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Abstract

This paper proposes indicators to assess government debt sustainability. Sustainable government finances can be achieved via three main channels: fiscal responses, economic growth and financial repression. The fiscal response provides information on the long-term country specific attitude towards fiscal sustainability and is estimated using Bohn (2008)'s approach. We combine the estimated fiscal response with a stochastic debt simulation and calculate the probability of debt-to-GDP ratios rising above some threshold. This is applied on historical data for seven OECD countries. In particular, the probability of debt-to-GDP ratios rising by more than 20% in the next decade clearly identifies countries that have sustainability concerns: Spain, Portugal and Iceland, from those that do not: US, UK, Netherlands and Belgium.

Keywords: fiscal policy, public debt, sustainability, interest rates
JEL Classification: E4, E6, H0, H6

1 Introduction

Defining the medium and long-term sustainability of government debt –and fiscal sustainability in general– has been one of the topics of debate in the current Euro crisis. The original sustainability norms envisaged at the creation of the European Monetary Union (EMU) were to follow the Maastricht Treaty criteria: ceilings of 3% and 60% on government deficits and debt-to-GDP ratios, respectively. However,

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these criteria have proven to be inadequate in the wake of the European sovereign debt crisis that followed the financial crisis of 2008.[1] Several countries were able to violate these criteria without consequences, while others that met the criteria have been nonetheless hit by the crisis. In particular, Spain had debt-to-GDP ratios and budget deficits well below these Maastricht limits, but has still suffered sovereign debt problems.

The objective of this paper is to find better and more informative economic measures that provide guidance on medium- and long-term fiscal sustainability.[2] We apply the sustainability analysis proposed by Bohn (1998, 2008) to distinguish the relative importance of three main channels in achieving debt sustainability in the past: fiscal reactions, real-growth and financial repression. First, a fiscal reaction function (FRF) provides information on the long-term country-specific behaviour of that country's government and its attitudes towards fiscal sustainability. A positive and significant FRF coefficient denotes a country that has been committed to reduce or maintain steady debt-to-GDP ratios conditional on short-term economic fluctuations and temporary government expenditures.[3] Second, real growth decreases the debt-to-GDP ratio directly. Third, financial repression –a term coined by Reinhart and Sbrancia (2011)– refers to circumstances where financial policies and instruments are traduced into negative or artificially low real interest rates on government bonds that erode the real value of government debt.

The main contribution of this paper is that we create two indicators to assess government debt sustainability. These indicators are the result of combining the estimated fiscal response with the stochastic debt simulation method proposed by Budina and van Wijnbergen (2008). In particular, these indicators are based on simulations of future debt levels, using the institutional attitude towards fiscal sustainability from the FRF coefficient, in addition to the historic volatility of interest and growth rates. This analysis generates a distribution of simulated debt paths, which shows the effect of fiscal responses and interest and growth rate volatility on debt-to-GDP ratios. To quantify these effects we propose two indicators. First $X_{90,j}$ is the probability that simulated future debt exceeds a threshold or debt limit of 90% within a period of $j = 10$ years. This particular debt threshold is taken from the empirical literature (Reinhart and Rogoff, 2010b; Kumar and Woo, 2012; Égert, 2012; Baum *et al.*, 2012)), which finds that above this high debt level real growth tends to decrease.[4] As an alternative we also use 60% limit from the Maastricht

[1] This debate is not new; we can learn from history that sovereign debt crises repeatedly have been following financial crises (Reinhart and Rogoff, 2008, 2010a).

[2] In that sense our paper complements Polito and Wickens (2012) who propose a short term indicator for fiscal sustainability and Bi (2011) who introduces a stochastic debt limit.

[3] In particular, a positive and significant FRF coefficient can be interpreted as a government that engages in fiscal austerity to reduce debt levels even when markets are not specifically concerned about those debt levels, nor is there international pressure (e.g. EU institutions) to reduce them. A reason for this might be that in advanced economies fiscally responsible politicians at the national level have larger re-election probabilities (Brender and Drazen, 2005, 2008).

[4] Another motivation is that the probability a sovereign debt crisis occurs increases in the debt level. Empirical work by Sturzenegger and Zettelmeyer (2007);De Paoli *et al.* (2009);

Treaty, but since most of the countries we analyse have ratios already above this level, this indicator is much less informative. Our second and preferred indicator is $X_{+20,j}$: the probability that debt increases more than 20 percentage points within a given time period of $j = 10$ years. These indicators, in combination with the evidence on previous fiscal responses, provide an important and valuable tool to assess the probability of future debt sustainability.

Given the long-term character of a fiscal response, we collected annual historic data on GDP and government finances for seven OECD countries: United States (US), United Kingdom (UK), Netherlands, Belgium, Spain, Portugal and Iceland.[5] However, in this paper we only analyse the post Second World War period.[6] We find that until the 1980s, the real growth dividend and financial repression were the main channels through which public debt was sustainable. In practical terms, this means that in this period it was not necessary to implement fiscal austerity plans to substantially reduce public debt. With financial liberalisation from the 1980s onward, however, a substantial rise in real interest rates occurred, which increased the importance of fiscal policy. We find that for the US, the UK, the Netherlands, and Belgium the fiscal response to increases in the debt-to-GDP ratio has been robust and positive for the whole sample as well as the post-war period. On the other hand, Spain, Portugal and Iceland have non-significant fiscal responses in the post-war period, which creates doubts about their capacity to reduce debt by fiscal austerity. In addition, by simulating future debt paths we demonstrate that their larger interest and growth rate variance requires a larger fiscal response to prevent debt levels from becoming unsustainable.

For the EMU countries adjustment has to come via a fiscal reaction: a high real growth dividend is not to be expected given the high development level of the economy and the difficulty of enacting structural reforms and financial repression is no longer a viable policy option within a monetary union. Thus, the importance of fiscal responses is increased for these countries. Using our two sustainability indicators: $X_{90,10}$ and $X_{+20,10}$, we can identify those countries for which debt sustainability is a concern. In particular, even when many countries have surpassed or are close to either the 60% debt ceiling of the Maastricht Treaty or the 90% threshold, our $X_{+20,10}$ indicator (the probability of debt levels increasing by 20 percentage points or more in a 10-year period) still provides valuable information on debt sustainability. Using this indicator we can easily single out those countries for which debt sustainability is problematic: Spain, Portugal and Iceland.

Furceri and Zdzienicka (2011) estimate output losses for defaulters of 2.5% to 11.1% over 2.5 to 14 years when compared to non-defaulters. Here the lower bound is for single debt crisis and the upper bound for a combined debt, financial and currency crisis.

[5] Due to large cross-country heterogeneity in fiscal policy, as well as in business cycles and temporary expenditure spells, we find that it is not informative to conduct panel-data analysis. For instance, our own panel regressions differ significantly from the country-specific regressions. These panel regression results are available upon request.

[6] The sources and length of the country-specific data is presented in the Appendix. We only use the pre-war sample as a robustness test in our main regressions.

The paper is organized in the following way: Section 2 provides a theoretical background on debt sustainability. Section 3 describes the data and our data sources. In Section 4 we elaborate on our empirical strategy and present country-specific econometric results. Section 5 describes our stochastic analysis and the debt sustainability indicators. Section 6 summarizes our main results.

2 Fiscal reaction functions and debt sustainability

We follow the methodological approach developed by Bohn (1998, 2008) to analyse debt sustainability using historical information. In essence, Bohn's approach is to equate fiscal sustainability with the stationarity of the debt-to-GDP time series – i.e. when the debt-to-GDP time series is stationary over time without a trend, one can consider that the debt-to-GDP ratio is sustainable. Most of the literature uses unit root or cointegration tests often in combination with the intertemporal budget constraint.[7] Bohn's approach is preferable to just using unit root and cointegration tests as it informs and distinguishes the channels via which debt is sustainable. Also Bohn's approach does not rely on consistency with the intertemporal budget constraint (IBC), which is not a sufficient condition for debt stationarity as it is possible to satisfy the IBC while simultaneously having a mildly explosive path of debt-to-GDP ratios (Bohn, 2007). An issue non of these approaches solves is their low power in distinguishing unit root from near unit root alternatives. In Section 5 we address this issue by using stochastic simulations.

Bohn's methodology has two main components: the accounting equation for government debt and a behavioural equation for the government's primary surplus. Both equations are connected by the use of an error-correction type specification where the primary surplus-to-GDP ratio (s) is a function of the debt-to-GDP ratio (d).[8] The starting point of his analysis is the budget accounting equation:

$$D_{t+1} = (D_t - S_t)(1 + r_t).$$

Government debt (D) at the beginning of period $t + 1$ is given by debt at the beginning of this period minus the primary surplus (S, the budget surplus excluding interest payments) over the period times the gross interest factor $(1 + r_t)$.[9]

Following the standard approach we use the debt-to-GDP ratio as our main analytical variable. This approach settles the debate concerning gross and real values, and it provides an economic meaningful scaling factor, which allows to analyse the

[7] See Afonso (2005) for a survey of these types of studies.

[8] In the rest of the paper upper case variables denote nominal values and lower case variables denote the nominal value to GDP-ratio.

[9] The use of historical data in Bohn's analysis also implies that we do not have to calculate or estimate risk premia in interest rates or GDP growth rates, as our historic data already incorporate these risk premia. For example, the risks that an ageing population poses to the sustainability of government finances (European Commission, 2009) are assumed to be incorporated in the risk premia and thus in the interest rates. Throughout this paper, interest rates thus refer to effective interest rates defined as the proportion of interest payments to the overall government debt level.

relative importance of public debt. Therefore, we re-write the budget accounting equation in GDP-ratio form:

$$\frac{D_{t+1}}{Y_{t+1}} = \left(\frac{D_t}{Y_t} - \frac{S_t}{Y_t}\right)(1 + r_t)\,\frac{Y_t}{Y_{t+1}},$$

which can be simplified to:

$$d_{t+1} = \frac{1 + r_t}{1 + y_t}(d_t - s_t), \tag{1}$$

where r is the real interest rate and y is the real GDP growth rate.[10] Note that for the derivation of Equation (1), we can also use nominal interest and GDP growth rates since inflation cancels out in the difference.

From this accounting equation we see that the evolution of the debt ratio is driven by the error-correction component $(d_t - s_t)$, which we estimate using a fiscal reaction function, and a parameter γ that summarizes the relationship between interest rates, growth rates and inflation:

$$\gamma_t = \frac{1 + r_t}{1 + y_t} \approx 1 + r_t - y_t. \tag{2}$$

We depart slightly from Bohn's classification[11] by combining these debt determinants into three groups:

- Fiscal reactions. These are captured by the estimated coefficient of the fiscal reaction function (FRF) and provide information on the historical fiscal reaction of governments (i.e. changes in primary surpluses) to changes in the debt-to-GDP ratio. These fiscal reactions are likely to be persistent and informative as in advanced economies fiscally responsible politicians at the national level have larger re-election probabilities (Brender and Drazen, 2005, 2008).

- Real growth dividend. This term has a beneficial effect on the debt-to-GDP ratios when real GDP growth is positive and sustained over time. Therefore, this term groups governmental policies –such as structural reforms– and external factors –such as foreign demand– on the real economy that have a medium- to long-term effect on real growth rates.

- Financial repression. Reinhart and Sbrancia (2011) define this term as prolonged periods with negative real interest rates. In our paper, however, financial repression is defined as the difference between the nominal interest and the inflation rate (i.e. the real effective interest rate on government debt). Thus, this category groups the monetary and financial policy instruments available to governments to reduce debt levels.

[10] Nominal interest rate is given by $R \approx (1 + r)(1 + \pi) - 1$, where π is inflation estimated from the GDP deflator. We approximate $r \approx R - \pi$.

[11] Bohn defined "growth dividend" as the difference between real interest rates on government debt and real GDP growth rates.

If economic growth y is larger than the interest rate r, then $\gamma < 1$ and the debt-to-GDP ratio decreases over time, in the absence of a fiscal response. If not, debt sustainability depends on the fiscal reaction function: primary surpluses should be sufficiently large relative to the debt-to-GDP ratio to arrive at a stationary debt-to-GDP level.

The second part of Bohn's methodology, therefore, consists in estimating the FRF. Estimation of the error-correction behavioural specification $(d - s)$ indicates whether the government increases its primary surplus as a reaction to changes in the debt-to-GDP ratio. In particular, we have to estimate the following regression:

$$s_t = \alpha + \rho d_t + \beta \mathbf{Z}_t + \varepsilon_t, \tag{3}$$

where ρ is the fiscal reaction parameter, $\mathbf{Z}_t$ is a set of other primary surplus determinants and ε_t is an error term. This specification tells us how governments react to debt accumulation given a structure of shocks occurring in the background. The use of $\mathbf{Z}_t$ is crucial to account for shocks and it consists of two variables: GVAR is a measure of temporary government spending (e.g. military expenditure during war periods) and YVAR measures cyclical fluctuations in output (e.g. business cycles). The presence of these shocks makes it difficult to detect if d is stationary. Including these variables, hence, is crucial for the results in Bohn (1998). To underpin the use of these variables, Bohn uses the classical tax-smoothing theory of Barro (1979), where temporary government expenses and the effects of business cycle slow downs should be financed by a higher budgetary deficit.

Substituting equation (3) in (1) yields:

$$d_{t+1} = \gamma_t (1 - \rho) d_t - \gamma \left(\alpha + \beta \mathbf{Z}_t + \varepsilon_t \right). \tag{4}$$

Now debt sustainability becomes a function of γ and ρ. We summarize this information with the parameter δ, and we distinguish three cases:

$$\delta = \gamma(1 - \rho) = (1 + r - y)(1 - \rho) \tag{5}$$

- $\delta < 1$ implies stationary debt-to-GDP ratios.[12] This can be achieved by different combinations of fiscal response ($\rho > 0$), financial repression ($r < 0$) and/or the growth dividend ($y > 0$).

- $\delta > 1$ but with $0 < \rho < r - y$ implies mildly explosive paths for debt-to-GDP ratios (but growing slowly enough to be consistent with IBC).[13]

[12] Bohn (1998) uses this equation to argue that the coefficient estimates of equation (3) are unbiased. He assumes that γ and $\alpha + \beta \mathbf{Z}_t + \varepsilon_t$ are stationary and continues be stating that if $(1 - \rho)\gamma < 1$ then d should be stationary. If d is stationary, the debt-to-GDP ratio follows a autoregressive process with near unit root behaviour and OLS coefficient estimates are unbiased. If $(1 - \rho)\gamma > 1$, coefficients and specifically ρ may be biased towards zero, which makes debt look even more non-stationary.

[13] $\rho = \frac{\gamma - 1}{\gamma}$ implies a difference-stationary debt that satisfies the unit root and cointegration conditions (this is the most studied scenario in the unit root literature). See Bohn (2007) for a formal proof.

- $\delta > 1$ with $\rho < 0$ and $r - y > 0$ characterizes exponentially growing debt. It also suggests that the government disregards debt when setting fiscal policy and thus, raises doubts about its creditworthiness.

Most of the literature concludes that if there is any corrective action ($\rho > 0$), debt (and fiscal policy in general) is sustainable as it satisfies the intertemporal budget constraint. This methodology is also referred to as examining fiscal reaction functions or model-based sustainability. However, we follow Bohn (1998, 2008) in placing the border between sustainable and unsustainable fiscal policy at the requirement to have a stationary process for debt-to-GDP ratio. Because if mildly explosive debt paths are allowed, the fiscal response required (ρ times d) to keep on this mildly explosive debt path is increasing in the debt level d and thus mildly explosive as well. Requiring $\delta < 1$ excludes the second case and is used by Ghosh *et al.* (2011) as well.

Requiring a stricter condition on sustainability makes the features of the FRF test not less convenient. Mendoza and Ostry (2008) describe two benefits and a number of possible limitations in detail. First, since asset pricing applies to all kinds of financial assets, the test does not require particular assumptions about debt management, or the composition of debt in terms of maturity and/or denomination structures. And second, that the FRF test does not require knowledge of the specific set of government policies on debt, taxes and expenditures. The FRF test determines whether the outcome of a given set of policies implicit in the past primary balance and debt data is in line with fiscal solvency, without knowing the specifics of those policies. A clear caveat to the FRF test is that it provides limited information when severe and fully unanticipated shocks occur, such as an unexpected shut down in the credit markets or a surprisingly large negative shock to the primary balance. Also, the required ρ must be larger in case of non-complete markets of state-contingent claims with precautionary saving behaviour to accommodate for the tighter debt limits imposed by these precautionary savings. A final important property is that a time-invariant conditional response of the primary balance to the debt level alone is a sufficient but not a necessary condition. A non-linear and/or time varying response can also generate fiscal solvency as long as the response is strictly positive above a certain debt-to-GDP threshold ratio. This implies that countries without a positive ρ and with $\gamma > 0$ not necessarily have unsustainable government finances. Theoretically, they could have a response that kicks in at some higher, not yet reached, debt level or specific set of government policies that will likely improve primary surplus in the future. In practical terms, this refers to non-linear relationships in equation (3), for which we test. To conclude, despite the limitations, testing for a positive FRF is an attractive strategy in assessing sustainability of government finances.

3 Data

We use the following time series: nominal GDP, real GDP, GDP deflator, gross debt, primary surplus, interest payments on gross debt[14] and government expenditures. YVAR is obtained from the real GDP series and GVAR from government expenditures as a percentage of GDP. The sources and the assumptions we made while preprocessing the data are described in the Appendix A.[15]

We have chosen to include the latest available data for all countries, except Iceland, which ends in 2007. This is done to avoid a significant change of the ρ coefficient due to the collapse of the banking system in 2008 and 2009, which is unrelated to fiscal policy. For the other countries the estimated ρ coefficients did not change significantly when the financial crisis is removed. Whenever possible we use gross debt, as this is the amount of debt that is relevant when examining the threat of a sovereign debt crisis, and general government data instead of central government data, as the general government is in the end accountable for all government liabilities.

To identify periods with financial repression, in Figure 1 we plot nominal interest rates against inflation (estimated from the GDP deflator). Financial repression was present in all countries until at least 1980. This is consistent with the findings in Reinhart and Sbrancia (2011). Financial repression was largest for Iceland and Portugal and took place there until the early nineties, and thus, government debt was very low until the early nineties as a result.

In Figure 2 we include the real growth rates in the post-war period for all countries. We observe that real growth rates have been on steady decline for all countries in this period. Spain and Portugal, however, experienced a growth boom in the 1960s, while Iceland did so in the late 1970s. Finally, in Figures 4 to 7 in the Appendix we show the time series for the debt-to-GDP ratio, the primary surplus to GDP ratio, and the γ parameter for all seven countries for the post-war sample. In addition, we show the military expenditure for the US and the UK.

[14] Or the budget balance and the interest payments, after which we can obtain the primary surplus.

[15] Table 4 presents a short summary of the available data, while Table 5 presents summary statistics and correlation coefficients of the data per country. Furthermore, we performed unit root tests on all the time series for all countries used in the analysis and were able to reject the presence of a unit root for all variables, except the debt-to-GDP ratio series. However, the use of this variable in our regressions has already been justified in Section 2. These unit-root tests are available upon request.

Figure 1: Financial repression: interest rates minus inflation, for seven countries in the post-war period

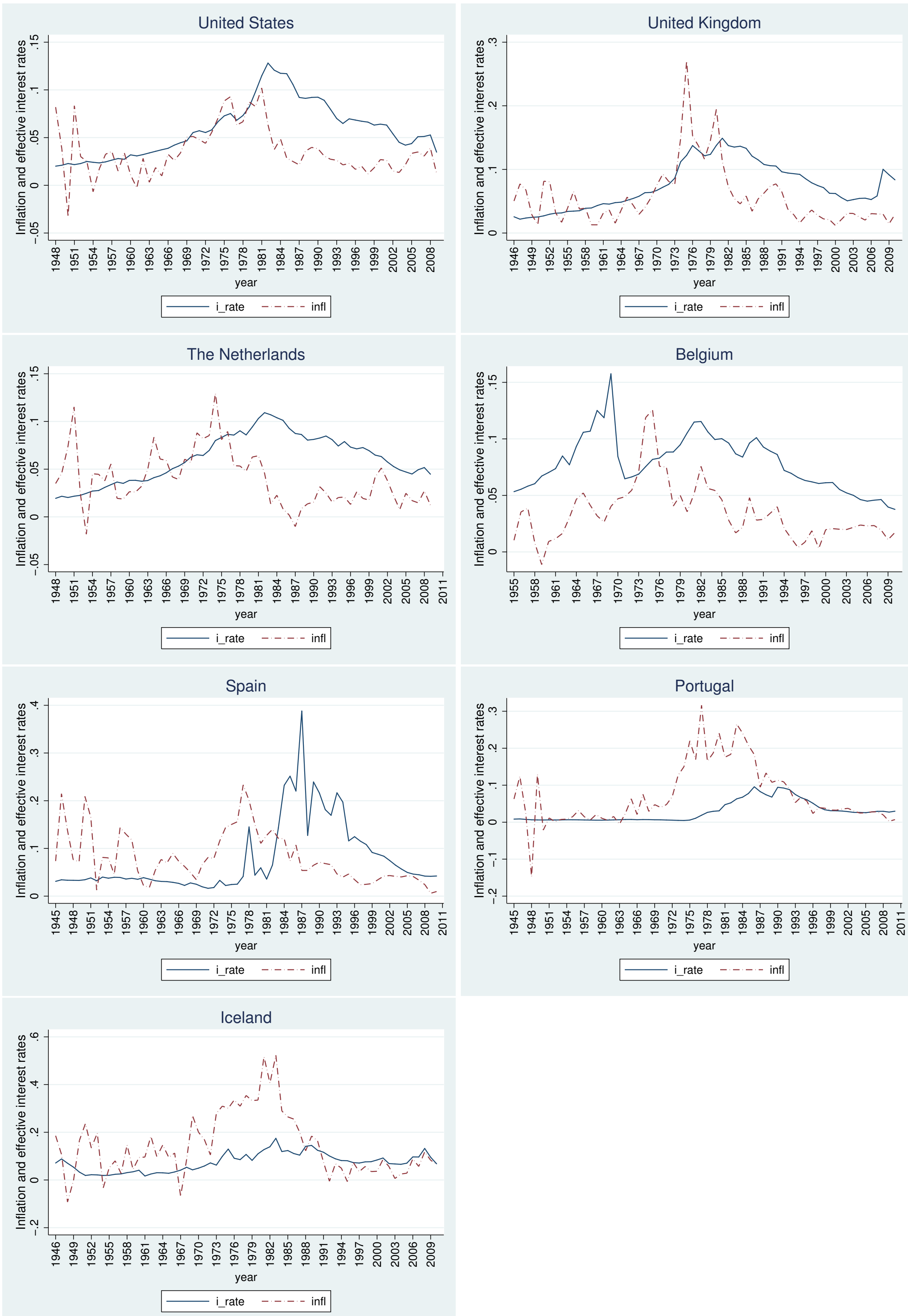


Figure 2: Real growth rates for seven countries in the post-war period

4 Estimating fiscal reaction functions

Our empirical strategy is straightforward and consists of two main components. First, we calculate the average values for the real interest rates and real growth rates and use these values to obtain γ from equation (2). Second, we estimate equation (3) for all countries to obtain the fiscal response parameter ρ. With both sets of information we can then estimate δ as defined in equation (5). Using this information we analyse if government finances have been sustainable and if it was due to prudent fiscal policy, financial repression or real growth.

We estimate all the regressions using both OLS and autocorrelation and heteroskedasticity consistent estimators. We estimate the post-war period[16] and we only present the multivariate regressions including the indicator of fluctuations in income growth (YVAR) and fluctuations in government expenditures (GVAR) as control variables, given the importance of these two variables for the analysis (cf. Bohn, 1998).[17]

Analogous to Bohn (2008), we use an HP-filter ($\lambda = 100$) to extract the trend component of log real GDP and define YVAR as the gap between the actual value and this trend in percentage points of GDP.[18] For the UK and the US, where military spending drives temporary government spending, we define GVAR as the military spending-to-GDP ratio. This is comparable to Bohn (2008) who defines GVAR as the gap between a permanent component of military outlays to GDP from an estimated AR(2) process and the actual values. Our approach probably overestimates temporary military spending by a constant term, which likely has no impact on ρ. For all other countries we use the cyclical component of government spending as GVAR, obtained analogously to YVAR.[19]

These multivariate regressions are the main component of our empirical analysis. However, we also check the robustness of these results. We include the real interest rate as an explanatory variable in equation (3).[20] The intuition is that the primary surplus can also react to changes in real interest rates. First, the government faces less pressure to reduce the debt with fiscal responses, when financial repression is strong enough to generate negative real interest rates. And second, high real interest

[16] The estimations for the full sample are presented as a robustness check in Appendix C. We also used Bai and Perron (1998, 2003) tests for endogenous structural breaks after the Second World War. The resulting sub-samples, however, are usually too short to estimate a stable fiscal reaction function that can assess the long-run institutional stance towards fiscal sustainability. In that case ρ picks up short-term policy fluctuations and is not suitable for our analysis.

[17] The univariate regressions are available upon request.

[18] A more sophisticated way is to estimate potential GDP first and then define the difference between actual and potential GDP as the output gap. This is used by the OECD (2005). We do not apply this method due to data limitations and because the structure of the economy likely changed over the centuries. In any case, our estimations generate comparable results to those in OECD (2005), so the potential measurement error is probably small.

[19] Mendoza and Ostry (2008) also use this approach. Their results are robust under a sensitivity analysis using other specifications.

[20] We also included inflation as an additional variable but it was not significant for most regressions, and when it was significant it did not change the main results.

rates can also force the government to apply fiscal austerity, even when the debt-to-GDP level is not that high. In the case of the US, Bohn (1998) found that interest rates are not a significant control variable.

We also examine whether the response of the primary surplus to an increase in the debt-to-GDP ratio is non-linear. There are different ways, however, to interpret these non-linearities. On one hand, non-linearities may arise because –above a certain debt-to-GDP ratio– the incentives for policy makers to increase the primary surplus are missing, causing a debt overhang problem. This concept was first introduced by Krugman (1988) and confirmed empirically by Callen *et al.* (2003) and Mendoza and Ostry (2008) for governments of emerging market economies. On the other hand, non-linearities may arise because policy makers get increasingly nervous about the possibility of losing access to capital markets. In that case there are larger fiscal responses at higher debt levels. For instance, In addition, high debt levels can raise financing difficulties for the government or have a detrimental effect on economic growth (Reinhart and Rogoff, 2010b; Kumar and Woo, 2012; Égert, 2012; Baum *et al.*, 2012). Bohn (1998, 2008) finds that for the US the conditional response of primary surplus to debt is stronger when the debt-to-GDP ratio is high by historical standards.

We test for non-linearities using two approaches. First, we add the quadratic terms: d_t^2 and $(d_t - \overline{d})^2$ as explanatory variables in equation (3), where $\overline{d}$ is the mean value of d. Second, we examine if the fiscal response is different above a certain level of debt-to-GDP. To test this we create three dummy variables: $dmax$, $dmax_{40}$ and $dmax_{60}$, where $dmax = 1$ if the debt-to-GDP ratio is above the historical debt average, and otherwise $dmax = 0$. Accordingly, $dmax_{40}$ and $dmax_{60}$ are equal to one if d is above 40% and 60%, respectively. We add each additional variable separately in equation (3), but only present the results for d_t^2 and $dmax_{60}$.

The country specific results are summarized in Table 1. The first part of this table presents a summary of the multivariate regression results (Tables 6 to 12 in the Appendix show the full econometric results). For the US, the UK, the Netherlands (NL) and Belgium (BE) the fiscal reaction coefficient (ρ) is positive and significant for the post-war sample. This shows that these governments have significant and strong fiscal responses to increases in the debt-to-GDP ratio, once we control for the business cycle (YVAR) and temporary expenditures (GVAR). For Spain (SP), Portugal (PT) and Iceland (IC) the fiscal response is positive, but not significant. Furthermore, when using non-linear specifications we find that for the United States and for the Netherlands the response to square debt is positive and significant. This means that the US and Dutch governments have a stronger fiscal response when debt-to-GDP ratios are above their historical average and/or above 60%. On the other hand, the non-linear coefficients are negative for Spain, Portugal and Iceland and significantly so for Spain and Portugal. In the last case, this creates additional doubts about the fiscal sustainability of these countries. In addition, these regression results are robust to the inclusion of the real interest rates, a re-definition of the interest rates for Portugal and an alternative definition of GVAR for the US, the UK and the Netherlands.[21]

Table 1: Summary of estimated coefficients, average values and the δ-parameter, for all countries in the post-war sub-sample.

	US 1948-2009	UK 1946-2009	NL 1948-2010	BE 1955-2010	SP 1946-2010	PT 1945-2010	IC 1946-2007
Estimated coefficients from linear regressions:							
ρ	0.090 ***	0.045 ***	0.074 ***	0.038 ***	0.048	0.003	0.014
yvar	0.373 **	0.258	0.341 **	0.620 ***	0.348 **	0.069	0.213 *
gvar	-0.118	-0.209 ***	0.069	-0.103 ***	-0.025	-0.042	-0.090 ***
constant	-0.024 **	-0.004	-0.026 ***	-0.016	-0.010	-0.009	0.010 **
Estimated coefficients from non-linear regressions:							
debt_sq	0.255 *	0.009	0.141 ***	0.144	-0.684 ***	-0.245 ***	-0.139
debt_60	0.045 *	-0.005	-0.015	-0.035	-0.080 ***	-0.048 ***	-
Average values:							
$\bar{r}$	0.020	0.018	0.022	0.044	-0.002	-0.044	-0.073
$\bar{y}$	0.029	0.023	0.035	0.028	0.042	0.039	0.058
$\bar{\gamma}$	0.991	0.995	0.987	1.016	0.958	0.920	0.869
Summary measure:							
δ	0.902	0.950	0.914	0.978	0.958	0.920	0.869

Notes: Average values for the real interest and real growth rates come from Figure 1, the full regression results are shown in Tables 6 to 12. Significance levels: *** p<0.01, ** p<0.05, * p<0.1 (computed using heteroskedasticity- and autocorrelation-consistent standard errors with Newey-West lag window of size 1). Dependent variable is the primary surplus to GDP ratio. Explanatory variable "YVAR" is the gap between log real GDP and its trend and "GVAR" is the gap between log of government expenditures and its trend for Netherlands, Belgium, Spain, Portugal and Iceland. Both trends are extracted using an HP-filter (lambda=100). "GVAR" equals military expenditure for the US and the UK.

In the middle part of Table 1 we summarize the information on average values that is presented in Figures 4 to 7. We observe that average real growth rates exceed real interest rates in all countries except Belgium in the post-war period. For Spain, Portugal and Iceland we find strong financial repression for most of the post-war period. For the US, the UK and the Netherlands financial repression took only place until the early 1980s and in Belgium there was no financial repression. This means that –for all countries except Belgium– government debt in the post-war

[21] Marinheiro (2006) constructed interest rates for Portugal which are about three percentage points higher on average than the ones estimated using actual interest payments. Our results do not change qualitatively using this alternative. However, the main results do not change. For the US and the UK we estimated GVAR alternatively as the gap between log of government expenditures and its trend extracted via an HP filter, for the Netherlands we used gas revenue as a proxy for GVAR following Wierts and Schotten (2008).

period was made sustainable as a result of financial repression (for part or the whole period), and thus, strong fiscal responses were not required in most countries.

Finally, in the bottom part of Table 1 we present the δ-parameter, which combines the regression results of the FRF with the historical averages. Recall that government finances are deemed sustainable if $\delta = \gamma(1-\rho) < 1$. If ρ is significantly positive and $\rho > (\gamma - 1)/\gamma$ then debt-to-GDP ratios are sustainable due to fiscal responsibility. If $\gamma < 1$ then this can be due to financial repression, the growth dividend, or a combination of both. From Table 1 we find that this parameter is smaller than one for all countries, implying debt sustainability. However, these post-war results do not assure that debt is or will be sustainable for all these countries in the near future. In particular, with the end of financial repression, which is not even feasible for members of the European monetary union, the importance of fiscal responses has greatly increased. Therefore, those countries with non-significant ρ parameters may have difficulties to maintain debt-to-GDP ratios at sustainable levels. This is made clear by analysing the behaviour of interest rates after the 1980s, when financial repression ended for most countries in our sample (see Table 2). Hence, the increase in real interest rates increases γ substantially and makes it necessary to have a strong fiscal response to keep government debt under control. Moreover, the absence of a linear fiscal response, in conjunction with a negative quadratic fiscal response for Spain, Portugal and Iceland rises the concern that debt may not be sustainable in these countries.

Table 2: Average interest rates, growth rates and γ-parameter for 1987-2010.

	US	UK	NL	BE	SP	PT	IC
$\overline{r}$	0.039	0.044	0.046	0.043	0.077	-0.002	0.022
$\overline{y}$	0.026	0.022	0.025	0.021	0.032	0.027	0.038
$\overline{\gamma}$	1.012	1.021	1.020	1.022	1.044	0.972	0.984

5 Stochastic debt sustainability indicators

The probability distribution of future debt levels is important in assessing fiscal sustainability. Higher interest and growth rate volatility increases the distribution of future debt levels and requires a larger fiscal response to keep government debt under control. To assess this relationship we extend the results in the previous section – where we used a simple historical average for γ– by simulating future interest and growth rate values, which in turn provide a probability distribution for future debt-to-GDP levels. We insert the simulated interest and growth rates into equation (4) and use that $E(\mathbf{Z_t}) = E(\varepsilon_t) = 0$ by construction.

$$d_{t+1} = \gamma_t(1-\rho)d_t - \gamma_t\alpha, \tag{6}$$

The expected steady state future debt level can be obtained by writing equation (6) as a differential equation as in Haselmann *et al.* (2002):

$$\Delta d_{t+1} = -\left[1-\gamma(1-\rho)\right] d_t - \gamma\alpha, \tag{7}$$

and solving for its steady state. The stationarity conditions are those from Section 2. For $\delta > 1$ no stable condition exists, while for $\delta < 1$ debt is stationary and converges towards $\overline{d} = (1-\gamma(1-\rho))^{-1}\gamma\alpha$. For $\alpha > 0$ the stabilizing debt level is negative (i.e. in the long run this government will have more assets than liabilities) and for $\alpha < 0$ the stabilizing debt level is positive. All the countries in our stochastic analysis converge towards a stable positive debt level with γ from Table 2 and ρ and α from Table 1.[22] For $\rho = 0$ only Portugal and Iceland have a stationary debt level. Divergence occurs slow however, only the UK and Spain present clearly explosive debt paths when $\rho = 0$. When we set $\rho = 0$ in our simulations below we use α equals the average primary surplus $\overline{\text{ps}}$. Changing the constant increases the projected median debt-to-GDP ratios at any given future date, with the Netherlands being the only exception. This occurs because the fiscal reaction coefficient reacts to both increases *and* reductions of the debt level from its long-run average.[23]

In simulating interest and growth rate volatility, we follow Budina and van Wijnbergen (2008) and use a stochastic two variable VAR model for real interest and growth rates to capture the historic volatility of interest and growth rates:

$$\begin{aligned} \begin{pmatrix} r_t \\ y_t \end{pmatrix} &= \alpha_0 + \sum_{j=1}^{\infty} A_j \begin{pmatrix} r_{t-j} \\ y_{t-j} \end{pmatrix} + \eta_t, \\ \operatorname{var}(\eta_t) &= \mathbf{\Sigma}. \end{aligned} \tag{8}$$

In this set-up shocks to real interest and growth rates are not correlated over time but are correlated within the same time period.[24] We run the simulations 10.000 times to obtain a debt path from 2010 to 2029 for two scenarios: one with $\rho = 0$ and another with $\rho > 0$.[25] For the US, UK, Netherlands and Belgium, which have positive and significant ρ coefficients we use the post-war coefficient values. For

[22] Iceland is an exception, it converges towards a negative debt level.

[23] The Netherlands had a relatively stable debt level of around 60% of GDP in the post-war period (see Figure 5 in the Appendix) and without a fiscal response its median projected debt level is declining steeply (due to the steady-state long-term conditions given by changes in r and y). Hence, the inclusion of the fiscal response "stabilizes" its debt level around its post-war average of 60%, and this results in the projected median debt level being lower with $\rho = 0$ than with $\rho > 0$.

[24] Equation (8) is estimated for each country using 1987 as a starting point. In this way we avoid using the historically low real interest rates levels when financial repression was present. The exception is Belgium for which we used historical debt and primary surplus from the post-war sample since it was the only country in our sample that did not rely on financial repression to make its fiscal policy sustainable post-war and Belgian debt peaked in 1987, so post-1987 data gives a skewed impression. In addition, we set the number of lags in equation (8) to two following the Akaike information criterion.

[25] For time $t+1$ we insert the realizations of time t and the shocks of time $t+1$ into equations (6) and (8), for time $t+2$ we use the just simulated realizations of time $t+1$ and the shocks of time $t+2$ as inputs and so on and so forth.

Spain, Portugal and Iceland, which did not have significant ρ coefficients in the post-war sample, we use $\rho = 0.04$ for illustrative purposes. The 95% and 99% debt quantiles are plotted in fan charts in Figures 8 and 9 in the Appendix.

In equation (6) fiscal policy for $\rho > 0$ responds to a deviation in the debt level from $\overline{d}$, which is its historical average. Shocks in interest and growth rates that drive the debt level away from $\overline{d}$ are thus in the subsequent period countered by a fiscal response. Similarly, shocks that drive the debt level towards $\overline{d}$ are mitigated by a smaller fiscal response. This effect is stronger if ρ is bigger relative to the interest and growth rate volatility. We observe this from From Figures 8 and 9 in the Appendix. The debt levels have relatively small 90% and 95% confidence bands for the first set of countries: the US, UK, Netherlands and Belgium. For the second group –Spain, Portugal and Iceland– these confidence bands are larger. From Figure 9 it is clear that the imposed values of $\rho = 0.04$ are not sufficiently large for Spain, Portugal and Iceland.

A positive and significant fiscal response has two main effects on our debt projections. First, it directly contributes to sustainable fiscal policy by lowering expected future debt levels. Second, it reduces the impact of uncertainty on interest and growth rates, which results in narrower confidence bands. To indicate both we develop a debt sustainability indicator $X_{\bar{d},j}$ which is defined as follows:

$$X_{\bar{d},j} = \frac{\Sigma_k I\left(\{d^k_{t+1}, \ldots, d^k_{t+j}\} > \bar{d}\right)}{k}, \tag{9}$$

where $I() = 1$ if $d_{t+i} > \bar{d}$ for $1 \leq i \leq j$ and d^k_{t+j} is simulation number k. As fixed debt threshold levels we choose the 60% of the Stability and Growth Pact, which gives the indicator: $X_{60,10}$, and the 90% of Reinhart and Rogoff (2010b) that provides the indicator $X_{90,10}$. We also calculated $X_{+20,10}$: the probability debt increases more then 20%-points between a 10-year period (in this case from 2010 to 2019).

We present a summary of our stochastic simulation results in Table 3. For the first group of countries: US, UK, Netherlands and Belgium, we find that both $X_{90,10}$ and $X_{+20,10}$ are zero or have extremely low values (with the exception of $X_{90,10} = 1$ for Belgium, given that this country is already above this threshold in 2009). In the case of the UK, the fiscal response is extremely important. Without a significant fiscal response the probability of the UK increasing it debt beyond 90% or experiencing an increase of 20% increases from almost zero to around half. For the other three countries of this group, recent low volatility in interest and growth rates yield relatively narrow confidence bands.

For the second group of countries: Spain, Portugal and Iceland we find that both sustainability indicators have high values. The possibility of a 20 percentage point increase in the debt-to-GDP ratio in Spain is around 60% and 25% in Portugal. Iceland already surpassed the 90% debt ceiling but has a 0.18 probability of increasing its already high debt levels in 20 additional percentage points. We can also observe that if these countries had a positive ρ value, these probabilities are significantly reduced, although they still remain well above zero.

Table 3: Summary of simulation outcomes for debt-to-GDP ratios in 2019.

	2009	2019 with $\rho > 0$			2019 with $\rho = 0$		
	d	d	$X_{90,10}$	$X_{+20,10}$	d	$X_{90,10}$	$X_{+20,10}$
United States	0.53	0.50	0.00	0.00	0.59	0.00	0.00
United Kingdom	0.68	0.77	0.02	0.03	0.89	0.47	0.56
Netherlands	0.57	0.58	0.00	0.00	0.58	0.00	0.01
Belgium	0.96	0.90	1.00	0.00	0.94	1.00	0.00
Spain	0.46	0.60	0.10	0.46	0.67	0.20	0.58
Portugal	0.76	0.76	0.21	0.11	0.84	0.40	0.25
Iceland	0.92	0.69	1.00	0.05	0.83	1.00	0.18

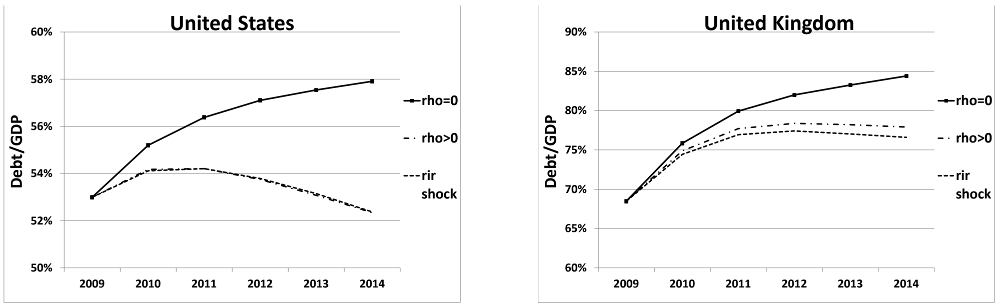
Notes: d stands for debt-to-GDP ratios, $X_{90,10}$ is the probability that debt reaches 90% of GDP and $X_{+20,10}$ is the probability that the debt-to-GDP ratio has increased by 20% or more by 2019. The gray areas are the country-specific relevant values, since from our regression results we find that the first four countries have $\rho > 0$, and the last three have $\rho = 0$.

In general, we know that fiscal responses are not the only mechanism to reduce debt levels. But from our empirical results, it is clear that a positive and significant FRF coefficient is crucial for debt sustainability, specially with countries where financial repression is no longer a viable policy option. As a way to illustrate the relative importance of fiscal and monetary policy, we compare the impact of including $\rho > 0$ with a reduction of the real interest rates (rir) by 2 percentage points in the US and the UK (two countries outside the EMU). This rir can be associated with financial repression and/or the use of monetary policy to decrease the effective real interest rate paid on governmental bonds.[26] As can be observed from Figure 3, in the US the reduction in the rir has an equivalent effect as applying their historical fiscal reaction coefficient (i.e. a ρ value around 9%). For the UK the rir shock has a bigger effect than the fiscal response (which has a ρ value around 5%). Although this is a simplistic exercise, it allows a crude comparison between the impact of fiscal and monetary policies on debt dynamics.

Finally, if we were to use the Maastricht criteria, we find that most countries in our sample have exceeded or are very close to the 60% debt ceiling. Thus, this criteria does not provide much economic information on debt sustainability. On the other hand, our $X_{90,10}$ and $X_{+20,10}$ indicators do provide more insights into probable future debt developments and we can single out those countries for which debt sustainability is a concern: Spain, Portugal and Iceland. In particular, our $X_{+20,10}$ debt sustainability indicator is independent from current debt levels, and as such, provides information for those countries that have exceeded certain debt thresholds.

[26]Note that EMU countries could also achieve a common real interest rate shock conditional on country-specific inflation rates. However, there are political and coordination issues that make this option more difficult to achieve than for individual countries outside the EMU.

Figure 3: Stochastic median debt projections, for the US and the UK from 2010 to 2014 with a real interest shock (rir shock), with a positive fiscal reaction ($\rho > 0$) and without ($\rho = 0$)



6 Summary and conclusions

Using historical data on public finances for seven OECD countries, in combination with the empirical methodology developed by Bohn (1998, 2008), we identify the three main channels through which governments can reduce the debt-to-GDP ratio. These case studies lead to the conclusion that using estimated fiscal reaction coefficients –in conjunction with the viability of a country to apply financial repression and/or increases average real growth rates– provides crucial information to assess debt sustainability. These fiscal reaction coefficients reflect country-specific institutions and attitudes towards debt sustainability that are essential to understand their prospects to effectively reduce debt levels in the medium term. In doing so, it is necessary to take a sufficiently long time period and to examine the existence of non-linearities.

We find that four countries: the US, UK, Netherlands and Belgium have persistently positive and significant fiscal reaction coefficients, conditional on temporary government spending (e.g. war expenditure) and cyclical economic fluctuations. These strong fiscal responses are found in both the full sample and also in the post-war period. Together with average moderate real growth rates (and high rates in some countries for some periods) and financial repression, these countries have experienced sustainable debt-to-GDP ratios over time. In particular, from the end of the Second World War to around the mid-1970s, the use of effective financial repression mechanisms in these countries allowed for drastic reductions in the debt-to-GDP ratio, which had reached significantly high levels due to military expenditures during the Second World War (specially in the US and UK). After the mid-1970s with the end of financial repression and lower real growth rates, these countries relied increasingly on fiscal responsibility (i.e. moderate primary surplus to GDP ratios) to maintain debt at sustainable levels. The role of fiscal policy has become even more important for those countries that belong to the euro area, and which do not have autonomous monetary or exchange rate policies. Debt sustainability in these countries is clearly reflected in the extremely low values in our $X_{+20,10}$ indicator.

On the other hand, for Spain, Portugal and Iceland, we do not find significant fiscal reaction coefficients. With the end of financial repression, this means that these countries are less prepared to maintain sustainable debt levels in the future. Our debt sustainability indicators: $X_{+20,10}$ and $X_{90,10}$ clearly identify this weakness in the debt dynamics of these countries by providing large positive probabilities (sometimes above 50%).

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Appendix

A Data sources and pre-processing

Under the subsequent country headings we describe our data sources, elaborate on the definitions used (general/central government) and whether breaks in the data are present. Table 4 presents a summary of the available data for each country.

Table 4: Available data per country

Country	Samples			Observations
US	1792-2009			218
UK	1691-2009			319
Netherlands	1816-1939	1948-2009		186
Belgium	1830-1913	1919-1939	1955-2009	158
Spain	1850-1935	1940-2010		157
Portugal	1852-2010			159
Iceland	1908-2010			103

In Figures 4-7 we plot the debt-to-GDP ratio, the primary surplus to GDP ratio, a smoothed series of interest minus growth rate and for the UK and the US the GVAR indicator.

As the effective interest rate we use the simple formula: $i_t^e = ip_t/d_{t-1}$ where i^e is the effective interest rate and ip is interest payment on debt d, both in nominal terms.[27]

United States

We use the data from Bohn (2008) from 1792-2009.[28] This is a continuous dataset on nominal and real GDP, government gross debt, government primary surplus, government interest expenditure and government military expenditure. A detailed description of the data used there can be found in Bohn (1991) and Bohn (2008), and references therein.

Government military expenditure is used as an indicator for temporary government spending GVAR as government expenditure in wartime is significantly different from government spending in peacetime. Using dummy variables for the war years[29] instead of actual military expenditure does not change the results significantly.

[27] This simple formula is almost perfectly correlated (0.9975) with a more precise specification given by: $i_t^e = \frac{ip_t}{2}\left(\frac{d_t}{\left(\frac{p_t}{p_{t-1}}\right)^{\frac{1}{2}}} + \frac{d_{t-1}}{\left(\frac{p_t}{p_{t-1}}\right)^{\frac{1}{2}}}\right)^{-1}$ where p is the GDP deflator.

[28] Henning Bohn kindly provided us with an updated database which runs until 2009. He used the 2011 Budget of the United States for this update.

[29] 1812-1815 War of 1812, 1846-1849 (Mexican-American War), 1861-1865 (American Civil War), 1917-1920 (World War I), 1940-1945 (World War II)

UK

The sample from the UK is from 1692-2010 with a break in 1800 and in 1946. There is a shift in the reporting year in 1800, prior to 1946 we use central government data and after 1946 we use general government data. We use military expenditure as a proxy for temporary government spending and there is a break in this series in 1980 probably due to a different specification. Prior to 1946 military expenditure and interest expenditure are the only two large items on the central governments budget. Non-military non-interest spending never exceeds 2% of GDP.[30] Data is obtained from six sources:

- Data on central government expenditure (1692-1945), interest expenditure (1692-1945), military expenditure (1692-1980), revenue (1692-1946), public debt (1692-1979), CPI as a proxy for the GDP deflator (1691-1792), a GDP deflator (1830-1946) and nominal GDP (1830-1946) has been obtained from Michell (1988).

- From Peacock and Wiseman (1961) real and nominal GDP is obtained for the years 1792, 1800, 1814, 1822, 1831. Constant growth rates in real and nominal GDP are assumed between these dates.

- Real GDP for 1700 and 1800 is obtained from Maddison (2003) world historic tables. Constant growth rates in real GDP is assumed between 1700 and 1792 and in the period 1691-1700.

- General government expenditure, interest expenditure, revenue and real and nominal GDP from 1946 onwards is obtained from the Office of National Statistics

- Public debt is obtained from the UK Ministry of Finance for 1980-2010

- Military expenditure for 1980-2010 is obtained from the OECD.

A GDP deflator and real GDP from 1692-2010 is obtained by coupling the various partial GDP series with each other. Furthermore GDP has been adjusted such that Ireland is excluded prior to 1920 as it is after 1920. Temporary government expenditure GVAR is military spending. As an alternative we use gap between the log of government expenditure and its trend.

Netherlands

Data is obtained from Bos (2007) and contains nominal GDP, a piecewise continuous GDP deflator, gross government debt and a decomposition of government revenue and government expenditure in their main components. It runs from 1815 till 2009 with gaps in the inter-war years. Bos acquires data on general government finances

[30]Except for 1836 and 1837. In these years the government compensated slave owners for outlawing slavery.

in the period 1815-1900 from the work of van Zanden (1996) and from 1900 onwards from Statistics Netherlands. In the period 1850-1900 only data on central government finances are available. Furthermore data on local government interest expenditure is missing until 1947.

We correct for that by using two assumptions. First, we assume that the interest rate on non-central government debt equals the interest rate on central government debt. In the Netherlands, the central government steps in and assumes full liability when local governments are in financial distress. Therefore local government default risk is equal to central government default risk. Second we assume that local government finances have run a balanced budget, as they are required by law, and we interpolate non-central government debt between 1850 and 1900 linearly. This seems a reasonable first assumption as in 1850 non-central government debt is 26.0% of general government debt, in 1900 it is 20.2%. If these assumptions underestimate local interest expenditure, primary surplus and implied interest rates prior to 1947 would be lower than their actual value. The effect on debt sustainability will be absent, as primary surplus and the implied interest rates have opposite signs in the accounting equation. This has been tested by using central instead of general government finances. As none of the regression coefficients except for the constant to changed by more than one standard deviation, we deem these assumptions reasonable.

Bos (2007) provides GDP deflators from 1815-1913, 1921-1939 and 1948-2009, Statistics Netherlands (CBS, 1959, 1994, 2001) provides a consumer price index from 1900-2009. A continuous GDP deflator is constructed by using consumer price indices to bridge the gap between the broken piece-wise continuous GDP deflators. We approximate the GDP deflator from 1913-1921 and from 1939-1948 by the consumer price index. The consumer price index is highly correlated with the GDP deflator in the period 1900-1913, 1922-1939 and 1949-2009: correlation is 0.998 on level and 0.949 on first differences.

Temporary government expenditure is defined as the residual of government expenditure after its HP-filtered mean has been removed. Note that Bohn (2008) uses military expenditure as an alternative measure of temporary government expenditure. Unlike the US, where military spending drives government spending prior to 1948, the only notable Dutch event is the Belgian war of independence in 1830. Wierts and Schotten (2008) argue gas revenue should be used from 1970s onwards as it had considerable impact in budgetary policy. Both alternative specifications are used in robustness checks and do not provide significant changes.

Belgium

The sample from Belgium is from 1830-1913, 1920-1939 and 1955-2010 with a break in 1970. Prior to 1970 central government data is used, after 1970 general government data. Data for Belgium has been obtained from 4 sources:

- A dataset on Belgium's central government finances from the independence of the state in 1830 until the first world war (1913) was created by Joseph Pirard and published in Pirard (1999). He reports central government revenue, expenditure, gross government debt, interest expenditure nominal GDP from 1830 onwards. In this book Pirard also publishes this data for the Inter bellum (1920-1939) and the years after the Second World War (1945-1995), which he obtains from other sources. finance data after 1945 as the increase in debt is always smaller than the difference between government revenue and government expenditure and much to persistent to be due to stock-flow adjustments. This might be due to the fact that some government bond redemptions are classified as government expenditure.

- Real GDP for the period 1830-1960 is obtained from Maddison (2003) world historic tables. For the years 1831-1839 no data is available here and thus a constant increase between 1830 and 1840 is assumed.
- Data on central government finances (revenue from 1955 until 1970 is obtained from the annual reports of the NBB, the Belgian central bank.
- From 1970 onwards data on general government finances and GDP is available from the AMECO database of the European Commission.

The nominal GDP estimates of Pirard are in the period 1970-1995 approximately 13% lower than the AMECO data. We correct for this by increasing every data-point in the nominal GDP series of Pirard by 13%. Temporary government expenditure GVAR is determined as the gap between the log of government expenditure and its trend.

Spain

The sample is from 1850 to 2010 with a gap for the Spanish Civil War (1936-1939). Data prior to 1995 is taken from Prados de la Escosura (2003) for GDP data in real and nominal terms and Comín and Díaz (2005) for the public sector data and concerns national and provincial government finances. After 1995 data is obtained from the AMECO database of the European Commission.

Temporary government expenditure GVAR is determined as the gap between the log of government expenditure and its trend.

Portugal

The sample is from 1850 to 2010. Data comes from Marinheiro (2006) for the period 1852-1995. In the statistical appendix to that paper Marinheiro describes the sources from which he obtains his data. This is a continuous dataset on nominal and real GDP, government gross debt, government primary surplus and government interest expenditure. The government finances are on cash basis. After 1995 data is obtained from the AMECO database of the European Commission.

Temporary government expenditure GVAR is determined as the gap between the log of government expenditure and its trend. Portugal defaulted on its government debt in 1892, which was ultimately resolved in 1902.

Iceland

The sample for Iceland is from 1908-2010. Data for Iceland has been obtained from two sources. A since 2000 defunct Icelandic organization "Þjóðhagsstofnun’" published general government revenue, expenditure, gross government debt, interest expenditure and real and nominal GDP from 1908 until 1999. Iceland statistics publishes data on general government revenue, expenditure, gross government debt, interest expenditure and real and nominal GDP from 1945 onwards. The data between 1945 and 1999 is identical to the data on the "Þjóðhagsstofnun" website.

Icelandic data concerns general government and contains long periods of high inflation. Temporary government expenditure GVAR is determined as the gap between the log of government expenditure and its trend. Iceland sought and received assistance from the IMF and the Scandinavian countries after the 2008 banking crisis turned into a sovereign debt crisis for Iceland. This is considered as a public debt default.

B Descriptive statistics and graphs

Table 5: Summary statistics and correlation coefficients

		N	mean	sd	min	max	ps	debt	yvar	gvar	mil
US	ps	62	0.00	0.02	-0.09	0.06	1.00				
	debt	62	0.42	0.13	0.24	0.84	0.30	1.00			
	yvar	62	-0.00	0.02	-0.07	0.03	0.12	-0.52	1.00		
	gvar	62	-0.58	0.01	-0.59	-0.53	0.17	0.42	-0.22	1.00	
	mil	62	0.08	0.03	0.04	0.16	0.03	0.39	-0.06	0.50	1.00
	rir	62	0.02	0.03	-0.06	0.09	-0.22	-0.17	0.05	-0.44	-0.41
UK	ps	65	0.02	0.03	-0.05	0.10	1.00				
	debt	65	0.78	0.53	0.33	2.36	0.51	1.00			
	yvar	65	-0.00	0.02	-0.07	0.05	-0.63	-0.51	1.00		
	gvar	65	-0.01	0.06	-0.23	0.10	0.06	-0.42	0.02	1.00	
	mil	65	0.05	0.05	0.03	0.43	0.05	0.60	-0.19	-0.39	1.00
	rir	65	0.02	0.04	-0.12	0.09	-0.23	-0.48	0.23	0.05	-0.26

		N	mean	sd	min	max	ps	debt	yvar	gvar	rir
NL	ps	62	0.03	0.03	-0.01	0.19	1.00				
	debt	62	0.67	0.26	0.38	1.65	0.83	1.00			
	yvar	62	0.00	0.03	-0.04	0.09	0.65	0.47	1.00		
	gvar	62	0.02	0.10	-0.10	0.59	0.78	0.73	0.63	1.00	
	rir	62	0.02	0.04	-0.08	0.10	-0.37	-0.19	-0.46	-0.33	1.00
BE	ps	56	0.02	0.03	-0.07	0.07	1.00				
	debt	56	0.86	0.30	0.45	1.34	0.34	1.00			
	yvar	56	0.00	0.03	-0.03	0.11	0.04	-0.26	1.00		
	gvar	56	0.03	0.15	-0.21	0.70	-0.21	-0.18	0.73	1.00	
	rir	56	0.04	0.03	-0.04	0.11	0.20	0.16	-0.31	-0.25	1.00
SP	ps	65	0.00	0.03	-0.09	0.09	1.00				
	debt	65	0.31	0.13	0.08	0.61	0.17	1.00			
	yvar	65	-0.00	0.03	-0.09	0.05	0.34	-0.20	1.00		
	gvar	65	-0.01	0.08	-0.21	0.21	-0.17	-0.08	-0.19	1.00	
	rir	65	0.00	0.09	-0.16	0.32	0.39	0.32	-0.19	0.19	1.00
PT	ps	66	-0.01	0.02	-0.07	0.03	1.00				
	debt	66	0.35	0.20	0.13	0.83	0.01	1.00			
	yvar	66	-0.00	0.04	-0.11	0.10	0.15	-0.06	1.00		
	gvar	66	0.00	0.09	-0.24	0.22	-0.20	0.11	-0.12	1.00	
	rir	66	-0.04	0.06	-0.23	0.18	0.31	0.19	0.23	0.03	1.00
IC	ps	65	0.01	0.03	-0.10	0.08	1.00				
	debt	65	0.26	0.20	0.03	0.97	-0.22	1.00			
	yvar	65	-0.00	0.05	-0.13	0.10	0.07	-0.18	1.00		
	gvar	65	0.01	0.13	-0.18	0.39	-0.34	-0.05	0.60	1.00	
	rir	65	-0.05	0.09	-0.26	0.18	0.07	0.35	0.22	0.07	1.00

Figure 4: United States and United Kingdom: Debt, primary surplus and military expenditure ratios to GDP, and gamma parameter, post-war samples

Notes: The *gamma* parameter is one plus the smoothed series of the effective interest rates minus the smoothed series of nominal GDP growth rates.

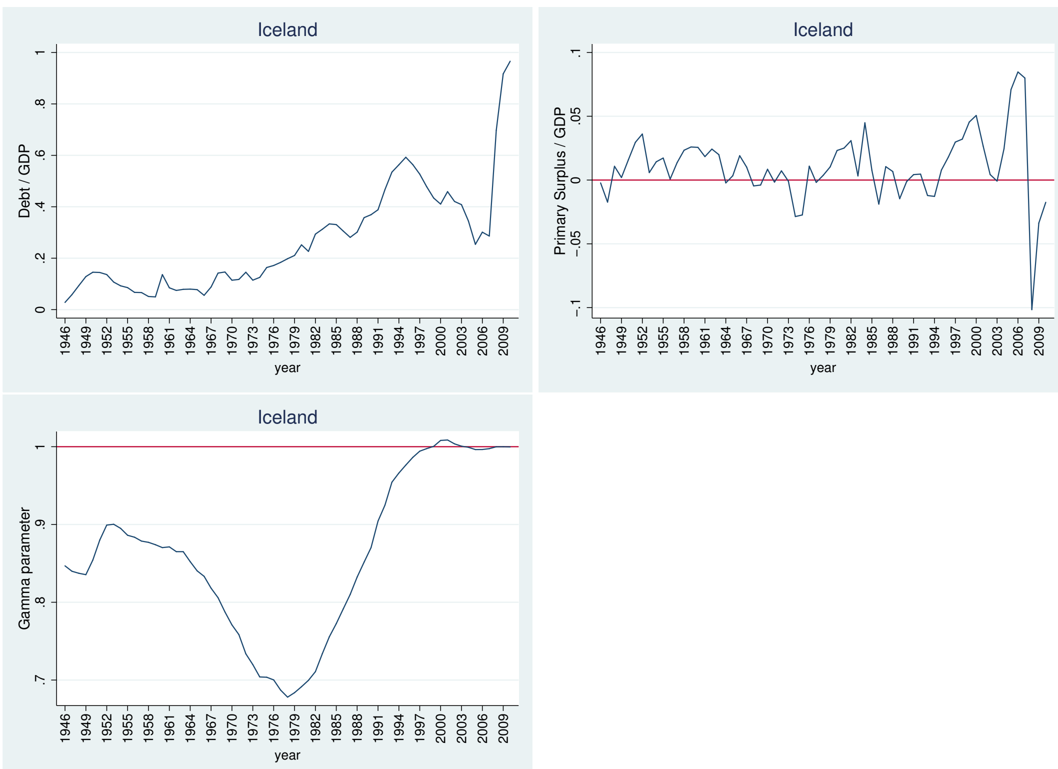
Figure 5: Netherlands and Belgium: Debt and primary surplus ratios to GDP, and gamma parameter, post-war samples

Notes: The *gamma* parameter is one plus the smoothed series of the effective interest rates minus the smoothed series of nominal GDP growth rates.

Figure 6: Spain and Portugal: Debt and primary surplus ratios to GDP, and gamma parameter, post-war samples

Notes: The *gamma* parameter is one plus the smoothed series of the effective interest rates minus the smoothed series of nominal GDP growth rates.

Figure 7: Iceland: Debt and primary surplus ratios to GDP, and gamma parameter, post-war sample



Notes: The *gamma* parameter is one plus the smoothed series of the effective interest rates minus the smoothed series of nominal GDP growth rates.

C Regression results

Table 6: United States, fiscal reaction function estimations and robustness tests, dependent variable is the primary surplus to GDP ratio.

	(1) 1948-2009	(2) 1948-2009	(3) 1948-2009	(4) 1948-2009	(5) 1948-2009	(6) 1792-2009
debt	0.090 ***	0.074 ***	0.090 ***	-0.153	0.046	0.095 ***
	[0.026]	[0.022]	[0.022]	[0.121]	[0.029]	[0.021]
	(0.023)	(0.023)	(0.023)	(0.093)	(0.028)	(0.013)
yvar	0.373 **	0.344 **	0.378 **	0.490 **	0.450 **	0.080
	[0.158]	[0.160]	[0.162]	[0.187]	[0.175]	[0.067]
	(0.124)	(0.124)	(0.121)	(0.126)	(0.123)	(0.046)
mil	-0.118		-0.189	-0.116	-0.112	-0.746 ***
	[0.110]		[0.118]	[0.115]	[0.115]	[0.110]
	(0.089)		(0.093)	(0.084)	(0.085)	(0.049)
gvar		0.113				
		[0.266]				
		(0.281)				
rir			-0.180 **			
			[0.077]			
			(0.087)			
debt_sq				0.255 *		
				[0.128]		
				(0.095)		
debt_60					0.045 *	
					[0.024]	
					(0.018)	
Constant	-0.024 **	0.039	-0.015	0.029	-0.009	0.004 *
	[0.009]	[0.153]	[0.009]	[0.025]	[0.009]	[0.002]
	(0.009)	(0.166)	(0.010)	(0.022)	(0.011)	(0.003)
Observations	62	62	62	62	62	218
R-squared	0.218	0.196	0.272	0.306	0.298	0.598

Notes: Variable "yvar" is the gap between log real GDP and its trend and "gvar" is the gap between log of government expenditures and its trend (trends are extracted using an HP-filter with lambda=100), "mil" is military expenditure as a percentage of nominal GDP, "rir" is the effective real interest rate, "debt_sq" is the debt-to-GDP ratio squared, "debt_60" is the debt-to-GDP ratio if it is larger than 60% and zero otherwise; [ ] = Heteroskedasticity- and autocorrelation-consistent standard errors (computed with Newey-West lag window of size 1); ( ) = ordinary standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 7: United Kingdom, fiscal reaction function estimations and robustness tests, dependent variable is the primary surplus to GDP ratio.

	(1)	(2)	(3)	(4)	(5)	(6)
	1946-2009	1946-2009	1946-2009	1946-2009	1946-2009	1691-2009
debt	0.045 ***	0.019 **	0.048 ***	0.026	0.052	0.048 ***
	[0.009]	[0.008]	[0.009]	[0.026]	[0.036]	[0.002]
	(0.007)	(0.007)	(0.008)	(0.026)	(0.029)	(0.002)
yvar	0.258	0.218	0.278	0.290	0.261	-0.251 **
	[0.203]	[0.196]	[0.201]	[0.219]	[0.206]	[0.115]
	(0.136)	(0.128)	(0.138)	(0.142)	(0.137)	(0.047)
mil	-0.209 ***		-0.210 ***	-0.231 ***	-0.212 ***	-0.705 ***
	[0.051]		[0.051]	[0.053]	[0.053]	[0.059]
	(0.071)		(0.071)	(0.077)	(0.072)	(0.017)
gvar		-0.205 ***				
		[0.057]				
		(0.049)				
rir			0.079			
			[0.099]			
			(0.085)			
debt_sq				0.009		
				[0.012]		
				(0.012)		
debt_60					-0.005	
					[0.025]	
					(0.020)	
Constant	-0.004	0.002	-0.008	0.004	-0.006	0.010 ***
	[0.008]	[0.008]	[0.008]	[0.013]	[0.016]	[0.003]
	(0.005)	(0.005)	(0.007)	(0.012)	(0.012)	(0.002)
Observations	64	64	64	64	64	319
R-squared	0.417	0.483	0.426	0.423	0.418	0.887

Notes: Variable "yvar" is the gap between log real GDP and its trend and "gvar" is the gap between log of government expenditures and its trend (trends are extracted using an HP-filter with lambda=100), "mil" is military expenditure as a percentage of nominal GDP, "rir" is the real interest rate, "debt_sq" is the debt-to-GDP ratio squared, "debt_60" is the debt-to-GDP ratio if it is larger than 60% and zero otherwise; [ ] = Heteroskedasticity- and autocorrelation-consistent standard errors (computed with Newey-West lag window of size 1); ( ) = ordinary standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 8: Netherlands, fiscal reaction function estimations and robustness tests, dependent variable is the primary surplus to GDP ratio.

	(1) 1948-2010	(2) 1948-2010	(3) 1948-2010	(4) 1948-2010	(5) 1816-2010
debt	0.074 ***	0.076 ***	-0.135 *	0.105 ***	0.031 ***
	[0.013]	[0.012]	[0.069]	[0.027]	[0.004]
	(0.011)	(0.011)	(0.048)	(0.029)	(0.003)
yvar	0.341 **	0.282 *	0.196	0.346 **	0.161
	[0.148]	[0.152]	[0.137]	[0.145]	[0.105]
	(0.101)	(0.106)	(0.093)	(0.101)	(0.064)
gvar	0.069	0.064	-0.090	0.043	0.027
	[0.047]	[0.047]	[0.061]	[0.049]	[0.048]
	(0.033)	(0.033)	(0.046)	(0.040)	(0.020)
rir		-0.095			
		[0.058]			
		(0.060)			
debt_sq			0.141 ***		
			[0.047]		
			(0.031)		
debt_60				-0.015	
				[0.012]	
				(0.013)	
Constant	-0.026 ***	-0.024 ***	0.046 *	-0.039 ***	-0.010 *
	[0.008]	[0.007]	[0.023]	[0.013]	[0.005]
	(0.007)	(0.007)	(0.017)	(0.014)	(0.004)
Observations	62	62	62	62	186
R-squared	0.795	0.804	0.849	0.800	0.379

Notes: Variable "yvar" is the gap between log real GDP and its trend and "gvar" is the gap between log of government expenditures and its trend (trends are extracted using an HP-filter with lambda=100), "rir" is the real interest rate, "debt_sq" is the debt-to-GDP ratio squared, "debt_60" is the debt-to-GDP ratio if it is larger than 60% and zero otherwise; [ ] = Heteroskedasticity- and autocorrelation-consistent standard errors (computed with Newey-West lag window of size 1); ( ) = ordinary standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 9: Belgium, fiscal reaction function estimations and robustness tests, dependent variable is the primary surplus to GDP ratio.

	(1) 1955-2010	(2) 1955-2010	(3) 1955-2010	(4) 1955-2010	(5) 1830-2010
debt	0.038 ***	0.037 ***	-0.217	0.098 *	0.026 ***
	[0.012]	[0.011]	[0.159]	[0.053]	[0.008]
	(0.013)	(0.012)	(0.106)	(0.040)	(0.006)
yvar	0.620 ***	0.674 ***	0.599 ***	0.575 **	0.325 ***
	[0.227]	[0.222]	[0.217]	[0.238]	[0.084]
	(0.211)	(0.212)	(0.202)	(0.210)	(0.083)
gvar	-0.103 ***	-0.101 ***	-0.093 ***	-0.105 ***	-0.030 **
	[0.036]	[0.032]	[0.034]	[0.038]	[0.012]
	(0.034)	(0.034)	(0.033)	(0.034)	(0.009)
rir		0.208 *			
		[0.122]			
		(0.139)			
debt_sq			0.144		
			[0.088]		
			(0.060)		
debt_60				-0.035	
				[0.031]	
				(0.022)	
Constant	-0.016	-0.024 **	0.084	-0.044	-0.009 **
	[0.012]	[0.009]	[0.061]	[0.029]	[0.004]
	(0.012)	(0.013)	(0.043)	(0.021)	(0.004)
Observations	56	56	56	56	158
R-squared	0.260	0.291	0.336	0.295	0.265

Notes: Variable "yvar" is the gap between log real GDP and its trend and "gvar" is the gap between log of government expenditures and its trend (trends are extracted using an HP-filter with lambda=100), "rir" is the real interest rate, "debt_sq" is the debt-to-GDP ratio squared, "debt_60" is the debt-to-GDP ratio if it is larger than 60% and zero otherwise; [ ] = Heteroskedasticity- and autocorrelation-consistent standard errors (computed with Newey-West lag window of size 1); ( ) = ordinary standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 10: Spain, fiscal reaction function estimations and robustness tests, dependent variable is the primary surplus to GDP ratio.

	(1) 1946-2010	(2) 1946-2010	(3) 1946-2010	(4) 1946-2010	(5) 1850-2010
debt	0.048	0.017	0.461 ***	0.061 **	0.026 ***
	[0.029]	[0.026]	[0.063]	[0.027]	[0.005]
	(0.024)	(0.022)	(0.093)	(0.024)	(0.005)
yvar	0.348 **	0.389 **	0.300 **	0.356 **	0.073
	[0.154]	[0.160]	[0.129]	[0.155]	[0.062]
	(0.114)	(0.101)	(0.100)	(0.112)	(0.048)
gvar	-0.025	-0.057 **	-0.066 ***	-0.028	-0.085 ***
	[0.032]	[0.028]	[0.024]	[0.031]	[0.029]
	(0.039)	(0.035)	(0.035)	(0.038)	(0.018)
rir		0.144 ***			
		[0.045]			
		(0.033)			
debt_sq			-0.684 ***		
			[0.108]		
			(0.150)		
debt_60				-0.080 ***	
				[0.017]	
				(0.042)	
Constant	-0.010	-0.001	-0.061 ***	-0.014 *	-0.005
	[0.008]	[0.007]	[0.007]	[0.007]	[0.004]
	(0.008)	(0.007)	(0.013)	(0.008)	(0.003)
Observations	65	65	65	65	157
R-squared	0.179	0.373	0.391	0.227	0.276

Notes: Variable "yvar" is the gap between log real GDP and its trend and "gvar" is the gap between log of government expenditures and its trend (trends are extracted using an HP-filter with lambda=100), "rir" is the real interest rate, "debt_sq" is the debt-to-GDP ratio squared, "debt_60" is the debt-to-GDP ratio if it is larger than 60% and zero otherwise; [ ] = Heteroskedasticity- and autocorrelation-consistent standard errors (computed with Newey-West lag window of size 1); ( ) = ordinary standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 11: Portugal, fiscal reaction function estimations and robustness tests, dependent variable is the primary surplus to GDP ratio.

	(1)	(2)	(3)	(4)	(5)
	1945-2010	1945-2010	1945-2010	1945-2010	1852-2010
debt	0.003	-0.003	0.196 ***	0.030 **	0.027 **
	[0.019]	[0.018]	[0.069]	[0.014]	[0.012]
	(0.013)	(0.012)	(0.067)	(0.014)	(0.008)
yvar	0.069	0.028	0.046	0.063	0.077 **
	[0.087]	[0.080]	[0.082]	[0.082]	[0.030]
	(0.067)	(0.067)	(0.064)	(0.062)	(0.023)
gvar	-0.042	-0.044	-0.070	-0.053	-0.043 **
	[0.046]	[0.039]	[0.045]	[0.045]	[0.018]
	(0.028)	(0.027)	(0.028)	(0.026)	(0.014)
rir		0.097 *			
		[0.051]			
		(0.039)			
debt_sq			-0.245 ***		
			[0.088]		
			(0.084)		
debt_60				-0.048 ***	
				[0.016]	
				(0.014)	
Constant	-0.009	-0.003	-0.037 ***	-0.016 **	-0.011 **
	[0.007]	[0.005]	[0.011]	[0.006]	[0.005]
	(0.005)	(0.005)	(0.011)	(0.005)	(0.004)
Observations	66	66	66	66	159
R-squared	0.056 _	0.142	0.171	0.216	0.166

Notes: Variable "yvar" is the gap between log real GDP and its trend and "gvar" is the gap between log of government expenditures and its trend (trends are extracted using an HP-filter with lambda=100), "rir" is the real interest rate, "debt_sq" is the debt-to-GDP ratio squared, "debt_60" is the debt-to-GDP ratio if it is larger than 60% and zero otherwise; [ ] = Heteroskedasticity- and autocorrelation-consistent standard errors (computed with Newey-West lag window of size 1); ( ) = ordinary standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

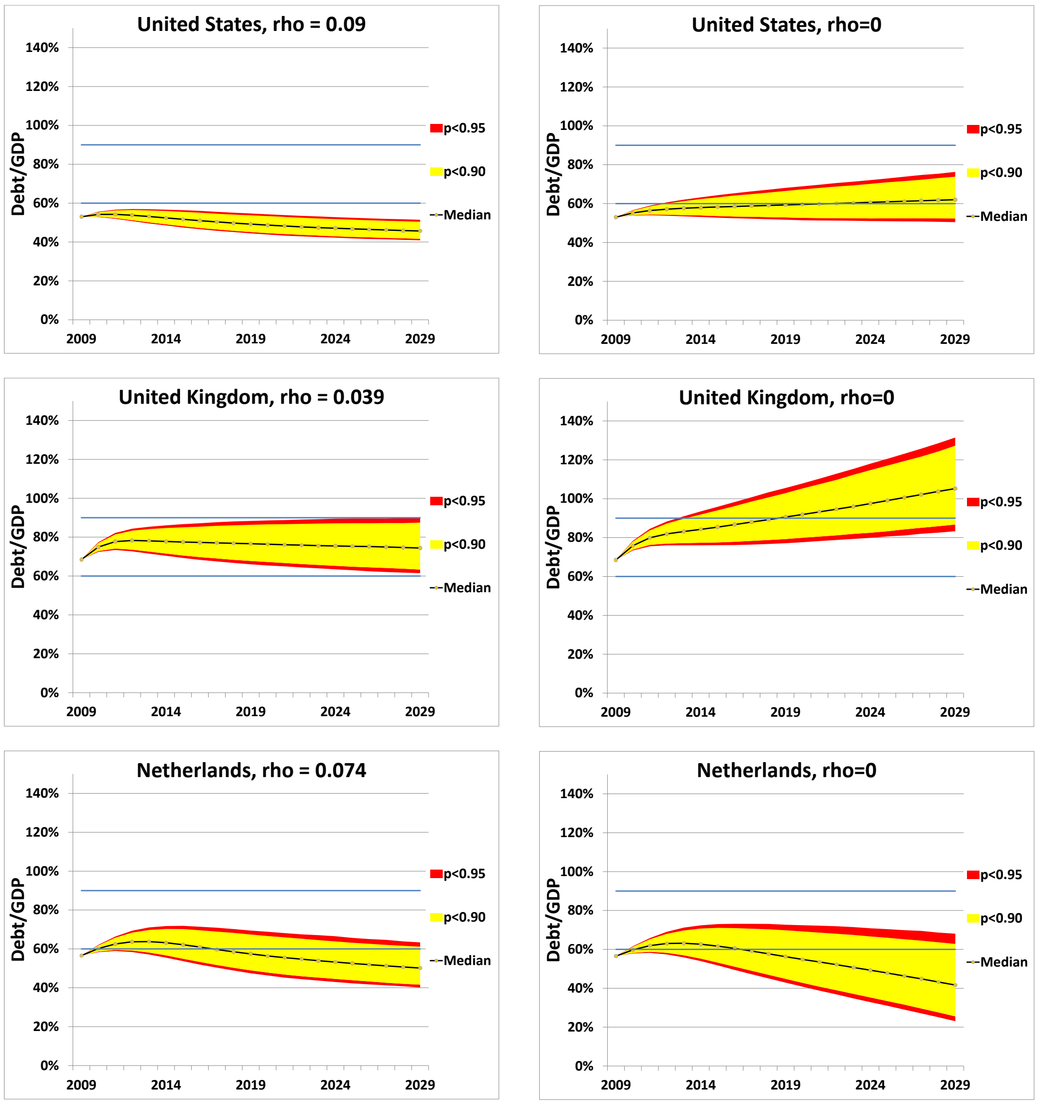
Table 12: Iceland, fiscal reaction function estimations and robustness tests, dependent variable is the primary surplus to GDP ratio.

	(1) 1946-2007	(2) 1946-2007	(3) 1946-2007	(4) 1908-2007
debt	0.014	0.010	0.093	0.047 **
	[0.018]	[0.019]	[0.072]	[0.021]
	(0.016)	(0.018)	(0.069)	(0.019)
yvar	0.213 *	0.201 *	0.193 *	0.122
	[0.112]	[0.112]	[0.101]	[0.075]
	(0.068)	(0.071)	(0.070)	(0.049)
gvar	-0.090 ***	-0.089 ***	-0.086 **	-0.059 **
	[0.033]	[0.033]	[0.033]	[0.026]
	(0.025)	(0.025)	(0.025)	(0.017)
rir		0.019		
		[0.029]		
		(0.031)		
debt_sq			-0.139	
			[0.120]	
			(0.118)	
Constant	0.010 **	0.012 **	0.003	-0.010 *
	[0.005]	[0.006]	[0.008]	[0.005]
	(0.005)	(0.006)	(0.008)	(0.005)
Observations	62	62	62	100
R-squared	0.217	0.222	0.236	0.169

Notes: Variable "yvar" is the gap between log real GDP and its trend and "gvar" is the gap between log of government expenditures and its trend (trends are extracted using an HP-filter with lambda=100), "rir" is the real interest rate, "debt_sq" is the debt-to-GDP ratio squared, "debt_60" is the debt-to-GDP ratio if it is larger than 60% and zero otherwise; [ ] = Heteroskedasticity- and autocorrelation-consistent standard errors (computed with Newey-West lag window of size 1); ( ) = ordinary standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

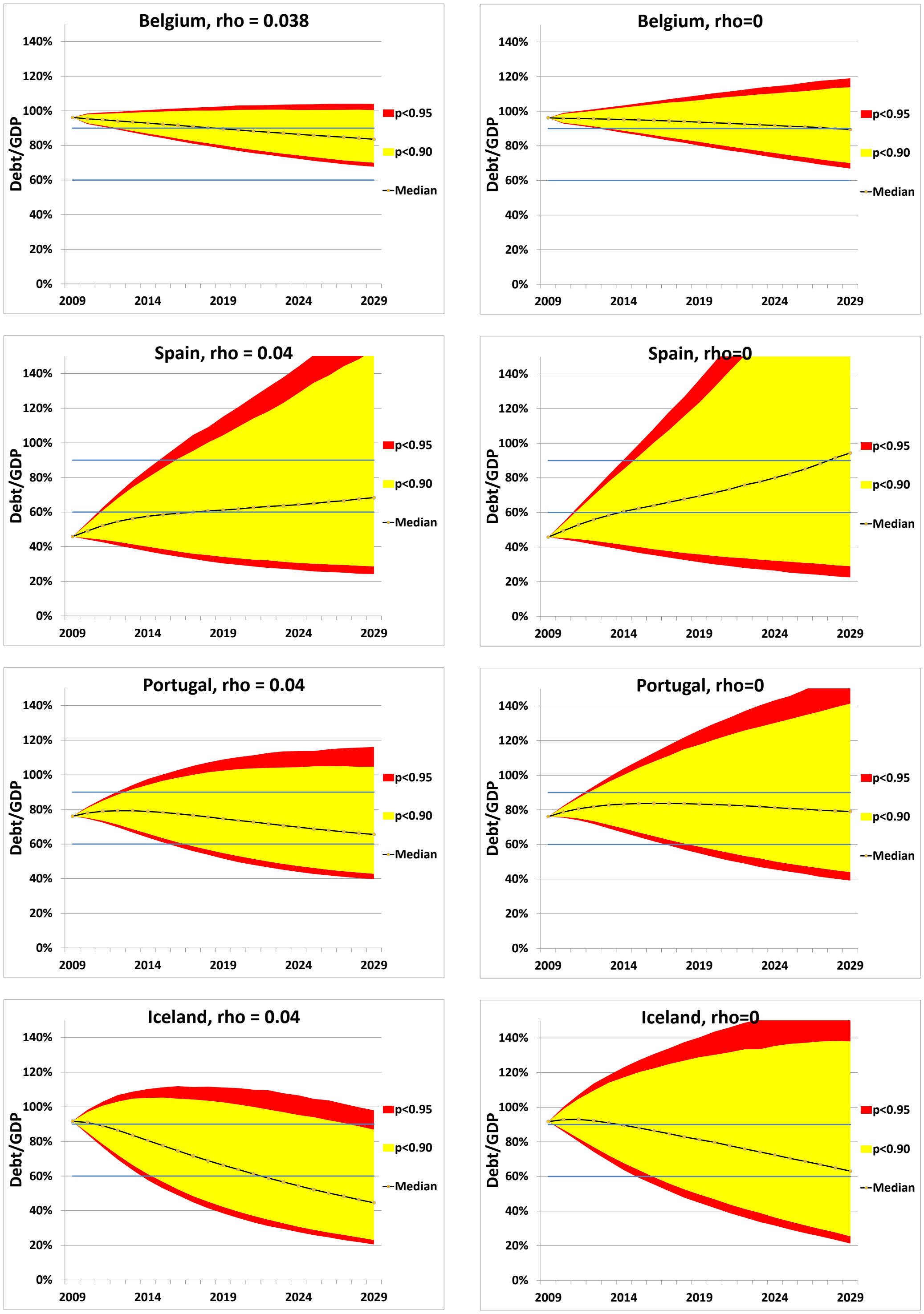
D Stochastic simulation results

Figure 8: Stochastic debt projections, for the US, UK and the Netherlands from 2010 to 2029 with a positive fiscal reaction ($\rho > 0$) and without ($\rho = 0$)



Notes: The red band with p<0.95 encompasses also the yellow band with p<0.90.

Figure 9: Stochastic debt projections, for Belgium, Spain, Portugal and Iceland from 2010 to 2029 with a positive fiscal reaction ($\rho > 0$) and without ($\rho = 0$)



Notes: The red band with p<0.95 encompass also the yellow band with p<0.90.

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