Quantitative easing and sovereign yield spreads: Euro-area time-varying evidence ☆

António Afonso [a,b,1], João Tovar Jalles [b,c,*]

[a] *ISEG/UL – University of Lisbon, Department of Economics, Portugal*
[b] *REM – Research in Economics and Mathematics, UECE – Research Unit on Complexity and Economics, R. Miguel Lupi 20, 1249-078 Lisbon, Portugal*
[c] *Centre for Globalization and Governance, Nova School of Business and Economics, Campus Campolide, Lisbon 1099-032, Portugal*

ABSTRACT

We assess the determinants of sovereign bond yield spreads in the period 1999:01–2016:07, considering non-conventional monetary policy measures in the Euro area. We use a 2-step approach to: (i) confirm and estimate the determinants of sovereign bond yield spreads; (ii) compute bivariate time-varying coefficient (TVC) models of each determinant and analyse the temporal dynamics. The baseline determinants of sovereign bond yield spreads in the Euro area are the bid-ask spread, the VIX, fiscal developments and rating developments, REER, and economic growth. QE measures implemented by the ECB in the aftermath of the crisis are also relevant. From the TVC analysis, the Covered Bond Purchase Programme contributed to reduce yield spreads, particularly in the 2011–2013 period. Longer-term refinancing operations contributed to reduce yield spreads in most countries.

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1. Introduction

There seems to be widespread understanding that an under-pricing of sovereign risk in the Economic and Monetary Union (EMU) occurred before the 2008–2009 economic and financial crisis, while an overpricing of it followed during the subsequent sovereign debt crisis. Such developments were caused both by the fluctuations in the risk appetite and by Euro area country-specific concerns regarding underlying economic fundamentals.

In this paper, we assess the determinants of sovereign bond yield spreads using the data between 1999 and 2016 while taking into account the existence of so-called non-conventional monetary policy measures in the Euro area, which followed the aftermath of the global financial crisis (GFC). For instance, in the Euro area, we can recall the announcement of the Outright Monetary Transactions (OMT) programme in July 2012 and the Quantitative Easing (QE) measures (January 2015), both of

which involve purchases on behalf of the European Central Bank (ECB) of national government bonds in secondary markets. Moreover, it is then important to consider additional developments notably the Covered Bond Purchase Programmes (CBPP), Securities Market Programme (SMP), the Asset-Backed Securities Purchase Programme (ABSPP), the Public Sector Purchase Programme (PSPP), the securities held for monetary purposes by the ECB (SHMP), and the Corporate Sector Purchase Programme (CSPP). Such QE measures implemented by the ECB might have had an effect on country specific Euro area yield spreads.[2]

In fact, the OMT programme has been credited with stabilizing European sovereign bond markets but has also been criticised on the grounds of re-introducing moral hazard considerations and market complacency towards weak national fundamentals. Similar objections have been raised against the, more general, QE programme as well. If these objections were well-founded, then in an analysis of yield spread determinants, the response of spreads to such determinants would be found to be small (or statistically insignificant) following the announcement of the OMT and QE programmes. Such a scenario could have far-reaching repercussions related to national governments' determination to promote (structural) reforms. On the other hand, if the announcement of the OMT and QE programmes were not followed by fundamental changes in the response of yield spreads to their determinants, then market-imposed discipline would not have been affected.

Our analysis aims to investigate these hypotheses, for which so far no empirical evidence has been presented. We use a panel of ten Euro-area countries (Austria, Belgium, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal and Spain) with monthly data between January 1999 and July 2016.

We conduct our analysis both in a country-by-country and panel setups. On the former, we rely on a time-varying coefficients model initially developed by Schlicht (1985, 1988) and which is statistically superior to the one-sided Kalman-Bucy filter. In practice, we use a 2-step approach: (i) confirm (by means of model selection methods) and estimate (by means of panel techniques) the determinants of sovereign bond yield spreads; (ii) compute bivariate time-varying coefficient (TVC) models of each determinant on government bond spreads and analyse the temporal dynamics of resulting estimates.

Our main results show that the baseline determinants of sovereign bond yield spreads in the euro area are: the bid-ask spread (liquidity measure), the VIX (international risk measure), fiscal developments (debt ratios and budget balance ratios), rating developments (credit risk), Real Effective Exchange Rate (REER), and economic growth. Moreover, in recent years additional relevant determinants were the QE measures implemented by the ECB in the aftermath of the economic and financial crisis.

In addition, several factors increased its influence on yield spreads after the 2009 crisis, notably the expected debt ratio difference, sovereign ratings, and the LTRO and CBPP1measures. From the TVC analysis, the CBPP1 non-standard measure has contributed to bring down sovereign yield spreads in all euro area countries in the analysis, particularly in the crisis period, 2011–2013. In addition, an example of a more standard measure, the longer-term refinancing operations (LTRO), also contributed to reduce yield spreads in most countries. Therefore, one can conclude that the ECB's intervention did contribute to contain sovereign yield spreads, implying indirectly some sort of expansionary monetary developments, particularly when bonds are kept until maturity in the ECB balance sheet (e.g. the CBPP1 program).

The remainder of the paper is organized as follows. Section 2 provides a review of the relevant literature. Section 3 outlines our econometric methodology. Section 4 discusses the data. Section 5 presents our empirical results. The last section concludes.

2. Literature review

Existing studies on EMU government bond yields model them as a function of three main variables (Manganelli and Wolswijk, 2009; Favero et al., 2010; Arghyrou and Kontonikas, 2012): an international risk factor, credit risk and liquidity risk. Most of the evidence suggests that markets attach additional risks to loosening fiscal stances (Afonso and Rault, 2015) and shifts in fiscal policy expectations (Elmendorf and Mankiw, 1999), notably its impact on the overall yield curve (Afonso and Martins, 2012). Regarding the effects of QE on sovereign yield spreads in the euro area, the literature is rather scarce. That said, Krishnamurthy and Vissing-Jorgensen (2011) study the effect of QE on US sovereign and corporate yields and Joyce et al. (2011) examine a similar issue in the U.K, where central bank asset purchases have reduced long-term government bond yields. Furthermore, Fawley and Neely (2013) compare QE programs across the US, the UK, Japan and the Euro area.

Previous literature explained spreads on the transfer of global financial risk to sovereign bonds through banking bailout schemes (Acharya et al., 2014); changing private expectations regarding the probability of default risk and/or a country's exit from the euro (Arghyrou and Tsoukalas, 2011) leading to a marked shift in market pricing behaviour from a 'convergence-trade' model before August 2007 to one driven by macro-fundamentals and international risk thereafter (Arghyrou and Kontonikas, 2012; Afonso et al., 2015); increased attention to fiscal developments (Afonso, 2010); contagion effects (De Santis, 2012; Arghyrou and Kontonikas, 2012; Afonso et al., 2014); and sovereign credit ratings events (Afonso et al., 2012).

The majority of the early studies on the European debt crisis capture the structural instability in the relationship between spreads and their determinants by imposing on the data exogenous break points and estimating sub-sample regressions differentiating between a pre-crisis and a crisis period (see e.g. Barrios et al., 2009; Arghyrou and Kontonikas, 2012; Caggiano and Greco, 2012).

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[2] Starting dates were: CBPP, July 2009; SMP, May 2010; PSPP, March 2015; ABSPP, November 2015; CSPP, June 2016.

Aβmann and Boysen-Hogrefe (2012), studied the determinants of government 10-years bond spreads of 10 Euro area countries, using weekly data between 2001 and 2010, and found using a time-varying coefficient model, that the budget balance and the outstanding amount of sovereign debt securities gained importance when the financial crisis begun.

Bernoth and Erdogan (2012) using a semiparametric time-varying coefficients panel data model to examine whether euro area spreads were linked to a shift in macroeconomic fundamentals or to increased pricing of international risk. They showed that since the onset of the financial crisis the market reaction to fiscal imbalances increased considerably.

Boysen-Hogrefe (2013), applied a dynamic factor model with time-varying factor loadings and time-varying idiosyncratic variances to analyse the co-movements of sovereign bond returns in 11 Euro area countries. Their results indicate that there are highly synchronized co-movements between euro zone bond returns in the core countries, while bond markets in the periphery countries seem to have decoupled.

D'Agostino and Ehrmann (2014), using a time-varying parameter stochastic volatility model for G7 countries, observed considerable time variation in the role of the various bond spreads determinants. They also found out that macro fundamentals, general risk aversion and liquidity risks were not priced in the first years of the monetary union.

Georgoutsos and Migiakis (2013) applied a Markov switching model to sovereign yield spreads in 10 EMU countries and found that market and economic sentiment conditions have significant impacts on the movement of sovereign bond spreads while the assumption that fiscal variables are the main determinants of sovereign spreads is rejected.

Delatte et al. (2014), estimated the government bond spreads of peripheral European countries by applying panel smooth threshold regression model. Their estimations confirm the previous finding of Aizenman et al. (2013) and Afonso et al. (2015) regarding the necessity of the changing in sensitivity of bond yields to fundamentals in order to explain yields during the crisis period. According to their results competitiveness, international risk and liquidity risk (to a lesser extent) gained an extra importance by investors. Klose and Weigert (2014) found that redenomination risk has played a role in the determination of sovereign yields, and that this risk is related to the expected valuations of newly introduced currencies: those of Portugal, Ireland, Spain and Italy are expected to depreciate, while newly introduced currencies of other countries are expected to appreciate following a break-up of the EMU. This aspect that part of the increase in bond yields represents redenomination risk that one or more countries will drop out of the European Monetary Union and reintroduce their own national currencies has also been analysed by Di Cesare et al. (2012).

Other papers have also provided evidence that structural instability is a more complex process. Costantini et al. (2014), analyzed the determinants of sovereign yield spreads in 9 EMU countries by applying a panel co-integration approach allowing for structural breaks. According to their results, fiscal imbalances and liquidity risks are the main determinants of sovereign bond spreads in the long run.

Afonso et al. (2014) identified two breaks in the process of spreads' determination, respectively occurring in summer 2007 and spring 2009. The results indicate the existence of divergence between core and periphery countries since early 2009 with the risk of the periphery relative to the core increasing rapidly.

Gómez-Puig et al. (2014) relying on panel data techniques, found that a part of the increase in the sovereign spreads in the core EMU countries can be explained by the changes in regional macroeconomic fundamentals and to local, regional and global market sentiments.

Gajewski (2014) studied the mechanisms of pricing the EMU countries' sovereign bonds in financial markets using the Augmented Mean Group estimator. According to the results, financial markets became more myopic after the crisis and both fundamental macroeconomic and fiscal variables started to impact more sovereign bond spreads. The results also show the higher importance of fiscal balance compared to government debt.

Pozzi and Sadaba (2015) focused on five Euro area countries and by applying a dynamic factor model with Markov switching parameters, found a permanent regime shift in risk pricing in the first half of 2008, notably in terms of pure country-specific risk.

Afonso and Jalles (2016) studied economic volatility by assessing the determinants of sovereign bond yield spreads in 10 Euro area countries computing bivariate time-varying coefficients of each determinant. Better budgetary positions or higher than expected GDP growth have negative impacts on the yield spreads while higher VIX, bid-ask spread and debt-to-GDP ratio have positive impacts on the yield spreads.

Paniagua et al. (2016) estimated a time-varying multi-parameter model by using the Kalman filter for the determinants of sovereign debt spreads in a panel of 11 EMU countries. They indicate that fiscal indebtedness, the shift in the global risk aversion and the worsening of the other fundamentals had significant impact on the evolution of long-term spreads in peripheral EMU countries.

Finally, Silvapulle et al. (2016) identified the presence of contagion in the long-term sovereign bond yield spreads of five peripheral EU countries by applying a semiparametric copula methodology. Their findings show the existence of contagion effects and indicate that the increased volatilities of sovereign bond yields of the sample countries are due to the international transmission of financial shocks and the market expectation of global volatility exposure.

3. Empirical methodology

There are several variables that positively affect an increase in government bond yield spreads relatively to Germany's, while others decrease it. The sensitivity of these variables might not be static over time, since countries underwent several structural (fiscal, regulatory and other) reforms over the period under scrutiny.

We take the following 2-step approach: (i) confirm (by means of model selection approaches) and estimate (by means of panel data analyses) that the usual suspects (determinants) affect government bond yield spreads are indeed appropriate and significant for our sample of countries and time span (from 1999:01 to 2016:07); (ii) compute bivariate time-varying coefficient models of each (key) determinant on government bond spreads and analyse the temporal dynamics of resulting estimates.

3.1. Model selection

We begin our analysis by taking a model selection analysis of our set of potential determinants of government bond spreads. It is well known that the inclusion of particular control variables in any regression can wipe out a given bivariate relationship (Easterly and Rebelo, 1993). We begin by dealing directly with model uncertainty on the determinants of government bond spreads. The motivation for the use of techniques dealing with uncertainty rests on the raising concern over the robustness of the candidate variables in any cross-section regression used to explain different success patterns in real income growth. We employ the widely used Bayesian Model Averaging (BMA) and the more recent Weighted-Average Least Squares (WALS) proposed by Magnus et al. (2010).

Essentially BMA treats parameters and models as random variables and attempts to summarise the uncertainty about the model in terms of a probability distribution over the space of possible models. To evaluate the posterior model probability the BMA uses the Bayesian Information Criteria (BIC) – for more details see Raftery (1995), Sala-i-Martin et al. (2004) and Malik and Temple (2009). In Section 4, the output of the BMA analysis includes the posterior inclusion probabilities (PIP) for variables. The higher the posterior probability for a particular variable the more robust that determinant for government bond spreads appears to be.

The WALS is claimed to be theoretically and practically superior to the BMA and presents two major advantages over it: its computational burden is trivial and it is based on a transparent definition of prior ignorance (Magnus et al., 2010). The statistical framework is a classical linear regression model with two subsets of explanatory variables. The focus regressors contain explanatory variables that one wants in the model because of theoretical or economic reasons about the phenomenon under investigation. The auxiliary regressors contain additional explanatory variables of which one is less certain. WALS relies on preliminary orthogonal transformations of the auxiliary regressors and their parameters, which greatly reduce the computational burden of this model-averaging estimator and allow for exploiting prior distributions corresponding to a more transparent concept of ignorance about the role of the auxiliary regressors.

In both the BMA and WALS, we consider a fixed building block of potential determinants (refer to Section 4.1 on the data) and then five inter-changeable thematic building blocks, namely: economic fundamentals, ratings and outlooks, fiscal determinants, refinancing operations and purchase programmes. We test each building block individually and then jointly.[3]

3.2. Panel data analysis

Once the model selection analysis is done, we move to our first step in directly estimating the determinants of sovereign bond yield spreads for the panel of 10 Euro area countries. Our main regression equation is:

$$spreads_{it} = \alpha_i + \rho_t + \beta X_{it} + \varepsilon_{it} \tag{1}$$

where $spreads_{it}$ denotes the bond yield spread relative to Germany's, X_{it} is a vector of determinants. As in the case of the model selection analysis, we consider a fixed building block (refer to Section 4.1 on the data) and then the abovementioned 5 inter-changeable thematic building blocks. The coefficient β measures the degree of sensitivity of sovereign spreads to a given determinant. α_i, ρ_t denote country and time effects, respectively. The former capture unobserved heterogeneity across countries, and time-unvarying factors such as geographical variables; the latter aim to control for global shocks. Finally, ε_{it} is a disturbance term satisfying usual assumptions of zero mean and constant variance.

Eq. (1) is first estimated by Ordinary Least Squares with robust standard errors clustered at the country level. We consider specifications with and without country and/or time effects for robustness. Then, due to potential endogeneity concerns of some of our variables in the X_{it} vector, we rely on a Two-Stage-Least-Squares estimator to re-run Eq. (1). We employ lags of the dependent variable and regressors are the instruments. We use the Hansen J statistic - test of overidentification - to test the validity of the overidentifying restrictions. With the Kleibergen-Paap LM statistic - underidentification test - we test whether our instruments are relevant.

3.3. Country specific time-varying coefficients model

In the second step, we generalize Eq. (1) above by introducing the assumption that the regression coefficients may vary over time. We estimate a time-varying coefficient model for each country i at the time:

$$spreads_{it} = \alpha_i + \beta_{it} X_{it} + \varepsilon_{it} \tag{2}$$

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[3] Akitoby and Stratmann (2008), Manganelli and Wolswijk (2009), Schuknecht et al. (2009) provide the underlying theoretical framework that allows us to justify the relevance of particular determinants and their expected signs used in the empirical section.

where the coefficient β_{it} is now assumed to change slowly and unsystematically over time and that the expected value of the coefficient at time t is equal to the value of the coefficient in time $t − 1$ (i.e. the coefficient is assumed to be a random walk). The change of the coefficient is given by v_t, which is assumed to be normally distributed with expectation zero and variance σ_i^2:

$$\beta_{it} = \beta_{it-1} + v_{it}. \tag{3}$$

Eqs. (2) and (3) are jointly estimated using the Varying-Coefficient Model proposed by Schlicht (1985, 1988). Here, the variances σ_i^2 are computed using a method-of-moments estimator, which coincides with the maximum-likelihood estimator for large samples (Schlicht, 1985, 1988). The model described in Eqs. (2) and (3) generalizes the classical regression model (Eq. (1)), which is obtained as a special case when the variance of the disturbances in the coefficients approaches to zero.

This approach has multiple advantages compared to other approaches used to compute time-varying coefficients such as rolling windows and Gaussian methods (Aghion and Marinescu, 2008). First, it allows using all observations in the sample to estimate the degree of responsiveness of each determinant in each year – a construction not possible in the rolling windows method. Second, changes in the degree of responsiveness of sovereign bond yield spreads in a given year come from innovations in the same year, rather than from shocks occurring in neighbouring years. Third, it translates the fact that changes in policy are slow and are dependent of the immediate past.

4. Data issues

4.1. Baseline data set

Our empirical analysis relies on a panel of ten Euro area countries (Austria, Belgium, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal and Spain) using monthly data between January 1999 and July 2016. Following existing literature, we will model spreads on a fixed block of determinants that deal with international risk conditions, liquidity risk and credit risk. First, international financial risk will be proxied by the S&P 500 implied stock market volatility index (VIX), a common proxy for global financial instability (Mody, 2009). We expect a higher (lower) value for the global risk factor to cause an increase (reduction) in government bond spreads. Second, the 10-year government bond bid-ask spread will serve as our measure of bond market illiquidity, with a higher value of this spread indicating a fall in liquidity leading to an increase in government bond yield spreads. Credit risk will be captured using a number of macro/fiscal indicators. Third, a real exchange rate appreciation is expected to increase spreads as justified by Arghyrou and Tsoukalas (2011) and Arghyrou and Kontonikas (2012).

In addition, to capture the effects of economic growth, we use the annual growth rate of industrial production (relative to that of Germany), capturing the argument of Alesina et al. (1992) according to which sovereign debt becomes riskier during periods of economic slack. Moreover, as far as fiscal determinants are concerned, we expect a higher (lower) value for the expected government budget balance (or public debt ratio) to reduce (increase) sovereign bond spreads. Furthermore, we collected sovereign ratings information (specifically rating notations and outlooks) directly from the three main rating agencies (Standard & Poors, Moody's and Fitch). We transformed the rating information into discrete variables with a linear scale to group the ratings into 17 categories, where we attribute the level 17 to triple A and where we put together the few observations below B-, which all receive a level of one in that same scale. The notations at and below BB+ and Ba1 are usually associated with speculative investments. One expects rating upgrades (downgrades) to decrease (increase) sovereign bond spreads. Finally, we also include lagged spreads to account for spreads' persistence (see Gerlach et al., 2010; Arghyrou and Kontonikas, 2012).[4]

Table 1 presents the summary statistics for the relevant variables while data definitions and sources are explained in more detail in the Appendix A.

4.2. The quantitative easing data

One of the main purposes of the paper is to check the potential effects of the ECB interventions on government bond yield spreads in the euro area. Therefore, we have collected data related to the ECB intervention through various strands of QE. In practice, the ECB classifies its policy measures as standard and non-standard measures. The description of these measures is detailed in below.

4.2.1. Standard measures

The open market operations of the Eurosystem consist of the main refinancing operations (MROs) and longer-term refinancing operations (LTROs). MROs are set by the governing council of the ECB and provides a bulk of liquidity to the banking system. We denoted the main refinancing operations fixed rate by MRO_F. It is obtained from the ECB and is available from 1 January 1999 until 16 March 2016, except for the period from 28 June 2000 to 15 October 2008. In this period the ECB set the main refinancing operations variable rate which we denoted by MRO_V. The interest rate levels are in percentage per annum.

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[4] For reasons of parsimony lagged spreads are omitted in output tables, but are available from the authors upon request.

Table 1
Summary statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
bond_spread	2110	1.117	2.528	−0.050	27.390
bond_spreead_5y	1816	1.030	3.508	−0.224	61.425
tbill_sprread_1y	1379	0.391	1.279	−0.315	17.773
tbill_spread_6m	1033	0.337	0.930	−0.265	7.611
Vix	2100	20.811	7.940	10.420	59.890
Reer	2090	98.900	11.102	70.125	144.533
bid_ask	2048	0.042	0.245	−0.004	5.886
ip_pch_deu	1990	−0.403	2.763	−10.776	20.385
expected_ob_deu	2110	−0.541	2.964	−9.700	6.400
Ltdebtshare	1824	89.112	5.863	72.033	99.380
expected_debt_deu	2110	10.966	30.401	−43.300	131.200
rating_sp	2110	14.448	3.597	1.000	17.000
rating_m	2110	14.600	3.788	1.000	17.000
rating_f	2110	14.625	3.507	1.000	17.000
outlook_sp	2110	−0.129	0.493	−1.000	1.000
outlook_m	2110	−0.082	0.494	−1.000	1.000
outlook_f	2110	−0.113	0.404	−1.000	1.000
mlf	2110	2.873	1.633	0.250	5.750
mro_f	1120	1.115	1.049	0.000	4.250
mro_v	1000	3.125	0.953	2.000	4.750
ltro	2110	309.945	284.072	45.000	1092.400
net_ltro	2110	274.114	287.771	20.800	1092.400
tltro_l	230	311.348	126.833	63.900	425.100
tltro_ll	10	399.300	0.000	399.300	399.300
smp	750	147.576	51.632	35.000	219.500
cbpp1	850	41.167	16.045	4.200	61.100
cbpp2	570	12.402	3.504	1.500	16.400
cbpp3	220	109.118	55.706	4.800	186.600
abspp	210	11.748	6.660	0.400	20.400
pspp	170	458.647	269.417	41.000	944.900
cspp	20	9.050	4.258	4.900	13.200
shmp	850	300849.900	274467.300	2901.000	1281420.000

Source: authors' computations.

CMRO is the monthly country-specific values for the MROs, these values are in Euro millions, data is obtained from the Bruegel database and it is available from January 2003. Two core countries, France and the Netherlands are not covered.

LTROs provide additional longer-term refinancing to the financial sector. We denoted the holdings of the Longer-term Refinancing Operations by LTRO, it includes LTROs, TLTRO_I and TLTRO_II. It is collected from the weekly financial statement of the ECB using the values at the end of each month. These values are in Euro billions. Net-LTRO is the accumulated values of the LTRO that excludes TLTROs (Net_LTRO = LTRO – TLTRO_I – TLTRO_II). From September 1, 2014 the accumulated values are based on our calculations using the values reported by the ECB in the weekly financial statement.

CLTRO is the monthly country-specific values for the LTROs, these values are in Euro millions. Data is obtained from the Bruegel database and it is available from January 2003. Two countries, France and the Netherlands are not covered.

4.2.2. Non-standard measures

The targeted longer term refinancing operations (TLTROs) provide financing to credit institutions for periods of up to four years. The accumulated amounts of the first series of the targeted longer term refinancing operations which we denoted by TLTRO_I are based on our own calculations using the reported settled values in the weekly financial statement of the ECB. The second series of the targeted longer-term refinancing operations started in June 2016 and is denoted by TLTRO_II. Data is available from July 2016 and it is collected from the weekly financial statement of the ECB.

The expanded asset purchase programme (APP) includes all the purchase programmes under which private and public sector securities are purchased to address the risks of a too prolonged period of low inflation. This programme consists of three terminated and four ongoing purchase programmes.

4.2.2.1. Terminated programmes. Securities Market Programme (SMP) was started on 10 May 2010 and was terminated on 6 September 2012. The existing securities will be held to maturity. Daily data is available from 17 May 2010 on the ECB database. Here we used the SMP holdings at the end of each month. These values are in Euro billions. Variable SMP_S is the country specific nominal holdings under SMP. Values are reported for the peripheral countries (Italy, Greece, Ireland, Portugal and Spain) at the end of each year and are in Euro billions.

Covered Bond Purchase Programme (denoted by CBPP1) started on 2 July 2009 and terminated on 30 June 2010 when it reached a nominal amount of €60 billion. The assets bought under this programme will be held to maturity. Daily data is available from the 9 July 2009. We used the holdings at the end of each month. These values are in Euro billions.

Covered bond Purchase Programme 2 (CBPP2) started on November 2011 and ended on 31 December 2012 when it reached the amount of €16.4 billion. The assets bought under this programme will be held to maturity. Daily data is available from 11 November 2011, we used the holdings at the end of each month. These values are in Euro billions.

4.2.2.2. Ongoing programmes. Covered Bond Purchase Programme 3 (CBPP3) started on 20 October 2014. As ECB mentions, this measure "helps to enhance the functioning of the monetary policy transmission mechanism, supports financing conditions in the euro area, facilitates credit provision to the real economy and generates positive spillovers to other markets". Daily data is available from 24 October 2014. We used the holdings at the end of each month. The values are in Euro billions.

Asset-Backed Securities Purchase Programme (ABSPP) started on 21 November 2014. Daily data is available from 28 November 2014. We used the holdings at the end of each month. These values are in Euro billions.

Public Sector Purchase Programme (PSPP) started on March 2015. Daily data is available from 13 March 2015. We used the holdings at the end of each month. These values are in Euro billions. PSPP_N is the country-specific monthly net purchases under PSPP. Monthly data is available on the ECB and it covers all the sample countries except Greece. The values are in Euro millions. Variable PSPP_S is the country-specific PSPP holdings at the end of the sample period. It covers all the sample countries except Greece. Values are in Euro millions. Corporate Sector Purchase Programme (CSPP) started on 8 June 2016. Daily data is available from 10 June 2016. We used the holdings at the end of each month. These values are in Euro billions. Finally, we also consider the securities held for monetary purposes by the ECB (SHMP), with the timespan starting on July 2009.

5. Empirical results

5.1. Selection of key yield spread determinants

In order to be able to estimate a so-called baseline specification, we first report the results of the Bayesian Model Averaging (BMA) and of the Weighted-Average Least Squares (WALS) procedures to select the core variables. Results are displayed in Tables 2a-2c, which are organized in a similar way. First, we show the output of BMA, which provides information about estimated coefficients, their t-ratios and posterior inclusion probabilities - PIP (the posterior probability that a variable is included in the model – ranging from zero to one). Then, our validation of the estimation results using the WALS instead is carried out by implementing the original procedure without any preliminary scaling of focus and auxiliary regressors. While the output of WALS is similar to that of BMA, the main difference is that former does not allow for computing the posterior inclusion probabilities. Estimation results for the focus and the auxiliary parameters are displayed in the upper and the lower panels of each table. For robustness purposes, setup 1 considers the expected overall balance (relative to Germany), long-term debt share and expected public debt (relative to Germany) as part of the focus regressors. Setup 2 considers those three variables as auxiliary regressors, leaving only the constant term as the focus regressor.

We can draw some initial conclusions. Starting with Table 2a, we observe that the fiscal variables appear consistently as key determinants of the yield spreads. As expected, higher (lower) differences of the expected debt (budget balance) vis-à-vis the expected respective variables for Germany, increase (decrease) the sovereign yield spreads (Table 2a). Moreover, liquidity and risk factors, proxied respectively by the bid-ask spread and by the VIX indicator are also responsible for the upward movements in the yield spreads.

In addition, looking at Table 2b, the improvement of sovereign rating notations and outlook conditions contribute to decrease the yield spreads. This initial result is in line with our a priori conjecture and with the existing results in the literature, as discussed in Section 2.

In terms of the so-called non-conventional monetary policy measures, our first indication points to the relevance of the holdings at the end of the month in the SMP in reducing the yield spreads (Table 2c). We have used the QE variables in levels in both the BMA and WALS exercises. Overall, the output of BMA is similar to that of WALS, which is reassuring. Next, we run our main panel regressions.

5.2. Panel analysis

For the baseline specification, we used industrial production indices in terms of their differences vis-à-vis Germany, fiscal policy variables differences towards Germany as well, and liquidity, international risk, real effective exchange rate data. In Table 3a, we can confirm for the 10 Euro area economies in our sample that all variables, when statistically significant, have the expected effect on the yield spreads, in line with previous studies.

Furthermore, better ratings and outlooks (irrespectively of the agency) also decrease the sovereign yield spreads (Table 3b).

Turning to some of the non-conventional measures of the ECB, we can conclude from Tables 4a, 4b (notably when using growth rates), that these interventions (although not all measures are statistically significant) contributed to reduce the average euro area sovereign yield spreads, which was, to some extent, an objective of such measures. Interestingly, the CBPP1 and the SMP have the highest effects in terms of reducing the sovereign yield spreads, when one considers the data set with growth rates (Table 4b). Regarding the securities (in level) held for monetary purposes by the ECB that also had one

Table 2a

Bayesian model averaging and weighted-average least squares (economic and fiscal fundamentals).

Model Type	BMA						WALS			
Setup	Setup 1			Setup 2			Setup 1		Setup 2	
	Coef.	t-stat	PIP	Coef.	t-stat	PIP	Coef.	t-stat	Coef.	t-stat
Focus regressors										
constant	−2.138	−2.83	1.00	−2.000	−2.16	1.00	−3.499	−4.09	−3.482	−4.09
Expected_OB_DEU	−0.176	−10.89	1.00				−0.175	−10.77		
Ltdebtshare	0.025	3.61	1.00				0.027	4.02		
Expected_debt_DEU	0.026	17.03	1.00				0.028	17.04		
Auxiliary regressors										
IP_pch_DEU	−0.090	−4.73	1.00	−0.089	1.44	0.74	−0.091	−4.92	−0.083	−4.61
VIX	0.012	1.52	0.77	0.011	1.44	0.74	0.018	3.67	0.013	2.90
REER	0.001	0.26	0.09	0.001	0.26	0.09	0.012	1.98	0.007	1.34
bid_ask	5.498	35.97	1.00	5.501	35.90	1.00	5.285	34.70	5.304	35.01
Expected_OB_DEU				−0.175	−10.77	1.00			−0.181	−11.42
Ltdebtshare				0.023	2.66	0.94			0.032	4.79
Expected_debt_DEU				0.026	16.93	1.00			0.026	16.48

Note: BMA stands for Bayesian Model Averaging; WALS stands for Weighted Average Least Squares. BMA's output includes coefficient estimates, their t-statistics and the PIP (probability of inclusion). WALS' output includes coefficient estimates and their t-statistics. Setup 1 considers the expected overall balance (relative to Germany), long-term debt share and expected public debt (relative to Germany) as part of the focus regressors. Setup 2 considers those three variables as auxiliary regressors, leaving only the constant term as the focus regressor. Refer to the main text for further details.

Table 2b

Bayesian model averaging and weighted-average least squares (ratings and outlooks).

Model Type	BMA						WALS			
Setup	Setup 1			Setup 2			Setup 1		Setup 2	
	Coef.	t-stat	PIP	Coef.	t-stat	PIP	Coef.	t-stat	Coef.	t-stat
Focus regressors										
Constant	4.762	19.04	1.00	4.834	19.25	1.00	4.762	19.00	4.954	20.01
Rating_SP	0.090	2.28	1.00				0.097	2.46		
Rating_M	−0.236	−6.43	1.00				−0.237	−6.45		
Rating_F	−0.266	−5.37	1.00				−0.277	−5.59		
Outlook_SP	−0.381	−6.09	1.00				−0.381	−6.11		
Outlook_M	−0.754	11.77	1.00				−0.760	−11.85		
Outlook_F	−0.321	−4.09	1.00				−0.315	−4.01		
Auxiliary regressors										
IP_pch_DEU	−0.052	−5.64	1.00	−0.050	−5.35	1.00	−0.057	−6.08	−0.054	−5.77
VIX	0.033	10.79	1.00	0.033	10.68	1.00	0.032	10.41	0.033	10.90
REER	0.013	5.31	1.00	0.012	4.93	1.00	0.014	5.70	0.012	4.64
bid_ask	4.149	37.56	1.00	4.164	37.62	1.00	4.019	36.36	3.996	36.40
Rating_SP				0.021	0.49	0.23			0.051	1.32
Rating_M				−0.222	−5.91	1.00			−0.229	−6.28
Rating_F				−0.210	−4.04	1.00			−0.235	−4.85
Outlook_SP				−0.387	−6.08	1.00			−0.388	−6.46
Outlook_M				−0.745	−11.37	1.00			−0.751	−13.05
Outlook_F				−0.289	−3.11	0.97			−0.255	-3.39

Note: BMA stands for Bayesian Model Averaging; WALS stands for Weighted Average Least Squares. BMA's output includes coefficient estimates, their t-statistics and the PIP (probability of inclusion). WALS' output includes coefficient estimates and their t-statistics. Setup 1 considers the expected overall balance (relative to Germany), long-term debt share and expected public debt (relative to Germany) as part of the focus regressors. Setup 2 considers those three variables as auxiliary regressors, leaving only the constant term as the focus regressor. Refer to the main text for further details.

of the most relevant contributions, together with the main refinancing operations-variable rate tenders, to decrease the yield spreads.

Our results are robust to several sensitivity exercises and robustness checks. First, we looked more closely at the impact of the Global Financial Crisis by splitting the baseline regressions into before and after (2009:01).[5] In Table 5, we see that, for instance, the market pricing of sovereign ratings and outlooks is essentially done after the crisis, being less relevant before that

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[5] The first incidence of QE interventions by the ECB can be traced to the Covered bond purchase programme (CBPP1) announced on 7 May 2009 and implemented on July 2009, and also the Securities Markets Programme (SMP) announced on 10 May 2009 and implemented in that same month. Therefore, we have flagged the Global Financial Crisis by splitting the baseline regressions into before and after 2009:01. Hence, no effective QE measures are available before that date.

Table 2c
Bayesian model averaging and weighted-average least squares (QE: refinancing operations and purchase programmes).

Model Type	BMA						WALS			
Setup	Setup 1			Setup 2			Setup 1		Setup 2	
	Coef.	t-stat	PIP	Coef.	t-stat	PIP	Coef.	t-stat	Coef.	t-stat
Focus regressors										
Constant	30.265	5.99	1.00	27.03	11.36	1.00	30.25	6.03	28.087	6.50
MLF	−0.887	−0.47	1.00				−1.407	−0.74		
MRO_F	2.246	1.02	1.00				3.155	1.40		
LTRO	0.001	1.78	1.00				0.001	1.85		
CBPP1	0.021	0.59	1.00				0.023	0.64		
SMP	0.002	0.94	1.00				0.002	0.82		
SHMP (log)	−0.252	−0.77	1.00				−0.209	−0.64		
Auxiliary regressors										
IP_pch_DEU	−0.205	−6.71	1.00	−0.200	−6.43	1.00	−0.197	−6.67	−0.191	−6.28
VIX	−0.005	−0.36	0.15	−0.005	−0.36	0.15	−0.023	−1.20	−0.019	−1.12
REER	−0.284	−15.99	1.00	−0.283	−15.7	1.00	−0.286	−17.24	−0.271	−15.39
bid_ask	5.39	24.00	1.00	5.421	24.30	1.00	5.157	24.50	5.261	23.88
MLF				0.371	0.60	0.32			−0.823	−0.52
MRO_F				0.386	0.49	0.26			2.349	1.25
LTRO				0.001	1.02	0.58			0.001	1.79
CBPP1				0.028	0.96	0.51			0.017	0.57
SMP				0.001	0.56	0.29			0.002	0.97
SHMP (log)				−0.019	−0.17	0.09			−0.140	−0.52

Note: BMA stands for Bayesian Model Averaging; WALS stands for Weighted Average Least Squares. BMA's output includes coefficient estimates, their t-statistics and the PIP (probability of inclusion). WALS' output includes coefficient estimates and their t-statistics. Setup 1 considers the expected overall balance (relative to Germany), long-term debt share and expected public debt (relative to Germany) as part of the focus regressors. Setup 2 considers those three variables as auxiliary regressors, leaving only the constant term as the focus regressor. Refer to the main text for further details.

Table 3a
Baseline determinants of Sovereign Spreads (alternative specifications).

Specification	(1)	(2)	(3)	(4)	(5)	(6)
Estimation & Effects	OLS pooled	OLS pooled	Country + Time FE	Country + Time FE	IV country FE	IV country FE
IP_PCH_DEU	−0.0938**	−0.0494**	−0.0683***	−0.0466	−0.0234***	−0.0177***
	(0.036)	(0.016)	(0.020)	(0.028)	(0.004)	(0.004)
VIX	0.0158***	0.0027	0.0717	−0.0886	0.0067***	0.0051***
	(0.004)	(0.007)	(0.061)	(0.058)	(0.001)	(0.001)
REER	0.0251**	−0.0182	0.0438**	−0.0195	0.0036**	−0.0002
	(0.011)	(0.022)	(0.018)	(0.021)	(0.001)	(0.001)
bid_ask	5.7355***	6.4462***	3.8841***	5.4431***	0.7688***	0.7840***
	(1.167)	(0.921)	(0.896)	(0.582)	(0.051)	(0.052)
Expected_Debt_DEU	0.0371**		0.0772**		0.0044***	
	(0.014)		(0.027)		(0.001)	
Expected_OB_DEU		−0.2594**		−0.0645		−0.0207***
		(0.091)		(0.064)		(0.004)
Observations	1940	1940	1940	1940	1895	1895
Number of countries	10	10	10	10	10	10
R-squared	0.6348	0.5931	0.8146	0.7368	?	?

Note: Dependent variable is the 10-year bond yield spread (relative to Germany). Estimations by OLS and IV as indicated in the second row. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. When applicable country and time effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.

  * Denote statistical significance at the 10, 5, and 1 percent level, respectively.
  ** Denote statistical significance at the 10, 5, and 1 percent level, respectively.
  *** Denote statistical significance at the 10, 5, and 1 percent level, respectively.

period. In addition, a measure such as the LTRO, aimed at liquidity-providing long-term refinancing operations, only contributes to the reduction of yield spreads after the crisis.

Another important evidence of the relevance of crisis is the fact that the international risk factor, the VIX, is price around 7–8 times more after the crisis. In the same vein, the level of liquidity also becomes a key determinant after the crisis, being either essentially not statistically significant before or priced at a lower magnitude.

In addition, performing the analysis for the sub-periods pre and post sovereign debt crisis, which for us is the same event and that we date at the end of 2009, does not greatly change the results (available on request).

Second, we replaced our main dependent variable for the yield spreads by other maturities of government bond spreads (5-years) or T-bill spreads (12 and 6 months) – alternative dependent variable 1, 2 and 3, respectively. In fact, some of the

Table 3b
Ratings and Outlooks determinants - IV with country effects.

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
IP_PCH_DEU	−0.0241***	−0.0235***	−0.0237***	−0.0205***	−0.0222***	−0.0208***	−0.0201***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
VIX	0.0078***	0.0074***	0.0075***	0.0072***	0.0071***	0.0071***	0.0085***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
REER	−0.0017	0.0023	0.0017	0.0029**	0.0026*	0.0030**	−0.0007
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
bid_ask	0.8453***	0.7939***	0.8045***	0.7888***	0.7881***	0.8066***	0.8695***
	(0.053)	(0.053)	(0.052)	(0.051)	(0.051)	(0.052)	(0.053)
Expected_Debt_DEU	−0.0035**	0.0007	−0.0015	0.0045***	0.0043***	0.0045***	−0.0023
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Rating_SP	−0.0697***						
	(0.011)						
Rating_M		−0.0307***					
		(0.008)					
Rating_F			−0.0552***				
			(0.011)				
Outlook_SP				−0.1255***			
				(0.022)			
Outlook_M					−0.0939***		
					(0.023)		
Outlook_F						−0.1408***	
						(0.026)	
avg_rating							−0.0598***
							(0.011)
avg_outlook							−0.2044***
							(0.030)
Observations	1895	1895	1895	1895	1895	1895	1895
Number of countries	10	10	10	10	10	10	10

Note: Dependent variable is the 10-year bond yield spread (relative to Germany). Estimations by Two Stage Least Squares with lags of the dependent variable and regressors used as instruments. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. Country effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.

* Denote statistical significance at the 10 percent level, respectively.
** Denote statistical significance at the 5 percent level, respectively.
*** Denote statistical significance at the 1 percent level, respectively.

non-conventional measures of the ECB may have had an effect on the intermediate bond maturities as well. Our results displayed in Tables 6a, 6b, 6c, show that most notably for the one year and 6-month maturities the LTRO reduced those sovereign spreads.

On the other hand, we see that while rating notations are statistically significant for the 5-year yield spreads, rating outlooks become more relevant for the shorter bonds' maturities (1 year and 6 months). Finally, the other baseline yield spread determinants keep their relevance for these shorter maturities as well.[6]

5.3. Time-varying coefficients model

We estimated the Time-Varying Coefficients (TVC) models for a set of relevant core determinants. Fig. 1 illustrates the time varying characteristics of several determinants of the sovereign yield spreads.

For instance, we can observe that in the interquartile charts, increases in the VIX indicator have an upward effect on the sovereign yield spreads, but the magnitude of the effect changes through time. In fact, that effect rises during the 2010–2012 period, and then becomes more mitigated as the economic and financial crisis tends to be less acute, notably after 2013. A somewhat similar result is present in terms of the bid-ask spread, where liquidity issues where more prominent in terms of the size of the effect in the period 2010–2014. In addition, the impact on yield spreads stemming from the REER also spikes up in the period 2011–2012, with a real exchange rate appreciation increase the spreads. Regarding the economic conditions, this determinant of the yields spreads is clearly more relevant and more heavily priced in the markets in the period 2009–2013, when the crisis hit the euro area harder.

Focussing on the country specific results, we have computed the TVC of the estimations for the expected government debt difference vis-à-vis Germany, the average ratings of the three main rating agencies, and two measures of monetary policy, CBPP1 and LTRO. Given the limit constraints for the size of the paper, the full set of country results for the TVC is placed on an "online appendix" (and also available on request from the authors).

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[6] We also assessed the relevance of the announcement dates of the QE-measures, notably since for some cases, such as the case of the OMT, there were no securities bought at all. The results were not too robust overall, although some evidence is captured for the OMT announcement date (2 August 2012).

Table 4a
Refinancing and purchase programme determinants (in levels) - IV with country effects.

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
IP_PCH_DEU	−0.0230***	−0.0236***	−0.0347***	−0.0009	−0.0235***	−0.0233***	−0.0090	−0.0174*	0.0087	−0.0191**
	(0.004)	(0.004)	(0.007)	(0.001)	(0.004)	(0.004)	(0.010)	(0.009)	(0.012)	(0.009)
VIX	0.0067***	0.0073***	0.0082**	0.0011***	0.0065***	0.0065***	0.0105**	0.0085**	0.0185*	0.0098**
	(0.001)	(0.001)	(0.003)	(0.000)	(0.001)	(0.001)	(0.005)	(0.004)	(0.010)	(0.004)
REER	0.0037***	0.0023	0.0042	0.0010***	0.0031**	0.0032**	0.0163*	0.0046	0.0334*	0.0125
	(0.001)	(0.002)	(0.005)	(0.000)	(0.001)	(0.001)	(0.009)	(0.007)	(0.017)	(0.008)
bid_ask	0.7621***	0.7837***	0.8543***	1.2235***	0.7809***	0.7798***	0.9596***	0.9051***	0.5828***	0.9189***
	(0.051)	(0.052)	(0.077)	(0.245)	(0.052)	(0.052)	(0.090)	(0.084)	(0.206)	(0.083)
Expected_Debt_DEU	0.0045***	0.0030***	0.0014	−0.0002	0.0041***	0.0043***	−0.0068**	−0.0002	−0.0122***	−0.0056**
	(0.001)	(0.001)	(0.002)	(0.000)	(0.001)	(0.001)	(0.003)	(0.003)	(0.004)	(0.003)
Announcement	−0.1089**									
	(0.051)									
MLF		−0.0203***								
		(0.007)								
MRO_F			−0.0139							
			(0.034)							
MRO_V				0.0089***						
				(0.002)						
LTRO					0.0001					
					(0.000)					
Net_LTRO						0.0001				
						(0.000)				
SMP							−0.0001			
							(0.001)			
CBPP1								0.0043*		
								(0.002)		
CBPP2									−0.0301*	
									(0.016)	
SHMP (log)										0.1122***
										(0.038)
Observations	1895	1895	901	944	1895	1895	681	781	504	781
Number of countries	10	10	10	10	10	10	10	10	10	10

Note: Dependent variable is the 10-year bond yield spread (relative to Germany). Estimations by Two Stage Least Squares with lags of the dependent variable and regressors used as instruments. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. Country effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.
* Denote statistical significance at the 10 percent level, respectively.
** Denote statistical significance at the 5 percent level, respectively.
*** Denote statistical significance at the 1 percent level, respectively.

Table 4b
Refinancing and purchase programme determinants (in growth rates) - IV with country effects.

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IP_PCH_DEU	−0.0223***	−0.0343***	−0.0013**	−0.0231***	−0.0235***	−0.0100	−0.0141	0.0034	−0.0172*
	(0.004)	(0.007)	(0.001)	(0.004)	(0.004)	(0.010)	(0.009)	(0.012)	(0.009)
VIX	0.0075***	0.0075**	0.0015***	0.0070***	0.0070***	0.0191***	0.0134***	0.0204**	0.0136**
	(0.001)	(0.003)	(0.000)	(0.001)	(0.001)	(0.007)	(0.004)	(0.009)	(0.005)
REER	0.0040***	0.0041	0.0009***	0.0037**	0.0035**	0.0179**	0.0115	0.0100	0.0058
	(0.001)	(0.005)	(0.000)	(0.001)	(0.001)	(0.009)	(0.008)	(0.014)	(0.007)
bid_ask	0.7625***	0.8503***	1.1232***	0.7805***	0.7802***	0.9601***	0.9322***	−1.4662***	0.9192***
	(0.051)	(0.077)	(0.249)	(0.051)	(0.051)	(0.090)	(0.084)	(0.319)	(0.084)
Expected_Debt_DEU	0.0047***	0.0022	−0.0005**	0.0042***	0.0038***	−0.0073**	−0.0053**	−0.0049	−0.0032
	(0.001)	(0.002)	(0.000)	(0.001)	(0.001)	(0.003)	(0.003)	(0.004)	(0.002)
MLF_gr	0.4797***								
	(0.149)								
MRO_F_gr		0.2861**							
		(0.127)							
MRO_V_gr			0.0760***						
			(0.025)						
LTRO_gr				−0.2205***					
				(0.072)					
Net_LTRO_gr					−0.2141***				
					(0.071)				

Table 4b (*continued*)

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SMP_gr						−0.7028[*]			
						(0.405)			
CBPP1_gr							−1.6232[***]		
							(0.501)		
CBPP2_gr								0.8942	
								(0.728)	
SHMP_gr									−0.3105
									(0.260)
Observations	1511	399	490	1511	1511	228	318	66	318
Number of countries	10	10	10	10	10	10	10	10	10

Note: Dependent variable is the 10-year bond yield spread (relative to Germany). Estimations by Two Stage Least Squares with lags of the dependent variable and regressors used as instruments. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. Country effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.
  [*] Denote statistical significance at the 10 percent level, respectively.
  [**] Denote statistical significance at the 5 percent level, respectively.
  [***] Denote statistical significance at the 1 percent level, respectively.

Table 5
Before and after Global Financial Crisis (2009:01) – IV with country effects (levels and growth rates of QE measures).

Specification GFC	(1) before	(2) after	(3) before	(4) after	(5) before	(6) after	(7) before	(8) after
IP_PCH_DEU	−0.0019[**]	−0.0300[***]	0.0003	−0.0238[***]	−0.0013[*]	−0.0282[***]	−0.0009	−0.0294[***]
	(0.001)	(0.007)	(0.001)	(0.007)	(0.001)	(0.007)	(0.001)	(0.007)
VIX	0.0018[***]	0.0101[***]	0.0009[***]	0.0086[***]	0.0014[***]	0.0110[***]	0.0014[***]	0.0108[***]
	(0.000)	(0.004)	(0.000)	(0.003)	(0.000)	(0.003)	(0.000)	(0.003)
REER	0.0011[***]	0.0027	−0.0002	−0.0010	0.0012[***]	0.0038	0.0011[***]	0.0021
	(0.000)	(0.006)	(0.000)	(0.006)	(0.000)	(0.006)	(0.000)	(0.006)
bid_ask	0.4184	0.9212[***]	0.6779[**]	0.9287[***]	0.3919	0.9259[***]	0.1042	0.9463[***]
	(0.310)	(0.080)	(0.300)	(0.080)	(0.316)	(0.080)	(0.311)	(0.080)
Expected_Debt_DEU	−0.0011[***]	−0.0036	0.0005[*]	−0.0087[***]	−0.0009[***]	−0.0044	−0.0008[**]	−0.0049
	(0.000)	(0.004)	(0.000)	(0.003)	(0.000)	(0.003)	(0.000)	(0.003)
avg_rating	0.0068	−0.0656[***]	0.0131[*]	−0.0840[***]	0.0088	−0.0693[***]	0.0138[**]	−0.0667[***]
	(0.007)	(0.021)	(0.007)	(0.021)	(0.007)	(0.020)	(0.007)	(0.020)
avg_outlook	0.0029	−0.1921[***]	−0.0045	−0.2537[***]	−0.0086	−0.1919[***]	−0.0094	−0.1959[***]
	(0.009)	(0.057)	(0.008)	(0.059)	(0.009)	(0.056)	(0.009)	(0.056)
MLF	−0.0111[***]	0.0258						
	(0.002)	(0.055)						
LTRO			0.0003[***]	−0.0004[***]				
			(0.000)	(0.000)				
MLF_gr					−0.1455[***]	0.6180[**]		
					(0.036)	(0.242)		
LTRO_gr							0.0825[***]	−0.2973[**]
							(0.014)	(0.123)
Observations	1,024	871	1,024	871	1,024	871	1,024	871
Number of countries	10	10	10	10	10	10	10	10

Note: Dependent variable is the 10-year bond yield spread (relative to Germany). Estimations by Two Stage Least Squares with lags of the dependent variable and regressors used as instruments. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. Country effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.
  [*] Denote statistical significance at the 10 percent level, respectively.
  [**] Denote statistical significance at the 5 percent level, respectively.
  [***] Denote statistical significance at the 1 percent level, respectively.

From those sets of TVC country specific results, we can draw several conclusions. The increase in the expected government debt ratio, versus the German one, is more strongly relevant as an upward determinant of yield spreads in the crisis period, peaking in 2012. This is true for all the euro area countries in our sample except in the cases of Austria and Finland (sovereigns that actually maintained a stronger rating in that period).

Considering now the market pricing of the sovereign ratings, we observe an increase in the effect on yield spreads in the period 2011–2012, when several downgrades occurred for most countries.

Turning to the QE measures, the CBPP1 non-standard measure has contributed to bring down sovereign yield spreads in all euro area countries in the analysis. Moreover, that downward effect has been very pronounced particularly in the crisis

Table 6a
Alternative Dependent Variable 1: 5-year Bond Spreads – IV with country effects.

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IP_PCH_DEU	−0.0236***	−0.0238***	−0.0181***	−0.0225***	−0.0230***	−0.0239***	−0.0191	−0.0186	−0.0226***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.013)	(0.013)	(0.005)
VIX	0.0070***	0.0069***	0.0050***	0.0081***	0.0077***	0.0067***	0.0176**	0.0189***	0.0078***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.007)	(0.007)	(0.002)
REER	0.0056***	0.0054***	0.0003	0.0027	0.0058***	0.0054***	0.0029	0.0029	0.0027
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.010)	(0.010)	(0.002)
bid_ask	2.0152***	2.0234***	1.9489***	2.2230***	2.0236***	2.0145***	2.3853***	2.4287***	2.2108***
	(0.106)	(0.106)	(0.106)	(0.124)	(0.106)	(0.106)	(0.185)	(0.200)	(0.124)
Expected_Debt_DEU	0.0060***	0.0057***		0.0022	0.0060***	0.0058**	0.0034	0.0062	0.0023
	(0.001)	(0.001)		(0.002)	(0.001)	(0.001)	(0.003)	(0.005)	(0.002)
avg_rating				−0.0281**				0.0017	−0.0278**
				(0.013)				(0.028)	(0.013)
avg_outlook				−0.1431***				−0.1659**	−0.1429***
				(0.039)				(0.080)	(0.038)
Expected_OB_DEU			−0.0134***						
			(0.005)						
Announcement	−0.1422**								
	(0.066)								
MLF_gr					0.3883**				
					(0.196)				
LTRO_gr						0.1568*			0.1573*
						(0.092)			(0.092)
SHMP_gr							−0.2648	−0.1711	
							(0.341)	(0.351)	
Observations	1613	1613	1613	1613	1613	1613	632	632	1613
Number of countries	9	9	9	9	9	9	9	9	9

Note: Dependent variable is the 5-year bond yield spread (relative to Germany). Estimations by Two Stage Least Squares with lags of the dependent variable and regressors used as instruments. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. Country effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.
* Denote statistical significance at the 10 percent level, respectively.
** Denote statistical significance at the 5 percent level, respectively.
*** Denote statistical significance at the 1 percent level, respectively.

Table 6b
Alternative Dependent Variable 2: 1-year Tbill – IV with country effects.

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IP_PCH_DEU	−0.0135***	−0.0140***	−0.0132***	−0.0139***	−0.0134***	−0.0139***	−0.0179**	−0.0187***	−0.0137***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.007)	(0.007)	(0.003)
VIX	0.0041***	0.0041***	0.0038***	0.0047***	0.0044***	0.0043***	0.0063*	0.0078***	0.0049***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)	(0.001)
REER	0.0026**	0.0024**	0.0010	0.0017	0.0027**	0.0025**	0.0106	0.0124*	0.0018
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.007)	(0.007)	(0.001)
bid_ask	2.0538***	2.0696***	2.1737***	2.0990***	2.0233***	2.1009***	2.5295***	2.4075***	2.1023***
	(0.285)	(0.285)	(0.288)	(0.284)	(0.285)	(0.284)	(0.446)	(0.439)	(0.284)
Expected_Debt_DEU	0.0014**	0.0012**		0.0017	0.0014**	0.0012*	−0.0021	0.0014	0.0016
	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.001)
avg_rating				0.0033				0.0101	0.0033
				(0.008)				(0.016)	(0.008)
avg_outlook				−0.0965***				−0.1309***	−0.0950***
				(0.024)				(0.045)	(0.024)
Expected_OB_DEU			−0.0115***						
			(0.004)						
Announcement	−0.0740**								
	(0.037)								
MLF_gr					0.2146*				
					(0.110)				
LTRO_gr						−0.1139**			−0.1068*
						(0.057)			(0.057)
SHMP_gr							0.3616**	0.4228**	
							(0.182)	(0.187)	
Observations	1200	1200	1200	1200	1200	1200	577	577	1200
Number of countries	9	9	9	9	9	9	9	9	9

Note: Dependent variable is the 1-year Tbill spread (relative to Germany). Estimations by Two Stage Least Squares with lags of the dependent variable and regressors used as instruments. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. Country effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.
* denote statistical significance at the 10 percent level, respectively.
** denote statistical significance at the 5 percent level, respectively.
*** denote statistical significance at the 1 percent level, respectively.

Table 6c
Alternative Dependent Variable 3: 6-month Tbill – IV with country effects.

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IP_PCH_DEU	−0.0204***	−0.0204***	−0.0179***	−0.0184***	−0.0191***	−0.0200***	−0.0128	−0.0155	−0.0179***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.012)	(0.012)	(0.005)
VIX	0.0054***	0.0054***	0.0049***	0.0062***	0.0057***	0.0056***	0.0127***	0.0134***	0.0063***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)	(0.001)
REER	0.0043***	0.0043***	0.0031**	0.0019	0.0044***	0.0044***	0.0201**	0.0236***	0.0020
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.008)	(0.008)	(0.002)
bid_ask	0.7371***	0.7327***	0.7685***	0.5655***	0.6798***	0.7328***	0.6904**	0.3588	0.5297***
	(0.205)	(0.205)	(0.208)	(0.203)	(0.205)	(0.204)	(0.307)	(0.295)	(0.201)
Expected_Debt_DEU	0.0015**	0.0015**		−0.0001	0.0016**	0.0013*	0.0010	0.0039	−0.0002
	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)	(0.002)	(0.004)	(0.001)
avg_rating				−0.0101				−0.0058	−0.0090
				(0.009)				(0.018)	(0.009)
avg_outlook				−0.1000***				−0.1333***	−0.0945***
				(0.028)				(0.050)	(0.028)
Expected_OB_DEU			−0.0071						
Announcement	−0.0016								
	(0.044)		(0.005)						
MLF_gr					0.2059				
					(0.134)				
LTRO_gr						−0.1330**			−0.1287**
						(0.064)			(0.064)
SHMP_gr							0.2423	0.4448**	
							(0.213)	(0.220)	
Observations	944	944	944	944	944	944	454	454	944
Number of countries	6	6	6	6	6	6	6	6	6

Note: Dependent variable is the 6-months Tbill spread (relative to Germany). Estimations by Two Stage Least Squares with lags of the dependent variable and regressors used as instruments. Robust standard errors clustered at the country level are in parenthesis below each coefficient estimate. Country effects were estimated but omitted for reasons of parsimony. A constant term was also estimated but omitted.

* Denote statistical significance at the 10 percent level, respectively.
** Denote statistical significance at the 5 percent level, respectively.
*** Denote statistical significance at the 1 percent level, respectively.

period, 2011–2013. In addition, and if we look at an example of a more standard measure, the LTRO, we can conclude that this measure also contributed to reduce yield spreads in most countries as well. In addition, the magnitude of the estimated downward effect of the CBPP1 on yield spreads turned out to be highest, followed by the SMP and the LTRO. Since the assets bought in the CBPP1 program will be held until maturity, this type of policy measure might have been seen in the markets has better anchoring the future downward expectations for the 10-year sovereign yield spreads. On the other hand, for the one year and 6-month sovereign bond maturities the LTRO (growth rate) reduced those sovereign spreads.

Finally, assessing quantitatively the costs of QE measures, which would be also useful, is a complex endeavor as one would have to assess the specific securities bought in the secondary market by the ECB. However, one does not have access to the information regarding which securities the ECB has actually purchased. Still, and according to the data available at the ECB's website, the ECB has spent around 2.5 trillion (euros) to implement its QE measures, up to the middle of 2018. This QE program was scheduled to last until September 2018, carrying monthly purchases of 30 billion euros of government debt and of private debt.

6. Conclusion

We have assessed the determinants of sovereign bond yield spreads in the period 1999:01–2016:07, taking into account the so-called non-conventional monetary policy measures in the euro area. Such QE measures implemented by the ECB might have had an effect on country specific Euro area yield spreads.

Regarding the so-called Quantitative Easing measures, purchases on behalf of the ECB of national government bonds, we have considered Covered Bond Purchase Programmes (CBPP), Securities Market Programme (SMP), and securities held for monetary purposes by the ECB (SHMP).

From a methodological point of view, we have implemented a two-step approach. First, we have confirmed, by means of model selection methods, and estimated (by means of panel analysis) the determinants of sovereign bond yield spreads. Second, we have computed bivariate time-varying coefficient models of each determinant on government bond yield spreads and analysed the temporal dynamics of the resulting estimates for such coefficients.

The main results are as follows. (i) Industrial production (difference vis-à-vis Germany), fiscal policy variables differences towards Germany as well, and liquidity, international risk, real effective exchange rate data when statistically significant, have the expected effect on the yield spreads. (ii) Better ratings and outlooks, from all three main rating agencies also decrease the sovereign yield spreads. (iii) Some non-conventional measures of the ECB contributed to reduce the average
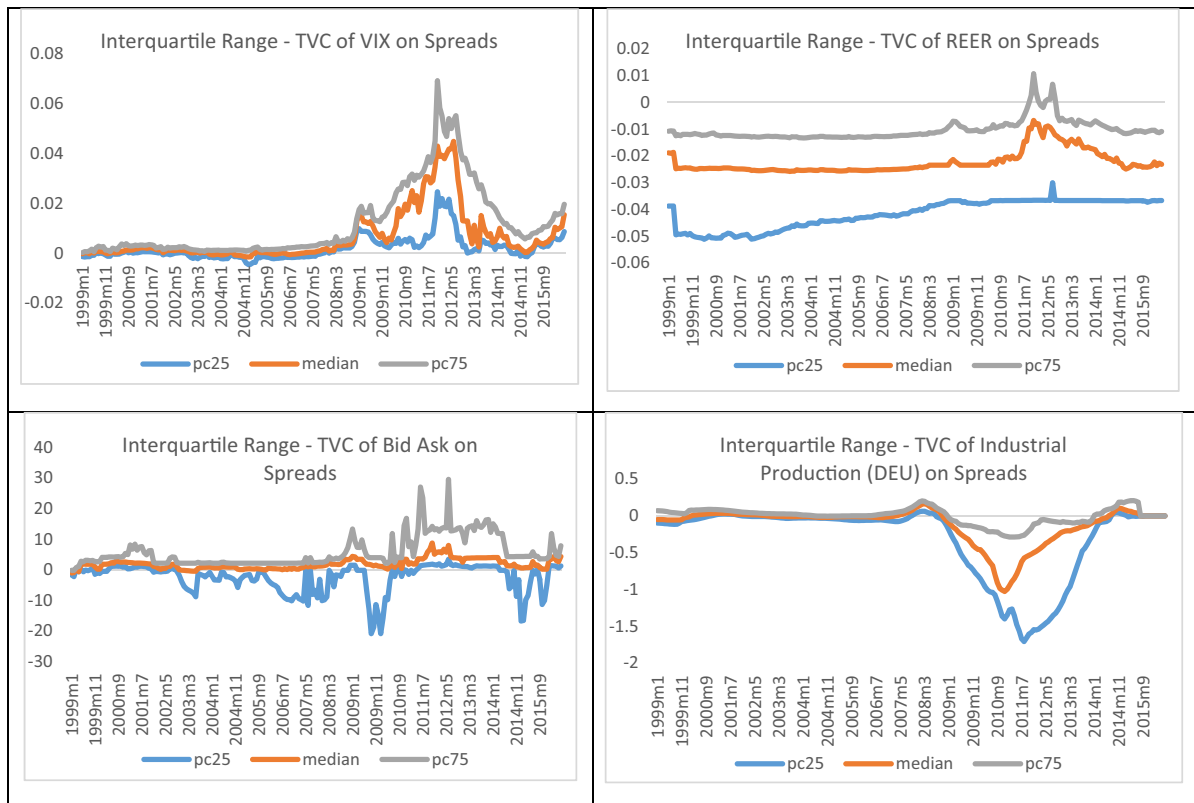
Fig. 1. TVC interquartile ranges, all countries over time. Note: The interquartile range of the country-specific time-varying coefficient model estimates is plotted. "pc25", "median", and "pc75" denote the 25th quartile, the median and the 75th quartile of the distribution across the 10 countries in our sample over time, respectively. Source: authors' calculations.

euro area sovereign yield spreads. (iv) Market pricing of sovereign ratings and outlooks is essentially done after the crisis (v) the international risk factor (VIX) is price around 7–8 times more after the crisis. (vi) Liquidity is also a key determinant after the crisis.

Regarding the second step we find that: (viii) the Time-Varying Coefficients models shows the VIX effect having a higher magnitude through the period 2010–2012. (ix) Liquidity issues where more prominent in terms of the size of the effect in the period 2010–2014. (x) The impact on yield spreads stemming from the REER also spikes up in the period 2011–2012. (xi) Industrial production is more heavily priced in the markets in the period 2009–2013. (xii) The increase in the expected government debt ratio, versus the German one, peaks in 2012 for all the euro area countries except in the cases of Austria and Finland. (xiii) Market pricing of the sovereign ratings increased in period 2011–2012. (xiv) The CBPP1 contributed to bring down sovereign yield spreads in all euro area countries particularly in the period 2011–2013. (xv) The LTRO contributed to reduce yield spreads in most countries as well.

One can conclude that the ECB's intervention did contribute to contain sovereign yield spreads, implying indirectly expansionary monetary developments, coupled with direct monetary policy development stemming notably form the effect of the main refinancing operations-variable rate tenders, in decreasing the yield spreads. On the other hand, and still from a policy perspective, it is unclear for how long the ECB will continue to implement its QE measures, which might be seen as a risk for the more fiscally and financially vulnerable euro area economies.

Appendix A.

See Table A1.

Table A1
Data description and sources.

Variable	Description	Source
Bond_Spread_DEU_10y	10 year bond yield spread against German bond	ECB; Own calculations
VIX	Chicago Board of Exchange Volatility Index	Bloomberg
BAS	10 year bond yield bid-ask Spread	Bloomberg; ECB
Reer	Real Effective Exchange Rate, CPI based	IFS
IP_PCH_DEU_p	Industrial Production Volume, percent change against Germany	IFS
IP_PCH_DEU	Annual growth rate differentials of IP(seas adjusted) vs Germany	IMF
LTDebtShare	Share of long-term general government debt	ECB
Expected_Debt_DEU/_p	Expected government debt against Germany,% of GDP	EC
Expected_OB_DEU/_p	Expected government budget balance against Germany,% of GDP	EC
Rating_SP	Credit rating S&P	Standard & Poors
Rating_M	Credit rating Moody's	Moody's
Rating_F	Credit rating Fitch	Fitch Ratings
Outlook_SP	Credit Outlook S&P	Standard & Poors
Outlook_M	Credit Outlook Moody's	Moody's
Outlook_F	Credit Outlook Fitch	Fitch Ratings
DF	Deposit Facility, percent per annum	ECB
MLF	Marginal Lending Facility, percent per annum	ECB
MRO_F	Main Refinancing Operations-fixed rate tenders, percent per annum	ECB
MRO_V	Main Refinancing Operations-variable rate tenders, percent per annum	ECB
LTRO	Longer-term Refinancing Operation (includes TLTRO_l and TLTRO_ll), Holdings	ECB
Net_LTRO	Longer-term Refinancing Operation, Holdings	ECB and own calculations
TLTRO_l	First Targeted Longer-term Refinancing Operation, Holdings	ECB and own calculations
TLTRO_ll	Second Targeted Longer-term Refinancing Operation, Holdings	ECB
CMRO	Country-specific values for MROs	Bruegel database
CLTRO	Country-specific values for LTROs	Bruegel database
SMP	Securities Market Programme, Holdings	ECB
CBPP1	Covered bond purchase programme 1, Holdings	ECB
CBPP2	Covered bond purchase programme 2, Holdings	ECB
CBPP3	Covered bond purchase programme 3, Holdings	ECB
ABSPP	Asset-Backed Securities Purchase Programme, Holdings	ECB
PSPP	Public Sector Purchase Programme, Holdings	ECB
CSPP	Corporate Sector Purchase Programme, Holdings	ECB
Bond_spread_DEU_5y	5 year bond yield against German bond	Bloomberg
Tbill_spread_DEU_1y	1 year treasury bill yield against German t-bill	Bloomberg
Tbill_spread_DEU_6m	6 month treasury bill yield against German t-bill	Bloomberg
Tbill_spread_DEU_3m	3 month treasury bill yield against German t-bill	Bloomberg
PSPP_NP	Breakdown of debt securities under the PSPP, monthly net purchases	ECB
PSPP_S	Breakdown of debt securities under the PSPP, holdings	ECB
SMP_S	Country-specific SMP holdings - nominal amounts	ECB
SHMP	Securities held for monetary purposes (holdings)	ECB
	Euro millions	

Notes: Expected budget balances and government debt are the differences vis-à-vis Germany of the European Commission vintage forecasts, taking the same value in the months between each forecast vintage. The volumes securities purchases are for the overall euro area.

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.intfin.2018.10.003.

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