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Scientific review

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Government Debt-Interest Rate Nexus in G7 Countries over a Long Horizon

Summary: The goal of this paper is to investigate the influence of government fiscal positions on long-term interest rates in G7 countries during the period 1948-2012. Our results suggest that a one percentage point increase in the stock of government debt in GDP is associated with an increase in government bond yields of 2.27-6.28 basis points, while an increase in government deficit in GDP of one percentage point is associated with an increase in government bond yields of 3.15-14.3 basis points. In addition, our results indicate that under reasonable assumptions and in the presence of widening output gaps, the neoclassical growth model predicts a rather low degree of crowding-out (around 36 percent), while the narrowing of the output gap leads to a complete crowding-out.

Key words: Government debt, Interest rate, G7, Crowding-out.

JEL: C23, E43, E62, H62, H63.

The main aim of this paper is to investigate the impact of government debt on real long-term interest rates (government bond yields) in G7 countries over the last 65 years. Real long-term interest rates are the main determinants of long-term saving and investment; hence, it is important to observe and understand their behaviour and key determinants. Higher interest rates can reduce investment and consumption and, by extension, economic growth. The extent of this adverse effect depends on the magnitude of the interest rate increase. The recent deterioration of fiscal positions in many countries reignited debates about the effects of government debt on long-term interest rates. As noted by Abel L. Costa Fernandes and Paulo R. Mota (2011), financial markets in the European Union (EU) have been greatly affected by the crisis of confidence on sovereign debt. Similar concerns have been heard around the globe.

This paper complements and extends the literature in the following directions: First, we use the longest available time span, 1948-2012, which, to the best of our knowledge, has not been tested before. The second distinctive feature of our approach is that we use panel cointegration techniques, which allow for both government debt and government deficit (a change in government debt) to be included simultaneously in the model, thus following the implications of the theoretical model extremely well. Finally, we undertake a simple exercise and assess the degree of crowding-out in G7 countries, which has not been done before in a similar manner. Papers typically assume some value for the degree of crowding-out and afterwards calculate the expected effect of a change in the debt-to-GDP ratio on interest rates

(see, for example, Eric Engen and Glenn Hubbard 2004; Thomas Laubach 2009; Peter Claeys, Rosina Moreno, and Jordi Surinach 2012). This provides them with a theoretical frame with which they compare their empirical findings. We, on the other hand, adopt a different approach and calculate the degree of crowding-out using our empirical results as an input.

The paper is organised as follows: Section 1 reviews the empirical literature on the topic, focusing first and foremost on panel studies, i.e. international evidence. Section 2 provides the theoretical background and discusses the theoretical effects of government debt on interest rates. Section 3 gives the description of the data and methodology, while the results as well as robustness checks are presented in Section 4. Section 5 uses these results as an input and assesses the degree of crowding-out in G7 countries. Finally, Section 6 concludes.

1. Review of Empirical Literature

In this literature review we give an overview of the international evidence (i.e. panel studies) on the relationship between fiscal positions and long-term interest rates. Single-country empirical analyses are vast; however, their focal point is typically the United States of America (see, for example, Engen and Hubbard 2004; Laubach 2009; Lloyd Thomas and Danhua Wu 2009). We, hence, restrain from presenting single-country studies as these are beyond the scope of current paper.

The papers of which we give an overview are given in Table 1.

Table 1 reveals several issues. First, there are no papers that analyse the period before 1960; moreover, the majority of the studies focus on the period after the 1980s. Second, only one paper among the ten presented in Table 1 analyses G7 countries (David Hauner and Manmohan Kumar 2009). Third, only two papers use panel cointegration techniques in their analysis (Silvia Ardagna, Francesco Caselli, and Timothy Lane 2007; Tigran Poghosyan 2014).

The key contribution of this paper, thus, lies in the fact that we analyse a group of countries that in previous analyses have been rather neglected. G7 countries represent the most advanced economies in the world and, as such, can be used as a benchmark for other countries. The conclusions regarding the relationship between long-term interest rates and government debt in these countries can serve for policy recommendations in less-developed economies who seek to catch up with the most advanced ones. Furthermore, we use the longest available period, which has not been used before, while the use of the error-correction model allows us to differentiate between the long and the short run and to simultaneously include government debt and government deficit in the model. Moreover, we broaden our baseline model with a number of additional variables and subject our results to a number of robustness checks, therefore removing the influence of model and sample composition on the conclusions. Finally, we undertake a simple exercise that allows us to assess the degree of crowding-out in G7 countries, which, to the best of our knowledge, has not been done before.

Table 1 Empirical Studies on the Impact of Public Debt on Interest Rates

Study	Period Country Estimation technique	Dependent variable	Control variables	Main finding(s)
Adrian Orr, Malcolm Eddey, and Michael Keneddy (1995)	1981-1994 (quarterly data) 17 OECD Panel data, error-correction model	Real interest rate	Rate of return on capital Net government debt in GDP Deficit in GDP Domestic portfolio risk of holding bonds Current-account balance relative to GDP Long-term average of past inflation Expected future inflation Exchange rate	A significant long-run effect of deficit to GDP ratio on long-term interest rates.
Ricardo Faini (2006)	1979-2002 EMU Dynamic panel, 3SLS	Real interest rate	Output gap Expected inflation Stock market real return Gross domestic public debt in GDP Primary deficit in GDP US real interest rate EMU average real interest rate Three-month real money market rate Level of government consumption	A one percentage point increase in the government debt-to-GDP ratio is found to result in an increase in interest rates of approximately 3 basis points.
Noriaki Kinoshita (2006)	1971-2004 19 OECD Static panel	Real long-term interest rates on government bonds	Ratio of current financial liabilities of the general government to nominal GDP Ratio of government final consumption expenditure to nominal GDP	A one percentage point increase in the government debt-to-GDP ratio raises interest rates by approximately 1.8-5.3 basis points.
Ardagna, Caselli, and Lane (2007)	1960-2002 16 OECD Panel cointegration GLS VAR	Nominal interest rate on 10-year government bonds	Nominal interest rate on 3-month treasury bills Inflation rate Primary deficit/GDP Public debt/GDP GDP growth rate Global indicators of world fiscal imbalances	A one percentage point increase in primary deficit increases long-term interest rates by 7.4-13.6 basis points (depending on specification), while a one percentage point increase in the government debt in GDP raises interest rates by about 0.6 basis points.
Hauner and Kumar (2009)	1960-2005 (quarterly data) G7 Panel OLS Cross-sectional fixed effects FGLS estimator with cross-section weights	Nominal 10-year government bond yield	Expected long-term inflation rate Returns on the domestic stock market Money growth rate Government net borrowing in percent of GDP Current account balance in percent of GDP US federal funds rate Reserve accumulation by the respective rest of the world	The weakening of budgetary positions that took place in recent years resulted in a noteworthy upward pressure on interest rates.
Emanuele Baldacci and Kumar (2010)	1980-2008 31 advanced and emerging economies Static panel, fixed effects	Nominal yields on 10-year government bonds	Short-term nominal interest rate Inflation Fiscal balance in percent of GDP Level of gross general government Debt in percent of GDP Output growth	A one percentage point increase in the government debt-to-GDP ratio raises interest rates by approximately 3-5 basis points. Moreover, a one percentage point increase in deficit to GDP ratio is found to raise real interest rate by 30 basis points in high-deficit countries (which is 10 basis points higher than in low-deficit countries) and in countries with debt levels above 80 percent of GDP (which is 2 basis points higher than in countries with debt lower than 80 percent).

Joseph Gruber and Steven Kamin (2012)	1988-2007 19 OECD Dynamic panel	Long-term (usually 10-year) interest rate on government bonds during the fourth quarter of the year	Short-term interest rate (three-month interbank rate) Two-year ahead projected rate of real GDP growth Two-year ahead projected rate of CPI inflation	A one percentage point increase in government debt-to-GDP ratio increases yields by 2 basis points in the long run in G7 countries.
Claey, Moreno, and Surinach (2012)	1990-2005 50 OECD and emerging economies Static panel Spatial panel model	Nominal long-term interest rate	Short-term interest rate Inflation GDP growth Spatial weight matrix	A one percent increase in debt results in interest rate increase of 2 percentage points.
Ari Aisen and David Hauner (2013)	1970-2006 60 advanced and emerging economies Dynamic panel system GMM	Nominal interest rate	Foreign nominal interest rate Expected depreciation Country-specific risk spread Expected inflation Real money supply Real GDP growth Budget deficit	There is a highly significant positive effect of budget deficits on interest rates on the order of about 26 basis points per 1 percent of GDP.
Poghosyan (2014)	1980-2010 22 advanced economies Panel cointegration PMG	10-year benchmark government bond yields	Debt/GDP ratio Real money market rate Inflation Primary balance ratio GDP growth rate	A one percentage point increase in government debt-to-GDP ratio increases government bond yields by approximately 2 basis points.

Source: Author.

Lastly, we would like to emphasise that a significant body of literature exists which focuses on government bond yield spreads (see, for example, Ioana Alexopoulou, Iryna Bunda, and Annalisa Ferrando 2009; Kerstin Bernoth, Jurgen von Hagen, and Ludger Schuknecht 2012; Balasz Csonto and Iryna Ivaschenko 2013, to name a few). We, however, do not consider this strand of literature as it is beyond the scope of our study.

2. Theoretical Background

Government fiscal positions can affect long-term interest rates in a number of ways. The first channel is *via* default risk premium, whereby a fear of government debt default requires a compensating increase in interest rates (Ardagna, Caselli, and Lane 2007; Gruber and Kamin 2012; Poghosyan 2014). Second, investors would be willing to hold government debt only if they are rewarded properly in terms of higher interests on this debt. Third, inflationary expectations also play a role, as fear of debt monetization leads to an interest rate increase proportional to the expected inflation (Gruber and Kamin 2012). Finally, an increase in debt can crowd-out private investment, causing lower steady-state capital stock, higher marginal product of capital and higher interest rates (Engen and Hubbard 2004). It is precisely this last effect that is at the focus of this paper.

Before proceeding, we would like to stress that, as noted by Davide Furceri and Ricardo Sousa (2011), government spending (in general) can result in significant crowding-out, by affecting (negatively) both private consumption and investment. In this paper, however, we focus only on the impact of debt (and deficit) on investment (for the impact of government spending on private spending, please consult Coenen Gunter and Roland Straub 2005; Ludger Linnemann 2006; Yasemin Ozerkek and Sandullah Celik 2010; Furceri and Sousa 2011, and references thereof).

Following Engen and Hubbard (2004), Laubach (2009) and Claeys, Moreno, and Surinach (2012), our starting point for assessing the crowding-out effect of government debt is a model based on typical (aggregate) Cobb-Douglas production function of the type:

$$Y = AK^{\alpha}L^{1-\alpha} \tag{1}$$

where A is the coefficient of total factor productivity, L is labour, K is capital, Y is output and α is the elasticity of capital. The share of total capital income in output is then calculated as:

$$\alpha = \frac{MPK * K}{Y}. \tag{2}$$

Since the interest rate, r, is determined by marginal product of capital, MPK, it can be expressed as:

$$r = MPK = \alpha \frac{Y}{K} = \alpha A \left(\frac{L}{K}\right)^{1-\alpha}. \tag{3}$$

In such a setting an exogenous increase in government debt (GD), *ceteris paribus*, affects the interest rate as follows:

$$\frac{\partial r}{\partial GD} = \frac{\partial r}{\partial K} * \frac{\partial K}{\partial GD} = \left[\alpha(\alpha - 1)\left(\frac{Y}{K^2}\right)\right]\frac{\partial K}{\partial GD}. \tag{4}$$

The direction of this relationship clearly depends on $\frac{\partial K}{\partial GD}$. If we assume that an increase in government debt reduces the capital stock by a fraction c, then $\frac{\partial K}{\partial GD} = -c$, and Equation (4) can be rewritten as

$$\frac{\partial r}{\partial GD} = \alpha(1 - \alpha)\left(\frac{cY}{K^2}\right). \tag{5}$$

Using the symbol k for capital-output ratio, i.e. $k = \frac{K}{Y}$, Expression (5) can be rewritten as:

$$\frac{\partial r}{\partial GD} = \alpha(1 - \alpha)\left(\frac{c}{Yk^2}\right) \tag{6}$$

or:

$$\frac{\partial r}{\partial \frac{GD}{Y}} = \alpha(1 - \alpha)\left(\frac{c}{k^2}\right). \tag{7}$$

Expression (7) is more convenient for our analysis as our variable of interest is not government debt stock but rather its share in GDP. The parameter c, as noted by Laubach (2009), denotes the degree of crowding-out. In the case $c = 0$ the hypothesis of Ricardian equivalence holds and implies that domestic private saving completely offsets the impact of higher public dissaving. If, however, $c = 1$, government debt fully crowds out capital, and the impact of government debt on interest rates is positive (since Y and K are positive and $0 < \alpha < 1$). Finally, in the case $0 < c < 1$, crowding-out is less than complete, which can occur due to central bank purchases of government debt as well as to lending to foreign savers. An increase in government

debt in GDP of one percentage point ($\partial \frac{GD}{Y} = 0.01$), according to (7), raises the interest rate by $\alpha(1-\alpha)\left(\frac{c}{k^2}\right)$.

3. Empirical Approach

3.1 Data and Methodology

We use the data for G7 countries (Canada, France, Germany, Italy, Japan, UK and USA) over the longest available time span: 1948-2012. Ali Abbas et al. (2010) provided the data on government debt since 1948; while the remaining variables, as well as the debt data for the most recent years, were collected from various sources (see Tables 2 and 3 for data details). The data for certain variables, countries and periods were, however, unavailable (hence, our panel is unbalanced), resulting overall in a smaller number of observations than the maximum of 455 (7 countries * 65 years). Nevertheless, this is, to the best of our knowledge, the only paper that uses such a long time span; the minimum number of observations per country per variable is 42 and the maximum is 65.

The determinants of real interest rates have been widely examined in both theoretical and empirical literature, but consensus regarding their relative empirical importance has not been reached yet. Since the data for majority of variables are unavailable for such a long time span, we present two baseline models – Model 1 and Model 2 – which we, later on, subject to a number of robustness tests and broaden with additional variables. Model 1 is a narrower one, whereby we focus on the core determinants of real government bond yields, namely, government debt, GDP growth rate and short-term interest rate. This model enables us to use the longest possible sample, i.e. the years from 1948 to 2012. A wider model, Model 2, additionally includes global long-term government bond yields, share price index and government consumption, to take into account other potentially important determinants of government bond yields. This model, however, due to data unavailability, refers to a shorter period (please refer to the last row of Tables 5-9 for information on the number of observations).

Table 2 Definitions and Sources of the Variables

Variable	Indicator	Source
Real GY	Real government bond yield (% per annum) = Nominal government bond yield − CPI inflation	International Financial Statistics
GOV debt	Gross general government debt (% of GDP)	Abbas et al. (2010) and World Economic Outlook
GDP growth	Gross domestic product, constant prices (% change)	International Financial Statistics and World Economic Outlook
IR	Average of money market rate and T-bill (% per annum)	International Financial Statistics
Global yields	Unweighted average of G7 real government bond yields	International Financial Statistics
Share prices	Prices of common shares of companies traded on national or foreign stock exchange (index, 2010 = 100)	OECD

Government consumption	General government final consumption expenditure (% of GDP)	World Development Indicators
Expected debt	5-year lead debt for years 1948-2007. For the last couple of years in our sample, we use the projected values (estimates) provided by the World Economic Outlook.	Abbas et al. (2010) and World Economic Outlook
Expected growth	5-year lead GDP growth for years 1948-2007. For the last couple of years in our sample, we use the projected values (estimates) provided by the World Economic Outlook.	International Financial Statistics and World Economic Outlook
Output gap	Deviations of actual GDP from potential GDP as a percent of potential GDP	OECD Outlook
CA balance	Current account balance, as a percentage of GDP	OECD Outlook
GDPpc	PPP converted GDP *per capita* at 2005 constant prices	Penn World Tables
CRISIS	Dummy variable that takes the value of 1 in the global financial crises of 2008 and 2009	
RECESSION	Dummy variable that takes the value of 1 in the recessionary period	Federal Reserve Bank of St. Louis Recession Indicator Series
DUMMY 1980	Dummy variable that takes the value of 1 for the period after 1980	
DUMMY EURO	Dummy variable that takes the value of 1 for the period after 1999 (when the euro was introduced)	
OIL CRISIS	Dummy variable that takes the value of 1 for 1973, 1974, 1979 and 1990	

Source: Author.

Table 3 Descriptive Statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
RealGY	412	2.70	2.96	−13.92	8.79
GOVdebt	455	61.51	41.27	4.44	242.59
GDPgrowth	408	3.07	2.72	−5.58	13.07
IR	425	5.48	3.79	0.00	19.80
Global yields	462	6.29	2.99	0.78	13.39
Share prices	394	51.62	51.96	2.10	289.70
Government consumption	368	18.22	2.89	10.49	24.37
Expected debt	458	64.08	42.38	4.44	248.58
Expected growth	430	2.91	2.66	−5.58	13.07
Output gap	197	−0.13	2.17	−5.58	5.39
CA balance	304	−0.23	2.39	−5.82	7.21
GDPpc	407	21555.03	9008.19	2793.98	43517.26
CRISIS	462	0.03	0.17	0	1
RECESSION	391	0.41	0.49	0	1
DUMMY 1980	462	0.52	0.50	0	1
DUMMY EURO	462	0.10	0.30	0	1
OIL CRISIS	455	0.06	0.24	0	1

Source: Author's calculations.

Expressions (5)-(7), presented in Section 2, have important repercussions for our choice of the empirical approach. Specifically, as noted by Engen and Hubbard (2004), they imply that it is the *level* of government debt that influences the *level* of interest rates, and the *change* in government debt, i.e. the deficit, that influences the *change* in interest rates. Therefore, deficit should not be among the set of explanatory variables for explaining the level of long-term government bond yields. Papers on the topic more often than not include both variables without paying much attention to this matter. Our approach to dealing with this issue is given below. Specifically, for samples where the time-series component is large, as is ours, the literature suggests several approaches: from the static or dynamic fixed-effect estimators (DFE) at one extreme to the mean group (MG) estimator proposed by Hashem Pesaran and Ron Smith (1995) at the other. The former assumes homogeneity of all slope coefficients, allowing only the intercepts to vary across cross-sectional units, while the latter allows the intercepts, slope coefficients and error variances to differ across cross-sectional units. An intermediate – pooled mean group (PMG) – estimator, proposed by Pesaran, Yongcheol Shin, and Smith (1999), on the other hand, allows the intercepts and short-run coefficients to differ freely across cross-sectional units (like the MG estimator), but imposes common long-run coefficients (like the fixed-effects estimator). In our testing we use all three estimators. This approach is essentially a panel version of the error-correction model; hence, our empirical specification takes the following form:

$$\Delta r_{it} = \phi_i[r_{it-1} - \theta_{0i} - \theta_{1i}GD_{it} - \theta_{ki}(Z_k)_{it}] + \delta_{11i}\Delta GD_{it} + (\delta_k)_{1i}\Delta(Z_k)_{it} + \varepsilon_{it} \quad (8)$$

where the number of nations $i = 1, 2, \ldots, N$; the number of periods $t = 1, 2, \ldots, T$; r is the real long-term interest rate (government bond yield); GD is government debt, Z_k is a vector of K ($k = 1, 2, \ldots, K$) control variables and ε is an i.i.d. error term. The specification given in (8) refers to the MG estimator. The PMG estimator assumes that $\theta_{1i} = \theta_1$ and $\theta_{ki} = \theta_k$, while the DFE additionally assumes that $\delta_{11i} = \delta_{11}$ and $(\delta_k)_{1i} = (\delta_k)_1$. One would expect ϕ_i to be negative if the variables exhibit a return to the long-run equilibrium.

The specification given in (8) fits the empirical implications of the simple model outlined in (5)-(7) extremely well, as it allows for both the government debt (i.e. the variable in levels) and government deficit (i.e. the differenced variable) to be included simultaneously in the regression. Specifically, debt will be included among the long-term variables; its change (deficit), among the set of short-term regressors.

3.2 Unit Root Testing

Before turning to estimations, we apply unit root tests. In Tables 12 and 13 in the Appendix, we present the results of Jorg Breitung (2000), Andrew Levin, Chien-Fu Lin, and Chia-Shang James Chu (2002), Kyung-So Im, Pesaran, and Shin (2003) and Fisher-type ADF tests for variable levels and differences. In all the cases an intercept, a trend and 3 lags were used. The results support the unit root hypothesis for real government bond yields (real GY), government debt (GOV debt) and short-term interest rate (IR). As for GDP growth, the results indicate that the data are stationary.

However, given that in panel unit root tests the null hypothesis assumes that all the panels contain a unit root, we undertake a more detailed analysis. An inspection of GDP growth variable for each country separately reveals that unit root hypothesis can be accepted for the majority of the countries and that the rejection of the null was due to two countries only, namely, Germany and USA. We, therefore, proceed assuming that all the series have a unit root.

In addition to performing unit root tests, we apply the panel cointegration test proposed by Joakim Westerlund (2007). Panel cointegration techniques have received a lot of attention recently; however, in many studies the null of no cointegration cannot be rejected, in spite of the fact that the theory suggests the opposite. As noted by Damiaan Persyn and Westerlund (2008), this happens because most residual-based cointegration tests necessitate the long-run parameters for the variables in their levels to be equal to the short-run parameters for the variables in their differences. This issue is circumvented in the approach suggested by Westerlund (2007), who proposed four new panel cointegration tests that are based on structural rather than residual dynamics. These tests check for the absence of cointegration by determining whether the individual panel members are error correcting. More precisely, two of these tests, *Gt* and *Ga,* are group mean statistics that test the null of no cointegration for the whole panel against the alternative of cointegration for some countries in the panel, while the other two, *Pt* and *Pa,* are the panel statistics that test the null of no cointegration against the alternative of cointegration for the panel as a whole. Rejection of the null hypothesis when using *Gt* and *Ga* statistics should be taken as evidence of cointegration of at least one of the cross-sectional units, while rejection of the null hypothesis when using *Pt* and *Pa* statistics should be taken as evidence of cointegration for the panel as a whole. The two tests labelled with *t* (*Gt* and *Pt*) are computed with the standard errors estimated in a standard way, while the other statistics (*Ga* and *Pa*) are based on Newey and West standard errors, adjusted for heteroscedasticity and autocorrelations. Since the panel cointegration test requires no missing data, we slightly adjust our sample so that only observations where all series values are not missing are included in the test equations. The results given in Table 4 (low *p*-values) indicate that we can reject the null of no cointegration at 1% level of significance.

Table 4 Panel Cointegration Test

Statistic	Value	Z-value	*p*-value
Gt	−3.053	−3.471	0.000
Ga	−18.663	−4.597	0.000
Pt	−8.150	−3.560	0.000
Pa	−16.894	−5.289	0.000

Source: Author's calculations.

4. Estimation Results

The results of our baseline specification are given in Table 5. The first three columns correspond to a narrower model (Model 1); while columns labelled 4, 5 and 6 correspond to a wider model (Model 2).

The results, in general, suggest that government debt affects bond yields positively and significantly. An increase in debt of one percentage point leads to an increase in bond yields of 3.4-4.5 basis points, depending on the estimator used.

GDP growth and short-term interest rate are also found to influence government bond yields positively, and this is in line with expectations. Specifically, the results suggest that those countries that grow faster pay higher interest rates, or, more precisely, that a one percentage point increase in GDP growth rate leads to an increase in government bond yields of 39.1-48.2 basis points. Short-term interest rate influences long-term rates positively *via* monetary policy effect, and we find that a one percentage point increase in this rate leads to an increase in government bond yields of 38-51 basis points. In Model 2, additionally, global yields and share prices are found to influence government bond yields positively and significantly (PMG estimator). Both findings are in line with expectations. Specifically, global bond yields are used to check whether long-term interest rates are a function of not only domestic variables but also international or global conditions. Share prices are used, following Robert Barro and Xavier Sala-i-Martin (1990) and Faini (2006), as a proxy of anticipated investment profitability, which should shift the investment curve to the right and increase long-term interest rates. Finally, government consumption is added to account for the impact of the composition of government spending on long-term government bond yield. It is found, however, to be insignificant.

As for the short-term coefficients, they are mostly statistically significant. A change in government debt, i.e. government deficit, influences long-term interest rates positively – an increase in deficit of one percentage point is associated with an increase in government bond yields of 10.3-16.8 basis points. A change in GDP growth is found to exert a positive impact on long-term yields, while a change in short-term interest rates exerts a negative impact. Only share prices have a significant short-term impact, and it is found to be negative.

To test the robustness of our findings, we undertake numerous robustness checks. These are given in Tables 6 and 7 for Model 1 and Tables 8 and 9 for Model 2. For space preservation reasons we present the results of the robustness checks for the PMG estimator only, i.e. imposing equality of the long-run coefficients while allowing heterogeneity among the short-run coefficients. The results for both models will be analysed simultaneously. In column 1 (Tables 6 and 8), we use the expected values of debt and GDP growth instead of the actual ones. Specifically, as noted by Laubach (2009), one of the problems that arises in this sort of analyses is that the current state of the business cycle plays an important role in the correlation between debt and bond yields, and several authors (see, for example, Engen and Hubbard 2004; Laubach 2009; Gruber and Kamin 2012) have used, therefore, projected values of deficits and debts, instead of the current ones. Moreover, government yields are

Table 5 Results – Baseline Specification

	Model 1			Model 2		
	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var. real GY	**PMG**	**MG**	**FE**	**PMG**	**MG**	**DFE**
Explanatory variables			***LONG-RUN COEFFICIENTS***			
GOVdebt	0.0408***	0.0436	0.0343**	0.0424***	0.0348	0.0455***
	(0.0115)	(0.0247)	(0.0108)	(0.0106)	(0.0440)	(0.0133)
GDPgrowth	0.454**	0.285	0.447**	0.391*	0.375	0.482*
	(0.147)	(0.298)	(0.169)	(0.185)	(0.229)	(0.227)
IR	0.438***	0.510***	0.404***	0.380*	0.226	0.426**
	(0.0709)	(0.110)	(0.0851)	(0.149)	(0.175)	(0.163)
Global yields				0.532**	0.479	0.424
				(0.167)	(0.282)	(0.219)
Share prices				0.0219***	0.0175	0.0263***
				(0.00568)	(0.0121)	(0.00770)
GOVconsumption				−0.325	−0.309	−0.264
				(0.189)	(0.427)	(0.215)
			SPEED OF ADJUSTMENT			
ec	−0.402**	−0.447***	−0.421***	−0.362***	−0.538***	−0.362***
	(0.0654)	(0.0586)	(0.0365)	(0.0603)	(0.0710)	(0.0397)
			SHORT-TERM COEFFICIENTS			
ΔGOVdebt	0.114***	0.135**	0.109***	0.106***	0.168**	0.103**
	(0.0237)	(0.0422)	(0.0325)	(0.0321)	(0.0570)	(0.0316)
ΔGDPgrowth	0.154**	0.168*	0.144**	0.114**	0.0791	0.130*
	(0.0422)	(0.0769)	(0.0512)	(0.0428)	(0.0701)	(0.0541)
ΔIR	−0.453**	−0.437**	−0.438***	−0.310**	−0.320***	−0.434***
	(0.147)	(0.136)	(0.0708)	(0.106)	(0.0831)	(0.0776)
ΔGlobal yields				−0.207	−0.227	−0.0684
				(0.196)	(0.227)	(0.170)
ΔShare prices				−0.0187	−0.0165*	−0.00852
				(0.00769)	(0.00734)	(0.00699)
ΔGOVconsumption				0.123	0.284	0.0648
				(0.377)	(0.270)	(0.225)
_cons	−1.657**	−2.515*	−1.387*	−1.346	−1.888	−1.520
	(0.251)	(1.020)	(0.564)	(0.704)	(4.440)	(1.463)
N	370	370	370	326	326	326

Notes: Short-run coefficients in MG and PMG, as well as long-run coefficients in MG, are averages of country-specific coefficients. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Author's calculations.

likely to be influenced by future growth rates, as these are better able to capture long-term expectations relevant to long-term yields and remove the influence of the business cycle. Since the projected values of debt and growth are unavailable for majority of the countries and years in the sample, we use 5-year lead rates, assuming that expectations equal current conditions 5 years ahead. For the last couple of years in our sample, we use the projected values (estimates) provided by the World Economic Outlook. The results suggest that expected values of debt significantly influence government bond yields. More precisely, an increase in expected debt of one percentage point leads to an increase in bond yields of 3.1 basis points. Expected growth rate is found to be insignificant.

In column 2 (Tables 6 and 8) we add a measure of output gap to our baseline specification, to take account of the state of the economy. It is found to be significant and negative, implying that an increase in the output gap of one percentage point, i.e. closing of an output gap between the actual and the potential GDP of one percentage point, leads to a decrease in government bond yields of 14.6 to 28.2 basis points. It should be stressed, however, that the number of observations falls to 183 in this case, because of the lack of data, which is why we do not include this variable into our baseline specification.

In column 3 (Tables 6 and 8) we, furthermore, include current account balance and GDP *per capita*. Current account balance (as percentage of GDP) is included following Hauner and Kumar (2009). It is found to be significant only when added to Model 1, and the results suggest that an increase in the share of current account balance in GDP of one percentage point leads to an increase in government bond yields of 36.4 basis points. GDP *per capita* is added to control for the impact of the size of the economy on long-term interest rates. We find that this impact is statistically significant and positive, implying that larger economies have higher government bond yields.

To investigate the impact of the state of the economy on bond yields, apart from including the output gap, we add a dummy variable (RECESSION) that takes the value of 1 in periods of recession and zero otherwise. Moreover, we multiply this dummy variable with government debt as a share of GDP. This serves to check whether recessionary periods influenced the responsiveness of government bond yields to changes in the debt-to-GDP ratio. The results on these two variables (columns 4 and 5 in Tables 6 and 8) are, however, insignificant.

In columns 6 and 7 (Tables 7 and 9), we, similarly, add a crisis dummy (CRISIS) to our baseline specification. This dummy takes the value of 1 for years 2008 and 2009 and zero otherwise. Moreover, we create and add an interaction term by multiplying the crisis dummy with the value of debt in GDP. As was the case with RECESSION, all the variables are found to be insignificant, suggesting that recent global financial crisis did not have a major impact on government bond yields.

In columns 8 and 9 (Tables 7 and 9) we add a dummy variable that takes the value of 1 for the period 1980-2012 and zero otherwise (DUMMY 1980). Specifically, a visual inspection of the data suggests that government bond yields reached a peak around the 1980s and have been falling since; i.e. a structural break seems to have occurred in the 1980s. Additionally, the data for some additional variables

(downloaded from sources such as World Development Indicators or World Economic Outlook) start in 1980, which is another reason for dividing the sample into these two subsamples. Moreover, we add and an interaction term whereby we multiply DUMMY 1980 with government debt. In this way we wanted to check if there is a change in the relationship between debt and bond yields for the two subperiods. Both variables are found to be statistically significant at conventional levels of significance, and positive and negative respectively. These results suggest that the impact of debt on bond yields was smaller in the period 1980-2012 in comparison to the previous period (1948-1979).

In column 10 (Tables 7 and 9) we add a dummy variable EURO to account for the introduction of the euro. The results are not significant.

Finally, in column 11 (Tables 7 and 9) we add a dummy variable for years of oil crisis (namely, 1973, 1974, 1979 and 1990). The results indicate that oil crises had a significant negative impact on government bond yields. Moreover, we create an interaction term by multiplying this dummy with GOV debt, and find that in the periods of oil crises the impact of government debt on long-term bond yields was even stronger.

Overall, Tables 6-9 confirm the robustness of our results, which, taken together with those given in Table 5, suggest that that a one percentage point increase in the stock of government debt in GDP is associated with an increase in government bond yields of 2.27-6.28 basis points, while a one percentage point increase in the government deficit in GDP is associated with an increase in government bond yields of 3.15-14.3 basis points. It should be noted that in the above interpretations we deliberately ignore the coefficient on GOV debt in columns that include variable output gap (column 2) and those that also include interaction terms with GOV debt, i.e. those labelled with numbers 5, 7, 9 and 12, and we use only the results in the remaining columns for drawing general conclusions. Specifically, in cases where a variable is used as an explanatory variable as well as in an interaction term, its coefficient becomes larger because part of its effect is captured by the interaction term. As for the output gap, let us note that in case this variable is included in the model, the coefficient on GOV debt variable becomes smaller, i.e. the results imply that a one percentage point increase in the stock of government debt in GDP is associated with an increase in government bond yields of only 1.03 basis points. The implications of this finding will be analysed in the next section.

Table 6 Robustness Checks for Model 1

Dep. var. real GY	(1)	(2)	(3)	(4)	(5)
Explanatory variables			***LONG-TERM COEFFICIENTS***		
GOVdebt		0.0103	0.0474**	0.0452***	0.0335*
		(0.00538)	(0.0150)	(0.0130)	(0.0162)
GDPgrowth		1.305***	1.378***	0.357	0.256
		(0.252)	(0.309)	(0.188)	(0.203)
IR	0.436***	0.399***	0.821***	0.556***	0.584***
	(0.0894)	(0.0367)	(0.107)	(0.0867)	(0.0924)
Expected debt	0.0311*				
	(0.0116)				
Expected growth	0.239				
	(0.197)				
Output gap		−0.282***			
		(0.0633)			
CA balance			0.364*		
			(0.166)		
GDPpc			0.000249***		
			(0.0000601)		
RECESSION				0.470	−1.195
				(0.850)	(1.760)
RECESSION × GOVdebt					0.0228
					(0.0242)
			SPEED OF ADJUSTMENT		
ec	−0.351***	−0.598***	−0.366***	−0.299***	−0.291***
	(0.0603)	(0.134)	(0.0695)	(0.0452)	(0.0380)
			SHORT-TERM COEFFICIENTS		
ΔGOVdebt		0.0315	0.110**	0.0669***	0.0524***
		(0.0307)	(0.0416)	(0.0191)	(0.0147)
ΔGDPgrowth		0.0838	0.109	0.123***	0.119**
		(0.0445)	(0.0810)	(0.0286)	(0.0377)
ΔIR	−0.470**	−0.127	−0.438***	−0.423**	−0.399**
	(0.166)	(0.120)	(0.127)	(0.151)	(0.145)
ΔExpected debt	0.00353				
	(0.0283)				
ΔExpected growth	−0.0604				
	(0.0433)				
ΔOutput gap		−0.796***			
		(0.185)			
ΔCA balance			0.141		
			(0.137)		
ΔGDPpc			−0.000993*		
			(0.000396)		
ΔRECESSION				−0.254*	−0.825
				(0.112)	(0.694)
ΔRECESSION × GOVdebt					0.00730
					(0.00818)
_cons	−1.000***	−1.209***	−5.394***	−1.574***	−1.222***
	(0.192)	(0.182)	(1.150)	(0.291)	(0.240)
N	377	183	268	348	348

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Author's calculations.

Table 7 Robustness Checks for Model 1 – Continued

Dep. var. real GY	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Explanatory variables				***LONG-TERM COEFFICIENTS***			
GOVdebt	0.0441***	0.0466***	0.0227*	0.0850***	0.0408***	0.0273**	0.0165
	(0.0117)	(0.0111)	(0.00960)	(0.0157)	(0.0116)	(0.0101)	(0.00910)
GDPgrowth	0.498**	0.447**	0.547***	0.591***	0.459**	0.199	0.0863
	(0.152)	(0.148)	(0.124)	(0.104)	(0.149)	(0.140)	(0.145)
IR	0.472***	0.490***	0.326***	0.329***	0.443***	0.532***	0.521***
	(0.0742)	(0.0735)	(0.0666)	(0.0595)	(0.0736)	(0.0659)	(0.0672)
CRISIS	1.601	1.273					
	(1.449)	(3.613)					
CRISIS × GOVdebt		−0.0310					
		(0.0397)					
DUMMY 1980			1.997***	6.147***			
			(0.446)	(0.903)			
DUMMY 1980 × GOVdebt				−0.0814***			
				(0.0167)			
DUMMY EURO					0.303		
					(1.144)		
OIL CRISIS						−7.740***	−16.96***
						(1.189)	(2.902)
OIL CRISIS × GOVdebt							0.97***
							(0.0553)
				SPEED OF ADJUSTMENT			
ec	−0.396***	−0.387***	−0.470***	−0.498***	−0.400***	−0.406***	−0.397***
	(0.0685)	(0.0589)	(0.0775)	(0.0898)	(0.0675)	(0.0780)	(0.0733)
				SHORT-TERM COEFFICIENTS			
ΔGOVdebt	0.105***	0.102***	0.0971***	0.127*	0.113***	0.0856***	0.0714***
	(0.0241)	(0.0233)	(0.0270)	(0.0612)	(0.0231)	(0.0167)	(0.0156)
ΔGDPgrowth	0.175***	0.245***	0.103**	0.0765*	0.154***	0.129**	0.137***
	(0.0464)	(0.0498)	(0.0371)	(0.0343)	(0.0420)	(0.0398)	(0.0361)
ΔIR	−0.456**	−0.425**	−0.433**	−0.414**	−0.455**	−0.360***	−0.308**
	(0.149)	(0.147)	(0.149)	(0.133)	(0.150)	(0.106)	(0.0985)
ΔCRISIS	0.414	−22.74***					
	(0.283)	(5.207)					
ΔCRISIS × GOVdebt		0.268***					
		(0.0458)					
ΔDUMMY1980			−1.228	0.696			
			(0.876)	(2.526)			
ΔDUMMY 1980 × GOVdebt				−0.0302			
				(0.0556)			
ΔDUMMY_EURO					−0.0138		
					(0.273)		
ΔOIL CRISIS						2.072***	1.978*
						(0.441)	(0.924)
ΔOIL CRISIS × GOVdebt							0.000701
							(0.0185)
_cons	−1.867***	−1.791***	−1.817***	−3.357***	−1.685***	−1.055***	−0.579***
	(0.275)	(0.256)	(0.303)	(0.563)	(0.255)	(0.195)	(0.172)
N	370	370	370	370	370	370	370

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Author's calculations.

Table 8 Robustness Checks for Model 2

Dep. var. real GY	(1)	(2)	(3)	(4)	(5)
Explanatory variables			*LONG-TERM COEFFICIENTS*		
GOVdebt		0.0336***	0.0628***	0.0453***	0.0508***
		(0.00580)	(0.0144)	(0.0103)	(0.0114)
GDPgrowth		0.110	1.338***	0.554**	0.625**
		(0.132)	(0.310)	(0.194)	(0.197)
IR	0.209	0.114*	0.279*	0.368*	0.368*
	(0.175)	(0.0541)	(0.133)	(0.151)	(0.151)
Global yields	0.449*	0.595***	1.053***	0.566***	0.571***
	(0.229)	(0.0944)	(0.185)	(0.162)	(0.158)
Share prices	0.012	−0.00808**	0.0211*	0.0247***	0.0250***
	(0.00773)	(0.00287)	(0.00825)	(0.00566)	(0.00536)
GOVconsumption	−0.0407	−0.575***	−0.530*	−0.282	−0.254
	(0.247)	(0.129)	(0.248)	(0.192)	(0.193)
Expected debt	0.0311*				
	(0.0145)				
Expected growth	0.292				
	(0.207)				
Output gap		−0.146***			
		(0.0272)			
CA balance			0.258		
			(0.156)		
GDPpc			0.000251**		
			(0.0000960)		
RECESSION				0.267	1.299
				(0.800)	(1.276)
RECESSION × GOVdebt					−0.0129
					(0.0137)
			SPEED OF ADJUSTMENT		
ec	−0.312***	−0.791***	−0.418***	−0.367***	−0.367***
	(0.0329)	(0.183)	(0.0888)	(0.0625)	(0.0700)
			SHORT-TERM COEFFICIENTS		
ΔGOVdebt		0.0138	0.143*	0.109**	0.110**
		(0.0412)	(0.0678)	(0.0342)	(0.0394)
ΔGDPgrowth		0.0921	0.100	0.0627	0.0340
		(0.0534)	(0.110)	(0.0416)	(0.0407)
ΔIR	−0.383**	−0.0990	−0.242**	−0.298**	−0.300**
	(0.143)	(0.159)	(0.0870)	(0.107)	(0.108)
ΔGlobal yields	−0.213	0.120	−0.232*	−0.204	−0.176
	(0.217)	(0.246)	(0.114)	(0.192)	(0.168)
ΔShare prices	−0.0121*	0.00387	−0.00687	−0.0228**	−0.0217*
	(0.00571)	(0.00589)	(0.00763)	(0.00857)	(0.00858)
ΔGOVconsumption	−0.302	0.983	0.787**	0.0408	−0.0179
	(0.305)	(0.525)	(0.260)	(0.399)	(0.418)
ΔExpected debt	0.0055				
	(0.00550)				
ΔExpected growth	−0.021				
	(0.0297)				
ΔOutput gap		−0.0416			
		(0.101)			
ΔCA balance			0.182		
			(0.149)		
ΔGDPpc			−0.000816*		
			(0.000414)		
ΔRECESSION				−0.416**	−1.099
				(0.134)	(0.571)
ΔRECESSION × GOVdebt					0.00802
					(0.00689)
_cons	−1.581***	6.080***	−5.436**	−2.063*	−2.559*
	(0.360)	(1.418)	(1.886)	(0.856)	(1.022)
N	330	183	264	325	325

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Author's calculations.

Table 9 Robustness Checks for Model 2 – Continued

Dep. Var. Real GY	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Explanatory variables	***LONG-TERM COEFFICIENTS***						
GOVdebt	0.0436***	0.0433***	0.0252*	0.0685***	0.0412***	0.0339***	0.0248**
	(0.0101)	(0.0104)	(0.00996)	(0.0193)	(0.0107)	(0.00944)	(0.00871)
GDPgrowth	0.433*	0.415*	0.426**	0.353*	0.374*	0.205	−0.0165
	(0.181)	(0.178)	(0.159)	(0.149)	(0.184)	(0.172)	(0.147)
IR	0.410**	0.487***	0.105	0.135	0.355*	0.410**	0.408**
	(0.148)	(0.146)	(0.124)	(0.117)	(0.146)	(0.137)	(0.129)
Global yields	0.504*	0.442**	0.496***	0.336*	0.537**	0.0202***	0.00822*
	(0.167)	(0.160)	(0.141)	(0.151)	(0.167)	(0.00485)	(0.00409)
Share prices	0.0226***	0.0240***	0.000844	−0.00564	0.0218***	−0.356*	−0.319
	(0.00568)	(0.00582)	(0.00662)	(0.00726)	(0.00577)	(0.177)	(0.169)
GOVconsumption	−0.336	−0.220	−0.243	−0.115	−0.307	0.626***	0.468***
	(0.181)	(0.179)	(0.158)	(0.144)	(0.189)	(0.150)	(0.128)
CRISIS	0.758	−2.329					
	(1.429)	(3.031)					
CRISIS × GOVdebt		0.000979					
		(0.0249)					
DUMMY 1980			3.256***	5.619***			
			(0.692)	(1.128)			
DUMMY 1980 × GOVdebt				−0.0613**			
				(0.0210)			
DUMMY EURO					−0.467		
					(0.941)		
OIL CRISIS						−10.08***	−21.86***
						(1.640)	(2.781)
OIL CRISIS ×GOVdebt							0.281***
							(0.050)
	SPEED OF ADJUSTMENT						
ec	−0.363***	−0.341***	−0.445***	−0.454***	−0.366***	−0.354***	−0.363***
	(0.0662)	(0.0520)	(0.0507)	(0.0572)	(0.0582)	(0.0896)	(0.102)
	SHORT-TERM COEFFICIENTS						
ΔGOVdebt	0.0998**	0.0938**	0.0673*	0.0220	0.104***	0.0875***	0.0640***
	(0.0378)	(0.0318)	(0.0289)	(0.0892)	(0.0310)	(0.0248)	(0.0176)
ΔGDPgrowth	0.113**	0.205***	0.0873	0.0885*	0.114**	0.0756	0.0957
	(0.01394)	(0.0382)	(0.0467)	(0.0434)	(0.0431)	(0.0459)	(0.0492)
ΔIR	−0.321**	−0.320**	−0.262**	−0.263**	−0.308**	−0.188**	−0.123
	(0.102)	(0.103)	(0.0954)	(0.0831)	(0.107)	(0.0625)	(0.0997)
ΔGlobal yields	−0.223	−0.161	−0.0962	−0.114	−0.205	0.0257	−0.0926
	(0.209)	(0.188)	(0.178)	(0.202)	(0.191)	(0.159)	(0.214)
ΔShare prices	−0.0194	−0.0164***	−0.0163*	−0.0130	−0.0188*	−0.0116	−0.00820
	(0.0100)	(0.00422)	(0.00762)	(0.00688)	(0.00746)	(0.00678)	(0.00741)
ΔGOVconsumption	0.124	0.0580	0.281	0.291	0.110	0.245	0.289
	(0.357)	(0.377)	(0.320)	(0.296)	(0.379)	(0.172)	(0.246)
ΔCRISIS	−0.127	−22.49***					
	(0.430)	(4.388)					
ΔCRISIS × GOVdebt		0.273***					
		(0.0516)					
ΔDUMMY 1980			−1.452	0.381			
			(0.835)	(2.250)			
ΔDUMMY_1980 × GOVdebt				0.0342			
				(0.0773)			
ΔDUMMY EURO					0.0133		
					(0.177)		
ΔOIL CRISIS						2.263***	3.228**
						(0.552)	(1.167)
ΔOIL CRISIS × GOVdebt							−0.0292
							(0.0180)
_cons	−1.383	−1.910**	−1.191*	−2.029***	−1.346	−0.823	0.0856
	(0.711)	(0.681)	(0.555)	(0.394)	(0.693)	(0.600)	(0.299)
N	326	326	326	326	326	326	326

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Author's calculations.

5. Is Crowding-Out in G7 Complete?

In this section we undertake a simple exercise to assess the degree of crowding-out suggested by our results. Specifically, Engen and Hubbard (2004), Laubach (2009) and Claeys, Moreno, and Surinach (2012) use expressions similar to (7) to obtain numerical predictions of the interest rate effects (assuming some value for c). Laubach (2009), for example, estimates the parameter k to be 2.5 in USA in 2005; c is assumed to be 0.6 and α is taken to be 0.33. In that setting a percentage point increase in the debt-to-GDP ratio would lead to an increase in the interest rate of 2.1 basis points. Engen and Hubbard (2004) examine several scenarios, assuming $\alpha = 0.33$, k = 2.82 and c = 1, 0.8 and 0.6, in turn. It should be stressed that Engen and Hubbard (2004) do not explicitly calculate k; rather we do it with their data (where K is taken to be \$31 trillion and Y to be \$110 billion), so that we can compare the results and implications of several papers. Engen and Hubbard (2004) find that a one percentage point increase in government debt in GDP would increase the interest rate by 2.4, 1.9 and 1.4 basis points, respectively. We, however, adopt an opposite approach and use our econometric results to assess the degree of crowding-out. More precisely, we use the following expression (derived from (7)):

$$c = \frac{\partial r}{\partial \frac{GD}{Y}} * \frac{k^2}{\alpha(1-\alpha)}\,. \tag{9}$$

In Table 10, consequently, we compute implied values of c by using Equation (9) in combination with our empirical results (i.e. taking ∂r to be 2.27 (minimum), 4.275 (average) and 6.28 (maximum)) and assuming k to be equal to 2.78. The value of k is calculated as the ratio between capital stock at constant 2005 national prices (in mil. 2005US$) and real GDP at constant 2005 national prices (in mil. 2005US$), averaged over all years and countries in our sample (we use the data from Pen World Tables (PWT 8.0)).

Table 10 Implied Degree of Crowding-Out (Assuming $\alpha = \frac{1}{3}$)

k	∂r	c
2.78	2.27	**0.79**
2.78	4.275	**1.49**
2.78	6.28	**2.18**

Source: Author's calculations.

The computations in Table 10 suggest that the degree of crowding-out is rather high. The lower bound of our results suggests that crowding-out is 79%; i.e. that only 21% of the increase in debt is offset by increased private saving or capital inflows from abroad. The remaining results suggest complete crowding-out of public savings on private savings.

The extent of crowding-out should depend, however, on the state of the economy. Specifically, an economy that is in a recession is unlikely to experience crowding-out in the case where the government increases its spending and, consequently, deficit and debt. It is only when spending continues after the economy has recovered that crowding-out becomes more likely. We have accounted for the state of the econ-

Table 11 Baseline Specifications Broadened by Output Gap and Its Interaction Term with Government Debt

	Model 1	Model 2
	LONG-TERM COEFFICIENTS	
GOVdebt	0.00841 (0.00496)	0.0298*** (0.00569)
GDPgrowth	0.926*** (0.271)	−0.267* (0.115)
IR	0.436*** (0.0379)	0.151** (0.0481)
Global yields		0.616*** (0.0970)
Share prices		−0.00686* (0.00284)
GOVconsumption		−0.543*** (0.129)
Output gap	−0.325** (0.125)	−0.0156 (0.0310)
Output gap*GOVdebt	0.000766 (0.00148)	−0.00119*** (0.000324)
	SPEED OF ADJUSTMENT	
ec	−0.604*** (0.104)	−0.783*** (0.175)
	SHORT-TERM COEFFICIENTS	
ΔGOVdebt	0.00333 (0.0260)	−0.0212 (0.0339)
ΔDPgrowth	0.106* (0.0426)	0.105* (0.0505)
ΔIR	−0.162 (0.116)	−0.158 (0.169)
ΔGlobal yields		−0.00705 (0.217)
ΔShare prices		−0.000858 (0.00918)
ΔGOVconsumption		0.864 (0.496)
ΔOutput gap	−0.197 (0.412)	0.642 (0.357)
ΔOutput gap*GOVdebt	−0.00761 (0.00483)	−0.00828 (0.00469)
_cons	−0.703*** (0.104)	5.931*** (1.139)
N	183	183

Source: Author's calculations.

omy in our model by including the output gap variable. Interestingly, as noted in Section 4, the coefficient on government debt variable becomes smaller in this case, implying that the degree of crowding-out (using Equation (9) and taking ∂r to be 1.03) is now only 36%. Moreover, we create an interaction term between output gap and

government debt and add it to our specifications with output gap. A significant coefficient on the interaction term (Table 11, Model 2) indicates that an increase in output gap of one percentage point, i.e. closing of the gap, weakens the responsiveness of government bond yields to changes in government debt.

Table 12 Panel Unit Root Tests for Variables in Levels (with Intercept and Trend)

Test	H_0	RealGY	GOVdebt	IR	GDPgrowth
Levin, Lin, and Chu *t*-stat	*Unit root*	−0,658	0,637	−1,496*	−3,929***
Im, Pesaran, and Shin *W*-stat	*Unit root*	−0,103	2,927	0,794	−5,735***
Fisher chi2	*Unit root*	11,914	4,667	11,468	58,084***
Breitung *t*-stat	*Unit root*	−0,447	5,624	1,238	−2,594***

Source: Author's calculations.

Table 13 Panel Unit Root Tests for Variables in Differences (with Intercept and Trend)

Test	H_0	RealGY	GOVdebt	IR	GDPgrowth
Levin, Lin, and Chu *t*-stat	*Unit root*	−2,630***	−2,130**	−9,517***	3,106
Im, Pesaran, and Shin *W*-stat	*Unit root*	−8,172***	−4,912***	−10,166***	−12,125***
Fisher chi2	*Unit root*	88,746***	50,125***	116,670***	143,137***
Breitung *t*-stat	*Unit root*	−3,076***	−3,321***	−8,855***	−4,357***

Source: Author's calculations.

It should be stressed, however, that there are a lot of other influences which have not been taken into account in our empirical specification, such as the impact of government debt held by the central bank (which does not crowd out private capital), private-sector debt acquired to boost consumption (which potentially crowds-out capital formation) and foreign-sector lending and purchases of domestic securities (Engen and Hubbard 2004). Furthermore, the estimates might be imprecise because the effect of uncertainty is excluded from the theoretical model; because the government, as a reaction to higher debt, may increase income taxes, thus affecting the pretax return on government bonds, i.e. the long-term interest rate (Kinoshita 2006); and, finally, because there are other effects on output, besides capital, that indirectly influence interest rates, which are not included in the model.

6. Conclusion

The goal of this paper is to investigate the influence of government fiscal positions on the long-term interest rates in G7 countries during the period 1948-2012. In view of recent economic and financial uncertainty fuelled by fiscal laxity in many countries, investigation of this relationship seems to be timely.

In our analysis we apply a panel version of the error-correction model, which, besides being appropriate for our sample, where the number of time periods exceeds the number of cross-sectional units, is motivated by the fact that it fits the empirical implications of the simple theoretical (neoclassical) model extremely well, as it allows for both the government debt (i.e. the variable in levels) and the government deficit (i.e. the differenced variable) to be included simultaneously in the regression. As noted by Engen and Hubbard (2004), the fact that it is the *level* of government debt that influences the *level* of interest rates and the *change* in government debt that

influences the *change* in interest rates is typically unjustifiably overlooked in empirical investigations.

Our results suggest that a one percentage point increase in the stock of government debt in GDP is associated with an increase in government bond yields of 2.27-6.28 basis points, while an increase in government deficit in GDP of one percentage point is associated with an increase in government bond yields of 3.15-14.3 basis points.

Theoretically, interest rates would not react to fiscal expansion in one of two cases: in the case of Ricardian equivalence and in the case where capital flows between integrated economies offset interest rate differentials caused by an increase in the supply of government bonds (Claeys, Moreno, and Surinach 2012). A significant impact of debt on interest rates, as suggested by our results, on the other hand, implies that some degree of crowding-out exists. In an attempt to assess this degree, in the final section of this paper we undertake a simple exercise and use the neoclassical growth model in combination with our empirical results to calculate the degree of crowding-out that occurred during the observed period. Our results indicate that under reasonable assumptions (k is 2.78, α is 0.33) and in the presence of widening output gaps, the neoclassical growth model predicts a rather low degree of crowding-out (around 36 percent) in G7 economies, while the narrowing (and disappearance) of the output gap leads to a complete crowding-out.

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