

# STOCHASTIC DEBT SUSTAINABILITY INDICATORS<sup>1</sup>

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This paper proposes indicators to assess government debt sustainability in the medium and long term. We follow the methodological approach by Bohn (2008) and distinguish three channels that contribute to sustainable government finances: economic growth, real interest payments and fiscal responses. We combine the estimated fiscal response with a stochastic debt simulation to create two indicators. The first captures the probability of debt-to-GDP ratios rising by more than 20 percentage points during a 10-year period. A government will fail on this indicator if its fiscal response to an increase in debt is not sufficient to control the swings in debt caused by shocks to real growth and interest payments. The second indicator captures the probability of debt levels being above 90% of GDP in 10 years. We estimate these indicators using historical data for nine OECD countries. We find that the probability of debt-to-GDP ratios rising by more than 20 percentage points in the next decade clearly identifies countries that have sustainability concerns: Italy, Spain, Portugal and Iceland, from those that do not: US, UK, Netherlands, Belgium and Germany.

*Keywords:* Fiscal policy, Public debt, Sustainability.

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## 1. Medium/long term debt sustainability assessment

Currently, being able to assess debt sustainability seems very relevant to European policy makers and the financial markets alike. These assessments are at the center of the debate and moreover, they also motivate changes in the direction of short-term economic policies as well as structural reforms. We contribute to this discussion by proposing two indicators for medium/long-term debt sustainability.

Fiscal policy is defined as the set of government policies that involve taxation, transfer payments and government investment and expenditure to promote growth, smooth the business cycle and redistribute income. Government debt is the accumulation of past fiscal deficits (negative surpluses), plus the interest payments on past debt. Hence, fiscal policy co-determines these deficits in conjunction with other macroeconomic factors and short-term shocks. Changes in the direction of current fiscal policies are usually motivated in part by the sustainability of this debt-to-GDP ratio as high government debt may lead to externalities. Economic actors experiencing these externalities may force the policy maker to change its fiscal policy.

Debt sustainability is formally defined as debt-to-GDP ratios that are stationary and mean-reverting (Bohn, 1998). In practical terms, debt is sustainable if increases in this ratio are reverted in the medium and long term. Thus, debt sustainability reduces the risk of default and avoids the negative externalities associated with high debt levels. The risk of default depends on expected future debt levels. With high expected debt levels the probability of ending up in a self-fulfilling vicious circle increases (Padoan *et al.*, 2012)—*i.e.* high government debt leads to an increase in risk premia, implying a higher discount rate for future government surpluses which justifies these higher risk premia. Given higher interest rates, current cash flow becomes more important relative to future cash flow limiting the sovereign's options to increase its surplus. When the market anticipates these rates will become so high that the government is no longer willing to take the actions necessary to repay its debt, the country will be excluded from the

international capital market altogether: a liquidity crisis, possibly followed by a default, emerges.

Defaults not only have a large negative impact on the economy of the defaulter<sup>2</sup>, with integrated financial markets default causes contagion across national borders (Arezki *et al.*, 2011).<sup>3</sup> Adding to that, in a monetary union the common central bank may need to deviate from its optimal policy in response to an unsustainable debt level in one member state, either to ensure monetary transmission or to prevent deflation. This may lead to suboptimal monetary outcomes for the other member states (Cooper *et al.*, 2010). Both reasons amplify the need for an indicator capturing the probability that future debt-to-GDP ratios are on an ever increasing path.

Furthermore, high debt levels themselves, and not only their anticipation, have empirically well-established detrimental effects on the economy: they lower future economic growth (Reinhart and Rogoff, 2010; Kumar and Woo, 2012; Baum *et al.*, 2012), may crowd-out private investment (Kumar and Woo, 2012) and increase the interest payments necessary to service the debt (Bayoumi *et al.*, 1995; Schuknecht *et al.*, 2009). Lower growth and higher interest rates also spill-over across borders via real economic and financial channels (Lejour *et al.*, 2011 and references therein). An indicator should therefore also capture the probability that debt will remain high over time. Caution is advised when deriving policy implications from this indicator. The debt level at which detrimental effects on the economy manifest is country-specific and depends on economic arrangements. Several countries have recently combined high debt-to-GDP levels with low interest rates. Nevertheless on average higher debt levels have yielded lower growth and higher interest rates.

## 2. How to assess debt sustainability?

Examining the evolution of the debt-to-GDP ratio given the current state of the economy and trends in growth, interest rates

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2. See Sturzenegger and Zettelmeyer (2007), De Paoli *et al.* (2009) and Furceri and Zdzienicka (2011) for quantification.

3. There can also be negative cross-border wealth effects if the defaulted debt is held by foreigners.

and fiscal policy is necessary for our two debt sustainability indicators. We answer this question by extending Bohn's debt sustainability approach with a stochastic simulation on future real growth and real interest rates.<sup>4</sup> Combining both methodologies we obtain two sustainability indicators. The first assesses upward volatility by providing the probability of a debt-to-GDP ratio increase of 20 percentage points, while the second provides the probability of breaching a given level (90% of GDP) after a 10-year period.

Bohn (1998, 2008) combines the accounting equation for the debt-to-GDP ratio with a behavioural equation for fiscal policy. The accounting equation describes the evolution of the debt-to-GDP ratio given shocks to the economy and the response of fiscal policy to the current debt-to-GDP ratio. The response of fiscal policy to the debt-to-GDP ratio is estimated by the behavioral equation and is referred to as the fiscal response. The accounting equation allows us to disentangle the channels that contribute to the evolution of the debt-to-GDP ratio ( $d_t = \text{debt}/\text{GDP}$ ):<sup>5</sup>

$$d_{t+1} = \left( \frac{1 + r_{t+1}}{1 + g_{t+1}} \right) (d_t - s_t).$$

There are three main channels that impact debt sustainability: real growth ( $g_{t+1}$ ), real interest rates ( $r_{t+1}$ ) and the fiscal response ( $s_t$ ).

1. Real growth of GDP ( $g_{t+1}$ ) increases the denominator of the debt-to-GDP ratio, and thus, directly reduces the size of debt relative to GDP. When real GDP growth is positive and sustained over time, the debt-to-GDP ratio is steadily reduced over time. Real growth rates are determined by several factors. These include demand evolution, firm anticipations, financial booms and crises, governmental policies—such as structural reforms—and external factors—such as

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4. It is possible to assess the stationarity of the debt-to-GDP ratio time series directly using unit root or cointegration tests. See Afonso (2005) for a survey of these types of studies. However, these test results are both unreliable and not informative (Bohn, 1998). They are unreliable because unit root tests have very low power in distinguishing unit root from near unit root alternatives and not informative as the test outcomes does not inform via which channels stationarity is not achieved. Finally, unit root tests provide a stationary picture and no indication on how future debt levels may evolve. For this purpose a simulation exercise is needed.

5. Here  $d$  is real debt over real GDP,  $r$  the real interest rate and  $s$  the primary surplus (government revenue minus non-interest government expenditure) over real GDP ratio. See section 2 of Lukkezen and Rojas-Romagosa (2012) for details.

foreign demand and technological progress—which have a medium to long-term effect on real growth rates.

2. The real interest payments equal the real interest rate ( $r_{t+1}$ ) times the level of debt. This is the amount of funds the government needs to service its debt. Governments can use monetary and financial policy instruments to erode the real value of government debt by traducing into negative or low real interest rates on government bonds. Reinhart and Sbrancia (2011) coin these policies as financial repression. However, in a monetary union these instruments can hardly be implemented by individual countries. Only the union as a whole can do so.
3. The fiscal response is contained in the primary surplus ( $s_t = \text{surplus}/\text{GDP}$ ). A positive primary surplus, meaning government revenue is bigger than non-interest government expenditure, reduces outstanding debt. The response of the primary surplus to the debt ratio is referred to as the fiscal response and must be estimated.

We estimate a behavioural equation for the government  $s_t = \alpha + \rho d_t + \beta Z_t + \varepsilon_t$  to obtain the fiscal response to the debt ratio. The fiscal response ( $\rho$ ) tells us if the medium/long term country-specific government commitment to stabilise debt levels is significant. A positive and significant response coefficient ( $\rho$ ) denotes a country that has been committed to reduce or maintain steady debt-to-GDP ratios ( $d_t$ ) conditional on short-term economic fluctuations and temporary government expenditures ( $Z_t$ ). It 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. Note that these responses are based on estimations from ex-post realizations which incorporate the effect of the business cycle. We thus abstract from a debate on whether the increase in debt is due to a demand or supply shock. These fiscal reactions turn out to be persistent over time. Larger re-election probabilities of fiscally responsible politicians at the national level in advanced economies (Brender and Drazen, 2005, 2008) probably contribute to this just as the quality of fiscal institutions does (Calmfors, 2010 and references therein).

The average contribution of real growth, real interest payments and the fiscal response shows whether and through which channels the debt-to-GDP ratio has been stationary in the past, meaning whether past monetary and financial arrangements and fiscal policy implementation is consistent with debt sustainability. In our set-up debt is stationary if  $\delta = \gamma(1 - \rho)$  with  $\gamma = (1 + r)/(1 + g)$ . This condition is usually stated as: if the interest rate on debt minus the growth rate of GDP minus the fiscal response coefficient is smaller than zero, debt will stabilise.

This does not imply sustainability, because the debt-to-GDP ratio can be stationary on average while high debt-to-GDP ratios, which are considered unsustainable, are still probable outcomes provided adverse shocks occur. We apply the stochastic debt simulation method proposed by Budina and van Wijnbergen (2008) to assess this. They obtain shocks to interest and growth rates<sup>6</sup> and combine these with the estimated fiscal response. This analysis combines the institutional attitude towards fiscal sustainability from the fiscal response coefficient, with the historic volatility of interest and growth rates from the simulation. The intuition works as follows: After an *adverse* interest or growth shock debt increases. A government that has a sustainable fiscal policy will respond to this shock by increasing its primary surplus over time to counter the increase in debt-to-GDP ratios. The opposite effect is in place after a *positive* interest or growth shock.

We generate a stochastic distribution of simulated debt paths yielding a distribution of probable debt-to-GDP ratios in the future. Plotting these debt distributions graphically easily illustrates debt sustainability. Moreover, we can employ the stochastic distribution of future simulated debt-to-GDP ratios to obtain our two sustainability indicators:

1. Our upward volatility indicator denotes the probability that the debt-to-GDP ratio increases by more than 20 percentage points within the next 10 years. This indicator, denoted as  $X_{+20,10}$ , takes the current debt level as a base line and examines the probability of a significant debt increase—hence non-sustainability—from this base line. It captures

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6. This method simulates interest and growth rates using a vector autoregression model, see equation (8) in Lukkezen and Rojas-Romagosa (2012).

whether the fiscal response is sufficient to control the debt-to-GDP ratio given volatility in interest and growth rates.

2. Our debt level indicator  $X_{90,10}$  denotes the probability that simulated future debt-to-GDP ratios exceed a threshold of 90% after a period of 10 years. This captures the idea that above a certain debt-to-GDP ratio negative externalities could occur even if debt-to-GDP ratios are stable. We take this particular threshold from Reinhart and Rogoff (2010), who find that above this debt level real growth decreases. The empirical literature is not conclusive, so using debt thresholds for policy purposes is debatable.<sup>7</sup>

Our analysis is based on ex-post outcomes and hence includes past monetary, financial and fiscal policies<sup>8</sup> implicitly. In the short-run primary surplus, real growth and effective interest rates are all determined endogenously and possibly have multiple equilibria. These equilibria may depend on the debt level (De Grauwe, 2011; Corsetti *et al.*, 2012). Evaluating this endogenous mechanism is beyond the scope of our analysis.<sup>9</sup> However as we know the *ex post* outcome, we know the end result of this endogenous mechanism. This assumption allows us to estimate  $\rho$  and contrast it with interest and growth rates. A precondition for these estimations then is that long time series covering at least 40 years should be available. Time series should span several business cycles and contain periods of high and low debt to prevent misinterpretation.

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7. Kumar and Woo (2012) and Checherita-Westphal and Rother (2012) doubt whether a clear threshold exists. Furthermore, this particular debt level is only indicative of what—in a wide sample of countries and time periods—Reinhart and Rogoff (2010) found to be the threshold level where negative externalities began. The actual threshold level, if it exists, is country specific and unknown. Alternatively a politically-defined debt threshold, like the 60% limit from the Maastricht Treaty could be used.

8. Our fiscal policy measure takes the business cycle into account and therefore implicitly incorporates the effect that too restrictive fiscal policies also negatively affect growth (even more in deep recessions and/or when the economy is in a liquidity trap) and have a negative (instead of a positive) effect on debt levels.

9. In particular, short term endogenous mechanisms can include regime-switching processes and/or changes on the fiscal multiplier that will directly affect short-term outcomes. By using historical data in our estimations our data already contains the *ex post* outcome, which means that we are taking the end-result of the endogenous mechanism as given. Hence, we are also assuming that in the medium term there are no structural changes in the economy (*i.e.* no regime-switching or significant changes in the fiscal multiplier).

### 3. Estimation and simulation

We have data for nine OECD countries: United States (USA), United Kingdom (GBR), Netherlands (NLD), Belgium (BEL), Germany (GER), Italy (ITA), Spain (ESP), Portugal (PRT) and Iceland (ISL).<sup>10</sup> The number of countries is limited due to the requirement of long time series spanning at least 40 years.

Figure 1 presents the debt-to-GDP levels for all the countries in our sample.<sup>11</sup> For a group of countries—US, UK, the Netherlands and Spain—we observe that they begin with high debt levels after the Second World War, which sharply decreased afterwards, but have increased in the later period—especially in the last decade. Another set of countries: Germany, Italy, Portugal and Iceland have experienced steady debt increases, even though these countries began the period with relatively low debt levels.

In Figure 2 we show the real growth rates.<sup>12</sup> Here we observe that most countries have experienced a steady decline in real growth in the post-war period. This means that the real growth channel to reduce debt levels has become less important over time. Accordingly, Figure 3 presents the smoothed series on effective nominal interest rates and inflation.<sup>13</sup> When inflation is larger, real interest rates are often negative and thus, for these periods we have financial repression. For most countries (with the exceptions of Belgium and Germany) we observe financial repression periods between the 1950s and the 1980s. However, after the 1980s real interest rates are positive, and thus, the financial repression channel was no longer a source of debt reduction. Therefore, after the 1980s, with declining real growth rates and positive real interest payment, positive fiscal responses became the main channel to reduce debt levels.

We estimate econometrically a fiscal response function and relate the estimated fiscal response coefficient with the average interest and growth rates to determine whether debt converges towards a steady state. Table 1 shows that for the US, the UK, the

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10. Description of the data and data sources in Lukkezen and Rojas-Romagosa (2012). Due to consistency with the pre WWII analysis in this work we use only net data for the US.

11. Note that the vertical scale can be different for each country.

12. The series have been smoothed in Figure 2 and the left-hand (y-axis) scale is the same for each country.

13. Effective nominal interest rates are calculated as government interest payments over debt.

Netherlands, Belgium, Germany and Italy the fiscal response to increases in the debt-to-GDP ratio has been robust and positive in the post-war period. On top of that the US, the Netherlands and Italy have a positive non-linear response, indicating that the primary surplus responds more strongly to debt at high levels. On the other hand, Spain, Portugal and Iceland have non-significant fiscal responses in the post-war period (and Spain and Portugal have even a negative non-linear response), which creates doubts about their capacity to reduce debt by implementing fiscal austerity.

Table 1. Debt sustainability summary

	USA 1948- 2009	GBR 1946- 2009	NLD 1948- 2010	BEL 1955- 2010	DEU 1970- 2011	ITA 1945- 2010	ESP 1946- 2010	PRT 1945- 2010	ISL 1946- 2007
$r$	0.020	0.018	0.022	0.044	0.034	0.004	-0.002	-0.044	-0.073
$y$	0.029	0.023	0.035	0.028	0.025	0.037	0.042	0.039	0.058
$\gamma$	0.991	0.995	0.987	1.016	1.009	0.968	0.958	0.920	0.869
$\rho(\text{debt})$	0.090***	0.045***	0.074***	0.038***	0.026*	0.066***	0.048	0.003	0.014
$\rho(\text{debt}^2)$	+ *	0	+ ***	0	0	+ ***	- ***	- ***	0
$\rho$	0.090	0.045	0.074	0.038	0.026	0.066	—	—	—
$\delta$	0.902	0.950	0.914	0.978	0.983	0.904	0.958	0.920	0.869

\* = significant at 10% level,

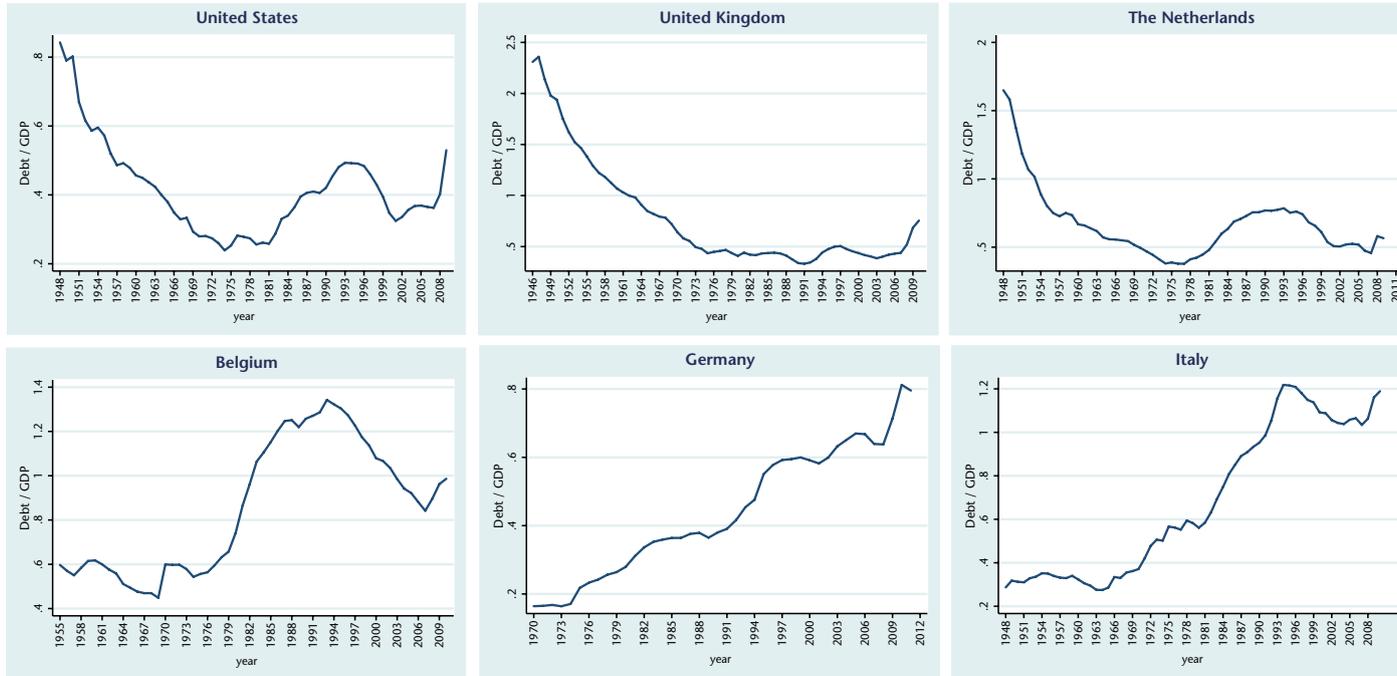
\*\*\* = significant at 1% level

Source : Lukkezen and Rojas-Romagosa (2012).

Of course, if these countries experience beneficial shocks (*i.e.* higher than expected growth rates or lower than expected interest rates), debt sustainability will be easier to achieve. As soon as a country that does not have a significant and strong fiscal response record—and has in addition insufficient real growth or cannot use financial repression instruments—is exposed to an adverse shock, debt will increase and may do so without bound. We capture exactly this effect in our simulation of future debt levels in Figure 4. The left part of the figure shows the simulation without a fiscal response whereas the right part shows the simulation with the estimated fiscal response.<sup>14</sup> The yellow area contains 90% of stochastic debt paths, the red area the next 5%, the black line denotes the median, and the 60% and 90% thresholds are highlighted by blue horizontal lines.

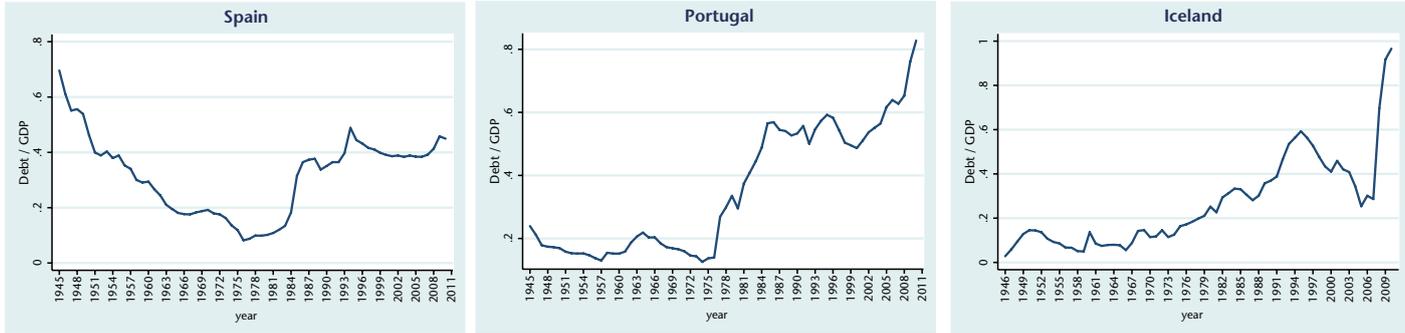
14. As mentioned before, for Spain, Portugal and Iceland the estimated fiscal response coefficient is not significant. However, for illustrative purposes we artificially set their fiscal response coefficient to  $\rho = 0.04$ .

Figure 1. Debt-to-GDP ratios in the post-war period



Source: Lukkezen and Rojas-Romogosa (2012).

Figure 1. Debt-to-GDP ratios in the post-war period



Source: Lukkezen and Rojas-Romagosa (2012).

Figure 2. Smoothed real growth rates in the post-war period

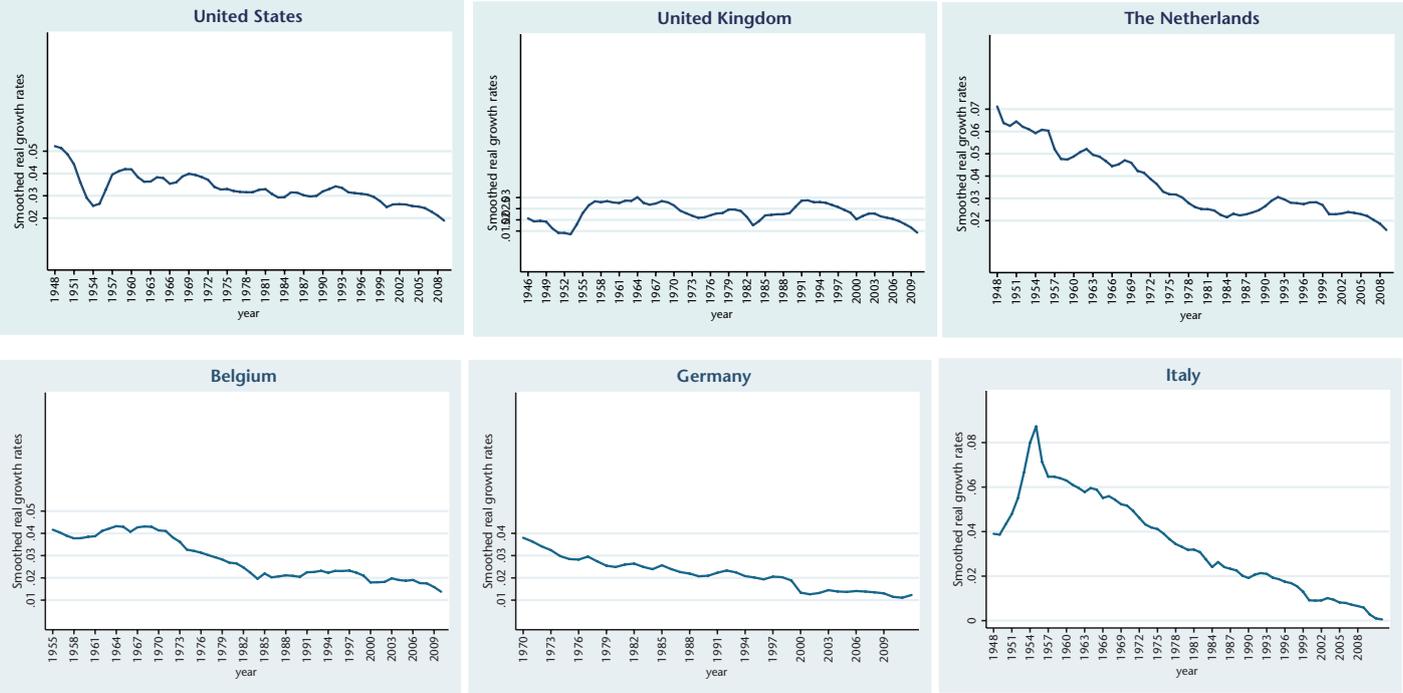
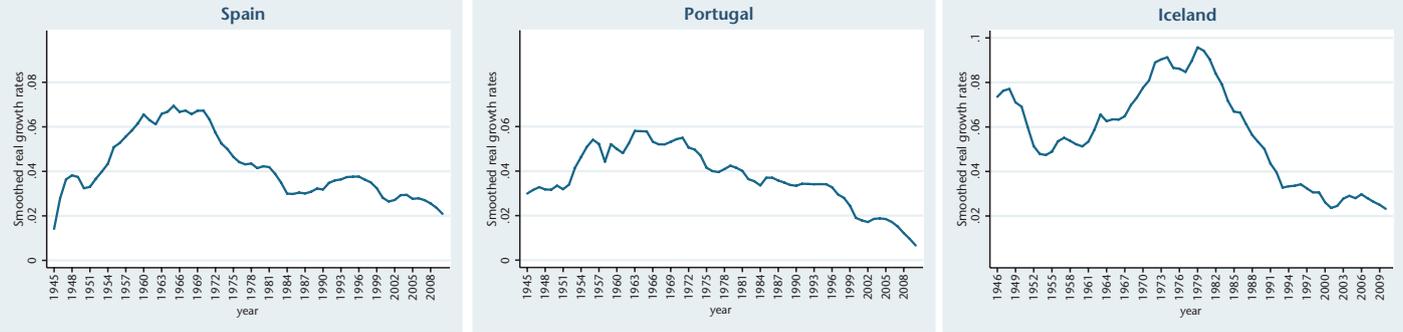
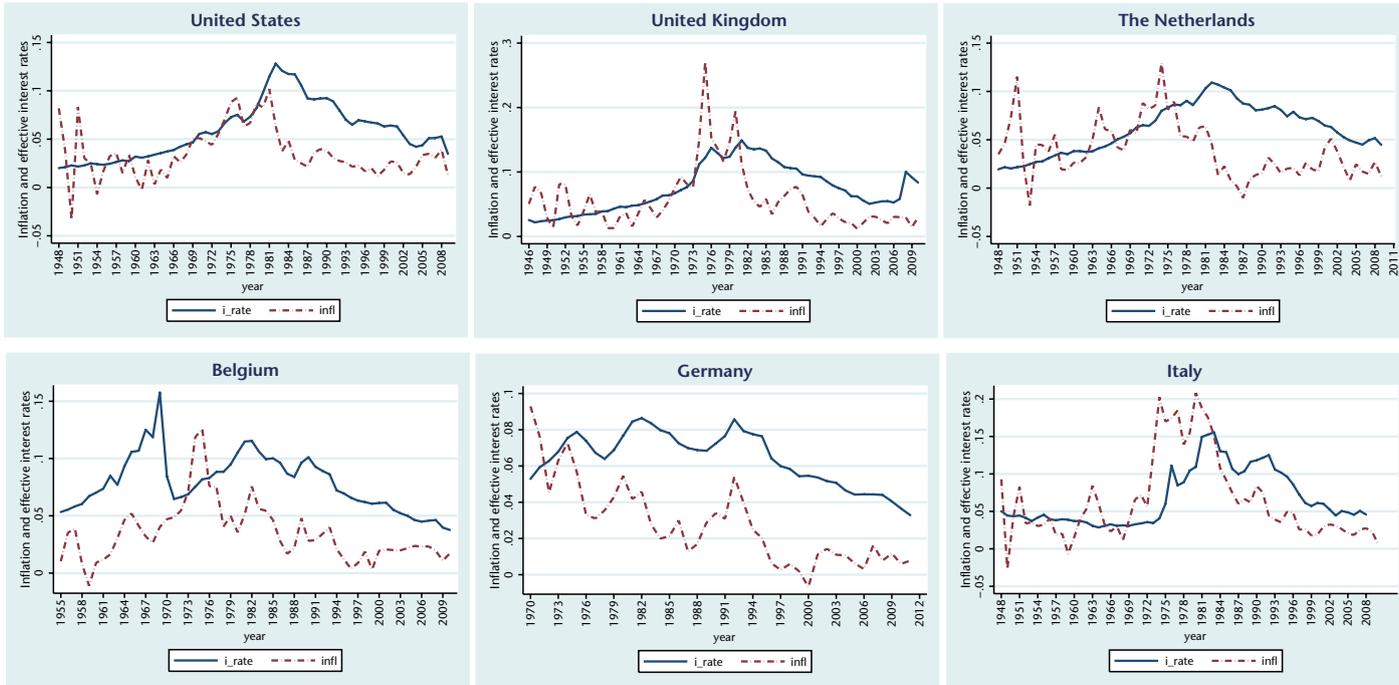


Figure 2. Smoothed real growth rates in the post-war period



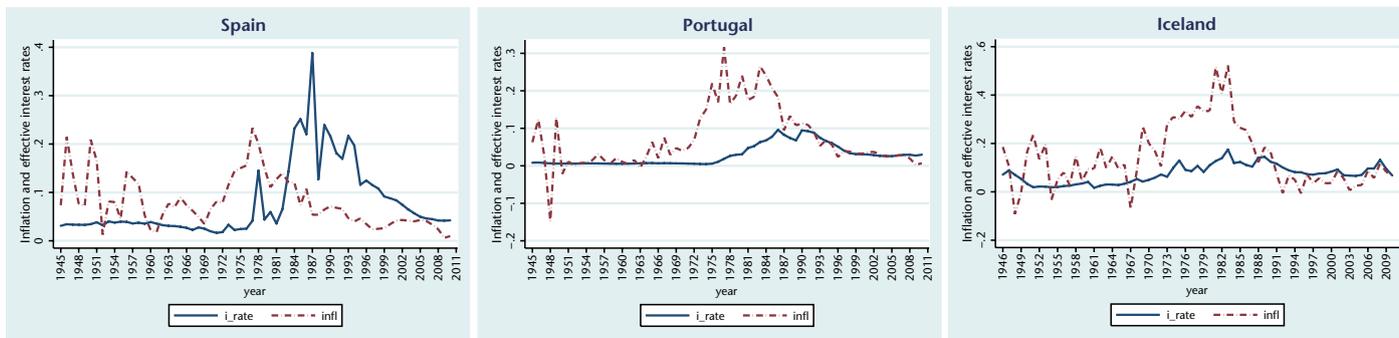
Source: Lukkezen and Rojas-Romagosa (2012).

Figure 3. Nominal interest rates and inflation in the post-war period



Source: Lukkezen and Rojas-Romgosa (2012).

Figure 3. Nominal interest rates and inflation in the post-war period



Source: Lukkezen and Rojas-Romagosa (2012).

Figure 4. Simulated debt paths, without (left) and with (right) fiscal response

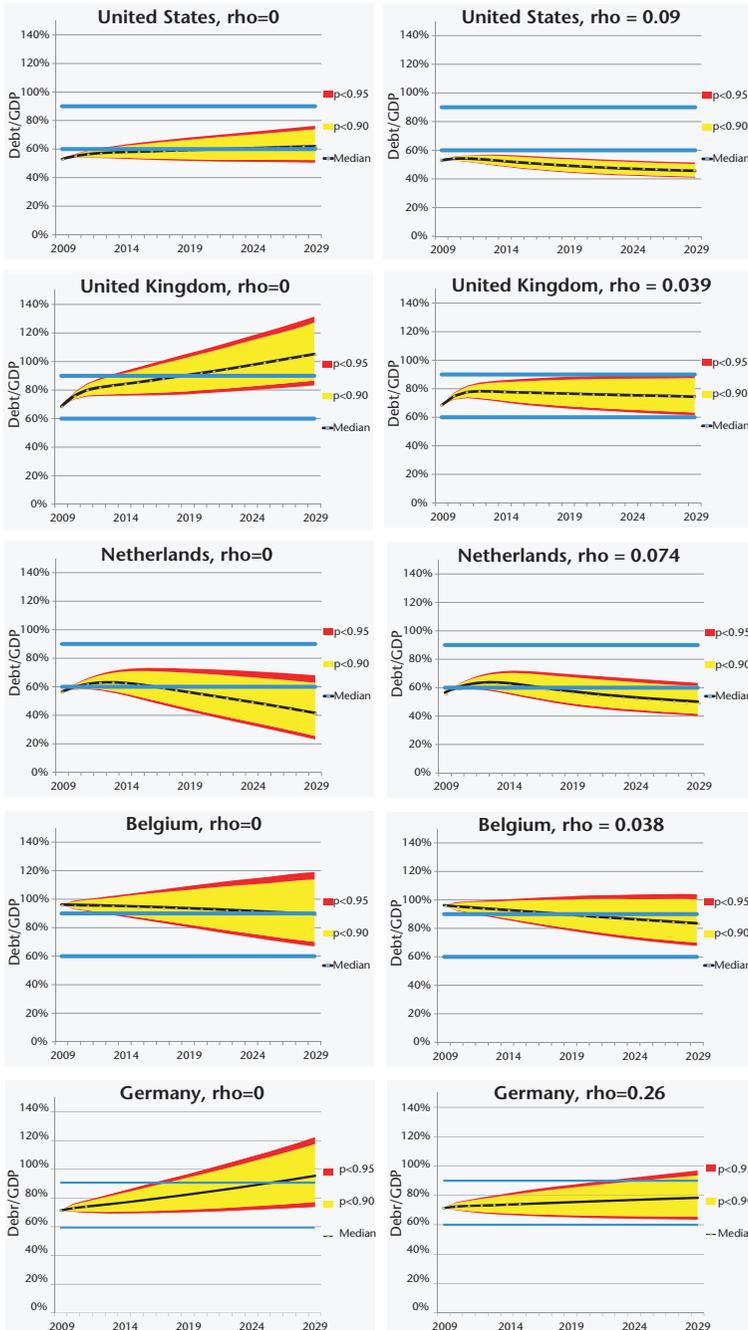
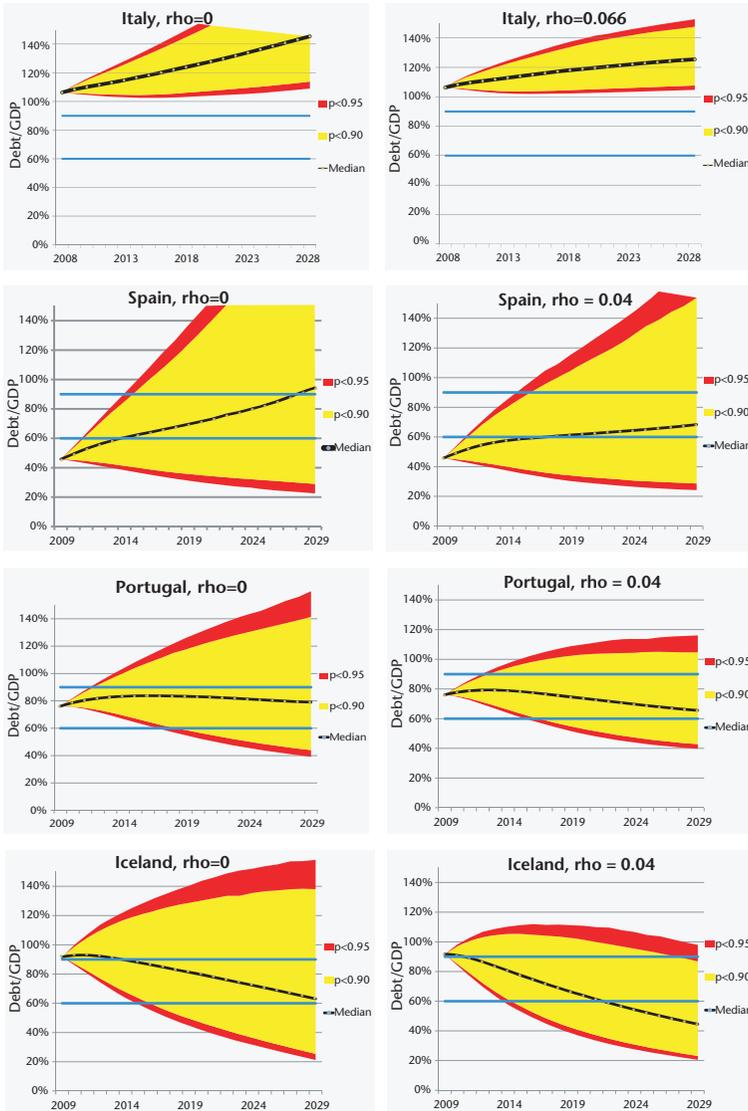


Figure 4. Simulated debt paths, without (left) and with (right) fiscal response



How do these distributions look like?

- **Steady state:** From the accounting equation it follows that debt is stationary if  $\delta = \gamma(1 - \rho) < 1$ . In this case the debt series has a steady state, which equals:

$$\frac{-\alpha(1+r)}{1+g - (1-\rho)(1+r)}$$

- **Slow convergence:**  $r$ ,  $g$  and  $\rho$  are a few percentage points in magnitude, thus small compared to 1. This means that convergence towards the steady state is slow. As there is significant volatility in interest and growth rates, this volatility will be dominant in the debt developments, not the convergence towards the steady state. Also this volatility will determine the width of the bandwidth around the steady state.
- **Skewed distribution:** As a shock changes the debt-to-GDP ratio by a percentage of that ratio, an adverse shock necessitates a larger response than a positive shock. This means that the effect of adverse shocks will be visible longer and the debt distribution will be skewed.

The debt distribution plots in Figure 4 show all the characteristics mentioned. Slow convergence towards some steady state, a width of the debt distribution which increases with interest and growth rate volatility and decreases with the size of the fiscal response and a skewness in the debt distribution—the median debt path lies below the average debt path.

The shocks in our simulations depend on the historic volatility of interest and growth rates. That means they do not contain unexpected exogenous events (e.g. war, natural disasters). In any case, the results of our simulation exercise are not informative on debt sustainability under such conditions as other concerns will receive higher priority than debt sustainability concerns. Nevertheless, under a business as usual scenario, it is still very useful to know the probability that debt could increase above a certain threshold or by a certain number of percentage points. From Figure 4 it becomes clear that the probability of being on an unsustainable debt path is non-zero for some countries: Italy, Spain, Portugal and Iceland.

This means that there is a reasonable chance that these countries have unsustainable debt levels.

**Table 2. Summary table showing the debt sustainability indicators in % of GDP**

	2009	2019, $\rho > 0$				2019, $\rho = 0$			
	debt	debt	95 % width	$X_{90,10}$	$X_{+20,10}$	debt	95 % width	$X_{90,10}$	$X_{+20,10}$
USA	53	50	10	0	0	59	15	0	0
GBR	68	77	21	1	3	89	26	53	56
NLD	57	58	21	0	0	58	28	0	1
BEL	96	90	23	47	0	94	26	69	0
DEU	71	75	22	1	1	82	26	14	11
ITA	106	118	35	100	20	124	47	100	43
ESP	46	60	78	12	46	67	94	23	58
PRT	76	76	55	16	11	84	66	35	25
ISL	92	69	72	100	5	83	92	36	18

Table 2 presents the debt sustainability indicators proposed in the last section. Specifically the indicator that the debt level increases by 20 percentage points in the next decade ( $X_{+20,10}$ ) distinguishes countries with no or only small debt sustainability issues (US, UK, Netherlands, Belgium and Germany) from countries with serious debt sustainability issues (Italy, Spain, Portugal, Iceland).

#### 4. How to use debt sustainability indicators?

From the Second World War up until the early eighties, the fiscal response was not important for debt sustainability, since in most developed economies real growth rates were relatively high and real interest payments were low (and even negative for some countries). This is not the case anymore: with relatively low real growth rates and positive real interest payments, strong fiscal responses are crucial for debt sustainability. Thus, by estimating historical fiscal responses using Bohn's approach we can test for current debt sustainability.

Our estimated fiscal response ( $\rho$ ) is an institutional variable that measures how over medium and long-time periods, the govern-

ment of a particular country deals with medium/long term changes in debt levels. In particular, it measures how fiscal policy reacts to changes in debt levels, once policy is adjusted to take into account the country-specific fiscal policy changes to unexpected increases in temporary expenditure and to the business cycle. As we need to correct for these variables in our estimate of the country-specific fiscal response, we need time series that encompass several business cycles.

Our simulated stochastic debt distributions and the indicators capture whether current fiscal policy generate sustainable future debt levels. They relate expected fiscal responses to expected economic shocks under current monetary and financial arrangements starting from the current state of the economy. Our preferred indicator,  $X_{+20,10}$ , shows the probability of an increase of debt of 20 percentage points in the next decade. A country that ‘fails’ on this indicator has a non-zero probability of a substantial debt increase in the coming decade. The debt level indicator,  $X_{90,10}$ , shows the probability of debt exceeding the 90% threshold.

It is important to note that our indicators provide information on medium and long-term debt sustainability. They are not suitable to analyze short-term debt sustainability. For instance, they cannot provide information on whether—for example—Spain will be able to roll over its debt in the coming months. On the other hand, our sustainability indicators—together with the estimated fiscal response—do provide information on whether it is reasonable for a country to join a monetary union. In such a union, the use of financial and monetary policies is limited for individual countries, making it unlikely for them to achieve debt reductions through policies that yield very low or negative real interest rates. This leads to an increased dependence on fiscal policy to tackle debt sustainability. It is precisely this medium—to long term institutional relation between fiscal policy and debt sustainability that is captured by our indicators.

For medium to long-term fiscal policy assessments, our indicators have several advantages over the current available indicators. 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. They are static and are not able to

capture volatility in the economy and the government's fiscal response to that. It is now clear that several countries were able to violate these criteria without consequences, while others that met the criteria have nonetheless been hit by the crisis. Sustainability indicators related to ageing (European Commission, 2009) can take volatility into account but have another drawback: they assume no fiscal response and project how government debt levels will explode *unless* the government enacts reforms. As such, they are valuable in putting this issue on the policy agenda. Whether these issues actually get solved, depends on the quality of the political process and the strength of fiscal institutions. Finally, cyclically adjusted budget balances (CABB) are dependent on projections of future growth, which are known to have an upward bias (Larch and Salto, 2005). This can distort the identification of actual fiscal policy. Furthermore, these estimates are vulnerable to endogeneity problems, since it becomes difficult to disentangle the effects of expected growth on the CABB from the effects CABB has through the fiscal multiplier on growth.

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