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The 90% public debt threshold: The rise and fall of a stylised fact

Balázs Égert[1]

Abstract

This paper analyses the original Reinhart-Rogoff dataset, made public by Herndon et al. (2013), on the basis of descriptive statistics and formal econometric testing. First, based on the public debt thresholds (30%, 60% and 90%) proposed by Reinhart and Rogoff (2010), descriptive statistics reveal that real GDP growth slows considerably as the central government debt-to-GDP ratio goes beyond the 30% threshold and that no further slowdown can be observed in the data as the debt-to-GDP ratio rises above 60% and 90% during the periods 1790-2009 and 1946-2009. For the United States (1946-2009), the negative nonlinear finding completely disappears for any level of public debt, once reverse causality and influential outliers are accounted for. Looking at general (and central) government debt during the more recent period of 1960-2009 suggests that economic slowdown occurs when public debt moves above 60% or 90% of GDP. But it seems more appropriate to determine nonlinearity and the associated debt threshold endogenously. Therefore, in a second stage, we put the Reinhart-Rogoff dataset to a formal econometric test by employing nonlinear threshold models. Overall, our estimation results indicate that the nonlinear relation from debt to growth is not very robust. Taken with a pinch of salt, our results suggest, however, that there may be a tipping point at around 20% of GDP, beyond which central government debt has a negative influence on growth. Further (and greater) thresholds may exist but their magnitude is highly uncertain. For general government debt (1960-2009), the threshold beyond which negative growth effects kick in is considerably higher at about 50%. Finally, individual country estimates reveal a large amount of cross-country heterogeneity. For some countries including the United States, a nonlinear negative link can be detected at about 30% of GDP. For others, the thresholds are surrounded by a great amount of uncertainty or no nonlinearities can be established. This instability may be a result of threshold effects changing over time within countries and depending on economic conditions, not captured in our estimations. Overall, our results can be seen as a formal econometric confirmation that the 90% public debt threshold is not in the data. But our results also seem to suggest that public debt might have a negative effect on economic performance kicking in at already fairly moderate public debt levels. Furthermore, the absence of threshold effects or low estimated thresholds may not preclude the emergence of further threshold effects, especially as public debt levels are rising to unprecedentedly high levels.

JEL classification codes: E6 ; F3 ; F4 ; N4
Keywords: public debt; economic growth; nonlinearity; threshold effects

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1. Introduction

Using simple descriptive statistics, Reinhart and Rogoff (2010) argued for the existence of strong negative effects of high public debt on economic growth. In particular, they pointed out that economic growth slows down considerably if the public debt-to-GDP ratio exceeds 90%. But some of the calculations presented in Reinhart and Rogoff (2010) seem to be flawed. Herndon et al. (2013) tried to reproduce the Reinhart-Rogoff descriptive statistics and uncovered simple spreadsheet errors and irregularities with regard to country and time coverage. As a result, the sharp drop in real GDP growth above the 90% debt threshold becomes a mild decrease and the strong conclusion, implied by the Reinhart and Rogoff finding, often used in the policy debate, that countries had better avoid the 90% debt threshold seems less obvious.

Many empirical papers published in the aftermath of Reinhart and Rogoff (2010) validated the debt 90% threshold. For instance, Cecchetti *et al*. (2011) find a threshold of 86% of GDP for a panel of 18 OECD countries and for the period from 1980 to 2010. Padoan *et al*. (2012) report similar effects for a similar group of countries but a longer period (1960 to 2010). Covering a mix of advanced and emerging market economies, Kumar and Woo (2010) finds a turning point at 90% of GDP. Checherita and Rother (2010) and Baum *et al*. (2012) report similar results for a set of euro area countries.

Yet, a new wave of papers started casting doubt on the one-size-fits-all feature of the 90% debt threshold. Caner *et al*. (2010) and Elmeskov and Sutherland (2012) show that the tipping point is probably lower: 77% for a set of 77 countries, and 66% for a dozen of OECD countries, respectively. Baglan and Yoldas (2013) identify a threshold effect of 20% of GDP for low-debt countries and a negative linear relationship between debt and growth for high-debt countries. Minea and Parent (2012) find a debt threshold at 115% of GDP. Panizza and Presbitero (2012) even argue that a negative correlation between debt and growth does not imply causality, as lower growth can result in a higher public debt to GDP ratio.

Using a variant of the Reinhart and Rogoff dataset, Égert (2012) demonstrated that the negative nonlinear relationship between debt and growth is very sensitive to empirical modelling choices. But even if you take the presence of such threshold effects as a given, they kick in at much lower levels of public debt (between 20% and 60% of GDP). This paper seeks to take this analysis a step further by putting the original Reinhart-Rogoff dataset used in Herndon et al. (2013), to a formal econometric testing. We attempt to identify the thresholds endogenously on the basis of the testing procedure proposed by Hansen (1999) for the periods 1790 to 2009 and 1946 to 2009. Furthermore, we discuss the implications of data definitions. The Reinhart and Rogoff dataset comprises central government debt. Yet more relevant for policy discussion is the general government debt, ie the consolidated debt of all levels of government included central government, social security administrations and subnational governments. The difference between the two public debt series can be sometimes very large. Finally, we also carry out country specific estimations on the Reinhart and Rogoff dataset to see whether the relationship between public debt and growth varies across countries.

The paper is organised as follows. Section 2 provides descriptive statistics of and a first visual glance at the Reinhart-Rogoff dataset. Section 3 presents the estimation strategy. Section 4 reports and discusses the empirical results. Section 5 finally summarises and provides some policy conclusions.

2. Stylised facts

Reinhart and Rogoff (2010) use descriptive statistics to show the detrimental effect of high levels of public debt on real GDP growth. They show for a group of twenty OECD countries and for 1946 to 2009 that average GDP growth drops from more than 3% to zero as the public debt-to-GDP ratio increases above 90%. But according to Herndon et al. (2013), the average annual growth is 1.9%, and not -0.1%, when public debt is above 90% of GDP (Table 1). Using a variant of the Reinhart and Rogoff dataset[2], Égert (2012) also found that the dramatic drop in real GDP growth did not occur above the 90% threshold (Table 1). In this paper, we use the Reinhart-Rogoff dataset made public by Herndon et al. (2013)[3] and our results are, unsurprisingly, in line with those reported in Herndon et al. (2013)[4].

While the averages computed by Herndon et al. (2013) do not indicate a negative real GDP growth for debt levels above 90%, their number still suggest that economic growth slows down as one moves above the 90% debt threshold. But annual data may be just too noisy to reveal us the true picture. We therefore computed 10-year non-overlapping averages for real GDP growth. The average of these multiyear averages, reported in Table 1, show that GDP growth does not slow down at high levels of public debt. In fact, there seems to be a deceleration only if public debt exceeds 30% of GDP. By contrast, GDP growth remains stable, or even slightly increases as public debt increases further. This observation remains valid for 5- or 8-year averages as well.[5]

But as argued by many observers, whether causality runs from debt to growth or whether lower growth results in higher debt remains to be seen. An easy way to tackle this problem is to compare average GDP growth with past debt levels. Looking at average annual growth rates indicates that there is no economic slowdown beyond the 90% debt ceiling. In fact, GDP growth decreases from 4% to 3% as public debt increases from below 30% to between 30% and 60%. Nevertheless, GDP growth remains stable at 3% as public debt moves above 60% and 90% of GDP. This finding holds equally for multiyear average growth rates.

[2] Égert (2012) matched data on central government debt obtained from the data appendix of Reinhart and Rogoff (2011) with real GDP growth rates available from the Barro-Ursúa macroeconomic dataset (Barro and Ursúa, 2011). The difference with the actual Reinhart and Rogoff data is that Égert (2012)'s data excludes Ireland and includes Switzerland and that the data series used in Égert (2012) are longer.

[3] Available here: http://www.peri.umass.edu/236/hash/31e2ff374b6377b2ddec04deaa6388b1/publication/566/

[4] There are three differences in the dataset used in the paper and the one used by Herndon et al. (2013). First, for France, the public debt series has a sudden break in 1978-1979 (8.8% in 1978 and 31.1% in 1979). We decided to use the series calculated from the separate nominal debt and nominal GDP series provided by Herndon et al. (2013). This leaves us with missing values from 1973 to 1977 but we avoid the abrupt break, probably due to a change in methodology/definition. Another difference is that Herndon et al. (2013) use the Greek public debt to GDP ratio starting in 1970, while the series can be computed from 1948 onwards. Finally, Herndon et al. (2013) exclude 1956 for the Netherlands, even though the observation is not missing from their background data file.

[5] These results are not reported here but can be obtained upon request from the author.

Table 1. Real GDP growth and central government debt as a % of GDP, 1946-2009

		Level of central government debt (as a % of GDP)			
		x<30%	30%< x<60%	60%<x<90%	x>90%
Reinhart-Rogoff (2010)	**Average annual growth rates**	3.9	2.9	3.5	-0.1
Herndon et al (2013)	**Average annual growth rates**	4.0	3.0	3.0	1.9
Egert (2012)	**Average annual growth rates**	3.4	2.4	1.9	1.9
This paper	**Average annual growth rates**	4.3	3.2	3.2	2.2
	Average of 10-year average growth rates	4.3	2.6	3.1	3.4
		Lagged level of central government debt			
		x<30%	30%< x<60%	60%<x<90%	x>90%
	Average of annual growth rates	4.1	3.1	3.1	2.9
	Average of 10-year average growth rates	3.6	2.6	2.8	2.7

The Reinhart-Rogoff dataset allows the assessment of more than 200 years for some countries. Annual average real GDP growth rates computed for 1790-2009 confirm the possibility of a negative correlation between central government debt and economic growth: GDP growth decreases steadily from 4% to 2% as government debt rises from below 30% to above 90% of GDP. But when looking at the relation between growth and lagged central government debt (in order to control for reverse causality), growth drops from about 4% to below 3% with debt exceeding 60% of GDP, but no further decline can be observed beyond 90% of GDP. For the period 1790 to 1939, Table 2 also shows that growth slows down above debt levels exceeding 30% but that growth accelerates mildly if debt is higher than 90%.

Table 2. Real GDP growth and central government debt as a % of GDP, 1790-2009

	Level of central government debt (as a % of GDP)			
	x<30%	30%< x<60%	60%<x<90%	x>90%
	Level of central government debt (as a % of GDP)			
1790-2010	4.0	3.1	2.5	2.2
1790-1939	3.7	2.9	1.9	2.3
	Level of lagged central government debt (as a % of GDP)			
1790-2010	3.7	3.0	2.6	2.7
1790-1939	3.2	2.7	2.1	2.6

Source: author's calculations based on the Reinhart-Rogoff dataset

Reinhart and Rogoff (2010) argue that the 90% debt threshold can be observed for the US economy: public debt exceeding the threshold of 90% goes in tandem with a decline in annual growth from about 3.5% to well below zero (Table 3). Our data replicates fairly well this finding. Nevertheless, this result is largely influenced by one single influential outlier, real GDP growth of -11% in 1946. This is well demonstrated in Table 3: when reducing the sample by one year from 1946-2009 to 1947-2009, average real GDP growth in the 90% and higher debt regime changes from -2% to 1%. Moving one step further and comparing GDP growth rates with central government debt a year earlier eliminates completely the finding that GDP growth slows down if debt goes above 90% of GDP. In fact, average real GDP growth rates are very close to 3% irrespective of the level of central government debt. More generally, it does not seem to make too much sense to compute averages for the 90%+ debt regime, considering that, for the period 1946

to 2009, there are only four years (and four observations) falling into this regime (1946 to 1949), including the influential outlier in 1946.

Table 3. Real GDP growth and central government debt as a % of GDP, United States

	period	x<30%	30%< x<60%	60%<x<90%	x>90%
		central government debt (as a % of GDP)			
Reinhart-Rogoff (2010)	1790-2009	4.0	3.4	3.3	-1.8
This paper	1790-2009	4.1	3.2	3.3	-2.0
		lagged central government debt (as a % of GDP)			
	1790-2009	3.7	4.1	3.2	2.9
		central government debt (as a % of GDP)			
	1946-2009	Na	3.4	3.3	-2.0
	1947-2009	Na	3.4	3.3	1.0
		lagged central government debt (as a % of GDP)			
	1946-2009	Na	3.3	3.2	2.9

Source: author's calculations based on the Reinhart-Rogoff dataset

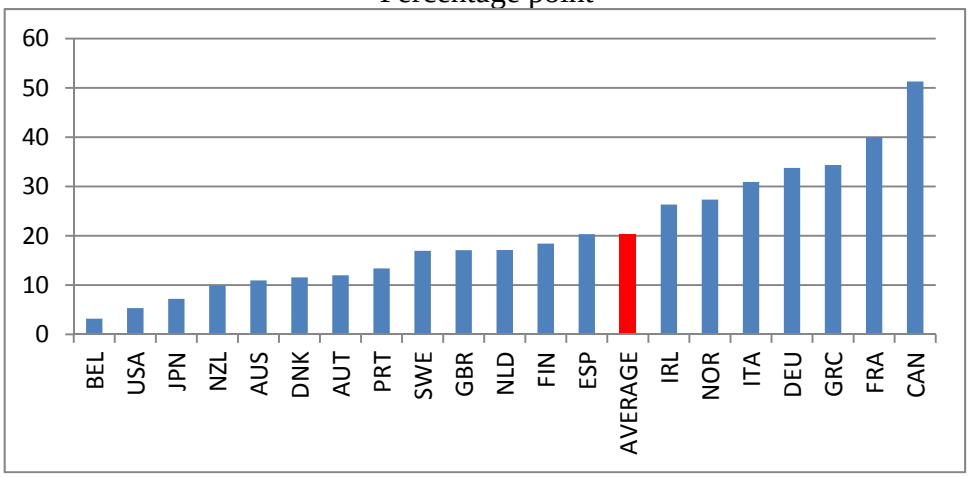
Reinhart and Rogoff (2010) and Herndon et al. (2013) are focusing on central government debt. Nevertheless, drawing far-reaching policy conclusions based on central government debt may be misleading. In fact, what matters for public debt is the consolidated debt of the government sector (general government debt), which includes not only central government but also social security administrations and subnational governments. As Figure 1 hereafter shows, the average difference is a little higher than 20 percentage points but it can go as far as 50 percentage points for Canada. For this reason, we also calculate averages using general government debt obtained from the OECD's Economic Outlook 92 database. Data on general government start in 1960 at the earliest but for some countries (Greece, Ireland, Portugal), they only start in the mid-1990s.[6] For the sake of comparability, average GDP growth rates are also calculated for central government data matching exactly the time span of the general government debt series.

As a matter of fact, average real GDP growth rates decline gently with general government debt increasing up to 90%, but it then drops from 3% to 2% as debt goes beyond 90% of GDP (Table 4). This important decline is confirmed when looking at GDP growth rates as a function of the (one year) lagged general government debt-to-GDP ratio but the smooth decline disappears at lower debt levels, where growth seems to be unrelated to the level of general government debt. A similar pattern can be observed when using multiyear averages. A smooth decline in growth rates occur when comparing debt and growth. But if we use lagged debt, the one percentage point slowdown in economic growth is evenly spread when moving from 30%-60% to above 90% of GDP. Let us now look at average growth rates in function of central government debt. Annual averages suggest a gradual slowdown in growth while multiyear averages indicate that growth decelerates considerably as central government debt goes beyond 60% of GDP (and not 90%).

[6] The data appendix provides more details on the time coverage.

Figure 1. The difference between general government debt (%of GDP) and central government debt (%of GDP), 2009

Percentage point



Source: Author's calculations using general government debt obtained from the OECD Economic Outlook 92 database and central government debt from the Reinhart-Rogoff dataset.

Table 4. Real GDP growth and general (and central) government debt as a % of GDP, 1960-2009

	x<30%	30%< x<60%	60%<x<90%	x>90%
	Average annual real GDP growth rate			
General government debt	3.3	3.0	2.8	1.9
Lagged general government debt	2.8	2.9	2.9	2.0
Central government debt	3.3	2.8	2.3	2.0
Lagged central government debt	3.0	2.8	2.6	2.2
	Average of 10-year average real GDP growth rates			
General government debt	3.6	3.3	2.8	2.1
Lagged general government debt	2.8	2.8	2.2	1.9
Central government debt	3.5	3.1	2.1	2.1
Lagged central government debt	2.7	2.7	1.7	2.0

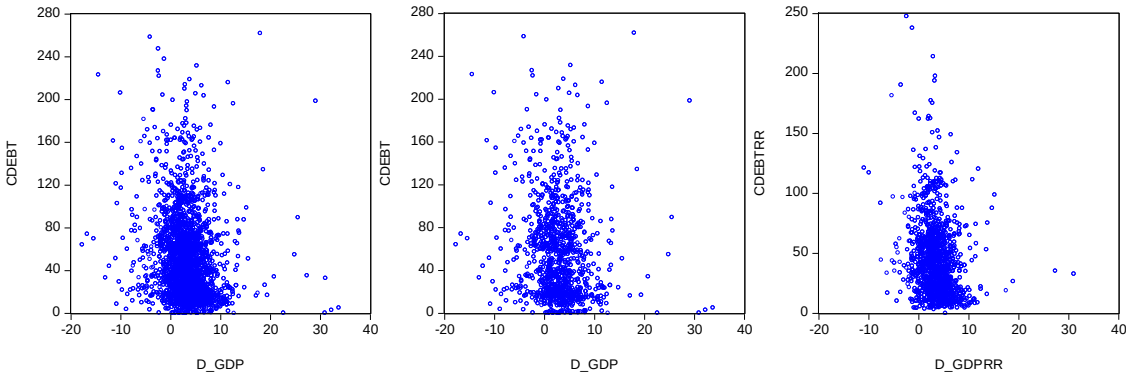
Another way of having a preliminary idea about the correlation between growth and debt is to plot the annual GDP growth rates against the debt ratio. The scatter plots presented in Panel A of Figure 2 are striking: annual GDP growth and the central government debt ratio do not appear to have any apparent relationship with one another for the sub-periods considered, perhaps with the exception of the period 1946-2009 where a little kink can be seen for low debt levels. The general picture does not change if public debt is plotted with a lag of one year (Panel B of Figure 2). Visual inspection yields a similar general impression for growth and general government for 1960 to 2009 (Panel C of Figure 2) and for the US economy (Figure 3).

Multi-year averages eliminate cyclical and other short-term effects, which may contaminate the scatter plots of annual figures. Therefore, Figure 4 plots non-overlapping 10-year averages for growth and central government debt for the period 1946-2009 (Reinhart-Rogoff data) and for general government debt for 1960 and 2009. Eyeball econometrics does suggest some kind of linear negative correlation between debt and growth, but no apparent threshold effects.

Figure 2. Public debt (%of GDP) and real GDP growth, annual data

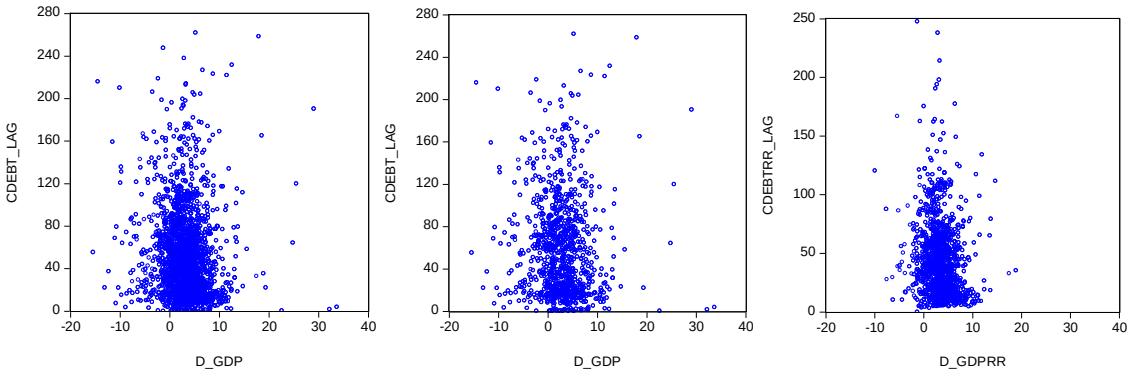
Panel A – Reinhart-Rogoff dataset, contemporaneous central government debt

1790-2009 1790-1939 1946-2009



Panel B – Reinhart-Rogoff dataset, lagged central government debt

1790-2009 1790-1939 1946-2009



Panel C – General government debt and central government debt, 1960-2009

General government debt Central government debt

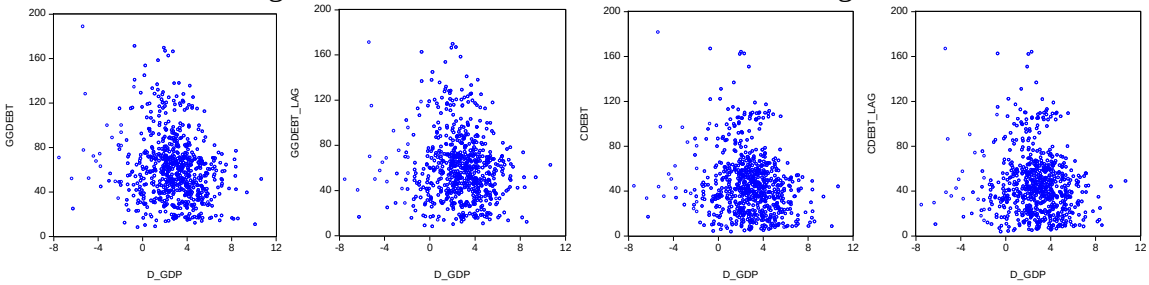


Figure 3. Central government debt (%of GDP) and real GDP growth, USA
Panel A – Reinhart-Rogoff dataset

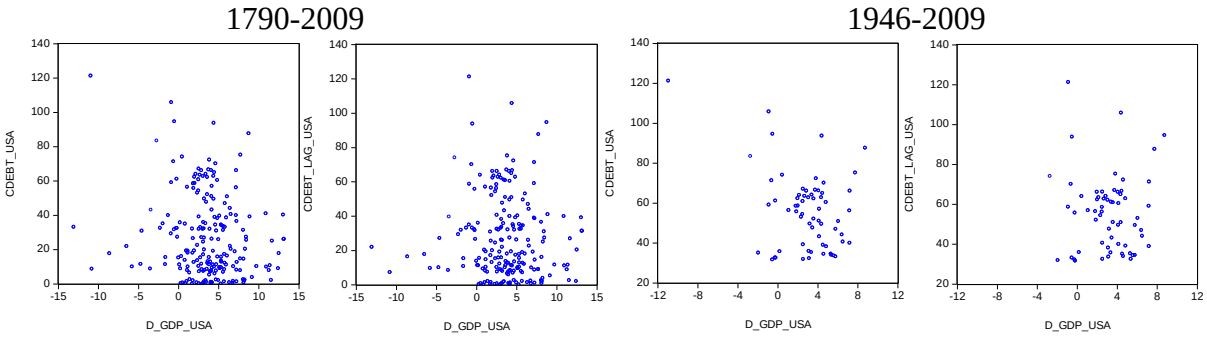
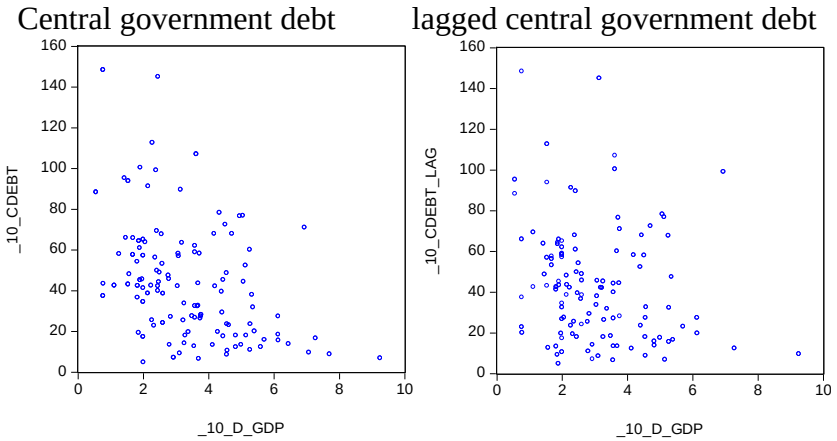
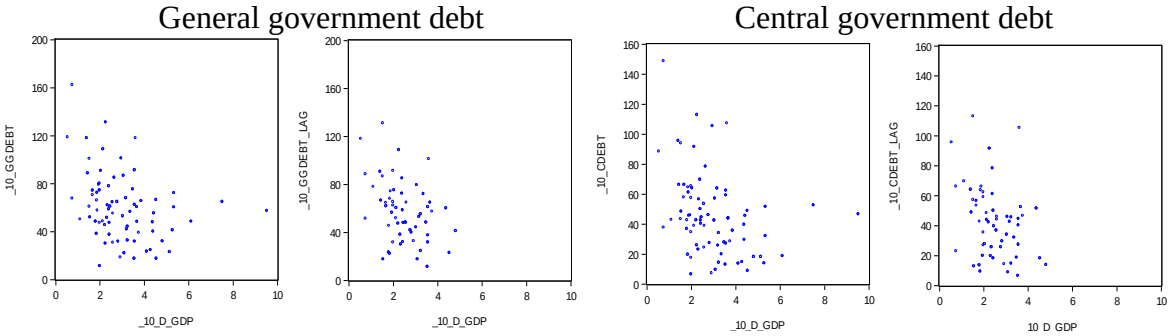


Figure 4. Public debt (%of GDP) and real GDP growth, annual data
Panel A – Reinhart-Rogoff dataset, 10-year non-overlapping averages, 1946-2009



Panel B – General and central government debt, 1960-2009



3. Econometric issues

We estimate bivariate threshold models, in which the effect of debt on growth depends on the level of debt. We use the testing procedure developed by Hansen (1999), which helps determine the threshold values endogenously through a grid search and which tests the different models sequentially against one another using bootstrapping methods. The linear specification is tested against a two-regime model. If the null hypothesis of the linear model can be rejected against the alternative of a two-regime model, the null of a two-regime model is tested against the alternative of a three-regime model. The two-regime and three-regime models can be written as follows.

$$\Delta y_t = \begin{cases} \alpha_1 + \beta_1 \cdot DEBT_t + \varepsilon_t & if \quad DEBT < T \\ \alpha_2 + \beta_2 \cdot DEBT_t + \varepsilon_t & if \quad DEBT \geq T \end{cases} \tag{1a}$$

$$\Delta y_t = \begin{cases} \alpha_1 + \beta_1 DEBT_t + \varepsilon_t & if \quad DEBT < T_1 \\ \alpha_2 + \beta_2 DEBT_t + \varepsilon_t & if \quad T_2 > DEBT \geq T_1 \\ \alpha_3 + \beta_3 DEBT_t + \varepsilon_t & if \quad DEBT \geq T_2 \end{cases} \tag{1b}$$

T is the value of the threshold of debt in the two-regime model and T_1 and T_2 are the lower and upper threshold values of debt in the three-regime model. A grid search with steps of 1% of the distribution is carried out to find the value of the threshold variable (public debt) that minimises the sum of squared residuals of the estimated two-regime model. The grid search starts at 20% of the distribution and stops at 80% to ensure that a sufficient number of observations falls into each regime. But we also experiment with alternative paramtetrisation (30%, 10%, 5% and 1%).

The three-regime model is estimated based on two threshold values of the threshold variable that minimise the sum of squared residuals across the estimated models. The threshold from the two-regime model is held fixed and a grid search is used to identify the second threshold. We impose the restriction that the two thresholds should be separated at least by 10% of our sample observations. Once the second threshold is identified, a backward grid search is performed to identify the first threshold as suggested by Hansen (1999).

We can proceed with the sequential testing of the models, once the thresholds are identified. Hansen (1999) shows that the null hypothesis of $\beta_1 = \beta_2$ from equations (3a) can be tested using a likelihood ratio test. Given that the likelihood ratio test statistic does not follow a standard asymptotic distribution as the threshold value is not identified under the null hypothesis, the distribution of the test statistic is obtained through bootstrapping with random draws with replacement. The bootstrap test is carried out using N=500 replications. If the likelihood ratio test statistic rejects the null hypothesis of the linear model against the two-regime model (on the basis of the bootstrapped critical values), whether there are three different regimes rather than only two regimes is also analysed. The bootstrap procedure described above is applied to the two-regime and three-regime models.

4. Estimation results

4.1 Central government debt and the Reinhart- Rogoff dataset

Reinhart and Rogoff (2010) imposed the 90% debt threshold without any formal testing. But it seems more appropriate, as argued earlier, to test empirically whether there are debt thresholds in the data and if so, where they are located. Before diving into the details, we have to emphasise that a serious problem with the correlation between public debt and growth is that any change in the growth rate of real GDP will have a mechanical effect on the debt-to-GDP ratio. Using the lagged public debt-to-GDP ratio helps circumvent this problem: in our bivariate setup, it is almost

certain that lagged debt may have an influence on growth but not the other way around. Therefore, we focus on the interpretation of this relationship (lagged debt and growth) in what follows.[7]

Table 5. **Reinhart-Rogoff dataset, 1790-2009**

		Minimum % of observations required in one regime				
		30%	**20%**	**10%**	**5%**	**1%**
		Nonlinear variable = lagged central government debt/GDP				
		Threshold variable = lagged central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.084**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		0.184	0.248	**0.060**	**0.082**	**0.054**
Coefficients	Low debt	0.015	-0.022**	0.044	0.044	0.699
	Middle debt			-0.018**	-0.018**	-0.020**
	High debt	-0.006	-0.009**	-0.006*	-0.006*	-0.007**
Debt thresholds (%)	Threshold 1	27.72	71.99	14.27	14.27	4.40
	Threshold 2			94.27	94.27	94.27
No. of OBS		2177	2177	2177	2177	2177
		Nonlinear variable = lagged <u>rate of growth</u> in central government debt/GDP				
		Threshold variable = lagged central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.002**	**0.004**	**0.000**	**0.002**	**0.002**
H0: 2-regimes *vs*. H1: 3-regimes		**0.004**	**0.002**	**0.000**	**0.002**	**0.000**
Coefficients	Low debt	0.003	0.004	0.004	0.004	0.004
	Middle debt	-0.041**	-0.038**	-0.038**	-0.038**	-0.010**
	High debt	-0.007**	-0.007**	-0.007**	-0.007**	-0.242**
Debt thresholds (%)	Threshold 1	23.64	19.62	19.62	19.62	13.48
	Threshold 2	52.98	67.86	67.86	67.86	155.00
No. of OBS		2120	2120	2120	2120	2120

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

Our estimation results indicate that there is a negative nonlinear relationship between (lagged) central government debt and growth for the period 1790 to 2009 (Table 5). But there is uncertainty whether this nonlinear relationship includes two or three different regimes and where the debt thresholds are. Depending on the minimum number of observations required to be included in the outer regimes: the results indicate a two-regime model with a threshold at about 30% of GDP if a large number of observations are included in one regime (30% of the observations) and a three-regime model with thresholds of 4% and 90%, if the minimum number of observations is 1% of total observations. Obviously, the lower the minimum number of observations in specific regimes, the higher the probability that a very low or very high threshold will be picked. But at the same time, the results may be less general because they will be more sensitive to outliers.

The coefficient estimates are negative in the high-debt regimes but they tend to be lower than the negative coefficients obtained for lower debt regimes. This could imply that the harmful effect of public debt on growth diminishes with rising debt, but it could also well be the case that lower coefficients indicate that a one percentage point increase in the public debt-to-GDP ratio means a lower rate of growth of debt for higher levels of debt. We therefore re-run the estimations using the (lagged) rate of growth of central government debt rather than the (lagged) level of the debt-to-GDP ratio as independent (nonlinear) variable and using, as before, the lagged public

[7] Appendix B reports results for the relationship between contemporaneous public debt and growth. The results do not differ too much from those obtained using lagged public debt.

debt-to-GDP ratio as the threshold variable. The new results seem to be more stable. Always the three-regime model is selected, with a lower threshold of around 20% of GDP and an upper threshold of roughly 60% of GDP. The coefficient estimates indicate that public debt higher than 20% of GDP starts having a negative impact on growth. But the negative coefficient in the upper debt regime remains lower compared to the one in the middle debt regime, which is inconsistent with the Reinhart-Rogoff claim. An exception is the case when only 1% of total observations is required to be in the outer regimes: the upper threshold moves to 150% of GDP and the negative coefficient becomes massively negative in the high debt regime.

Results obtained for the period 1946-2009 are broadly in line with the earlier results (Table 6). The negative effect of central government debt on growth kicks in at about 20% of GDP. In some cases, there is another debt threshold at about 60% of GDP, but the coefficients above this threshold are lower than below it. We carry out the estimations again using the growth rate of public debt as a nonlinear variable. The results indicate the presence of a 20% debt threshold above which a one percent change in central government debt reduces growth by 0.04 percentage points. Furthermore, there is some but not very robust evidence for another debt threshold which is somewhere between 55% and 130% of GDP, beyond which the negative impact on growth grow much stronger.

Table 6. **Reinhart-Rogoff dataset, 1946-2009, annual data**

		Minimum % of observations required in one regime				
		30%	20%	10%	5%	1%
		Nonlinear variable = lagged central government debt/GDP				
		Threshold variable = lagged central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.016**	**0.000**	**0.000**	**0.002**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		0.140	**0.054**	**0.006**	**0.000**	**0.000**
Coefficients	Low debt	0.025*	0.028	0.050	0.238**	0.238**
	Middle debt		-0.022**	-0.023**	0.047**	0.047**
	High debt	-0.011**	-0.012**	-0.013**	-0.007*	-0.007*
Debt thresholds (%)	Threshold 1	26.73	19.33	14.43	10.02	10.02
	Threshold 2		64.60	64.60	22.68	22.68
No. of OBS		1189	1189	1189	1189	1189
		Nonlinear variable = lagged <u>rate of growth</u> in central government debt/GDP				
		Threshold variable = lagged central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		0.220	0.194	**0.024**	0.108	**0.070**
Coefficients	Low debt	0.016	0.019	0.030**	0.019	0.018
	Middle debt			-0.026**		-0.039**
	High debt	-0.040**	-0.040**	-0.063**	-0.040**	-0.187**
Debt thresholds (%)	Threshold 1	24.54	21.14	13.25	21.14	21.14
	Threshold 2			55.11		126.53
No. of OBS		1164	1164	1164	1164	1164

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

4.2 General government debt

We repeat the above exercise replacing central government debt by general government debt, a more relevant measure for policymakers. The tests of nonlinearity indicate that the null hypothesis of a linear model cannot be accepted against the alternative of a two-regime model, and sometimes even a three-regime model is selected over a two-regime model (Table 7). The estimated thresholds appear to be sensitive to the parametrisation of the threshold models

(minimum number of observations required in a specific regime) and range from 50% to 90% of GDP when lagged general government debt is the nonlinear variable. By contrast, the results are more straightforward if the rate of growth of the general government debt ratio is taken as the nonlinear variable. In that case, the significant negative impact of public debt on growth becomes visible if debt exceeds 45-50% of GDP: a one percent growth in debt reduces growth by almost 0.1 percentage points. These results are broadly confirmed by estimations performed on central government debt data even though the degree of uncertainty is much greater (Table B4 in Appendix B): a tipping point lies somewhere in the range of 30% to 70% beyond which a one percent change in central government debt decreases growth by 0.04 – 0.12 percentage points.

Table 7. **General government debt, 1960-2009**

		Minimum % of observations required in one regime				
		30%	20%	10%	5%	1%
		Nonlinear variable = lagged general government debt/GDP				
		Threshold variable = lagged general government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.026**	**0.016**	**0.000**	**0.000**	**0.002**
H0: 2-regimes *vs*. H1: 3-regimes		0.148	0.102	**0.092**	**0.008**	**0.010**
Coefficients	Low debt	-0.037**	-0.043**	-0.029*	0.077**	0.077**
	Middle debt			-0.009	0.006	0.006
	High debt	-0.022**	-0.022**	-0.021**	-0.012**	-0.012**
Debt thresholds (%)	Threshold 1	49.75	42.61	34.64	20.37	20.37
	Threshold 2			88.98	88.98	88.98
No. of OBS		687	687	687	687	687
		Nonlinear variable = lagged rate of growth in general government debt/GDP				
		Threshold variable = lagged geneal government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.002**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		0.442	0.292	0.136	**0.004**	**0.000**
Coefficients	Low debt	0.016	0.016	0.016	0.106**	0.123**
	Middle debt				-0.011	-0.012
	High debt	-0.063**	-0.063**	-0.063**	-0.075**	-0.075**
Debt thresholds (%)	Threshold 1	44.59	44.59	44.59	17.63	16.79
	Threshold 2				49.22	49.22
No. of OBS		666	666	666	666	666

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

4.3 Individual country estimates

Thus far, we have assumed that the debt-growth relationship is homogenous across countries: the same slope coefficients and debt thresholds are assumed to hold for the 20 countries included in the Reinhart-Rogoff dataset. Yet this assumption may be too restrictive given that public debt can affect economic growth differently in different countries. There are a number of channels through which public debt is likely to hamper long-term growth. They are as follows:

- First, tax hikes needed to service a higher public debt crowd out private investment by reducing disposable income and saving, raise the distortionary costs of taxation, and are likely to result in non-neutral tax treatment within and across asset classes, thus amplifying distortions.
- Second, soaring public debt will push up long-term sovereign yields in a nonlinear fashion, as the likelihood of default increases. High long-term rates crowd out productive public investment, and, more importantly, reduce private investment by

increasing the cost of capital. Reduced investment in R&D will have long-lasting negative impacts on growth (Elmeskov and Sutherland, 2012).

- Third, public authorities, especially in countries with weak institutions, may decide to inflate away debt, and high inflation has a notoriously detrimental effect on growth (Kumar and Woo, 2010).

Whether debt will have a nonlinear negative effect on growth, and at what level, depends on the importance of the interest rate channel. The overall negative impact will be given by the combination of the three channels. Against this backdrop, here we set out to assess possible country-specific nonlinearities by estimating threshold models for individual countries using the Reinhart and Rogoff dataset of central government debt.

The results, summarised in Table 8, highlight several country specificities. First of all, a robust nonlinear negative relationship linking public debt and growth can be established only for a handful of countries including Belgium, Finland, Germany and the United States. The debt threshold beyond which the negative impact of debt on growth kicks in is very low, around or even below 30% of GDP. But the negative effects are very different: relatively small for Belgium but more important for Germany and the US economy. Second, for another subgroup of countries including Austria, Canada and Ireland, there is a large degree of uncertainty around the tipping point, which ranges somewhere between 30% and 70%, as it is sensitive to modelling choices, namely to the minimum number of observations included in one regime (10% vs. 20%). Third, there is no nonlinear relationship between public debt and growth in some countries such as Australia and Spain. In these two countries, there is not even a negative linear link between debt and growth. Fourth, in some other countries like Denmark, Italy and Japan, even though the presence of nonlinearity can be detected, the relation between debt and growth is positive in the high debt regime. Finally, in the remaining countries, whether public debt has a negative or positive influence on real GDP growth above a certain level of the central government debt-to-GDP ratio depends on the minimum number of observations required for individual regimes.

Table 8. Country-specific results, 1790-2009

Nonlinear variable = lagged growth rate of central government debt/GDP
Threshold variable = lagged central government debt/GDP

	Test of nonlinearity (p-value)		Coefficients			Debt thresholds (%)		No obs
	lin vs 2reg	2reg vs. 3reg	low	middle	high	Low	High	
Minimum % of observations required in one regime: 20%								
AUS	0.28	0.42	0.068*					140
AUT	**0.00**	**0.02**	0.027	0.093	-0.236**	18.94	58.15	104
BEL	**0.02**	0.46	0.061		-0.021*	29.36		153
CAN	**0.00**	**0.00**	0.096	-0.240**	-0.605**	45.36	55.42	74
DEU	**0.00**	**0.00**	0.074**	-0.002	-0.159**	13.43	24.09	57
DNK	**0.00**	1.00	-0.037		0.056**	40.53		83
ESP	0.55	0.29	0.001					127
FIN	**0.00**	**0.00**	0.020	-0.013	-0.113**	12.02	16.96	80
FRA	**0.00**	**0.00**	-0.060**	-0.006**	0.086**	35.33	70.44	92
GBR	0.33	0.11	0.036					161
GRC	**0.00**	**0.00**	0.059**	-0.270**	-0.003	24.57	110.74	105
IRL	**0.00**	1.00	-0.208**		-0.133**	27.84		62
ITA	**0.00**	0.13	-0.063		0.068**	28.58		107
JPN	**0.00**	**0.00**	0.116*	0.062	-0.053	19.41	54.08	96
NLD	**0.01**	**0.00**	-0.072**	0.075	-0.187**	47.87	70.69	100
NOR	**0.00**	**0.00**	-0.023	-0.022	0.087**	21.57	26.99	112
NZL	**0.00**	**0.00**	0.108	-0.064	-0.241**	37.11	53.45	67
PRT	**0.00**	**0.00**	-0.018	-0.085	0.082	54.27	70.12	87
SWE	**0.00**	1.00	0.099**		0.002	18.88		112
USA	**0.00**	**0.03**	0.000	0.035	-0.159**	17.25	33.73	201
Minimum % of observations required in one regime: 10%								
AUS	0.146	0.052	0.068*					140
AUT	**0.000**	0.744	0.027		-0.198**	18.94		104
BEL	**0.052**	0.278	0.089		-0.021*	18.33		153
CAN	**0.000**	**0.000**	0.096	-0.135	-0.476**	45.36	77.59	74
DEU	**0.000**	**0.000**	0.073**	-0.001	-0.164**	13.43	27.20	57
DNK	**0.000**	1.000	-0.037		0.056**	40.53		83
ESP	0.326	0.004	0.001					127
FIN	**0.000**	**0.000**	0.020	-0.013	-0.113**	12.02	16.96	80
FRA	**0.000**	**0.000**	-0.043**	-0.006**	-0.241*	70.44	105.10	92
GBR	**0.046**	0.644	0.153**		0.017	38.15		161
GRC	**0.000**	**0.000**	0.059**	-0.270**	-0.003	24.57	110.74	105
IRL	**0.000**	**0.000**	-0.148**	-0.060	-0.369**	65.50	77.17	62
ITA	**0.000**	0.512	-0.136		0.075**	27.57		107
JPN	**0.000**	**0.000**	0.005	-0.293**	0.096**	54.08	70.20	96
NLD	0.904	0.000	-0.113**					100
NOR	**0.006**	0.498	0.057		-0.010	22.34		112
NZL	**0.000**	**0.000**	-0.090	-0.358	0.061	53.45	94.51	67
PRT	**0.000**	**0.000**	-0.018	-0.140	0.088	54.27	71.69	87
SWE	**0.004**	**0.000**	0.171**	-0.067	0.031	15.62	57.07	112
USA	**0.002**	**0.042**	0.000	0.035	-0.159**	17.25	33.73	201

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

5. Conclusions

The aim of this paper was to contribute to the empirical literature on the identification of a possible debt threshold beyond which negative effects for economic growth appear. We analyse the original Reinhart-Rogoff dataset, made public by Herndon et al. (2013), relying on descriptive statistics and formal econometric testing. First, employing the debt thresholds (30%, 60% and 90%) proposed by Reinhart and Rogoff (2010), we show using descriptive statistics that real GDP growth slows considerably as the central government debt-to-GDP ratio goes beyond the 30%

threshold and that no further slowdown can be observed in the data as the debt-to-GDP ratio rises above 60% and 90% during the periods 1790-2009 and 1946-2009. For the United States (1946-2009), the negative nonlinear finding completely disappears for any level of public debt, once reverse causality and influential outliers are accounted for. Looking at general (and central) government debt during the more recent period of 1960-2009 suggests that economic slowdown occurs when public debt moves above 60% or 90% of GDP.

Given that it is more appropriate to determine possible threshold effects in an endogenous fashion, in a second stage, we put the Reinhart-Rogoff dataset to a formal econometric test by employing nonlinear threshold models to investigate the presence of a possible negative nonlinear relationship between debt and growth. Overall, our estimation results indicate that the nonlinear relation from debt to growth is not very robust. Taken with a pinch of salt, our results suggest, however, that there may be a tipping point at around 20% of GDP, beyond which debt has a negative influence on growth. Further (and greater) thresholds may exist but their magnitude is highly uncertain. For general government debt (1960-2009), the threshold beyond which negative growth effects kick in is considerably higher at about 50%. Finally, individual country estimates reveal a large amount of cross-country heterogeneity. For some countries such as Germany and the United States, a nonlinear negative link can be detected at about 30% of GDP. While negative nonlinearities, surround by a huge amount of uncertainty regarding the quantitative effects, seem to be present in some, no robust or absolutely no negative nonlinearities can be established in a number of countries. This instability may be a result of nonlinear effects changing over time within countries and economic conditions.

Our results can be seen as a formal econometric confirmation that the 90% public debt beyond which economic growth slows significantly is not in the data: the previous stylised fact is indeed a statistical fallacy. But our results also seem to suggest that public debt might have a negative effect on economic performance kicking in at fairly moderate public debt levels. Nevertheless, the magnitude of those effects and the precise size of the thresholds may vary to a great extent across countries. Furthermore, the absence of threshold effects or low estimated thresholds may not preclude the emergence of further threshold effects, especially as public debt levels are rising to unprecedentedly high levels.

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Appendix A

Table A1. **Data coverage: Reinhart and Rogoff (2010) *vs*. the dataset used in the paper**

	Reinhart and Rogoff data in this paper based on Herndon et al. (2013)	General government debt OECD Economic Outlook database
Australia	1852-2009	1988-2009
Austria	1880-2009	1970-2009
Belgium	1835-2009	1969-2009
Canada	1925-2009	1961-2009
Denmark	1881-2009	1980-2009
Finland	1914-2009	1975-2009
France	1880-2009	1967-2009
Germany	1950-2009	1960-2009
Greece	1884-2009	1995-2009
Ireland	1926-2009	1998-2009
Italy	1880-2009	1960-2009
Japan	1886-2009	1970-2009
Netherlands	1880-2009	1960-2009
New Zealand	1932-2009	1993-2009
Norway	1880-2009	1970-2009
Portugal	1880-2009	1995-2009
Spain	1851-2009	1980-2009
Sweden	1880-2009	1970-2009
United Kingdom	1831-2009	1966-2009
USA	1791-2009	1960-2009

Appendix B

Table B1. **Reinhart-Rogoff dataset, 1790-2009, annual data**

		Minimum % of observations required in one regime				
		30%	20%	10%	5%	1%
		Nonlinear variable = central government debt/GDP				
		Threshold variable = central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.020**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		0.338	0.136	**0.052**	**0.022**	**0.022**
Coefficients	Low debt	-0.030**	-0.032**	0.034	-0.039**	-0.039**
	Middle debt			-0.024**	-0.028**	-0.028**
	High debt	-0.018**	-0.018**	-0.014**	-0.017**	-0.017**
Debt thresholds (%)	Threshold 1	62.52	71.99	14.92	63.36	63.36
	Threshold 2			97.61	104.85	104.85
No. of OBS		2239	2239	2239	2239	2239
		Nonlinear variable = rate of growth in central government debt/GDP				
		Threshold variable = central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.014**	**0.004**	**0.004**	**0.002**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Coefficients	Low debt	-0.005	-0.002	-0.001	-0.001	-0.001
	Middle debt	-0.094**	-0.104**	-0.117**	-0.117**	-0.117**
	High debt	-0.006	-0.003	0.001	0.002	0.002
Debt thresholds (%)	Threshold 1	23.64	17.74	15.94	15.94	15.94
	Threshold 2	62.52	75.07	97.61	104.85	104.85
No. of OBS		2176	2176	2176	2176	2176

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

Table B2. **Reinhart-Rogoff dataset, 1946-2009, annual data**

		Minimum % of observations required in one regime				
		30%	20%	10%	5%	1%
		Nonlinear variable = central government debt/GDP				
		Threshold variable = central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.052**	**0.000**	**0.002**	**0.002**	**0.002**
H0: 2-regimes *vs*. H1: 3-regimes		0.106	0.212	0.122	**0.012**	**0.018**
Coefficients	Low debt	0.006	-0.044**	-0.044**	0.104**	0.104**
	Middle debt			-0.026**	-0.038**	-0.038**
	High debt	-0.021**	-0.026**	-0.026**	-0.024**	-0.024**
Debt thresholds (%)	Threshold 1	27.59	63.47	63.47	9.25	9.25
	Threshold 2				63.47	63.47
No. of OBS		1214	1214	1214	1214	1214
		Nonlinear variable = rate of growth in central government debt/GDP				
		Threshold variable = central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Coefficients	Low debt	-0.053**	-0.045**	-0.032**	-0.032**	-0.032**
	Middle debt	-0.090**	-0.090**	-0.093**	-0.093**	-0.093**
	High debt	-0.196**	-0.217**	-0.242**	-0.242**	-0.242**
Debt thresholds (%)	Threshold 1	26.16	18.41	15.18	15.18	15.18
	Threshold 2	55.59	59.57	65.76	65.76	65.76
No. of OBS		1188	1188	1188	1188	1188

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

1.

Table B3. **General government debt, 1960-2009, annual data**

		Minimum % of observations required in one regime				
		30%	20%	10%	5%	1%
		Nonlinear variable = general government debt/GDP				
		Threshold variable = general government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.050**	**0.022**	**0.004**	**0.002**	**0.01**
H0: 2-regimes *vs*. H1: 3-regimes		**0.094**	**0.084**	**0.034**	**0.044**	**0.03**
Coefficients	Low debt	-0.038**	-0.035**	-0.084**	-0.084**	-0.084**
	Middle debt	-0.026**	-0.023**	-0.050**	-0.050**	-0.050**
	High debt	-0.032**	-0.032**	-0.041**	-0.041**	-0.041**
Debt thresholds (%)	Threshold 1	49.75	49.75	36.48	36.48	36.48
	Threshold 2	69.74	70.48	60.39	60.39	60.39
No. of OBS		708	708	708	708	708
		Nonlinear variable = rate of growth in general government debt/GDP				
		Threshold variable = general government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		**0.004**	**0.004**	**0.008**	**0.000**	**0.000**
Coefficients	Low debt	-0.054**	-0.054**	-0.055**	-0.064**	-0.064**
	Middle debt	-0.126**	-0.127**	-0.144**	-0.158**	-0.158**
	High debt	-0.199**	-0.204**	-0.332**	-0.429**	-0.514**
Debt thresholds (%)	Threshold 1	49.22	49.22	49.22	51.46	51.46
	Threshold 2	67.10	70.48	96.03	116.78	127.90
No. of OBS		687	687	687	687	687

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

Table B4. **Central government debt, 1960-2009, annual data**

		Minimum % of observations required in one regime				
		30%	20%	10%	5%	1%
		Nonlinear variable = central government debt/GDP				
		Threshold variable = central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.002**	**0.000**	**0.002**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		0.382	0.358	**0.000**	**0.000**	**0.000**
Coefficients	Low debt	-0.061**	-0.061**	0.124**	0.124**	0.124**
	Middle debt			0.002	0.002	0.002
	High debt	-0.033**	-0.033**	-0.022**	-0.022**	-0.022**
Debt thresholds (%)	Threshold 1	37.98	37.98	16.33	16.33	16.33
	Threshold 2			79.25	79.25	79.25
No. of OBS		708	708	708	708	708
		Nonlinear variable = lagged central government debt/GDP				
		Threshold variable = lagged central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		**0.080**	**0.086**	**0.000**	**0.006**	**0.010**
Coefficients	Low debt	-0.075**	-0.075**	0.113**	0.105**	0.105**
	Middle debt	-0.038**	-0.038**	0.011	0.008	0.008
	High debt	-0.027**	-0.027**	-0.011**	-0.014**	-0.014**
Debt thresholds (%)	Threshold 1	46.45	34.23	16.33	16.33	16.33
	Threshold 2	34.23	46.45	73.31	84.28	84.28
No. of OBS		687	687	687	687	687
		Nonlinear variable = rate of growth in central government debt/GDP				
		Threshold variable = central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
H0: 2-regimes *vs*. H1: 3-regimes		0.114	**0.044**	**0.002**	**0.002**	**0.000**
Coefficients	Low debt	-0.055**	-0.041**	-0.022	-0.022	-0.022
	Middle debt		-0.068**	-0.074**	-0.074**	-0.074**
	High debt	-0.148**	-0.188**	-0.276**	-0.276**	-0.276**
Debt thresholds (%)	Threshold 1	54.43	23.64	16.33	16.33	16.33
	Threshold 2		58.86	79.25	79.25	79.25
No. of OBS		687	687	687	687	687
		Nonlinear variable = lagged rate of growth in central government debt/GDP				
		Threshold variable = lagged central government debt/GDP				
Test of nonlinearity		Bootstrapped p-value				
H0: linear *vs*. H1: 2-regimes		**0.030**	**0.032**	**0.002**	**0.002**	**0.004**
H0: 2-regimes *vs*. H1: 3-regimes		**0.056**	**0.032**	**0.034**	**0.026**	**0.012**
Coefficients	Low debt	-0.006	-0.006	0.038**	0.043**	0.043**
	Middle debt	0.039**	0.039**	-0.014	-0.014	-0.014
	High debt	-0.037**	-0.037**	-0.124**	-0.124**	-0.124**
Debt thresholds (%)	Threshold 1	34.84	34.84	14.08	13.23	13.23
	Threshold 2	49.56	49.56	73.31	73.31	73.31
No. of OBS		666	666	666	666	666

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

Table B5. Country-specific results

Minimum % of observations required in one regime: 20%

	Test of nonlinearity (p-value)		Coefficients			Debt thresholds (%)		No obs
	lin vs 2reg	2reg vs. 3reg	low	middle	high	Low	High	
Nonlinear variable = central government debt/GDP Threshold variable = central government debt/GDP								
AUS	0.44	0.28	-0.026					146
AUT	**0.00**	**0.00**	0.370*	0.025	0.183	14.82	35.36	110
BEL	**0.01**	**0.10**	0.149**	0.030**	0.055*	29.36	68.06	159
CAN	**0.00**	**0.00**	0.117	0.036	0.078	52.22	68.11	78
DEU	**0.00**	**0.00**	0.022	-0.113*	-0.170*	11.54	20.87	59
DNK	**0.00**	**0.00**	0.007	-0.012	-0.054*	23.41	45.86	89
ESP	**0.00**	**0.08**	0.132**	0.018	0.061**	40.30	57.40	135
FIN	**0.00**	**0.00**	0.421**	0.068**	0.216*	12.90	28.49	84
FRA	**0.00**	0.15	0.155**		-0.002	23.62		101
GBR	**0.08**	0.25	-0.031*		-0.011*	68.19		167
GRC	**0.00**	0.98	-0.108*		-0.030**	68.54		112
IRL	**0.00**	**0.00**	0.186**	0.041*	0.080**	44.17	77.17	70
ITA	**0.00**	**0.01**	0.108	-0.026	-0.064	32.78	74.52	115
JPN	**0.00**	0.96	0.418**		-0.023**	19.41		102
NLD	**0.00**	0.79	-0.073**		-0.038**	50.49		106
NOR	0.30	0.00	0.106**					118
NZL	**0.00**	**0.00**	-0.101	-0.005	-0.053	50.03	74.09	71
PRT	**0.00**	**0.00**	0.288**	0.003	0.073*	17.34	44.43	92
SWE	**0.00**	**0.00**	-0.177*	-0.053*	-0.098	20.86	36.13	118
USA	**0.08**	0.14	-0.074**		-0.031**	36.25		207
Nonlinear variable = rate of growth of central government debt/GDP Threshold variable = central government debt/GDP								
AUS	**0.00**	0.52	0.041		-0.312**	38.90		143
AUT	**0.00**	0.23	-0.075**		-0.311**	16.79		107
BEL	**0.00**	0.17	-0.036		-0.228**	38.53		156
CAN	**0.00**	**0.00**	-0.046	-0.329**	-0.189**	45.36	66.97	76
DEU	**0.00**	**0.00**	-0.024	-0.118	-0.335**	14.36	24.09	58
DNK	**0.00**	**0.00**	-0.086**	-0.023	-0.151**	22.79	37.74	86
ESP	**0.00**	0.64	-0.014		-0.150**	38.89		131
FIN	**0.00**	**0.00**	-0.075**	-0.073**	-0.160**	14.99	33.52	82
FRA	**0.00**	**0.00**	-0.065**	0.004**	-0.210**	59.42	98.30	96
GBR	**0.00**	**0.02**	-0.033	-0.359**	-0.206**	47.80	132.64	164
GRC	**0.00**	**0.01**	0.006	0.021**	-0.225*	51.70	108.24	108
IRL	**0.00**	**0.00**	0.013	-0.306**	-0.172**	27.58	65.50	64
ITA	**0.00**	**0.00**	-0.231**	-0.451**	-0.041	28.58	84.64	111
JPN	**0.00**	**0.00**	0.005	-0.108**	-0.239**	16.83	30.09	99
NLD	**0.00**	**0.00**	-0.197**	0.099	-0.116**	50.27	68.87	103
NOR	**0.00**	**0.05**	-0.104**	-0.114*	0.070	25.32	30.80	115
NZL	**0.00**	**0.00**	-0.158**	-0.565**	-0.069	55.22	68.16	69
PRT	**0.00**	**0.00**	-0.062	-0.182**	0.003	15.97	54.94	89
SWE	**0.00**	**0.00**	-0.230**	-0.131**	-0.057	18.15	41.92	115
USA	**0.00**	**0.06**	-0.003**	-0.241**	0.017**	8.07	15.78	204

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

Table B6. Country-specific results

Minimum % of observations required in one regime: 20%

Nonlinear variable = lagged central government debt/GDP Threshold variable = lagged central government debt/GDP								
	Test of nonlinearity (p-value)		**Coefficients**			**Debt thresholds (%)**		**No obs**
	lin vs 2reg	**2reg vs. 3reg**	**low**	**middle**	**high**	**Low**	**High**	
AUS	0.12	0.35	-0.007					143
AUT	**0.00**	**0.00**	0.489**	0.046*	0.153*	15.24	36.45	107
BEL	0.11	0.07	0.010					156
CAN	**0.00**	**0.00**	0.059	0.038	0.086*	44.44	53.64	76
DEU	**0.00**	**0.00**	0.061	-0.068	0.258*	8.36	11.54	58
DNK	**0.00**	1.00	0.079*		0.001	21.82		86
ESP	**0.00**	0.16	0.102**		0.018	51.89		131
FIN	**0.00**	**0.00**	0.031	0.038	0.178*	12.02	26.43	82
FRA	**0.00**	**0.00**	0.335**	0.029*	0.074**	25.67	81.45	96
GBR	**0.00**	**0.00**	-0.056**	-0.008	-0.026**	43.23	135.69	164
GRC	**0.00**	**0.00**	0.341**	0.003	0.036*	22.43	121.53	109
IRL	**0.00**	1.00	-0.191**		-0.031*	27.84		64
ITA	**0.00**	0.63	0.206**		0.010	32.78		111
JPN	**0.00**	**0.00**	0.096	-0.040**	-0.121**	16.83	48.03	99
NLD	**0.00**	1.00	-0.064**		-0.032**	50.36		103
NOR	**0.00**	1.00	0.283**		0.201**	24.53		115
NZL	**0.00**	1.00	0.002		0.029*	58.03		69
PRT	**0.00**	**0.00**	0.267**	0.004	0.063	18.31	54.27	89
SWE	**0.00**	**0.02**	0.209**	0.045*	0.146**	16.89	35.26	115
USA	**0.02**	0.36	-0.119*		-0.021*	22.17		204

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

Table B7. Country-specific results

Minimum % of observations required in one regime: 10%

	Test of nonlinearity (p-value)		Coefficients			Debt thresholds (%)		No obs
	lin vs 2reg	2reg vs. 3reg	low	middle	high	Low	High	
Nonlinear variable = central government debt/GDP Threshold variable = central government debt/GDP								
AUS	**0.060**	**0.044**	-0.570**	-0.037**	-0.097**	12.46	71.79	146
AUT	**0.000**	**0.000**	0.452*	0.017	0.175	11.93	35.36	110
BEL	**0.010**	**0.046**	-0.081**	-0.006	-0.031**	40.87	96.63	159
CAN	**0.000**	**0.000**	0.172**	0.049*	0.115**	50.93	76.38	78
DEU	**0.000**	**0.000**	0.022	-0.113*	-0.170*	11.54	20.87	59
DNK	**0.000**	**0.000**	0.509**	0.024	0.132**	10.94	23.41	89
ESP	**0.002**	0.116	-0.068**		-0.025**	103.65		135
FIN	**0.000**	**0.000**	-0.573**	-0.039	-0.172*	8.97	33.96	84
FRA	**0.000**	**0.098**	0.109*	-0.003	-0.023*	22.82	116.65	101
GBR	0.102	0.106	-0.004					167
GRC	**0.000**	0.682	-0.108*		-0.030**	68.54		112
IRL	**0.000**	**0.000**	0.186**	0.041*	0.080**	44.17	77.17	70
ITA	**0.000**	0.188	0.218*		-0.002	32.78		115
JPN	**0.000**	**0.000**	0.252	-0.037**	-0.107**	19.41	47.74	102
NLD	**0.000**	**0.026**	0.153**	0.026	0.056**	36.06	58.95	106
NOR	**0.020**	**0.000**	0.423**	0.191**	0.244**	16.39	27.78	118
NZL	**0.000**	**0.000**	-0.057	0.005	-0.016	64.30	119.43	71
PRT	**0.000**	**0.000**	-0.693**	-0.104**	-0.223**	11.64	34.80	92
SWE	**0.028**	**0.006**	0.177**	0.014	0.055	16.81	47.91	118
USA	**0.068**	0.150	-0.074**		-0.031**	36.25		207
Nonlinear variable = rate of growth of central government debt/GDP Threshold variable = central government debt/GDP								
AUS	**0.000**	0.190	0.041		-0.312**	38.90		143
AUT	**0.000**	0.198	-0.075**		-0.311**	16.79		107
BEL	**0.000**	**0.000**	-0.040	0.095	-0.284**	61.07	104.89	156
CAN	**0.000**	**0.000**	-0.066	-0.138	-0.479**	53.30	74.42	76
DEU	**0.000**	**0.000**	-0.024	-0.618**	-0.121*	14.36	35.32	58
DNK	**0.000**	**0.000**	-0.043	-0.023	-0.133**	8.39	37.74	86
ESP	**0.000**	0.170	-0.002		-0.160**	35.27		131
FIN	**0.000**	**0.000**	-0.075**	-0.073**	-0.160**	14.99	33.52	82
FRA	**0.000**	**0.000**	-0.065**	0.004**	-0.220**	59.42	115.19	96
GBR	**0.000**	**0.088**	-0.033	-0.359**	-0.206**	47.80	132.64	164
GRC	**0.082**	**0.006**	0.006	0.021**	-0.225*	51.70	108.24	108
IRL	**0.000**	**0.000**	0.013	-0.306**	-0.172**	27.58	65.50	64
ITA	**0.000**	**0.000**	-0.231**	-0.451**	-0.041	28.58	84.64	111
JPN	**0.000**	**0.000**	0.014	-0.441**	-0.127**	15.04	69.31	99
NLD	**0.016**	**0.000**	-0.197**	0.099	-0.116**	50.27	68.87	103
NOR	**0.000**	**0.000**	-0.115**	-0.433**	0.004	22.09	35.39	115
NZL	**0.000**	1.000	-0.138**		-0.563**	68.16		69
PRT	**0.000**	**0.000**	-0.093**	-0.413**	-0.008	12.29	73.12	89
SWE	**0.000**	**0.000**	-0.230**	-0.146**	-0.063*	18.15	53.06	115
USA	**0.000**	**0.086**	-0.003**	-0.241**	0.017**	8.07	15.78	204

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.

Table B8. Country-specific results

Minimum % of observations required in one regime: 10%

	Test of nonlinearity (p-value)		Coefficients			Debt thresholds (%)		No obs
	lin vs 2reg	2reg vs. 3reg	low	middle	high	Low	High	
Nonlinear variable = lagged central government debt/GDP Threshold variable = lagged central government debt/GDP								
AUS	**0.040**	0.100	-0.045		-0.002	74.18		143
AUT	**0.000**	**0.000**	0.489**	0.046*	0.153*	15.24	36.45	107
BEL	**0.000**	**0.068**	-0.081**	-0.008	-0.035*	39.57	77.71	156
CAN	**1.000**	**0.000**	0.020					76
DEU	**0.000**	**0.000**	0.061	-0.068	0.258*	8.36	11.54	58
DNK	1.000	0.000	-0.016					86
ESP	**0.000**	0.220	0.102**		0.018	51.89		131
FIN	**0.000**	**0.000**	0.817**	0.097**	0.353**	9.15	26.43	82
FRA	**0.000**	**0.000**	0.335**	0.029*	0.074**	25.67	81.45	96
GBR	**0.000**	**0.098**	-0.056**	-0.008	-0.026**	43.23	135.69	164
GRC	**0.000**	1.000	0.209**		-0.005	19.54		109
IRL	**0.000**	**0.000**	-0.283**	-0.053**	-0.079**	27.84	72.58	64
ITA	**0.000**	0.268	0.206**		0.010	32.78		111
JPN	**0.000**	**0.000**	0.835**	-0.010	0.036	11.50	70.20	99
NLD	**0.000**	**0.000**	0.139**	0.024	0.056**	39.12	71.53	103
NOR	**0.000**	**0.006**	0.416**	0.249**	0.313**	24.53	33.44	115
NZL	**0.000**	1.000	0.061*		0.039**	119.43		69
PRT	**0.000**	**0.000**	-0.385**	-0.047**	-0.079**	12.29	72.45	89
SWE	**0.000**	**0.000**	0.297**	0.050**	0.158**	15.99	35.26	115
USA	**0.008**	**0.048**	1.539**	0.003	0.042**	5.69	53.46	204
Nonlinear variable = lagged rate of growth of central government debt/GDP Threshold variable = lagged central government debt/GDP								
AUS	0.146	0.052	0.068*					140
AUT	**0.000**	0.744	0.027		-0.198**	18.94		104
BEL	**0.052**	0.278	0.089		-0.021*	18.33		153
CAN	**0.000**	**0.000**	0.096	-0.135	-0.476**	45.36	77.59	74
DEU	**0.000**	**0.000**	0.073**	-0.001	-0.164**	13.43	27.20	57
DNK	**0.000**	1.000	-0.037		0.056**	40.53		83
ESP	0.326	0.004	0.001					127
FIN	**0.000**	**0.000**	0.020	-0.013	-0.113**	12.02	16.96	80
FRA	**0.000**	**0.000**	-0.043**	-0.006**	-0.241*	70.44	105.10	92
GBR	**0.046**	0.644	0.153**		0.017	38.15		161
GRC	**0.000**	**0.000**	0.059**	-0.270**	-0.003	24.57	110.74	105
IRL	**0.000**	**0.000**	-0.148**	-0.060	-0.369**	65.50	77.17	62
ITA	**0.000**	0.512	-0.136		0.075**	27.57		107
JPN	**0.000**	**0.000**	0.005	-0.293**	0.096**	54.08	70.20	96
NLD	0.904	0.000	-0.113**					100
NOR	**0.006**	0.498	0.057		-0.010	22.34		112
NZL	**0.000**	**0.000**	-0.090	-0.358	0.061	53.45	94.51	67
PRT	**0.000**	**0.000**	-0.018	-0.140	0.088	54.27	71.69	87
SWE	**0.004**	**0.000**	0.171**	-0.067	0.031	15.62	57.07	112
USA	**0.002**	**0.042**	0.000	0.035	-0.159**	17.25	33.73	201

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively. The estimations are carried out with country fixed effects.