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JEL Codes: E43, E44, E58 and G15

Keywords: conventional and unconventional monetary policy, Economic and Monetary Union, European Central Bank, European financial markets and European sovereign bond spreads

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EUROZONE GOVERNMENT BOND SPREADS: A TALE OF DIFFERENT ECB POLICY REGIMES

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ABSTRACT

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We aim to determine Eurozone sovereign bond spreads and the ECB's influence through a generalised model. In a multidimensional structure we regress an extensive set of variables for different factors on spreads, and empirically identify the best-fit through a general-to-specific process. We cannot identify a satisfactory specification with macro fundamental factors. Different regimes in the spreads' structure explains this. Spreads are after 2012/2013 well explained by market risk-based factors, and our specification is robust for earlier periods. When we add EMU-specific factors, it is shown that Target2 balances reduce spread as they increase convertibility risk costs until 2012/2013, and that the ECB's asset purchases subsequently reduce spreads, especially in the periphery. The break between these two periods coincides with an alteration of policy over two sets of Presidencies: Duisenberg – Trichet in the first period and Draghi-Lagarde in the second. Either set has interpreted and implemented the mandate of the central bank in a very different way. While under Duisenberg-Trichet the ECB has only acted in the Eurozone money market, under Draghi-Lagarde the central bank has increasingly been involved in the capital market.

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1. Introduction[*]

The Economic and Monetary Union (EMU) has irrevocably changed continental Europe over the past twenty-five years. Already in the early stages it was evident that member states grew substantially more interconnected macroeconomically than could be attributed to the mere adoption of the euro as a single currency. The European Central Bank (ECB), established in July 1998, can be considered as the first supra-national European institution (see e.g.: De Haan *et al.*, 2005). In the depths of the sovereign debt crisis, the countries' mutual financial and economic interdependence showed up, bringing the monetary union to near break point. The pressure of containing the crisis and the political desire to preserve the euro caused significant stress but also forged greater financial economic ties. As this was essentially a financial crisis, remedies were sought and found in the monetary policy domain, leading to the initiation and implementation of several unconventional measures by the ECB, including the start of large asset management programs.[1] The Eurozone's bond market, which quickly adopted the euro and grew rapidly to equal the US, has been at the nexus of these developments, reaping the joys of macroeconomic convergence in the first decade, but also suffering the pains of the Eurozone's debt crisis in the next, and increasingly experiencing the presence of the ECB in the last decade. Being at the intersection of the macroeconomy, national and European policy making and being the transmission and increasingly the playground for the ECB's monetary policy, the Eurozone bond market offers an empirically rich auditorium for chronicling EMU's financial economic history.

In studying the drivers of Eurozone sovereign bond spreads, we uncover the roles played by macroeconomic factors, by financial linkages, by political (un)certainty through market sentiment and by the ECB's monetary policy in bringing these spreads together or in causing their divergence. Our main research question is what the fundamental drivers have been of long-term government bond spreads within the Eurozone since EMU commenced in 1999. Since the ECB's monetary policies were after the 2012/2013 increasingly complemented with unconventional policies, we study the ECB's influence on spread over and above the identified significant factors. Our aim, in other words, is to identify a general model that can describe the determinants of Eurozone government bond spreads over the past twenty-five years that also gives the rightful place to the effect of the ECB's changing policies.

[*] The authors wish to thank Giacomo Czajkowski for the empirical work he conducted under our supervision. The analyses and opinions expressed in this paper are those of the authors.

[1] Details of the ECB's different asset purchase programs (APP, CBPP1, CBPP2, CBPP3, ABSPP, PSPP), the Pandemic emergency purchase program (PEPP) initiated in March 2020 and the Transmission Protection Instrument (TPI) announced in July 2022 are available on www.ecb.europa.eu.

Our study builds on and also bridges two major fields in the literature. One is research on the determinants of Eurozone sovereign bond yield spreads that starts in the mid-2000s and has to date revealed a great number of variables with time-varying influence on those spreads. The other is research on the impact of ECB monetary policies on Eurozone government bond spreads which grows into its own particularly after 2012 when the ECB starts its unconventional policies in earnest. In our aim to identify one model to describe Eurozone sovereign bond spread dynamics, we start from a general unrestricted model specification that can establish the relation of a vector of multidimensional factors on spreads. Through a general-to-specific empirical approach we incorporate all combinations of variables that have previously been shown to have explanatory power and identify what has then, additionally, been the measurable impact of ECB's policies.

The rest of this paper is organised as follows. Section 2 places our research in the nearest related fields and our benchmark studies. Section 3 outlines our four hypotheses. Section 4 presents the models and section 5 details the data that we use for these models. Section 6 describes the results of our empirical study from the testing of our hypotheses. Section 7 summarizes our main conclusions.

2. Related Literature

Our research bridges the field that studies the determinants of Eurozone sovereign bond spreads and the field that specifically studies the impact of the ECB's monetary policies thereon.

A few years after the start of EMU, when the spreads of the bonds of sovereign member states narrow, authors commence to study the determinants of this convergence. One strand leans predominantly on macroeconomic and fiscal dynamics in the Eurozone countries themselves to explain the dynamic in bond spreads, adding bond market liquidity conditions and market sentiment indicators as complementary explanatory factors (e.g.: Maltritz, 2012; Afonso *et al.*, 2014; Aristei and Martelli, 2014; D'Agostino and Ehrmann, 2014; Gómez-Puig *et al.*, 2014; DeWachter *et al.*, 2015; Gibson *et al.*, 2015; Boysen-Hogrefe, 2017; Delatte *et al.*, 2017; Paniagua *et al.*, 2017). These papers find that in the early EMU period, up until 2009, macroeconomic factors and especially the fiscal position of the countries themselves assume a primary role in explaining their bond spreads. Market liquidity, proxied oftentimes by the size of domestic bond markets, and (international) sentiment indicators, when included, also turn out to be significant explainers. Studies that include the sovereign debt crisis in their sample period, detect that shocks to the macroeconomy, and especially the fiscal deficit, are largely responsible for the divergence in Eurozone spreads between 2009 and 2012. Importantly, these studies also note a strong divide between core and periphery in this respect (e.g.: Gibson *et al.*, 2015), note that market sentiment variables gain in importance in the crisis period (e.g: Aristei and Martelli, 2014; Gómez-Puig *et al.* 2016) and that political uncertainty, globally or in the Eurozone countries themselves, aggravate investors' risk aversion (e.g.: DeWachter *et al.*, 2015; Boysen-Hogrefe, 2017). Evidence on the role of financial linkages is mixed, with Bahai (2020) documenting that trade or financial linkages between countries in the Eurozone do not matter for spreads, but Delatte *et al.* (2017) documenting that rising risks in the bank sector do. Among these macro fundamental studies into the determinants of Eurozone spreads, Gómez-Puig *et al.* (2014) test the importance of the three named categories - macroeconomy, financial linkages, market sentiment – with the most comprehensive set of variables for the period 1999-2012, finding significance of several in both the total period and in varying combination in the pre-crisis and post-crisis period and for the group of core and peripheral countries.

Another strand takes the approach to determine Eurozone sovereign and corporate bond spreads through risk factors that are commonly accepted to drive bond returns in financial markets (see for corporate bond spreads, e.g.: Mahieu and Pieterse-Bloem, 2013; Pieterse-Bloem *et al.*, 2016). For sovereign bond spreads, credit risk and liquidity risk take centre stage in studies. Credit risk is typically measured through spreads in Credit Default Swaps (CDS) on Eurozone issuers, as these special derivatives are constructed on the probability of default of the reference entity (see e.g.: Blommestein *et al.*, 2016). Liquidity risk is in contrast to the macro fundamental studies not measured through a stock variable but typically through price-based variable, being most often the difference in the bid-ask spread in bond prices of Eurozone sovereign issuers (see e.g.: Buis *et al.*, 2020). This strand generally finds that credit risk is the primary driver and liquidity risk is the secondary driver of Eurozone bond returns in normal times, but that their order can reverse and that they can negatively interact in crisis times (e.g.: Manganelli and Wolswijk, 2009; Beber *et al.*, 2009; Montfort and Renne, 2014; Pelizzon *et al.*, 2016; Dufour *et al*, 2017; Ribeiro *et al.*, 2017; Schwarz, 2019; O'Sullivan and Papavassiliou, 2020). The set of risk factors is occasionally complemented with volatility risk, measured mostly with the implied volatility in stock returns (VIX and VSTOXX, such as in Ribeiro *et al.*, 2017). Afonso *et al.* (2015) is an example of a study that combines such international risk with liquidity risk in the Eurozone bond markets and macroeconomic drivers, specifically for the detection of time-varying determinants.

Both the macro fundamental-based and market risk-based approaches for the study into the determinants of Eurozone sovereign bond spreads contain early evidence from the pre-2012 period that the ECB policy response to the sovereign debt crisis reduced stress in the Eurozone bond markets and resulted in a tightening of sovereign spreads. This is typically detected via the inclusion of dummy variables, to mark the start of the Securities Markets Programme (SMP) program, targeted longer-term refinancing operations (TLTRO), Draghi's "whatever-it-takes" statement or subsequent announcement of the Outright Monetary Transactions (OMT), or by subdividing the sample period marked by these moments. The impact of the ECB's monetary policy on Eurozone government bond spreads quickly grows into a field of its own after 2012 when the ECB increasingly uses unconventional tools. In this field a set of studies focuses on the announcement effect of ECB policies on Eurozone spreads through event studies to detect abnormal returns in a window around the date that ECB announces new measures (e.g.: Falagiarda and Reitz, 2015; Krishnamurthy *et al.*, 2018; Altavilla *et al.*, 2019; Afonso *et al.*, 2020; Belke and Gros, 2021; Farinha and Vidrago, 2021) or uses market news (index) of these announcements in a form of regression model (e.g.: De Santis, 2020). These studies invariable show some impact of the ECB's announcement of its TLTRO and a much more significant impact of the announcement of its SMP and later asset purchase programs in reducing spreads, especially in the periphery. Early studies that use ECB monthly purchase data under the SMP program detect both a positive dampening effect from its announcement and from the actual purchases made by the ECB of bonds of countries that were in this programme (e.g.: Eser and Schwaab, 2016; Jäger and Grigoriades, 2017). As the ECB commences its broader asset purchase programs, first in October 2014, and data of monthly purchases become subsequently available from the ECB's reporting and balance sheet, other studies utilize this information to attach a number of basis point reduction in different Eurozone sovereign spreads directly to these interventions (e.g.: De Pooter *et al.*, 2018; Blot *et al.*, 2020). Studies that control for the time-varying heterogeneity of Eurozone spreads in a multidimensional factor structure still detect a sizeable and significant effect from the ECB's asset purchase programs (e.g.: Kinateder and Wagner, 2017; Afonso *et al.*, 2018; Afonso and Jalles, 2019).

We rely on several of these branches of the literature when we research, empirically, if a general model can explain the dynamic of Eurozone sovereign bond spreads over the past twenty-five years, using both a macro fundamental and market risk model framework and incorporating variables that have previously shown to play a significant role. We do not utilize news or announcements of the ECB's monetary policies, but rather use price and stock series that directly measure what the impact of the ECB's various instruments has been on spreads over time.

3. Hypotheses

In our pursuit of a general model to describe the behaviour of Eurozone spreads, we take Gómez-Puig *et al.* (2014) as our starting point as they have, in our view, conducted the most comprehensive study into their determinants for the period up to 2012. We follow their approach and similarly use a macro fundamental-based modelling framework, identifying the best specification of this model with a very extensive set of variables for the macroeconomy, financial linkages and market sentiment approach for 1999 - 2012, and extend this specification to 2013 – 2021. Therefore, the first hypothesis that we test is the following:

Hypothesis 1: *A general macro fundamental-based model can be specified that describes the drivers of Eurozone sovereign bond spreads for the entire EMU period to this date.*

If we fail to reject this hypothesis then our specification will incorporate variables that measure the ECB's conventional and unconventional monetary policies in order to be able to judge what their influence has been. If we must reject this first hypothesis because we cannot identify a specification that fits the entire period well, then we must logically subsequently investigate the possibility that the dynamic in Eurozone bond spreads is structurally different in different episodes of EMU's history. Therefore, the next hypothesis that we test is the following:

Hypothesis 2: *The dynamics of Eurozone long-term sovereign bond spreads are subject to different regimes.*

If we must reject this hypothesis, then our research continues to retest Hypothesis 1 but with a fundamentally different modelling framework and empirical estimation procedure. In the case that we do find that spreads are subject to different regimes, and having already found through the rejection of Hypothesis 1 that a good model specification for 1999-2012 does not work as well for the period thereafter, follows that it is very likely that a regime break occurs at or shortly after Draghi's "whatever-it-takes" statement, as is also extensively documented in various empirical studies described in the previous section. In that case, we can investigate if a market risk-based model framework with the same empirical estimation procedure results a specification that explains the dynamic in Eurozone bond spreads well in the most recent years of EMU beyond 2012. Therefore, the next hypothesis that we test is the following:

Hypothesis 3: *A general market risk-based model can be specified that describes the drivers of Eurozone long-term sovereign bond spreads after 2012/2013.*

If we fail to reject this third hypothesis, then we can extend it to early period of EMU to investigate its explanatory power. We can also include variables for the ECB's monetary policy in the regime where the specification from whichever model is the best, following Afonso *et al.* (2018) to similarly link the identified relationships in spreads with the actions of the ECB into one multidimensional factor structure.

The testing of these three hypotheses will either result in one good specification for the macro fundamental-based model or a good specification for this model and/or the market risk-based model for different regimes, if present. This enables us to next research whether the drivers of spreads are different for the core and peripheral countries, as many other studies in the fields of the determinants of the spreads and impact of the ECB's monetary policy on the Eurozone's bond markets find evidence of significant different (strength of) determinants and monetary policy impact. Specifically, we can with our model framework analyse to what extend a divide between the core and periphery has existed, and how it may have evolved over different regimes if those are present. We therefore lastly test the following hypothesis:

Hypothesis 4: *The specific covariates that drive spreads are markedly different for the core and peripheral Eurozone countries.*

We test Hypothesis 4 by applying the best specification of our model to a group of countries that most studies group among the core and periphery. If we fail to reject this last hypothesis, then we will gain further insights into the separate drivers of the spreads in these two country groups over the course of time within the EMU.

4. Model specification

We wish to determine the drivers of government bond spreads of Eurozone countries in a multidimensional factor structure through a time-series regression model that enables factor-specific, time-specific and region-specific heterogeneities and a general-to-specific selection approach in our empirical specification procedure, similar to Gómez-Puig *et al.* (2014) and Afonso *et al.* (2015). Our general unrestricted model specification should encompass the relevant category of factors for a macro fundamental-based (*MF*) model and a market risk-based (*MR*) model. The general unrestricted model that satisfies these conditions is the following:

$$SPR_{itm} = \alpha + \mathrm{X}'^{M}_{rtm}\,\beta + FE_i + \varepsilon_i \;, \tag{1}$$

where SPR_{itm} denotes the government bond yield spread for each country *i* at time *t* and maturity *m*. X'^{M}_{rtm} is a vector of covariates for model *M* with *M = [MF; MR]* revealed at same time *t* as the spreads and specific to region *r* with *r = [country i ; Eurozone ; Global]* with *i* being the set of Eurozone countries. The covariates may also be specific to same maturity *m* as the spread(s). We incorporate country-fixed effects (FE_i) and include a random error term (ε_i) specific for each country, which will pick up time-dependent noise and, if significant, also the explanatory power of one or more variables omitted from vector X'^{M}_{rtm}.

For the Macro Fundamental-based *(MF*) model, the vector X'^{M}_{rtm} is further specified as:

$$\mathrm{X}'^{MF}_{rtm} = [ME\;;\;FL\;;\;MS;\;EMU]_{rtm} \;, \tag{2a}$$

to denote the covariates for the categories of macroeconomic *(ME*), financial linkages (*FL*) and market sentiment (*MS*) factors for each region *r*, at time *t* and maturity *m*.

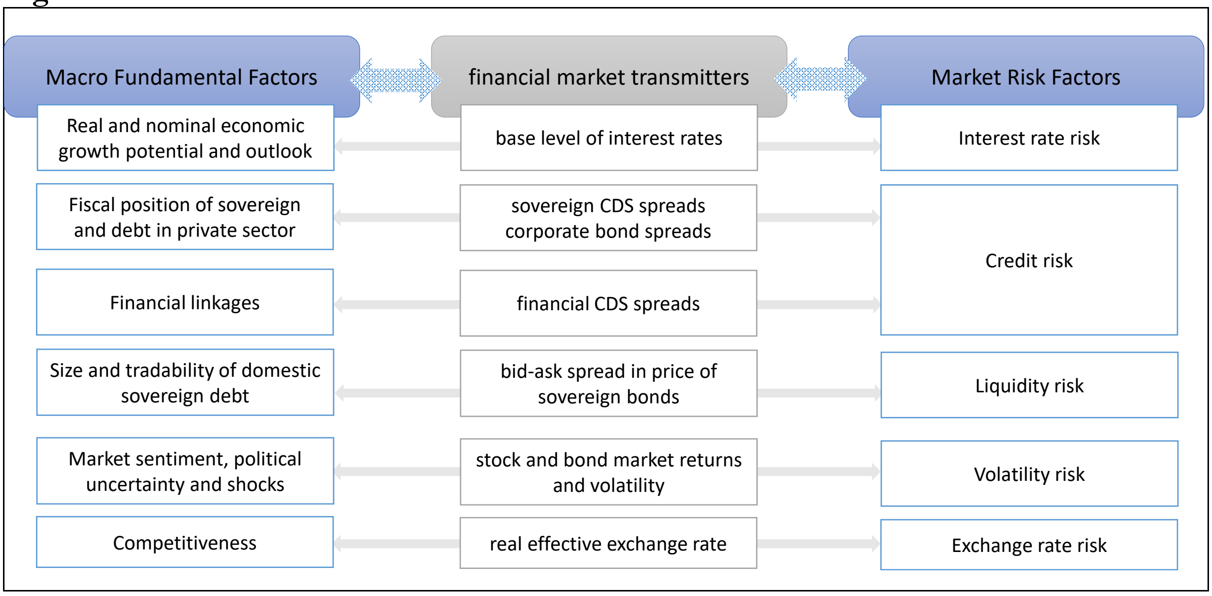
Market risk factors commonly accepted in the literature to be present in spreads are interest rate risk (*IR*), credit risk (*CR*), liquidity risk (*LR*), volatility risk (*VR*) and exchange rate risk (*ER*). Therefore, for the Market Risk-based (*MR*) model, the vector $\mathfrak{X}'^{M}_{rtm}$ is rather specified for each region *r*, at time *t* and maturity *m* as:

$$\mathfrak{X}'^{MR}_{rtm} = [IR;\ CR\ ; LR\ ; VR\ ; ER\ ; EMU]_{rtm}\ . \tag{2b}$$

Our Macro Fundamental-based (*MF*) and Market risk-based (*MR*) models are non-competing models. Figure 1 below contains a schematic representation of how the factors for either are related, via financial market indicators. For instance, the macro fundamental factor of an economy's real and nominal economic growth potential is reflected in the risk-free term structure of interest rates, which defines the market risk-based factor of interest rate risk. The latter also influences an economy's growth potential again. The connection between the other macro fundamental and market risk factors is similarly provided and is relatively superficial as it is only meant to illustrate that both models often intend to measure the influence of the same fundamental factors, only the Market Risk-based model does so more directly from variables that can be observed in financial markets. Our *MF* and *MR* models overlap on the use of stock and bond market returns and volatility measures, which in the context of the *MF* model are indicators for market sentiment (*MS*) and in the context of the *MR* model for volatility risk (*VR*).

As we are applying our models to the Eurozone, the named factors in Figure 1 are in various ways influenced by the unique set up EMU. Whereas for the majority of them this is embedded in measures (such as the benefits of a common currency for intra-Eurozone trade and consequently countries' economic growth potential), EMU's fragility risk and convertibility risk are two main

Figure 1: Connection between Marco Fundamental Factors and Market Risk Factors



risks identified in the literature that have the ability to play large overtures in financial markets. EMU's fragility risk rises from the fact that countries in a monetary union are forsaking the control over the currency in which their sovereign debt is denominated, which may feed self-fulfilling debt default dynamics.[2] EMU convertibility risk is the risk that a member state may break-away from the Eurozone to subsequently redenominate its bonds in its own currency, which may inflate the risk premium of remaining member states beyond the level that can be justified by their economies' fundamentals.[3] We capture these risks in a category *EMU* and include them in both models.

5. The Data

In this section we describe the data, for both our dependent and independent variables.

5.1. Dependent variable: Eurozone sovereign yield spreads

We construct our dependent variable as the difference between the yield of each of the original EMU country's bond against the bond yield of Germany in the 10-year maturity.[4] We include the nine initial member states (Austria, Belgium, Finland, France, Ireland, Italy, Netherlands, Portugal and Spain) and initially also Greece who joined EMU in 2001[5]. Our dependent variable is therefore:

$$SPR_{itm} = YTM_{itm} - YTM_{btm} , \quad (3)$$

where *SPR* stands for the spread, *YTM* for the yield to maturity, *i* are the Eurozone countries, *b* is the benchmark for the Eurozone (i.e. Germany), *t* is time and *m* is the 10-year maturity.

We gather benchmark yield data from Refinitiv DataStream with a monthly frequency, selecting the end-of-month observation for the period from January 1999 to December 2021. Table 1 shows the statistical properties of our monthly spreads. The mean is above four for Greece, above one for Ireland, Italy, and Portugal and very close to one for Spain. Greece also has by far the highest

[2] De Grauwe (2013) postulates that financial markets can force monetary union members into default more easily than stand-alone countries, as the first have ceased control over the currency of their debt. The monetary unión is fragile and the member states' bonds more vulnerable to changing market sentiments and susceptible to self-fulfilling liquidity crises compared to stand-alone countries, which is empirically confirmed by De Grauwe and Ji (2013).
[3] Eijffinger *et al.* (2018) develop a model of sovereign debt and default and argue that ex-ante unknown costs of exiting EMU can lead to the contagion of bad sovereign debt dynamics from a troubled member state (such as Greece) to (more) healthy member states. The convertibility risk is on account of the latter re-denominating its debt into a new currency which is subsequently devalued and rational external lenders pricing in the consequences of a potential upcoming exit by raising interest rates for initially untroubled member states following a Grexit-type rumors shock.
[4] The 10-year tenor is our maturity of choice, as long-term considerations on country's debt dynamics in the anticipated state of the macroeconomy and the EMU, manifest themselves well at this maturity. The 10-year segment also offers good quality data, because it is a benchmark maturity. In the 10-year maturity, Germany is considered the benchmark issuer by the majority of market participants and its bonds are therefore the best proxy for the riskless rate among the Eurozone countries. The majority of studies mentioned in Section 2 take Eurozone government bond yields relative to the German government bond yield in the 10-year maturity as the dependent variable.
[5] Luxembourg's small debt financing requirements has led to an absence of bonds that are near enough the 10-year maturity at various times in our sample period.

maximum at 34.78 percent, followed by Portugal with 14.628 percent. The lowest maximum of 0.799 percent is by the Netherlands, while the second lowest is by Finland with 0.826 percent. The minimum values of all countries are in negative territory, with the exception of Italy and Greece. The lowest minimum spread value is for France at -0.196. The standard deviation across the different spreads ranges from the lowest value of 0.138 for the Netherlands to the highest value of 6.023 for Greece followed by 2.526 for Portugal. The skewness and kurtosis statistics indicate that for all countries, the spreads to Germany are distributed with high density towards the lower end of the distribution and with rather long tails towards the maximum. This skewness to towards the minimum value is also born out by fact that the median values for all countries with the exception of Finland are below the means. With respect to the skewness, there are some surprising differences among the countries: the skewness of Belgium spreads is nearly as large as that of Greek spreads, and Italy's spreads bear relatively the least skewness towards the minimum level. We show the correlation matrix of the spreads in Appendix I in Table I.1. There is a high degree of collinearity amongst all countries' spreads, averaging 0.658 over our total sample period. Low covariance countries are Finland and The Netherlands and high covariance countries are Belgium, France, Portugal and Greece.

The statistical picture is as expected: Eurozone peripheral countries have high maximum values of spreads, high standard deviations and are the most skewed in their distribution, and vice versa for Eurozone core countries. Italy, in many studies typically placed among the peripheral countries, merits this grouping on its mean spread, but not on the other statistical properties of its spread.

Table 1. Descriptive statistics of the Eurozone sovereign bond spreads, in percentages for January 1999 – December 2021

Country	Mean	Median	St. Dev.	Min	Max	Skew.	Kurt.
AUT	0.277	0.238	0.233	-0.027	1.296	1.776	6.982
BEL	0.433	0.316	0.433	-0.057	2.756	2.427	10.005
FIN	0.194	0.201	0.143	-0.081	0.826	1.001	6.046
FRA	0.289	0.274	0.253	-0.196	1.327	1.563	6.479
GRE	4.359	1.708	6.023	0.021	34.78	2.486	10.416
IRL	1.100	0.414	1.768	-0.085	8.843	2.418	8.309
ITA	1.200	1.067	1.077	0.030	5.210	1.264	4.411
NDL	0.167	0.140	0.138	-0.155	0.799	1.390	6.020
PRT	1.807	0.673	2.526	-0.029	14.628	2.345	8.814
ESP	0.974	0.707	1.114	-0.051	5.497	1.804	6.255

Notes: The descriptive are based on 276 monthly observations for each country's spread, expressed in percentages. Spreads are calculated according to Eqt. (3). In the Country columns, AUT is Austria, BEL is Belgium, FIN is Finland, FRA is France, GRE is Greece, IRL is Ireland, ITA is Italy, NDL is The Netherlands, PRT is Portugal and ESP is Spain. St. Dev. is the one standard deviation level, Min is the minimum value of the spread range and Max it's maximum value, Skew. is skewness and Kurt. is kurtosis. Source is Refinitiv DataStream.

Figure 2. Monthly 10-year Eurozone sovereign bond spreads, in percentages for January 1999 – December 2021

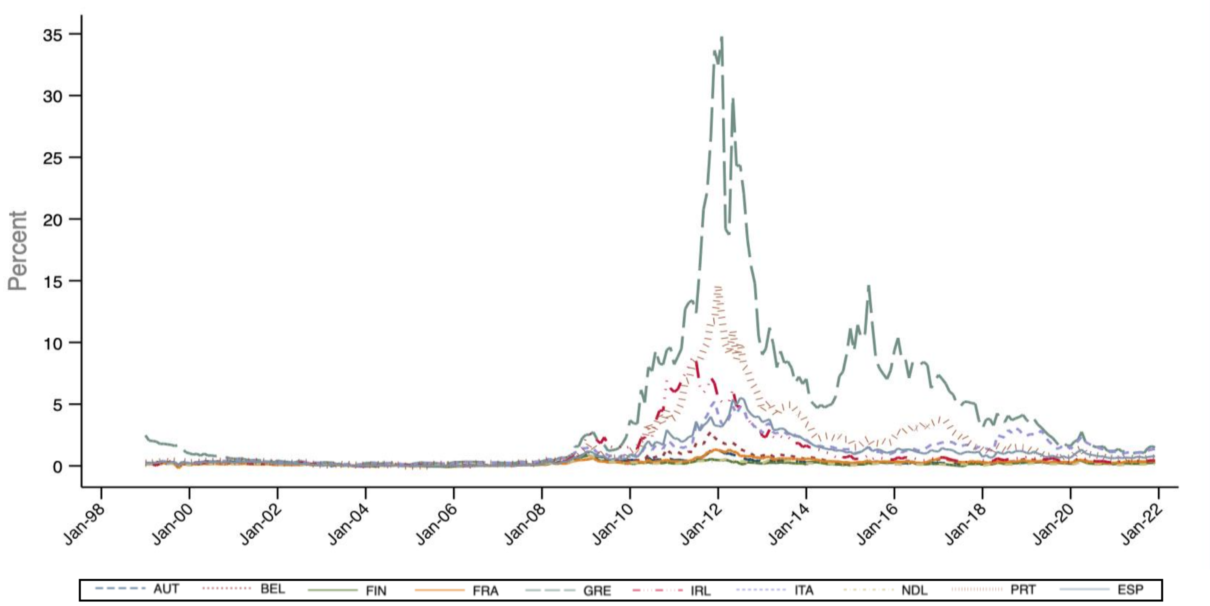


Figure 2 displays the monthly spreads over time for our ten sovereign issuers. The behaviour of the spreads varies substantially over our period of interest. Judging from Figure 2, there appear to be at least three different and distinct periods, each with their own spread dynamic. The first runs from the start of EMU in 1999 up until and including 2008 and is characterized by very low levels of all spreads and a high degree of convergence and collinearity. The second period appears to start around 2009, showing a rapid increase and extensive divergence in spreads. The formation of different groups of countries is also visible with peripheral countries showing a larger increase than core countries in their spreads to Germany. A third period is noticeable after the peak in the summer of 2012, where a decline in spreads becomes visible from around 2013. Some idiosyncratic outliers remain in some months, and spreads do not regain the lows of the first period.

5.2. Independent Variables

For the construction of our set of independent covariates, we start from Gómez-Puig *et al.* (2014)'s comprehensive set for $i=10$ countries (including Greece) for the EMU period that includes the sovereign debt crisis but precedes the direct interventions of the ECB in the bond markets through their asset purchasing programs (1999 – 2012). Theirs is a set of 40 main variables in the categories for the macroeconomy, financial linkages and market sentiment, a number of which are defined at country, regional and or global level. We are able to directly replicate 35 main variables, also at these various geographical levels, and find good alternatives for 3.[6] We add our own uniquely sourced and constructed variables in those three categories and add two new categories for market risk and EMU dynamics and populate those with new variables. A complete list of our independent variables is given in Table 2, for the macroeconomy in Panel A, for financial linkages in Panel B, for market sentiment in panel C, for market risks in panel D and for EMU in panel E.

The macroeconomy variables describe the Eurozone country's and regional real and nominal growth potential (*U, EuroU, INF, EuroINF, CAC, EuroCAC, IPR*) and business and consumer confidence for their outlook *(MEI, PMI, CCI, EuroCCI*). Debt dynamics is measured through the deficit and debt stocks (DEF, *EuroDEF, GOVDEBT, EuroGOVDEBT, DEBTOUT, EuroDEBTOUT, BANDEBT, NFCDEBT, HOUDEBT*). Financial linkage variables measure foreign bank claims (*EXTDEBTBAN, EXTDEBTPUB, EXTDEBTPRI*) and cross-border bank relations (*CBAN*). Market sentiment is measured by returns and volatility in the stock market (*STOCKR, EuroSTOCKR, GlobalSTOCKR, STOCKV, EuroSTOCKV, GlobalSTOCKV*), and in the bond market (*EuroCSPREAD, RAT, MOVE, IBOXXNFC, IBOXXFIN*) and by political uncertainty indexes (*EuroINSTAB, EPU, EuroEPU, GlobalEPU, GlobalRISK, GlobalKCFSI*). For market risk we take the central bank's target interest rates (*FEDFR, DFRATE, ECBFED*) and for credit risk we take the CDS par spreads for each Eurozone sovereign issuer (*CDS*). For liquidity risk as add the bid-ask spread of Eurozone sovereign bonds (*LIQUIDITY*) to the measures for the size of these markets. For volatility risk we add one measure (*STOCK*) which we construct from *STOCKR* and *STOCKV* to the market sentiment variables, and for exchange rate risk we add the real effective exchange rate of Eurozone countries (*REER*). Finally, we measure EMU dynamics through outstanding payment balances (*TARGET2*) and ECB operations in the money market (*MRO, LTRO*) and asset purchases in the bond market (*QE*). We construct the *TARGET2* variable by dividing each country's absolute balance in TARGET2 by that country's GDP. We gather balance sheet data from the ECB and the different National Central Banks (NCB) for our MRO, LTRO and QE variables and calculate month-on-month growth rates for these stock variables. Appendix I contains the descriptive statistics of all variables (in Tables I.2a,b).

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[6] The 5 missing variables from Gomez-Puig *et al.* (2016) are: *IFS* and *GlobalIFS, EuroDEFAULT, EuroITRAXXFIN* and *EuroITRAXXNF, EuroIRVIX-1Y* and *EuroIRVIX-10Y*. The two IFS series compare a target debt-GDP ratio with a forecast based on the government budget constraint, built by Polito and Wickens (2011, 2012) which we were not able to obtain from the authors. We do have debt and deficit ratios separately. *EuroDEFAULT* is a constructed series for the probability of two or more credit events, calculated by Lucas *et al.* (2013) which are also not able to obtain. The *ITRAXX* series are the European 5-year CDS index in the financial and non-financial sectors and are not available to us due to missing licence. We obtain *IBOXX* series instead on the total return of the Eurozone senior unsecured financial and non-financial CDS indexes. We find an alternative for the *EuroDEFAULT* and *ITRAXX* series in the CDS series of the Eurozone sovereigns themselves, whereas the creditworthiness of the corporate sector and financial sector in the Eurozone, and for the latter also their financial linkage with the sovereign are already captured by other variables. The two interest rate volatility indexes are proxied with *MOVE*.

Table 2. List of independent variables for Macro Fundamental Factors and Market Risk Factors

Name	Description	Frequency	Source
Panel A: Variables for Macro Economy			
U EuroU	Unemployment rate in each country For Eurozone	Monthly data are linearly interpolated from quarterly observations	Eurostat
INF EuroINF	Inflation rate. HICP in each country For Eurozone	Monthly interannual rate of growth	Eurostat
DEF EuroDEF	Government deficit-to-GDP for each country For Eurozone	Monthly data are linearly interpolated from quarterly observations	Eurostat
GOVDEBT EuroGOVDEBT	Government debt-to-GDP for each country For Eurozone	Monthly data are linearly interpolated from quarterly observations	Eurostat
CAC EuroCAC	Current-account-balance-to-GDP net position towards the rest of the world for each country For Eurozone	Monthly data are linearly interpolated from quarterly observations	OECD
IPR	Industrial production at country level	Monthly	OECD
MEI	Main Economic Indicator Used as substitute for PMI with 0.75 correlation	Monthly	OECD
DEBTOUT EuroDEBTOUT	Domestic Debt Securities Amounts Outstanding in each country and in Eurozone (in USD billions)	Monthly data, linearly interpolated from quarterly observations.	BIS Debt securities statistics. Table 18
PMI	Purchasing Managers' Index at country level (excl. Portugal, Finland, and Belgium)	Monthly	Bloomberg
CCI EuroCCI	Consumer confidence indicator based on surveys in each country, and in Eurozone	Monthly	European Commission (DG ECFIN)
BANDEBT	Banks' debt-to-GDP	Monthly data are linearly interpolated from quarterly observations.	ECB Monetary Financial Institutions' balance sheets and own estimates. GDP is from Eurostat
NFCDEBT	Non-financial corporations' debt-to-GDP	Monthly data are linearly interpolated from quarterly observations.	ECB Monetary Financial Institutions' balance sheets and own estimates. GDP is from Eurostat
HOUDEBT	Households' debt-to-GDP of country	Monthly data are linearly interpolated from quarterly observations.	ECB Monetary Financial Institutions' balance sheets and own estimates. GDP is from Eurostat
Panel B: Variables for Financial Linkages			
EXTDEBTBAN	Foreign bank claims on banks debt-to-GDP.	Monthly data are linearly interpolated from quarterly observations	BIS Consolidated banking statistics. Table 9C. GDP has been obtained from the OECD*
EXTDEBTPUB	Foreign bank claims on government debt-to-GDP	Monthly data are linearly interpolated from quarterly observations	BIS Consolidated banking statistics. Table 9C. GDP has been obtained from the OECD*
EXTDEBTPRI	Foreign bank claims on non-financial private debt-to-GDP	Monthly data are linearly interpolated from quarterly observations	BIS Consolidated banking statistics. Table 9C. GDP has been obtained from the OECD*
CBAN	Cross-border banking linkages. Percentage of the total foreign claims on one country held by another country's banks.	Monthly data are linearly interpolated from quarterly observations	BIS Consolidated banking statistics. Table 9D and own estimates*
Panel C: Variables for Market Sentiment			
STOCKR	Stock returns. Differences of logged stock index prices of the last and the first day of the month for each country	Monthly	DataStream
STOCKV	Stock volatility. Monthly standard deviation of the daily returns of each country's stock market general index	Monthly	DataStream
GlobalSTOCKR	Stock returns. Differences of logged S&P500 index prices of the last and first day of the month	Monthly	DataStream
EuroCSPREAD	Credit Spread. Difference between the yields of the iBoxx indices containing BBB-rated European corporate bonds and AAA-rated European corporate bonds. Monthly average of daily data	Monthly	DataStream
EuroSTOCKR	Eurozone stock returns. Differences of logged stock indices (Eurostoxx-50) prices of the last and the first day of the month for each country	Monthly	DataStream
EuroSTOCKV	Eurozone stock volatility. Eurostoxx-50 implied stock market volatility index. Monthly average of daily data	Monthly average of daily data	www.stoxx.com

GlobalSTOCKV	Global stock volatility. Chicago Board Options Exchange Market Volatility Index. (Implied volatility of S&P 500 index options),		Bloomberg
RAT	Credit rating scale built from Fitch, Moody's, S&P ratings for each country	Monthly	
IBOXXFIN IBOXXNFC	Total return index of the Eurozone senior unsecured financial and non-financial CDS		
MOVE	Merrill Lynch Option Volatility Estimate Index on US Treasuries		
EuroINSTAB	Euro instability Market expectation of the probability that at least one euro area country will have left the currency union at the end of 2013	Monthly average of daily data, for the period 2010:8–2012:8	Built by Klose and Weigert (2014)
EPU EuroEPU GlobalEPU	Index of economic policy uncertainty for Germany, France, Italy, and Spain, for Eurozone and for the United States	Monthly	www.policyuncertainty.com. Built by Baker *et al.* (2013)
GlobalRISK	Global Risk Aversion. The spread between 10-year fixed interest rates on US swaps and the yield on 10-year Moody's Seasoned AAA US corporate bonds.	Monthly average of daily data	DataStream
GlobalKCFSI	Kansas City Financial Stress Index. Based on 11 financial market variables, each of which captures one or more key features of financial stress.	Monthly	www.kansascityfed.org. Built by Hakkio and Keeton (2009)
Panel D: Variables for Market Risk			
FEDFR	Fed funds rate. Federal Reserve target interest rate	Monthly average of daily data	FRED
DFRATE	Deposit facility rate. ECB target interest rate		ECB
ECBFED	Monthly differential between Fed Funds Rate and ECB Deposit Facility Rate		ECB, FRED
CDS	Single Name Credit Default Swap's Par Spread for each Eurozone sovereign expressed in basis points		IHS Markit
LIQUIDITY	Each country daily Ask-Bid Price differential for 10-year sovereign		DataStream
STOCK	Country stock returns amplified by their monthly volatility. STOCKR*STOCKV. Measure of implied risk appetite.	Monthly	
REER	Real Broad Effective Exchange Rate harmonized from January 1999		
Panel E: Variables for EMU			
TARGET2	Millions of Target2 euros over GDP, expressed in millions at country level.	Monthly ratio with GDP data interpolated from quarterly	ECB
MRO	Main Refinancing Operations by each National Central Bank.	Monthly percentage change	Bruegel, ECB Voice 5.1 in CB balance sheet.
LTRO	Long-Term Refinancing Operations by each National Central Bank.		Bruegel, ECB Voice 5.2 in CB balance sheet.
QE*	Securities held for monetary policy purposes by each National Central Bank.		ECB Voice 7.1 in CB balance sheet. Prior to June 2016 National data estimated from Aggregate ECB data through Country Capital Key (GDP).

* For 7.1. we have data available in panel form from 2016 but only time series aggregate from 2009. To fill out series at NCB level, we decompose our aggregate 2009 series by estimating the individual holdings of each NCB with the Country Capital Key (CCK) from the available data starting in 2016. Our assumption that the CCK was used from 2009 to 2016 is the same as that for the first month of 2016 is valid as changes in the CCK seem to have happened only once, and after 2016.

6. Empirical results

Our empirical approach for determining a model that best explains the determinants of Eurozone sovereign spreads follows a general-to-specific estimation procedure: using the extensive number of covariates described above (in Section 5.2) in a generally unrestricted linear regression, and stepwise excluding variables for lack of statistical and economic significance in order to retain those that do and then continue with various regressions until the combination amongst them is found that provides the strongest explanatory power. In order to determine the empirical relevance of the Fixed Effects (*FE*) and Random Effects (*RE*) methods for our panel data, we use the Hausman test statistic to test for non-correlation between the unobserved effect and the regressors and confirm the preference for the Fixed Effects regressor model.[7] Therefore, all our econometric estimations are performed through a Fixed Effect (*FE*) regressor model. We report results for the testing of each of our four hypotheses, which chronicles our empirical journey.

6.1. Identifying the Macro Fundamental-based model for 1999-2021

We test Hypothesis 1 with the Macro Fundamental-based (*MF*) model of Eqts. (1) and (2a), populating vector $\mathfrak{X}'^{MF}_{rtm}$ with variables for the macroeconomic, financial linkages and market sentiment drivers listed in Table 2 in Panels A, B and C respectively. Similar to Gómez-Puig *et al.* (2014), we apply a general-to-specific approach. Specifically, our empirical analysis starts with a general unrestricted statistical model including all explanatory variables to capture the essential characteristics of the underlying dataset (results in Table I.3 in Appendix I for FE regression with all variables). We then move in steps with our testing procedures to eliminate statistically insignificant variables. We carefully check the validity of the reductions versus old and new variable combinations at each stage to ensure congruence of the finally selected model. We thus find the combination of variables that best explain the dynamics of Eurozone sovereign bond spreads.

While our aim is to find a generalised model for the whole period of twenty-five years, we first set out to identify the best-fit model specification with our variable set for the period 1999 – 2012.[8]

[7] Gómez-Puig *et al.* (2016) similarly perform the Hausman test and give preference to FE over RE. Contrary to them we do not perform a pooled-OLS regression, because it is a simple regression that does not account for country time independent unobservable factors, thus making FE or RE both superior to OLS in terms of estimation as these methods do account for these unobservables.

[8] Gómez-Puig *et al.* (2016) define within their sample period of 1999-2012 two different periods by the moment that Greece announced a much higher than expected budget deficit which they consider the start of the Eurozone sovereign debt crisis, thereby defining January 1999 up until November 2009 as their pre-crisis period, and a crisis period from December 2009 to the end of 2012. In our iterations we also estimate these two periods separately. Results are not reported here, but can be provided upon request.

Table 3: Best specifications for Macro Fundamental-based model, for 1999-2012 and extended to 2013-2021

	Model 1		Model 2		Model 3	
All Countries	1999-2012	2013-2021	1999-2009	2013-2021	2009-2012	2013-2021
RAT	0.271***	0.311**				
	(4.20)	(2.93)				
STOCKV			-8.112***	69.52**	39.19	43.97*
			(-4.56)	(2.66)	(1.45)	(2.19)
EuroCCI					0.199**	0.032
					(2.55)	(1.32)
MOVE	0.005**	0.00997			-0.018	0.002
	(2.68)	(1.42)			(-1.16)	(0.51)
EuroCSPREAD					3.099*	0.706**
					(1.90)	(2.66)
EuroSTOCKV			0.0269***	-0.0392**	-0.103	-0.039**
			(13.57)	(-2.98)	(-1.77)	(-2.63)
CAC	-0.082	-0.0000640				
	(-1.17)	(-0.03)				
DEF	0.038*	-0.0170	-0.0137	0.00470	0.05**	-0.022*
	(1.89)	(-1.32)	(-1.54)	(0.56)	(2.43)	(-1.88)
GOVDEBT					0.095***	-0.054*
					(3.33)	(-2.07)
DEBTOUT	-0.000	0.000000335	0.000000275	0.000		
	(-1.50)	(0.38)	(1.27)	(1.53)		
BANDEBT	771.7***	-58.84				
	(3.67)	(-0.36)				
HOUDEBT			419.4***	186.3	3231.0***	707.6
			(3.57)	(0.65)	(5.80)	(1.01)
NFCDEBT					-1036.8	235.9
					(-1.79)	(0.32)
INF			-0.0350	0.210***	-0.085	0.137**
			(-1.55)	(3.73)	(-0.37)	(3.16)
U			0.00533	0.251**	0.423***	0.129*
			(0.21)	(2.27)	(3.47)	(1.91)
EuroDEF					-0.162	-0.00837
					(-1.36)	(-0.22)
EuroGOVDEBT	0.052	-0.00710			0.056	0.0356
	(1.74)	(-0.38)			(0.88)	(0.74)
EXTDEBTPUB	-0.118**	0.000128	-0.00673	-0.014	-0.076**	0.00845
	(-2.46)	(0.01)	(-0.29)	(-1.18)	(-2.27)	(0.56)
Constant	-6.659***	-4.122	-1.385***	-2.510	-21.17***	-0.382
	(-3.35)	(-1.44)	(-3.47)	(-1.63)	(-4.03)	(-0.13)
R^2	0.826	0.560	0.758	0.514	0.662	0.618

Notes: Results for *i=10* countries. In the ordinary brackets below the parameter estimates are the corresponding z-statistics, computed using White (1980)'s heteroskedasticity-robust standard errors. ***, ** and * indicate significance at 1%, 5% and 10%, respectively. Model 1 has been optimized for the interval 1999-2012, Model 2 for 1999-2009 and Model 3 for 2013-2021.

With the variables listed in Table 2, Panels A-C, we find, through our many iterations, that we have all the necessary variables to reproduce the most common findings of the field that uses a macro fundamental approach to determine the drivers in Eurozone government bond spreads. The best replicated model that we identify through our general-to-specific approach for 1999-2012 for *i=10* countries is Model 1 in Table 3. Model 2 is optimized for 1999-2009 and Model 3 for 2012-2021. All three models are extended to the remaining period. All are estimated with macroeconomic and financial linkages variables in absolute terms for the Eurozone countries. When we transform these variables relative terms to Germany, the model performs worse[9]. The models in Table 3 show estimation results using White (1980)'s heteroskedasticity-robust standard errors.[10] In Appendix I, we list results for Model 1 without heteroskedasticity-robust standard errors (in Table I.4) and we give the specification of all three models in Table 3 for the core and peripheral countries (in Tables I.5a and I.5b).

From our replications efforts, of which only the best fit results are shown in Table 3, we detect several findings which we summarize here. First, we notice that macroeconomic and financial linkages variables do not perform well. From the first category, it is mostly the government deficit (*DEF*) and various debt ratios (*GOVDEBT, BANDEBT, HOUDEBT*) that have some explanatory power in the period 1999-2012, while other macroeconomic variables are mostly insignificant. All, including the debt and deficit variables, are particularly unstable across the various dimensions and specifications. From the set of financial linkages variables it is only foreign bank claims on government debt (*EXTDEBTPUB*) that consistently shows significance, often however with the wrong sign. We attribute this poor performance to the fact that variables in these two categories are of low frequency and have been interpolated, are frequently missing datapoints in the early years of EMU, and are largely backward-looking. Secondly, we notice that consistent results in variables and coefficients are largely driven by the market-sentiment variables. We attribute this to the fact that we have complete series at a monthly frequency for this category that are also same-time to our spreads. We otherwise note some findings from their combined performance with the macroeconomic variables, such as that bond ratings (*RAT*) and volatility (*MOVE*) explain the drivers in spreads well in combination with deficit and debt variables in the first period, and stock volatility *(STOCKV* and *EuroSTOCKV*) and corporate bond credit spreads

[9] Gómez-Puig *et al.* (2016) transform macroeconomic and financial linkages variables relative to Germany. Results of our estimations with relative variables are not reported here but available upon request. Our results corroborate those of D'Agostino and Ehrmann (2014) who find that the Eurozone countries' macroeconomic fundamentals to be considerably more important than those of the benchmark country Germany.

[10] When we are not controlling for heteroskedastic standard errors, the significance of our variables increases. While we come closer to exact results of Gómez-Puig *et al.* (2016), we decide that it is important to always include White (1980) heteroskedastic-robust standard errors.

in the Eurozone (*EuroCSPREAD*) show their significance mostly in the subsequent period. Thirdly, when we extend our replication efforts to 2013-2021 in our attempt to identify a generalised model, we notice that market sentiment variables are consistent in terms of statistical significance and economic interpretation, that inflation (*INF*) and unemployment (*U*) now also pick up significance but that previously significant macroeconomic variables either loose significance or have the wrong sign. The extended period testing reinforces our earlier observation of the overall poor fit of macroeconomic and financial linkages set and good fit of the market sentiment set for spreads. Fourthly, we notice that data that is available to us in panel format for the Eurozone countries performs better in specifications than comparable variables that are available at regional or global level. We realise that despite our incorporation of country fixed-effects, the macroeconomic and market sentiment dynamics specific to each Eurozone country is important for spreads. Fifthly, we notice that Greece is a rather large outlier. If we exclude Greece from our estimations, the model does not turn significant or stable overall, but we realise that Greece contributes to the instability of the model in all periods. When we look more closely at the macroeconomic and market sentiment variables specific to Greece, we see strong gyrations in a number of them that are clearly to do with the series of events triggered by the Greek government's announcement in Q32009 of a significantly worse fiscal positions. Greece's Public Sector Involvement in March 2012 exchanges the sovereigns outstanding bonds into bonds with longer maturities and lower coupons, causing a de facto discontinuity in the Greek bond yield series.[11] Realising that Greece is a special case as it is the only Eurozone country whose debt was restructured, we decide to omit Greece from tests for our next hypotheses.

Last but not least, the striking peculiarity in all our replications, including in our best-fit models listed in Table 3, is the presence of a large and significant constant term.[12] However much we try with variable combinations and permutations, we are not able to identify a specification with an insignificant constant term. The presence of a significant constant term points to an omitted variable problem that our extensive set of macroeconomic, market linkages and market sentiment variables is unable to solve. We conclude from our generic-to-specific approach that we are not able to find a satisfactory model that is robust across time and reject our Hypothesis 1.

Our supposition is that over the course of the periods that we separately analyse, a growing disconnect between macro-fundamentals and bond spreads is evident. The facts that macroeconomic and financial linkages perform best in the first periods and that market-sentiment

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[11] See https://www.esm.europa.eu/system/files/document/esmdp11.pdf for details of Greece's PSI.

[12] Note that the best-fit models reported in Gómez-Puig *et al.* (2016, Table 4) also have significant constant terms.

variables perform the best of all three categories with their performance increasing over subsequent periods is testimony to this disconnect.

6.2. Testing for unknown breakpoints in the distribution of spreads

The majority of previous studies (on either the determinants of Eurozone sovereign yields spreads, or the impact of central bank monetary policy on those spreads) analyse the drivers in spreads over different sub-sample periods. Typically, when the sample period extends beyond 2008, a pre-crisis and post-crisis period is distinguished, and when it extends beyond 2012, a further period is included to capture the extra policy actions that the ECB took to contain the eurozone sovereign debt crisis. Studies tend to define the marking moment for the selection of the subsamples *a priori* on the historically decisive economic or political event itself, such as the collapse of Lehman Brothers in September 2008 or Draghi's "whatever-it-takes" statement in July 2012. The psychological bias towards these watershed events renders the research approach vulnerable to an inappropriate an incorrect marking of sub-sample periods.[13] In order to avoid this, we prefer to let the data speak and determine, empirically with the appropriate econometric tests, the moments in time when the spreads behave significantly different from one period to the next.

We therefore test Hypothesis 2 with the methodology developed for panel data in Ditzen *et al.* (2021) and Karavias *et al.* (2021), which is based on the time-series approach of the Bai-Perron (1998) sequential test, to econometrically determine the presence of unknown breakpoints.[14] To the best of our knowledge, such a sequential test has not previously been applied to the distributions of the various Eurozone sovereign spreads, and over the full length of EMU's existence. We test this for the set of *i=9* countries, as one conclusion from our previous analysis is to omit Greece as it too much of a special case that distorts results.

We are interested in structural changes across the distribution of spreads over time. As there may be multiple regimes induced by the breaks, we specify different regressions:

$$
\begin{aligned}
SPR_{it_0m} &= t_{im}\delta_1 + \bar{t}_{im}b_{i1} + e_{i1m} \quad for\ t_0 = T_0, \dots, T_1,\\
SPR_{it_1m} &= t_{im}\delta_2 + \bar{t}_{im}b_{i2} + e_{i2m} \quad for\ t_1 = T_1, \dots, T_2,\\
&\dots\\
SPR_{it_sm} &= t_{im}\delta_{s+1} + \bar{t}_{im}b_{is+1} + e_{is+1m} \quad for\ t_s = T_s, \dots, T_{s+1}.
\end{aligned}
\tag{4}
$$

[13] The psychological bias results from known human behavioural trait to remember negative news the most and attach the largest weight to it (see, e.g., Ecker *et al.*, 2022).
[14] Our breakpoint estimation and test methodology is sensitive to parametrisation, and therefore the (subjective) choices that we make with respect to the parameters.

The model is for the spreads (*SPR*) of *i=9* countries, *T* periods and with *s* structural breaks, where $t = T_{j-1}, \dots, T_j$ with $j = 1, \dots, s+1$ with $T_0 = 0$ and with $T_{s+1} = T$, enabling the identification of *s+1* regimes and *s* breakpoints.

As the spread is a measure expressed in terms of divergence from zero, a trend regression that accounts for countries' averages will capture the distribution of spreads over time. This is the essence of the model described by all Eqts. (4), in which the first term on the right-hand side ($t_{im}\delta_j$) describes the regime dependent trend coefficient, while the second term ($\bar{t}_{im}b_{ij}$) is always the regime dependent country average coefficient which is followed by the error term.

The null hypothesis that we are testing first is that there are no structural breaks. If we reject this null hypothesis that there are no structural breaks, then we must accept that there are *s* breaks. To subsequently find the exact number and corresponding months of these breakpoints we use a sequential testing methodology, which can be generalized as an incrementation of *s+1* until we fail to reject the null hypothesis. The testing procedure follows an estimating technique that can be described as:

$$\widehat{\boldsymbol{T}}_{\boldsymbol{S}} = arg \min_{T_S \in T_{S,\varepsilon}} SSR(\boldsymbol{T}_{\boldsymbol{S}}) \,, \tag{5}$$

where $SSR(\boldsymbol{T}_{\boldsymbol{S}})$ is the sum of squared residuals (SSR) based on *s* number of hypothetical breakpoints constructed from the residuals of Eqts. (4). The minimum SSR is found by constructing a matrix of all the SSR for each possible point in time of the breakpoint with *s* number of breaks. That is to say that we construct the SSR over progressive sample periods until we find the absolute minimum SSR that gives us $\widehat{\boldsymbol{T}}_{\boldsymbol{S}}$.[15]

We take from Ditzen *et al.* (2021) and Karavias *et al.* (2021) the specification of the sequential hypothesis that needs to be tested, and reformulate this to our specific case as the following F-test:

$$F(s+1|s) \;=\; \sup_{\boldsymbol{1 \le j \le s+1}} \; \sup_{\tau \in \boldsymbol{T_{j,\varepsilon}}} F\left(\tau | \widehat{\boldsymbol{T}}_{\boldsymbol{S}}\right) , \tag{6}$$

where $\widehat{\boldsymbol{T}}_{\boldsymbol{S}} = \{\widehat{T}_1, \widehat{T}_2, \dots, \widehat{T}_S\}$ is the collection of breakpoints estimated from Eqt. (5) and $\tau = s+1$.[16]

[15] $\widehat{\boldsymbol{T}}_{\boldsymbol{1}}$ for 1 breakpoint first splits the sample in 2 regimes *(s+1=1+1)* and then computes the SSR from the calculated residuals of the two regimes' trend regressions, and finally sums the SSR of the two regimes. We repeat the process by moving the breakpoint forward in time until we have identified all possible unknown breakpoints in the data and have constructed our matrix. At that point, we confront the constructed SSRs until we find the absolute minimum SSR, which gives us $\widehat{\boldsymbol{T}}_{\boldsymbol{1}}$. This process is then repeated for as long as Eqt. (5) holds.

[16] We compare the sum of the best estimated sum of SSR in Eqt. (5) with *s+1* breaks with the one with *s* breaks. If we reject the null of *s* breaks in time, then the SSR of *s+1* should be smaller than that for the model with a *s* breaks. This is done through the F-test specified in Eqt. (6).

Table 6. Results from sequential breakpoint test

F-test	Test Statistic	Critical value 1%	5%	10%
F(1|0)	381.61	12.29	8.58	7.04
F(2|1)	584.88	13.89	10.13	8.51
F(3|2)	100.31	14.80	11.14	9.41
F(4|3)	86.66	15.28	11.58	10.04
F(5|4)	90.44	15.76	12.25	10.58

Table 7. Results from sequential estimation

Breakpoint	Date	[95% conf. interval]	
1	Sep 2002	Feb 1996	Apr 2009
2	Mar 2007	Dec 2006	Jun 2007
3	Aug 2010	Jul 2010	Sep 2010
4	Jan 2014	Dec 2013	Feb 2014
5	Sep 2017	Jul 2014	Nov 2020

Table 6 displays the results from our unique application of the sequential tests on our panel of nine Eurozone sovereign spreads (*i=9* countries, excluding Greece). The first column of Table 6 shows that the F-statistic exceeds the critical value of 1%, thus leading us to reject the first null hypothesis of 0 break points. We report the F-statistic for 5 tests, as all breakpoints between 1 and 5 are significant at a 1% level.

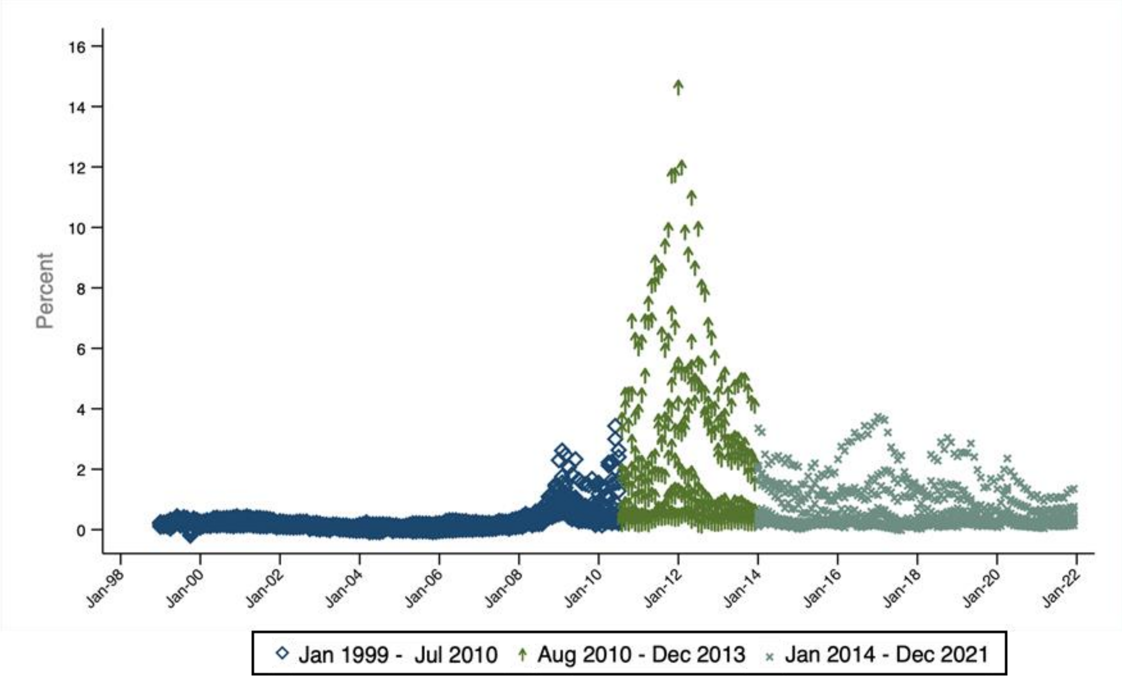
Table 7 reveals the point in time of the breakpoints that are estimated by Eqt. (5), again for *i=9* countries. Observing the 95% confidence interval, minor from major breakpoints can be distinguished from the length of the monthly range around the breakpoint date, with a small number of months in the interval pointing to a major breakpoint, and vice versa. Breakpoints 3 and 4 in Table 7 have the smallest possible range of 3 months each. This implies that the two moments in the centre of this range, being August 2010 and January 2014, are the major breakpoints in the characteristics of the distribution of the Eurozone sovereign bond spreads.[17]

Figure 3 displays the evolution of the spreads and the major breakpoints identified among them, defining by colour those that belong to the 3 regimes that are generated from them. Eurozone sovereign spreads visibly react somewhat to the initial eruption of the global financial crisis in 2008, including the moment of the Lehman Brothers collapse. Spreads react more severe to the initial upsets in Greece in 2009, but not severe enough to break the trend in their joint distribution. According to our sequential test, this only occurs in August 2010 when the Eurozone is more deeply emersed into its debt crisis. The convertibility risk premium in the Eurozone runs high in the early summer of 2012 when Grexit odds fuel the fears of a break-up of the Eurozone. Draghi's "whatever-it-takes" moment in 2012 is aimed to quell the convertibility risk and occurs, in Figure 3, at the peak of the spreads. Spreads subsequently decline but, distribution-wise, settle into a new regime only in January 2014.

Since the sequential breakpoint test confirms the presence of different regimes in our spreads, we formally conclude that we fail to reject our Hypothesis 2.

[17] This difference between major and minor breaks is visible from Table 6 as well, as the F-statistic for 2 breakpoints has the highest value of all, being F(2|1) in Table 6, reinforcing our conclusion of these 2 major breakpoints.

Figure 3: Regimes in Eurozone sovereign bond spreads, defined by sequential breakpoint analysis



We recognise the three regimes identified by the sequential test as distinct episodes in the history of EMU. The first regime (January 1999 - July 2010) is the period of the elimination of intra-Eurozone exchange rate risk following the creation of the single market and further convergence under the initial EMU make-up. The second regime (August 2010 - December 2013) is the sovereign debt crisis period during which convertibility risk rises and EMU's fragility transpires. In this period policymakers act with various rescue programs and the ECB's Lender of the Last Resort (LOLR) function, which was shown wanting, is repaired with the addition of unconventional monetary policy tools.[18] This starts modestly at first with the extended LTROs in 2009 and SMP program in 2010 and in earnest following the OMT announcement in August 2012 when convertibility risk spikes. The third regime (January 2014-December 2021) is when the ECB brings it policy interest rate in negative territory and directly intervenes, not just in the rescue program countries' bond markets but in all Eurozone countries', through its various quantitative easing programs to contain credit and liquidity risk contagion between countries.

Our supposition is that the ECB's transferal from conventional to increasingly unconventional monetary policy coincides with two sets of Presidencies over these regimes. The first two Presidents, Duisenberg and Trichet, enacted between 1 July 1998 to 31 October 2011 a principally conventional monetary policy. Nine months into his Presidency, Draghi announces the OMT and subsequently introduces various quantitative easing (QE) programs leading to a substantial

[18] Saka *et al.* (2015) empirically confirm that Draghi's OMT announcement restores in large part the LOLR function of the ECB and effectively curbs EMU fragility risk.

expansion of the ECB's balance sheet which Lagarde has continued following her appointment in November 2019. The Draghi-Lagarde Presidency has been a principally unconventional monetary policy. While under Duisenberg – Trichet the ECB only acted in the Eurozone money market, under Draghi – Lagarde the central bank's also and increasingly acts in the capital market through a self-enabled expansion of the ECB's mandate. At this point of our research journey, the outcome of the sequential breakpoint test gives preliminary evidence to the impact that this shift in ECB monetary policy has had on the structure of Eurozone sovereign bond spreads.

6.3. Identifying the specification for the Market Risk-based Model for 2012-2021

Having failed to identify a robust specification of the Macro Fundamental-based (*MF*) model, we switch our theoretical framework to that of a Market Risk-based (*MR*) model. Our observations from our testing of the first hypothesis that market sentiment variables show good robustness in their coefficients and sign and that there is a growing disconnect between macroeconomic indicators and spreads, motivate us to turn to real financial markets variables instead, which are generic and consistently present over time. Being now aware of the presence of three distinct regimes in our spreads, we aim to just find the best specification for period after 2012/2013, being mostly our third regime.

We test Hypothesis 2 with the Market Risk-based model of Eqts. (1) and (2b), populating vector $\mathfrak{X}'^{MR}_{rtm}$ with variables that can describe the various market risk factors. The empirical work starts by including the largest and most important risk factors to the model and gradually adding more variables until we are convinced to have identified a holistic and robust risk framework that satisfies the following conditions: insignificant constant terms; economic and statistical significance of the coefficients, in line with the literature; strong theoretical and financial-economic rationale of the overall specification. We prioritise panel variables over time series, as we want to uncover country-specific influences.

We commence with the most specific explanatory factor, which for bond spreads, is **credit risk**. As CDS spreads are constructed on the probability of default, we believe that they are the best possible proxy for credit risk. We gather CDS par spreads for single-name Eurozone sovereigns as the reference issuer from IHS Markit.[19] As CDS's also incorporate bank counterparty and regulatory risk[20], it does not surprise us that we find that our *CDS* variable carries most of the

[19] Fortunately we already decided to exclude Greece, because the discontinuity in data is most directly present in the CDS series for Greece, where levels simply completely disappear for several months in 2012, when it was uncertain whether the PSI, dressed up as a 'voluntary' bond exchange program, constitutes a credit event.

[20] Counterparty risk is the risk that the bank acting as the financial intermediary in the CDS with the end-investor fails on its obligations (Giglio, 2016). Regulatory risk arises when regulators insist that banks receive higher capital charges for uncollateralised derivatives transactions (Klingler and Lando, 2018).

explanation of the levels and variance in our spreads. The next factor that the literature assigns a risk premium to is **liquidity risk.** We prefer not to use the level of outstanding bonds as we find this stock measure too crude, and use the bid-ask spread in the sovereign bonds instead. Both variables (*CDS* and *LIQUIDITY*) are available in panel format. While our aim is to find a best specification for the period after 2012/2013, we find that from only these two risk factors, we have a satisfactory model basis over all our three identified regimes, with high R-squared's and all constant terms statistically insignificant. We show this specification in Table 8, Panel A. In regime 1 is the best fit, with statistically significant coefficients at least at a 1% level for both explanatory variables and an R^2 of 91.2%. Specifications for the second and third regime have highly significant coefficients for CDS and barely insignificant *LIQUIDITY* coefficients, and consequently lower but still high R^2 (85.4% and 70.2% respectively).

We next select the best fitting variable from Table 2 Panels C and D for our three other risk factors (interest rate risk, volatility risk and exchange rate risk) to add to the baseline model in Table 8 Panel A, with which we again conduct a generic-to-specific approach. For **interest rate risk,** we take *DFRATE* and *FEDFR* in our belief that base level of interest rates influences both the level and the dispersion of spreads.[21] Our *FEDECB* variable measures the (de)synchronisation of monetary policy between the US and the Eurozone. For **volatility risk**, we include *GlobalSTOCKV*, together with *VSTOXX* which is more Eurozone specific and *MOVE* which is bond specific.[22] Realising that *GlobalSTOCKV, VSTOXX* and *MOVE* are single time series, we include the panel series for Eurozone countries' stock returns and volatility (*STOCKR* and *STOCKV)* and the product of these two (*STOCK).* While EMU indeed abstracts from **exchange rate risk** within the Eurozone, the Eurozone as a whole is still influenced by its relative competitiveness vis-à-vis the rest of the world. This is captured by the *REER.* variable, which is also available to us in panel format. The cost of EMU's **convertibility risk** grows the more the Eurozone countries become economically intertwined, which is captured by *TARGET2* and also available to us in panel format.

To identify which covariates add the most to the base line specification with *CDS* and *LIQUIDTY*, we again conduct our selection through a stepwise path independent fixed effects regression approach, meaning that we explore all possible combinations of the named variables. We show in the Appendix in Table I.6. a random sample from the specifications we obtained in this process.

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[21] Manganelli and Wolswijk (2009) show that Eurozone government bond spreads are driven by the level of short-term interest rates set for the Eurosystem by the ECB.

[22] The VIX (which is our *GlobalSTOCKV* variable) is most often used by authors and known in the literature as the global investor fear indicator.

Table 8. Best base-line specifications for the Market Risk-based model, for all three regimes

Specification	A. Baseline fit			B. Extended baseline fit		
Regimes	1	2	3	1	2	3
CDS	0.884*** (12.86)	1.026*** (10.50)	0.862*** (9.63)	0.774*** (14.01)	1.040*** (11.18)	0.947*** (11.32)
LIQUIDITY	0.0869*** (2.97)	0.254 (1.78)	0.593 (1.63)	0.132** (2.78)	0.257*** (4.98)	0.542* (1.88)
FEDECB				-0.014** (-2.87)	0.652** (2.73)	0.104*** (3.45)
STOCK				-0.113*** (-8.50)	-0.235 (-1.65)	-0.051 (-1.61)
TARGET2				-0.265*** (-5.12)	-0.334*** (-3.73)	-0.187 (-1.76)
Constant	0.00737 (0.35)	0.118 (1.06)	0.0644 (1.21)	-0.006 (-0.38)	-0.02 (-0.16)	-0.157 (-1.44)
R^2	0.912	0.854	0.702	0.927	0.875	0.762

Notes: FE regression results with White (1980) heteroskedasticity-robust standard errors; ***, ** and * indicate significance at 1%, 5% and 10%; z-statistic in parenthesis. Regimes 1, 2 and 3 are Jan1999-Jul2010, Aug2010-Dec2013 and Jan2014-Dec2021.

We are able to make a number of general observations from our various iterations. First, *CDS* is always highly significant in all three regimes. Second, *LIQUIDITY* remains significant in regime 1 and turns significant in subsequent regimes in most specifications with added variables. Third, *FEDECB* performs better than the *DFRATE* and *FED*. DFRATE, is significant and positive in the first regime, meaning to say that when the ECB raises its policy rate, spreads widen in the Eurozone. *DFRATE* loses significance in the crisis period, and, counter-intuitively, also changes sign. As this approximately coincides with the ECB's decision to bring its policy rate into negative territory, we conclude that negative interest rates has been an impotent tool on spreads. Fourth, out of all our volatility risk variables *STOCK* is the only one that is consistent over regimes in terms of expected sign. Fifth, *REER* appears very inconsistent sign-wise and is also insignificant. Sixth, *TARGET2* is very robust statistically in the first two regimes across many specifications and is also economically consistent across all three regimes. Based on these observations, we settle on the specification shown in Table 8 Panel B as the best extension of our baseline model.

From this extended baseline specification, we wish to determine whether the ECB's monetary policy actions has, separately and independently, influenced spreads. Since the ECB adds over the course of the last twenty-five years unconventional tools to its conventional toolkit, we need variables that best describe both sets. Since we already have *DFRATE* among the interest rate

Table 9. Best specification for the Market Risk-based model, for all three regimes

Regimes	1	2	3
CDS	0.773***	1.055***	0.963***
	(12.99)	(12.24)	(12.82)
LIQUIDITY	0.136**	0.225***	0.592*
	(2.79)	(4.09)	(2.16)
FEDECB	-0.00971*	0.431	0.0816**
	(-1.95)	(1.77)	(2.97)
STOCK	-0.119***	-0.477**	-0.0644**
	(-7.49)	(-2.57)	(-2.40)
TARGET2	-0.289***	-0.335***	-0.168
	(-5.59)	(-3.69)	(-1.66)
LTRO	3.89e-08	-1.30e-08***	7.20e-09*
	(0.41)	(-42.38)	(1.89)
QE		-1.348**	-1.223***
		(-2.92)	(-4.26)
Constant	-0.0166	-0.0320	-0.105
	(-0.98)	(-0.22)	(-1.05)
R^2	0.931	0.879	0.781

Notes: FE regression results with White (1980) heteroskedasticity-robust standard errors; ***, ** and * indicate significance at 1%, 5% and 10%; z-statistic in parenthesis. Regimes 1, 2 and 3 are Jan1999-Jul2010, Aug2010-Dec2013 and Jan2014-Dec2021.

variables (which is also the main conventional monetary policy tool), we add *MRO*, *LTRO* and *QE,* with the former two mostly conventional and the last our main unconventional monetary policy indicator that starts in regime 2.

We include *QE, LTRO* and *MRO,* in our extended baseline model through different combinations. In the Appendix we show the specifications for their possible combination in Table I.7. We first note that none of the variables from our extended baseline model (*CDS, LIQUIDITY, FEDECB, STOCK, TARGET2*) are affected by the inclusion of whichever combination of ECB monetary policy stock variables, leaving both the strength of their coefficients and their significance intact, attesting to the stability of our extended baseline model (Panel B in Table 8). We deduct three further main observations related to the additional explanatory power of the monetary policy variables themselves. First, *QE* coefficients are always significant at a 5% level in regime 2 and at a 1% level in regime 3, with very large negative coefficients. Second, *MRO* always has extremely small coefficients. Third, *LTRO* is always negative in regime 2 but with an extremely small coefficient and not significantly different from zero in regime 3. This indicates that this instrument only worked to dampen spreads in the crisis period when LTRO operations were enlarged. Beyond 2014, this instrument loses its effect, potentially because it got overwhelmed by the QE programs' effect on spreads. The second and third observations make us wonder whether to include *MRO* and *LTRO* at all, but if we are to include one then results indicate that *LTRO* should be preferred over *MRO* in combination with *QE*. We settle on this latter combination of ECB stock-variables to add to our extended baseline specification, resulting in our final best overall specification of the Market Risk-based model shown in Table 9.

From the *CDS* term in Table 9 it can be seen that the credit risk premium increases during the crisis and goes down afterwards but do not compress to the level of the first regime of convergence, whereas the coefficients for the *LIQUIDITY* premium monotonically increase over subsequent regimes. The *FEDECB,* measuring the synchronisation of Fed and ECB policies, is not significant in regime 2 when both policy rates are at the zero lower bound. The switching of the sign of the *FEDECB* coefficient between regime 1 and regime 3 is caused by the fact that only in regime 3, the Federal Reserve rate is consistently above the ECB rate. In regime 3, evidently a larger, positive divergence is interpreted as a tightening of financial conditions by investors and tends to lift spreads higher in the Eurozone. The relation between *STOCK* and our yield spreads is negative and stable economically and statistically across the three regimes. As *STOCK* is the Eurozone's stock returns amplified by their implied volatility, it can be interpreted as a measure of investor risk appetite. The negative coefficient on *STOCK* signals that when risk appetite runs high, investors are also willing to take risk in Eurozone spreads, leading to a decline of those spreads. As expected, the sign and magnitude of *TARGET2* is negative and fairly large in regimes 1 and 2, as growing financial entwined of countries in the Eurozone acts as a dampener on spreads, but turns insignificant in regime 3. Of our various ECB variables, *LTRO* shows some significance and had its largest, dampening effect on spreads in the crisis period, but only marginally so. By contrast, *QE* is significantly negatively related to the yield spread since purchases started in 2015.

While we set out to identify the best specification for the period after 2012/2013, our empirical approach unexpectedly yields a specification that works in all three regimes. The different power of strength and in some cases also different signs of the explanatory variables' coefficients across the different regimes is in accordance with our economic intuition and knowledge of these periods. Formally, it follows that not only do we fail to reject our Hypothesis 3, we also discover that our best specification for the Market Risk-factor model performs very well for pre-2012 period too.

Our supposition is that Eurozone bond spreads are best explained through a Market Risk-based model complemented by the impact of the ECB's direct interventions in the money markets and increasingly in the capital markets. The ECB's negative policy interest rates did not work, and the ECB's targeted LTROs only very marginally in the crisis period to contain spreads. The ECB's direct capital market interventions did work very effectively to reduce spreads, overwhelming in recent years TARGET2 imbalances that signal high and rising costs of convertibility risk.

6.4. Testing for differences between core and peripheral countries

We test Hypothesis 4, by estimating our best-fit specification of the Market Risk-based model for all countries in the Eurozone apart from Greece for a group of countries that most studies consider to be the core (Austria, Belgium, Finland, France, Netherlands) and the periphery (Ireland, Italy, Portugal, Spain) in the Eurozone. Table 10 displays the results of this estimation.

From the dynamics within the core and the periphery we make the following observations. The credit risk premium (*CDS*) is much larger for peripheral countries' spreads than for the core. Liquidity risk can, in specifications split for core and periphery, no longer explain the variation in spread, with the exception of core countries' spreads in the last regime, where the *LIQUIDITY* coefficient is larger than the *CDS* coefficient. *FEDECB* turns out not to matter for periphery in any regime, whereas it is significant for the core, first in a negative sense and then in a positive sense, but also no longer significant in regime 3. *STOCK*, or risk appetite among investors dampens spreads for core and periphery in regime 1, and then for periphery subsequently only in regime 2 and for core only in regime 3. *TARGET2*, or the costs of convertibility risk, acts as a dampener on spreads, but only significantly so in regime 1 for the periphery and in regime 2 for the core.

Table 10: Best overall specification of the Market Risk-based model for core and peripheral countries over three regimes

Country group	Core			Periphery		
Regimes	1	2	3	1	2	3
CDS	0.607***	0.806***	0.148**	0.851***	1.071***	1.042***
	(8.00)	(14.32)	(3.25)	(14.36)	(10.93)	(21.23)
LIQUIDITY	-0.006	0.072	0.360*	0.154	0.329	0.565
	(-0.30)	(0.88)	(2.42)	(1.79)	(2.19)	(1.43)
FEDECB	-0.025**	0.172**	0.007	-0.002	0.683	0.106
	(-3.84)	(3.18)	(1.59)	(-0.67)	(0.86)	(2.24)
STOCK	-0.113***	0.102	-0.113***	-0.121*	-0.736**	-0.006
	(-5.13)	(0.72)	(-8.28)	(-2.93)	(-4.27)	(-0.18)
TARGET2	-0.237	-0.216**	-0.007	-0.231**	-0.260	-0.199
	(-1.93)	(-3.81)	(-0.29)	(-4.19)	(-1.22)	(-1.74)
LTRO	-5.17e-08	-1.40e-08***	6.60e-09***	-0.000*	0.046	0.186
	(-0.93)	(-58.71)	(8.37)	(-3.09)	(0.14)	(2.27)
QE		-0.319	-0.380*		-2.249*	-1.999***
		(-1.52)	(-2.75)		(-2.44)	(-9.42)
Constant	0.0153	0.0258	0.177***	-0.011	0.0967	-0.188
	(1.16)	(0.82)	(7.68)	(-0.69)	(0.43)	(-0.95)
R^2	0.889	0.789	0.139	0.954	0.888	0.849

Notes: FE regression results with White (1980) heteroskedasticity-robust standard errors; ***, ** and * indicate significance at 1%, 5% and 10%; z-statistics in parenthesis. Regimes 1, 2 and 3 are Jan1999-Jul2010, Aug2010-Dec2013 and Jan2014-Dec2021.

The separation of the two countries groups shows that *LTRO* only worked in the core and not at all in the periphery. *QE* has brought spreads down much more in the periphery than in the core.

Despite a higher number of individual insignificant variables, the best-fit specification of the Market Risk-based model continues to show stability, judging from insignificant error terms, and high explanatory power in the R-squared. Only in regime 3 does the model seem to break down for core countries' spreads (as the constant term is significant and the R-squared drops to 14%). This result merits further future research into the drivers of core countries' bond spreads.

Formally, based on these results we conclude that indeed dynamics are very different between core and periphery, leading us to accept our Hypothesis 4.

Our supposition is that especially peripheral countries in the Eurozone have benefitted from ECB's direct capital market interventions. In recent years, liquidity risk takes over from credit risk as the driver of core countries' spreads. Why this happens exactly, and what the role of ECB's shifting policies and mandate may have been in this respect, is left for future research.

7. Concluding Remarks

We determine the drivers on government bond spreads of Eurozone countries through a multidimensional factor structure model caters for both a Macro Fundamental-based (*MF*) and a Market Risk-based (*MR*) infill of the set of factors and inclusion of EMU-specific factors in both.

Our research journey starts with the question whether a general model can be specified that describes the drivers of 10-year Eurozone bond spreads to Germany for ten sovereign member states for the entire EMU period. We aim to identify the best specification through a general-to-specific estimation of our Macro Fundamental-based (*MF*) model, using a comprehensive set of variables for macroeconomic, financial linkages and market sentiment factors for the period up to 2012. The main conclusion from our empirical analysis is that we are not able to identify a specification that is statistically stable and robust for this first period. When we extend our best-fit specification of the *MF* model for this early period to 2013-2021, the model performs even worse. Through our empirical analysis we become increasingly aware that Greece is a special case and decide to exclude this country henceforth from our estimations.

As a likely cause of our failure to identify one general model is the presence of different regimes, we subsequently test for unknown breakpoints in the distribution of Eurozone sovereign bond spreads. Our sequential breakpoint test for nine remaining countries indeed confirms the presence of different and distinct regimes, being January 1999 to July 2010, August 2010 to December 2013 and January 2014 to December 2021, and shows that the height of EMU's convertibility risk is in July 2012 and stemmed by Draghi's "whatever-it-takes" statement.

With this knowledge we lower the bar and focus on the last period in EMU's history. We switch our theoretical framework to that of a Market Risk-based (MR) model, as we observed from our estimations of the *MF* model that market sentiment variables show good robustness that seems to improve over time. This motivates us to turn to real financial markets variables as indicators for risk factors commonly found in bond returns. While we set out to identify the best specification for the MR model, again through a general-to-specific estimation procedure, for the period after 2012/2013, our empirical analysis unexpectedly yields a specification that is stable and robust in all three regimes. This specification for a good baseline fit contains CDS spreads to describe credit risk, the bid-ask spread in sovereign bonds for liquidity risk, the difference between target rate set by the Fed and the ECB, and stock returns in Eurozone countries amplified by their volatility. The overall best-fit specification of the *MR* model contains variables from the EMU-specific risk set. Outstanding balances of countries in Target2 relative to GDP, worked as dampener on spread as investors took note of this cost of convertibility risk, but only in the first two regimes. As for the conventional and unconventional monetary tools of the ECB, MRO and negative interest rates did not influence spreads at all and (T)LTROs did a little bit in the crisis period. Asset purchases made under the various QE programs have had by far the largest impact in reducing spreads.

The last stretch in our empirical journey is to estimate this best-fit specification of our *MR* model separately for the group of core and peripheral countries. The main result is that QE had a much larger effect on spreads of peripheral countries and that LTROs and Target2 balances had a larger effect on spreads of core countries. In the last period, the model specification is not able to describe spread dynamics in the core countries anymore. Our results show that in recent years, liquidity risk takes over from credit risk as the driver of core countries' spreads.

Overseeing the total of our empirical results, the determinants Eurozone sovereign bond spreads tell the tale of different regimes which are predominantly characterized by the ECB's transferal from conventional to increasingly unconventional monetary policy, coinciding with the change from the first two Presidencies of Duisenberg and Trichet to that of Draghi and Lagarde. Both sets of Presidencies have interpreted and implemented the mandate of the central bank in a very different way. While under Duisenberg and Trichet the ECB only acted in the Eurozone money market, under Draghi – Lagarde the central bank increasingly acts in the capital market. The growing detachment of sovereign bond spreads with macro fundamentals and ability of a Market-Risk factor model to explain the drivers in Eurozone sovereign bonds with ample explanatory power of the ECB's QE purchases, especially for spreads of peripheral countries, all speak to this tale.

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References

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 & Economics*, 19(1), 49-56.

Afonso, A., Arghyrou, M.G., Bagdatoglou, B. and Kontonikas, A., 2015. On the time-varying relationship between EMU sovereign spreads and their determinants. Economic Modelling, 44, 363-371.

Afonso, A., Arghyrou, M. G., Gadea, M. D. and Kontonikas, A., 2018. "Whatever it takes" to resolve the European sovereign debt crisis? Bond pricing regime switches and monetary policy effects. *Journal of International Money and Finance*, 86, 1-30.

Afonso, A. and Jalles, J. T., 2019. Quantitative easing and sovereign yield spreads: Euro-area time-varying evidence. *Journal of International Financial Markets, Institutions and Money*, 58, 208-224.

Afonso, A., Jalles, J. T. and Kazemi, M., 2020. The effects of macroeconomic, fiscal and monetary policy announcements on sovereign bond spreads. *International Review of Law and Economics*, 63, 105924.

Altavilla, C., Brugnolini, L., Gürkaynak, R. S., Motto, R. and Ragusa, G., 2019. Measuring euro area monetary policy. *Journal of Monetary Economics*, 108, 162-179.

Aristei, D. and Martelli, D., 2014. Sovereign bond yield spreads and market sentiment and expectations: Empirical evidence from Euro area countries. *Journal of Economics and Business*, 76, 55-84.

Bahaj, S., 2020. Sovereign spreads in the euro area: Cross border transmission and macroeconomic implications. *Journal of Monetary Economics*, 110, 116-135.

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

Baker, S. R., Bloom, N. and Davis, S. J., 2013. Measuring economic policy uncertainty. *Working paper 13-02*. Chicago, IL: Booth School of Business, University of Chicago.

Beber, A., Brandt, M.W. and Kavajecz, K.A., 2009. Flight-to-quality or flight-to-liquidity? Evidence from the euro-area bond market. *Review Financial Studies,* 22, 925–957.

Belke, A. and Gros, D., 2021. QE in the euro area: Has the PSPP benefited peripheral bonds? *Journal of International Financial Markets, Institutions and Money*, 73, 101350.

Benetton, M. and Fantino, D., 2021. Targeted monetary policy and bank lending behavior. *Journal of Financial Economics*, 142(1), 404-429.

Blommestein, H., Eijffinger, S.C.W. and Qian, Z., 2016. Regime-dependent determinants of Euro area sovereign CDS spreads. *Journal of Financial Stability*, 22, 10-21.

Blot, C., Creel, J., Hubert, P. and Labondance, F., 2020. The role of ECB monetary policy and financial stress on Eurozone sovereign yields. *Empirical Economics*, 59(3), 1189-1211.

Boysen-Hogrefe, J., 2017. Risk assessment on euro area government bond markets–The role of governance. *Journal of International Money and Finance*, 73, 104-117.

Buis, B., Pieterse-Bloem, M. Verschoor, W.F.C. and Zwinkels, R.C.J., 2020. Expected issuance fees and market liquidity. *Journal of Financial Markets*, 48, 100514

D'Agostino, A., and Ehrmann, M., 2014. The pricing of G7 sovereign bond spreads–The times, they are changing. *Journal of Banking & Finance*, 47, 155-176.

De Grauwe, P., 2013. The European Central Bank as lender of last resort in the government bond markets. *CESifo Economic Studies*, 59(3), 520-535.

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 Haan, J., Eijffinger, S.C.W. and Haller, S., 2005. The European Central Bank: Credibility, Transparency, and Centralization. CESifo book series, MIT Press, Cambridge Massachusetts.

De Pooter, M., Martin, R. F. and Pruitt, S., 2018. The liquidity effects of official bond market intervention. *Journal of Financial and Quantitative Analysis*, 53(1), 243-268.

De Santis, R. A., 2020. Impact of the asset purchase programme on euro area government bond yields using market news. *Economic Modelling*, 86, 192-209.

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 & Finance*, 50, 308-325.

Ditzen, J., Karavias, Y. and Westerlund, J., 2021. Testing and Estimating Structural Breaks in Time Series and Panel Data in Stata. arXiv:2110.14550v2

Dufour, A., Stancu, A. and Varotto, S., 2017. The equity-like behaviour of sovereign bonds. *Journal of International Financial Markets, Institutions and Money*, 48, 25-46.

Ecker, U.K.H., Lewandowsky, S., Cook, J., Schmid, P., Fazio, L.K., Brashier, N., Kendeou, P., Vraga, E.K. and Amazeen, M.A., 2022. The psychological drivers of misinformation belief and its resistance to correction. *Nature Reviews Psychology*, 1, 13-29.

Eijffinger, S.C.W., Kobielarz, M.L. and Uras, B.R., 2018. Sovereign default, exit and contagion in a monetary union. *Journal of International Economics*, 113, 1-19.

Eser, F. and Schwaab, B., 2016. Evaluating the impact of unconventional monetary policy measures: Empirical evidence from the ECB′ s Securities Markets Programme. *Journal of Financial Economics*, 119(1), 147-167.

Farinha, J. B. and Vidrago, J., 2021. The impact of the ECB's asset purchase programme on core and peripheral sovereign yields and its transmission channels. *Journal of Economic Asymmetries*, 24, e00213.

Falagiarda, M. and Reitz, S., 2015. Announcements of ECB unconventional programs: Implications for the sovereign spreads of stressed euro area countries. *Journal of International Money and Finance*, 53, 276-295.

Gibson, H. D., Hall, S. G. and Tavlas, G. S., 2015. Are all sovereigns equal? A test of the common determination of sovereign spreads in the euro area. *Empirical Economics*, 48(3), 939-949.

Giglio, S., 2016. Credit default swap spreads and systemic financial risk. *Working Paper* 15, ESRB.

Gödl, M. and Kleinert, J., 2016. Interest rate spreads in the eurozone: Fundamentals or sentiments? *Review of World Economics*, 152(3), 449-475.

Gómez-Puig, M., Sosvilla-Rivero, S. and del Carmen Ramos-Herrera, M., 2014. An update on EMU sovereign yield spread drivers in times of crisis: A panel data analysis. *North American Journal of Economics and Finance*, 30, 133–153.

Hakkio, C. S. and Keeton, W. R., 2009. Financial stress: What is it, how can it be measured, and why does it matter? *Federal Reserve Bank of Kansas City Economic Review*, second quarter, 5–50.

Jäger, J. and Grigoriadis, T., 2017. The effectiveness of the ECB's unconventional monetary policy: Comparative evidence from crisis and non-crisis Euro-area countries. *Journal of International Money and Finance*, 78, 21-43.

Karavias, Y., Westerlund, J. and Narayan, P., 2021. Structural Breaks in Interactive Effects Panels and the Stock Market Reaction to COVID-19. *Journal of Business & Economic Statistics*, online access

Kinateder, H. and Wagner, N., 2017. Quantitative easing and the pricing of EMU sovereign debt. *Quarterly Review of Economics and Finance*, 66, 1-12.

Klingler, S. and Lando, D., 2018. Safe haven CDS Premiums. *Review of Financial Studies*, 31(5), 1856–1895.

Krishnamurthy, A., Nagel, S. and Vissing-Jorgensen, A., 2018. ECB policies involving government bond purchases: Impact and channels. *Review of Finance*, 22(1), 1-44.

Lemke, W. and Werner, T., 2020. Dissecting long-term Bund yields in the run-up to the ECB's Public Sector Purchase Programme. *Journal of Banking & Finance*, 111, 105682.

Lucas, A., Schwaab, B. and Zhang, X., 2013. Conditional euro area sovereign default risk. *Working paper* 269. Sveriges Riksbank.

Klose, J. and Weigert, B., 2014. Sovereign yield spreads during the Euro-crisis: Fundamental factors versus redenomination risk. *International Finance*, 17, 25–50.

Maltritz, D., 2012. Determinants of sovereign yield spreads in the Eurozone: A Bayesian approach. *Journal of International Money and Finance*, 31(3), 657-672.

Mahieu, R.J. and Pieterse-Bloem, M., 2013. Factor decomposition and diversification in European corporate bond markets. *Journal of International Money and Finance*, 32, 194-213.

Manganelli, S. and Wolswijk, G., 2009. What drives spreads in the euro area government bond market? *Economic Policy*, 24(58), 191-240.

Monfort, A. and Renne, J. P., 2014. Decomposing euro-area sovereign spreads: credit and liquidity risks. *Review of Finance*, 18(6), 2103-2151.

O'Sullivan, C. and Papavassiliou, V. G., 2020. On the term structure of liquidity in the European sovereign bond market. *Journal of Banking and Finance,* 114, 105777.

Pelizzon, L., Subrahmanyam, M.G., Tomio, D. and Uno, J., 2016. Sovereign credit risk, liquidity, and ECB intervention: Deus ex machina? *Journal of Financial Economics,* 122, 86–115.

Pieterse-Bloem, M., Qian, Z., Verschoor, W.F.C. and Zwinkels, R.C.J., 2016. Time-varying importance of country and industry factors in European corporate bonds. *Journal of Empirical Finance*, 38, 429-448.

Polito, V. and Wickens, M., 2011. Assessing the fiscal stance in the European Union and the United States, 1970–2011. *Economic Policy,* 26, 599–647.

Polito, V. and Wickens, M., 2012. A model-based indicator of the fiscal stance. *European Economic Review*, 56, 526–551.

Ribeiro, P. P., Cermeño, R. and Curto, J. D., 2017. Sovereign bond markets and financial volatility dynamics: Panel-GARCH evidence for six euro area countries. *Finance Research Letters*, 21, 107-114.

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.

Schwarz, K. (2019). Mind the gap: Disentangling credit and liquidity in risk spreads. *Review of Finance*, 23(3), 557-597.

White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, 48, 817–838.

Appendix I: Complementary Tables and Figures

Table I.1. Correlations of Eurozone sovereign bond spreads, for January 1999-December 2021

Country	AUT	BEL	FIN	FRA	GRE	IRL	ITA	NDL	PRT	ESP
AUT	1.000									
BEL	0.886	1.000								
FIN	0.808	0.642	1.000							
FRA	0.814	0.886	0.603	1.000						
GRE	0.670	0.834	0.354	0.839	1.000					
IRL	0.711	0.878	0.459	0.703	0.765	1.000				
ITA	0.644	0.786	0.464	0.905	0.806	0.652	1.000			
NDL	0.872	0.759	0.824	0.728	0.525	0.628	0.577	1.000		
PRT	0.696	0.887	0.384	0.867	0.945	0.855	0.831	0.592	1.000	
ESP	0.648	0.819	0.403	0.875	0.876	0.780	0.898	0.627	0.913	1.000

Notes: The correlations are based on 276 monthly observations for each country's spread, expressed in percentages. Spreads are calculated according to Eqt. (3). In the Country columns, AUT is Austria, BEL is Belgium, FIN is Finland, FRA is France, GRE is Greece, IRL is Ireland, ITA is Italy, NDL is The Netherlands, PRT is Portugal and ESP is Spain. Source: Refinitiv DataStream

Table I.2a. Descriptive statistics for independent variables (for *i=10* countries)

Variables	Obs.	Mean	St. Dev.	Min	Max	P1	P99	Skew.	Kurt.
U	3036	9.164	4.612	3.1	27.9	3.3	26.1	1.793	6.609
EuroU	3036	9.337	1.345	7	12.2	7.2	12.2	0.458	2.343
INF	3036	1.757	1.391	-2.9	7.1	-1.8	5.3	0.042	3.435
EuroINF	3036	1.673	0.993	-0.6	5	-0.3	4.1	-0.014	3.181
DEF	2901	-3.177	4.769	-41.8	11	-16.7	6.3	-1.439	9.931
EuroDEF	2585	-3	2.274	-12.1	0.9	-9.467	0.4	-0.879	3.637
GOVDEBT	2919	84.824	34.763	23.64	209.753	27.508	184.374	0.805	3.575
EuroGOVDEBT	2849	80.924	10.507	66.011	99.989	66.565	99.104	-0.002	1.391
CAC	2822	0.14	5.888	-52.1	28.046	-14.84	11.521	-1.327	11.694
EuroCAC	3003	0.855	1.548	-2.492	3.944	-2.044	3.858	0.171	1.923
IPR	2750	0.178	3.981	-32.251	68.942	-11.687	11.669	2.948	61.092
MEI	2760	100.163	1.854	88.941	105.786	94.253	103.746	-1.167	6.272
DEBTOUT	3036	652000	721000	17322.83	2820000	22480.37	2560000	1.226	3.130
EuroDEBTOUT	3036	7250000	2420000	2960000	11859518	3010000	11707310	-0.295	1.999
PMI	1932	51.823	5.254	28.493	69.4	34.602	63.997	-0.698	5.090
CCI	3035	-11.678	13.747	-81.3	16.6	-66.4	9.7	-1.896	8.121
EuroCCI	3036	-10.595	5.169	-24.5	-0.8	-22.6	-1.5	-0.362	2.441
BANDEBT	3014	400.552	119.172	111.833	735.678	135.486	710.222	0.37	3.147
NFCDEBT	2486	165.332	57.293	33.098	375.222	43.149	349.651	0.94	4.686
HOUDEBT	2486	205.101	60.884	75.095	345.728	85.749	328.306	0.087	2.238
EXTDEBTBAN	2189	17.944	20.167	.436	152.018	0.94	110.711	3.226	16.025
EXTDEBTPUB	2189	14.095	7.791	.142	40.548	.249	35.354	0.787	3.361
EXTDEBTPRI	2189	38.771	40.655	2.424	284.968	2.683	246.641	3.134	14.913
STOCKR	2996	-0.002	0.06	-0.328	0.253	-0.184	0.145	-0.636	5.874
STOCKV	3035	0.013	0.007	0.003	0.064	0.004	0.041	2.165	9.702
GlobalSTOCKR	3036	0.003	0.044	-0.181	0.165	-0.121	0.13	-0.535	5.287
EuroCSPREAD	2849	1.264	0.791	0.302	4.6	0.411	4.396	1.934	7.443
EuroSTOCKR	3036	-0.001	0.053	-0.181	0.146	-0.168	0.122	-0.495	3.898
EuroSTOCKV	3036	23.796	9.114	12.172	63.272	12.642	57.767	1.594	6.026
GlobalSTOCKV	3036	20.142	8.253	10.125	62.639	10.264	57.737	1.987	9.061
RAT	2902	10.251	12.249	1	59	1	51	1.605	5.030
IBOXXFIN	3036	169.726	46.459	95.53	245.256	96.201	244.092	0.091	1.678
IBOXXNFC	3036	173.622	51.309	95.69	255.18	96.401	253.88	0.063	1.570
MOVE	3036	86.578	29.367	41.867	221.943	45.164	195.81	1.17	5.167
EuroINSTAB	352	41.039	12.606	12.56	59.227	12.56	59.227	-0.763	3.014
EPU	1656	124.814	70.148	11.287	597.936	33.27	380.179	2.027	8.981
EuroEPU	3036	157.129	70.653	47.692	433.277	54.993	392.831	0.803	3.785
GlobalEPU	3036	134.596	65.911	44.783	503.963	49.599	425.779	1.997	9.184
GlobalRISK	3036	2.086	0.681	0.688	3.36	0.829	3.277	0.182	1.890
GlobalKCFSI	3036	0.171	1.069	-0.902	5.621	-0.876	5.515	2.698	12.706

Notes: The *i=10* countries include Greece and is therefore constitutes the set of variables from Table 2, Panels A, B and C. Obs. is the number of observations, St. Dev. is the one standard deviation, Min and Max are the minimum and maximum values, P1 and P99 1 and 99 percentile values, Skew. is skewness and Kurt. is kurtosis. CBAN is not reported because this variable this specific to every country-pair in the Eurozone. Descriptive statistics for the set of CBAN variables are available upon request.

Table I.2b. Descriptive statistics for independent variables (for *i=9* countries)

Variables	Obs	Mean	St. Dev.	Min	Max	P1	P99	Skew.	Kurt.
U	2760	8.53	3.86	3.1	26.4	3.3	24.2	1.810	7.582
EuroU	2760	9.337	1.345	7	12.2	7.2	12.2	0.458	2.343
INF	2760	1.751	1.312	-2.9	7.1	-1.2	5.3	0.172	3.557
EuroINF	2760	1.673	0.993	-0.6	5	-0.3	4.1	-0.014	3.181
DEF	2628	-2.813	4.548	-41.8	11	-16.4	6.4	-1.622	12.09
EuroDEF	2350	-3	2.274	-12.1	0.9	-9.467	0.4	-0.879	3.637
GOVDEBT	2658	79.106	28.809	23.64	159.629	26.596	137.954	0.360	2.299
EuroGOVDEBT	2590	80.924	10.507	66.011	99.989	66.565	99.104	0.002	1.391
CAC	2587	0.759	5.579	-52.1	28.046	-11.487	11.693	-1.613	15.508
EuroCAC	2730	0.855	1.548	-2.492	3.944	-2.044	3.858	0.171	1.923
IPR	2750	0.178	3.981	-32.251	68.942	-11.687	11.669	2.948	61.092
MEI	2760	100.163	1.854	88.941	105.786	94.253	103.746	-1.167	6.272
DEBTOUT	2760	700000	738000	17322.83	2820000	21854.381	2600083	1.091	2.797
EuroDEBTOUT	2760	7250000	2420000	2960000	11859518	3010000	11707310	-0.295	1.999
PMI	1932	51.823	5.254	28.493	69.4	34.602	63.997	-0.698	5.090
CCI	2760	-9.061	9.392	-47.9	16.6	-38.2	10.1	-0.769	4.159
EuroCCI	2760	-10.595	5.169	-24.5	-0.8	-22.6	-1.5	-0.362	2.441
BANDEBT	2740	408.45	117.079	113.153	735.678	153.552	710.562	0.458	3.094
NFCDEBT	2260	164.521	58.969	33.098	375.222	42.168	350.689	0.971	4.620
HOUDEBT	2260	206.847	60.987	75.095	345.728	88.628	329.153	0.108	2.221
EXTDEBTBAN	1990	19.164	20.727	2.363	152.018	2.558	112.142	3.119	15.027
EXTDEBTPUB	1990	14.274	6.766	4.445	40.548	4.923	34.923	1.008	3.692
EXTDEBTPRI	1990	41.142	41.716	5.053	284.968	8.836	250.469	3.053	14.058
STOCKR	2724	-0.001	0.057	-0.328	0.253	-0.175	0.134	-0.624	5.850
STOCKV	2760	0.012	0.007	0.003	0.061	0.004	0.041	2.260	10.342
GlobalSTOCKR	2760	0.003	0.044	-0.181	.165	-0.121	0.13	-0.535	5.287
EuroCSPREAD	2590	1.264	0.791	0.302	4.6	0.411	4.396	1.934	7.443
EuroSTOCKR	2760	-0.001	0.053	-0.181	.146	-0.168	.122	-0.495	3.898
EuroSTOCKV	2760	23.796	9.114	12.172	63.272	12.642	57.767	1.594	6.026
GlobalSTOCKV	2760	20.142	8.253	10.125	62.639	10.264	57.737	1.987	9.061
RAT	2760	7.792	9.376	1	34	1	34	1.513	4.036
IBOXXFIN	2760	169.726	46.46	95.53	245.256	96.201	244.092	0.091	1.678
IBOXXNFC	2760	173.622	51.31	95.69	255.18	96.401	253.88	0.063	1.57
MOVE	2760	86.578	29.367	41.867	221.943	45.164	195.81	1.170	5.167
EuroINSTAB	320	41.039	12.608	12.56	59.227	12.56	59.227	-0.763	3.014
EPU	1380	130.457	74.557	11.287	597.936	31.984	397.716	1.834	7.826
EuroEPU	2760	157.129	70.655	47.692	433.277	54.993	392.831	0.803	3.785
GlobalEPU	2760	134.596	65.912	44.783	503.963	49.599	425.779	1.997	9.184
GlobalRISK	2760	2.086	0.681	0.688	3.36	0.829	3.277	0.182	1.890
GlobalKCFSI	2760	0.171	1.069	-0.902	5.621	-0.876	5.515	2.698	12.706
FEDFR	2760	1.79	1.961	0.125	6.5	0.125	6.5	0.995	2.645
DFRATE	2760	1.269	1.719	-0.5	4.75	-0.5	4.75	0.548	1.796
FEDECB	2760	0.521	1.276	-2.25	2.775	-2.25	2.775	0.011	2.208
CDS	2366	0.669	1.06	0.021	10.041	.027	5.135	3.927	24.18
LIQUIDITY	2357	0.197	.371	-0.814	3.797	-.038	2.23	5.463	38.356
STOCK	2724	-0.017	.145	-1.991	.866	-.647	0.288	-4.211	42.308
REER	2760	99.107	4.541	80.2	115.26	85.5	108.14	-0.635	4.301
TARGET2	2520	-0.181	.0669	-3.438	1.378	-2.077	1.207	-0.816	4.979
MRO	2270	5244.784	91066.761	-1	3900000	-1	89999.992	35.939	1488.616
LTRO	2270	15471.475	541000	-1	23399998	-0.62	3.229	39.10	1609.025
QE	1490	0.056	0.154	-0.047	1.416	-0.03	0.914	6.124	48.174

Notes: The *i=9* countries exclude Greece and add variables from Table 2, Panels D and E to the set. Obs. is the number of observations, St. Dev. is the one standard deviation, Min and Max are the minimum and maximum values, P1 and P99 1 and 99 percentile values, Skew. is skewness and Kurt. is kurtosis. CBAN is not reported because this variable this specific to every country-pair in the Eurozone. Descriptive statistics for the set of CBAN variables are available upon request.

Table I.3: Results of regression of all Macro Fundamental-based factor variables on *SPR* for period 1999-2012, for *i=10* countries

U	2.719**	(3.55)
EuroU	-12.22	(-1.64)
INF	0.971	(2.06)
EuroINF	-8.136	(-1.92)
DEF	0.0795	(1.01)
EuroDEF	-0.890	(-0.87)
GOVDEBT	0.0418	(1.48)
EuroGOVDEBT	0.854	(1.58)
CAC	-0.0661	(-0.26)
EuroCAC	1.397	(0.57)
IPR	0.148**	(3.02)
MEI	-0.101	(-0.12)
DEBTOUT	0.0000271	(2.07)
EuroDEBTOUT	-0.00000417	(-2.68)
PMI	-0.0278	(-0.17)
CCI	-0.113***	(-5.16)
EuroCCI	-0.858	(-1.76)
BANDEBT	-0.0688	(-1.09)
NFCDEBT	0.213***	(6.15)
HOUDEBT	0.279***	(9.38)
EXTDEBTBAN	0.354	(1.05)
EXTDEBTPUB	0.355**	(3.75)
EXTDEBTPRI	0.739***	(5.19)
STOCKR	-9.097	(-1.75)
STOCKV	102.3**	(3.04)
GlobalSTOCKR	-6.662	(-1.04)
EuroCSPREAD	1.858	(0.93)
EuroSTOCKR	20.53	(1.68)
EuroSTOCKV	0.0439	(0.33)
GlobalSTOCKV	-0.212*	(-2.46)
RAT	0.191	(1.89)
IBOXXFIN	-0.676	(-1.43)
IBOXXNFC	0.695	(1.26)
MOVE	0.0191	(0.69)
EuroINSTAB	-0.0153	(-0.29)
EPU	-0.00229	(-0.73)
EuroEPU	0.00632	* (2.13)
GlobalEPU	0.00409	(1.08)

GlobalRISK	2.319	(1.33)
GlobalKCFSI	-4.217	(-1.42)
Constant	-95.24	(-1.37)
R^2	0.841	

Notes: FE regression results of regression of all variables for macro-fundamental factors (listed in Table 2, Panels A, B and C). In the ordinary brackets below the parameter estimates are the corresponding z-statistics, computed using White (1980)'s heteroskedasticity-robust standard errors. *** , ** and * indicate significance at 1%, 5% and 10%, respectively.

Table I.4. Best specifications for Macro Fundamental-based model for 1999-2012 (Model 1 in Table 3), estimated with and without heteroskedasticity-robust standard errors

Model 1	Coefficient	Homoskedastic SE	Heteroskedastic SE
RAT	0.271	4.20***	23.97***
MOVE	0.005	2.68**	3.47***
CAC	-0.082	-1.17	-3.31***
DEF	0.038	1.89*	3.24***
DEBTOUT	-0.00	-1.50	-4.47***
BANDEBT	771.7	3.67***	12.27***
EuroGOVDEBT	0.052	1.74	5.67***
EXTDEBTPUB	-0.118	-2.46**	-9.67***
Constant	-6.659	-3.35***	-9.67***
R^2		0.826	0.826

Notes: FE regression results. Estimated coefficients in the first column and their corresponding z-statistics computed using White (1980)'s heteroskedasticity-robust standard errors in column 'Homoskedastic SE' and in column 'Heteroskedastic SE' when it is not used. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table I.5. Best specifications for Macro Fundamental-based model for two country groups

Panel A:	Model 4		Model 5		Model 6	
Core	1999-2012	2013-2021	1999-2009	2013-2021	2009-2012	2013-2021
RAT	0.0646	-0.003			0.0108	-0.014
	(1.62)	(-0.10)			(0.19)	(-0.70)
EuroEPU	0.000805	-0.0001			-0.0006*	-0.0000
	(1.36)	(-0.95)			(-2.25)	(-0.45)
EuroCSPREAD	0.171***	0.244***			0.367**	0.254**
	(9.98)	(4.68)			(4.05)	(4.35)
MOVE			0.001	0.00158		
			(1.88)	(1.77)		
EuroSTOCKV			0.015***	0.00132		
			(8.85)	(0.77)		
GlobalRISK	-0.242*	-0.073	-0.097**	-0.120	0.123	-0.069
	(-2.41)	(-1.25)	(-4.26)	(-1.56)	(1.26)	(-1.39)
CAC					0.008	-0.004
					(0.26)	(-2.09)
GOVDEBT	-0.0131*	0.003	-0.003	0.001	0.048**	0.00211
	(-2.49)	(0.66)	(-0.34)	(0.44)	(3.95)	(0.56)
DEBTOUT	0.0000***	-0.0000*	-8.30e-08	-9.99e-08**	0.0000008*	-0.0000002*
	(4.65)	(-2.16)	(-0.80)	(-2.84)	(2.34)	(-2.25)
U					-0.137	0.038*
					(-0.98)	(2.14)
EuroGOVDEBT	0.0244***	-0.007	0.0221*	-0.009*	-0.042**	-0.015**
	(5.63)	(-1.74)	(2.44)	(-2.56)	(-2.97)	(-2.51)

EuroDEBTOUT	-0.000*** (-4.48)	2.82e-08 (1.52)	-1.02e-08 (-0.60)	1.12e-08 (1.12)	8.49e-08 (1.60)	5.78e-08* (2.71)
EXTDEBTPRI	0.007** (3.31)	-0.000841 (-0.57)	0.003*** (5.26)	-0.001 (-0.76)	-0.008 (-0.74)	-0.002 (-1.55)
EXTDEBTBAN	-0.013** (-3.28)	0.009* (3.88)	-0.002 (-1.80)	0.011*** (6.13)	-0.028** (-4.01)	0.007** (3.00)
Constant	-0.155 (-0.29)	0.564 (1.74)	-1.402*** (-6.07)	1.162** (4.51)	0.422 (0.19)	0.855* (2.70)
R^2	0.814	0.433	0.818	0.284	0.679	0.477

Panel B:	Model 7		Model 8		Model 9	
Periphery	1999-2012	2013-2021	1999-2009	2013-2021	2009-2012	2013-2021
STOCKV	4.649 (0.59)	19.77 (0.80)			7.457 (0.50)	19.77 (0.80)
EuroCSPREAD	0.260 (1.19)	0.235 (0.45)	0.330*** (6.84)	0.796** (2.92)	2.157 (1.75)	0.235 (0.45)
CAC			-0.013 (-0.90)	0.001 (0.08)		
U	0.135** (2.96)	0.105 (1.31)			0.630* (2.30)	0.105 (1.31)
GOVDEBT	0.055 (1.20)	-0.074 (-1.53)	0.040** (3.61)	-0.084* (-2.51)	0.173* (2.46)	-0.074 (-1.53)
BANDEBT	1639.9* (2.40)	529.8 (0.55)			1246.7 (1.07)	529.8 (0.55)
NFCDEBT	-1309.6 (-1.01)	-24.25 (-0.02)	-15.76 (-0.19)	1646.7* (2.45)	-3730.3*** (-34.72)	-24.25 (-0.02)
EuroCAC			0.069 (2.02)	0.297 (1.27)		
EuroGOVDEBT	-0.140 (-2.00)	0.021 (0.32)	-0.031** (-2.97)	0.045 (1.21)	-0.854 (-1.92)	0.0207 (0.32)
EXTDEBTPUB	-0.433*** (-9.39)	0.004 (0.04)			-0.535** (-3.63)	0.004 (0.04)
EXTDEBTPRI	-0.009 (-0.80)	0.007 (0.23)			0.215 (1.71)	0.007 (0.23)
EXTDEBTBAN			-0.005 (-1.79)	0.009 (0.13)		
Constant	5.917 (1.80)	4.760*** (5.94)	-0.612 (-1.58)	3.613** (2.49)	42.56 (1.49)	4.760**** (5.94)
R^2	0.840	0.603	0.910	0.590	0.734	0.609

Notes: FE regression results. In the ordinary brackets below the parameter estimates are the corresponding z-statistics, computed using White (1980)'s heteroskedasticity-robust standard errors. ***, ** and * indicate significance at 1%, 5% and 10%, respectively. Models 4 and 7 have been optimized for the interval 1999-2012, Models 5 and 8 for 1999-2009 and Models 6 and 9 for 2012-2021.

Table I.6: Nine specifications for Market Risk-based models, with different combinations of risk factor variables

Regime	January 1999 – July 2010			August 2010 – December 2013			January 2014 – December 2021		
Models	1	2	3	4	5	6	7	8	9
CDS	0.924*** (10.38)	0.776*** (12.66)	0.774*** (14.01)	1.040*** (11.55)	1.027*** (10.63)	1.055*** (10.33)	0.962*** (11.55)	0.944*** (12.06)	0.940*** (11.48)
LIQUIDITY	0.107** (3.09)	0.137*** (4.06)	0.132** (2.78)	0.239*** (5.58)	0.249* (1.94)	0.224*** (4.52)	0.435 (1.52)	0.656* (2.13)	0.581* (1.91)
DFRATE	0.0345*** (7.25)			-0.326 (-1.52)			-0.429** (-2.95)		
FEDFR		0.00723* (2.01)			0 (.)			0.0903** (3.23)	
FEDECB			-0.0143** (-2.87)			0.555** (3.22)			0.103*** (3.96)
GlobalSTOCKV	0.001 (0.60)								
EuroSTOCKV		0.003*** (4.11)							-0.000556 (-0.26)
STOCKV						-6.127 (-0.84)			
STOCKR					0.171 (0.51)				
MOVE				-0.00687** (-4.11)				-0.00348* (-3.26)	
STOCK			-0.113*** (-8.50)				-0.0714* (-2.66)		
TARGET2		-0.261*** (-5.21)	-0.265*** (-5.12)	-0.338*** (-3.83)		-0.333*** (-3.71)	-0.178 (-1.77)	-0.177 (-1.69)	-0.189 (-1.72)
REER	-0.001 (-0.24)				0.00776 (0.22)				
Constant	-0.024 (-0.07)	-0.0837* (-3.35)	-0.006 (-0.38)	0.554*** (5.06)	-0.651 (-0.19)	0.0351 (0.28)	-0.185 (-1.63)	0.0999* (1.90)	-0.147 (-1.71)

R^2	0.920	0.925	0.927	0.880	0.854	0.875	0.731	0.769	0.761

Notes: FE regression results. In the ordinary brackets below the parameter estimates are the corresponding z-statistics, computed using White (1980)'s heteroskedasticity-robust standard errors. *** , ** and * indicate significance at 1%, 5% and 10%, respectively.

Table I.7: Specifications for best-fit extended baseline Market Risk-based models, with five combinations of ECB monetary policy variables

Regime:	1	2	3	1	2	3	1	2	3
Model:		**(1)**			**(2)**			**(3)**	
Variables included:		MRO LTRO QE			MRO LTRO			MRO QE	
CDS	0.773*** (12.98)	1.055*** (12.23)	0.965*** (13.08)	0.773*** (12.98)	1.040*** (11.14)	0.949*** (11.58)	0.773*** (13.00)	1.055*** (12.24)	0.965*** (13.10)
LIQUIDITY	0.136** (2.79)	0.225*** (4.08)	0.586* (2.15)	0.136** (2.79)	0.258*** (5.00)	0.536* (1.87)	0.136** (2.79)	0.225*** (4.08)	0.586* (2.15)
ECBFED	-0.009* (-1.95)	0.429 (1.76)	0.0817** (2.97)	-0.009* (-1.95)	0.649** (2.71)	0.104*** (3.44)	-0.009* (-1.95)	0.432 (1.78)	0.0816** (2.97)
STOCK	-0.119*** (-7.50)	-0.475** (-2.54)	-0.064** (-2.40)	-0.119*** (-7.50)	-0.228 (-1.55)	-0.051 (-1.61)	-0.119*** (-7.50)	-0.479** (-2.59)	-0.064** (-2.42)
TARGET2	-0.289*** (-5.59)	-0.335*** (-3.68)	-0.168 (-1.66)	-0.289*** (-5.59)	-0.334*** (-3.72)	-0.187 (-1.75)	-0.289*** (-5.59)	-0.335*** (-3.68)	-0.168 (-1.66)
MRO	6.77e-09 (0.18)	0.000** (2.32)	-0.000** (-3.09)	6.77e-09 (0.18)	0.000** (2.38)	-0.000** (-2.67)	6.85e-09 (0.19)	-6.32e-08** (-3.14)	-0.00** (-3.09)
LTRO	3.88e-08 (0.41)	-3.05e-08*** (-4.01)	7.03e-09 (1.85)	3.88e-08 (0.41)	-3.07e-08*** (-4.08)	4.54e-09 (1.25)			
QE		-1.348** (-2.91)	-1.210*** (-4.26)					-1.349** (-2.92)	-1.209*** (-4.26)
Constant	-0.016 (-0.98)	-0.032 (-0.23)	-0.104 (-1.04)	-0.016 (-0.98)	-0.024 (-0.16)	-0.155 (-1.42)	-0.016 (-0.98)	-0.031 (-0.22)	-0.103 (-1.04)
R^2	0.931	0.879	0.782	0.931	0.876	0.763	0.931	0.879	0.782

Table I.7 (cntd).

Regime:	1	2	3	1	2	3
Model:		**(4)**			**(5)**	
Variables included:		LTRO QE			QE	
CDS	0.773*** (12.99)	1.055*** (12.24)	0.963*** (12.82)	0.774*** (14.01)	1.056*** (12.28)	0.963*** (12.84)
LIQUIDITY	0.136** (2.79)	0.225*** (4.09)	0.592* (2.16)	0.132*** (2.78)	0.224*** (4.06)	0.592* (2.16)
ECBFED	-0.009* (-1.95)	0.431 (1.77)	0.081** (2.97)	-0.014*** (-2.87)	0.431 (1.78)	0.081** (2.97)
STOCK	-0.119*** (-7.49)	-0.477** (-2.57)	-0.064** (-2.40)	-0.113*** (-8.50)	-0.482** (-2.63)	-0.064** (-2.42)
TARGET2	-0.289*** (-5.59)	-0.335*** (-3.69)	-0.168 (-1.66)	-0.265*** (-5.12)	-0.335*** (-3.70)	-0.168 (-1.66)
MRO						
LTRO	3.89e-08 (0.41)	-1.30e-08*** (-42.38)	7.20e-09* (1.89)			
QE		-1.348** (-2.92)	-1.223*** (-4.26)		-1.349** (-2.92)	-1.222*** (-4.25)
Constant	-0.016 (-0.98)	-0.032 (-0.22)	-0.105 (-1.05)	-0.006 (-0.94)	-0.033 (-0.23)	-0.105 (-1.05)
R^2	0.931	0.879	0.781	0.927	0.879	0.781

Notes: FE regression results for extension of the Model shown in Table 9 with different combinations of ECB monetary policy variables. In the ordinary brackets below the parameter estimates are the corresponding z-statistics, computed using White (1980)'s heteroskedasticity-robust standard errors. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Appendix II. Robustness checks for Macro Fundamental-based model

Table II.1: Best specifications for Macro Fundamental-based model, for 1999-2012 and extended to 2013-2021 for *i=9* countries (without Greece)

	Model 1		Model 2		Model 3	
	1999-2012	2013-2021	1999-2009	2013-2021	2009-2012	2013-2021
RAT	0.201***	0.0645				
	(5.15)	(1.05)				
STOCKV			-8.250***	15.66***	10.27	9.004**
			(-6.08)	(3.76)	(0.61)	(2.32)
EuroCCI					0.104	-0.00780
					(1.79)	(-0.80)
MOVE	0.00572***	0.00122			-0.0110	0.000373
	(5.10)	(0.63)			(-1.59)	(0.28)
EuroCSPREAD					1.433**	0.573**
					(3.07)	(3.29)
EuroSTOCKV			0.0269***	-0.00715	-0.0411***	-0.0188**
			(14.79)	(-1.43)	(-3.81)	(-2.95)
CAC	0.0148	0.000488				
	(0.63)	(0.34)				
DEF	-0.00547	-0.00576	-0.00693**	-0.00403	0.0155	-0.00707
	(-0.28)	(-1.07)	(-2.44)	(-0.56)	(1.07)	(-1.77)
GOVDEBT					0.0957	-0.00135
					(1.50)	(-0.23)
DEBTOUT	-0.00000197	-0.000000245	-1.40e-08	6.87e-08		
	(-1.57)	(-1.03)	(-0.08)	(0.26)		
BANDEBT	0.0042*	0.00389**				
	(1.99)	(2.69)				
HOUDEBT			0.00134***	0.00343*	0.0693***	0.00164
			(3.44)	(2.32)	(3.61)	(0.55)
NFCDEBT					-0.0193	0.00206
					(-1.38)	(0.51)
INF			-0.0128	0.179***	0.363	0.152**
			(-0.76)	(3.44)	(1.75)	(2.79)
U			0.0510	0.140**	0.193	0.135**
			(1.41)	(3.15)	(0.79)	(2.74)
EuroDEF					-0.0335	-0.0174
					(-0.76)	(-1.06)
EuroGOVDEBT	0.0546**	-0.0123			-0.0687	-0.0213
	(2.70)	(-1.00)			(-0.62)	(-1.21)
EXTDEBTPUB	-0.0584*	-0.0227	0.0388*	-0.0214	-0.0614*	-0.0138
	(-2.10)	(-1.53)	(2.02)	(-1.59)	(-2.24)	(-1.09)
Constant	-4.966***	-0.117	-1.441***	-1.169**	-13.61***	0.464
	(-5.19)	(-0.09)	(-3.95)	(-3.15)	(-3.82)	(0.37)
R^2	0.818	0.436	0.773	0.543	0.691	0.633

Notes: FE regression results for Specification of Macro Fundamental-based Model shown in Table 3, but here for *i=9* countries (without Greece). In the ordinary brackets below the parameter estimates are the corresponding z-statistics, computed using White (1980)'s heteroskedasticity-robust standard errors. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

For robustness we check if inclusion or exclusion of Greece makes a significant difference. We can do so for results reported in sections 6.1 and 6.2, as we have the Greek data available for these results. We cannot do this for results reported in sections 6.3 and 6.4, as the Greek CDS have gaps.

In Section 6.1 we report our best-fit specification of the Market Fundamental-based model in Table 3 for all countries. We report results for the same best-fit specification in Table II.1 above without Greece. Focussing on Model 1, it can be seen that results are very similar and that specification with Greece has slightly less explanatory power. The most notable difference is in variables indicating the fiscal position of the government and the bank sector. Specifically, the government debt (*DEF*) no longer carries any explanation for spreads without Greece. Also, the amount of debt in the banking sector (*BANDEBT*) and external debt of the public sector (*EXTDEBTPUB*) are less significant. The government debt ratio for the Eurozone is in the specification with Greece significant whereas without Greece is it not. We can conclude that results are fairly robust for Greece, but that this country does affect the significance of variables to do debt increase of the government and debt stocks in the banking and government sectors.

In Section 6.2 we report results of our sequential breakpoint test in the dynamics of spreads for Eurozone countries excluding Greece (in Table 6) and for sequential estimation to associate the identified breakpoints with dates (Table 7) for the set excluding Greece. If we include Greece, then results for Table 6 are not so significantly different that they are worthwhile to report here. For our sequential estimation we do find somewhat different results which we are reporting in Table II.2. The month associated with the first four breakpoints occurs if we include Greece some 3 to 4 months earlier than in the case of the other nine Eurozone countries. For the first two breakpoint the range is also significantly wider. Breakpoints 3 and 4 still have the smallest range of 3 months, implying that these remain the two major breakpoints. In the case of all Eurozone countries including Greece these breakpoints are in May 2010 and October 2013 rather than in August 2010 and January 2014. We conclude that, overall, results from our breakpoint test are robust for the set of Eurozone countries, but that the three-month earlier occurrence of the major breakpoints shows that Greece led the Eurozone in and out of the sovereign debt crisis.

Table II.2. Results from sequential estimation, for *i=10* countries (with Greece)

Breakpoints	Date	[95% conf. interval]	
1	May 2002	Jan 1989	Sep 2015
2	Dec 2006	Jan 2006	Nov 2011
3	May 2010	Apr 2010	Jun 2010
4	Oct 2013	Sep 2013	Nov 2013
5	Nov 2017	Dec 2016	Oct 2018