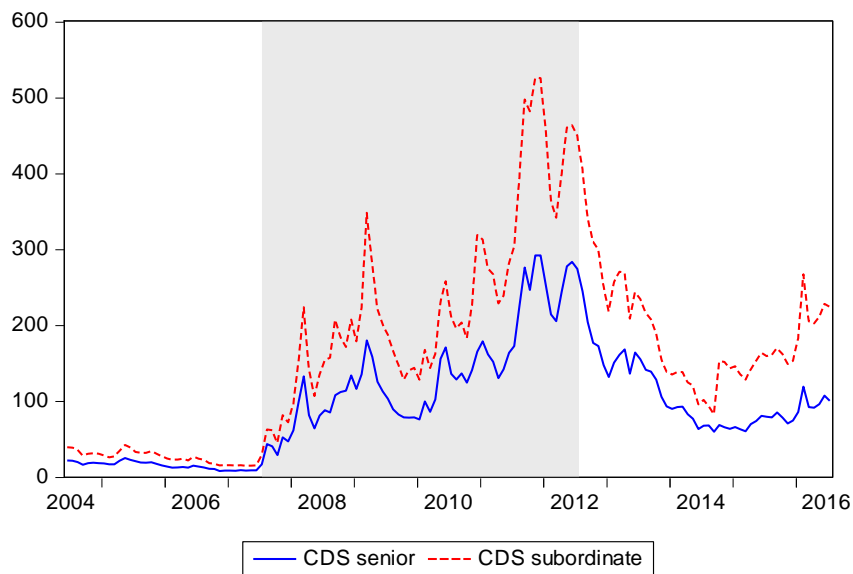
Note: This table presents descriptive statistics (mean and standard deviation) across countries, country-groups and time periods. The sample countries include Austria (AT), Belgium (BE), Finland (FI), France (FR), Ireland (IE), Italy (IT), the Netherlands (NL), Portugal (PT), Spain (ES) and Greece (EL). The following country-groups are considered: All countries including Greece (All+EL). All countries excluding Greece (All). Core countries: Austria, Belgium, Finland, France and the Netherlands. Periphery countries including Greece: Greece, Ireland, Italy, Portugal and Spain (Per+EL). Periphery excluding Greece (Per)

Figure 2: ECB monetary policy indicators



Note: This figure plots the ECB main refinancing operations rate (MRO) and the amount (in millions of euros) of securities held by the ECB for monetary policy purposes (SHMP) over the period July 2009 - July 2016. Left vertical axis: / – percentage points; Right vertical axis: – euro millions. Source: European Central Bank.

Figure 3: European banking sector CDS



Note: This figure plots the Markit CDS indices covering 25 senior (CDS senior) and junior subordination (CDS subordinate) European banks over the period June 2004 - July 2016, measured in basis points. The shaded area denotes the period July 2007 - July 2012. Source: Markit

We also use an intercept dummy variable to reflect the effect of the OMT announcement on the relationship between spreads and fundamentals. The dummy variable (D^{OMT}) is equal to 1 since August 2012 and 0 otherwise. Finally, we capture banking sector risk in the euro area using two banking CDS indices published by Markit. The indexes respectively cover 25 senior (CDS senior) and junior subordination (CDS subordinate) European banks. The use of CDS data to measure bank credit risk is consistent with several previous studies (Acharya et al., 2014; Acharya and Steffen, 2015; Drechsler et al., 2016). The relevant data is presented in Figure 3. It confirms the strong correlation between banking and sovereign risk, as both measures of banking risk mirror the movements of spreads reported in Figure 1.¹¹ Specifically, both CDS indexes are close to zero before the financial crisis, but increase since summer 2007, reaching a maximum at the end of 2011, and decline, albeit to a level higher than their pre-crisis mean, since summer 2012. In baseline estimates of equation (2), we use the lagged CDS senior index, while in robustness checks we employ the CDS subordinate index.

4. Empirical findings

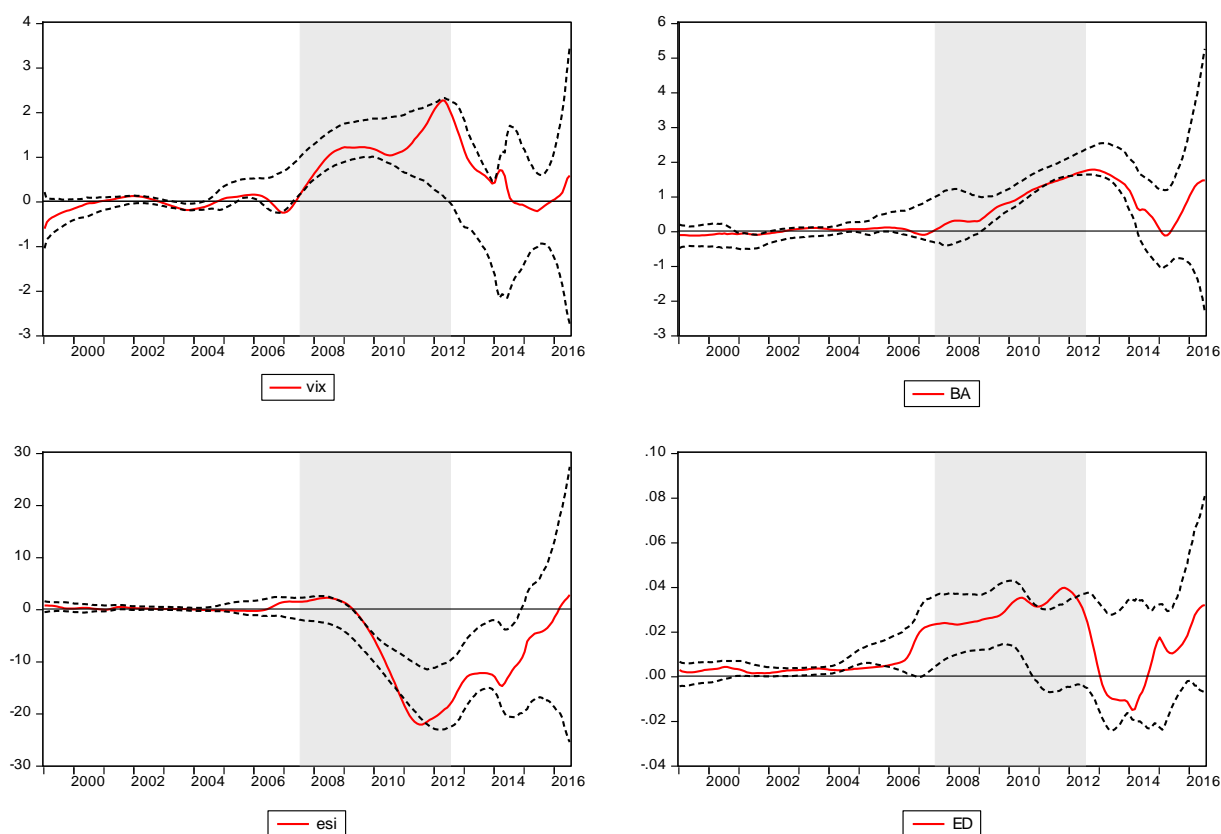
4.1. Modelling spreads using a time-varying panel approach

TVP estimates and pricing regimes

The TVP estimates of equation (1) for the full panel of core and periphery sample countries, excluding Greece, are reported in Figure 4. The figure provides clear evidence for the existence of three pricing regimes in euro area sovereign bond markets. The first covers the period from the euro's launch in 1999 to approximately mid-2007. During this period, the estimated TVP coefficients of all risk sources (global financial risk, liquidity risk and credit risk) are zero or near-zero. The sole exception is the expected gross government debt-to-GDP ratio relative to Germany, whose coefficient has a small but statistically significant positive value throughout most of the pre-crisis period. Figures 5 and 6 present TVP estimates for the core and periphery country groups, respectively, again excluding Greece in the case of the

¹¹ Bank credit risk is not included as explanatory variable in the model for spreads since, given the high correlation between sovereign risk and banking risk and the existing literature on the sovereign-bank nexus, reverse feedback from the former (our dependent variable) to the latter cannot be ruled out. As De Grauwe and Ji (2013, p.23) point out, "In the existing empirical literature there has been a tendency to add a lot of other variables on the right hand side...In fact, the addition of these variables creates a risk of false claims that the fundamental model explains the spreads well".

Figure 4: TVP coefficients – Full panel excluding Greece



Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016. Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The estimation bandwidth parameter (h) is set to 0.15 and the bandwidth correction parameter (ϵ) to 0.08. The panel includes Austria, Belgium, Finland, France, Ireland, Italy, the Netherlands, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (vix), the bid-ask spread of 10-year government bonds (BA), the logarithm of the Economic Sentiment Index relative to Germany (esi), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

latter. They show that the first pricing regime applied both to core and periphery EMU countries, although the role of expected debt in determining spreads is noticeably more pronounced in the periphery, signalling higher penalties on fiscal imbalances for this group of countries. On the other hand, core countries present higher statistical significance for the coefficient of expected growth.

The second pricing regime approximately extends between mid-2007 and mid-2012, and involves a rapid increase both in the absolute value as well as statistical significance of the coefficients of all risk factors.¹² Again, this trend is common both for core as well as

¹² Note that for a very small number of observations in this regime, as well as in the third pricing regime discussed below, the point estimates of the estimated TVP coefficients fall outside the confidence interval (CI)

periphery countries. However, the absolute values of the estimated TVP coefficients are, overall, noticeably higher for the group of periphery countries, capturing the larger risk exposure of the periphery. The signs of the estimated TVP coefficients are in line with the theoretical expectations. The only exception, as Figure 5 indicates, is expected relative sovereign debt in the group of core countries. The negative coefficient reflects the fact that spreads of core countries increased during the crisis period, while expected debt relative to Germany decreased, and thereby captures some kind of mispricing of credit risk. However, this is consistent with portfolio re-allocation from core country bonds towards Germany, which operated as a safe-haven for investors during the crisis. Nevertheless, Figure 5 suggests that for the vast majority of observations the negative debt TVP coefficient is statistically insignificant.

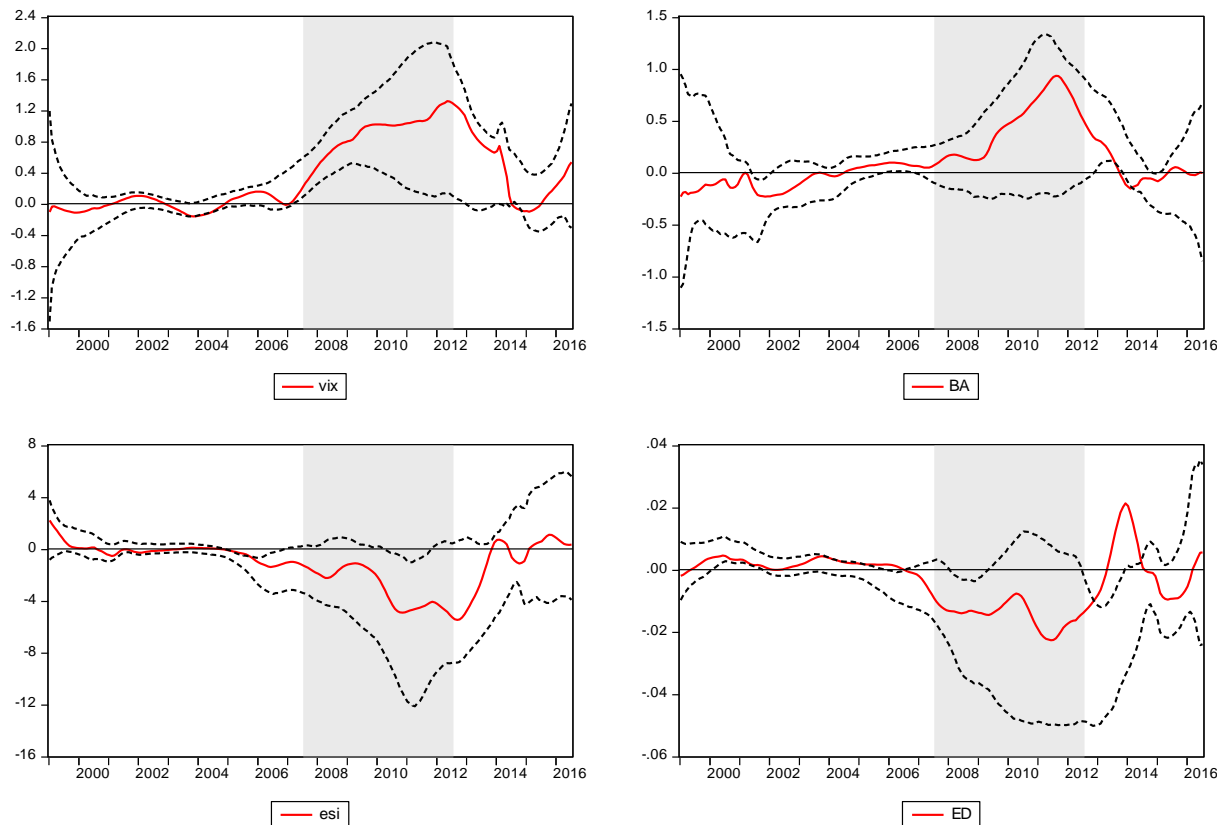
Finally, we provide evidence for a third pricing regime, covering the period between approximately mid-2012 to the end of our sample. This period is characterised by a reduction in the absolute values and/or statistical insignificance of the estimated TVP coefficients. As far as the international risk factor is concerned, its coefficient maintains a positive, albeit declining, value until approximately mid-2014. This, however, is statistically significant only for the core panel. Thereafter, the *vix* coefficient takes near-zero and insignificant values in all three panels. Liquidity risk also presents a positive yet declining TVP coefficient during the third regime. This is statistically significant until mid-2014 for the full and periphery panels and until the end of 2013 for the core panel (see Figures 5 and 6). Thereafter, the coefficient of *BA* takes a zero and insignificant value in core countries. On the other hand, starting from early 2015 the *BA* coefficient registers a significant increase for the periphery panel signaling stronger pricing valuation of liquidity conditions in of sovereign yield spreads.

Expected relative growth maintains a negative and significant coefficient well into the third regime, albeit with a declining absolute value. For the full panel, statistical significance is maintained until the end of 2014; for core countries until summer 2013 and for periphery

calculated using the wild bootstrap methodology. These can be regarded as outliers produced by the bootstrapping exercise, with no impact on the reliability of our results: the standard calculation of a CI involves use of a parameter's point estimate as the central point of the CI estimation and calculation of the CI around the point estimate. This ensures that the point estimate always falls within the estimated CI bounds. Bootstrap methods, on the other hand, follow a different CI estimation approach, involving multiple estimates of the parameter in question (in our case 1000, one per bootstrap iteration) and the empirical setting of an upper and lower CI bound within which 95 per cent (or any other predetermined proportion) of these estimates fall. In this methodology of CI construction, it is possible for a parameter's point estimate to fall outside the empirically constructed CI. Indeed, for a 95 per cent CI calculated using our bootstrapping methodology, the a priori expectation is that the point estimate will fall outside the calculated CI in 5 per cent of observations.

countries until summer 2015. By the end of our sample, *esi* takes near-zero and insignificant values in all three panels. Finally, the TVP coefficient of expected relative debt ratio registers a sharp decline in mid-2012 in the full panel, becoming statistically insignificant in mid-2013. However, starting from early 2014 the *ED* coefficient resumes an upwards movement. This falls short of being statistically significant at the 95% level, although it is close to being so. The movements of the *ED* coefficient in the full panel are mainly driven by the periphery group, although the increase towards the end of our sample is also recorded for core countries.

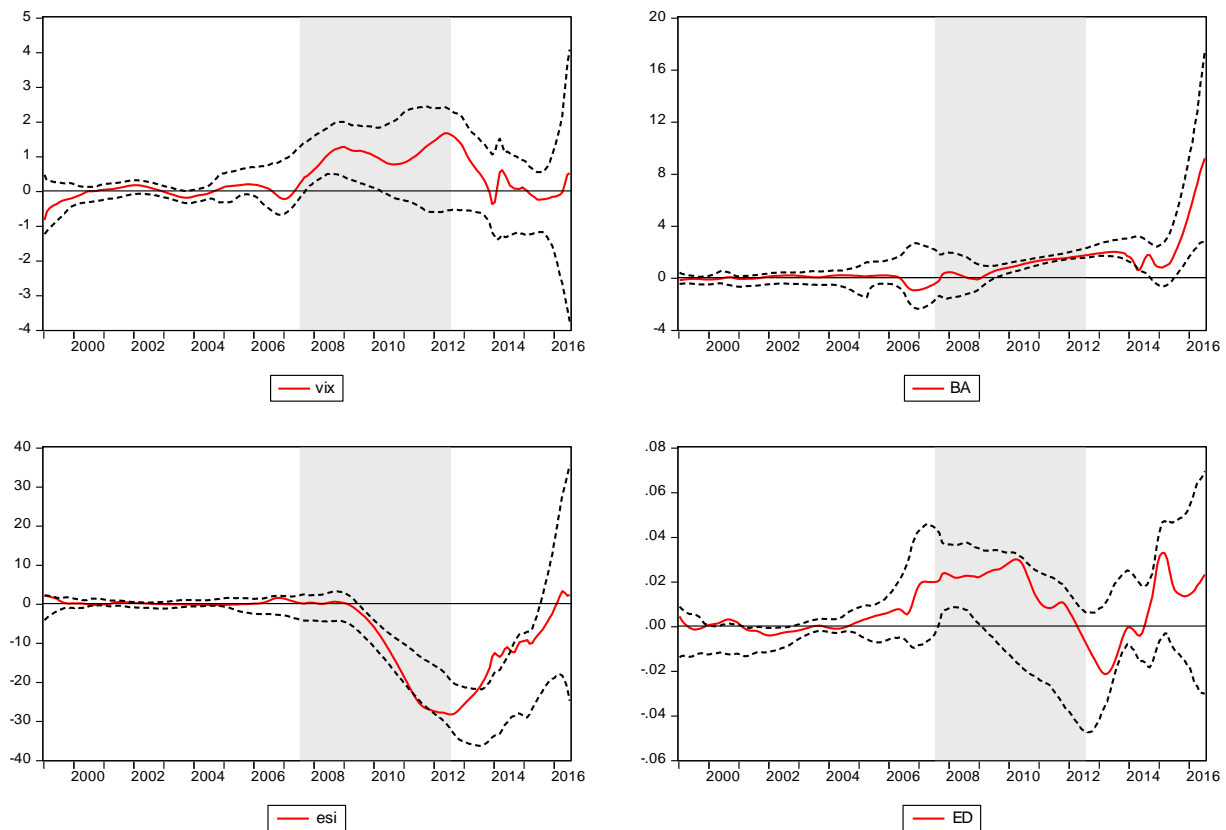
Figure 5: TVP coefficients – Core countries



Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016. Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The estimation bandwidth parameter (h) is set to 0.15 and the bandwidth correction parameter (ε) to 0.08. The panel includes Austria, Belgium, Finland, France and the Netherlands. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (*vix*), the bid-ask spread of 10-year government bonds (*BA*), the logarithm of the Economic Sentiment Index relative to Germany (*esi*), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (*ED*). The shaded area denotes the period July 2007 - July 2012.

We have tested the robustness of our findings in a number of ways. First, we repeated the estimations including Greece into the analysis. The results are reported in Figures 7 (full panel) and 8 (periphery panel). Our findings remain broadly robust, although the inclusion of Greece increases the absolute values of the TVP estimates in both panels, as well as the bounds of their 95% confidence intervals towards the end of the sample period. The latter is consistent with the highly idiosyncratic circumstances faced by Greece in 2015-2016, including a major confrontation with its official lenders in the first half of 2015, which brought Greece very near to withdrawing from the EMU and led to the imposition of (still in place) capital controls; and the exclusion of Greek bonds from the ECB's QE programme announced in January 2015.

Figure 6: TVP coefficients – Periphery countries excluding Greece

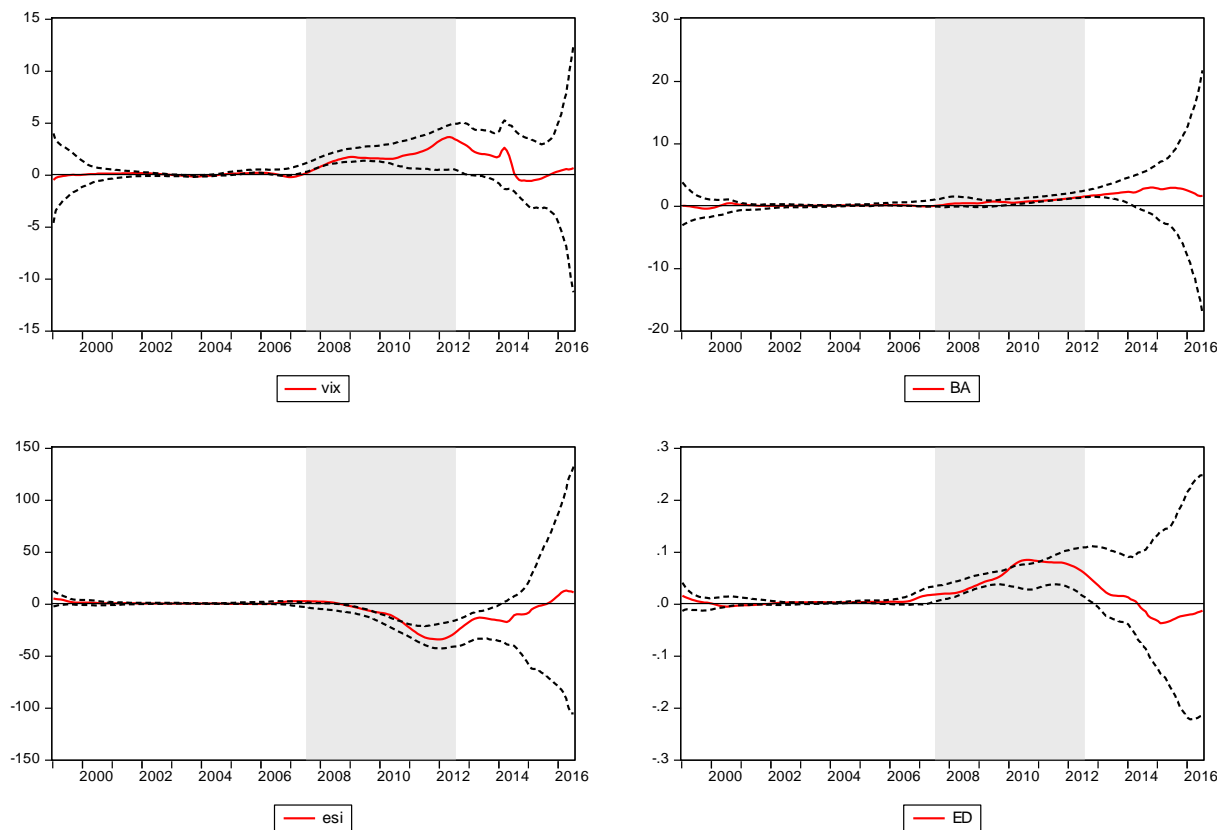


Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016. Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The estimation bandwidth parameter (h) is set to 0.15 and the bandwidth correction parameter (ε) to 0.08. The panel includes Ireland, Italy, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (vix), the bid-ask spread of 10-year government bonds (BA), the logarithm of the Economic Sentiment Index relative to Germany (esi), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

Second, to address any endogeneity concerns, we repeated the estimation of equation (1) using the first lag rather than the contemporaneous values of the independent variables. We report the full panel results in Figure A2 in the Appendix. They are consistent with the findings reported above. The same applies to the core and periphery panels.¹³

Third, we have tested the robustness of our findings to changes in the value of the bandwidth estimation parameter h . Specifically, we estimated equation (1) using three alternative h -values, namely 0.10, 0.20 and 0.30, to assess the tradeoff between the bias of the TVP estimates and their variance. The results of the TVP point estimates for the full panel are

Figure 7: TVP coefficients – Full panel including Greece

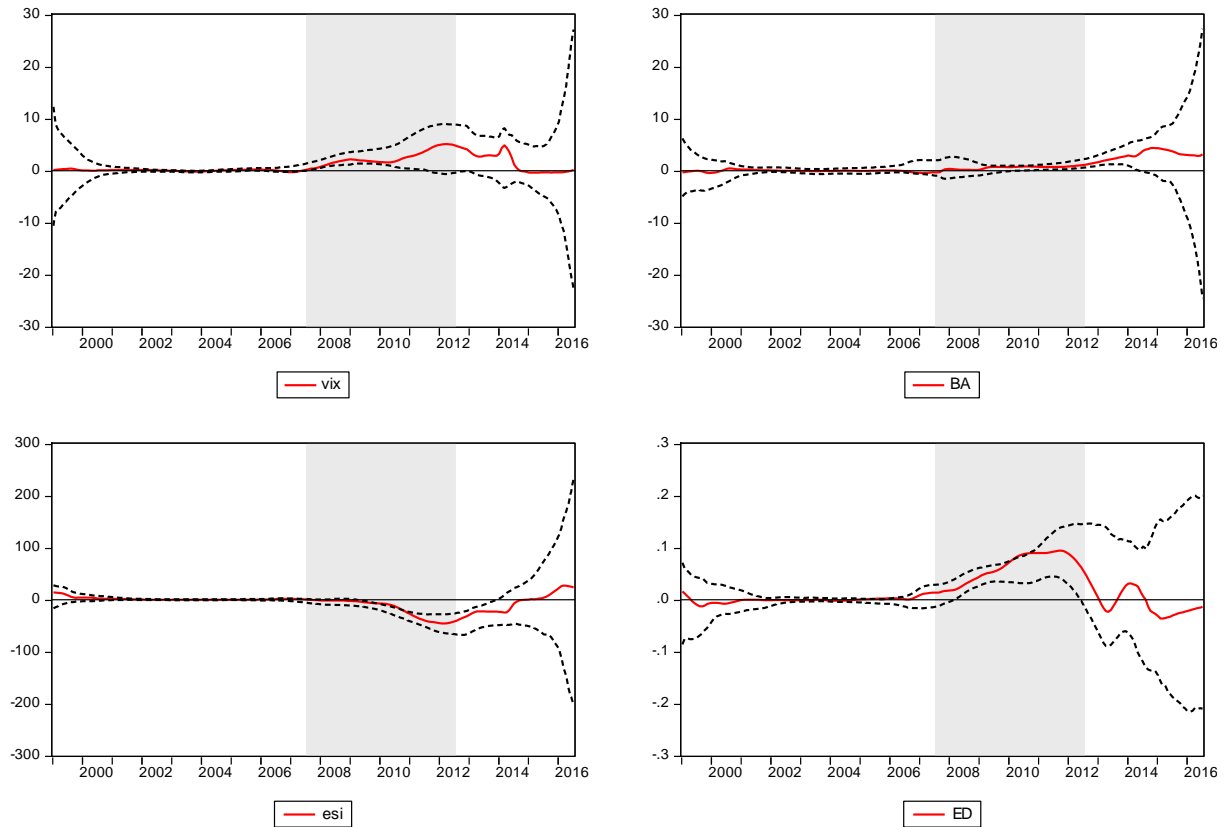


Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016. Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The estimation bandwidth parameter (h) is set to 0.15 and the bandwidth correction parameter (ε) to 0.08. The panel includes Austria, Belgium, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (vix), the bid-ask spread of 10-year government bonds (BA), the logarithm of the Economic Sentiment Index relative to Germany (esi), and the 1-year ahead expected debt-to-GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

¹³ These results are not shown to save space but are available upon request.

reported in Figure A3 in the Appendix. These are consistent with those obtained by our benchmark model, where h is set equal to 0.15. Finally, we have tested the robustness of our findings to alternative values of the bandwidth correction parameter ε . The results for the full panel are reported in Figure A6 in the Appendix. Again, the results are consistent with those obtained from the benchmark model, which sets $\varepsilon = 0.08$.¹⁴

Figure 8: TVP coefficients – Periphery countries including Greece



Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016. Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The estimation bandwidth parameter (h) is set to 0.15 and the bandwidth correction parameter (ε) to 0.08. The panel includes Ireland, Italy, Greece, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (vix), the bid-ask spread of 10-year government bonds (BA), the logarithm of the Economic Sentiment Index relative to Germany (esi), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

¹⁴ The results of the robustness tests relating to the values of h^* and ε in the core and periphery countries are consistent with those reported in Figures 5 and 6, respectively. To save space, we do not report them, but they are available upon request.

Discussion

Overall, our TVP analysis confirms the existence of the pre-crisis and crisis bond-pricing regimes identified by previous studies on the determinants of sovereign bond yield spreads in the euro area. In addition to these regimes, however, we find evidence of a third regime introduced in the second part of 2012. Apart from the study by Delatte et al. (2017), the previous literature on regime-dependent sovereign bond pricing has not analysed the implications of the OMT announcement and more generally the role of ECB policy interventions. That study concludes that the change in the regime following the announcement represents a restoration of the regime that was in place prior to the crisis. This inference, however, is not consistent with the movements of spreads since August 2012, which by comparison to the pre-crisis regime are on average higher; and have stabilized at levels noticeably higher, and more variable across countries, (see Figure 1 and Panel A of Table 1). These stylized facts imply that the third regime is not identical to the pre-crisis regime, but a new, distinct regime, where markets are pricing sources of risk that were: (a) either less penalized by markets, or (b) not priced at all during the pre-crisis period.

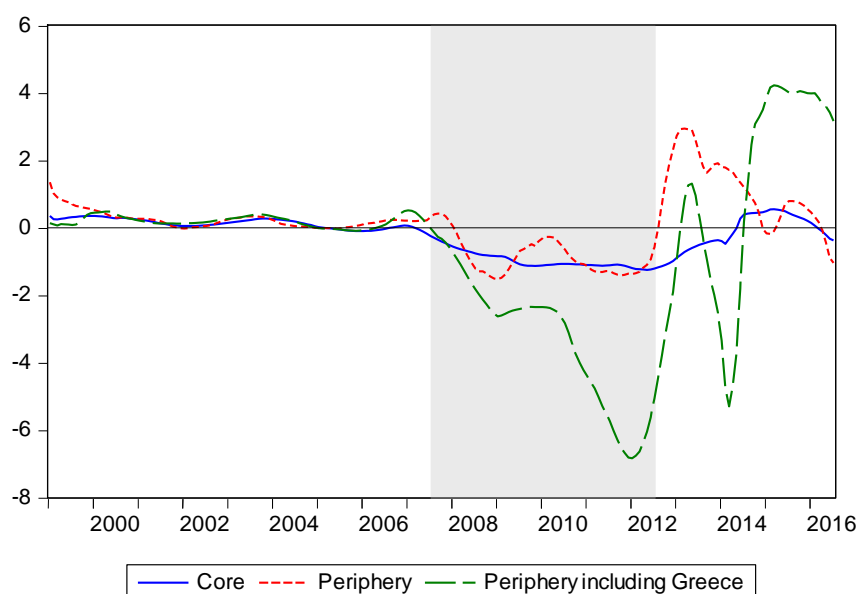
With regards to the former argument, our analysis above confirmed that during a substantial part of the third regime, markets continued to price fundamentals in way that was less pronounced compared to the second regime but more pronounced compared to the first. Furthermore, liquidity risk in periphery countries continues to be priced at the end of our sample and the same may hold for expected relative debt ratios, whose TVP coefficient is close to being significant at the 5% level for the full panel. As far as the latter argument is concerned, valuable insights are provided by the time effects in equation (1). Time effects capture the *net* impact of country-invariant factors that may increase or decrease spreads over time beyond the level predicted by the model's explanatory variables. Hence, if non-zero, they will signal the importance of factors other than global financial risk, liquidity risk and credit risk.

The time effects for the core and periphery panels are presented in Figure 9. In both panels, during the pre-crisis regime time effects were near zero. Time effects become much more important during the crisis period. Between summer 2007 and late 2011, they take increasingly negative values. This implies that over that period, spreads would have been even higher in the absence of mitigating factors pushing spreads below fundamentals-

consistent values.¹⁵ Such factors include the provision of programmes of financial assistance to those countries mostly affected by the crisis (Greece, Portugal and Ireland), and the introduction of institutional innovations such as the European Financial Stability Facility (EFSF), whose primary target was to set in place a previously non-existing fiscal back-stop at the union level.¹⁶

These mitigating influences started to disappear in early 2012, especially in periphery countries, as suggested by the sharply increasing time effects in Figure 9. Greece, Italy and

Figure 9: Time effects – Core and periphery countries



Note: This figure plots the estimated time effects from Equation (1) over the period January 1999 - July 2016. The panel of core countries includes Austria, Belgium, Finland, France and the Netherlands. The panel of periphery countries (excluding Greece) includes Ireland, Italy, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (vix), the bid-ask spread of 10-year government bonds (BA), the logarithm of the Economic Sentiment Index relative to Germany (esi), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

¹⁵ For the panel of core countries, the maximum difference is estimated in the range of 120 basis points and is observed in early 2012. In the periphery panel excluding Greece, the maximum difference (approximately 150 basis points) is recorded in early 2009 and early 2012. When Greece is included in the periphery panel, the difference records its maximum level between late 2011 and the first half 2012, taking values ranging between 600 and 700 basis points.

¹⁶ While financial support occurred at the country-level, it is possible that they reduced the upward pressure on spreads of other countries through “benign” spillover effects. See Arghyrou and Kontonikas (2012), De Santis (2014), Saka et al. (2015) and Ehrmann and Fratzcher (2017) among others, for analyses of spillover effects in the context of the European debt crisis. It can also be argued that bailouts and the creation of the EFSF improved market sentiment (or helped to avoid further deterioration) and reduced overall uncertainty, since they demonstrated the willingness of policymakers to fight the crisis. The idea that time effects may capture market sentiment is consistent with De Grauwe and Ji (2013) and Gibson et al. (2016).

Spain recorded significant spread increases in spring 2012. These tensions may reflect a negative view by market participants about the adequacy of measures taken up to that point to fully and successfully resolve the crisis. Crucially, the EMU had not set in place a mechanism endowed with enough resources to fund rescue programmes in case they were needed to stabilize notably the Italian and Spanish bond markets and banking systems. With Italian and Spanish spreads already in the range of 500 basis points, this dynamic, if left unchecked, could result into a collapse of Italian and Spanish bond markets, representing an imminent threat to the existence of the euro.¹⁷

It is precisely this threat the ECB sought to address by announcing the OMT programme. The ECB offered a guarantee that no EMU country would be left to leave the euro and change its euro-denominated bonds into bonds denominated in a new (and largely devalued) national currency.¹⁸ This guarantee changed the bond pricing regime, resulting into lower spread values. Nevertheless, this did not happen immediately. Although spreads entered a downward path immediately after the OMT announcement, Figure 9 suggests that time effects in the periphery panel kept on rising until the end of 2013. Thereafter, they declined only gradually. We interpret this as evidence of residual redenomination risk carried over from the crisis period. This interpretation is consistent with De Santis (2015) who finds that following the OMT announcement redenomination risk declined but remained at positive levels.

In addition, the time effects estimated for the periphery panel including Greece provide further evidence in favour of the redenomination risk interpretation. Unlike time effects excluding Greece, the series depicts an upward movement since mid-2014, reaching a maximum in June 2015, at the peak of Greece's confrontation with its official lenders. Thereafter, the series stabilizes but at significantly positive values.¹⁹ As the possibility of Greece exiting the EMU increased in 2015, the argument that the time effects reported for the post-OMT period mainly capture redenomination risk gains further credibility. This is an important differentiating factor between the first (pre-crisis) and third (post-OMT) pricing

¹⁷ As Di Cesare et al. (2012) point out, concerns about a possible break-up of the euro area became widespread by late spring/early summer 2012. The volume of Google searches of "euro break-up" or similar keywords using peaked, while a survey of central bank reserve managers by the UBS bank revealed that about three quarters of them expected at least one country to leave the euro area within five years.

¹⁸ ECB officials have publicly stated that one of the targets of the unconventional policy interventions was to reduce redenomination risk (Krishnamurthy et al., 2015). Apart from President Draghi's "whatever it takes to preserve the euro" speech of 26 July 2012, other examples include the speech by ECB Executive Board Member Benoît Cœuré on 3 September 2013 (<http://www.ecb.europa.eu/press/key/date/2013/html/sp130902.en.html>), where he discussed redenomination risk in the context of the OMT.

¹⁹ Overall, Figure 9 provides strong evidence to support Greece's significant idiosyncratic features relative to the rest of the periphery countries, justifying our choice to exclude it from our baseline periphery panel.

regimes. Redenomination risk did not exist in the former but existed for the best part of the latter. This helps to explain the difference in average spread values observed between the two regimes.

4.2. ECB policy, banking risk and bond pricing regimes

In this section, we investigate the link between monetary policy, banking risk and bond pricing regimes. We start by modelling the point estimates of the TVP coefficients obtained in the first stage of our analysis on an intercept dummy variable capturing the effect of the OMT announcement, as well as ECB policy measures and bank credit risk.²⁰ The sample period for this analysis is August 2009 – July 2016, covering the third and second (partially) bond pricing regimes identified in the first stage, and is dictated by non-availability of data on the ECB's securities holdings prior to July 2009. Table 2 presents OLS estimates of equation (2) with Newey and West (1987) standard errors. Panel A refers to the full set of countries, while Panels B and C present the results for the core and periphery groups, respectively.²¹

The findings in column 1 of Table 2 – Panel A correspond to the specification where only the OMT dummy variable is used to explain the TVP coefficients of the full panel group (the dummy variable is equal to 1 since August 2012 and 0 otherwise). They show that in most instances the OMT effect is statistically significant at the 5% level, or lower, and its sign consistent with lower sensitivity of spreads to fundamentals. Evidence for the core and periphery groups in Panels B and C, respectively, is also consistent with a weaker response of spreads to the risk factors since summer 2012. An exception is the reaction of spreads to liquidity conditions in the periphery panel, which becomes stronger, with the point estimate of the TVP coefficient of *BA* more than doubling. The OMT dummy has a positive sign in the case of the core group's expected relative debt, which we interpret as evidence for correction of the mispricing that occurred during the second regime, while consistently depicting a negative sign for the periphery group.

We then add in equation (2) the lagged growth of securities held by the ECB for monetary policy purposes, a proxy for non-conventional interventions, and the lagged change in the MRO, a measure of conventional monetary policy shifts. The results in column 2 of Table 2 show that including these variables does not alter the findings pertaining to the OMT effects.

²⁰ All the TVP coefficients are stationary according to the Lee and Strazicich (2003) unit root test, which allows for structural breaks in the series' deterministic components. The regressors included in the right-hand side of equation (2) are also stationary series. The results of these tests are available upon request.

²¹ Note that Greece is excluded from both the full panel and the panel of periphery countries.

Table 2: Modelling TVP parameters on ECB policy and bank credit risk

Panel A: Full panel

	β_t^{vix}			β_t^{BA}			β_t^{esi}			β_t^{ED}		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Constant	1.451*** (0.137)	1.471*** (0.138)	0.231 (0.201)	1.242*** (0.102)	1.279*** (0.098)	0.145 (0.158)	-15.230*** (2.133)	-16.052*** (2.016)	-4.907* (2.566)	0.033*** (0.001)	0.034*** (0.001)	0.033*** (0.004)
D_t^{OMI}	-1.037*** (0.195)	-1.084*** (0.197)	-0.611*** (0.139)	-0.273 (0.201)	-0.326 (0.202)	0.106 (0.117)	6.259** (2.626)	7.174*** (2.494)	2.926 (1.849)	-0.027*** (0.004)	-0.027*** (0.004)	-0.027*** (0.004)
$\Delta shmp_{t-1}$	-	-0.059* (0.034)	0.026* (0.015)	-	-0.107*** (0.033)	-0.029* (0.016)	-	2.357*** (0.576)	1.596** (0.443)	-	-0.001 (0.0004)	-0.001 (0.0005)
ΔMRO_{t-1}	-	-1.389* (0.763)	0.401 (0.408)	-	-0.951* (0.562)	0.686 (0.536)	-	7.910 (8.959)	-8.170 (6.694)	-	0.005 (0.016)	0.007 (0.013)
CDS_{t-1}	-	-	0.735*** (0.103)	-	-	0.672*** (0.100)	-	-	-6.605*** (1.131)	-	-	0.001 (0.003)
Adj R ²	0.513	0.526	0.853	0.053	0.078	0.567	0.197	0.276	0.561	0.597	0.588	0.583

Panel B: Core countries

	β_t^{vix}			β_t^{BA}			β_t^{esi}			β_t^{ED}		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Constant	1.087*** (0.034)	1.097*** (0.033)	0.403** (0.177)	0.663*** (0.054)	0.680*** (0.053)	0.341*** (0.059)	-3.936*** (0.360)	-4.098*** (0.330)	-0.567 (0.810)	-0.015*** (0.002)	-0.016*** (0.002)	-0.010** (0.004)
D_t^{OMI}	-0.647*** (0.125)	-0.671*** (0.125)	-0.406*** (0.120)	-0.615*** (0.071)	-0.632*** (0.068)	-0.503*** (0.049)	2.937*** (0.674)	3.130*** (0.659)	1.784*** (0.661)	0.016*** (0.003)	0.015*** (0.003)	0.013*** (0.003)
$\Delta shmp_{t-1}$	-	-0.027* (0.015)	0.020* (0.012)	-	-0.048*** (0.010)	-0.025*** (0.007)	-	0.463*** (0.112)	0.222*** (0.083)	-	0.0003 (0.0002)	-0.0001 (0.0003)
ΔMRO_{t-1}	-	-0.738* (0.414)	0.263 (0.454)	-	-0.073 (0.338)	0.415* (0.237)	-	2.170 (2.521)	-2.924 (2.421)	-	-0.013 (0.013)	-0.021* (0.011)
CDS_{t-1}	-	-	0.411*** (0.098)	-	-	0.201*** (0.041)	-	-	-2.092*** (0.480)	-	-	-0.003* (0.002)
Adj R ²	0.472	0.475	0.715	0.770	0.779	0.882	0.400	0.422	0.678	0.470	0.464	0.486

Panel C: Periphery countries

	β_t^{vix}			β_t^{BA}			β_t^{esi}			β_t^{ED}		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Constant	1.103*** (0.094)	1.107*** (0.097)	0.117 (0.252)	1.227*** (0.105)	1.253*** (0.105)	0.911** (0.454)	-18.025*** (2.884)	-19.004*** (2.786)	2.083 (2.086)	0.015*** (0.003)	0.014*** (0.004)	0.044*** (0.005)
D_t^{OMT}	-0.804*** (0.168)	-0.824*** (0.170)	-0.447** (0.177)	1.300** (0.587)	1.298** (0.614)	1.429** (0.559)	5.338 (3.785)	6.552* (3.701)	-1.486 (2.026)	-0.010* (0.006)	-0.009 (0.006)	-0.021*** (0.004)
$\Delta shmp_{t-1}$	-	-0.011 (0.024)	0.056*** (0.016)	-	-0.077** (0.029)	-0.053 (0.034)	-	2.810*** (0.760)	1.370*** (0.407)	-	0.003* (0.001)	0.001 (0.001)
ΔMRO_{t-1}	-	-0.788 (0.749)	0.641 (0.546)	-	1.101 (1.190)	1.595 (1.029)	-	15.410 (12.888)	-15.016* (8.317)	-	0.023 (0.015)	-0.021 (0.017)
CDS_{t-1}	-	-	0.587*** (0.128)	-	-	0.203 (0.265)	-	-	-12.497*** (1.078)	-	-	-0.018*** (0.003)
Adj R ²	0.432	0.428	0.719	0.124	0.106	0.099	0.068	0.127	0.667	0.102	0.113	0.543

Note: This table presents OLS estimates with heteroscedasticity and autocorrelation consistent standard errors (in parentheses) of Equation (2) over the period August 2009 - July 2016 (84 observations). The dependent variable is, respectively, the time-varying panel coefficient of Equation (1) associated with the logarithm of the Chicago Board Options Exchange Volatility Index (β_t^{vix}), the bid-ask spread of 10-year government bonds (β_t^{BA}), the logarithm of the Economic Sentiment Index relative to Germany (β_t^{esi}), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (β_t^{ED}). The set of explanatory variables includes a dummy variable that is equal to 1 since August 2012 and 0 otherwise (D_t^{OMT}), the lagged first difference of the logarithm of securities held for monetary policy purposes by the ECB ($\Delta shmp_{t-1}$), the first difference of the ECB main refinancing operations rate (ΔMRO_{t-1}), and the lagged European banking sector senior subordination CDS index (CDS_{t-1}). The full panel (Panel A) includes Austria, Belgium, Finland, France, Ireland, Italy, the Netherlands, Portugal and Spain. The panel of core countries (Panel B) includes Austria, Belgium, Finland, France and the Netherlands. The panel of periphery countries (Panel C) includes Ireland, Italy, Portugal and Spain. *, **, *** indicate statistical significance at the 10%, 5% and 1% level, respectively

The evidence highlights the important role of non-conventional monetary policy actions since the growth of the ECB's security holdings is statistically significant in many instances. The sign of the estimated coefficients indicates that the expansion of the ECB's balance sheet is typically associated with lower sensitivity of spreads to liquidity risk and credit risk, when the latter is proxied by expected relative growth. This result holds for the full panel, as well as the core and periphery groups. On the other hand, the effect of conventional monetary policy actions is statistically insignificant at the 5% level in all cases.

Finally, motivated by the evidence in Delatte et al. (2017) about the importance of bank credit risk as a source of time variation in the relationship between spreads and fundamentals, we add the lagged European banking sector senior subordination CDS index to the set of explanatory variables in equation (2). The results are presented in column 3 of Table 2. They show that bank credit risk is an important driver of the TVP coefficients, with the adjusted R^2 rising by 25% on average, across the various specifications. An increase in bank credit risk is typically associated with larger (in absolute magnitude) point estimates, indicating heightened sensitivity of spreads to fundamentals, and the effect is statistically significant at the 1% level. The only consistent exception to this general rule involves the impact of bank risk on the coefficient of the expected relative debt ratio. As far as the other coefficients are concerned, the results in columns 1 and 2, which do not account for developments in the banking sector, remain broadly robust to the inclusion of the bank credit risk measure in column 3. Similar findings are obtained when the European banking sector junior subordination CDS index is used as a proxy for banking risk.²²

Overall, the evidence in Table 2 suggests that ECB interventions *and* banking risk are both important in explaining the time-varying relationship between spreads and fundamentals between 2009 and 2016. However, it is plausible that bank credit risk is itself affected by ECB policy interventions. This implies that an indirect effect of policy interventions on the sensitivity of spreads to fundamentals, working through changes in banking risk, can co-exist with a direct one. In fact, Chodorow-Reich (2014) uses a high-frequency event study and shows that during 2008-2009 banking risk in the U.S. declined following non-conventional monetary policy announcements. Fratzscher et al. (2014) take a similar approach, producing

²² These results are not shown to save space but are available upon request.

Table 3: The impact of ECB policy on bank credit risk

	CDS senior			CDS subordinate		
	(1)	(2)	(3)	(1)	(2)	(3)
Constant	1.695*** (0.217)	1.744*** (0.211)	0.277 (0.313)	2.892*** (0.393)	2.967*** (0.387)	0.154 (0.561)
D_t^{OMT}	- 0.640*** (0.237)	- 0.724*** (0.232)	- 0.163** (0.062)	- 1.014** (0.419)	- 1.144*** (0.419)	- 0.237** (0.105)
$\Delta shmp_{t-1}$	-	- 0.141*** (0.039)	- 0.028*** (0.009)	-	- 0.213*** (0.063)	- 0.036** (0.016)
ΔMRO_{t-1}	-	-1.875* (1.010)	0.271 (0.331)	-	-3.002 (1.947)	0.305 (0.498)
vix_{t-1}	-	-	0.001 (0.226)	-	-	0.317 (0.424)
$\Delta eesi_{t-1}$	-	-	-2.265 (1.660)	-	-	- 7.683** (3.277)
CDS_{t-1}	-	-	0.873*** (0.038)	-	-	0.837*** (0.044)
Adj R^2	0.233	0.296	0.917	0.212	0.252	0.907

Note: This table presents OLS estimates with heteroscedasticity and autocorrelation consistent standard errors (in parentheses) of Equation (3) over the period August 2009 - July 2016 (84 observations). The dependent variable is, respectively, the European banking sector senior (CDS senior) and junior subordination (CDS subordinate) CDS index. The set of explanatory variables includes a dummy variable that is equal to 1 since August 2012 and 0 otherwise (D_t^{OMT}), the lagged first difference of the logarithm of securities held for monetary policy purposes by the ECB ($\Delta shmp_{t-1}$), the first difference of the ECB main refinancing operations rate (ΔMRO_{t-1}), the lagged logarithm of the Chicago Board Options Exchange Volatility Index (vix_{t-1}), the lagged first difference of the logarithm of the euro area Economic Sentiment Index ($\Delta eesi_{t-1}$), and the lagged respective CDS index (CDS_{t-1}). *, **, *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

consistent findings, when analysing the impact of ECB policy announcements in the period 2007-2012.²³ Hence, we proceed by modelling our empirical measures of bank credit risk on the OMT announcement dummy, the two variables that capture conventional and non-conventional monetary policy developments and several control variables. The latter include the first lag of vix , growth expectations and bank credit risk.

The results are reported in Table 3. The OMT effect is negative and statistically significant, capturing a decline in bank credit risk associated with the OMT announcement. This finding is consistent with the results of Fratzscher et al. (2014). The lagged growth of ECB security holdings is strongly significant too. It displays a negative coefficient, indicating that non-conventional monetary policy interventions led to lower banking risk. These effects are more pronounced in the equations modelling the subordinate CDS. The impact of lagged

²³ Delatte et al. (2017) interpret the gradual reversion to the non-crisis regime since summer 2012, suggested by their estimates, in the light of the OMT announcement by arguing that the ECB was successful in taming aggregate banking risk and severing the sovereign-bank nexus. Nevertheless, they do not formally test these conjectures.

MRO changes on bank credit risk, however, is statistically insignificant. Therefore, the evidence again stresses the significance of non-conventional monetary policy.

Summarising, this section presents strong evidence that the announcement of the OMT programme influenced the mechanism linking spreads to global financial risk, liquidity risk and credit risk. The expansion of the ECB's balance sheet provided extra stimulus and further weakened the link between spreads and fundamentals. Importantly, the impact of policy interventions is both direct and indirect, the latter materialising through reductions in bank credit risk. The direct effect suggests that the OMT and purchases of sovereign bonds in the secondary market improved expectations by signalling that the ECB stands ready to prevent the collapse of sovereign bond markets due to existing fiscal liabilities. The indirect effect hints that the ECB reassured investors that sovereigns will not be called upon to finance unsustainable contingent fiscal liabilities originating from extensive bank losses.

4. Summary and concluding remarks

In this paper, we investigate the hypothesis that ECB policy interventions can affect the model used by markets to price EMU sovereign bonds. Our empirical strategy consists of two steps. First, we use a TVP panel methodology to model the ten-year government bond yield spread against Germany of ten EMU countries on proxies of international financial risk liquidity risk and credit risk over the period January 1999 to July 2016. Second, we estimate the impact of ECB interventions on the time-varying sensitivity of spreads to each risk factor, controlling for the effects of bank credit risk.

Our work brings together multiple branches of the literature on the European sovereign debt crisis. Our main findings are as follows. First, we present evidence consistent with the predictions of theoretical models regarding multiple equilibria and the role of shifts in expectations. Second, we find that the announcement of OMT in August 2012 was a game changer for the evolution of the European debt crisis, as it led to new bond-pricing regime. This regime is characterised by a weakened link between spreads and fundamentals, but with higher spreads relative to the pre-crisis era and a residual redenomination risk, carried over from the crisis regime, in the periphery countries. Third, we show that ECB policy interventions affect the relationship between spreads and fundamentals not only directly, but also indirectly, working through the bank credit risk channel.

The OMT announcement and the expansion of the ECB's balance sheet through purchases of sovereign bonds expressed the commitment of the ECB to preserve the single

currency and enabled markets to exit the crisis regime. This assessment, however, comes with two important caveats. The first is that as unconventional monetary policy measures have played a significant role in supporting euro area sovereign bonds, their reversal in the future may cause renewed market turbulence. The second is that the downward pressure on sovereign borrowing costs could be a source of moral hazard in fiscal and structural reforms. On this important question, opinions are divided: some authors, including Claeys and Leandro (2016) arrive at reassuring conclusions, whereas other contributions, including Sinn (2014) and Deutsche Bundesbank (2016), strike a much more sceptical tone. Given its far-reaching implications, the question merits considerable attention on behalf of academic authors. Meanwhile, and as long as the jury is still out, the prudent policy approach would be not to discount the risks of financial instability and moral hazard.

References

- Acharya, V., Drechsler, I. and Schnabl, P. (2014). A pyrrhic victory? Bank bailouts and sovereign credit risk. *Journal of Finance*, 69, 2689-2739.
- Acharya, V. and Steffen, S. (2015). The “greatest” carry trade ever? Understanding eurozone bank risks. *Journal of Financial Economics*, 115, 215-236.
- Afonso, A., Arghyrou, M.G. and Kontonikas, A. (2014). Pricing sovereign bond risk in the European Monetary Union area: an empirical investigation. *International Journal of Finance and Economics*, 19, 49-56.
- Afonso, A., Arghyrou, M.G., Bagdatoglou, G. and Kontonikas, A. (2015). On the time-varying relationship between EMU sovereign spreads and their determinants. *Economic Modelling*, 44, 363-371.
- Altavilla, C., Giannone, D. and Lenza, M. (2014). The financial and macroeconomic effects of OMT announcements. European Central Bank, Working Paper No 1707.
- Altavilla C., Carboni G. and Motto R. (2015). Asset purchases programmes and financial markets: Lessons from the euro area. European Central Bank, Working Paper No 1864.
- Alter, A. and Schüler, Y.S. (2012). Credit spread interdependencies of European states and banks during the financial crisis. *Journal of Banking and Finance*, 36, 3444-3468.
- Arghyrou, M.G. and Tsoukalas, J. (2011). The Greek debt crisis: Likely causes, mechanics and outcomes. *World Economy*, 34, 173-191.
- Arghyrou, M.G. and Kontonikas, A. (2012). The EMU sovereign debt crisis: Fundamentals, expectations and contagion. *Journal of International Financial Markets, Institutions and Money*, 22, 658-677.
- Aßmann, C. and Boysen-Hogrefe, J. (2012). Determinants of government bond spreads in the euro area: In good times as in bad?. *Empirica*, 39, 341-356.
- Attinasi, M-G., Checherita, C. and Nickel, C. (2009). What explains the surge in euro area sovereign spreads during the financial crisis of 2007-09? European Central Bank, Working Paper No 1131.
- Barrios, S., Iversen, P., Lewandowska, M. and Setzer, R. (2009). Determinants of intra-euro-area government bond spreads during the financial crisis. European Commission, Economic Papers No 388.
- Beber, A., Brandt, M. and Kavajecz, K. (2009). Flight-to-quality or flight-to-liquidity? Evidence from the euro-area bond market. *Review of Financial Studies*, 22, 925-957.

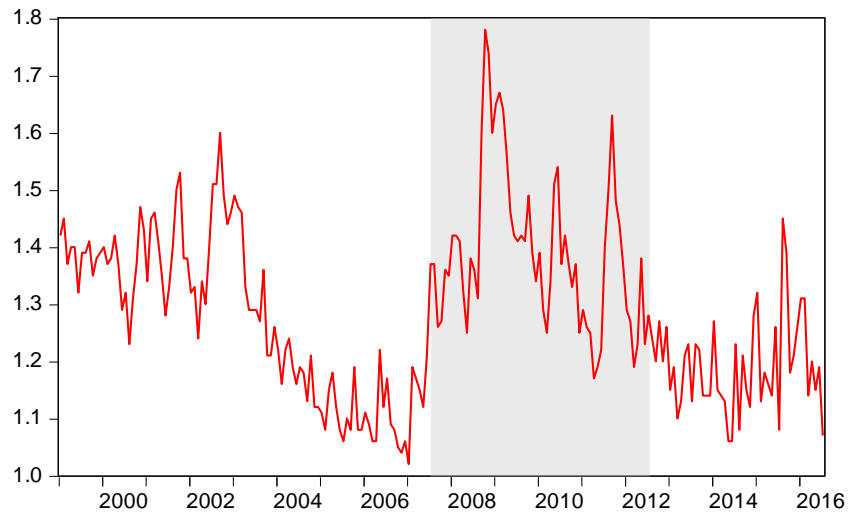
- Bernoth, K. and Erdogan, B. (2012). Sovereign bond yield spreads: A time-varying coefficient approach. *Journal of International Money and Finance*, 31, 639-656.
- Cai, Z. (2007). Trending time-varying coefficient time series models with serially correlated errors. *Journal of Econometrics*, 136, 163–188.
- Caggiano, G. and Greco, L. (2012). Fiscal and financial determinants of Eurozone sovereign spreads. *Economics Letters*, 117, 774-776.
- Chodorow-Reich, G., 2014. Effects of unconventional monetary policy on financial institutions. *Brookings Papers on Economic Activity*, Spring 2014, 155-204.
- Claeys, G. and Leandro, A. (2016). The European Central Bank’s quantitative easing programme: Limits and risks. Bruegel Policy Contribution No 4.
- Constantini, M., Fragetta, M. and Melina, G. (2014). Determinants of sovereign bond yield spreads in the EMU: An optimal currency area perspective. *European Economic Review*, 70, 337-349.
- D’Agostino, A. and Ehrmann, M. (2014). The pricing of G7 sovereign bond spreads – The times, they are a-changin. *Journal of Banking and Finance*, 47, 155-176.
- Dai, J. and Sperlich, J. (2010). Simple and effective boundary correction for kernel densities and regression with an application to the world income and Engel curve estimation. *Computational Statistics and Data Analysis*, 54, 2487-2497.
- De Bruyckere, V., Gerhardt, M., Schepens, G. and Vander Venet, R. (2013). *Journal of Banking and Finance*, 37, 4793-4809.
- De Grauwe, P. and Ji, Y. (2013). Self-fulfilling crises in the Eurozone: An empirical test. *Journal of International Money and Finance*, 34, 15-36.
- De Santis, R. A. (2014). The euro area sovereign debt crisis: Identifying flight-to-liquidity and the spillover mechanisms. *Journal of Empirical Finance*, 26, 150-170.
- De Santis, R.A. (2015). A measure of redenomination risk. European Central Bank, Working Paper No 1785.
- De Santis, R.A. (2016). Impact of the asset purchase programme on euro area government bond yields using market news. European Central Bank, Working Paper No 1939.
- Delatte, A.L., Fouquau, J. and Portes, R. (2017). Regime-dependent sovereign risk pricing during the euro crisis. *Review of Finance*, 21, 363-385.
- Deutsche Bundesbank (2016). The macroeconomic impact of quantitative easing in the euro area. Monthly Report 06/2016.
- Dewachter, H., Iania, L., Lyrio, M. and de Sola Perea, M. (2015). A macro-financial analysis of the euro area sovereign bond market. *Journal of Banking and Finance*, 50, 308-325.

- Di Cesare, A., Grande, G., Manna, M. and Marco, T. (2012), Recent estimates of sovereign risk premia for euro-area countries. Banca d'Italia, Occasional Paper No 128.
- Drechsler, I., Drechsel, T., Marques-Ibanez, D. and Schnabl, P. (2016). Who borrows from the lender of last resort? *Journal of Finance*, 71, 1933-1974.
- Ehrmann, M. and Fratzscher, M. (2017). Euro area government bonds – Fragmentation and contagion during the sovereign debt crisis. *Journal of International Money and Finance*, 70, 26-44.
- Eser, F. and Schwaab, B. (2013). Assessing asset purchases within the ECB's securities markets programme. European Central Bank, Working Paper No 1587.
- Favero, C., Pagano, M. and von Thadden, E.L. (2010). How does liquidity affect government bond yields? *Journal of Financial and Quantitative Analysis*, 45, 107-134.
- Fratzscher, M., Lo Duca, M. and Straub, R. (2014). ECB Unconventional monetary policy actions: Market impact, international spillovers and transmission channels. Paper presented at the 15th Jacques Polak Annual Research Conference, International Monetary Fund, November 13-14, 2014.
- Garcia, J.A. and Werner, S.E.V. (2016). Bond risk premia, macroeconomic factors and financial crisis in the euro area. European Central Bank Working Paper No 1938.
- Gerlach, S., Schulz, A. and Wolff, G. (2010). Banking and sovereign risk in the euro-area. Centre for Economic Policy Research Discussion Paper No. 7833.
- Gibson, H.D., Hall, S.G. and Tavlas, G.S. (2016). The effectiveness of the ECB's asset purchase programs of 2009 to 2012. *Journal of Macroeconomics*, 47, 45-57.
- Ghysels, E., Idier, J., Manganelli, S. and Vergote, O. (2014). A high frequency assessment of the ECB's securities markets programme. European Central Bank, Working Paper No 1642.
- Koijen, R.S., Koulischer, F., Nguyen, B. and Yogo, M. (2016). Quantitative easing in the euro area: The dynamics of risk exposures and the impact on asset prices. Bank De France, Document de Travail No 601.
- Krishnamurthy, A., Nagel, S. and Vissing-Jorgensen, A. (2015). ECB policies involving government bond purchases: Impact and channels. Unpublished Working Paper.
- Lee, J. and Strazicich, M.C. (2003). Minimum Lagrange multiplier unit root test with two structural breaks. *Review of Economics and Statistics*, 85, 1082-1089.
- Li, D., Chen, J. and Gao, J. (2011). Non-parametric time-varying coefficient panel data models with fixed effects. *Econometrics Journal*, 14, 387-408.

- Manganelli, S. and Wolswijk, G. (2009). What drives spreads in the euro-area government bond market? *Economic Policy*, 24, 191-240.
- Monfort, A. and Renne, J.P. (2013). Decomposing euro-area sovereign spreads: credit and liquidity risks. *Review of Finance*, 18, 2103-2151.
- Paniagua, J., Sapena, J. and Tamarit, C. (2016). Sovereign debt spreads in EMU: The time-varying role of fundamentals and market distrust. *Journal of Financial Stability*, in press.
- Racine, J.S. (2008). Nonparametric econometrics: A primer. *Foundations and Trends in Econometrics*, 3, 1-88.
- Robinson, P.M. (1989). *Nonparametric estimation of time-varying parameters. Statistical analysis and forecasting of economic structural change*. Springer: Berlin.
- Obstfeld, M. (1996). Models of currency crises with self-fulfilling features. *European Economic Review*, 40, 1037-48.
- Saka, O., Fuertes, A.M. and Kalotychou, E. (2015). ECB policy and Eurozone fragility: Was De Grauwe right? *Journal of International Money and Finance*, 54, 168-185.
- Sinn, H.W. (2014). *The Euro trap: On bursting bubbles, budgets, and beliefs*. Oxford University Press: Oxford.
- Su, L., and Ullah, A., (2006). Profile likelihood estimation of partially linear panel data models with fixed effects. *Economics Letters*, 92, 75-81.
- Sun, Y., R. J. Carroll and Li, D., (2009). Semiparametric Estimation of Fixed Effects Panel Data Varying Coefficient Models. *Advances in Econometrics*, 25, 101–29.
- Szczerbowicz, U. (2015). The ECB unconventional monetary policies: Have they lowered market borrowing costs for banks and governments. *International Journal of Central Banking*, 11, 91-127.
- Trebesch, C. and Zettelmeyer, J. (2014). ECB interventions in distressed sovereign debt markets: The case of Greek bonds. CESifo Working Paper No 4731.

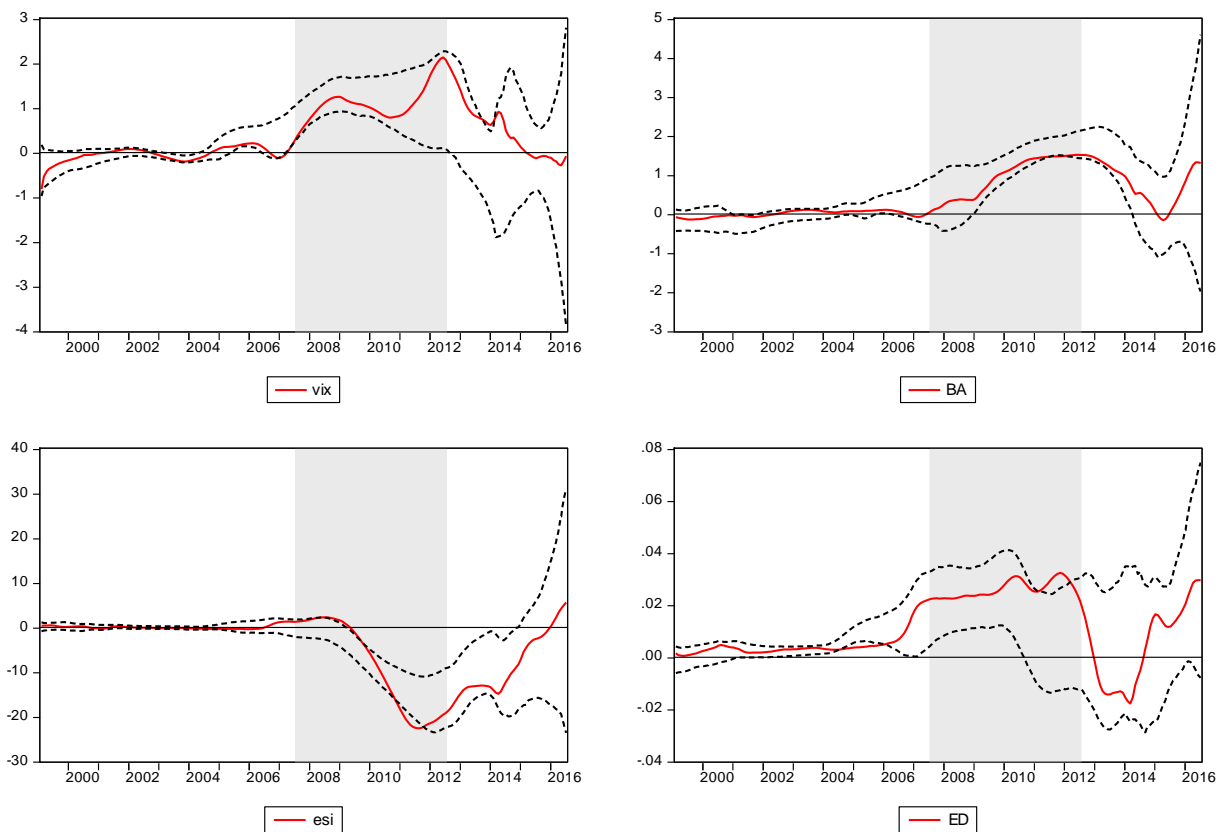
APPENDIX

Figure A1: Log of VIX



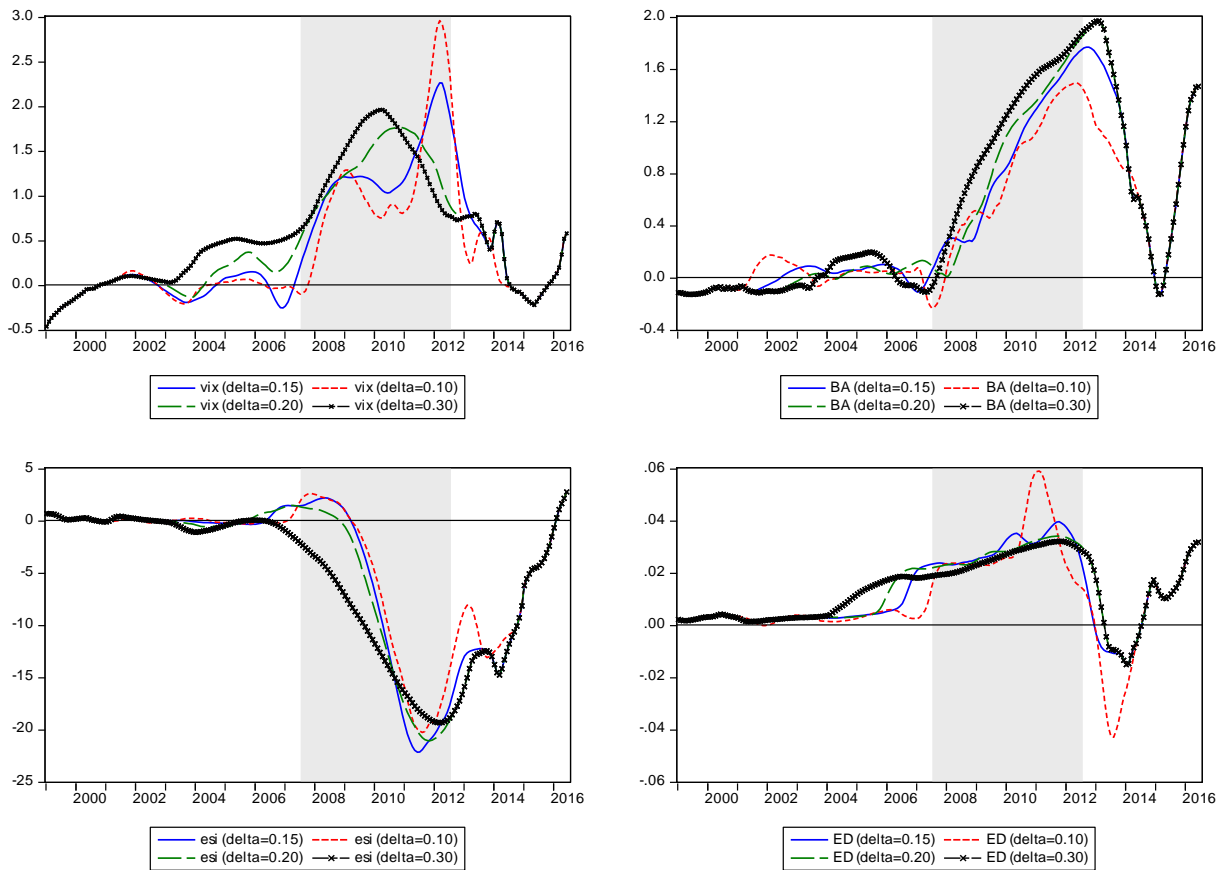
Note: This figure plots the logarithm of the Chicago Board Options Exchange Volatility Index (VIX) over the period January 1999 - July 2016. The shaded area denotes the period July 2007 - July 2012. Source: Chicago Board of Exchange.

Figure A2: TVP coefficients – Full panel – Using first lag of regressors



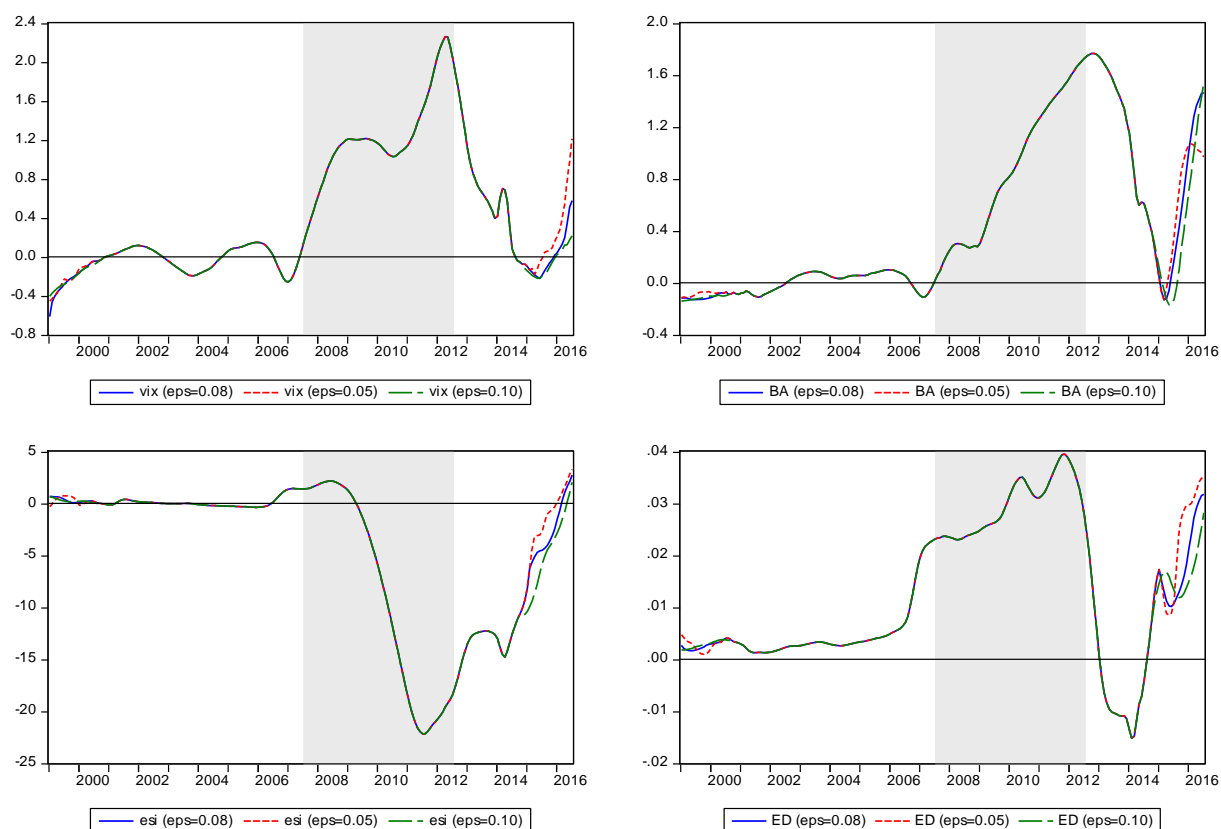
Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016. Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The estimation bandwidth parameter (h) is set to 0.15 and the bandwidth correction parameter (ε) to 0.08. The panel includes Austria, Belgium, Finland, France, Ireland, Italy, the Netherlands, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the lagged logarithm of the Chicago Board Options Exchange Volatility Index (vix), the lagged bid-ask spread of 10-year government bonds (BA), the lagged logarithm of the Economic Sentiment Index relative to Germany (esi), and the lagged 1-year ahead expected gross government debt to GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

Figure A3: TVP coefficients – Full panel – Alternative bandwidth parameters



Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016, using four alternative values for the bandwidth parameter: $h = 0.15, 0.10, 0.20$ and 0.30 . In all cases, the bandwidth correction parameter (ε) is set to 0.08 . Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The panel includes Austria, Belgium, Finland, France, Ireland, Italy, the Netherlands, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (vix), the bid-ask spread of 10-year government bonds (BA), the logarithm of the Economic Sentiment Index relative to Germany (esi), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

Figure A4: TVP coefficients - Full panel – Alternative bandwidth correction parameters



Note: This figure plots non-parametric estimates of Equation (1) over the period January 1999 - July 2016, using three alternative values for the bandwidth correction parameter: $\varepsilon = 0.08, 0.05$ and 0.10 . In all cases, the bandwidth parameter (h) is set to 0.15 . Time-varying panel (TVP) coefficients and 95% confidence intervals (dotted lines), calculated using the wild bootstrap method (1000 iterations), are shown. The panel includes Austria, Belgium, Finland, France, Ireland, Italy, the Netherlands, Portugal and Spain. The dependent variable is the 10-year government bond yield spread versus Germany. The set of explanatory variables includes the logarithm of the Chicago Board Options Exchange Volatility Index (vix), the bid-ask spread of 10-year government bonds (BA), the logarithm of the Economic Sentiment Index relative to Germany (esi), and the 1-year ahead expected gross government debt to GDP ratio relative to Germany (ED). The shaded area denotes the period July 2007 - July 2012.

Table A1 - Data Description and Sources

Variable	Description	Source
Spread	10-year bond yield spread against German bund	ECB
vix	Chicago board options exchange volatility index	Bloomberg
BA	10-year bond bid-ask spread	Bloomberg
esi	Economic sentiment index relative to Germany	Eurostat
ED	Expected general government gross debt differential against Germany (% of GDP)	Eur. Comm. Economic Forecasts
MRO	Main refinancing operations rate (% per annum)	ECB
shmp	Securities held by the ECB for monetary policy purposes, weekly financial statements	ECB
D ^{OMT}	Dummy variable equal to 1 since August 2012 and 0 otherwise	Own calculations
CDS senior	CDS index covering 25 senior subordination European Banks	Markit
CDS junior	CDS index covering 25 senior junior subordination European Banks	Markit