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Abstract

This paper explores the determinants of sovereign interest rate spreads of euro area countries (vis-à-vis Germany), using panel regressions with annual data for 2000-2019. It focuses on the role of fundamental factors, namely fiscal, macroeconomic and institutional variables, while considering also some contextual factors such as global risk aversion and controlling for the influence of central banks' asset purchases. Through extensive testing of various (fiscal) variables, interactions and non-linearities, the analysis confirms that sovereign spreads respond to fundamental variables, especially the government debt, indicating that such response is non-linear. The results also show that structural factors, such as potential growth and the quality of institutions, can largely mitigate the impact from government debt on spreads. Indeed, in countries with the highest potential growth and strongest institutions, the marginal effect of government debt on spreads would be close to zero. From a policy angle, the results are a reminder that, even in an environment of persistently low rates, more solid fundamentals allow governments to benefit from lower borrowing costs and less risk exposure. They also highlight that policies aimed at reinforcing potential growth and government effectiveness can be expected to improve investors' perception of sovereign risk and their forbearance of higher debt.

JEL Classification: H63, E43, E62, C23, O52.

Keywords: interest rates, sovereign bond spreads, government debt, sovereign risk, debt sustainability.

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CONTENTS

1. INTRODUCTION

Interest rates paid by governments on their debts have fallen for decades, but cross-country differentials between those rates have behaved idiosyncratically. This is conspicuous in Europe, particularly within the euro area. Differentials between yields on euro area government bonds, also known as spreads, fell in the early years of the Economic and Monetary Union (EMU), shot up in the financial and debt crisis, and since then have hovered at non-negligible levels. There are recurrent market spikes such as those affecting Greece in 2015, Italy in 2018, and vulnerable countries across the board at the onset of the Covid-19 crisis in March 2020. More generally, some authors argue that the volatility of spreads has recently increased in advanced economies (Born et al., 2020).

In this paper, we investigate the relationships between spreads on euro area government bonds and fundamental factors. A casual look at the data suggests that spreads are correlated with fundamental characteristics, such as public debt levels. However, that influence is unlikely to obey simple laws, making it a challenge to capture in empirical work (De Haan et al., 2014). Building on the existing literature, we conjecture that fundamental conditions likely to affect spreads (henceforth, spread fundamentals) are of three main kinds: fiscal, macroeconomic (including external), and institutional. Moreover, 'context' variables are considered, measuring financial market conditions (e.g. through indicators capturing international risk aversion) and the role of monetary policy, including the Eurosystem programme of government securities purchases.

Relative to the existing empirical literature (see for instance Capelle Blancard et al., 2019), our contribution is two-fold. Firstly, we focus on euro area economies with an up-to-date (but pre-Covid) evaluation.[1] Many papers consider a broader set of countries. Drivers of spreads may be more homogenous within the euro area, where there are specific institutional reasons to expect spreads to reflect fundamental factors. Moreover, our work encompasses the full post- global financial crisis period of the 2010s, expanding the time span in comparison to earlier estimates and including the recent regime of 'persistent spreads'. Secondly, our paper considers the variety of ways through which fundamental factors can affect spreads, emphasising that the influence of fundamentals may be non-linear and context-dependent. It may involve interactions between fundamentals, as well as between fundamentals and contextual factors such as global risk aversion. We examine all these possibilities, paying also attention to pitfalls in estimation.

Using panel data, we estimate various specifications involving inter alia government debt, the external position, potential growth, and the quality of institutions. Variables representative of global risk environment, monetary policy conditions and official lending policies are also tested, both autonomously and in combination with fundamental variables. As suits an examination of fundamental drivers, we use annual data covering the twenty year-period (2000-2019) since the inception of EMU.

We find clear evidence that euro area spreads respond to fundamental variables, especially government debt, through several channels. Higher government debt significantly contributes to higher spreads, with strong indications that this effect is non-linear. That is, the marginal effect of additional debt on spreads increases with the level of debt. This result is robust to specification choices, e.g. presence or not of country fixed effects, although the magnitude of the effect is sample-dependent. We also find effects from other fundamental factors, including in combination with government debt. Importantly, the results show that structural factors, such as potential growth and the quality of institutions, can largely mitigate the impact from government debt on spreads. Global risk aversion affects spreads as well, both on its own and interacting with high debt levels. Finally, the regressions point to a possible influence of the Eurosystem's interventions on government long-term interest rates' spreads.[2]

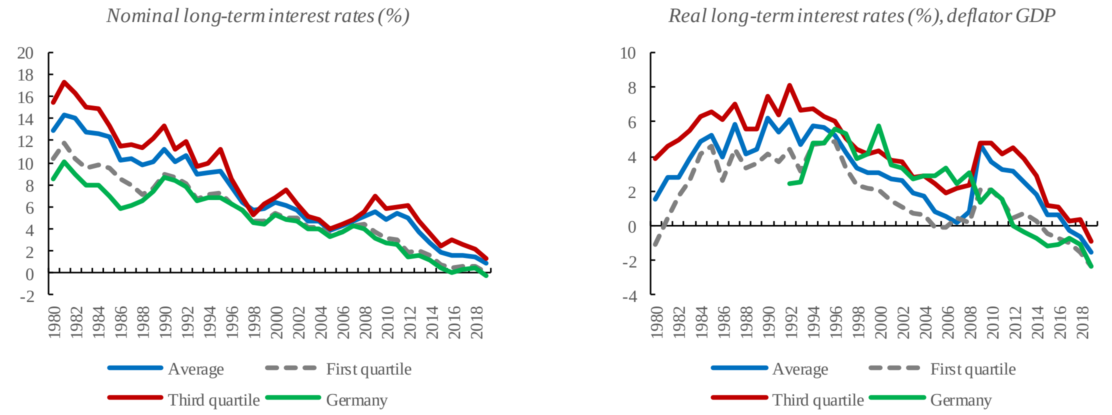
[1] See European Commission, 2011 for earlier attempts to estimate spreads' regressions. In a more recent paper, Ortmans and Tripier, 2020 look at the dynamic response of sovereign bond spreads to the COVID-19 pandemic outbreak in the euro area.
[2] The relatively weaker statistical evidence of these results could be driven by the low data frequency, as it is well established in the literature that the asset purchases have been a significant determinant of sovereign yields in the euro during the recent years (recent references include e.g. Afonso and Jelles, 2019, de Santis, 2020).

The rest of the paper is organised as follows. Section 2 sets the scene by surveying the evolution of interest rates on government bonds and spreads over the past decades. Section 3 reviews the empirical literature on the determinants of government spreads and presents our empirical estimation strategy. Section 4 exposes the main estimation results, stressing the role of government debt in explaining spreads in a non-linear fashion, together with other fundamentals and presents robustness tests and alternative specifications. Section 5 concludes.

2. DEVELOPMENTS IN GOVERNMENT INTEREST RATES AND SPREADS

Interest rates have fallen across the board since the early 1980s. [3] Lower nominal rates have come along with declining inflation, but real interest rates also have receded dramatically. On average, ten-year nominal rates on EU government bonds have fallen by over 10 percentage points since the early 1980s. Real rates have fallen by about 5 percentage points since the early 1990s (see Graph 1).

Graph 1. **Long-term interest rates on 10-year government bonds, nominal and real**, EU countries (%)



Source: Ameco, authors' calculations.

At the global level, the fall in interest rates has triggered an intense debate about its underlying causes. The prevailing approach interprets the real interest rates as the equilibrating factor in a saving investment framework, and its decline as reflecting positive shifts in savings propensities, negative shifts in desired investment, or a combination of both. Candidate explanations include demography and ageing; the emergence of thrifty nations; rising inequality; sluggish productivity; less capital-intensive growth; and a decline in the relative price of investment (for more details, see Box 1). The emphasis on real saving and investment factors is not universally accepted. For instance, another approach stresses the role of finance and monetary policy (Borio et al., 2019; OECD, 2017). In this view, monetary policy choices drove down market rates through their influences on financial leverage and boom bust cycles. The implications for interest rates prospects and policy prescriptions differ markedly from the common approach. [4] (for more details, see Box 1) A related debate that erupted, notably with the seminal Blanchard (2019) paper, concerns the interest – growth rate differential that would appear more frequently negative than traditionally thought, also reflecting the trend decline in interest rates. [5]

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[3] Interest rates refer here to long-term interest rates on 10-year government bonds (see also Table A2 in the annex for data sources used in the paper). The trend decline visible in the graph likely applies to all maturities. Long-term interest rates are the most relevant for government funding, since sovereign debt with maturities above 5 years constitute a significant share of bond markets and a reference for other interest rates.

[4] The two approaches may be opposed, but also provide complementary insights. Some papers can be read in this light. For instance, the leveraging cycle may be a major contributor to shifts in risk aversion and thereby demand for safe assets (Gourinchas and Rey, 2018).

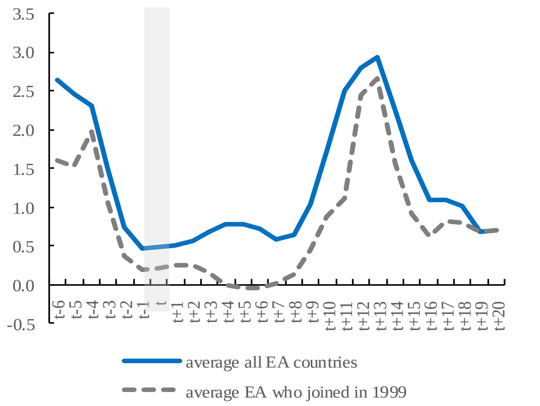
[5] The empirical evidence on this phenomenon has however been challenged by other papers (e.g. ECB, 2019).

The fall in government bond yields has occurred together with a large increase in public indebtedness. As a matter of principle, the causality can of course run two ways. As contracting new debt appears affordable in a low interest rate environment, lower borrowing costs may have incentivised governments to raise their debts (see European Commission, 2021); similarly, low interest rates may have constituted a disincentive to adjust public balance sheets, fostering deleveraging forbearance or only slow debt reduction. The reverse causality, the expected positive effect of higher debt triggering higher interest rates, is not directly visible in the data. Nonetheless, it could be that interest rates would be even lower had governments pursued more conservative debt policies (Rachel and Summers, 2019).

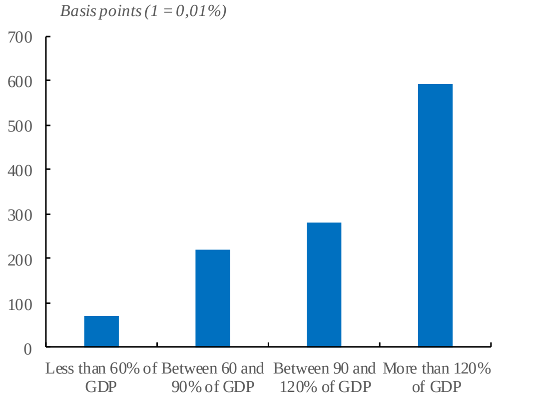
The links between the fundamentals of a country and its borrowing costs are far clearer when looking at what countries pay for their debt in relative terms, i.e., in terms of bond spreads. A rapid inspection of the data suggests that such links exist specifically in the euro area, when government interest rates are measured relative to the German Bund, the de facto safe government bond in the area. The evidence pictured in Graph 2 highlights the known ups and downs of government bond spreads since the inception of EMU, first converging towards minimal levels and then spiking in the global financial crisis, when pubic debts rose steeply and worries about their sustainability swelled. Spreads have largely reversed following the 'whatever it takes' pronouncement by the President of the European central bank (ECB) in the summer of 2012 and the ensuing ECB announcement and policies (such as the programme of Outright monetary operations and Quantitative Easing). Interestingly however, spreads have remained non-negligible in recent years.[6] A simple look at the evidence suggests the existence of a relationship between these spreads and the debt position. While there are instances of high spreads without high public debts (but possibly reflecting other problems), a high debt is almost always associated with a significant spread.

Graph 2. **Government spreads' developments and their relation to government debt level, euro area countries**

Governement long-term interest rates' spreads – average before / after the euro introduction (pps.)



Governement long-term interest rates' spreads and government debt level (2000-19)



Note: 1) The left panel graph represents the (non-weighted) average nominal spreads on 10-year government bonds (vis-à-vis German yields) calculated, respectively, over all euro area members and those who joined the euro area in 1999, i.e. Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. Year t represents the year when the euro was introduced. 2) The right panel graph represents the average spreads depending on the government debt to GDP ratio level (calculated over all EA countries on data since 2000).

Source: Ameco, ECB, authors' calculations.

Put shortly, not all government debts are created equal in the euro area. While all governments have seen their borrowing rates fall in line with the global fall in the risk free rate and a high degree of capital market integration, significant spreads have persisted on the debt issuances of sovereigns with

[6] Moreover, there have been recurrent bouts of increases in the spreads of vulnerable countries triggered by 'news' considered worrying for fiscal sustainability. For instance the extreme stress over Greece in 2015, but also the jitters that affected Italy at various moments, especially in 2018 following the access to power of new political forces, Portugal in the early days of the government elected in 2015, or even France in the run-up to the presidential elections in 2017. Our study focuses on the average effects of fundamentals on spreads rather than on explaining the high-frequency fluctuations of spreads associated with such news and other events. Reconciling the two may nonetheless be interesting, and the dynamic specification of our panel presented in section 6 is a small step in that direction.

the weakest characteristics. This obviously has major policy implications. Empirically, it suggests that the specific influence of fundamental variables may be more readily found and estimated on spreads, rather than on absolute levels of interest rates. The remainder of this paper focuses on this relationship between spreads and fundamentals.

3. DRIVERS OF INTEREST RATE DIFFERENTIALS IN THE EU: LITERATURE REVIEW AND EMPIRICAL STRATEGY

3.1. REVIEW OF THE EMPIRICAL LITERATURE

Many papers with a European focus have examined the behaviour of interest rate spreads following the sovereign debt stresses of the early 2010s. Fewer papers study the most recent years. Spreads are typically measured vis à vis the US or the German bond rate. Most papers assume that spreads capture a combination of risk premia. [7]

The literature generally finds significant effects of fundamental factors on spreads, starting with fiscal variables. Among those, the stock of government debt (usually gross debt measured as a share of GDP) is found to have a positive effect on spreads. In addition, 'flow' fiscal determinants such as the primary balance or gross financing needs (a proxy for rollover risk) have been argued to be useful in explaining spreads (Afonso *et al.*, 2015; Gabriele *et al.*, 2017; Capelle-Blancard *et al.*, 2019). One important finding is some evidence of non-linearity (De Grauwe and Ji, 2012; Afonso *et al.*, 2015). The finding of a non-linearity may be connected to the literature on debt limits (Gosh *et al.*, 2013; see also Fournier and Fall, 2017; Cerovic *et al.*, 2018; Berti *et al.*, 2012): as debt increases and gets closer to the limit, financial markets price in a higher risk that shocks push the economy beyond the debt limit, leading to default. However, markets may also switch between 'risk off' and 'risk on' waves, under-pricing risk across the board in the former and overestimating it in the latter (De Grauwe and Ji, 2012).

Non-fiscal imbalances are also found in some papers to be an important determinant of government spreads. In the euro area, the net foreign debt (a.k.a. net international investment position) has been found to impact spreads (Ben Salem and Castelletti-Font, 2016). Other external variables sometimes tested include the current account and the real effective exchange rate (De Grauwe and Ji, 2012; Afonso *et al.*, 2015; Capelle-Blancard *et al.*, 2019). A common interpretation is that private sector imbalances eventually weigh on the government accounts through subsequent recessions and bailouts, as observed in the boom and bust cycle of several euro area countries in the 2000s/2010s.

Finally, in terms of fundamentals, more generic variables such as GDP growth or the quality of institutions are considered. The strength of growth is a proxy of future taxes and as such of earning and repayment capacity. While potential growth seems conceptually more appropriate and is used by some authors (Poghosyan, 2012), others rely on observed growth, or introduce other economic variables

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[7] The sovereign risk premium (sovereign spreads measure) usually contains three main components: credit or default risk, liquidity risk and international risk aversion. See for example Afonso et al. (2015), Afonso and Felix (2014), De Haan et al. (2014), and Capelle-Blancard et al. (2019). Some authors such as D'Agostino and Ehrmann (2014) also consider exchange rate (or currency denomination) risk for non euro area countries. Gros (2018) argues that redenomination risk reappeared for Italy in 2018. In a recent analysis focusing on the euro area, Garcia et al. (2021) find on the other hand a limited role for redenomination risk. In our study focusing on spreads and their links to economic and fiscal fundamentals, we do not explicitly isolate redenomination risk (nor deal with issues of contagion), while it is likely that for some countries/years (e.g. Greece in 2012 or Italy in 2018), a redenomination risk component was present. In practice, measures of redenomination risk for euro area countries present some limitations. In particular, measures based on sovereign CDS rates (exploiting contract differences before/after 2014) can only be computed as from 2014 (and not for all countries), while measures based on governments bonds denominated in different currencies are not available for all countries, and can be affected by other factors (as government bonds issued in currencies other than the euro tend to have a less liquid, potentially more segmented, market). Moreover, since previous papers showed that redenomination risk is a short-term phenomenon, annual data used in our paper are likely to be too aggregated to reflect such risk.

such as the unemployment rate (Gomez-Puig *et al.*, 2014; D'Agostino and Ehrmann, 2014). [8] More recently, some papers have explored the incidence of institutional factors. Capelle-Blancard et al. (2019) finds a significant impact of environmental, social and governance indicators on spreads in OECD countries. Jalles (2019) highlights that better fiscal institutions (measured by the Commission's fiscal rule index) tend to lower sovereign bond yields in EU countries. [9] Other papers analyse the role of governance or political factors, with a focus on emerging countries (Presbitero et al., 2015; Eichler, 2014). Chen and Chen (2018) and Jeanneret (2018) find an effect of the quality of public institutions on default probability. Gomez-Puig et al. (2014) tests the impact of economic policy uncertainty on spreads. These variables may capture aspects of the government's ability or willingness to collect revenues and preserve fiscal discipline.

The empirical literature suggests that the effects of fundamentals on spreads are neither stable nor simple (Capelle-Blancard et al., 2019; De Haan et al., 2014). The link of spreads to fundamentals appears to vary with circumstances and therefore not be constant over time. This is relevant for the specific experience of EMU (Monteiro and Vasicek, 2019; D'Agostino and Ehrmann, 2014). There also appears to be cross-country heterogeneity in the relationship between spreads and macro-fiscal conditions (De Haan et al., 2014). This could relate to institutional features (e.g. quality of institutions, credibility of the country, adherence to a monetary union). The difficulties in establishing a consistent view of the role of fundamental factors means that there are sometimes disagreements on the part they play in driving observed spreads, and correspondingly on the departure of markets from 'fundamental values'. Pogoshyan (2012) and Giordano et al. (2013), for instance, take opposite views in the case of Portugal in the early 2010s. In fact, the definition of financial market mispricing is inherently difficult, as elaborated by De Haan et al. (2014).

In addition to fundamental variables, the empirical literature finds that financial and monetary conditions contribute to explaining spreads. [10] Traditional indicators of liquidity factors are the market size of the national government debt or bid-ask spreads (Codogno et al., 2003). Some papers post-dating the global financial crisis highlight the incidence of global risk sentiment, captured e.g. by the VIX or VSTOXX index (Monteiro and Vasicek, 2019; Afonso *et al.*, 2015). The potential 'catalytic effect' of official lending on countries such as Greece, Ireland, Portugal and Cyprus is also stressed by some authors (e.g. Corsetti *et al.*, 2019). By supporting medium-term debt sustainability, concessional loan may also help reduce the risk premium on privately-held government bonds. Finally, of potentially high relevance in recent years is the incidence of monetary policy. For the euro area this includes the announcement of the Outright Monetary Transactions (OMT) in 2012 and the purchase of government securities as part of Quantitative easing (QE) from 2015 onwards (Monteiro and Vasicek, 2019; Afonso and Kazemi, 2018).

All in all, methodological worries include the risk of a too eclectic approach and model dependency. De Grauwe and Ji (2002) stresses that financial risk measures and credit ratings are endogenous to the variable of interest (spreads). For instance, rating agencies react to movements in spreads, so including these variables may spuriously increase the fit of the regression. De Haan et al. (2014) draws attention to the methodological uncertainties when trying to pin down the influence of fundamentals on spreads. These authors show the role of modelling choices on the results, such as sample selection, parameter homogeneity across countries, the inclusion of financial risk factors and the treatment of time variability.

[8] The point is sometimes made that since fiscal sustainability is a forward looking notion, expected values of fundamentals rather than actual values should preferably be used. Inflation also features in the literature, but more in the context of emerging countries. Its effect on sovereign risk is ambivalent: inflation reduces the real value of outstanding debt but is associated with macroeconomic instability. It seems less relevant as a determinant of spreads for euro area countries in the recent period.

[9] Compared with our approach, this study uses the Commission's forecasts (rather than outturn values), as measures of economic fundamentals.

[10] Papers focusing on fundamentals tend to limit themselves to annual data. Those highlighting financial factors often use infra-annual data, e.g. monthly data (implying some interpolation for the fundamental variables).

3.2. EMPIRICAL STRATEGY

We analyse the role of fundamental variables in explaining sovereign spreads of euro area economies. We focus the analysis on the influence of fundamentals, especially fiscal variables, given their major implications for economic policy. The paper also considers the influence of institutional variables, an emerging theme in the literature on spreads for advanced economies. Relative to the existing papers, our paper specifically centres on the euro area economies, where spreads may exhibit specific behaviours. [11] We use data from the inception of the euro and extending to the recent years (up to 2019 included), which makes for a longer sample than earlier studies and includes the interesting 'post-financial crisis' period. [12]

Our approach recognises that unsettled modelling choices bear on empirical results (De Haan et al., 2014). Given the risk of model dependency, we rely on a range of specifications and stress robustness as an important criterion. As further elaborated below, we start with a 'benchmark model' in static form and then estimate alternatives, testing for non-linearities, additional variables, dynamic formulation, sample selection and time-sensitivity of parameters. The latter acknowledges that despite the relative homogeneity of the group of countries chosen (euro area countries), different 'structural breaks' affected the estimation sample, thus requiring testing the robustness of the results to the time sample.

Our benchmark estimation ('Step 1') **is defined as follows:**

$$spr_{it} = \alpha + \beta.NIIP_{it} + \gamma.GDPp_{it} + \delta.geff_{it} + \varepsilon.D_{it} + \theta.size_{it} + \mu.vix_t + \rho.PSPP_t + \alpha_i + u_{it} \quad (1)$$

where $i = 1\ to\ n$ (countries) and $t = 1\ to\ T$ (years). Spreads (spr_{it}) on 10-year government bonds (vis-à-vis German government bonds) are regressed on key fundamental variables namely, general government gross debt to GDP ratio (D_{it}), country net international investment position to GDP ratio ($NIIP_{it}$), potential real GDP growth ($GDPp_{it}$) and an index of government effectiveness ($geff_{it}$), as well as variables capturing liquidity risk ($size_{it}$ measuring the relative country size), international risk aversion (vix_t), and the (potential) effect of the Eurosystem public sector purchase programme ($PSPP_t$). α_i measures country random effects ($\alpha_i \approx iid(0, \sigma^2)$). [13], [14]

The model is estimated over 2000-2019 on annual data for euro area (alternatively EU) economies. Given few data gaps, the panel data include around 270 (480 when all EU) observations and is only slightly unbalanced. Admittedly, fiscal, macro, and financial data present a challenging mix in terms of available and preferable frequencies. The choice of low frequency is driven by the paper's focus on

[11] All estimations were run in parallel on the broader sample of EU economies as complementary analysis. The results are fairly similar overall, with few differences (see section 4.5).

[12] The exact definition and sources of these variables are provided in the annex (Table A2).

[13] In line with standard practice, we only consider the determinants of the country of interest, and not the ones of the benchmark country (here Germany). However, some part of the spread dynamics is likely to be driven also by the dynamics of German yield. For instance, in times of uncertainty, German yields tend to decrease due to a "flight to safety", while other EA yields jointly increase. The latter phenomenon should however be captured through the VIX variable. Other phenomena such as spillover and contagion effects, which effectively partially de-link the sovereign yields from their country fundamentals could also be at play. Afonso and Félix (2013) show that countries with worse macro and fiscal fundamentals are in fact more vulnerable to contagion effects.

[14] In the regressions, a crisis dummy variable to capture the spike of spreads in 2012 is also included. This choice is supported by alternative regressions, including time fixed effects (see below). Moreover, in the regressions covering all EU countries, a variable measuring short-term interest rates' spreads is considered to reflect differences in monetary policy regimes.

fundamentals (in particular its fiscal angle) and the availability of variables associated to this approach. In this context, annual data appear to strike the right balance between information content and noise. [15]

To account for potential non-linearities of the relationship between spreads and government debt, alternative versions of equation (1) are tested, along different dimensions:

Step 2: Debt level non linearities

$$spr_{it} = \alpha + \beta.NIIP_{it} + \gamma.GDPp_{it} + \delta.geff_{it} + \varepsilon_1.D_{it} + \varepsilon_2.nl(D_{it}) + \theta.size_{it} + \mu.vix_t + \rho.PSPP_t + \alpha_i + u_{it} \quad (2)$$

where $nl(D_{it}) = D_{it}^2$ or $(D_{it} - T).\Delta_T$ depending on the specification tested, with Δ_T representing a dummy variable taking value 1 when debt is greater than a certain threshold (60% and 90% of GDP are tested). Hence, different forms of non-linearities are tested to account for non-linear effects depending on the debt level: a quadratic debt term (as in De Grauwe and Ji, 2013) and a debt-threshold term. [16]

Step 3 : Debt dynamics and structure

$$spr_{it} = \alpha + \beta.NIIP_{it} + \gamma.GDPp_{it} + \delta.geff_{it} + \varepsilon_1.D_{it} + \boxed{\varepsilon_2.D_{it}.flow_{it} + \epsilon.flow_{it}} + \theta.size_{it} + \mu.vix_t + \rho.PSPP_t + \alpha_i + u_{it} \quad (3)$$

where $flow_{it} = PB_{it}$ or ΔD_{it} or GFN_{it} or $maturity_{it}$ depending on the specification tested, with PB_{it} representing government primary balance as a share of GDP, ΔD_{it} representing the change in the government debt-to-GDP ratio, GFN_{it} representing government gross financing needs as a share of GDP, and $maturity_{it}$ the average maturity of government debt. Such specification includes separate effects from and a possible interaction between fiscal stocks (debt), fiscal flows (primary balance, change in the debt ratio or GFN), and the term structure (GFN or average maturity). The latter variables are potentially particularly relevant in countries that benefited from official lending with very long repayment maturity (and where GFN are limited compared with what could be expected – given the debt burden – for an average market access country). Additional regressions further explore the effect of the (holders) structure of debt on spreads, by directly testing a government debt variable net of debt held by the Eurosystem and official lenders (DM_{it}). [17]

Step 4: Debt interactions with other macro-structural features and 'context' variables

$$spr_{it} = \alpha + \beta.NIIP_{it} + \gamma.GDPp_{it} + \delta.geff_{it} + \varepsilon_1.D_{it} + \boxed{\varepsilon_2.D_{it}.X_{(i)t}} + \theta.size_{it} + \mu.vix_t + \rho.PSPP_t + \alpha_i + u_{it} \quad (4)$$

where $X_{(i)t} = NIIP_{it}$ or $GDPp_{it}$ or $geff_{it}$ or $size_{it}$ or vix_t or $PSPP_t$ depending on the specification tested. Such an interactive term between government debt and each other explanatory variables allows for differentiating the responsiveness of spreads to debt depending on countries' other macro-structural features (external debt, potential growth, government effectiveness, [18] or relative market size), and on

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[15] By using annual data, the influence of some variables such as monetary policy or financial lending may be underplayed, given that higher variation of these variables is averaged. In general, the limited data sample calls for caution when interpreting some results. However, the time sample constraint is mitigated in a panel, where the degrees of freedom increase with the number of cross-sections.

[16] This type of specification is most often found in the literature on fiscal reaction functions (see Celasun *et al.*, 2006). In the case of interest rate spreads, it can also be justified by Afonso et al. (2019), which show that spreads are sensitive to the Commission releases of the excessive deficit procedure (and releases of higher debt forecasts). Hence, we expect an (additional) sensitivity of spreads when the debt ratio crosses the Stability and Growth Pact reference value of 60% of GDP. Also, as the 90% of GDP threshold is used as a reference value, notably in EU DSA frameworks, this level is tested.

[17] Such a measure is akin to the 'free float' measure used by the ECB.

[18] For example, Fournier and Bétin (2018) show that countries with weak institutions (notably measured by government effectiveness) are more likely to default than others, for any given level of debt.

'context' variables (international risk aversion or the Eurosystem's policies). This kind of specification may help in capturing the seemingly state-contingent link between spread and government debt.

Additional robustness checks are carried out, notably i) to test the possibility of time-varying debt effects, ii) for the inclusion of time or country fixed effects (see below on the latter), iii) to test the sensitivity of the results to the geographical sample selection, and iv) to test the relevance of a dynamic form (via an error-correction model). The latter aims at accounting for the possibility that the main variables are non-stationary (see section 4.5). [19, 20]

Equations (1) to (4) are estimated using the Generalised Two-stage Least Squares (G2SLS) method. The *government debt to GDP ratio* (as well as other fiscal variables) [21] is instrumented by its lag, given the possible endogeneity of this variable (see Afonso *et al.*, 2015 for a similar approach). [22] Nonetheless, as the debt dynamic responds only slowly to changing market yields, this potential problem should not be overstated. [23] Similarly, the *net international investment position to GDP ratio* can be assumed as essentially exogenous (by definition, the NIIP is a measure affected by both the assets and liabilities' positions of the public and the private sector). The use of *potential GDP growth* (rather than actual growth, which however is also tested) should also limit the endogeneity of the growth variable (as well as multicollinearity issues). The *relative country size*, used as a proxy of the liquidity of its bond market, is preferred to other indicators such as bid-ask spreads or the overall outstanding amount of government debt to limit endogeneity and multicollinearity issues with the government debt ratio. Also with a view to mitigate endogeneity problems, the *VIX index*, a global US-based risk factor, is preferred to the VSTOXX index, an EU-specific variable.

We tested the inclusion of both country fixed effects (FE) and random effects (RE), while favouring the latter. In this model, the coefficients of the explanatory variables are assumed to be equal across countries, while a term is added to capture country heterogeneity. Differently from the most common approach followed in the empirical literature, we preferred a RE model to the FE model. [24] Several reasons support this choice: first, the model includes a number of explanatory variables that already capture structural differences between countries varying very slowly over time (such as country's relative size or government effectiveness, see below). Then, the remaining features that are not captured in our model and that could influence spreads (e.g. the specific performance of a DMO, the results of specific elections, etc.) are unlikely to be correlated with the explanatory variables, and

[19] Reassuringly, the main variables of interest appear to be cointegrated, albeit cointegration was tested on the relatively short time span available for our sample.

[20] The variables retained in our specifications were selected as follows: based on our review of the literature, we chose a set of variables found most relevant in other studies, and complemented them with specific fiscal variables, the latter constituting the focus of this research. We also tested other variables for improvements of the fit. For instance, alternative estimations run (in addition to the regressions presented in the paper) included variables such as actual GDP growth, total factor productivity growth, current account balance, alternative institutional variables to government effectiveness, GDP per capita, world GDP growth, credit ratings agencies' sovereign ratings and sovereign crisis history. However, the results were generally not found to be improved by the use of these alternative variables. Moreover, ratings suffer from critical endogeneity issues as discussed in section 3.1 of the paper.

[21] This includes the primary balance, GFN, and average maturity. The PSPP variable is also instrumented.

[22] To deliver consistent estimators, a valid instrument (IV) must satisfy both exogeneity (instrument uncorrelated with the disturbance term) and relevance (IV correlated with the regressor instrumented). Since all fiscal variables and debt interacted variables are instrumented by their lag, exogeneity can be credibly assumed (with lags of these variables and the current level of spreads not being co-determined). Similarly, using lags as instruments also insures relevance, given fiscal variables' autoregressive properties.

[23] This reflects a relatively long debt maturity of debt. In the euro area, the average maturity of debt (securities) is around 7 ½ years, ranging from 6.3 years in Luxembourg to more than 11 years in Austria (ECB, 2020).

[24] Bell and Jones (2015) shows that in the context of macroeconometric panels (as opposed to microeconometric panels), the more parsimonious RE model is often superior to the FE model.

represent instead non observable statistical 'noise'. Last, an Hausman test tends to confirm that a random effects model is more appropriate than a fixed effects model. [25]

4. EMPIRICAL RESULTS

4.1. INFLUENCE OF FUNDAMENTALS IN THE BENCHMARK REGRESSION

In line with the literature, the empirical results point to a significant impact of government debt and other macro-structural features on sovereign interest rates' spreads in the euro area. According to the benchmark regression (Table 1, regression (1)), a 1 pp. increase in the *government debt-to-GDP ratio* leads to an increase of close to 3 bps. in sovereign spreads (see Table 1). [26] The results also confirm the significant influence of the *NIIP variable*, suggesting that investors take concerns about private sector solvency into account (in the regressions, a 1 pp. of GDP deterioration of the net external position increases sovereign spreads by less than 1 bp.). [27] This result is notably in line with Ben-Salem and Castelletti Font (2017). A lower *potential GDP growth*, negatively associated with debt sustainability, is also found to trigger higher government interest rates' spreads (a 1 pp. decrease in the annual potential growth rate raises spreads by more than 20 bps.). Stronger *government effectiveness*, generally correlated to a higher repayment capacity / willingness to repay debt, tends to reduce sovereign spreads, although its direct effect is only significant at 10% (and not always significant in subsequent regressions). The latter result could reflect the relatively low variability of this variable across EA countries compared to other parts of the world (see European Commission (2019) - Box 1.2). Last, the regressions confirm the (negative) influence of the *relative size of the country*, as a proxy of the liquidity risk premium (a higher liquidity risk premium is demanded in smaller economies). These results are overall robust to different robustness checks carried out in the paper (for instance, to the geographical sample selection or to the consideration of other forms of the model – see section 4.5).

The regressions are also indicative of the impact of contextual variables, related to international volatility or to the Eurosystem's interventions on the secondary markets (through its Public Sector Purchase Programme). In line with the literature, the international risk factor (measured by the VIX), which captures investors' risk aversion, is found to significantly (positively) influence sovereign spreads' developments. [28] The regressions also point to a possible influence of the Eurosystem's interventions on government long-term interest rates' spreads. The results denote in particular an impact of aggregate Eurosystem purchases of government bonds, while an alternative specification using instead as regressor the country-specific purchases as a share of GDP is inconclusive (this regressor being non significant). [29] This would suggest the effectiveness of the Eurosystem's interventions to support financing conditions. Other papers based on event studies identified a sizeable impact of the

[25] Reassuringly, regressions using a FE model show similar results in terms of the values of the coefficients. However, there is a considerable loss of precision (owing to the addition of 16 fixed effects regressors) and some variables are less significant, given their relative inertia over time (the fixed effects model measures *within* rather than *between* effects). See section IV of the annex.

[26] This estimation is in the lower part of the 2 - 7 basis points estimated range found in previous papers (Poghosyan, 2012; Rachel and Summers, 2019).

[27] Larger private sector net foreign liabilities are associated with an increase of the default risk of the latter. This evolution may in turn dampen the government soundness directly through negative effects on economic activity, tax revenue and (higher) public spending, and indirectly if the government has to eventually bailout some entities.

[28] The VIX variable is uniform across countries, essentially acting as time fixed effects. The crisis dummy 2012 is however also significant, illustrating specific EA developments that year.

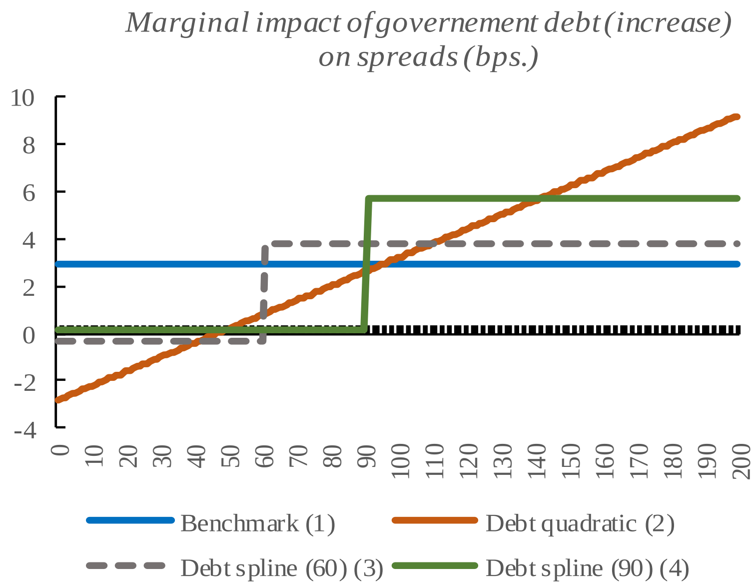
[29] Under the PSSP up to 2019, differences were very limited between countries (when looking at Eurosystem purchases by country as a share of national GDP). These results may change when including data from 2020 onwards, as purchases under the Pandemic Emergency Purchase Programme can depart from the usual capital key.

PSPP announcements on higher-yield member countries such as Italy and Spain (Rostagno *et al.*, 2019; Bulligan and Delle Monache, 2018; Neugebauer, 2018).

4.2. DEBT NON-LINEARITIES: THE ROLE OF THE DEBT LEVEL

The regressions confirm the presence of debt non-linearities. The quadratic form (Table 1, regression (2)) suggests that the reaction of spreads to government debt becomes positive only for debt ratios above about 50% of GDP, [30] but the marginal impact strongly increases thereafter and is higher than found in the benchmark regression for debt ratios beyond 95% of GDP (see Graph 3). Other non-linear forms such as those tested through regressions (3) and (4) of Table 1, with a debt spline function (above 60% and 90% of GDP) also corroborate a higher responsiveness of spreads to changes in the debt ratio for medium to high debt levels. At debt levels exceeding 100 percent of GDP, the marginal impact is typically in the high part of the range of estimates found in the rest of the literature. The basic message is that the sensitivity of spreads to additional debt may be somewhat more important when the debt-to-GDP ratio is already high, and may be underestimated when relying on a basic linear estimation.

Graph 3. **Marginal impact of government debt to GDP ratio (increase) on spreads: estimations' results based on Table 1 equations (1) – (4).**



Source: Authors' calculations.

[30] This level is obtained by calculating the partial derivative of spreads to debt $(\varepsilon_1 + 2.\varepsilon_2.D)$ from Table 1 regression (2).

Table 1. **Estimation results: benchmark and non-linear forms (debt level).** Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), Euro area countries, 2000-19

VARIABLES (expected sign)	(1) Benchmark	(2) Debt quadratic	(3) Debt spline (60)	(4) Debt spline (90)
niip_gdp (-)	**-0.00602****	**-0.00780*****	**-0.00673****	**-0.00718****
	(0.00276)	(0.00274)	(0.00300)	(0.00279)
GDPgp (-)	**-0.207****	**-0.170****	**-0.199****	**-0.174****
	(0.104)	(0.0777)	(0.0993)	(0.0776)
gee (-)	**-0.613***	**-0.395**	**-0.492**	**-0.371**
	(0.314)	(0.333)	(0.337)	(0.338)
relative_size (-)	**-0.151*****	**-0.0889****	**-0.126*****	**-0.0936****
	(0.0529)	(0.0350)	(0.0473)	(0.0410)
vix (+)	**0.0154*****	**0.0138***	**0.0160****	**0.0128***
	(0.00504)	(0.00721)	(0.00655)	(0.00773)
pspp_gdp (-)	**-0.0255***	**-0.0202**	**-0.0232***	**-0.0228***
	(0.0136)	(0.0128)	(0.0128)	(0.0128)
gdebt_gdp (+, linear)	**0.0291*****	**-0.0281****	**-0.00335**	**0.00143**
	(0.00840)	(0.0128)	(0.0134)	(0.00653)
debt_sq (+)		**0.000300*****		
		(7.55e-05)		
debt_60 (+)			**0.0415***	
			(0.0228)	
debt_90 (+)				**0.0559*****
				(0.0175)
crisis (+)	**2.289*****	**2.537*****	**2.360*****	**2.483*****
	(0.825)	(0.920)	(0.866)	(0.896)
Constant	**0.307**	**1.830****	**1.486***	**1.254***
	(0.594)	(0.738)	(0.820)	(0.720)
Observations	261	261	261	261
Number of cty_num	17	17	17	17
Country RE	YES	YES	YES	YES
R2	0.572	0.643	0.602	0.647
RMSE	1.294	1.227	1.260	1.205

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Model estimated through generalised two-stage least squares, with debt and PSPP instrumented by their lag. Random effects are included. Robust standard errors in parentheses. ***, ** and * denote p-values less than or equal to 1%, 5% and 10%. Countries include all EA countries except for Germany (benchmark country) and Estonia (the country joined the EA in 2011, date as from which there is no market long-term interest rate data for this country).
Source: Authors' calculations.

4.3. DEBT NON-LINEARITIES: THE ROLE OF THE DEBT DYNAMICS AND STRUCTURE

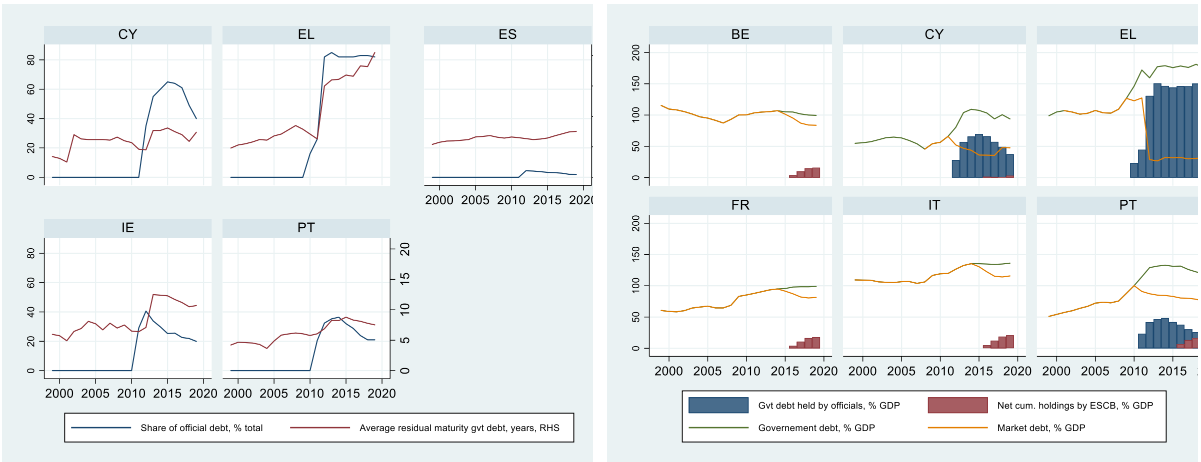
The combination of a high stock (debt) and flow (primary deficit, change in the debt-to-GDP ratio or *gross* financing needs) compounds to adversely affect spreads. The model based on the change in the debt-to-GDP ratio (see Table 2, regression (3)) is found to have the highest explanatory power. This confirms previous results that the debt dynamics has a strong bearing on spreads and the risk of financial stress (Bassanetti et al. 2016). Moreover, the interaction term between the debt ratio level and the change in the debt ratio is also significant: when the stock of debt is already high, spreads are more sensitive to a further deterioration of public finances. In other words, governments with more moderate debt levels have more leeway (or more fiscal space) to use fiscal policy, without fearing an increase of spreads. The same feature is found when using, instead of the change in the debt ratio, the primary balance or gross financing needs (GFN). Interestingly, the model based on GFN (Table 2, regression (4)), a flow variable that includes additionally debt amortisations, [31] is not found to improve the overall explanatory power of the regression compared with the model based on the primary balance (Table 2, regression (2)) or on the change in the debt ratio (Table 2, regression (3)), or compared with other non-linear forms (see section 4.2).

Relatedly, the average (residual) maturity of debt, which has significantly increased over the past years, especially in countries that benefited from official lending, is not found to have a significant impact on spreads. (see Table 2, regression (5)). Hence, the distinct role of the maturity structure of government debt on investors' appreciation of sovereign risk cannot be put into evidence by the regressions. This result could however reflect a lack of precision of the regressions, given the limited number of countries benefitting from official lending in the sample. A 'synthetic' variable of 'market' government debt, where the Eurosystem holdings of government bonds and official lending are netted out (see Table 2, regression (6) and Graph 4 right panel), is found to significantly impact sovereign spreads' developments. In other words, even after controlling for the potential influence of Eurosystem's interventions and of official lending, government debt has a significant impact on sovereign spreads. Yet, the overall performance of this last regression in Table 2 appears limited compared with the benchmark model, and other non-linear forms tested so far.

Graph 4. **Government debt held by the official sector and net cumulated government bonds' holdings by the Eurosystem, selected countries**

Share of government debt held by the 'official' sector (ESM/EU/IMF) and average residual maturity of debt, post-programme euro area countries

Government debt held by the 'official' sector, by the Eurosystem and 'market' debt, high debt euro area countries, % of GDP



Source: Ameco, ECB, national sources.

[31] The change in the debt ratio is the sum of headline deficit (itself equal to the sum of the primary deficit and net interest payments) and stock-flow adjustments. It is also affected by growth valuation effects. Stock-flow adjustments include cash-accrual differences, other debt creating / reducing flows (e.g. related to bank recapitalisations or privatisations) and other valuation effects (e.g. when a significant share of debt is issued in foreign currency). *Gross financing needs* (GFN) include additionally debt amortisations (or debt principal repayments). Hence, while the change in the debt ratio represents the part of financing needs related to 'new' debt creation (and growth valuation effects), GFN also include financing needs related to rollover needs of (old) accumulated maturing debt. This variable is therefore affected by the maturity structure of outstanding debt. For example, in the case of Greece, GFN are contained (despite the high level of debt) by the very long maturity of debt.

Table 2. **Estimation results: benchmark and non-linear forms (debt dynamics and maturity).** Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), Euro area countries, 2000-2019

VARIABLES (expected sign)	(1) Benchmark	(2) Debt & PB	(3) Debt & ΔDebt	(4) Debt & GFN	(5) Debt & avg maturity	(6) Debt market
nllp_gdp (-)	-0.00602**	-0.00553*	-0.00677***	-0.00929***	-0.00749***	-0.0124***
	(0.00276)	(0.00286)	(0.00215)	(0.00326)	(0.00258)	(0.00302)
GDPgp (-)	-0.207**	-0.158	-0.127	-0.248	-0.204**	-0.331*
	(0.104)	(0.116)	(0.117)	(0.156)	(0.0962)	(0.183)
gee (-)	-0.613*	-0.745***	-0.619**	-0.570	-0.647**	-0.894*
	(0.314)	(0.227)	(0.252)	(0.395)	(0.296)	(0.494)
relative_size (-)	-0.151***	-0.106***	-0.103***	-0.136**	-0.117***	-0.126***
	(0.0529)	(0.0236)	(0.0329)	(0.0551)	(0.0437)	(0.0457)
vix (+)	0.0154***	0.0186***	0.0201**	0.0204***	0.0132**	0.00120
	(0.00504)	(0.00632)	(0.00796)	(0.00712)	(0.00518)	(0.00727)
pspp_gdp (-)	-0.0255*	0.00317	-0.00602	-0.0279	-0.0261**	
	(0.0136)	(0.0124)	(0.0158)	(0.0234)	(0.0125)	
gdebt_gdp (+, linear)	0.0291***	0.0260***	0.0162***	0.00217	0.0186	
	(0.00840)	(0.00413)	(0.00395)	(0.00679)	(0.0114)	
pb_gdp		0.467***				
		(0.124)				
debt_pb (-)		-0.00687***				
		(0.000956)				
Δgdebt_gdp			-0.111**			
			(0.0555)			
debt_Δgdebt (+)			0.00222***			
			(0.000418)			
gfn_gdp				-0.139		
				(0.0949)		
debt_gfn (+)				0.00180***		
				(0.000605)		
avg_maturity					0.0428	
					(0.101)	
debt_maturity (-)					0.000105	
					(0.000729)	
debt_market (+)						0.0124**
						(0.00528)
crisis (+)	2.289***	2.386**	1.938***	2.122***	2.422***	2.442***
	(0.825)	(0.932)	(0.570)	(0.687)	(0.839)	(0.890)
Constant	0.307	0.109	0.608	1.878*	0.606	2.084*
	(0.594)	(0.602)	(0.683)	(1.037)	(0.922)	(1.230)
Observations	261	261	261	233	260	261
Number of cty_num	17	17	17	17	17	17
Country RE	YES	YES	YES	YES	YES	YES
R2	0.572	0.600	0.678	0.604	0.587	0.484
RMSE	1.294	1.344	1.172	1.294	1.313	1.430

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Model estimated through generalised two-stage least squares, with debt, PB and PSPP instrumented by their lag. In regressions (2) and (3), spreads are directly regressed on the lagged values of debt and change in debt / GFN given the effect of the debt restructuring in 2012 in Greece. Random effects are included. Robust standard errors in parentheses. ***, ** and * denote p-values less than or equal to 1%, 5% and 10%. Countries include all EA countries except for Germany (benchmark country) and Estonia (the country joined the EA in 2011, date as from which there is no market long-term interest rate data for this country). *debt_pb, debt_Δgdebt, debt_gfn and debt_maturity* represent government debt interacted with respectively the primary balance, the change in the debt ratio, gross financing needs and the average maturity of debt.

Source: Authors' calculations.

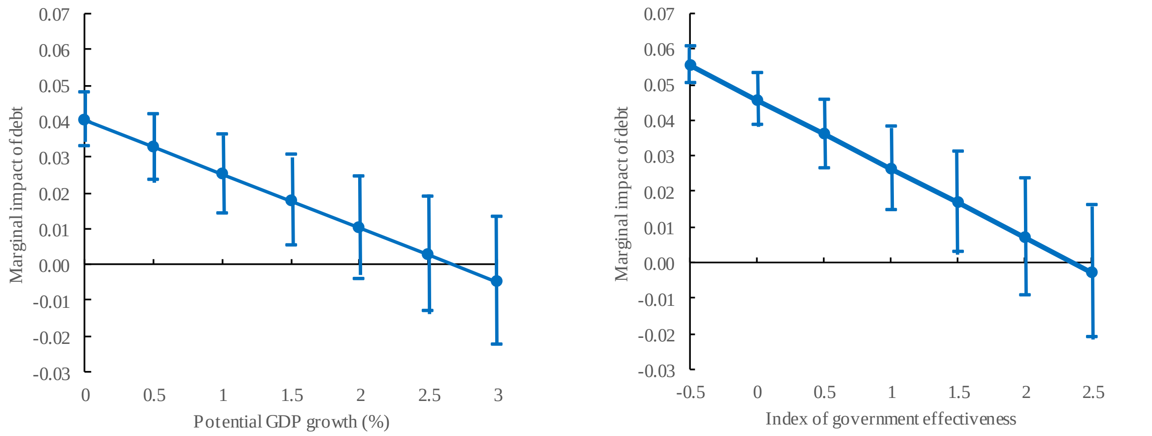
4.4. DEBT INTERACTIONS WITH OTHER MACRO-STRUCTURAL FEATURES AND CONTEXT VARIABLES

The estimations confirm that the sensitivity of spreads to government debt can be heightened or mitigated by other macro-structural features. The estimations show significant interaction terms between government debt and the external position, potential growth and government effectiveness (see Table 3 – respectively regressions (2), (3) and (4)). This means that spreads are not only responsive to other fundamentals than government debt, but that a deterioration of those fundamentals raises the sensitivity of spreads to public debt.

The results concerning potential growth (regression (3)), which also correspond to the best fit, are especially interesting. Graph 5 shows how the marginal impact of government debt on spreads varies with potential growth. A high potential growth mitigates the impact from government debt on spreads. Taken at face value, the estimates suggests that the responsiveness of spreads to government debt would be close to zero when potential growth exceeds 2,5 %. By contrast, for countries with a weak potential growth, spreads are more sensitive to government debt. Effectively, the marginal impact of debt on spreads is higher than found in the benchmark regression when potential growth falls below 0,75 %. Similarly, in countries with the highest government effectiveness index value (e.g. countries where the government effectiveness index is around 2), the marginal effect of government debt on spreads would be close to zero according to regression (4), while countries deemed to have less strong institutions (e.g. countries where the government effectiveness index is less than 0.5), the marginal effect of government debt on spreads is far higher (an increase of government debt of 1 pp. of GDP raises spreads by close to 4 bps.).

Graph 5. **Marginal impact of government debt on spreads, depending on...**

*... potential growth (*Table 3, *regression (3))* | *... government effectiveness (*Table 3, *regression (4))*



Note: the chart reports the (total) marginal impact of government debt on spreads conditional to a given level of potential growth/government effectiveness. Bars represent the confidence interval of the estimated coefficients.

Source: Authors' calculations.

The sensitivity of spreads to government debt also increases with international investors' risk aversion (Table 3, regression (5)). On the other hand, spreads' responsiveness to debt would not be more acute in smaller countries (Table 3, regression (6), where the interactive term between debt and the relative economic size is not significant). The Eurosystem's interventions are not found either to affect the relationship between spreads and debt (Table 3, regression (7)), suggesting that "the disciplinary function of markets [would] not been lost" due to these policies (Schnabel, 2020).

Table 3. **Estimation results: non-linear forms due to interaction with other macro-structural features and contextual variables.** Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), Euro area countries, 2000-2019

VARIABLES (expected sign)	(1) Benchmark	(2) Debt & NIIP	(3) Debt & growth	(4) Debt & gvt. effectiveness	(5) Debt & VIX	(6) Debt & size	(7) Debt & PSPP
niip_gdp (-, linear)	**-0.00602****	**0.00644***	**-0.00776*****	**-0.00752****	**-0.00844*****	**-0.00530***	**-0.00726*****
	(0.00276)	(0.00349)	(0.00223)	(0.00293)	(0.00311)	(0.00299)	(0.00277)
GDPgp (-, linear)	**-0.207****	**-0.167****	**0.914*****	**-0.192****	**-0.208****	**-0.206****	**-0.198****
	(0.104)	(0.0809)	(0.292)	(0.0922)	(0.105)	(0.104)	(0.0946)
gee (-, linear)	**-0.613***	**-0.691*****	**0.0306**	**0.851***	**-0.432**	**-0.714****	**-0.512**
	(0.314)	(0.231)	(0.373)	(0.472)	(0.353)	(0.297)	(0.319)
relative_size (-, linear)	**-0.151*****	**-0.0872*****	**-0.0707****	**-0.132*****	**-0.141*****	**-0.0470**	**-0.136*****
	(0.0529)	(0.0274)	(0.0299)	(0.0494)	(0.0502)	(0.0872)	(0.0488)
vix (+, linear)	**0.0154*****	**0.0183*****	**0.0241*****	**0.0126****	**-0.168**	**0.0157*****	**0.0159*****
	(0.00504)	(0.00510)	(0.00856)	(0.00544)	(0.105)	(0.00496)	(0.00464)
pspp_gdp (-, linear)	**-0.0255***	**-0.0229***	**-0.00508**	**-0.0220***	**-0.0187***	**-0.0242***	**0.0541**
	(0.0136)	(0.0124)	(0.0145)	(0.0130)	(0.0112)	(0.0130)	(0.0459)
gdebt_gdp (+, linear)	**0.0291*****	**0.0118*****	**0.0403*****	**0.0458*****	**-0.0210**	**0.0323*****	**0.0321*****
	(0.00840)	(0.00291)	(0.00751)	(0.00738)	(0.0178)	(0.00950)	(0.0115)
debt_niip (-)		**-0.000180*****					
		(2.63e-05)					
debt_growth (-)			**-0.0150*****				
			(0.00341)				
debt_gee (-)				**-0.0194*****			
				(0.00448)			
debt_vix (+)					**0.00264****		
					(0.00130)		
debt_size (-)						**-0.00124**	
						(0.000889)	
debt_pspp (-)							**-0.000987**
							(0.000606)
crisis (+)	**2.289*****	**2.430*****	**2.440*****	**2.434*****	**2.289*****	**2.313*****	**2.271*****
	(0.825)	(0.895)	(0.789)	(0.865)	(0.802)	(0.841)	(0.797)
Constant	**0.307**	**1.104****	**-2.636***	**-1.276**	**3.453****	**0.222**	**-0.198**
	(0.594)	(0.499)	(1.422)	(0.883)	(1.575)	(0.588)	(0.938)
Observations	261	260	261	240	261	261	261
Number of cty_num	17	17	17	17	17	17	17
Country RE	YES	YES	YES	YES	YES	YES	YES
R2	0.572	0.633	0.702	0.621	0.531	0.577	0.583
RMSE	1.294	1.277	1.131	1.291	1.380	1.286	1.279

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note : Model estimated through generalised two-stage least squares, with debt and PSPP instrumented by their lag. Random effects included. Robust standard errors in parentheses. ***, ** and * denote p-values less than or equal to 1%, 5% and 10%. Countries include all EA countries except for Germany (benchmark country) and Estonia (the country joined the EA in 2011, data as from which there is no market long-term interest rate data for this country).

Source: Authors' calculations.

4.5. ADDITIONAL ROBUSTNESS CHECKS

In order to further explore the sensitivity of the results to modelling choices, several robustness checks are carried out, more specifically to test the sensitivity of the results to time-dependent debt coefficients, to the sample selection, and to investigate the relevance of a dynamic form (via an error-correction model differentiating short-term dynamics from the long-term relationship). Additional robustness checks have also been performed for the inclusion of time or country fixed effects (the latter instead of random effects), and are presented in section IV of the annex.

Testing the robustness of the results to time-dependent debt coefficients

The empirical literature explores the sensitivity of the results to time effects via different techniques. Most papers simply estimate their models over sub-samples to test the stability of their (main) regression. Others allow for time-varying coefficients, either through interaction of the variables with time dummies (e.g. before / after the financial crisis; Afonso *et al.*, 2015; De Haan *et al.*, 2014), or on the basis of more sophisticated techniques allowing the estimation of time-varying coefficients through Bayesian techniques (D'Agostino and Ehrmann, 2014), or state-space techniques (Monteiro and Vasicek, 2019). The latter methods have been used in a limited number of papers, relying on monthly data (given the larger number of observations needed). Last, notably to identify potential 'bubbles' in bond pricing, some authors test simple time fixed effects (De Grauwe *et al.*, 2012).

Interacted time slope dummy variables show that the relationship between spreads and debt has evolved over time. In order to test the potential time-dependency of the debt coefficient, regressions interacting government debt with time dummy variables are run. The time slope dummy variables distinguish between the pre-financial crisis period (up until 2007), the financial crisis-period (from 2008-12), and the post-financial crisis period (since 2013). This specification is similar to Afonso *et al.* (2015) and De Haan *et al.* (2014), and allows for time-varying coefficients as in (5) below:

$$spr_{it} = \alpha + \beta.NIIP_{it} + \gamma.GDPp_{it} + \delta.geff_{it} + \varepsilon_1.D_{it} + \varepsilon_2.I_{2008}.D_{it} + \varepsilon_3.I_{2013}.D_{it} + \theta.size_{it} + \mu.vix_t + \rho.PSPP_{it} + \alpha_i + u_{it} \quad (5)$$

with I_{2008} a dummy variable that takes value 1 as from 2008 (and 0 otherwise) and I_{2013} a dummy variable that takes value 1 as from 2013 (and 0 otherwise). These regressions are run over the benchmark model, as well as the specifications with the highest fit (namely the debt spline (90), the debt & change in debt ratio and the debt & growth models).

The results suggest that the relationship between spreads and debt has not been stable over time. According to the benchmark model, the responsiveness of spreads to debt would have increased during the global financial crisis (an increase of spreads by close to 5 bps. for each increase of the debt ratio by 1 pp. of GDP), while declining afterwards to a level higher than pre-financial crisis however (see Table 4 regression (2)). The same pattern is estimated when differentiating the regression for high debt countries (regression (4)), with an even more acute change in the slope during the years 2008-12. On the other hand, the influence of growth conditional on the debt level (regression (8)) appear stable throughout the estimation period (with no statistical evidence of an increased / reduced impact during / after the financial crisis). The results of the regression interacted debt and the change in debt are more difficult to interpret (regression (6)), but they can be read as indicating that the sensitivity of spreads to fiscal problems first shot up in the financial crisis and then declined, without disappearing. Overall, these results points at the difficulty to entirely remove the time-dependency of estimated coefficients, suggesting that there has been already several 'regimes' in the euro area with specific incidences of fundamentals on spreads. The inclusion of the VIX as a proxy factor of volatility doesn't suffice to control for such changes.

Table 4. **Estimation results, benchmark and additional regressions with time slope dummy variables.** Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), Euro area countries, 2000-2019

VARIABLES	(1) Benchmark	(2) Interracted time dummies	(3) Debt spline (90)	(4) Interracted time dummies	(5) Debt & ΔDebt	(6) Interracted time dummies	(7) Debt & growth	(8) Interracted time dummies
niip_gdp	**-0.00602****	**-0.00711****	**-0.00718****	**-0.00778****	**-0.00677*****	**-0.00609****	**-0.00776*****	**-0.00607****
	(0.00276)	(0.00298)	(0.00279)	(0.00325)	(0.00215)	(0.00255)	(0.00223)	(0.00259)
GDPgp	**-0.207****	**-0.0977***	**-0.174****	**-0.120****	**-0.127**	**-0.189**	**0.914*****	**0.689*****
	(0.104)	(0.0500)	(0.0776)	(0.0574)	(0.117)	(0.139)	(0.292)	(0.183)
gee	**-0.613***	**-0.286**	**-0.371**	**-0.0341**	**-0.619****	**-0.731*****	**0.0306**	**-0.0556**
	(0.314)	(0.268)	(0.338)	(0.470)	(0.252)	(0.281)	(0.373)	(0.327)
relative_size	**-0.151*****	**-0.111*****	**-0.0936****	**-0.0696**	**-0.103*****	**-0.106*****	**-0.0707****	**-0.0828****
	(0.0529)	(0.0323)	(0.0410)	(0.0432)	(0.0329)	(0.0394)	(0.0299)	(0.0353)
vix	**0.0154*****	**-0.0969****	**0.0128***	**-0.0294**	**0.0201****	**0.000321**	**0.0241*****	**0.0479*****
	(0.00504)	(0.0407)	(0.00773)	(0.0279)	(0.00796)	(0.0153)	(0.00856)	(0.0167)
pspp_gdp	**-0.0255***	**-0.0282***	**-0.0228***	**-0.0173**	**-0.00602**	**-0.0171**	**-0.00508**	**-0.0324****
	(0.0136)	(0.0164)	(0.0128)	(0.0125)	(0.0158)	(0.0202)	(0.0145)	(0.0163)
gdebt_gdp	**0.0291*****	**0.0139*****	**0.00143**	**-0.00369**	**0.0162*****	**0.0144*****	**0.0403*****	**0.0358*****
	(0.00840)	(0.00499)	(0.00653)	(0.00873)	(0.00395)	(0.00437)	(0.00751)	(0.00536)
gdebt_d2008		**0.0351*****						
		(0.0115)						
gdebt_d2013		**-0.0278*****						
		(0.00799)						
debt_90			**0.0559*****	**0.00955**				
			(0.0175)	(0.0448)				
debt_90_d2008				**0.163*****				
				(0.0474)				
debt_90_d2013				**-0.122*****				
				(0.0222)				
Δgdebt_gdp					**-0.111****	**-0.107***		
					(0.0555)	(0.0595)		
debt_Δgdebt					**0.00222*****	**0.00119**		
					(0.000418)	(0.00115)		
debt_Δgdebt_d2008						**0.00151**		
						(0.00101)		
debt_Δgdebt_d2013						**-0.00168*****		
						(0.000511)		
debt_growth							**-0.0150*****	**-0.0155*****
							(0.00341)	(0.00301)
debt_growth_d2008								**-0.00730**
								(0.00809)
debt_growth_d2013								**0.0123**
								(0.00763)
crisis	**2.289*****	**0.377**	**2.483*****	**1.247*****	**1.938*****	**1.457*****	**2.440*****	**2.161*****
	(0.825)	(0.270)	(0.896)	(0.461)	(0.570)	(0.391)	(0.789)	(0.511)
Constant	**0.307**	**1.865*****	**1.254***	**1.651****	**0.608**	**1.394***	**-2.636***	**-2.049****
	(0.594)	(0.584)	(0.720)	(0.784)	(0.683)	(0.783)	(1.422)	(0.854)
Observations	261	261	261	261	261	261	261	261
Number of cty_num	17	17	17	17	17	17	17	17
Country RE	YES	YES	YES	YES	YES	YES	YES	YES
R2	0.572	0.613	0.647	0.738	0.678	0.722	0.702	0.787
RMSE	1.294	1.275	1.205	1.001	1.172	1.056	1.131	0.893

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

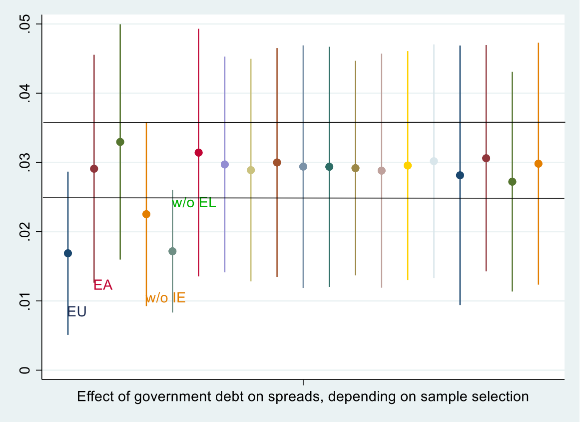
Note: The dummy variable d2008 is set to 1 as from 2008, and to 0 otherwise; the dummy variable d2013 is set to 1 as from 2013, and to 0 otherwise. In all regressions, the crisis dummy allows controlling for the specific effect of the 2012 crisis on spreads (all else being equal). This is also true in regressions (2), (4), (6) and (8), which aim at testing time-variant coefficients, through time-slope dummies.

Source: Authors' calculations.

Testing for the robustness of results to the sample selection

Previous results appear relatively robust to changes in the sample selection. Some papers test the heterogeneity of some of the coefficients across country groups (De Haan *et al.*, 2014) or explore the sensitivity to the exclusion of one or several countries (Capelle-Blancard *et al.*, 2019; De Haan *et al.*, 2014). In this paper, the sensitivity of the results to the (country) sample choice is tested, first by broadening the sample to all EU counties, then, by dropping countries one by one from the sample. Our estimates confirm that previous findings are robust to the sample selection choice (see Graph 6 and section IV of the annex). In particular, the sensitivity of spreads to government debt is found to remain significant across these different regressions, with limited differences in magnitude. Yet, the impact of debt on spreads appears somehow lower when broadening the sample to all EU countries (while, interestingly, the net external position variable grows more significant). Moreover, quantitative results are sensitive to the exclusion of Greece and to, a lesser extent, of Ireland from the sample.

Graph 6. **Estimated response of spreads to government debt (Benchmark model), depending on the sample selection.**



Note: The bars represent confidence intervals of the estimated coefficients.
Source: Authors' calculations.

Testing for the relevance of a dynamic form via an ECM

Static and dynamic models are used in the literature. Static forms (i.e., a model explaining the level of spreads) are commonly found. Dynamic models are also present. In this case, some papers include a lag of the dependent variable among regressors to account for the persistence of spreads (Capelle-Blancard, *et al.*, 2019; Afonso *et al.*, 2015; Afonso and Felix, 2014). Other papers estimate an error-correction model (ECM), where one captures both the 'long-run' relation of spreads to regressors and the short-run dynamics of adjustment (Ben Salem and Castelletti Font, 2016; OECD, 2016; Poghosyan, 2012).

Macroeconomic data are often non-stationary, an issue which dynamic approaches such as error correction models (ECM) can help address. ECMs are particularly desirable if variables are non-stationary, with the additional advantage that they can help depict economic relationships going through a transition stage towards equilibrium, distinguishing short and long-run dynamics.

Specifically, we estimate an error-correction model similar to the static benchmark regression, without context variables. [32] In the case of our benchmark regression, unit root tests are not clear-cut, but they give some indication that certain variables may be non-stationary (see Annex IV for unit root tests and cointegration analysis). Taking a cautious approach, this section tests an ECM specification with all benchmark variables whose order of integration could be I(1), as follows:

$$\Delta Spr_{i,t} \;=\; \alpha_0 + \beta_1.\Delta NIIP_{i,t} + \beta_2.\Delta GDPp_{i,t} + \beta_3.\Delta D_{i,t} + \beta_4.\Delta gef_{i,t} + \beta_5.\Delta size_{i,t}$$

[32] Prior to estimating the ECM, we carry out stationarity and cointegration tests. As reported in section IV of the annex, some variables have a unit root and panel cointegration analysis shows that spreads and NIIP, real potential GDP growth, the government debt ratio, government effectiveness, and size are cointegrated.

$$+ \theta . Spr_{i,t-1} + \alpha_1 . NIIP_{i,t-1} + \alpha_2 . GDPp_{i,t-1} + \alpha_3 . D_{i,t-1} + \alpha_4 . gef_{i,t-1} + \alpha_5 . size_{i,t-1} + \eta_{i,t} \quad (6)$$

The dynamic model confirms the relevance of key fundamentals such as government debt, NIIP, government effectiveness and relative size, with magnitudes similar to those in the static form. The coefficients of the error correction term is negative and significant. Government debt, NIIP, government effectiveness and relative size are all significant in the long-term relation and the sensitivity of spreads to these variables is fairly close to the one found in the static specifications (see long-run elasticities in Table 6). Government debt also appears relevant in the short run (see Tables 5 and 6).

Table 5. **Estimation results, error correction model (ECM).** Dependent variable is the first difference of nominal spreads on 10-year government bond yields (vis-à-vis German bonds), EA countries, 2000-2019

VARIABLES (expected sign)		VARIABLES (expected sign)	
		Coefficient of the Error Correction Term	**-0.429*** (0.0409)
Short-run coefficients		*Long-run coefficients*	
Δ Net Intl. Investment position (dN*IIP*) (-)	**-0.0102** (0.00628)	**Net Intl. Investment position (N*IIP*) (-)**	**-0.00238**** (0.00113)
Δ Real potential GDP (dGDPgp) (-)	**-0.0415** (0.0921)	**Real potential GDP (GDPgp) (-)**	**-0.0518** (0.0840)
Δ Government debt (d*D*) (+)	**0.0444*** (0.0264)	**Government debt (*D*) (+)**	**0.00742***** (0.00252)
Δ Government effectiveness (dgee) (-)	**-1.555** (1.352)	**Government effectiveness (gee) (-)**	**-0.346***** (0.122)
Δ Country size (d_relative_size) (-)	**-0.911** (0.796)	**Country size (relative_size) (-)**	**-0.0501**** (0.0212)
		Crisis dummy	**1.599**** (0.787)
		Constant	**0.458** (0.333)
Observations	246		
Number of cty_num	17		
RE	YES		
Time FE	NO		
R2	0.336		
RMSE	1.133		

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Models estimated through GLS. Random effects are included. Robust standard errors. ***, ** and * denote p-values less than or equal to 1%, 5% and 10%, respectively. Countries included are all EA except Germany (benchmark country) and Estonia (variable spread not available).

Source: Authors' calculations.

Table 6. **Elasticities of spreads on 10-year government bonds to different variables**

Short-run equation		
Explanatory variable	**Parameter estimated**	**Short-run elasticity of nominal spreads** to each explanatory variable (for significant coefficients only)
NIIP	-0.0102	n.s.
Potential GDP (real)	-0.0415	n.s.
Government debt	0.0444*	0.0444
Government effectiveness	-1.555	n.s.
Relative size	-0.911	n.s.
Coefficient of the Error Correction Term		
	Parameter estimated	**Adjustment speed towards equilibrium**
	- 0.429***	0.429
Long-run equilibrium equation (Error Correction Term)		
Explanatory variable	**Parameter estimated** (Coefficients of the error correction terms not factored out)	**Long-run elasticity of nominal spreads** to each explanatory variable (for significant coefficients only)

Note: Error correction model estimated as indicated in Table 5.
Source: Authors' calculations.

5. CONCLUDING REMARKS

This paper investigated the empirical drivers of sovereign bond spreads in the euro area with an emphasis on the influence of fundamental determinants, while controlling for the influence of global risk aversion and central banks' asset purchases. Evidence is found that fiscal fundamentals, particularly the level of the debt-to-GDP ratio but also its dynamic, affect spreads significantly. They appear to do so in a non-linear fashion and in a mutually reinforcing way. Other macroeconomic fundamentals including the net external position and potential growth, as well as government effectiveness, also have a bearing on spreads, both on their own and in interaction with government debt. This implies that the incidence of fiscal fundamentals may be importantly mitigated or aggravated by other macroeconomic or institutional factors. These results dovetail with earlier empirical findings. From a policy angle, they are a reminder that even in an environment of persistently low rates, more solid fundamentals allow governments to benefit from lower borrowing costs and less risk exposure. Such findings echo previous research that establishes that higher indebted countries generally experience less favourable interest – growth rate differentials (Lian et al., 2020). Moreover, our results highlight that policies aimed at reinforcing potential growth and government effectiveness can be expected to improve investors' perception of sovereign risk and their forbearance for higher debt.

The results also show that the behaviour of spreads can only partly be explained by fundamental variables. There are several limitations to such study. First, even in a relatively homogenous panel focusing on euro area economies only, it remains empirically difficult to decide between alternative specifications of fundamentals with approximately similar explanatory power in the data. There is also limited but non-negligible dependence on the inclusion of specific countries. Second, it is also difficult to entirely remove the time-dependency of estimated coefficients. This suggests that there have indeed been already several 'regimes' in the euro area with specific incidences of fundamentals on spreads. Observed volatility factors such as global risk aversion only help to some extent in capturing these regime changes. While the latter part of the 2010s featured a regime of persistent, though contained spreads, the 2020s may involve yet other developments given the surge in public borrowings following the Covid-19 crisis and the further evolution of the European fiscal and monetary response.

Box 1. **A GLOBAL DECLINE IN THE LEVEL OF RISK-FREE REAL LONG-TERM RATES. THE DRIVERS**

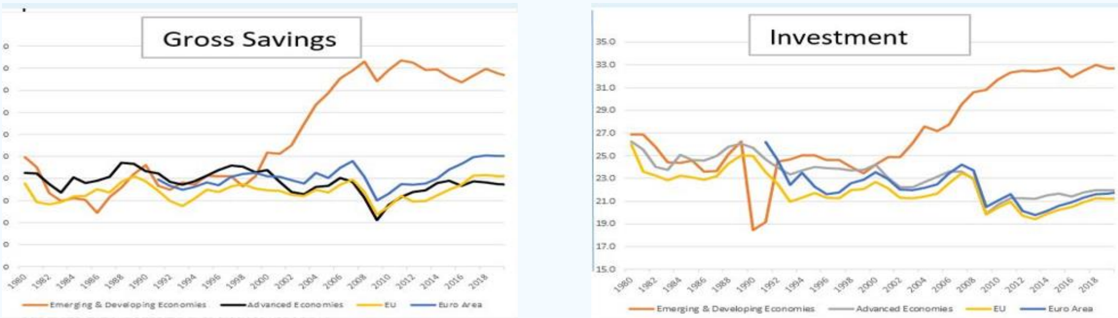
The forces behind the fall in risk-free, real (long-term) interest rates remain ambiguous. A rich array of theoretical and empirical literature explores the topic, proposing, broadly, two complementary strands of explanations for the falling level of risk-free real interest rates. The importance of each factor is difficult to quantify accurately, but some factors such as productivity, demographics or safe asset shortage seem relatively more influential.

A traditional strand of studies explores structural, long-term determinants, featuring a saving and investment framework at global level, where the real interest rate operates as balancing factor. In this theoretical setup, pining down the fundamentals of real interest rates hinges in turn on the real drivers of saving (supply of funds) [33] and investment (demand for funds). Studies in this category abound, including the longer standing secular stagnation literature (Hansen 1939, Summers 2014). By their nature, factors considered here operate over the long term, having been at play, in structural manner, before the recent crises. In a nutshell, this literature states that equilibrium interest rates have permanently declined for structural reasons linked to both supply and demand, shifting both the saving and investment curves (IMF 2014, Rachel and Smith 2015), and leading to an excess of desired saving over desired investment, i.e. to a 'global savings glut' (Bernanke 2005) (Graph 1).

- **On the saving side**, demographic changes such as expected ageing, [34] rising income or wealth inequality, income growth in emerging economies, especially China, are among the factors invoked to explain increased (private) saving and a rightward shift in the supply of funds schedule (Aksoy et al 2016). In addition, tight fiscal policy (surpluses) also increased public saving over certain periods (IMF 2014).

- **On the investment side,** a set of factors would have subdued the firms' demand for funds, leading to a decline /leftward shift in the investment schedule. Amongst these are low total factor productivity (TFP) growth, [35] sluggish invention and innovation, lower physical capital and investment needs (due to demographic changes and a stable labour-capital ratio), a decline in the relative price and thus value of investment, and low investment profitability. Such circumstances would eventually result in a persistent output gap and/or slow rate of economic growth (Eichengreen 2015, Gordon 2015), being also associated with low inflation (Summers, 2014).

Graph 1. Gross savings and investments, % of GDP, selected regions



Source: Macrobond, IMF.

A second strand of literature questions the traditional view and expands it, proposing a monetary and financial narrative to the movements in real rates, and thus a role for policy. This angle casts doubt on the view that real interest rate decline would have been driven solely by variations in desired saving and investment. First, some studies show that *demographics are not the sole or most important factor* having affected interest rates (Gourinchas and Rey 2018). Others posit only an indirect link between long-term rates and structural factors, operating via policy real rates, which are those assumed to respond to secular factors (OECD 2017). To make the case that money is non-neutral, some authors go as far as suggesting that secular stagnation itself may not be a structural feature of the economy, but a result of policy. This can happen if

[33] The supply of funds may come from private saving, public saving (the budget surplus), or monetary policy actions (IMF 2014).

[34] Structural factor theories regard projected future ageing as a process having induced precautionary savings and thereby depressed interest rates. Consistent with a life-cycle hypothesis, this propensity to save requires certain conditions: forward-looking middle-age savers, with sufficient income margin to save, and non-reliant on a PAYG system (see also Table 1 in Annex A1). Once ageing is realised and the middle age cohorts responsible for saving reach retirement, dissaving is expected.

[35] Standard growth models predict that a decline of TFP growth by 1ppt lowers the real interest rate in the range between 100 - 200 bps (Rachel & Smith 2015).

policy fails to address booms over successive cycles, leading to frequent busts whose toll on the real economy traps the latter at low rates and low potential output (Rungcharoenkitkul et al. 2019). *International monetary and financial spillovers*, rather than common movements in global saving and investment, represent a major sway for the real interest rates of smaller, more open economies. Influencers are the monetary policy and interest rates of countries dominating global monetary and financial conditions, such as the US (Hamilton et al. 2015, Borio et al. 2017). The contribution of such global, common component to real rate variation appears large and increasing over time (IMF 2014). In a nutshell, studies in the monetary and financial strand find that the drivers of real long-term interest rates, by order of their relevance, are i) conventional monetary policy and international spillovers via capital flows and global trends, ii) saving-investment imbalances and demographics, and iii) unconventional monetary policy and the supply and demand for safe assets (government bonds). Depending on the study, these factors may in fact encompass a set of interlinked elements:

Monetary policy. Some studies provide empirical evidence that **conventional monetary policy** regimes (gold standard, Bretton Woods, inflation targeting), defined by the central banks' interest rate-setting behaviour (reaction function) are relevant (Borio et al. 2017) and that the monetary policy rate played a role in reducing real interest rates (OECD 2017). A shift towards inflation targeting since the late 1980s – early 1990s appears partly responsible for the low interest environment. [36] After the global financial crisis, **unconventional monetary policy** in the form of asset purchases and forward guidance accompanied and amplified previous conventional monetary policy shifts and existing market expectations, further compressing term premia and thereby long-term interest rates. [37] Central bank bond purchases should lower real interest rates and may keep government bond yields low both directly (via bond demand) and indirectly, by signalling an easy monetary policy stance in the future (OECD 2017). According to some authors, the monetary policy interest rate anchors the real economy and can prevent it from stagnating at low real rates in the long term by leaning against the wind (Borio et al. 2019, Rungcharoenkitkul et al. 2019). As monetary policy underpins the term structure of market interest rates, it essentially underpins all economic activity via financing flows, making the real economy finance-based and money non-neutral. Besides, if monetary policy insufficiently leans against the wind of asset prices and credit booms, setting policy rates to only address inflation (and the output gap), at somewhat lower levels than financial stability would require, successive busts may cause long-lasting drops in the real economy's potential and equilibrium real rate. This would require a stronger monetary policy response thereafter, with policy today constraining policy tomorrow.

Destabilising financial cycles. For authors like Borio, if policy systematically fails to control the financial cycle, the economy may set at permanently lower real interest rates. Moreover, in boom-bust financial cycles, busts are associated to asset price decline and *deleveraging*. Evidence from the EU after the global financial crisis, suggests that public and private sector active deleveraging through debt repayment was often associated to reduced lending to the real economy, depressed investment, thus protracting the downturn and weighing on the real interest rate (Praet 2017). Yet, in that episode deleveraging played only a temporary, asymmetric role across EU countries, so it seems unlikely that it could drive a multi-decade, global or European level decline in the real interest rates.

Regulatory and prudential framework. Micro and macro prudential frameworks, for individual institutions and the system as a whole, are an emerging policy field explicitly designed to address the financial cycle and the financial system's procyclicality. Regulating risk-taking behaviour plays an important role in modulating booms and busts, with consequences for portfolio management and the supply and demand of safe assets (see below). For some authors, prudential policy helps monetary policy keep the real economy away from the low interest and output trap (Borio et al. 2019).

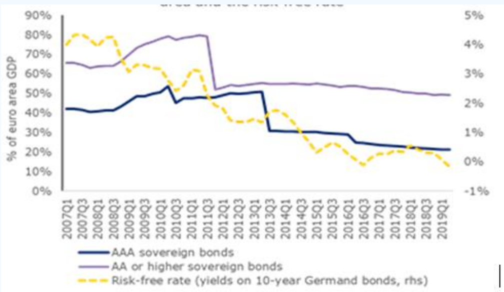
Safe asset shortage. An increased demand for the asset class of highly-rated sovereign bonds, coupled with a scarce supply of such assets is a leading explanation for the secular decline in real risk-free rates (Gourinchas and Rey 2018, OECD 2017). This global imbalance deepened after the global financial crisis also played an increasing role at euro area level. ***On the demand side,*** global uncertainty, risk aversion, portfolio

[36] This factor concerns the decline of *nominal* rates. Both components of long-term nominal interest rates, the expected short-term (policy) rates and the term premium, mirrored this shift towards inflation targeting, as inflation expectations became better anchored in both the short and long term. Term premia decline drove nominal rates down systematically since the late 1980s and turned even negative after the global financial and EA debt crises. Besides increased certainty regarding inflation and the path of future short rates, declining and negative term premia likely reflect that the investors' preferred habitat moved to the long term.

[37] Market expectations of persistently low interest rates in the years to come are likely to reflect a historically low level of the real equilibrium rate. This is because the monetary policy stance is usually defined in relation to the natural or equilibrium real rate (Fischer 2016; Lane 2019). This induces a circular relationship between monetary policy rates and equilibrium real interest rates.

considerations such as the relative risk of investing in equities versus bonds, but also policy, have fuelled a higher demand for safe assets. Before the global financial crisis, emerging market investors drove the safe assets demand and their scarcity. [38] With the crisis, risk appetite fell globally and both advanced and emerging economy investors increasingly preferred highly-rated government bonds. [39] Regulatory changes for banks and institutional investors and more collateralised operations have also boosted safe asset demand. Not least, central bank bond purchases have increased this demand. In the euro area, the Eurosystem's asset purchase programmes have withdrawn from the market a significant share of outstanding, highly rated sovereign debt since 2015. In 2020, this driver expanded with the pandemic emergency purchase programme and should remain relevant looking ahead. ***On the supply side***, in the euro area, the share of highly-rated government bonds declined and became more concentrated in a few countries (Lane 2019, Gourinchas and Rey 2017). This effect is also visible at global level, as the supply of highly rated assets in percentage of global GDP has recently collapsed. Downgrades by credit rating agencies since the financial crisis have led to fewer European countries being rated (AA and AAA) while sovereign net debt issuance by highly rated EU countries has significantly slowed down or even declined – Graph 2.

Graph 2. Outstanding 'safe' sovereign debt securities in the EA and the risk free rate



Source: Moody's, S&P, Fitch, Eurostat and DG ECFIN calculations.

Some of the studies quoted strike balanced conclusions regarding the two strands of drivers. *Over long periods*, global real rates are driven by both macro structural forces, such as productivity or demographics, as well as by financial forces, especially the boom and bust cycles in the 1930s and in the 2000s (Gourinchas and Rey (2018). The global Consumption–to-Wealth ratio (C/W) with strong predictive power for long-run real risk-free interest rates, unveils four drivers of these rates' decline: i) productivity slowdown (via reduced consumption); ii) ageing (via increased saving, although demographics are not the main savings driver); iii) deleveraging and iv) a fall in risk appetite. Similarly, the worldwide and substantial fall in real interest rates since the 1980s had different common drivers (a global component), *depending on the period* (IMF 2014). These drivers were a) monetary policy in the 1980s and early 1990s; b) fiscal policy improvement in advanced economies during the rest of the 1990s and c) three shifts since the late 1990s. By order of their impact, these were i) *Portfolio shifts* towards bonds (a higher equity premium); [40] ii) *Investment collapse* in advanced economies, as investment profitability dropped since the global financial crisis; [41] iii) *Saving substantial increase* in emerging market economies, especially China, due to high income growth during 2000–07.

In sum, the different conceptual frameworks and factors underpinning the fall in risk-free real interest rates paint an eclectic picture. Based on different samples in terms of the number of advanced economies and years analysed, studies show that both monetary and financial drivers, as well real as saving and investment determinants may be at play, with different intensities, depending on the country and period scrutinised. (See Table A1 in the Annex for an overview of the real interest rates co-movement with different variables).

[38] The increasing share of emerging markets in global wealth implies a higher global demand for such assets, mainly supplied by advanced economies.

[39] The share of risk-averse investors has likely increased due to the global financial crisis, lowering real risk-free rates (Hall 2016; Caballero et al 2017).

[40] See also Table 1 in the Annex A1 for the sources of a higher equity premium.

[41] Particularly in the euro area, Japan, and the UK.

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ANNEX

I. ADDITIONAL ELEMENTS ON LITERATURE

Table A1. **Expected sign of the level of real (long-term) interest rate drivers, by channel** (+) Positive correlation (same sign) (-) Negative correlation (opposite sign)

Channel	Drivers	Expected Sign	Hypothesis or findings on the channel at play and the study where referenced
1. Saving and Investment factors			
1.1. Saving or Supply of funds (Saving shift)	(includes public and private saving)	–	An increase in income raises saving (the supply of funds) and lowers the interest rate (price) that equilibrates the supply and demand for loanable funds. An increase in saving reduces rates via tight fiscal policy (surpluses increase public saving) or higher GDP growth (increasing saving through consumption habit). For ageing, see below (IMF 2014). Household savings played a minor role for the long-term relationship in all countries Germany and, to a lesser extent, France and Italy. (OECD 2017)
	• (Expected) ageing of population / demographic pressures / life expectancy / • Old age demographic dependency ratio (OADR) defined as population aged 65 and over/ population aged 15-64	–	Under the life cycle model, whereby saving rates are highest for the middle age group to smooth consumption, projected (expected) ageing assumes increased saving for precautionary reasons (Gourinchas and Rey 2018) and thus decreases real interest rates. Since ageing translates into an increased OADR, the latter is also negatively correlated with real interest rates. The dependency ratio played a minor role in all countries but Germany and Italy. (OECD 2017) When this ageing process is completed (and the OADR is already high), the opposite relationship (positive correlation) applies: Realised (contemporaneous) ageing would imply lower saving / dissaving, increasing real interest rates and reducing global investment (IMF 2014). Causality in the contemporaneous relationship between (realised) ageing and savings could go either way: (a) pensioners dissaving, which increases the interest rate, but also (b) low rates may encourage dissaving by limiting the amount of accumulated wealth.
	• Increased labour market participation • Economic dependency ratio (EDR) defined as inactive persons aged 14 and over plus persons aged 0-14 / total persons employed	– +	Higher labour market participation of women and older workers implying a fall in the total economic dependency ratio is also conducive to higher savings and lower real interest rate (Lisack, N., R. Sajedi and G. Thwaites 2019). Note that EDR and OADR may have opposite evolutions, both associated to a fall in interest rates.
1.2. **Investment or Demand for funds (Investment shift)**		+	A decline in investment reduces interest rates due to a decrease in investment profitability; a decrease in the relative price of capital and investment goods – machinery, IT - has an ambiguous

Channel	Drivers	Expected Sign	Hypothesis or findings on the channel at play and the study where referenced
			effect on investment and real interest rates, depending on the elasticity of investment to its relative price. (IMF 2014)
	Real potential GDP growth	+	In a 'secular stagnation' hypothesis negligible economic growth, a savings glut (excess of savings over to investment) and low interest rates are associated (Summers, (2013) and (2014), Summers and Rachel (2019); Via real monetary policy rates responding to secular trends (OECD 2017), low policy rates today bode low interest and policy rates tomorrow.
	• Productivity growth	+	Expectations of lower productivity growth, at home and abroad, reflecting lower population growth, dampen investment and raise saving. (Gourinchas and Rey 2018)
			Via ageing, as an older labour force is less productive than a young one. (Lane 2019)
			Low TFP and LIRE may be in a circular relationship: low interest rates may result in resource allocation towards less productive sectors. The survival of unproductive firms lowers TFP growth at macroeconomic level, which further depresses investment and consumption and eventually pushes real interest rates further down. (Gopinath et al 2017)
2. Monetary policy, financial and regulatory factors, international spillovers, safe asset shortage, also linked to portfolio management and risk taking behaviour			
	Real central bank policy rate (Conventional monetary policy) / (Monetary repression)	+	The central banks' interest rate-setting behaviour (reaction function) significantly influences real interest rates. Changes in monetary policy regimes may be associated with changes in risk premia, in particular inflation risk premia, which are part of the study's measure of real rates. (Borio et al. 2017)
			In a standard IS-LM model, monetary policy easing (tightening) can shift leftward (rightward) the supply of funds, reducing (increasing) the real rate. (IMF 2014).
			Real policy interest rates are positively correlated with long-term interest rates both in the long-term cointegration relationship and in the short run. Monetary policy rates are the main driver of real short-term rates in the UK, Italy and the US. Real policy rates respond to secular trends (OECD 2017).
	Central bank holding of government bonds (Unconventional monetary policy) - see also demand for safe assets	−	Central bank bond purchases may keep government bond yields low both directly (via bond demand) and indirectly, by signalling an easy monetary policy stance in the future. A rising share of bond purchases should lower real interest rates. QE pushed down real long-term interest rates in the US and UK (Kaminska and Zinna 2014, Meaning and Zhu 2011; Hofmann and Zhu 2013), or US and Japan, but not in Canada or the largest EA countries. (OECD 2017)
	Strong macro-prudential policy / financial regulation, financial repression	−	Via constrained credit to the real sector and control of risk taking (see also deleveraging). (IMF 2014, Gourinchas and Rey 2018)

Channel	Drivers	Expected Sign	Hypothesis or findings on the channel at play and the study where referenced
	Foreign long-term real interest rate (government bond yields)	+	Variable likely to capture both increasing financial openness with spillovers via financial markets and monetary policy, and common global trends affecting nominal interest rates and inflation. It is the main driver in Canada, France and Japan. (OECD 2017). Countries' real interest rates appear to reflect Idiosyncratic variations in the interest rates of countries dominating global monetary and financial conditions, rather than common movements in global saving and investment. (Borio et al. 2017)
	Safe asset shortage	–	
	• Demand for safe assets (bonds) / Fall in risk appetite - see also unconventional MP	–	An increase in desired safe assets holdings associated to risk aversion (a fall in risk appetite) explains the secular decline in real risk-free rates. (Gourinchas and Rey 2018, OECD 2017, IMF 2014)
	• Supply of safe assets (government debt level)	+	Credit rating downgrades leave highly rated bonds in scarce supply, compressing safe bonds' yields. High government debt ratios tend to be associated with higher real interest rates. (OECD 2017)
	• Portfolio shifts towards bonds - The relative risk of holding equities vs. bonds - The relative demand for bonds vs. equities	–	The equity premium varies over time. It is larger and drives interest rates down when the demand for bonds (safe assets) increases relative to that for equities and when the risk of investing in equities as opposed to bonds is higher. (IMF 2014)
	• Uncertainty (index)	--	Uncertainty inspires risk aversion and thus a preference or higher demand for safe assets (bonds). The relationship holds only for some countries (Canada, US). (OECD 2017)
	Deleveraging	–	Outside the effective lower bound (ELB), an expected (positive) deleveraging shock lowers the risk-free rate one for one, with no effect on the consumption or risk-premia components of the Consumption/Wealth ratio. (Gourinchas and Rey 2018). Active deleveraging (debt repayment) in a downturn may squeeze the resources the private and public sector allocate to investment, delaying the recovery and weighing on the real interest rate (evidence from some EU countries after the global financial crisis).

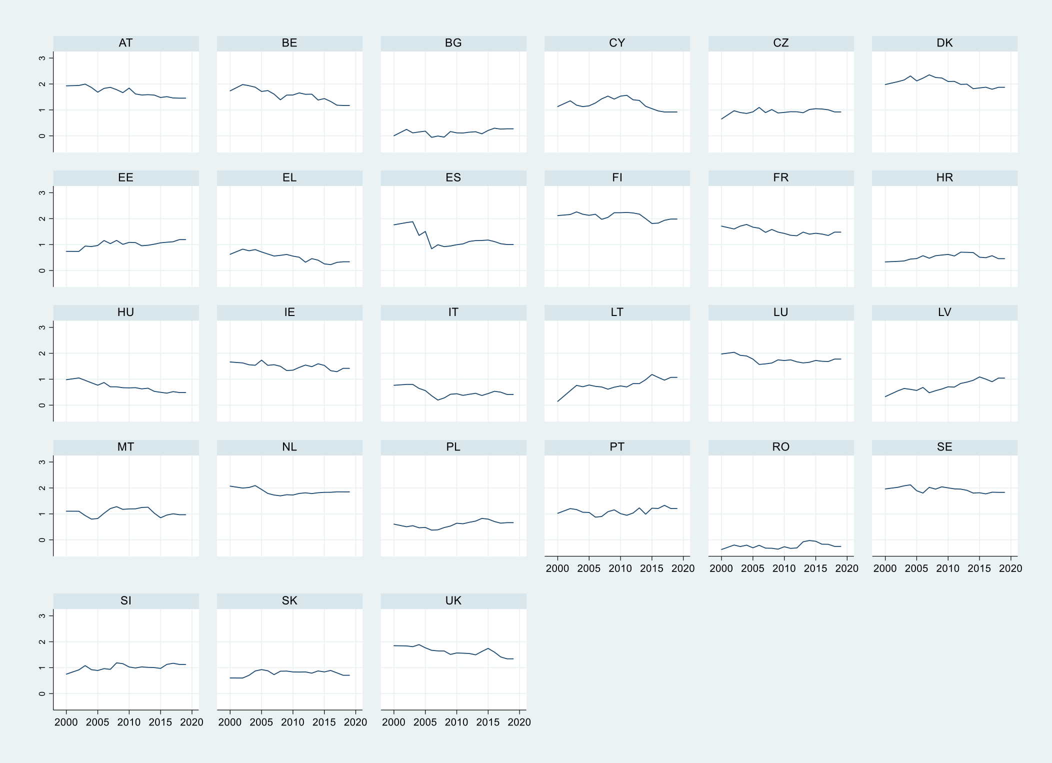
Source: Authors' compilation.

II. ADDITIONAL INFORMATION ON VARIABLES AND DATA SOURCES

Table A2. **Main variables and data sources**

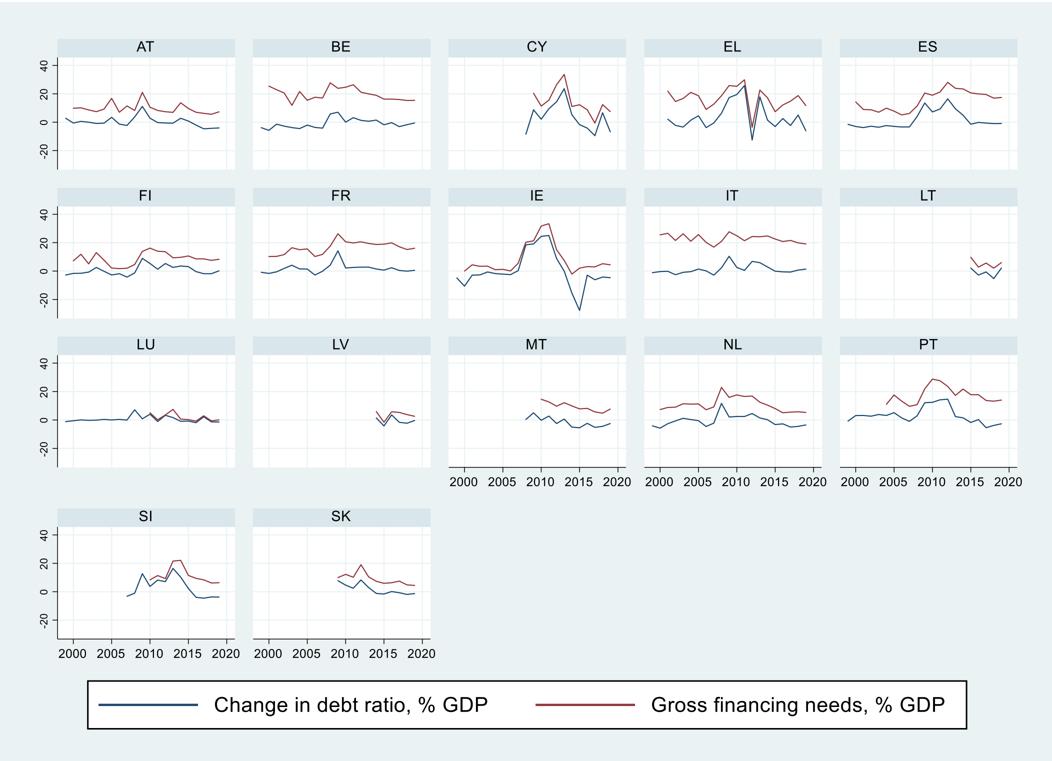
Variable	Definition	Data sources
Nominal government long-term interest rate spreads	10-year sovereign bond yield country i - 10-year sovereign bond yield Germany (pps.)	Ameco
Government debt	Maastricht government debt (% of GDP)	Ameco
Net international investment position	Net international investment position (% of GDP)	Ameco, IMF
Real potential GDP growth	%	Ameco
Government effectiveness (index)	Index capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Values range from -2.5 (weak government effectiveness) to 2.5 (strong)	World Bank's Worldwide Governance Indicators database (see Kaufmann et al. (2011))
Country size	Relative size computed as a country (nominal) GDP divided by EU/EA (nominal) GDP.	Ameco
VIX	Financial market volatility index referring to the US S&P 500	Bloomberg
PSPP	Net cumulated purchases of government bonds by the Eurosystem under the public sector purchase programme ("at historical purchase value") (% of GDP)	ECB
Primary balance	Government primary balance (% of GDP)	Ameco
Government gross financing needs	Sum of fiscal deficit, stock-flow adjustments and debt amortisations (% of GDP)	Ameco, ECB, BIS
Change in government debt	Change in government debt-to-GDP ratio(equal to the sum of fiscal deficit and stock-flow adjustments, as well as growth valuation effects (pps. of GDP)	Ameco
Average maturity of debt	Average residual maturity of government debt (in years)	OECD, ECB, national sources
'Market' debt	Maastricht government debt – government debt held by the official sector (for EL, IE, PT, ES and CY) – net cumulated purchases of government bonds by the Eurosystem, (% of GDP)	Ameco, ECB, national sources
Nominal government short-term interest rate spreads	3-month interbank rate of country i – 3-month interbank rate of Germany (Euribor as from 1999)	Ameco
Crisis	Dummy variable that takes value 1 in 2012, and 0 otherwise	Authors

Graph A1. **Government effectiveness, index**, EU countries



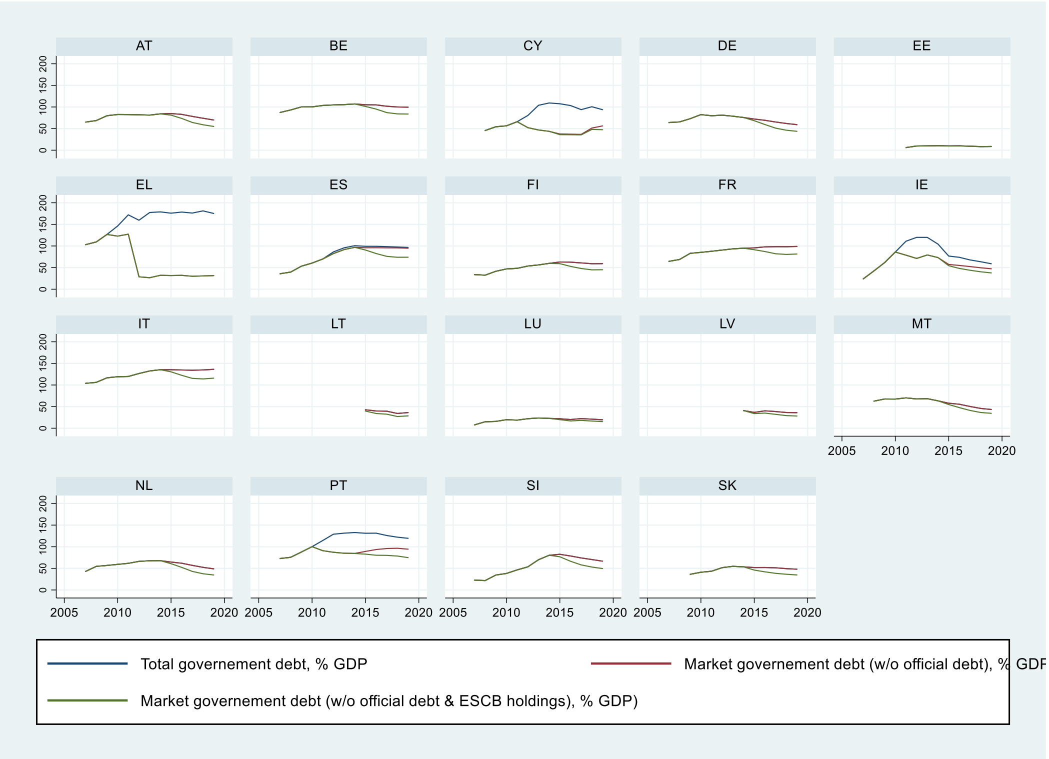
Source: World Bank (WGI).

Graph A2. **Government change in debt and gross financing neds,** EA countries (by entry date)



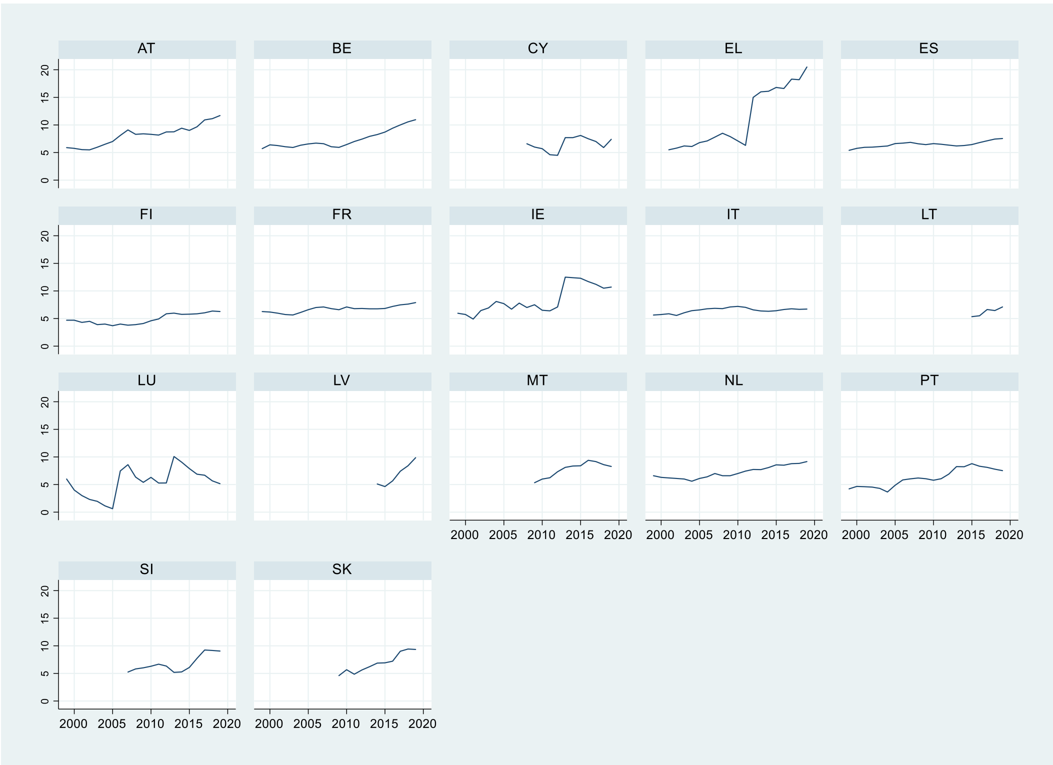
Source: Ameco, ECB, BIS.

Graph A3. '**Market' government debt** (computed as Total government debt – Share held by the 'official' sector (ESM/EU/IMF) – Share held by the Eurosystem (under PSPP)), EA countries (by entry date)



Source: Ameco, ECB, national sources.

Graph A4. **Average residual maturity of government debt**, EA countries (by entry date)



Source: OECD, ECB, national sources.

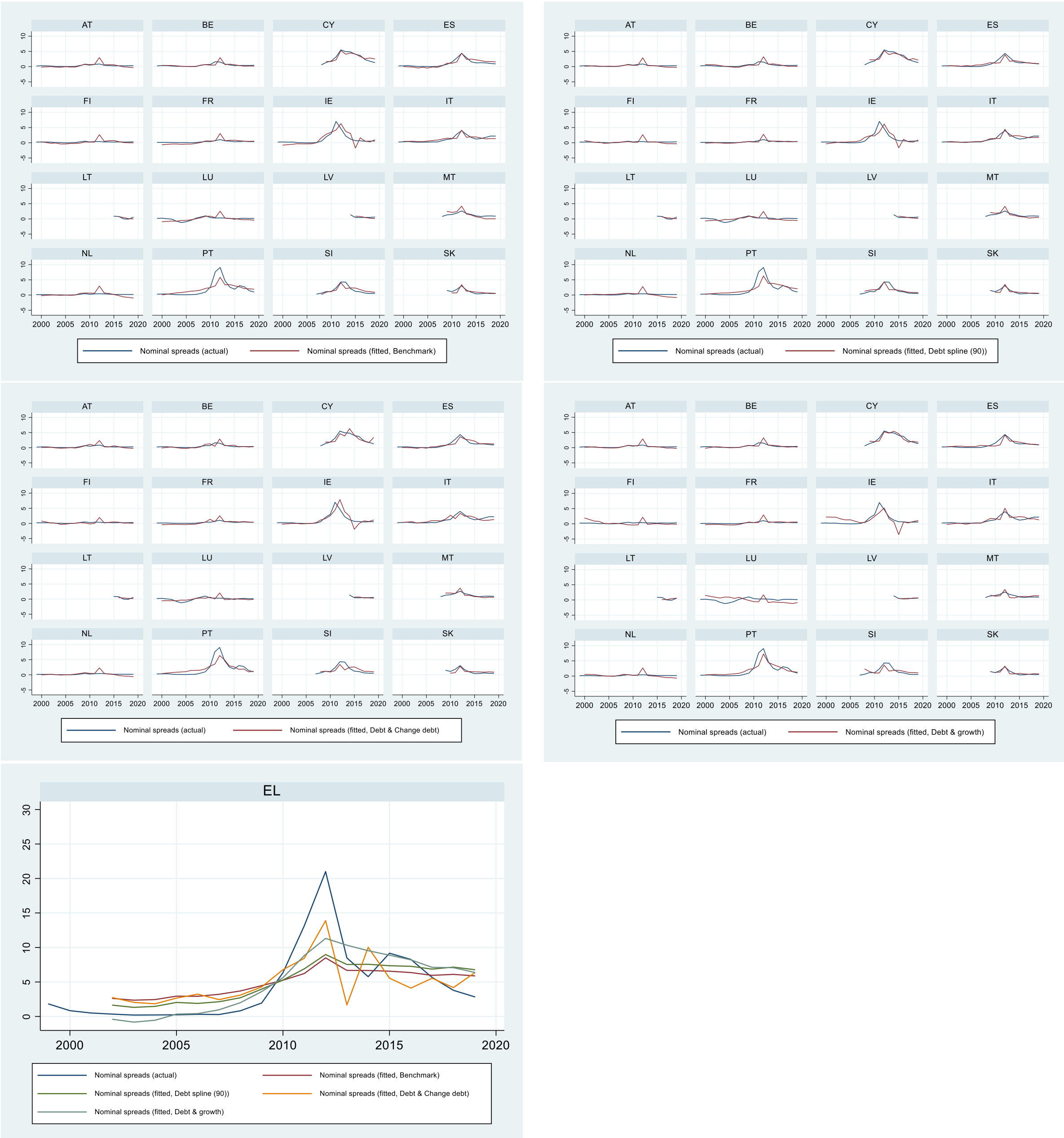
Graph A5. **Short-term interest rates' spreads**, non EA countries

Source: Ameco.

III. ADDITIONAL GRAPHS ON FITTED VALUES AND RESIDUALS (SELECTED REGRESSIONS PRESENTED IN SECTIONS 4)

While government interest rates' spreads appear strongly related to fundamentals in our regressions (the R2 stands around 0.6 or above), fundamentals do not appear to explain all variations. Differences between actual and fitted values are particularly large for some countries (e.g. EL, and to a lesser extent PT and IE), where the model fails in particular to fully explain the spreads' spike in 2011-12. [42] These results point to financial markets' sentiments playing a significant role, or to some potential mispricing, a finding previously reported by e.g. De Grauwe and Ji (2012) and Al-Amine and Willems (2020).

Graph A6. **Actual and fitted spreads (benchmark, debt spline (90), debt & change in debt and debt & growth models),** sample countries.



Source: Authors' calculations.

[42] In the case of IE, the substantial residual in 2015 corresponds to the large technical revision of the GDP.

IV. ADDITIONAL ROBUSTNESS CHECKS

Testing for the sensitivity of the results to the sample selection

- *All EU countries*

Table A3. **Estimation results, benchmark and non-linear forms**. Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), EU countries, 2000-19

	(1)	(2)	(3)	(4)	(5)
VARIABLES	**Benchmark**	**Debt spline (90)**	**Debt & ΔDebt**	**Debt & growth**	**Debt & gvt. effectiveness**
spread_st	**0.396*****	**0.401*****	**0.414*****	**0.453*****	**0.438*****
	(0.0639)	(0.0551)	(0.0617)	(0.0697)	(0.0848)
niip_gdp	**-0.00864*****	**-0.00807*****	**-0.00803*****	**-0.00840*****	**-0.00920*****
	(0.00168)	(0.00219)	(0.00163)	(0.00260)	(0.00202)
GDPgp	**-0.253*****	**-0.247*****	**-0.197****	**0.312**	**-0.239*****
	(0.0760)	(0.0769)	(0.0915)	(0.291)	(0.0693)
gee	**-0.871*****	**-0.679*****	**-0.777*****	**-0.359**	**-0.155**
	(0.217)	(0.217)	(0.180)	(0.344)	(0.277)
relative_size	**-0.0914****	**-0.0682****	**-0.0756*****	**-0.0760*****	**-0.0881****
	(0.0373)	(0.0319)	(0.0243)	(0.0264)	(0.0366)
vix	**0.0210*****	**0.0206*****	**0.0197****	**0.0244****	**0.0186****
	(0.00809)	(0.00799)	(0.00813)	(0.00972)	(0.00859)
gdebt_gdp	**0.0169*****	**-0.00186**	**0.0102*****	**0.0282*****	**0.0283*****
	(0.00601)	(0.00654)	(0.00371)	(0.00883)	(0.00813)
debt_90		**0.0547*****			
		(0.0160)			
Δgdebt_gdp			**-0.0770**		
			(0.0535)		
debt_Δgdebt			**0.00189*****		
			(0.000575)		
debt_growth				**-0.00980*****	
				(0.00285)	
debt_gee					**-0.0124*****
					(0.00476)
crisis	**1.495*****	**1.575*****	**1.205*****	**1.505*****	**1.540*****
	(0.542)	(0.593)	(0.345)	(0.552)	(0.569)
Constant	**1.259****	**1.826*****	**1.318****	**-0.496**	**0.521**
	(0.504)	(0.627)	(0.543)	(1.423)	(0.633)
Observations	483	483	483	483	437
Number of cty_num	27	27	27	27	27
Country RE	YES	YES	YES	YES	YES
R2	0.610	0.658	0.681	0.654	0.635
RMSE	1.153	1.082	1.106	1.125	1.152

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note : Model estimated through generalised two-stage least squares, with debt and PB instrumented by their lag. Random effects included. In regressions (3), spreads are directly regressed on the lagged values of debt and the change in debt given the effect of the debt restructuring in 2012 in Greece. Robust standard errors in parentheses. ***, ** and * denote p-values less than or equal to 1%, 5% and 10%. Countries include all EU countries except for Germany (benchmark country).

Source: Authors' calculations.

- *Dropping critical countries*

Table A4. **Estimation results, benchmark and sensitivity to country sample choice.** Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), EA countries, 2000-19

VARIABLES	(1) Benchmark EA	(2) w/o EL	(3) w/o IE	(4) w/o PT	(5) w/o CY	(6) w/o ES
niip_gdp	**-0.00602****	**-0.00705*****	**-0.00512**	**-0.00635****	**-0.00528***	**-0.00541***
	(0.00276)	(0.00222)	(0.00425)	(0.00260)	(0.00276)	(0.00307)
GDPgp	**-0.207****	**-0.140*****	**-0.455****	**-0.208****	**-0.197***	**-0.207***
	(0.104)	(0.0422)	(0.230)	(0.104)	(0.106)	(0.109)
gee	**-0.613***	**-0.438***	**-0.614**	**-0.668****	**-0.683****	**-0.610***
	(0.314)	(0.248)	(0.393)	(0.320)	(0.312)	(0.345)
relative_size	**-0.151*****	**-0.100*****	**-0.155*****	**-0.156*****	**-0.152*****	**-0.163****
	(0.0529)	(0.0281)	(0.0594)	(0.0557)	(0.0556)	(0.0648)
vix	**0.0154*****	**0.0124***	**0.0135****	**0.0146*****	**0.0181*****	**0.0163*****
	(0.00504)	(0.00709)	(0.00533)	(0.00555)	(0.00501)	(0.00548)
pspp_gdp	**-0.0255***	**-0.0144**	**-0.0191**	**-0.0258***	**-0.0220**	**-0.0235***
	(0.0136)	(0.0101)	(0.0131)	(0.0144)	(0.0136)	(0.0136)
gdebt_gdp	**0.0291*****	**0.0172*****	**0.0225*****	**0.0281*****	**0.0300*****	**0.0314*****
	(0.00840)	(0.00452)	(0.00678)	(0.00956)	(0.00843)	(0.00912)
crisis	**2.289*****	**1.631*****	**2.185*****	**2.047****	**2.294*****	**2.281****
	(0.825)	(0.399)	(0.781)	(0.859)	(0.877)	(0.898)
Constant	**0.307**	**0.562**	**1.240***	**0.547**	**0.262**	**0.148**
	(0.594)	(0.608)	(0.718)	(0.650)	(0.565)	(0.634)
Observations	261	243	242	242	250	242
Number of cty_num	17	16	16	16	16	16
Country RE	YES	YES	YES	YES	YES	YES
R2	0.572	0.595	0.581	0.576	0.552	0.566
RMSE	1.294	0.757	1.271	1.273	1.313	1.328

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note : Model estimated through generalised two-stage least squares, with debt instrumented by its lag. Random effects included. Robust standard errors in parentheses. ***, ** and * denote p-values less than or equal to 1%, 5% and 10%.

Source: Authors' calculations.

Testing for the relevance of simple time fixed effects

The introduction of simple time fixed effects overall confirm previous findings, in terms of significance and sign of the explanatory variables (see Table A5). A test of joint significance indicates that time fixed effects should be included in the model. Yet, when looking at individual coefficients, only a (positive and) significant coefficient is found for the years 2011 and 2012 across regressions. In this case, the VIX variable often becomes insignificant or weakly significant given that the latter already captures time fixed effects. So overall, the inclusion of the VIX variable and a time dummy for the year 2012 seems a better modelling strategy that the inclusion of time fixed effects.

Table A5. **Estimation results, benchmark and additional regressions with time fixed effects.** Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), EA countries, 2000-19

	(1)	(2)	(3)	(4)	(5)
VARIABLES	**Benchmark**	**Debt spline (90)**	**Debt & ΔDebt**	**Debt & growth**	**Debt & gvt. effectiveness**
niip_gdp	**-0.00784*** **	**-0.00780*** **	**-0.00710*** **	**-0.00771*** **	**-0.00811*** **
	(0.00232)	(0.00227)	(0.00190)	(0.00162)	(0.00241)
GDPgp	**-0.168***	**-0.117** **	**-0.118**	**0.911*** **	**-0.149** **
	(0.0900)	(0.0577)	(0.112)	(0.228)	(0.0721)
gee	**-0.666** **	**-0.272**	**-0.614** **	**0.100**	**1.072** **
	(0.309)	(0.321)	(0.246)	(0.317)	(0.474)
relative_size	**-0.109*** **	**-0.0664** **	**-0.0916*** **	**-0.0562** **	**-0.107** **
	(0.0391)	(0.0331)	(0.0282)	(0.0241)	(0.0425)
vix	**0.0539**	**0.0550** **	**0.0510***	**-0.121** **	**-0.0723** **
	(0.0348)	(0.0225)	(0.0302)	(0.0564)	(0.0350)
pspp_gdp	**-0.0139**	**0.00295**	**-0.00964**	**-0.0389** **	**-0.0314***
	(0.0234)	(0.0161)	(0.0208)	(0.0159)	(0.0183)
gdebt_gdp	**0.0194*** **	**-0.00266**	**0.0143*** **	**0.0390*** **	**0.0447*** **
	(0.00661)	(0.00528)	(0.00331)	(0.00548)	(0.00719)
debt_90		**0.0595*** **			
		(0.0169)			
Δgdebt_gdp			**-0.151***		
			(0.0797)		
debt_Δgdebt			**0.00249*** **		
			(0.000590)		
debt_growth				**-0.0142*** **	
				(0.00275)	
debt_gee					**-0.0223*** **
					(0.00523)
Observations	261	261	244	261	240
Number of cty_num	17	17	17	17	17
Time FE	YES	YES	YES	YES	YES
Country RE	YES	YES	YES	YES	YES
R2	0.622	0.698	0.723	0.756	0.677
RMSE	1.246	1.134	1.086	1.036	1.210

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Due to the introduction of time fixed effects, the crisis (2012) dummy is omitted in these regressions.

Source: Authors' calculations.

Testing for the relevance of a random effects model versus a fixed effects model

An Hausman test concludes in some cases that a random effects model should be preferred to a fixed effects model (see statistics reported at the end of Table A6). Looking at the results of selected regressions run with fixed versus random effects model, we see that the main results related to the sensitivity of spreads to debt are confirmed. Some variables appear however not significant (such as the NIIP, or government effectiveness) given their relative inertia, which is largely confounded with the country fixed effects.

Table A6. **Estimation results, benchmark and additional regressions with country fixed effects.** Dependent variable is nominal spreads on 10-year government bond yields (vis-à-vis German bonds), EA countries, 2000-19

	(1)	(2)	(3)	(4)	(5)
VARIABLES	**Benchmark**	**Debt spline (90)**	**Debt & ∆Debt**	**Debt & growth**	**Debt & gvt. effectiveness**
niip_gdp	**-0.00329**	**-0.00132**	**-0.00716*** **	**-0.00488**	**-0.00213**
	(0.00449)	(0.00560)	(0.00236)	(0.00710)	(0.00675)
GDPgp	**-0.174** **	**-0.145** **	**-0.168**	**0.934*** **	**-0.169** **
	(0.0842)	(0.0698)	(0.133)	(0.290)	(0.0803)
gee	**-1.134**	**-1.067***	**-1.129**	**-0.207**	**1.204**
	(0.792)	(0.610)	(0.823)	(0.411)	(0.873)
relative_size	**-0.466*** **	**0.192**	**-0.523** **	**0.468***	**0.139**
	(0.166)	(0.356)	(0.211)	(0.281)	(0.294)
vix	**0.0251*** **	**0.0207** **	**0.0311*** **	**0.0282*** **	**0.0186** **
	(0.00918)	(0.00963)	(0.0102)	(0.00913)	(0.00800)
pspp_gdp	**-0.0387***	**-0.0411***	**-0.0221**	**-0.0204**	**-0.0400**
	(0.0234)	(0.0240)	(0.0279)	(0.0207)	(0.0247)
gdebt_gdp	**0.0394** **	**0.0119** **	**0.0253** **	**0.0556*** **	**0.0755*** **
	(0.0163)	(0.00596)	(0.0114)	(0.00781)	(0.0165)
debt_90		**0.0699*** **			
		(0.0215)			
∆gdebt_gdp			**-0.120***		
			(0.0691)		
debt_∆gdebt			**0.00208*** **		
			(0.000482)		
debt_growth				**-0.0149*** **	
				(0.00347)	
debt_gee					**-0.0302*** **
					(0.00673)
crisis	**2.160*** **	**2.230*** **	**1.824*** **	**2.178*** **	**2.215*** **
	(0.749)	(0.816)	(0.496)	(0.779)	(0.772)
Constant	**1.300**	**0.265**	**2.161**	**-5.450*** **	**-3.927** **
	(1.169)	(1.204)	(1.550)	(1.999)	(1.916)
Observations	261	261	261	261	240
Number of cty_num	17	17	17	17	17
Country FE	YES	YES	YES	YES	YES
R2	0.484	0.569	0.583	0.614	0.529
RMSE	1.278	1.167	1.149	1.105	1.244
Chi(2)	45.62	22.45	6.32	9.78	21.53
Prob>Chi(2)	0	0.0076	0.708	0.369	0.0105

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculations.

ECM, stationarity and cointegration tests

- *Unit root tests ECM variables*

In general, few papers discuss stationarity issues in this literature. D'Agostino and Ehrmann (2014) find that for the spreads and some explanatory variables, the presence of a unit root cannot be excluded. However, when running residual diagnostics, they find that residuals in their (level) regressions are stationary. Afonso and Kazemi (2018) report that the null hypothesis of non-stationarity is broadly rejected for the sample series.

Tests for a trend with time regressor (available upon request) show that, over the period used for time trend analysis (1960-2020), the series NIIP, relative_size, vix, and PSPP feature trends visible from the graphs and from regressions with time term coefficient statistically significant at 5%. For these series, stationarity tests are performed with intercept and trend. For the series spread, GDPgp, gov debt and gee, the time trend coefficient is not statistically significant at 5% over the period analysed, and stationarity tests are therefore conducted with Intercept only and with intercept and trend as a back-up, for precautionary reasons (43). The period for stationarity analysis (unit root tests) is 1999-2019 (44). The crisis dummy can only take values of zero or one, thus being bounded and non-stochastic by nature.

Unit root tests show that several variables have a unit root, as follows (see also Table A8):

Panel unit root tests (intercept) (Levin, Lin & Chu t* and Im, Pesaran and Shin).

I(0) series - Stationary with zero mean: gee, spread and GDPpg if indication of no time trend from regression with time trend coefficient is correct.

I(1) series - Unit root / Pure random walk (stationary in 1st diff): possibly Gov Debt (in levels, it passes one test only).

Panel unit root tests (intercept and trend) (Levin, Lin & Chu t* and Im, Pesaran and Shin)

I(0) series - Stationary around a linear (deterministic) trend: Vix and PSPP.

I(1) series - Unit root/random walk with a drift (white noise): possibly NIIP and relative_size (in levels, they pass one test only), and gee, spread and GDPpg (if their trend is stochastic and UR tests should have been done with intercept and trend, instead of intercept only) [45].

In sum:

Vix and PSPP are clearly I(0) and thus optional in the ECM.

Gov Debt, NIIP, relative_size, gee, spread and GDPpg could be either I(0) or I(1), either because in levels they pass one test only or because unit root tests could be performed more conservatively with intercept and trend, to account for possible stochastic trends([46]); in a precautionary approach, we consider all these series to be I(1).

[43] In a seminal study, Nelson and Plosser, 1982 argue that macroeconomic data is better characterised as random walks with drift than as stationary with a time trend. Moreover, results about the order of integration of a series are sensitive to the option chosen for the unit root (UR) test, i.e. whether test is done with 'intercept' only, 'intercept and trend' or 'None', amongst which, the 'intercept and trend' choice is most likely to show a variable non-stationary in levels / a higher order of integration. For these reasons, even when regressions with time term coefficient indicate testing with intercept only, we also conduct UR tests more conservatively, with 'intercept and trend'.

[44] Since the power of unit root (UR) tests depends on the span of data, with longer spans preferred (Kennedy, 1998), we analyse time trends over both the full period available for some series in our annual dataset (1960-2020) and the period strictly used in the analysis (1999-2019). Messages are consistent in all cases, mainly because series do not extend much before 1999. For this reason and for accurate cointegration results, panel UR and cointegration test are then run strictly over the period used in the regression, 1999-2019.

[45] See the first Note above.

[46] All unit root tests have difficulties discriminating between an I (1) process and an I(0) process with a shift in its mean, because UR tests are misled by structural breaks in series (Rappoport and Reichlin, 1989, among others). This is commonly the case with series such as output growth, but could also be the case for government debt.

Table A7. **Unit root test results,** over the period 1999-2019, EA19 except DE and EE

Variable	Test	Levin, Lin & Chu t				Im, Pesaran and Shin				Result
	.	H0: Unit root (assumes common unit root process)				H0: Unit root (assumes individual unit root process)				
		Level		**First difference**		**Level**		**First difference**		
		T-stat	**P value**	**T-stat**	**P value**	**T-stat**	**P value**	**T-stat**	**P value**	
Spreads (explained)	Individual intercept(*)	-3.120	0.0009	-8.83043	0.000	-2.250	0.0122	-5.398	0.000	I(0)
	Individual intercept and trend	-1.249	0.1058	-7.848	0.000	0.059	0.5239	-3.114	0.0009	I(1)
NIIP (explanatory)	Individual intercept and trend(*)	-1.8983	0.0288	-7.2558	0.000	-0.0021	0.4992	-4.2971	0.000	I(0) or I(1)
Real potential GDP growth (explanatory)	Individual intercept(*)	-5.829	0.000	-6.114	0.000	-1.889	0.0294	-4.532	0.000	I(0)
	Individual intercept and trend	-0.118	0.4529	-7.026	0.000	1.445	0.9258	-3.426	0.0003	I(1)
gDebt (explanatory)	Individual intercept(*)	-2.587	0.0048	-2.34546	0.0095	0.46811	0.6801	-2.423	0.0077	I(0) or I(1)
Gee (explanatory)	Individual intercept(*)	-9.1483	0.0000	-8.23628	0.000	-4.3359	0.0000	-5.6315	0.000	I(0)
	Individual intercept and trend	-4.2383	0.0000	-8.03776	0.0000	-1.1441	0.1263	-4.1365	0.0000	I(0) or I(1)
Rekative_size (explanatory)	Individual intercept and trend(*)	-2.4505	0.0071	-6.36842	0.0000	-0.6313	0.2639	-3.1128	0.0009	I(0) or I(1)
Vix (explanatory, optional)	Individual intercept and trend(*)	-4.6510	0.0000	-10.3517	0.0000	-4.3011	0.0000	-4.2174	0.0000	I(0)
PSPP (explanatory, optional)	Individual intercept and trend(*)	-7.9802	0.0000	-6.04402	0.0000	-3.8890	0.0001	-4.4095	0.0000	I(0)

Note: (*) Test recommended by regressions with time term coefficient.

Source: Authors' calculations.

- *Cointegration tests*

Cointegration tests and the analysis of ECM residuals show that the variables included in the ECM are cointegrated.

Table A8. **Panel cointegration test results,** over the period 1999-2019, EA19 except DE and EE

Model / Test	**Ho: No cointegration** **H1: All panels are cointegrated**	**Statistic**	**P value**	**Result**
Pedroni	Panel PP-Statistic	-1.693136	0.0452	Reject the null
	Panel ADF-Statistic	-3.137430	0.0009	
	Group ADF-Statistic	-4.070285	0.0000	
Kao	Modified Dickey-Fuller t	-4.8798	0.0000	Reject the null
	Dickey-Fuller t	-3.8177	0.0001	
	Augmented Dickey-Fuller t	--5.2781	0.0000	
	Unadjusted modified Dickey-Fuller t	-4.6059	0.0000	
	Unadjusted Dickey-Fuller t	-3.7304	0.0001	

Source: Authors' calculations.

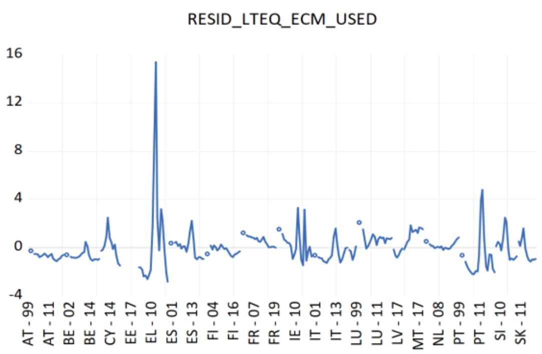
Table A9. **Unit root test results for the residuals of the long-term equation**, tested with individual intercept and trend, over the period 1999-2019, EA19 except DE and EE

Residuals of the long-term equation - test	**Levin, Lin & Chu t*** (null assumes common UR)		**Im, Pesaran and Shin** (null assumes individual UR)	
	Test Value	P value	Test Value	P value
	-3.78127	0.0001	-1.45190	0.0733

Source: Authors' calculations.

Long-term equation ECM: There is no common unit root (the residuals of the common panel long-term equation are stationary); in individual cross-sections, the hypothesis of non-stationarity can only be rejected with 10% confidence. The variables may be used in a common ECM; in some cross-sections the variables may not be cointegrated and thus should not be used in country-specific ECMs.

Graph A7. **Residuals of the ECM's long-term equation**, 1999-2019, EA19 except DE and EE



Source: Authors' calculations.

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