The Office of the Czech Fiscal Council

The Effect of General Government Debt on Government Bond Interest Rates

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Research Study

Macroeconomic and Fiscal Analyses Section

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Introduction

A key determinant of the long-term sustainability of public finances is the difference between the interest rate that the government must pay on its debt and the nominal growth rate of the economy. The greater this interest-growth differential, the greater the budget surpluses the government must run in order to stabilize the debt-to-GDP ratio.

When analysing the long-term sustainability of public finances, one should consider not only the size of public sector debt and the interest rate paid on it, but also the link between them. Taking the effect of debt on government bond interest rates into account influences not only the size of the debt, but also the time left until legislative debt brakes are hit.

This study is linked to an earlier publication of the Czech Fiscal Council (CFC) that showed that a feedback loop between debt and interest rates accelerates debt growth.[1] In incorporating this feedback loop into its reports, the CFC aims for a logical consistency with economic theory, specifically with the concept of the risk premium.

Quantifying the relationship between debt and government bond interest rates is challenging, not only because it likely varies over time. Existing research informs us that this relationship is all but straightforward. Moreover, one might be led to believe that sovereign risk premia are of little relevance to the Czech Republic, whose debt-to-GDP ratio fluctuates around 30%. Yet, to long-term projections, often characterized by population ageing, the relationship does indeed matter.

Several factors affect the estimation of the relationship between debt and interest rates. The 2008 financial crisis, as well as the subsequent sovereign debt crises, have instilled in financial markets a sensitivity to default risk that perhaps borders on over-sensitivity. At the same time, convergence processes to more developed economies put downward pressure on risk premia. Government bonds of individual countries are substitutes (to varying degrees) and this makes the relationship between debt and interest rates in one country subject to developments abroad. Central banks also play an important role, as their monetary-policy decisions influence yield spreads of government bonds between countries.

This paper quantifies the effect of general government debt on the interest rate on long-term bonds issued by the central government. We use two types of models, a pooled mean group (PMG) model and a fixed-effects model. The data sample consists of EU countries, which provides for estimating the relationship between debt and interest rates with much higher debt-to-GDP ratios than have been observed in the Czech Republic so far. Due to the Great Recession probably having shifted investors' risk perceptions, our sample begins in 2008.

The paper proceeds as follows. The first chapter presents the existing literature, focusing on post-crisis research. The second chapter surveys how fiscal councils abroad choose to address the feedback loop between debt and interest rates. The third chapter describes the methods and data sample used and the fourth one presents the resulting estimates. The last chapter concludes with a more general discussion of the results.

1 Literature Review

According to macroeconomic theory, fiscal expansion increases the interest rate in the economy, which in turn leads to a decrease in investment, and thus to a lower economic growth potential. The difference between the interest rate at which the government borrows and the nominal growth rate of the economy is key to fiscal sustainability. A higher interest rate means higher debt service costs, higher government expenditures, and thus a lower budget balance, while weaker economic growth translates into accelerated debt growth relative to GDP. Over the past decade, several studies have investigated the determinants of the interest rate at which the government is able to borrow, as well as the relationship between debt and interest rates on government bonds.

In contradiction to theory, some empirical studies uncover a negative relationship between government debt and government bond interest rates. Ardagna et al. (2007) attribute such a negative relationship to portfolio and liquidity effects. When investors, despite growing indebtedness, perceive newly issued bonds to be of high quality, they buy them instead of the previously available lower-quality

[1] Czech Fiscal Council: Report on the Long-Term Sustainability of Public Finances, June 2019, p. 43.

bonds, so their price rises and the interest rate falls (the portfolio effect); perhaps investors from developing countries are willing to buy newly issued bonds of indebted, developed countries or regulatory requirements on institutional investors fuel the demand for government bonds.[2] The liquidity effect denotes the fact that the greater the volume of government bonds issued, the easier it is for investors to purchase and sell them. Higher liquidity stimulates investor interest and the demand for bonds rises. Again, their price increases and their interest rate falls. Because of the liquidity effect, countries with higher debt may afford to offer lower interest rates on their bonds.

From the viewpoint of the post-crisis literature, the relationship between debt and interest rates as described neglects the role of risk and of the behavioural and psychological aspects of risk assessment and perception. When pre-crisis studies mention the risk premium, it is usually in connection to an impending default. These studies view the demand for a risk premium as a signal of trouble rather than a persistent component of the link between debt and interest rates. However, this changed with the experience of the financial and sovereign debt crises. Risk aversion has become a cornerstone of the post-crisis considerations of the effect of fiscal indicators (debt, deficit) on government bond interest rates (see, for example, Haugh et al., 2009).

The risk premium, which is embodied in the interest rate, consists of premia for liquidity and default risks. Risk-neutral investors require – as compensation for accepting the risk of default – a premium equal to the expected loss of the real value of the debt (Alcidi and Gros, 2018, 2019). This expected loss increases with the amount of debt, as the probability of funds being returned declines. Even though increased expenditures (e.g., pensions) need not affect the capacity of government to repay its bonds outstanding directly, they may be sending a more general signal about its ability to manage public finances (Haugh et al., 2009). Furthermore, a high and growing debt provides an incentive for the government to devalue it via default or inflationary monetary policy of the central bank. Some investors are risk-averse rather than risk-neutral; and since risk aversion fluctuates over time, the relationship between debt and interest rates may vary, even in the absence of any changes in the expected loss, amount of debt, inflation or default risk (Alcidi and Gros, 2018, 2019).

In the post-crisis period, responses of financial markets represent a growing constraint on fiscal policy. According to Haugh et al. (2009), prior to the 2008 crisis this constraint was diluted by abnormally low risk aversion. Turner and Spinelli (2012) argue that sovereign debt risk premia nowadays play a more important role in determining the interest rate on government bonds than before the crisis. On a sample of 23 OECD countries between 1980 and 2010, they estimate the following relationship: each percentage point of the debt-to-GDP ratio above 75% increases the interest rate-growth differential by 4 basis points.[3] The effect is lower in the pre-crisis period (3 basis points) than after the crisis (8 basis points), with the euro area countries accounting for the larger part of the increase.[4] In a follow-up study that includes 22 OECD countries between 1980 and 2012, Turner and Spinelli (2013) explicitly report an estimate for the countries outside of the euro area: an additional percentage point of the debt-to-GDP ratio in excess of 75% increases the differential by 2.5 basis points, when financed entirely from domestic sources, and by 3.5 to 5 basis points when financed from abroad.

Some institutions and international organizations, such as the International Monetary Fund (IMF), the European Commission (EC), and the Organization for Economic Co-operation and Development (OECD), regularly assess their members' debt sustainability. This requires the expected future interest rates on government bonds to be determined. A common approach is to view the interest rate on government bonds as the sum of the risk-free interest rate and risk premia (Alcidi and Gros, 2018).[5]

When determining the risk premium, the institutions mentioned rely on the relationship between debt and government bond interest rates observed in the past. The OECD works with a risk premium of 4 basis points per each percentage point of debt in excess of 75% of GDP (Turner and Spinelli, 2012). The IMF uses 3 basis points and a 60% threshold, while the EC opts for 4 basis points

[2] The Basel regulatory framework for banks assigns a low risk weight to government bonds.
[3] Under the assumption of a constant growth rate of the economy, debt would affect the differential through the interest rate.
[4] Prior to the crisis, there was pronounced convergence of long-term government bond interest rates in the euro area. This process was so marked that it masked the characteristics of individual countries, including their indebtedness (Turner and Spinelli, 2012). Janáček et al. (2012, p. 125), too, note the emergence of the relationship between debt and interest rates after the crisis.
[5] The interest rate on U.S. Treasury Bonds or on German or Swiss government bonds is usually used to proxy the risk-free rate.

and a 60% threshold (Alcidi and Gros, 2018).[6] The IMF and the EC consider a floor to the interest rate of 4.5 and 5%, respectively; the figures are based on a long-term historical average. The risk premium usually applies to long-term debt only, i.e., to ten-year government bonds (Alcidi and Gros, 2018). In the case of short-term debt, the risk premium tends to be substantially lower or is not applied at all (Alcidi and Gros, 2018).

Kučera et al. (2017) and Kučera and Szabo (2019) estimate the neutral Czech bond yield curve and identify three types of risk premia. The term premium relates to the uncertainty regarding the future value of money; the credit risk premium is linked to fiscal health and the risk of default. The last one, the portfolio effect, has to do with specific demand effects. According to Kučera et al. (2017), an increase in the GDP growth rate leads to a decrease in the interest rate on long-term government bonds by 0.35 percentage points. This is attributable to lower long-run uncertainty and reduced credit risk: higher GDP growth lowers the interest rate-growth differential, strengthening sustainability and mitigating the risk of default on government debt. The increase in long-term interest rates in 2009–2012 was due to the credit risk premium. Because the risk of default on government debt rises with the length of the time period under consideration, the influence of fiscal health is observed primarily for interest rates on long-term government debt. The importance of fiscal health to the credit risk premium increases with bond maturity and converges to zero for short-term bonds (Kučera et al., 2017).

2 Fiscal Councils' Practices

Fiscal councils of Slovakia, the U.S., and the U.K. consider the relationship between debt and government bond interest rates in their reports.[7]

2.1 Slovakia

The Slovak Council for Budget Responsibility (CBR) applies an interest-rate penalty of 1.3 percentage points per percentage point of the debt-to-GDP ratio, when debt stands at 40% of GDP and the current account is balanced (CBR Secretariat, 2014, p. 51). The CBR models the response of the interest rate to debt as non-linear, so the debt penalty per percentage point of debt to GDP increases as debt grows. Incorporating this penalty into the long-term sustainability analysis for Slovakia means that the debt-to-GDP ratio is projected to reach 80% some 4 years earlier than would be the case if the penalty were neglected (CBR Secretariat, 2014).

The CBR has estimated the relationship from a regression analysis with 2000Q4–2013Q3 quarterly data on the V4 countries (Slovakia, Czech Republic, Poland, Hungary). Spreads on government bonds relative to Germany are the explained variable. The explanatory variables include the square of the debt-to-GDP ratio, the current account balance (in % of GDP and net of transfers), and one- and two-period lagged values of the explained variable. The model is estimated with two-stage least squares. Lagged values of the explanatory variables (debt and current account) are employed as instruments (CBR Secretariat, 2014, appendix 8).

2.2 United States

The U.S. Congressional Budget Office (CBO) considers the period 1990–2007 when determining interest rates. This period was characterized by stable inflationary expectations and an absence of serious economic slowdowns or financial crises.[8] When forecasting expected interest rates on government bonds, the CBO compares the values of their determinants in the past with their expected values in the future. The factors considered include, among others, labour force growth, total factor productivity growth, and debt (CBO, 2019). CBO bases its estimates of the effects of labour force growth and federal debt on government bond interest rates on the data available, as well as on theoretical

[6] Even though the parameters used by the IMF and the EC differ by a mere basis point, they may lead to opposite conclusions on debt sustainability, due to a self-reinforcing mechanism (feedback loop) between debt and interest rates. Alcidi and Gros (2018, p. 23) offer a numerical example.
[7] Determined by researching the publications available on the websites of fiscal councils in Anglo-Saxon countries and of the fiscal councils which are part of the EU Independent Fiscal Institutions network. The list therefore need not be exhaustive.
[8] Given the U.S. dollar's role as a worldwide reserve currency and unit of account, the U.S. risk premium is both low and specific.

models and the existing literature. Market expectations about the risk premium are inferred from the yield on thirty-year Treasury bonds.

In its publications, the CBO explicitly draws attention to the risks of a high and growing federal debt, cautioning against a slowdown of economic growth in the long run and increasing debt service costs, which would entail an outflow of capital abroad. High and growing debt puts upward pressure on the interest rate, by impairing investors' confidence in the U.S. fiscal position and the U.S. dollar, as well as by increasing inflationary expectations. Nonetheless, according to the CBO, there is no known value of the debt-to-GDP ratio, beyond which a fiscal crisis would become likely or unavoidable (CBO, 2019).

2.3 United Kingdom

The approach of the U.K. Office for Budget Responsibility (OBR) to debt and interest rates evolved gradually. Early OBR reports on sustainability (e.g., OBR, 2011) do not incorporate the sovereign risk premium in their debt projections. They do, nonetheless, provide an alternative scenario in which an increase in the budget deficit by one percentage point increases the interest rate by 20 to 30 basis points; the figures were adopted from earlier IMF and CBO studies (OBR, 2011, pp. 81-82). More recent reports (e.g., OBR, 2018) apply the assumption that the interest rate-growth differential equals 0.2 percentage points; thus, they set the long-term interest rate slightly above the long-term growth rate of the economy. This baseline projection is supplemented with sensitivity scenarios, in which the differential is one percentage point higher/lower than the 0.2 baseline.

3 Data and Methods

This study estimates the relationship between debt and the interest rates on government bonds with annual data of EU countries between 2008 and 2018. This period is chosen in respect of the fact that the financial crisis and subsequent sovereign risk crises have changed how capital markets perceive risk. Estimates based on data from the pre-crisis period need not be relevant to the present, as risk aversion before the crisis was abnormally low (Haugh et al., 2009) and the link between fiscal indicators and government bond interest rates was therefore weaker (Turner and Spinelli, 2012). However, one should also keep in mind that, in the period chosen, the European Central Bank (ECB) as well as some national central banks have been performing quantitative easing, and thereby affecting government bond prices and interest rates.

Given the divergent behaviour of some key economic and fiscal variables in the euro area and the non-euro EU countries, we perform separate estimations on the sample of nine non-euro EU countries and the sample of seventeen euro-area countries.[9] The euro-area sample allows for estimating the relationship of interest at high debt[10] not yet common in the non-euro EU countries. Furthermore, the common currency does not require controlling for some difficult-to-measure factors, such as expected exchange rate movements and exchange rate risk, expected inflation or central banks' credibility. The downside, however, is that, because of the common currency and the ECB's quantitative easing as well as its implicit guarantees to use this unconventional measure if need be, the relationship between government debt and interest rates may be specific to the euro-area, i.e., different from the relationship in the Czech Republic.

The literature offers no straightforward recommendation for modelling the relationship between fiscal variables and government bond interest rates. For example, Ardagna et al. (2007) suggest including both debt and deficit as explanatory variables, while Engen and Hubbard (2004) link the level of the interest rate to the level of debt, and the change in the interest rate to the budget balance, which, in economic (though not accounting) terms, corresponds to the change in debt.

The resulting estimates vary with the fiscal and control variables included in the model specifications as well as with the estimation method. For this reason, multiple model specifications are reported in what follows. Two types of models are used: a fixed-effects model and a pooled mean group model (Pesaran et al., 1999).

[9] The sample of non-euro EU countries includes Bulgaria, Croatia, Czech Republic, Denmark, Hungary, Poland, Romania, Sweden, and the United Kingdom. The euro-area sample includes all 19 euro-area countries except Estonia and Luxembourg. Moving Denmark, whose currency is pegged to the euro, from one sample to the other does not affect the estimation results.
[10] In the empirical part, "debt" refers to the debt-to-GDP ratio.

For the fixed-effects model to capture a long-run relationship, the included variables must be either stationary, or integrated of the same order and cointegrated. Fixed effects can control for a range of supply and demand factors not included in the model, provided the factors are constant in time (country-specific fixed effects) or affect the countries included in the sample in the same manner (period-specific fixed effects).

In the pooled mean group (PMG) model, the explained variable is of type I(1), while among the explanatory variables both I(1) and I(0) variables may appear. The PMG model is constructed to distinguish between short- and long-run relationships. The long-run relationship is a cointegration relationship between I(1) variables, while first differences of I(1) variables and I(0) variables enter into the short-term part of the model. The existence of a long-run relationship indicates, in economic terms, that the system of variables tends to converge to some long-run equilibrium. In the PMG model, the long-run relationship is assumed to be common to all countries in the sample. The process of convergence toward the equilibrium, however, may occur at a different speed in each country. The PMG model coefficients are estimated with the maximum likelihood method.

The variables' allocation to individual specifications is driven primarily by the requirements for types of variables. Variables are included in order to avoid the omitted variable bias and to limit serial- and cross-dependence in the residuals. Specifications are evaluated based on the robustness of the coefficient estimate for the debt variable, and also based on the Akaike information criterium (AIC), the adjusted coefficient of determination (adjusted R^2), and the goodness of fit of estimated and actual values.

Sometimes, expressing variables in spreads (differences) relative to Germany helps stationarize them or eliminates shocks hitting countries across the EU. While it is preferable to estimate relationships between variables expressed in the same manner, i.e., either as levels or spreads, this is not always possible, since some variables are not of the required type when expressed in the preferred manner. In such cases, we resort to including explanatory variables that differ from the explained variable in how they are expressed. In the literature, one finds studies which explain spreads in interest rates with variables in spreads as well as in levels. The second approach implicitly assumes that the value of the explanatory variable in the reference country (in our case Germany) is risk-free.

The interest rate is defined as the yield rate on ten-year government bonds, expressed either in nominal or real terms. The real interest rate is derived from the nominal one, by ex-post adjustment for inflation through the GDP deflator or a two-year average of the harmonized index of consumer prices (HICP).[11]

As for the fiscal variables, this paper focuses on the debt of the general government (sector S.13 in the 2010 European System of Accounts).[12] Table 1 lists and defines the variables used henceforth. Subscripts *i* and *t* denote the country and time period, respectively.

Table 1 Definitions of Variables

Variable	Description	Source
$ca_{i,t}$	Current account balance (with the rest of the world) net of secondary income, seasonally and calendar unadjusted; in % of GDP.	Eurostat (bop_gdp6_q)
$d\text{-}debt\text{-}above XX_{i,t}$	Binary variable equal to one if $debt_{i,t}$ exceeds XX % of GDP; otherwise zero.	
$debt_{i,t}$	General government debt; in % of GDP.	Eurostat (gov_10q_ggdebt)
$ecb\text{-}debt\text{-}held_t$	Debt securities issued by governments of euro-area countries and held by the ECB in period *t;* in billions of euros.	ECB Statistical Data Warehouse (BSI)
$gap_{i,t}$	Output gap between actual and potential domestic product in constant market prices; in % of potential product. If the value is positive, the economy is above its potential; if negative, it is below its potential.	Ameco (AVGDGP)

[11] The nominal interest rate on government bonds, its expression in real terms via the GDP deflator, as well as its spreads are non-stationary in the sample of non-euro EU countries. To have at least one explained variable of type I(0), the interest rates are adjusted using the HICP. The HICP values are, however, influenced by (sometimes) highly volatile energy and food prices, which might introduce extra noise into the interest rates. To mitigate this issue, a two-year average of the HICP is used. Using a three- or four-year average produces a non-stationary variable.

[12] In its annual Reports on the Long-Term Sustainability of Public Finances, the Czech Fiscal Council uses the term "public institutions sector" ("sektor veřejných institucí") to refer to the general government, in order to maintain terminological consistency with Act No. 23/2017 Coll., on budgetary responsibility rules. The meaning is the same.

Variable	Description	Source
infl-dflt$_{i,t}$	Inflation rate measured by GDP deflator; in %.	Ameco (PVGD)
int-dflt$_{i,t}$	Maastricht criterion bond yields (interest rate on central government bonds with approximately 10-year residual maturity on the secondary market, gross of tax) in country *i* and period *t* adjusted for inflation in country *i* and period *t* using the GDP deflator.	Eurostat (irt_lt_mcby_a), Ameco (PVGD)
int-hicp$_{i,t}$	Maastricht criterion bond yields (interest rate on central government bonds with approximately 10-year residual maturity on the secondary market, gross of tax) in country *i* and period *t* adjusted for inflation using the average of the current and past (*t* and *t-1*) HICP values.	Eurostat (irt_lt_mcby_a, prc_hicp_aind)
int-nom$_{i,t}$	Maastricht criterion bond yields (interest rate on central government bonds with approximately 10-year residual maturity on the secondary market, gross of tax) in country *i* and period *t* in nominal terms.	Eurostat (irt_lt_mcby_a)
liq19$_{i,t}$ *(liq28*$_{i,t}$*)*	Share of general government debt of country *i* in period *t* on the total general government debt of the 19 euro-area countries (28 non-euro EU countries); in %.	Eurostat (gov_10dd_edpt1)
p-debt-aboveXX$_{i,t}$	Percentage points of *debt*$_{i,t}$ in excess of XX %; equal to zero when *debt*$_{i,t}$ is equal to or lower than XX % of GDP.	
prim-balance$_{i,t}$	Primary balance (i.e., net of interest expenditure) of the central government; in % of GDP.	Eurostat (gov_10dd_edpt1)
prim-deficit$_{i,t}$	Primary deficit of the central government; in % of GDP. It is derived from *prim-balance*$_{i,t}$. Positive values of *prim-balance*$_{i,t}$ (surpluses) become zeros and negative values (deficits) change sign.	
ez-…$_t$	Euro-area level variables in period *t*.	
…-spread$_{i,t}$	Variables whose values are expressed in spreads; Germany is the reference country.	

More detailed information on the data sample, including descriptive statistics, selected variables' graphs, correlation coefficients and variables' (non)stationarity, is provided in the appendix.

4 Results

The following subchapters analyse the relationship between interest rates on long-term government bonds and general government debt in the non-euro EU countries (4.1) and in the euro-area countries (4.2).

4.1 Non-Euro EU Countries

Table 2 presents the estimation results of four different PMG model specifications. For the purposes of this study, the coefficient estimate of the long-run relationship between debt, as the explanatory variable, and the respective explained variable is of interest. The error correction term indicates the speed of adjustment, i.e., what percentage of the short-term deviation from the long-run equilibrium is corrected in the course of a single period (one year). For the system to converge to the long-run equilibrium, the error correction term should be between negative one and zero. Such values indicate that the interest rate on government bonds reacts to deviations of the explanatory values from their equilibrium levels and acts to restore equilibrium in the long run.

Only a variable of type I(1) may be selected as the explained variable in a PMG model. In the non-euro sample, two variables are of type I(1): the GDP-deflator adjusted real interest rate (*int-dflt*) and the nominal interest rate spread (*int-nom-spread*).

Baseline Specifications 1 and 2 link the interest rates on government bonds to a single explanatory variable, the debt-to-GDP ratio.[13] Specifications with lags (3,3) are, with respect to the Akaike information criterion (AIC), preferred to specifications with fewer lags, while estimation fails when more than three lags of both, the explained and explanatory variable, are included.[14]

[13] It follows from the construction of the PMG model that, when *debt* is included in level form in the long-run part of the model, its first differences, which in economic terms are in fact the general government balance, are automatically included in the short-term part of the model.

[14] The maximum likelihood method is used to estimate PMG model coefficients. In our data sample, the estimation fails when five or more variables (also counting lagged variables and differences) are included, due to encountering the log of a non-positive number in the calculation.

Specification 1 points to a statistically significant and positive long-run relationship between debt and the real interest rate on government bonds. Its estimate, however, is unstable. Restricting the lags included from three to two for the explained and explanatory variable increases the coefficient estimate for *debt* by a factor of 2.8. This is unfortunate, since, given the computational limitations (see footnote 14), adding control variables to our PMG specifications requires a simultaneous decrease in the number of lags included.

In Specification 2, the nominal interest rate spread is the explained variable. The *debt* coefficient estimate indicates that an additional percentage point in the debt-to-GDP ratio increases the interest rate on government bonds by 3.5 basis points. This estimate is robust. Reducing the number of lags from three to two worsens the model's overall quality (higher AIC), but leaves the *debt* coefficient estimate unchanged up to three decimal places.

Table 2 PMG Model Estimation Results for Non-Euro EU Countries

	(1)	(2)	(3)	(4)
Explained variable:	***int-dflt***	***int-nom-spread***	***int-nom-spread***	***int-nom-spread***
Lags (dep var, indep vars)	(3,3)	(3,3)	(2,2,2)	(1,1,1)
Number of observations	72	72	81	90
Long-run relationships				
Debt	*0.029* *(1.44*10^{-9})* *[0.000] ****	*0.035* *(2.97*10^{-8})* *[0.000] ****	*0.040* *(9.69*10^{-9})* *[0.000] ****	*0.038* *(0.017)* *[0.029] ***
Infl-dflt-spread			*0.177* *(1.17*10^{-8})* *[0.000] ****	*0.356* *(0.032)* *[0.000] ****
Short-run relationships				
Error correction term	*-0.400* *(0.559)* *[0.473]*	*-0.318* *(0.406)* *[0.438]*	*-0.910* *(0.533)* *[0.097] **	*-0.572* *(0.157)* *[0.001] ****
Δ *Int-dflt(-1)*	*-0.386* *(0.451)* *[0.397]*			
Δ *Int-dflt(-2)*	*-0.457* *(0.276)* *[0.106]*			
Δ *Int-nom-spread(-1)*		*-0.223* *(0.309)* *[0.476]*	*0.375* *(0.219)* *[0.096] **	
Δ *Int-nom-spread(-2)*		*-0.012* *(0.145)* *[0.936]*		
Δ *Debt*	*0.590* *(0.286)* *[0.047] ***	*0.044* *(0.153)* *[0.776]*	*-0.105* *(0.170)* *[0.543]*	*4*10^{-4}* *(0.058)* *[0.994]*
Δ *Debt(-1)*	*-0.145* *(0.083)* *[0.091] **	*0.051* *(0.050)* *[0.318]*	*0.124* *(0.092)* *[0.188]*	
Δ *Debt(-2)*	*0.004* *(0.204)* *[0.986]*	*0.005* *(0.059)* *[0.931]*		
Δ *Infl-dflt-spread*			*-0.052* *(0.125)* *[0.682]*	*-0.103* *(0.037)* *[0.008] ****
Δ *Infl-dflt-spread(-1)*			*0.181* *(0.101)* *[0.082] **	
Ecb-debt-held				*4.19*10^{-6}* *(3.64*10^{-6})* *[0.255]*
Constant	-0.781 (0.375) *[0.045] ***	*0.017* *(0.880)* *[0.985]*	*-0.738* *(0.887)* *[0.411]*	*0.075* *(0.335)* *[0.824]*
Model evaluation				
AIC	*-1.289*	*-2.073*	*-2.743*	*1.224*

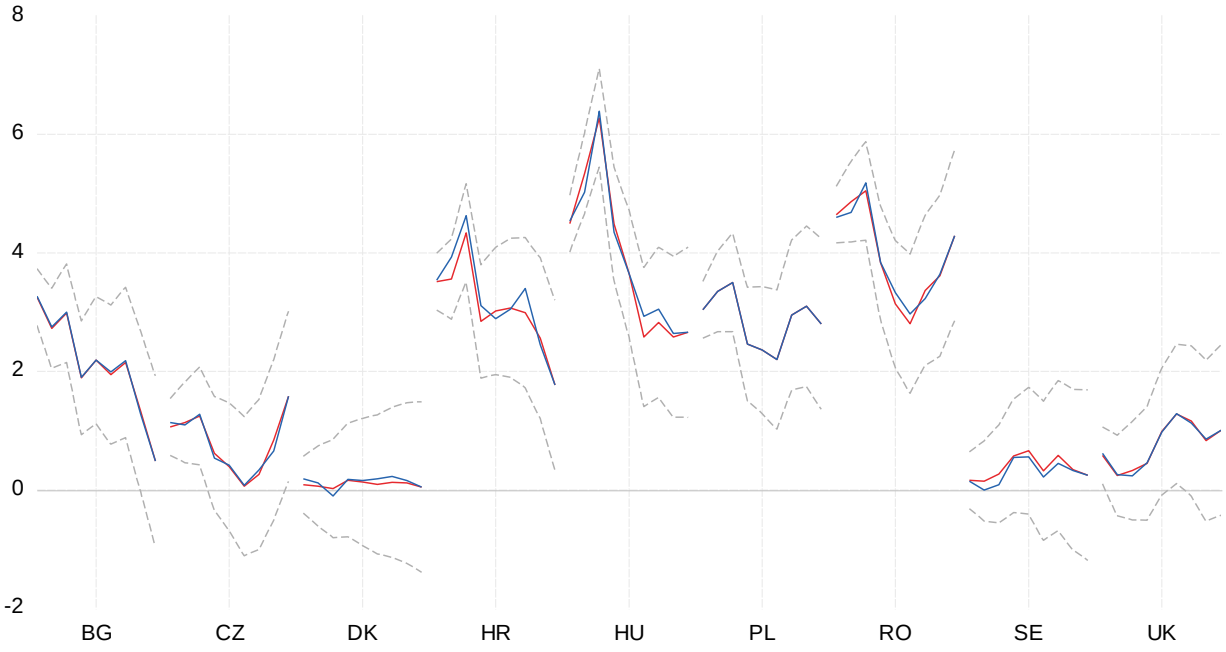
	(1)	(2)	(3)	(4)
Residuals[15]				
Normally distributed	*No*	*No*	*No*	*No*
Serially uncorrelated	*No*	*No*	*No*	*No*
Cross-independent	*No*	*No*	*Yes*	*Yes*
Ex-post estimates evaluation				
Root mean squared error	*0.271*	*0.124*	*0.119*	*0.500*
Mean absolute error	*0.160*	*0.081*	*0.074*	*0.315*

Note: standard errors in ( ), p-values in [ ].

Specification 3 includes the spread of inflation rates (*infl-dflt-spread*) as an additional variable in the long-run relationship. The variable controls for differences in inflationary pressures and economic cycles. Including the spread of inflation rates improves the model overall (lower AIC) despite the necessary reduction of lags from three to two.

Specification 4 includes an additional variable, *ecb-debt-held*, to control for the possible spill-over effect of the ECB's quantitative easing on interest rates outside of the euro area. Because the variable is stationary, it is included in the short-run part of the specification. The results suggest that the ECB's quantitative easing did not have a statistically significant effect on the interest rates on government bonds of non-euro EU countries. Once again, despite the required reduction of lags, the coefficient estimate for *debt* changes only a little. Its loss of statistical significance has to do with fewer lags, not with the additional control variable itself.

Figure 1 Actual and Fitted Values, *int-nom-spread* 2010–2018, Specification 3



Note: vertical gridlines for individual countries are drawn for 2014. Actual values in blue, fitted in red, fitted ± 2 standard errors in grey. The differences between actual and fitted values for Poland are small and their curves cannot be distinguished in the available resolution.

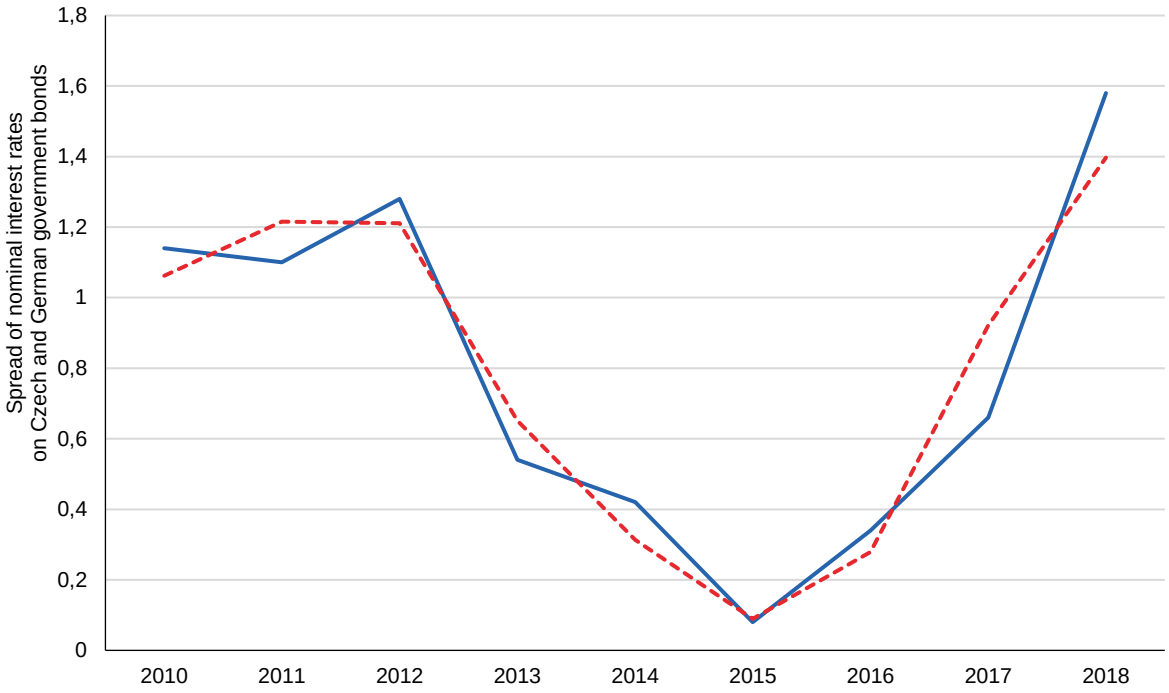
Out of the PMG specifications in Table 2, we prefer Specification 3. It is more robust than Specification 1, its fitted values align more closely with actual values than those of Specification 4, and it is less dependent on lagged values of the explained variable than Specification 2. Figure 1 compares actual nominal interest rate spreads with those fitted by Specification 3. So does Figure 2, but in detail for the Czech Republic. The results of the preferred specification suggest that, **in the non-euro EU**

[15] Normality is assessed on the grounds of the Jarque-Bera test, autocorrelation according to the Ljung-Box test, and cross-dependence according to the Pesaran's cross-dependence test. These tests are available in EViews 11, which we use for estimation.

countries, on average, an additional percentage-point increase in the debt-to-GDP ratio increases the interest rate on government bonds by 4 basis points. The confidence intervals of this estimate, as well as of other selected point estimates, henceforth are reported in the appendix.

There is one caveat to Specification 3. Should the alignment of fitted and actual values be attributable solely to the lags of the explained variable, the coefficient estimates might prove unstable, once we append future observation to the sample. Estimating Specification 3, with only one lag of the explained variable, results in a coefficient estimate for *debt* equal to 0.059 with a p-value 0.000 and AIC 0.020. Checking the robustness of Specification 3 to new data, by shortening the panel and performing an in-sample forecast, is not possible, since shortening the panel, even by a single year, simultaneously requires fewer lags for the maximum likelihood method to estimate the coefficients.

Figure 2 Actual and Fitted Values of Interest Rate Spreads of Czech and German Government Bonds



Note: actual values in blue, values fitted by Specification 3 in red.

One disadvantage of the PMG model is that it does not allow for the inclusion of dummy variables or of variables derived from *debt* but containing sequences of zero values (e.g. *p-debt-aboveXX*). To check for non-linearities or thresholds in the relationship between debt and the interest rate on government bonds, we estimate fixed-effects models. When identical variables are included, the PMG estimates outperform fixed-effects estimates (judging by the alignment of fitted and actual values). For this reason, in the fixed-effect models we focus on specifications with the explained variable of type I(0), as these cannot be estimated with the PMG model.

Table 3 reports the results of an OLS panel regression. All specifications include statistically significant country-specific fixed effects. The real interest rate spread (*int-hicp-spread*) is the explained variable; out of the possible explained variables, it is the only stationary one in the non-euro EU sample. Its lagged values are included to control for autocorrelation. Explanatory variables are not lagged, as one year should allow the financial markets enough reaction time.

Specification 5 estimates the effect of *debt* on the interest rate, controlling for the primary balance and the output gap. No significant effect is observed. This result is robust to the following changes: including two instead of three lags of the explained variable (Specification 6), omitting *gap-spread* or *prim-balance*, and replacing *prim-balance* with its one-sided alternative *prim-deficit.*

It may be the case that debt affects the interest rate on government bonds only above some threshold. In Specification 7, the variable *debt-spread* is replaced with *p-debt-above60*. The latter indicates the number of percentage points of the debt-to-GDP ratio in excess of the 60% Maastricht criterion. The estimated effect of 4.7 basis points per an additional percentage point of debt to GDP above

the 60% threshold is insignificant at conventional levels (p-value 0.223). Reducing the lags from three to two produces a highly insignificant coefficient estimate for *debt* (Specification 8) and introduces cross-dependence into the residuals.

Table 3 Fixed-Effects Model Estimation Results for Non-Euro EU Countries

Explained variable: *Int-hicp-spread*	**(5)**	**(6)**	**(7)**	**(8)**
Int-hicp-spread(-1)	*0.732* *(0.116)* *[0.000]* ***	*0.723* *(0.122)* *[0.000]* ***	*0.737* *(0.116)* *[0.000]* ***	*0.734* *(0.123}* *[0.000]* ***
Int-hicp-spread(-2)	*-0.313* *(0.144)* *[0.034]* **	*-0.234* *(0.109)* *[0.035]* **	*-0.275* *(0.133)* *[0.044]* **	*-0.167* *(0.094)* *[0.079]* *
Int-hicp-spread(-3)	*-0.013* *(0.100)* *[0.896]*		*0.052* *(0.091)* *[0.572]*	
Debt-spread	*0.023* *(0.025)* *[0.366]*	*0.024* *(0.021)* *[0.243]*		
Prim-balance	*-0.107* *(0.069)* *[0.128]*	*-0.032* *(0.072)* *[0.662]*	*-0.114* *(0.068)* *[0.099]* *	*0.007* *(0.066)* *[0.912]*
Gap-spread	*-0.037* *(0.077)* *[0.632]*	*-0.080* *(0.067)* *[0.237]*	*-0.010* *(0.077)* *[0.894]*	*-0.064* *(0.070)* *[0.367]*
P-debt-above60			*0.047* *(0.038)* *[0.223]*	*0.010* *(0.034)* *[0.757]*
Constant	*1.426* *(0.630)* *[0.027]* **	*1.254* *(0.532)* *[0.021]* **	*0.628* *(0.323)* *[0.057]* *	*0.609* *(0.289)* *[0.039]* **
Model evaluation				
R2	*0.819*	*0.770*	*0.821*	*0.765*
Adjusted R2	*0.775*	*0.725*	*0.777*	*0.720*
F-test p-value	*0.000* ***	*0.000* ***	*0.000* ***	*0.000* ***
AIC	*2.413*	*2.651*	*2.401*	*2.670*
Durbin-Watson statistic	*1.964*	*1.774*	*2.033*	*1.833*
Number of observations	*72*	*81*	*72*	*81*
Residuals				
Normally distributed	*Yes*	*No*	*Yes*	*No*
Serially uncorrelated	*Yes*	*Yes*	*Yes*	*Yes*
Cross-independent	*Yes*	*Yes*	*Yes*	*No*
Ex-post estimates evaluation				
Root mean squared error	*0.805*	*0.936*	*0.762*	*0.913*
Mean absolute error	*0.663*	*0.735*	*0.628*	*0.704*

Note: standard errors in ( ), p-values in [ ].

As a next step, in Specification 7, we use *p-debt-aboveXX* with different thresholds. Testing thresholds higher than 60% is not possible, because the respective variables are non-stationary. Table 4 reports the coefficient estimates for *p-debt-aboveXX*. The higher the threshold considered, the more statistically significant the estimate. The drops in p-value at the 45% and 55% thresholds are striking.[16] We also estimate a quadratic relationship between debt and the interest rate, yet it performs no better than the linear specifications do.

The point estimate from Specification 7 is sensitive to changes in the number of observations. Estimating the model for shorter time periods, 2008–2015, 2008–2016, 2008–2017 and 2012–2018, yields

[16] The two highest thresholds produce statistically significant estimates when the real interest rate adjusted with current-year HICP (rather than a two-year average as in *int-hicp-spread*) is used as the explained variable. The estimates for *p-debt-above55* and *p-debt-above60* are, respectively, 0.084 (p-value 0.064) and 0.083 (p-value 0.067). Just as with *int-hicp-spread*, we observe that the statistical significance of coefficient estimates increases with the threshold. Marked drops in p-value occur at the 45% and 55% debt-to-GDP thresholds.

estimates for *p-debt-above60* that range from slightly negative and highly insignificant (estimate -0.018 with p-value 0.700 for 2008–2015) to positive and nearly significant (0.085 with p-value 0.110 for 2012–2018); however, autocorrelation begins to appear in the latter's residuals. The coefficient estimates from Specifications 5 and 6 are more robust to changing periods. When estimated for the periods listed, the estimates remain between 0.022 and 0.035 with p-values between 0.132 and 0.399. Thus, the point estimates from Specifications 5 and 6, pointing to a penalty of 2.4 basis points (p-value 0.243) per an additional percentage point of debt-to-GDP, are preferred. Specification 7 and Table 4 are of interest with respect to the changes in statistical significance at different debt thresholds.

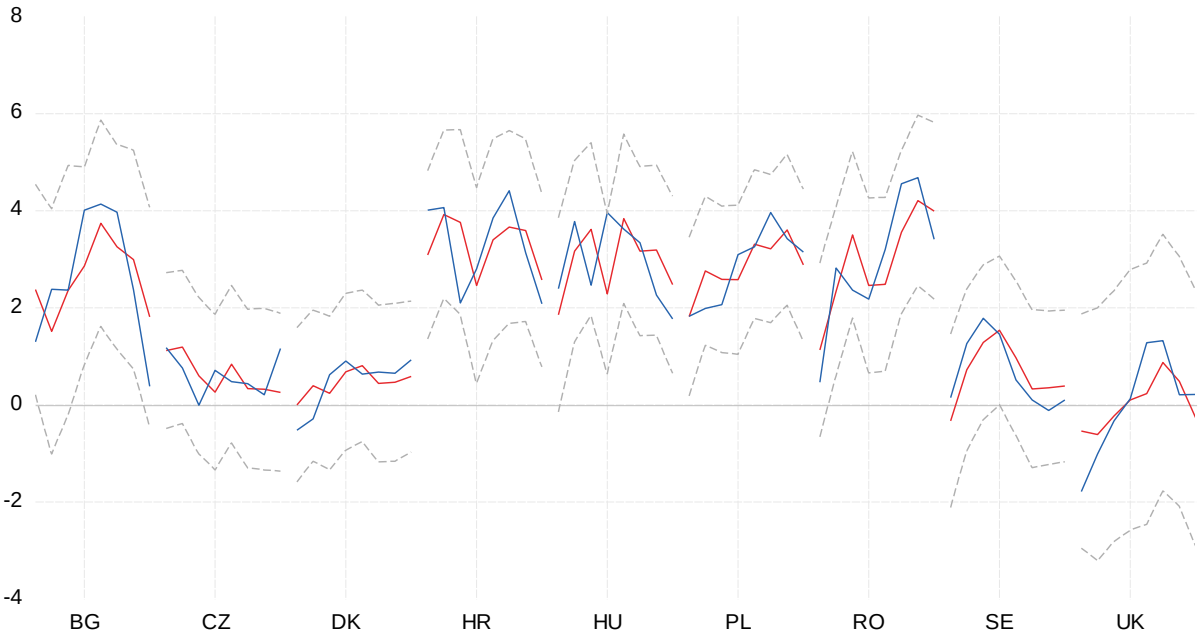
Table 4 Estimates at Varying Debt Thresholds, Non-Euro EU Countries

Debt variable	Coefficient estimate	P-value	Number of non-zero observations
p-debt-above30	*-0.006*	*0.814*	*64*
p-debt-above35	*-0.004*	*0.887*	*59*
p-debt-above40	*0.009*	*0.781*	*55*
p-debt-above45	*0.034*	*0.343*	*45*
p-debt-above50	*0.037*	*0.312*	*42*
p-debt-above55	*0.046*	*0.233*	*36*
p-debt-above60	*0.047*	*0.223*	*35*

Note: estimates were produced by changing the threshold of the *p-debt-aboveXX* variable in Specification 7.

Figure 3 shows that the values of *int-hicp-spread* fitted by Specification 5 deviate considerably from the actual values in certain years. Due to the insignificance of the explanatory variables, the fitted values are based merely on the explained variable's past values and country-specific fixed effects. When comparing the goodness-of-fit of Specification 5 with one where *int-hicp-spread* is explained by its own past values and country-specific fixed effects, we observe a negligible decline in R^2 by 0.01 and by 0.001 in adjusted R^2.

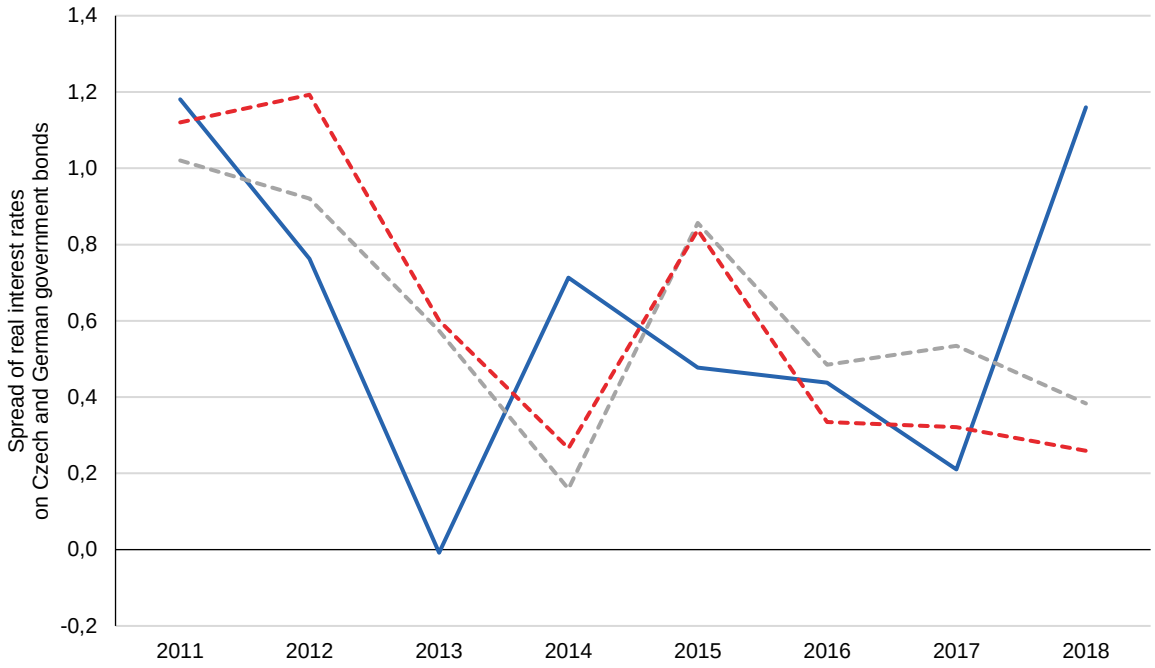
Figure 3 Actual and Fitted Values, *int-hicp-spread* 2011–2018, Specification 5



Note: vertical gridlines are drawn for 2014. Actual values in blue, fitted in red, fitted ± 2 standard errors in grey.

Figure 4 zooms in on the Czech Republic, showing that Specification 5 is slightly preferred to Specification 6 (mean absolute errors for the Czech Republic 0.378 and 0.437, respectively). At the same time, however, a specification containing only lagged values of the explained variable and a constant provides, in the case of the Czech Republic, somewhat better fitted values of the interest rates spreads than Specification 5 (mean absolute error 0.373). This is in stark contrast to the PMG model, where the alignment of fitted and actual values improves substantially once the debt variable is added.

Figure 4 Actual and Fitted Values of Interest Rate Spreads of Czech and German Government Bonds



Note: actual values in blue, values fitted by Specification 5 in red, values fitted by a specification with a constant term and lagged values of the explained variable in grey.

Based on the comparison of Figures 4 and 2, as well as on the mean errors reported in Tables 3 and 2, we prefer the point estimate from the PMG model (Specification 3 in particular) to the point estimates from the fixed-effects model.

4.2 Euro-Area Countries

For the purposes of the analyses of the Office of the Czech Fiscal Council more generally and of the Report on the Long-Term Sustainability of Public Finances specifically, we are concerned about how the interest rate on government bonds responds at debt-to-GDP ratios not yet commonly encountered in the non-euro EU countries. Therefore, we now turn to examining the sample of euro-area countries, where the average general government debt-to-GDP ratio reaches 79%, in comparison to 50% in the non-euro EU countries (see the descriptive statistics tables in the appendix).

Keeping in mind that the relationship between debt and interest rates may be specific in the euro area, because of the common currency, in this subchapter we do not aim to estimate the effect of debt on government bond interest rates. We have already inferred this piece of information from the sample of non-euro EU countries. Instead, in this subchapter we inspect the possible non-linearities in the relationship between debt and the interest rate on government bonds in the presence of high debt.

Table 5 reports the estimation results of three fixed-effects model specifications, which we use again to identify non-linearities. Both country- and time-specific fixed effects are included. The latter are needed to control for the high degree of cross-dependence in bond yields across the euro area.

Specification 9 is similar to Specification 7 (in Table 3) but contains two additional control variables, *euro* and *el2012*. $Euro_{i,t}$ takes the value one, if country *i* is a euro-area member in period *t*; it controls for the fact that some countries adopted the common currency during the period under investigation. *El2012* equals one for Greece in 2012 and helps keep autocorrelation in check.

Table 5 Fixed-Effects Model Estimation Results for Euro-Area Countries

	(9)	(10)	(11)
Explained variable:	***int-nom-spread***	***int-dflt***	***int-nom-spread***
Int-dflt(-1)		*0.233* *(0.047)* *[0.000] ******	
Int-dflt(-2)		*-0.190* *(0.041)* *[0.000] ******	
Int-nom-spread(-1)	*0.263* *(0.054)* *[0.000] ******		*0.262* *(0.054)* *[0.000] ******
Int-nom-spread(-2)	*-0.287* *(0.049)* *[0.000] ******		*-0.278* *(0.049)* *[0.000] ******
P-debt-above60	*0.032* *(0.010)* *[0.003] ******	*0.034* *(0.016)* *[0.032] **	
Debt-spread			*0.035* *(0.011)* *[0.003] ******
*Debt-spread * d-debt-above100*			*-0.006* *(0.011)* *[0.592] ******
Prim-balance		*-0.200* *(0.047)* *[0.000] ******	
Prim-balance-spread	*-0.074* *(0.030)* *[0.013] **		*-0.069* *(0.030)* *[0.023] **
Infl-dflt-spread	*-0.113* *(0.074)* *[0.129]*		*-0.125* *(0.075)* *[0.096] **
Euro	*-1.605* *(0.492)* *[0.002] ******	*-0.314* *(0.748)* *[0.676]*	*-1.515* *(0.488)* *[0.002] ******
El2012	*10.336* *(1.025)* *[0.000] ******	*10.875* *(1.586)* *[0.000] ******	*10.298* *(1.029)* *[0.000] ******
Constant	*2.451* *(0.552)* *[0.000] ******	*1.002* *(0.814)* *[0.221]*	*2.988* *(0.530)* *[0.000] ******
Joint statistical significance			
*Debt-spread, debt-spread * d-debt-above100*			*[0.005] ******
Model evaluation			
R^2	*0.916*	*0.877*	*0.917*
Adjusted R^2	*0.893*	*0.847*	*0.894*
F-test p-value	*0.000 ****	*0.000 ****	*0.000 ****
AIC	*2.791*	*3.714*	*2.720*
Durbin-Watson statistic	*1.741*	*1.835*	*1.746*
Number of observations	*144*	*153*	*144*
Residuals			
Normally distributed	*No*	*No*	*No*
Serially uncorrelated	*Marginally*	*Yes*	*Marginally*
Cross-independent	*Yes*	*Yes*	*Yes*
Ex-post estimates evaluation			
Root mean squared error	*0.886*	*1.332*	*0.874*
Mean absolute error	*0.629*	*0.988*	*0.621*

Note: standard errors in ( ), p-values in [ ]. The variable *gap-spread* is excluded from the euro-area specifications, because it causes increased autocorrelation in the residuals. When included, the coefficient estimate for *p-debt-above60* is slightly lower.

The estimates of Specification 9 suggest that each additional percentage point of debt to GDP in excess of 60% increases the interest rate on government bonds in the euro area on average by 3.2 basis points. This estimate is statistically significant, unlike in the sample of non-euro EU countries (Specification 7). The coefficient estimate for *p-debt-above60* is robust to several specification changes, including the omission of some variables (e.g., *prim-balance-spread*), their substitution (*prim-deficit* for *prim-balance*) or additions (*ca*, *liq19*, *gap-spread*). It is also robust to replacing *p-debt-above60* with *debt-spread*. Even switching from a linear specification between debt and the interest rate to a quadratic one does not change the estimation results much.

In Specification 9, one may replace the period-specific fixed effects with variables pertaining to the euro area as a whole (*ea-debt, ea-prim-balance, ea-ca, ecb-debt-held*)[17] and observe an estimate of the effect of debt on government bond interest rate of 3.3 basis points (p-value 0.002).

Specification 9 is rather sensitive to changes of the period under investigation. When estimated, in turn, for the periods 2008–2015, 2008–2016 and 2008–2017, the resulting coefficient estimates for the debt variable are 0.060 (p-value 0.000); 0.049 (p-value 0.000); and 0.043 (p-value 0.000), respectively. The pattern of the interest rate's decreasing sensitivity to debt may be due to the experiences of severe crises gradually fading, but it may also be a consequence of the ECB's quantitative and qualitative easing policies.[18]

Specification 10 tests the robustness of the estimation results of Specification 9, by changing the explained variable. The coefficient estimate for *p-debt-above60* remains similar and again we observe a pattern of declining sensitivity when shortening the estimation period (statistically significant point estimates 0.104 for 2008–2015; 0.071 for 2008–2016; and 0.58 for 2008–2017).

When investigating the effect of debt at various thresholds, we proceed as in the sample of non-euro EU countries. In Specification 9, which we prefer to Specification 10 due to slightly better qualities of the model as a whole (AIC, adjusted R^2, alignment of fitted and actual values), we replace the variable *p-debt-above60* with its variations with different thresholds. Table 6 reports the results of this exercise.

Table 6 Estimates at Varying Debt Thresholds, Euro-Area Countries

Debt variable	Coefficient estimate	P-value	Number of non-zero observations
p-debt-above30	*0.031*	*0.001* ***	*182*
p-debt-above40	*0.031*	*0.002* ***	*165*
p-debt-above50	*0.029*	*0.004* ***	*148*
p-debt-above60	*0.032*	*0.003* ***	*127*
p-debt-above70	*0.038*	*0.002* ***	*99*
p-debt-above80	*0.044*	*0.002* ***	*83*
p-debt-above90	*0.051*	*0.005* ***	*65*
p-debt-above95	*0.046*	*0.023* **	*61*
p-debt-above100	*0.037*	*0.103*	*48*
p-debt-above105	*0.024*	*0.342*	*39*

Note: estimates were produced by changing the threshold of the *p-debt-aboveXX* variable in Specification 9.

In contrast to the non-euro EU countries, no threshold stands out as the floor from which the interest rate on government bonds would begin to respond to changes in debt. However, at very high debt, i.e., above 100% of GDP, the response is no longer statistically significant. We check this by means of an interaction variable in Specification 11 (Table 6). Its results are marginally better than those of Specification 9. One possible explanation is that investors who hold government bonds at debt-to-GDP ratios exceeding 100% are relatively risk-neutral compared to investors who hold government bonds at lower debt-to-GDP ratios. They may require lower compensation per percentage point of debt-to-GDP (relative to Germany's debt), and therefore the average increase in the interest rate in response to a one percentage-point increase in debt to GDP falls from 3.5 to 2.9 basis points, when debt exceeds 100% of GDP. In our sample, the reduced estimate would apply to parts of the debts

[17] The euro-area variable always enters net of its value for country analyzed.
[18] The pattern could reflect the ECB's determination to do "whatever it takes" (M. Draghi's speech in July 2012) to preserve the common currency. Alternatively, the commitment could have led to a structural break in the relationship between debt and the interest rate in 2012. We are not able to test this empirically, because the period starting in 2012 is very short, especially taking into account the lags included in the models.

accumulated by Belgium, Ireland, Greece, Cyprus, and Portugal. These countries have been pressed by international institutions to adopt prudential budgetary measures to varying degrees. The engagement of credible institutions in the process of debt crisis resolution may also contribute to lower sensitivity of the interest rate to debt.

5 Discussion and Conclusion

This paper quantifies the effect of the (general government) debt-to-GDP ratio on the interest rate on (central) government bonds. To this end, it employs two types of models, a panel regression with fixed effects and a pooled mean group model (PMG). The former allows for the testing of possible non-linearities in the relationship between debt and government bond interest rates, such as debt thresholds, while the latter exploits time series dynamics to estimate a long-run equilibrium relationship between the variables of interest. The models are estimated with 2008–2018 annual data, separately for the non-euro EU countries and the euro area.

To determine the sensitivity of government bond interest rates to the debt-to-GDP ratio, we prefer Specification 3. Our preference stems from the low standard errors of coefficient estimates as well as from the fair fit between the estimated and actual values for the Czech Republic (see Figure 2). The results of Specification 3 suggest that, in the non-euro EU countries on average, an additional one-percentage-point increase in the general government debt-to-GDP ratio increases the interest rate on long-term central government bonds by 4 basis points. Conveniently, this estimate lies inside the 90% confidence intervals of the coefficient estimates from our fixed-effects models.

Results from the sample of non-euro countries suggest that the sensitivity of interest rates to debt is most likely to be activated when debt to GDP exceeds 55%. Although the respective coefficient estimate (in Table 4) is not statistically significant at the conventional levels, the associated drop in p-value is striking, and the coefficient's size roughly corresponds to the sensitivity estimated with the PMG model. Results from the sample of euro-area countries imply that the sensitivity of the interest rate to debt drops by 17% (0.006/0.035; see Specification 11) when debt exceeds 100% of GDP. Applying this 17% reduction to the 4 basis points estimated for the non-euro EU countries gives a more lenient risk premium of 3.3 basis points per one percentage-point of debt to GDP.[19]

We conclude the following: **for debt-to-GDP ratios between 55% and 100%, a one percentage-point increase in the debt-to-GDP ratio raises the interest rate on government bonds by 4 basis points. For debt-to-GDP ratios above 100%, an additional percentage point (of debt) is associated with an interest-rate increase of 3.3 basis points.**

Table 9 Estimates of Interest Rate Sensitivity to Debt from the Literature and Practice

Source	Sensitivity estimate	Applied to debt	Inferred from
CFC Office (2020)	4 or 3.3 b.p. conditional on the size of the debt	Above 55% and 100% of GDP, respectively	EU, 2008–2018
CBR (Slovakia)	1.3 p.p., non-linear	At 40% of GDP	V4, 2000–2013
Turner and Spinelli (2013)	2.5 - 5 b.p. outside the euro area	Above 75% of GDP	OECD, 1980–2012
Turner and Spinelli (2012)	3 b.p. prior to 2009, 8 b.p. afterwards	Above 75% of GDP	OECD, 1980–2010
OECD	4 b.p.	Above 75% of GDP	
IMF	3 b.p.	Above 75% of GDP	
European Commission	4 b.p.	Above 75% of GDP	

Table 9 reports the estimates of the debt and interest rate relationship from different sources. Our estimate of the interest rate's sensitivity to debt in the non-euro EU countries comes close to the values used by the European Commission, the OECD, and the IMF. It also falls within the range reported by Turner and Spinelli (2012) for the OECD countries outside the euro area. The 55% threshold we infer is lower than usually considered; nonetheless, Turner and Spinelli (2012) explicitly caution that the thresholds in the literature are arbitrarily set. None of our sources consider a reduction in sensitivity at very high debt. Particularly in the case of international organizations, this may be at-

[19] See Specification 11, particularly the coefficient estimates for *debt-spread* and *debt-spread*d-debt-above100*. The decrease by 0.006 from 0.035 is a decline by approximately 17%.

tributed to concerns about overly optimistic projections of debt growth, as applying a low sensitivity of interest rates to debt lowers the differential between the interest rate and the growth rate of the economy, which is a central parameter in debt sustainability analyses.

In the Report on the Long-Term Sustainability of Public Finances (CFC, 2019), a premium of 3.9 basis points is applied to each percentage point of the general government debt to GDP in excess of 55%. The projection thus leads to debt corresponding to 222% of GDP in 2069. If no premium is considered, the result would be a debt-to-GDP ratio of 175%.

If we were to use the results of this study and apply a premium of 4.0 basis points, debt in 2069 would amount to some 224% of GDP. If we were to take into account the more lenient premium once debt exceeds 100% of GDP, debt in 2069 would stand at 214% of GDP. The softer premium does not make much difference, because it applies only after the debt-to-GDP ratio surpasses 100%, which is projected to happen in 2055.

Taking the relationship between the government bond interest rate and debt into consideration substantially changes the dynamics of public finance projections. It accentuates the effect of today's fiscal decisions on future debt and sustainability. The higher interest rate, which results from a higher risk premium, does not apply solely to new debt; it makes all existing debt more expensive when refinanced. So, an increase in the interest rate on government bonds in response to high debt can make the general government debt unexpectedly costly. In the light of this, the application of a high-debt penalty in the sustainability reports published by the Czech Fiscal Council appears justified and the magnitude that has been used so far (3.9 basis points in excess of 55% of GDP) as reasonable.

Nevertheless, the sensitivity of this paper's estimates to changes in the period under investigation, coupled with the various estimates in the literature, support the notion that a universal, always applicable high-debt penalty does not exist. The relationship between general government debt and the interest rate on government bonds is subject to circumstances. As for the current ones, let's mention the recollections of the financial, economic, and sovereign risk crises as well as the commitment and potential of international institutions and central banks to mitigate them.

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Appendix

Confidence Intervals of Selected Point Estimates

	Coefficient estimate	90% CI	95% CI	99% CI
SPECIFICATION 3 *debt*	*0.040*	*(0.040; 0.040)*	*(0.040; 0.040)*	*(0.040; 0.040)*
SPECIFICATION 5 *debt-spread*	*0.023*	*(-0.019; 0.064)*	*(-0.027; 0.072)*	*(-0.043; 0.089)*
SPECIFICATION 9 *p-debt-above60*	*0.032*	*(0.015; 0.049)*	*(0.011; 0.052)*	*(0.005; 0.059)*

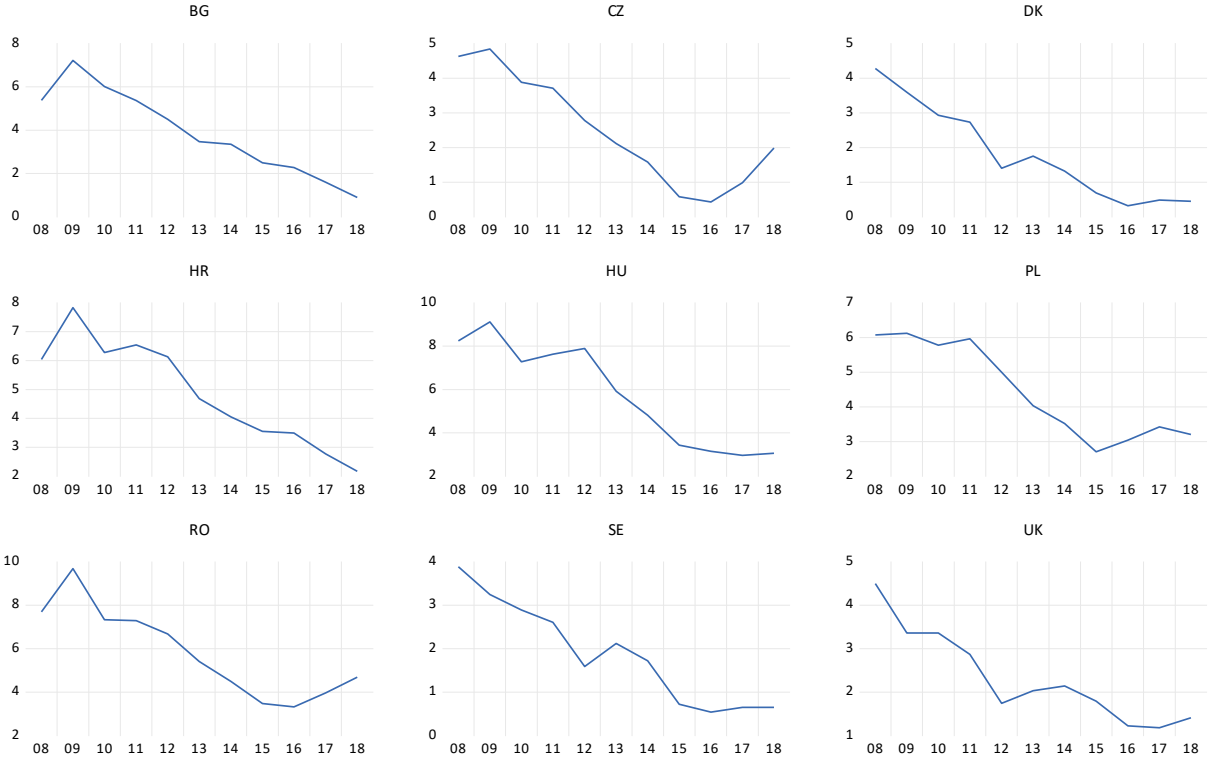
Descriptive Statistics, Sample of Non-Euro EU Countries (99 observations)

	Mean	Median	Max	Min	Std. deviation
Ca	*-0.365*	*-0.700*	*10.600*	*-24.400*	*5.786*
Debt	*49.733*	*44.200*	*87.900*	*12.400*	*21.112*
Debt-spread	*-22.876*	*-27.500*	*25.900*	*-66.500*	*21.746*
Gap	*-0.919*	*-0.867*	*9.269*	*-5.612*	*2.501*
Gap-spread	*-0.697*	*-0.735*	*7.468*	*-5.696*	*2.270*
Infl-dflt	*2.293*	*1.896*	*16.016*	*-1.425*	*2.088*
Infl-dflt-spread	*0.905*	*0.618*	*15.109*	*-2.638*	*2.209*
Int-dflt	*1.395*	*1.301*	*5.422*	*-7.168*	*2.221*
Int-dflt-spread	*1.139*	*1.060*	*4.739*	*-10.213*	*2.285*
Int-hicp	*1.468*	*1.416*	*4.811*	*-4.026*	*1.620*
Int-hicp-spread	*1.289*	*1.096*	*4.682*	*-5.420*	*1.774*
Int-nom	*3.698*	*3.360*	*9.690*	*0.320*	*2.232*
Int-nom-spread	*2.053*	*1.990*	*6.470*	*-0.100*	*1.699*
P-debt-above60	*5.447*	*0.000*	*27.900*	*0.000*	*9.217*
Prim-balance	*-0.725*	*-0.500*	*4.600*	*-8.300*	*2.502*
Prim-deficit	*-1.354*	*-0.500*	*0.000*	*-8.300*	*1.892*

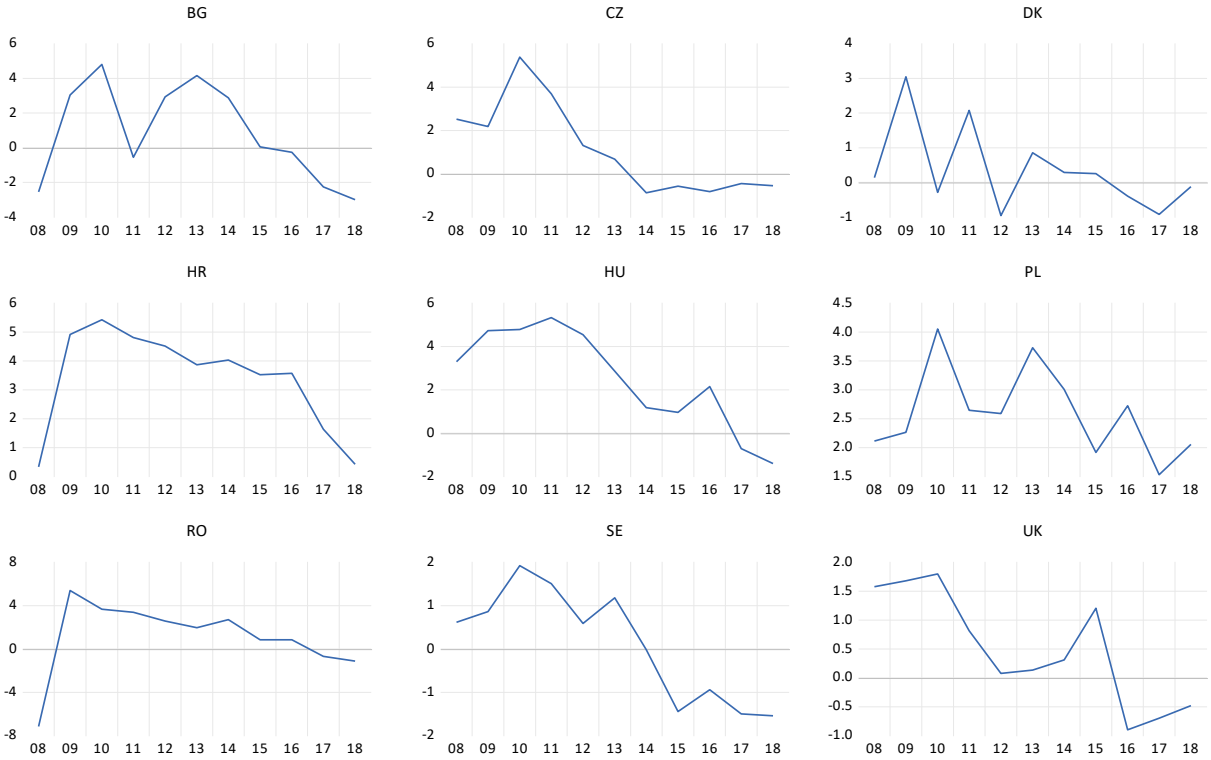
Descriptive Statistics, Sample of Euro-Area Countries (176 observations)

	Mean	Median	Max	Min	Std. deviation
Ca	*0.683*	*0.700*	*12.500*	*-15.000*	*5.312*
Debt	*79.439*	*72.600*	*181.100*	*14.600*	*34.978*
Debt-spread	*7.257*	*3.200*	*120.200*	*-50.600*	*36.286*
Ecb-debt-held	*59.486*	*26.627*	*176.544*	*6.170*	*60.330*
Gap	*-1.711*	*-1.209*	*6.632*	*-15.901*	*3.753*
Gap-spread	*-1.582*	*-0.919*	*5.215*	*-15.919*	*3.605*
Infl-dflt	*1.307*	*1.269*	*11.725*	*-9.730*	*1.999*
Infl-dflt-spread	*-0.081*	*-0.076*	*10.818*	*-11.575*	*2.126*
Int-dflt	*2.341*	*1.527*	*24.471*	*-6.132*	*4.052*
Int-dflt-spread	*2.085*	*1.320*	*23.121*	*-7.785*	*3.961*
Int-nom	*3.635*	*3.295*	*22.5*	*0.290*	*3.008*
Int-nom-spread	*1.980*	*1.050*	*21.000*	*-0.090*	*2.566*
P-debt-above60	*24.576*	*12.600*	*121.100*	*0.000*	*29.686*
Prim-balance	*-1.126*	*-0.500*	*5.600*	*-29.300*	*3.824*
Prim-deficit	*-1.843*	*-0.500*	*0.000*	*-29.300*	*3.267*

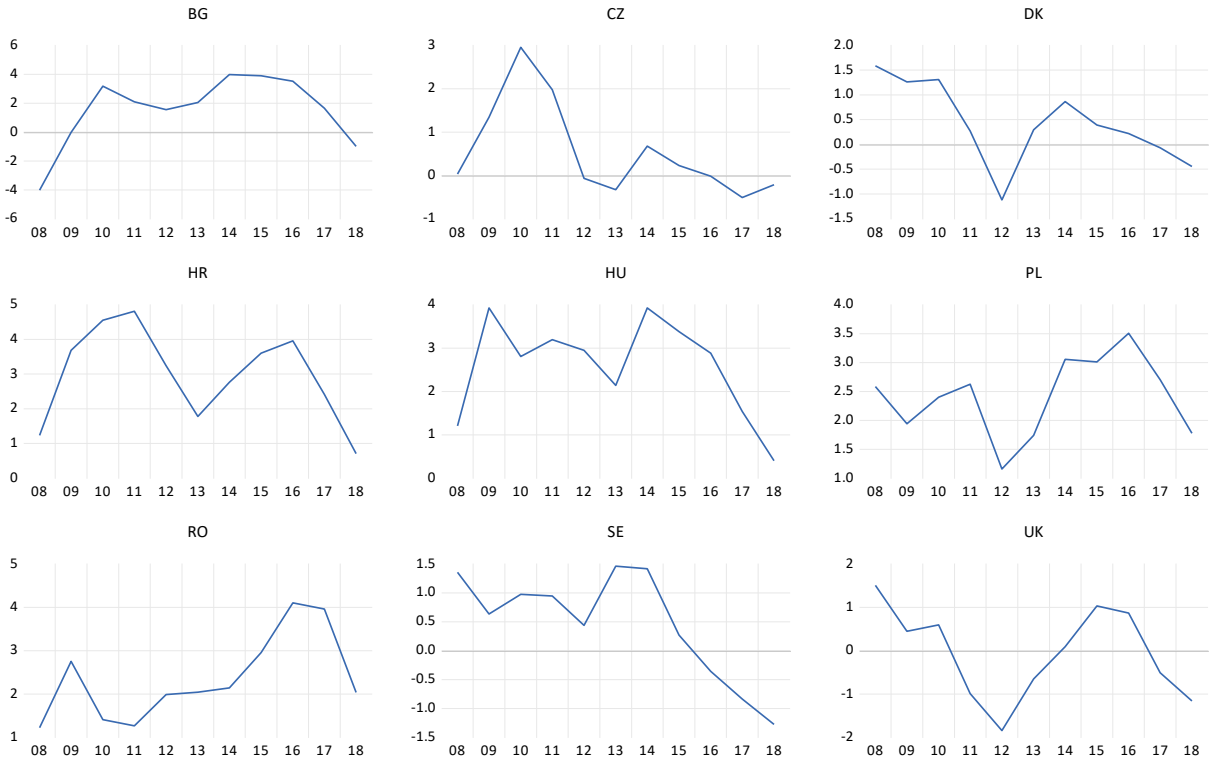
Variable *int-nom*, Non-Euro EU Countries, 2008–18



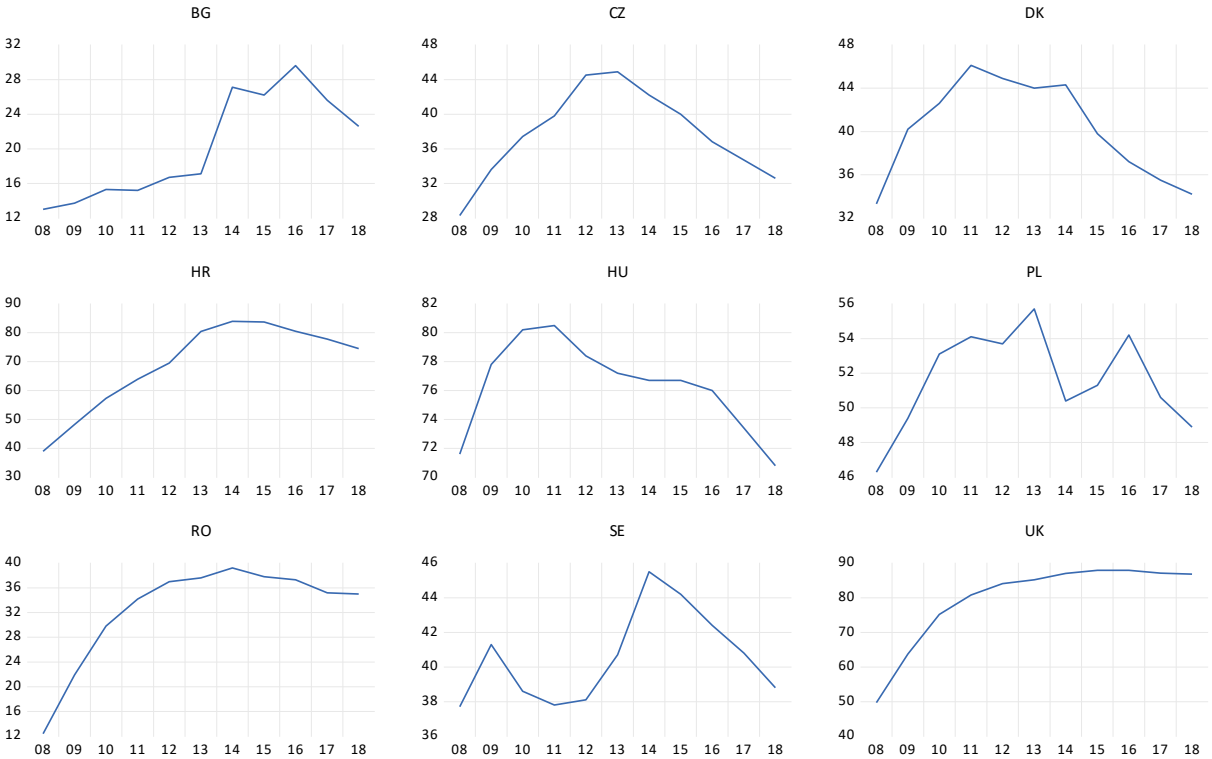
Variable *int-dflt*, Non-Euro EU Countries, 2008–18



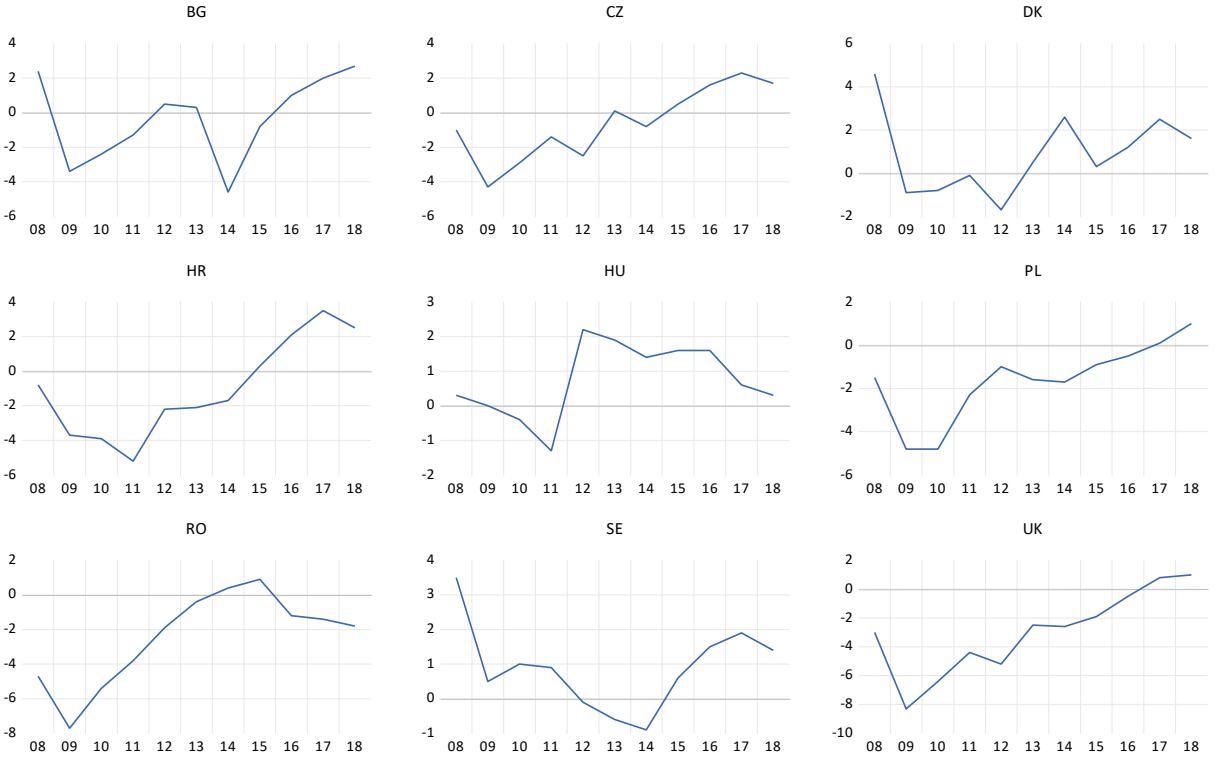
Variable *int-hicp*, Non-Euro EU Countries, 2008–18



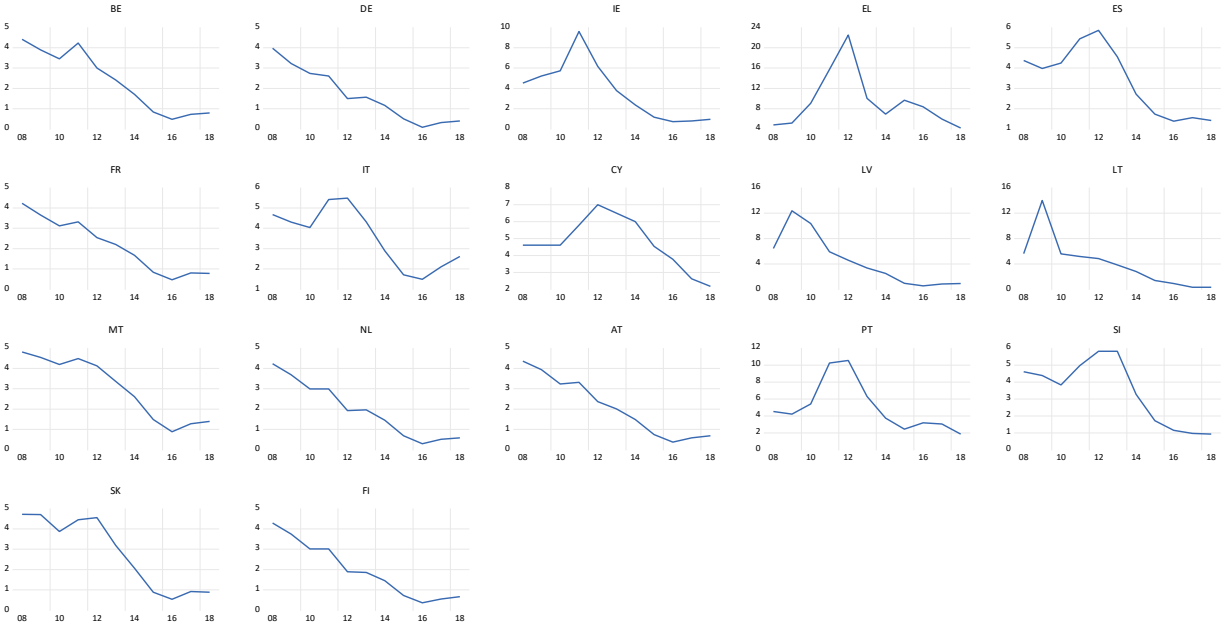
Variable *debt,* Non-Euro EU Countries, 2008–18



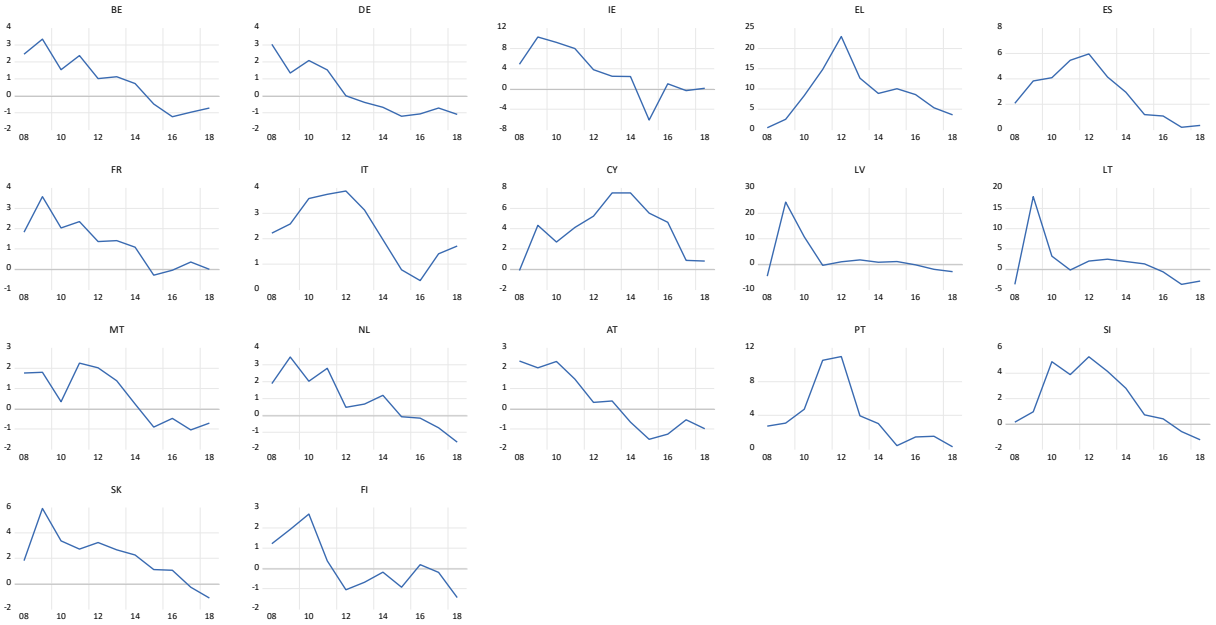
Variable *prim-balance*, Non-Euro EU Countries, 2008–18



Variable *int-nom*, Euro-Area Countries, 2008–18



Variable *int-dflt*, Euro-Area Countries, 2008–18



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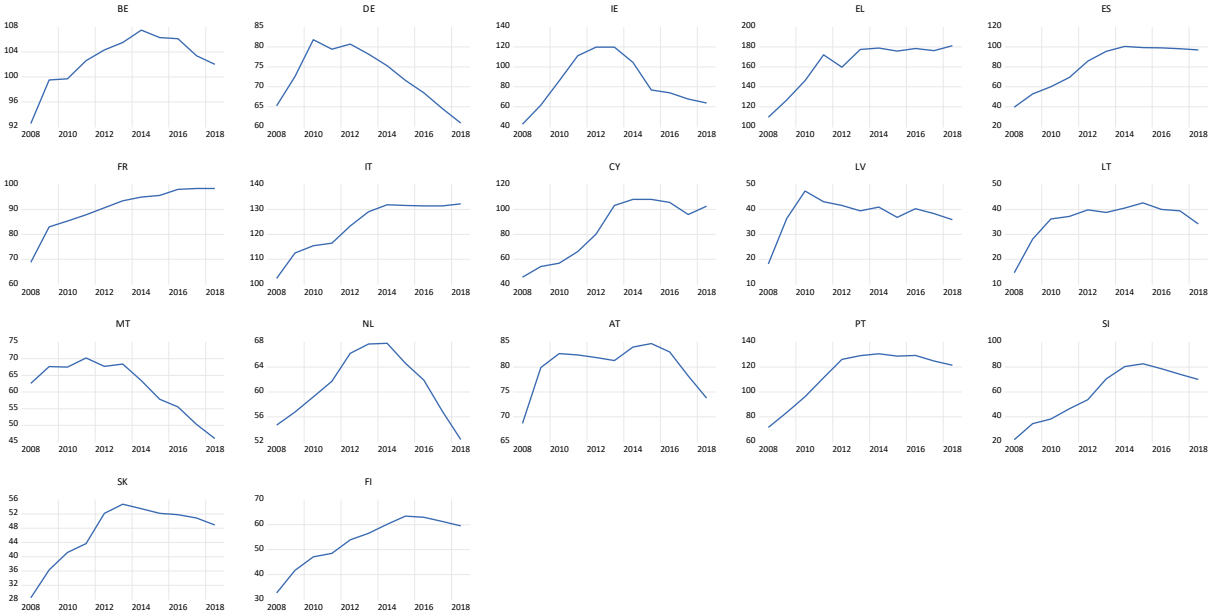

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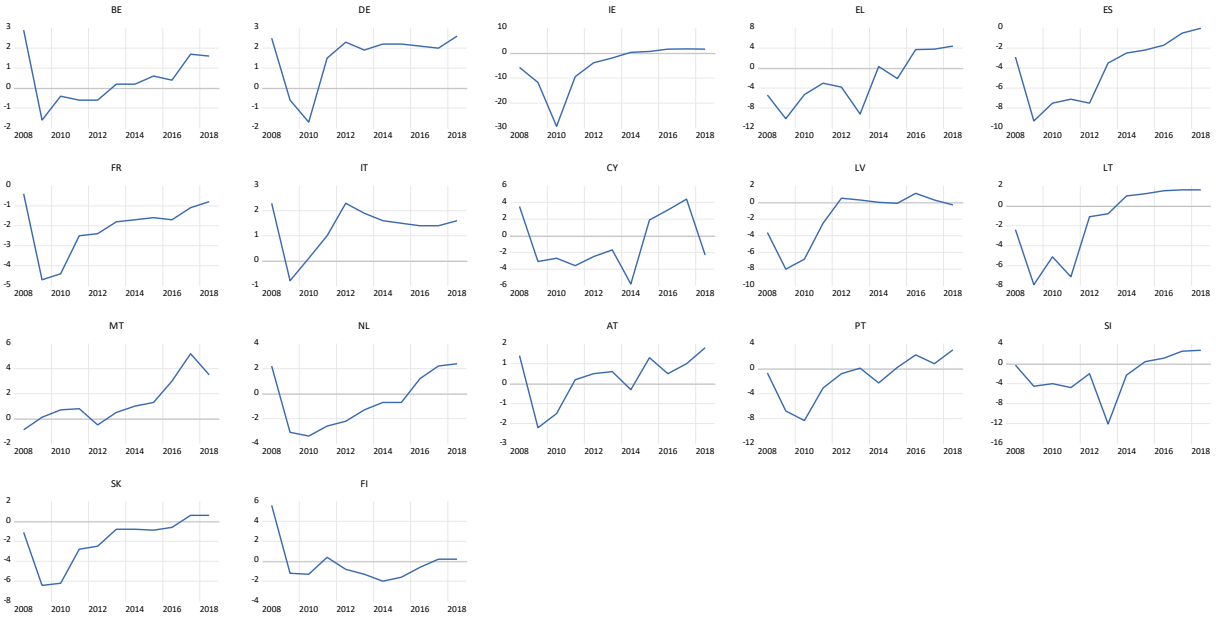
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Variables by Type, Sample of Non-Euro EU Countries

I(0)	I(1)
EXPLAINED VARIABLES	
Int-hicp-spread	*Int-dflt* *Int-dflt-spread* *Int-nom-spread* *Int-hicp*
DEBT VARIABLES	
Debt-spread *P-debt-above60*	*Debt* *P-debt-above75*
OTHER FISCAL VARIABLES	
Prim-balance *Prim-deficit*	*Prim-balance-spread*
OTHER CONTROL VARIABLES	
Gap-spread *Infl-dflt*	*Ca* *Ca-spread* *Gap* *Infl-dflt-spread*

Note: from the threshold variables only *p-debt-above60* and *p-debt-above75* are shown.

Variables by Type, Sample of Euro-Area Countries

I(0)	I(1)
EXPLAINED VARIABLES	
Int-dflt *Int-dflt-spread* *Int-hicp* *Int-hicp-spread* *Int-nom-spread*	*Int-nom*
DEBT VARIABLES	
P-debt-above60 *P-debt-above75* *Debt-spread*	*Debt*
OTHER FISCAL VARIABLES	
Prim-balance *Prim-deficit*	*Prim-balance-spread*
OTHER CONTROL VARIABLES	
Ca *Ca-spread* *Infl-dflt* *Infl-dflt-spread* *Liq19* *Liq19-spread* *Gap-spread* *Ecb-debt-held* *Ez-ca* *Ez-debt* *Ez-prim-balance*	*Gap*

Note: from the threshold variables, only *p-debt-above60* and *p-debt-above75* are shown.

Correlation Coefficients, Sample of Non-Euro EU Countries

	Debt	*Debt-spread*	*Ecb-debt-held*	*Gap-spread*	*Infl-dflt-spread*	*Int-dflt*	*Int-hicp-spread*	*Int-nom-spread*	*P-debt-above60*	*Prim-balance*
Debt	*1*									
Debt-spread	*0.949 [0.000]*	*1*								
Ecb-debt-held	*-0.219 [0.030]*	*-0.233 [0.020]*	*1*							
Gap-spread	*-0.263 [0.008]*	*-0.119 [0.242]*	*0.457 [0.000]*	*1*						
Infl-dflt-spread	*-0.273 [0.006]*	*-0.181 [0.073]*	*0.406 [0.000]*	*0.435 [0.000]*	*1*					
Int-dflt	*0.228 [0.023]*	*0.052 [0.611]*	*0.239 [0.017]*	*-0.238 [0.018]*	*-0.454 [0.000]*	*1*				
Int-hicp-spread	*0.199 [0.049]*	*0.202 [0.045]*	*-0.506 [0.000]*	*-0.248 [0.013]*	*-0.237 [0.018]*	*0.289 [0.004]*	*1*			
Int-nom-spread	*0.135 [0.184]*	*0.080 [0.430]*	*0.095 [0.349]*	*0.014 [0.888]*	*0.282 [0.005]*	*0.536 [0.000]*	*0.518 [0.000]*	*1*		
P-debt-above60	*0.881 [0.000]*	*0.851 [0.000]*	*-0.203 [0.044]*	*-0.200 [0.047]*	*-0.127 [0.210]*	*0.011 [0.273]*	*0.107 [0.294]*	*0.155 [0.127]*	*1*	
Prim-balance	*-0.016 [0.874]*	*0.126 [0.213]*	*-0.376 [0.000]*	*-0.108 [0.288]*	*-0.089 [0.383]*	*-0.347 [0.000]*	*-0.134 [0.186]*	*-0.255 [0.011]*	*0.021 [0.837]*	*1*

Note: p-values in [ ].

Correlation Coefficients, Sample of Euro-Area Countries

	Debt-spread	*Ecb-debt-held*	*Gap-spread*	*Infl-dflt-spread*	*Int-dflt*	*Int-nom-spread*	*P-debt-above60*	*Prim-balance*	*Prim-balance-spread*
Debt-spread	*1*								
Ecb-debt-held	*0.244 [0.001]*	*1*							
Gap-spread	*-0.398 [0.000]*	*0.119 [0.116]*	*1*						
Infl-dflt-spread	*-0.233 [0.002]*	*0.046 [0.542]*	*0.399 [0.000]*	*1*					
Int-dflt	*0.256 [0.001]*	*-0.364 [0.000]*	*-0.632 [0.000]*	*-0.651 [0.000]*	*1*				
Int-nom-spread	*0.381 [0.000]*	*-0.176 [0.019]*	*-0.719 [0.000]*	*-0.311 [0.000]*	*0.844 [0.000]*	*1*			
P-debt-above60	*0.959 [0.000]*	*0.095 [0.211]*	*-0.490 [0.000]*	*-0.218 [0.004]*	*0.370 [0.000]*	*0.514 [0.000]*	*1*		
Prim-balance	*0.152 [0.044]*	*0.439 [0.000]*	*0.202 [0.007]*	*0.280 [0.000]*	*-0.467 [0.000]*	*-0.271 [0.000]*	*0.066 [0.381]*	*1*	
Prim-balance-spread	*0.097 [0.199]*	*0.353 [0.000]*	*0.266 [0.000]*	*-0.409 [0.000]*	*-0.409 [0.000]*	*-0.285 [0.000]*	*0.032 [0.676]*	*0.941 [0.000]*	*1*

Note: p-values in [.]