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Limits to government debt sustainability

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ECONOMICS DEPARTMENT

LIMITS TO GOVERNMENT DEBT SUSTAINABILITY

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By Jean-Marc Fournier and Falilou Fall

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ABSTRACT / RÉSUMÉ

Limits to Government Debt Sustainability

The recent euro area sovereign debt crisis has shown the importance of market reactions for the sustainability of debt. The objective of this paper is to calculate endogenous government debt limits given the markets assessment of the probability to default. The estimated primary balance reaction function to growing debt has the “fiscal fatigue” property (a loosening fiscal effort makes the primary balance insufficient to support rising debt) at high debt levels. It is the combination of this feature of the primary balance reaction function with the market interest rate reaction to growing debt that determines the government debt limit beyond which debt cannot be rolled over. An application of this framework to OECD countries over the period 1985 – 2013 shows that current debt limits are high for most of the OECD thanks to particularly low current interest rates. It shows also for some countries that current debt levels are not sustainable without a change in government behaviour as compared to the past. Most importantly, the framework illustrates the state contingent nature of debt limits and therefore the vulnerability of governments to a change in macroeconomic conditions and to market reactions.

JEL classification codes: E27, E44, E61, E62, H62, H63, H68

Keywords: Debt, sustainability, fiscal policy, primary balance

Les limites à la viabilité de la dette publique

La récente crise de la dette souveraine dans la zone euro a montré l'importance des réactions des marchés pour la viabilité de la dette. L'objectif de ce document est de calculer les limites endogènes de la dette publique compte tenu de l'évaluation que font les marchés de la probabilité de défaut. À de hauts niveaux d'endettement, la fonction de réaction estimée du solde primaire à une dette croissante présente la propriété de « fatigue budgétaire » (c'est-à-dire qu'un relâchement des efforts budgétaires aboutit à un solde primaire insuffisant pour soutenir l'accroissement de la dette). Cette propriété de la fonction de réaction du solde primaire, combinée à la réaction des marchés à l'accroissement de la dette via les taux d'intérêt, détermine la limite de la dette publique au-delà de laquelle celle-ci ne peut plus être refinancée. L'application de ce cadre aux pays de l'OCDE pour la période 1985-2013 montre que les limites actuelles de la dette sont hautes pour la majorité d'entre eux, grâce à des taux d'intérêt particulièrement bas actuellement. Elle montre également que les niveaux d'endettement actuels ne sont pas viables pour un certain nombre de pays. Surtout, ce cadre montre que les limites de la dette sont conditionnées par l'état de l'économie et que par conséquent, les États sont vulnérables à toute évolution de la situation macroéconomique et aux réactions des marchés.

JEL classification codes: E27, E44, E61, E62, H62, H63, H68

Mots-clés : dette, viabilité, politique budgétaire, solde primaire

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LIMITS TO GOVERNMENT DEBT SUSTAINABILITY

By

Jean-Marc Fournier and Falilou Fall¹

1. Introduction and main findings

1. The recent euro area sovereign debt crisis has shown the importance of market reactions for the sustainability of debt. Uncertainties surrounding Greek debt developments fuelled a rapid increase of interest rates for some euro area countries and in particular for Ireland, Italy, Portugal and Spain. Formerly sustainable debt levels suddenly appeared risky, precipitating the launch of consolidation policies.

2. The aim of this analysis is to calculate debt limits and to investigate the role of country-specific determinants. The debt limit is defined as the debt level at which a sovereign borrower loses market access and hence cannot service its debt. The analysis takes into account the reaction of governments and markets to increasing debt in the analysis of debt dynamics. The framework follows Ghosh et al. (2013) and is developed for and applied to OECD countries. The analysis also shows how fiscal space can vanish quickly if the macroeconomic context changes (e.g. following a drop of the potential growth rate). In addition, even when debt is well below its debt limit, good times cannot be taken as granted: when market confidence is lost, interest rates can increase sharply in a self-fulfilling crisis.

3. This paper is structured as follows. First, the government primary balance reaction function to increasing debt is estimated. It shows a non-linear reaction of governments to increasing debt: at a low level of debt, governments barely react to increasing debt, but when debt crosses a threshold, governments tend to react more strongly with improvements in their primary balance; however, at debt above a high threshold, fiscal fatigue sets in, with governments reducing their efforts. Second, a model is solved to calculate the debt limit. This model incorporates the estimated primary balance behaviour in the standard debt accumulation dynamics, with the interest rate determined by the probability of default. Third, the interest rate reaction to debt is estimated. This estimation provides an alternative calculation of debt limits.

1. The authors are members of the Economics Department of the OECD. The authors are grateful to Peter Hoeller, Christian Kastrop, Catherine Mann, Jean-Luc Schneider, David Turner, European Commission officials and participants at an internal seminar for their helpful comments on earlier drafts. Special thanks go to Debra Bloch for statistical assistance and Celia Rutkoski for assistance in preparing this document. This paper is part of an OECD project on government debt and fiscal frameworks. The other papers include an OECD Economic Policy Paper (Fall et al., 2015) that summarises the whole project, a working paper that assesses different debt concepts for fiscal risk and sustainability analysis (Bloch and Fall, 2015) and a working paper on macroeconomic uncertainties, prudent debt targets and fiscal rules (Fall and Fournier, 2015).

4. The results show high debt limits of about two times GDP for many countries. This reflects that at medium to high debt, the primary balance surplus reaction to debt is large. It is also driven by the very low current level of interest rates in many countries thanks to the highly accommodative monetary policy to underpin the recovery. Therefore, the debt limit is state dependent and evolves with the behaviour of the government, monetary policy, market reactions and growth prospects. Hence, the debt limit does not predict the timing of a default, but rather indicates sustainability given actual economic conditions.

5. The main conclusions are as follows:

- Debt limits crucially depend on fiscal behaviour, and hence can be increased by a good fiscal track record.
- Countries with debt levels higher than about 120% of GDP react strongly to a further increase of debt, despite the cost this can imply for the population. However, there is considerable uncertainty about governments' behaviour at high debt levels, and hence on debt limits, as very few OECD countries have experienced debt higher than 120% of GDP.
- The interest rate is more sensitive to debt in euro area countries, and hence the corresponding debt limit is lower.
- The gap between the interest rate and growth rate plays the largest role in explaining debt limit differences across OECD countries. In most OECD countries, this gap is currently negative supporting high debt levels.
- Self-fulfilling debt crisis can occur at debt levels much lower than the debt limit.
- Debt limits are lower in countries that face larger fiscal shocks (e.g. small open economies with low diversification).
- Fiscal sustainability is vulnerable to large structural changes such as a drop in potential output, even at low debt levels.

2. Estimating the fiscal reaction function

2.1. Estimation method

6. The estimation of fiscal reaction functions follows the framework of Ghosh et al. (2013), which suggests that at a high level of debt, there is fiscal fatigue that sets in, implying that governments do not increase their primary balance to limit debt accumulation. Since Bohn's (1998) seminal work, there have been several papers that have presented fiscal reaction functions, among which are Galí and Perotti (2003), de Mello (2008), Celasun et al. (2006), Mendoza and Ostry (2008), Burger et al. (2011), Burger and Marinkov (2012) and Medeiros (2012). They estimate a relationship between the primary balance and various potential determinants.

7. Ghosh et al. (2013) are the first to explore the debt sustainability implications of a non-linear response of the primary balance to rising debt. However, Bohn (1998; 2008) already found a non-linear relationship. The primary surplus is more responsive to increases in debt at a higher level for the United States (over 1916–95 and 1792–2003). By contrast, Mendoza and Ostry (2008), who look at international evidence, find that the response of the primary balance to debt weakens at higher debt levels.

8. Ghosh et al. (2013) presume that the primary balance follows a cubic polynomial function of the lagged debt ratio and find statistically significant estimates. Medeiros' (2012) results also suggest the existence of fiscal fatigue, which occurs at a debt ratio of 80% to 90% for a set of EU countries. However, these results are highly dependent on the error specification terms and sensitive to the presence of a few countries with very high debt levels.

9. To increase the robustness of the estimation of the “fiscal fatigue” hypothesis, the primary balance reaction function is estimated with debt thresholds, in a specification relating the primary balance to the output gap, fiscal one-offs, the sovereign debt ratio, and country fixed effects:

$$PB_{it} = \beta_1 GAP_{it} + \beta_2 OT_{it} + \beta_3 (D_{it-1} 1_{D_{it-1} < d_1} + d_1 1_{d_1 \leq D_{it-1}}) + \beta_4 (D_{it-1} 1_{d_1 \leq D_{it-1} < d_2} + (d_2 - d_1) 1_{d_2 \leq D_{it-1}}) + \beta_5 D_{it-1} 1_{d_2 \leq D_{it-1}} + \beta_6 OO_{it} + u_i + v_{it} \quad (1)$$

where PB_{it} denotes the primary balance of country i at year t as a per cent of GDP, GAP_{it} denotes the output gap, OT_{it} denotes the openness ratio multiplied by the term of trade, OO_{it} denotes fiscal one-offs, D_{it} denotes the debt/GDP ratio and d_1 and d_2 are estimated thresholds beyond which the fiscal reaction to debt changes. The debt level and the primary balance can be the common consequence of country-specific unobserved features, which are captured by country fixed-effects u_i . Furthermore, the persistence of the primary balance could make debt endogenous. This source of endogeneity is addressed to the extent possible by modelling v_{it} with an AR(1) process. The endogeneity bias issue is thus likely to be small and could not be further mitigated in the absence of credible exogenous instruments.

10. This specification includes a continuous piecewise-linear function of public debt because the sensitivity of the primary balance to debt can depend on the debt level itself. β_3 , β_4 and β_5 are respectively the variation of the primary balance associated with a 1 percentage point increase of the debt-to-GDP ratio when the debt level is respectively below the first threshold d_1 , between d_1 and d_2 and above d_2 . In particular, β_5 aims at capturing fiscal fatigue, namely that the primary balance would not necessarily keep pace with higher interest rate payments.

11. The estimation of debt thresholds follows the methodology developed by Hansen (1999). For a known couple of debt thresholds (d_1 , d_2), the primary balance reaction function can be estimated. The joint estimates of (d_1 , d_2) are the values which minimize the sum of squared errors $S(d_1, d_2)$ and these values can be found with a grid search. To estimate d_1 and d_2 , a sequential search in which one searches thresholds one by one is made, letting the other one fixed. This is consistent with a joint estimate (Chong, 1994; Bai, 1997; Bai and Perron, 1998) and reduces the computation cost dramatically. In practice the grid search is made with 2 GDP percentage point steps to estimate a first threshold, with an arbitrary value taken for the second threshold. Then the second threshold is estimated with a grid search in which the first estimated threshold does not vary. As discussed in Bai (1997), the second threshold is asymptotically efficient, but the first one is not. Thus, it is re-estimated. Bai (1997) shows that this re-estimation is asymptotically efficient. Finally, the threshold estimate is refined with a search in the neighbourhood of the result with 0.25 GDP percentage point steps.

12. Sovereign debt ratios and output gap data are taken from the Economic Outlook 95 database published in May 2014. The fiscal one-off variable is the sum of capital transfer one-offs (defined as the difference between actual capital transfers and the underlying HP-filtered capital transfers) and other one-offs reported by country desks. The sample starts in 1985 for those countries for which data are available and ends in 2013, covering 31 OECD countries (gross debt data are missing for Chile, Mexico and Turkey).

2.2. Estimation results

13. The baseline results (Table 1, Column 1) indicate that countries increase the primary balance smoothly, if debt is between 0 and about 120% of GDP. The primary balance is much more sensitive to debt when debt is between 120% of 170% of GDP. At these debt levels, OECD countries generate a high surplus to keep the debt sustainable, even if this can imply a high cost for the population. Fiscal fatigue is captured by the negative sensitivity to debt when it is above 170% of GDP. Fiscal one-offs are transmitted mechanically into the primary balance. As expected, a favourable development of the term of trade boosts the fiscal surplus, and this effect increases with openness. These results are in line with findings by Gosh et al. (2013) and Medeiros (2012), though the thresholds are lower in the latter study.

14. Results are robust to several important changes, and other likely determinants of the primary balance that are not included in this parsimonious baseline. First, the baseline results still hold when replacing the primary balance by the cyclically-adjusted primary balance (Table 1, Column 2). Second, the estimates do not provide any significant reaction of governments to high debt when net debt is used (Table 1, Column 3). That is why gross debt is used in the debt limit calculation. The reaction to public debt still holds when public financial assets are low (Table 1, Column 4). By contrast, if financial assets are close to GDP, then the primary balance becomes insensitive to the debt level.

15. The sharp fiscal consolidation at a high debt level only occurs, when the real interest rate (measured by the gap between the 10-year government bond yield and core inflation) puts pressure on the government (Table 1, Column 5). However, this additional effort does not off-set the long-term interest rate payment cost when the debt level is below 170% of GDP as the associated coefficient is significantly below unity.

16. Negative one-offs tend to have adverse effects beyond the year when they took place, as illustrated when one adds a lagged one-off variable (Table 1, Column 8). Countries with fiscal councils generate higher primary fiscal positions if debt is low, and are less sensitive at high public debt, with no significant change of the counter-cyclical role of fiscal policy (Table 1, Column 9). Not surprisingly, IMF programmes can be associated with a higher primary fiscal balance, but this finding is not robust to the addition of many control variables instead of fixed effects (Table 1, Column 10 and 14). Higher inflation raises primary fiscal positions, potentially because higher inflation has a stronger effect on receipts (more likely to be automatically linked to nominal income) than on spending (Table 1, Column 11 and 14). Rising financial asset and housing prices boost primary fiscal positions, because of additional tax receipts on capital and property income. A higher old-age dependency ratio is associated with a weaker fiscal position (Column 14), reflecting the difficulty to smoothly adjust the fiscal balance to this structural change.

17. Considering only euro area countries confirms both the existence of a sharper consolidation at a high debt level and the existence of fiscal fatigue at even higher ones (Table 1, Column 12). Using the Maastricht debt definition instead of the OECD public debt measure provides a non-significant negative estimate for fiscal fatigue, consistent with the fact that euro area countries are under pressure to target a reduction as measured according to Maastricht rules. Finally, countries with rising public debt in the previous year also generate larger deficits, beyond the fiscal position persistence captured by the AR(1) process of the residual (Table 1, Column 13). Taking into account this link with public debt variation does not alter the shape of the fiscal reaction function to the debt level itself.

18. Estimates of fiscal behaviour at high debt levels are driven by the few countries that have experienced such high levels. The robustness is investigated by dropping countries one by one, while constraining the thresholds to be equal to those of the baseline for the sake of comparability. If one drops Greece, the fiscal stance is tightening faster for debt lower than 120% of GDP and fiscal fatigue would

materialise at 120% of GDP. If one drops Japan, then the coefficient capturing fiscal fatigue is not significant anymore. Dropping any of the other countries does not alter the fiscal reaction function results.

19. The choice of the number of thresholds aims at capturing two behavioural assumptions. The first threshold reflects that debt matters less for fiscal policy at a low than at a high level. The second threshold reflects that there is a level beyond which default can become a rational choice, and hence fiscal fatigue becomes more likely. The estimation of the first threshold is not significant, as the sensitivity of fiscal policy to debt is likely to increase continuously with the debt level, rather than shifting up at a specific threshold. In practice, replacing the first threshold by another one implies only a small change of the overall fiscal reaction function. By contrast, the second threshold is significant:² the evidence that there is a specific level at which fiscal fatigue can occur is more clear-cut. In addition, if one considers a fiscal reaction function with only one threshold, the estimated threshold coincides with the fiscal fatigue coefficient (Table 1, Column 7).

20. Last, a specification with a cubic function of debt (not shown in the table) as in Ghosh et al. (2013) is consistent with the baseline results. In such a specification, the cubic term dominates when the debt level is high, and hence this imposes an arbitrary functional form which yields a highly negative primary balance if debt goes beyond two times GDP.

2. Using the Hansen (2000) log-likelihood ratio test with a Gaussian distribution of residuals, the 5% confidence interval is [140%, 185%] in the baseline specification.

Table 1. Fiscal reaction function

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable	Primary balance	Cyclically-adjusted primary balance	Primary balance	Primary balance	Primary balance	Primary balance	Primary balance
Gap	0.42*** (0.029)		0.41*** (0.027)	0.43*** (0.029)	0.49*** (0.034)	0.35*** (0.037)	0.42*** [0.029]
Lag (debt) below d1	0.017* (0.009)	0.022** (0.0084)		0.025 (0.016)	0.059** (0.024)	0.030*** (0.011)	
Lag (debt) between d1 and d2	0.064** (0.027)	0.074*** (0.025)		2.60** (1.09)	0.003 (0.011)	-0.19** (0.076)	
Lag (debt) below d2							0.023*** [0.009]
Lag (debt) above d2	-0.11*** (0.041)	-0.10*** (0.038)		-0.83* (0.43)	-0.11*** (0.040)	0.22 (0.206)	-0.089** [0.039]
One-off	-1.00*** (0.036)	-0.98*** (0.034)	-0.99*** (0.035)	-1.01*** (0.038)	-1.03*** (0.041)	-0.93*** (0.062)	-0.99*** [0.036]
Openness x Terms of trade	0.034*** (0.008)	0.025*** (0.007)	0.018** (0.008)	0.029*** (0.008)	0.035*** (0.009)		0.034*** [0.008]
Lag (net debt below d1)			-0.012 (0.022)				
Lag (net debt between d1 and d2)			0.049*** (0.015)				
Lag (net debt above d2)			0.014 (0.010)				
Lag (assets (a))				0.022 (0.018)			
Lag (debt below d1 x a)				-0.017 (0.026)			
Lag (debt between d1 and d2 x a)				-3.01** (1.39)			
Lag (debt above d2 x a)				0.86* (0.52)			
Lag (real interest rate (r))					-0.027 (0.090)		
Lag (debt below d1 x r)					0.24 (0.25)		
Lag (debt between d1 and d2 x r)					0.32** (0.14)		
Lag (debt above d2 x r)					0.91 (0.67)		
d1	123%	123%	-18%	156%	51%	137%	-
d2	168%	168%	28%	164%	157%	161%	168%
Sample	1985-2013	1985-2013	1985-2013	1985-2013	1985-2013	1985-2007	1985-2013
Country fixed effects	yes	yes	yes	yes	yes	yes	yes
N	709	702	672	699	604	523	709
Rho	0.75	0.75	0.75	0.73	0.67	0.71	0.75
R2	0.633	0.575	0.657	0.635	0.661	0.512	0.632

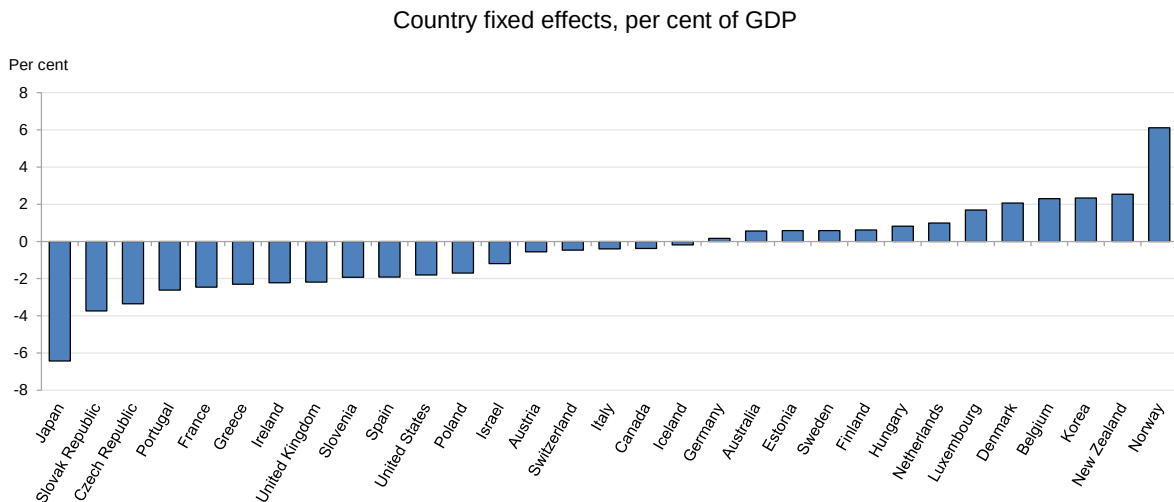
Table 1. Fiscal reaction function (cont.)

	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable	Primary balance	Primary balance	Primary balance	Cyclically-adjusted primary balance	Primary balance	Primary balance	Primary balance
Gap	0.42*** (0.029)	0.41*** (0.032)	0.43*** (0.029)	0.39*** (0.031)	0.58*** (0.053)	0.41*** (0.029)	0.38*** (0.043)
Lag (debt) below d1	0.018* (0.009)	0.020* (0.018)	0.011 (0.010)	0.018* (0.010)	0.070*** (0.015)	0.033*** (0.009)	-0.008 (0.007)
Lag (debt) between d1 and d2	0.065** (0.027)	0.064*** (0.017)	0.046* (0.024)	0.067** (0.028)	0.73*** (0.13)	0.075*** (0.024)	-0.074** (0.037)
Lag (debt) above d2	-0.11*** (0.040)	-0.074* (0.042)	-0.098** (0.040)	-0.11*** (0.041)	-0.24** (0.11)	-0.15*** (0.057)	-0.14** (0.064)
One-off	-1.04*** (0.039)	-1.00*** (0.036)	-0.97*** (0.038)	-1.01*** (0.037)	-1.02*** (0.056)	-1.02*** (0.038)	-1.02*** (0.046)
Openness x Terms of trade	0.033*** (0.008)	0.033*** (0.0084)	0.033*** (0.0083)	0.034*** (0.009)	0.0054 (0.0127)	0.028*** (0.008)	0.011*** (0.004)
Lag (One-off)	-0.12*** (0.039)						
Fiscal council		0.022** (0.010)					
Fiscal council x Lag (debt)		-0.029** (0.012)					
Fiscal council x Gap		0.025 (0.060)					
IMF programme			0.017** (0.007)				0.011 (0.007)
Inflation				0.097*** (0.035)			0.14*** (0.055)
Lag (Δ debt)						-0.077*** (0.013)	
Old age dependency ratio							0.001** (5e-04)
Lag (debt x r)							0.26*** (0.051)
Lag (Government size)							-0.099*** (0.028)
Euro area							-0.005 (0.004)
House prices change							0.073*** (0.016)
Stock prices change							0.012*** (0.003)
d1	123%	88%	117%	123%	152%	123%	137%
d2	168%	168%	168%	168%	167%	180%	180%
Sample	1985-2013	1985-2013	1985-2013	1985-2013	1985-2013 euro area	1985-2013	1985-2013
Country fixed effects	yes	yes	yes	yes	yes	yes	no
N	706	709	709	658	193	684	512
Rho	0.75	0.75	0.75	0.76	0.61	0.69	0.71
R2	0.637	0.636	0.636	0.637	0.765	0.643	0.653

Note: Panel regression with AR(1) Prais-Winsten correction and panel heteroskedasticity-robust standard errors. Standard errors are in parenthesis. Norway is excluded from the third specification because it is not comparable to the other OECD countries: its high net financial worth mainly reflects past oil-related government receipts.

21. Country fixed effects provide a measure of the average deviation of the primary surplus of a country relative to the OECD average reaction to the output gap and the debt-to-GDP ratio (Figure 1). This also allows showing country-specific shocks affecting the fiscal balance (Figure 2). The standard deviation of residuals of the baseline estimate provides a measure of the size of shocks to the fiscal balance. The standard deviation of the output gap multiplied by the output gap coefficient provides a measure of the impact of macroeconomic shocks on the fiscal balance. Similarly, the openness and terms of trade coefficient is used to measure the effect of term of trade shocks on the fiscal balance.

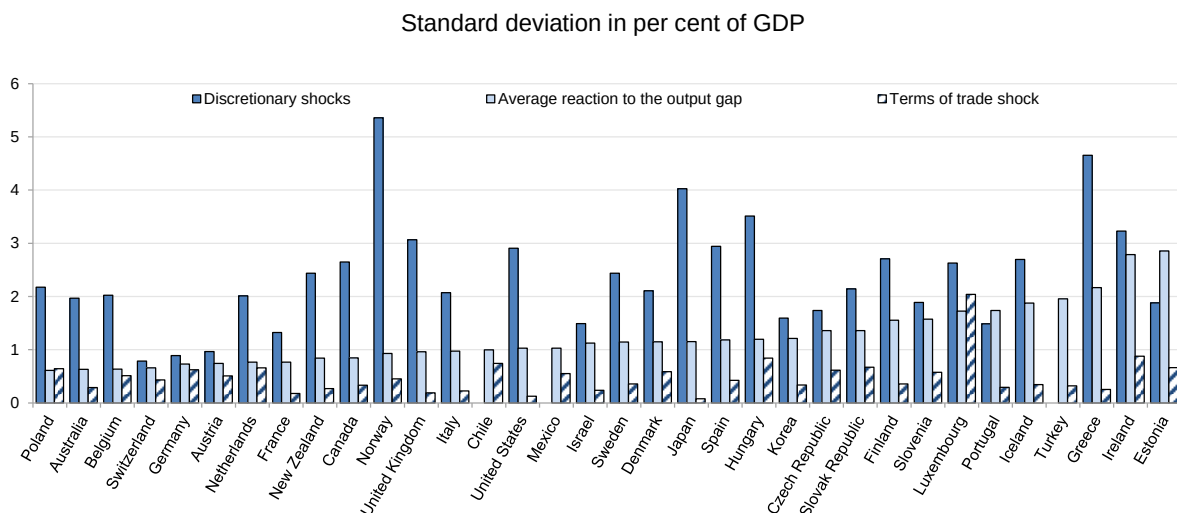
Figure 1. Fiscal balance: Deviation from OECD average



Note: Data for fiscal one-offs are centred for each country and the 2013 terms of trade level is taken as a reference before calculating the fixed effects.

Source: Baseline estimates.

Figure 2. Shocks affecting the fiscal balance



Note: The discretionary shock measure also includes non-discretionary shocks that are not captured by the model (e.g. measurement errors for macroeconomic shocks). The effect of the term of trade shock reflects both the terms of trade volatility and the openness ratio.

Source: Baseline estimates.

3. The debt limit in a model-based approach

3.1. The theoretical framework

22. The theoretical framework considers the conditions for solving the rational expectations equilibrium of the government budget constraint and the credit market.³ First, it considers the debt accumulation dynamics:

$$d_{t+1} - d_t = \underbrace{(r(p_{t+1}) - g)d_t}_{\text{accumulation of past debt}} - \underbrace{(\mu + f(d) + \varepsilon_t)}_{\text{primary balance}} \quad (2)$$

where g denotes the growth rate, μ denotes the average stance of fiscal policy, $f(d)$ the reaction of the primary balance to debt as measured by the baseline estimate and ε_t captures macroeconomic shocks to the primary balance and p_{t+1} is the default probability.

23. Second, the link of credit market reactions to debt developments is gauged by the assessment of the probability of default which is a component of the interest rate. The stochastic model linking the interest rate with the risk of default identifies the level at which the government loses market access. The probability of default in the next period p_{t+1} is the probability that debt d_{t+1} goes beyond its maximum level d^* :

$$p_{t+1} = P(d_{t+1} > d^*) \quad (3)$$

And the interest rate compensates for the risk of default:

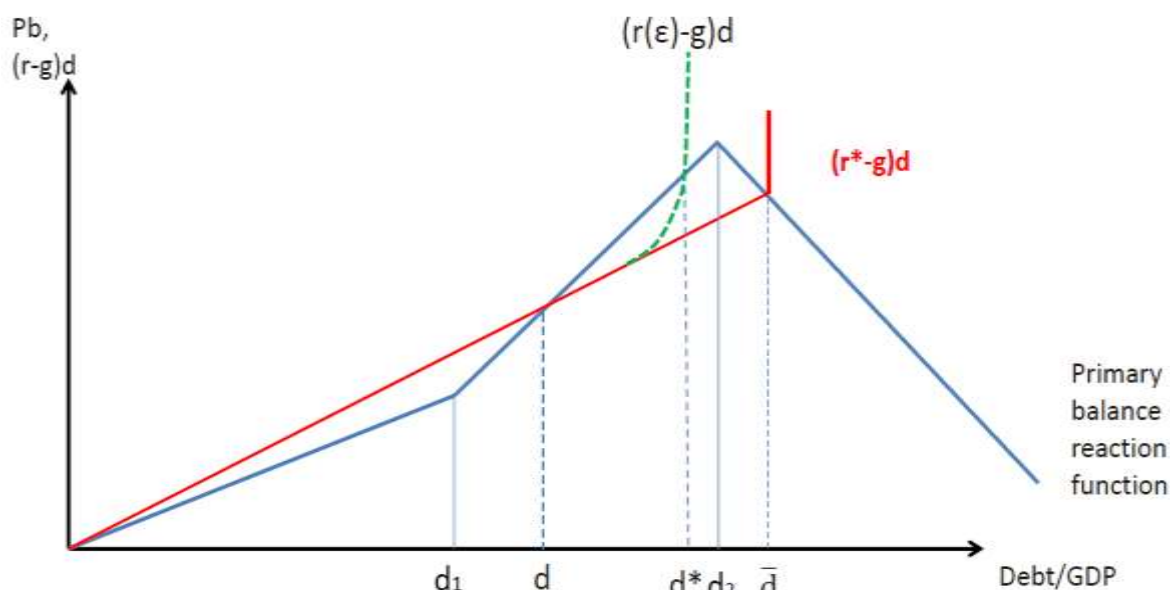
$$1 + r^* = (1 - p_{t+1})(1 + r_t) + p_{t+1}\theta(1 + r_t) \quad (4)$$

where r^* denotes the risk-free interest rate and θ the assumed recovery rate. As a result, the interest rate is a function of the probability of default, $r = r(p_{t+1})$.

24. Accordingly, debt stabilises when the effect of past debt accumulation is exactly offset by the primary balance, as illustrated in Figure 3. There is a stable equilibrium $\underline{d}$ for which the government would be able to generate a higher surplus if a shock increases the debt ratio. By contrast, when the debt level approaches the debt limit, then the government is facing an interest rate spiral, and at the debt limit, the interest rate goes towards infinity, which means that the government loses market access.

3. The theoretical model is borrowed from Ghosh et al. (2013).

Figure 3. Determination of the debt limit



Note: g is the growth rate, r is the interest rate, r^* is the risk-free interest rate, $r(\varepsilon)$ is the interest rate with a risk premium, pb is the primary balance, d is the debt-to-GDP ratio, $\bar{d}$ is the stable equilibrium debt-to-GDP ratio, d^* is the stochastic debt limit depending on the probability of default and $\bar{d}$ is the deterministic debt limit corresponding to the intersection between the risk-free interest payment and the fiscal reaction function. d_1 and d_2 are two estimated thresholds signalling changes in the reaction function to increasing debt.

25. This model is first solved for a given value of d^* which is set arbitrarily. This value can be interpreted as the maximum debt limit as evaluated by investors. Then, the equations above can be rearranged so that the probability of default is a solution to a fixed point problem:

$$p = \Pr(\varepsilon < (r^* - g)d - \mu - f(d) - (d^* - d) + (1 - \theta)(1 - r^*)dp / (1 - p) \quad (5)$$

26. The model can be solved for any value of d^* . If this assumed and arbitrary d^* is higher than the true debt limit, then the default would occur at a level lower than d^* . By contrast, if investors' debt limit belief is below the theoretical debt limit, then default would occur at the debt level slightly higher than the debt limit belief. One can thus create a function that takes this arbitrary debt limit d^* as an argument and returns the difference between the arbitrary level and the level at which the model shows the default should occur. If this difference is zero, default occurs exactly at the level that was assumed to be the limit: this provides the solution. If there are several solutions, the debt limit is the highest one. This debt limit depends of macroeconomic conditions, but it does not depend on the current level of debt.

27. As the formation of the risk premium is a complex phenomenon, an alternative calculation is carried out based on a market-based approach. For a given risk premium included in the observed market interest rate r , the government reaches its debt limit for the highest debt stabilising level:

$$d_{t+1} - d_t = 0 = \underbrace{(r - g)d_t}_{\text{accumulation of past debt}} - \underbrace{(\mu + f(d))}_{\text{primary balance}} \quad (6)$$

28. This modelling exercise illustrates that the debt limit and the sovereign interest rate pattern crucially hinge on confidence. Even at a low debt level, multiple equilibria can exist, and a self-fulfilling spiral between debt and the interest rate can be triggered by a loss of confidence in the absence of a lender of last resort. For instance, if debt holders assume a public debt limit different from the theoretical one, say 170% of GDP instead of 190%, then the model suggests that the default would occur at about 172%, which

illustrates that the debt limit assumed by the investors is self-fulfilling. This model illustrates that in the case of loss of confidence that is not justified by fundamentals, and if the government's behaviour remains responsible, then it is appropriate for a lender of last resort to keep the government interest rate sufficiently low.

3.2. Country-specific debt limits

29. The calculation of country-specific debt limits makes use of the following elements. The fiscal reaction function follows the estimated reaction function (Table 1, Column 1). The long-term real growth rate is measured as the average annual potential growth rate expected by the OECD in the near future (i.e. from 2014 to 2017). The risk-free real interest rate is calculated as the 10 year sovereign bond yield minus the 10 year CDS premium minus expected core inflation in 2014. Expected inflation is preferred to past observations as interest rates and CDS levels should reflect future developments. The output gap standard deviation is multiplied by the coefficient linking the output gap to the primary balance to calibrate the size of the shock to the primary balance, which follows a triangular distribution. The recovery rate in case of default is set at 90% for all countries, in line with Ghosh et al. (2013). μ is the country specific fixed effect plus the median of residuals, so as to reduce sensitivity to extreme events.

30. Table 2 reports the data inputs, the corresponding calculations of debt limits. The results are roughly comparable to the magnitudes found by Ghosh et al. (2013). The fiscal reaction function estimated here takes also into account fiscal consolidation efforts observed in the wake of the crisis, especially in the euro area, and this can explain why debt limits are slightly higher. A striking feature is that for several countries, a behaviour change is needed to find a solution, suggesting that these countries need to change their fiscal behaviour for their debt trajectory to become sustainable. For the other countries, debt limits are above the level at which fiscal fatigue kicks in, because default would materialise when the government chooses not to compensate interest rate payments by higher primary surpluses.

31. The market-based debt limit provides an upper bound of the debt limit because it does not take into account the interest rate rise as debt approaches its limit. That is why it is higher than the debt limits built based on a model-based interest rate.

Table 2. Debt limits

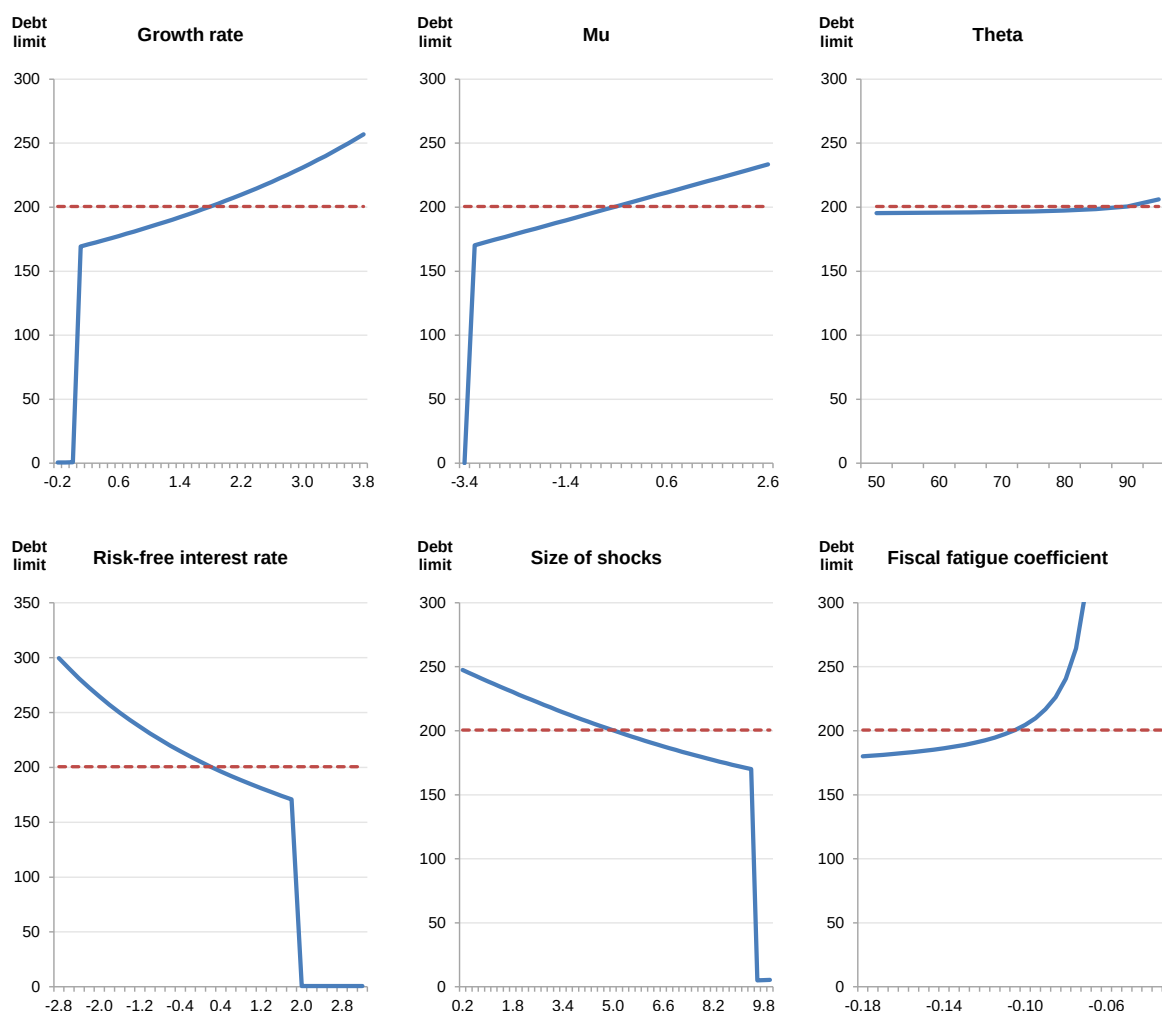
	g	r	r*	$\bar{\varepsilon}$	μ	OECD estimate	
						$\bar{d}_{model}$	$\bar{d}_{market}$
AUS	3.2%	1.4%	0.9%	2.7%	0.6%	250	263
AUT	1.7%	0.1%	-0.5%	3.2%	-0.6%	231	249
BEL	1.5%	0.9%	0.1%	2.7%	2.3%	245	251
CAN	2.1%	0.6%	0.2%	3.6%	-0.4%	217	246
CHE	2.1%	0.3%	-0.1%	2.8%	-0.5%	236	254
CHL	5.2%	1.9%	0.9%	4.2%	n.a.	n.a.	n.a.
CZE	2.6%	-0.1%	-0.9%	5.8%	-3.3%	203	247
DEU	1.2%	-0.5%	-0.9%	3.1%	0.2%	235	257
DNK	1.1%	0.1%	-0.4%	4.9%	2.1%	224	258
ESP	0.9%	2.2%	1.0%	5.0%	-1.9%	n.s.	175
EST	3.3%	n.a.	n.a.	12.1%	0.6%	n.a.	n.a.
FIN	1.6%	0.4%	-0.1%	6.6%	0.6%	200	249
FRA	1.7%	0.7%	-0.1%	3.3%	-2.5%	196	211
GBR	2.4%	0.9%	0.5%	4.1%	-2.2%	194	226
GRC	1.1%	7.0%	1.9%	9.2%	-2.3%	n.s.	n.s.
HUN	1.3%	1.5%	-0.7%	5.1%	0.8%	222	219
IRL	1.1%	1.6%	0.7%	11.8%	-2.2%	n.s.	184
ISL	1.0%	3.6%	1.6%	8.0%	-0.2%	n.s.	171
ISR	3.4%	1.4%	0.1%	4.8%	-1.2%	235	250
ITA	0.4%	2.2%	0.7%	4.1%	-0.4%	172	180
JPN	0.9%	-1.4%	-2.2%	4.9%	-6.4%	n.s.	194
KOR	3.5%	0.5%	-0.4%	5.1%	2.3%	307	334
LUX	2.1%	-0.7%	-1.3%	7.3%	1.7%	253	314
MEX	3.0%	2.4%	1.2%	4.4%	n.a.	n.a.	n.a.
NLD	1.6%	0.9%	0.2%	3.3%	1.0%	223	240
NOR	2.5%	0.6%	0.3%	3.9%	6.1%	297	330
NZL	2.7%	2.1%	1.5%	3.6%	2.5%	233	251
POL	2.8%	1.7%	0.7%	2.6%	-1.7%	219	221
PRT	0.5%	3.1%	0.6%	7.4%	-2.6%	n.s.	n.s.
SVK	2.9%	1.6%	0.7%	5.8%	-3.7%	n.s.	203
SVN	1.2%	2.4%	0.4%	6.7%	-1.9%	n.s.	177
SWE	2.6%	0.6%	0.3%	4.9%	0.6%	230	272
TUR	4.7%	3.8%	1.5%	8.3%	n.a.	n.a.	n.a.
USA	2.4%	1.0%	0.7%	4.4%	-1.8%	193	229

Note: n.s. = no solution (no finite interest rate solution, if past fiscal behaviour prevails). n.a. = not available. g is the average annual potential growth rate between 2014 and 2017, r is the 10 year interest rate in mid-2014, r* is the 10 year interest rate in mid-2014 minus the risk premium as priced with the corresponding credit default swap, $\bar{\varepsilon}$ is the maximum size of annual macroeconomic shocks considering a triangular distribution of shocks with the same variance as the one found in the baseline estimations, μ is the constant of the primary balance reaction function, $\bar{d}_{model}$ is the model-based debt limit and $\bar{d}_{market}$ is the debt limit corresponding to the current market interest rate.

32. The role of each determinant is investigated by looking at the sensitivity of the debt limit with respect to the OECD average. The debt limit increases with the growth rate and the average level of the primary surplus (Figure 4). This debt limit is not affected by the recovery rate. It decreases with the risk free interest rate and the size of shocks. The sensitivity to the interest rate and growth rate is almost symmetric: what really matters is the interest rate-growth rate differential. The panel showing the sensitivity to the fiscal fatigue coefficient suggests that the debt limit crucially depends on the size of this coefficient. Of course, the debt limit is also sensitive to the level at which fiscal fatigue kicks in. This stylised exercise shows that small changes in structural parameters do not matter much, but large changes

can imply that no solution can be found. However, when a country has little fiscal margin left, then even a small change in the interest rate or in the growth rate can have a large impact on the debt limit.

Figure 4. Debt limit sensitivity
Vertical axis: Debt limit in per cent of GDP



Note: For each panel, the title refers to the parameter that is varied, all other parameters being set equal to the OECD average. Parameter values are reported on the horizontal axis, and the corresponding debt limit is reported on the vertical axis. Below a growth threshold, or above a risk-free interest rate threshold, there is no solution. Horizontal lines denote the debt limit that would prevail in the virtual baseline country in which its parameter is set equal to the OECD average.

33. The debt limit is a moving target as growth, the interest rate, the primary balance and uncertainty about macroeconomic shocks vary over time. However, pre-crisis debt limits are quite similar to current debt limits for most countries: the higher pre-crisis interest rate is offset by the lower size of uncertainties (Table 3). However, the picture changes sharply in countries such as Greece. The potential growth rate was believed to be much higher, the interest rate and uncertainties much lower than now, so that the debt limits seemed to be high. This is consistent with the low risk premium that prevailed before the crisis. The debt limits are also calculated based on long-term growth rate and interest rate prospects. The OECD Long-Term Baseline database projection in 2030 is combined with the pre-crisis uncertainty level to assess debt limits that would prevail when the long lasting effect of the crisis will have faded. For most countries, the rise in interest rates is offset by the decrease of uncertainties and the rise in the potential growth rate.

Table 3. Debt limits before, during and after the crisis
Per cent of GDP

	Pre-crisis		Current		Long-term prospects
Interest rate	Model based	Market based	Model based	Market based	Model based
Year	2007	2007	2014	2014	2030
AUS	209	229	250	263	201
AUT	178	203	231	249	183
BEL	204	227	245	251	219
CAN	203	239	217	246	181
CHE	180	211	236	254	172
CZE	236	285	203	247	n.s.
DEU	182	201	235	257	183
DNK	187	209	224	258	213
ESP	200	243	n.s.	175	173
FIN	179	239	200	249	169
FRA	n.s.	186	196	211	181
GBR	n.s.	195	194	226	179
GRC	255	282	n.s.	n.s.	n.s.
HUN	256	274	222	219	208
IRL	221	280	n.s.	184	185
ISL	215	274	n.s.	171	186
ISR	n.a.	n.a.	235	250	n.s.
ITA	n.s.	190	172	180	189
JPN	n.s.	n.s.	n.s.	194	n.s.
KOR	220	275	307	334	177
LUX	258	318	253	314	201
NLD	176	199	223	240	204
NOR	230	287	297	330	>330
NZL	190	217	233	251	208
POL	186	213	219	221	n.s.
PRT	n.s.	178	n.s.	n.s.	n.s.
SVK	344	44	n.s.	203	n.s.
SVN	n.a.	n.a.	n.s.	177	n.s.
SWE	196	228	230	272	181
USA	182	202	193	229	176

Note: n.s. = no solution (no finite interest rate solution, if past fiscal behaviour prevails). n.a. = not available. Pre-crisis debt limits are calculated with the 2007 interest rate and the average potential growth rate between 2004 and 2007. Current debt limits are the baseline debt limits reported in Table 2. Long-term prospect debt limits are calculated with the Long-term Baseline interest rate and potential growth rate projected in 2030. In the model based interest rate calculations, the interest rate includes a modelled risk premium, which increases with debt. The model-based debt limit corresponds to the market interest rate in 2007, 2014 and 2030.

Source: OECD calculations.

34. An important determinant of differences across OECD countries is the gap between growth and interest rates. This can be illustrated by the analysis of the difference between a country's debt limit and the debt limit of a virtual OECD average country. This difference can be decomposed into contributions of the three main components. The debt limit d_i^* is a function of the risk-free interest rate – growth rate differential $r_i - g_i$, the shock size $sd(\varepsilon_i)$, and of the average past primary surplus μ_i :

$$d_i^* = f(r_i - g_i, sd(\varepsilon_i), \mu_i)$$

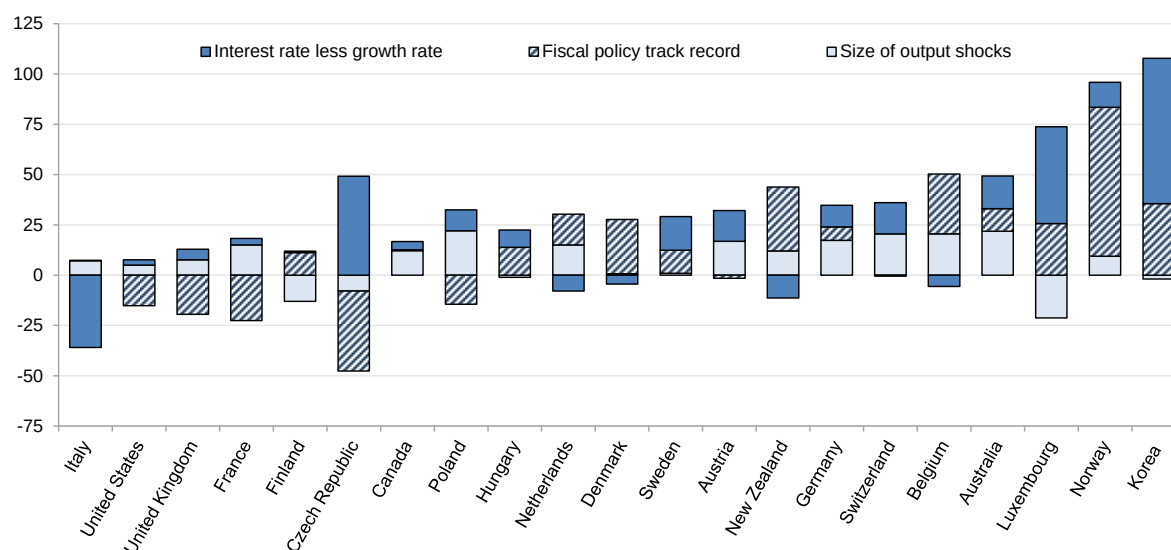
The role played by each of these three determinants can be investigated by replacing each of them one by one by the corresponding OECD average. This provides the following decomposition of the debt limit:

$$d_i^* = \underbrace{f(r_i - g_i, sd(\varepsilon_i), \mu_i) - f(\bar{r} - \bar{g}, sd(\varepsilon_i), \mu_i)}_{r_i - g_i \text{ contribution}} + \underbrace{f(\bar{r} - \bar{g}, sd(\varepsilon_i), \mu_i) - f(\bar{r} - \bar{g}, \overline{sd(\varepsilon_i)}, \mu_i)}_{sd(\varepsilon_i) \text{ contribution}} + \underbrace{f(\bar{r} - \bar{g}, \overline{sd(\varepsilon_i)}, \mu_i) - f(\bar{r} - \bar{g}, \overline{sd(\varepsilon_i)}, \bar{\mu})}_{\bar{\mu} \text{ contribution}} + \underbrace{f(\bar{r} - \bar{g}, \overline{sd(\varepsilon_i)}, \bar{\mu})}_{OECD \text{ average}}$$

35. This decomposition depends on the order of replacement of each determinant, and an average of contributions across possible orders is considered. This exercise shows that the gap between the interest rate and growth rate and the fiscal track record contribute more than macroeconomic volatility in explaining differences across OECD countries (Figure 5).

Figure 5. Debt limit drivers

Deviation from the OECD average in % of GDP



Note: This figure compares the debt limit of a given country to the 200% debt limit that would prevail in a virtual OECD average country, in which each determinant is equal to the corresponding OECD average. Contributions are debt limit differences associated with replacing a country-specific characteristic by the corresponding OECD average. For some countries no solution exists.

Source: OECD calculations.

3.2. Sensitivity to the number of thresholds of the fiscal reaction function

36. The sensitivity of the debt limit to the shape of the fiscal reaction is investigated by replacing the two-threshold specification by a one-threshold specification. This sensitivity analysis is performed because the choice of two thresholds, despite its economic grounding, is somewhat arbitrary. The fiscal reaction function with one threshold ignores that the fiscal reaction to debt can increase when debt is getting closer to dangerous levels; and hence embeds a bit less fiscal tightening at a high debt level. As a result, the model based debt limit is lower, and no solution exists for a few additional countries (Italy, the United States) (Table 4). This robustness checks illustrate that the high baseline debt limit hinges on the assumption that governments react strongly to debt when debt is between 120% and 170% of GDP. The market based debt limits are broadly unchanged, as the lower reaction to rising debt is offset by a slightly lower fiscal fatigue coefficient.

Table 4. Debt limit sensitivity to the number of thresholds
Per cent of GDP

	Two threshold specification		One threshold specification (less fiscal tightening at a high debt level)	
Interest rate	Model based	Market based	Model based	Market based
Year	2014	2014	2014	2014
AUS	250	263	235	267
AUT	231	249	210	247
BEL	245	251	225	247
CAN	217	246	192	241
CHE	236	254	217	255
CZE	203	247	173	248
DEU	235	257	213	256
DNK	224	258	203	258
ESP	n.s.	175	n.s.	n.s.
FIN	200	249	177	250
FRA	196	211	169	202
GBR	194	226	170	224
GRC	n.s.	n.s.	n.s.	n.s.
HUN	222	219	198	211
IRL	n.s.	184	n.s.	171
ISL	n.s.	171	n.s.	n.s.
ISR	235	250	208	246
ITA	172	180	n.s.	n.s.
JPN	n.s.	194	n.s.	178
KOR	307	334	310	362
LUX	253	314	239	334
NLD	223	240	201	235
NOR	297	330	294	350
NZL	233	251	217	252
POL	219	221	195	214
PRT	n.s.	n.s.	n.s.	n.s.
SVK	n.s.	203	n.s.	193
SVN	n.s.	177	n.s.	n.s.
SWE	230	272	209	277
USA	193	229	n.s.	222

Note: n.s. = no solution (no finite interest rate solution, if past fiscal behaviour prevails). n.a. = not available. In the model based interest rate calculation, the interest rate includes a modelled risk premium, which increases with debt. The market-based debt limit corresponds to the current market interest rate.

Source: OECD calculations.

4. The debt limit with an estimated reaction of the interest rate to debt

4.1. Estimation

37. An empirical estimation of the effect of debt on the interest rate is used as an alternative approach to the model based interest rate described above. The following long-term interest rate equation aims at capturing market reactions to growing debt (see De Grauwe and Ji (2012) and Haugh et al. (2009) among others for alternative estimates of interest rate determinants):

$$r_{it}^l = \beta_{4,1} r_{it}^s + \beta_{4,2} g_{it-1} + \beta_{4,3} \pi_{it-1}^c + \beta_{4,4} D_{it-1} + \beta_{4,5} \text{emu}_{it} D_{it-1} + u_{4,i} + \varepsilon_{4,it}$$

where π_{it}^c denotes core inflation.

38. The long-term nominal interest rate is determined to a large extent by the short-term interest rate (Table 5). The negative coefficient associated with the growth rate reflects the yield curve flattening, when growth becomes stronger. The interest rate increases with public debt, but this increase is small and not always significant for non-euro area countries, while it is significant and larger for euro area countries. This euro area effect is more pronounced for small countries in the euro area (Table 5, Column 2). This approach based on market reactions provides an illustration of the difference between euro area and non-euro area countries, which partly reflects a different belief on the capacity of the central bank to act as a lender of last resort and the higher risk of debt restructuring when devaluation is not possible. Compared to the non-linear, model-based interest rate, such a linear link generates a higher interest rate reaction at debt levels well below the debt limit, while the interest rate reaction is less pronounced when the country is getting very close to the debt limit.

Table 5. Long-term interest rate determinants

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	10-year interest rate	10-year interest rate	10-year interest rate	10-year interest rate	10-year real interest rate	10-year interest rate
Core inflation	0.084 [0.057]	0.024 [0.067]	0.079 [0.057]	0.079* [0.046]		
GDP deflator						-0.008 [0.026]
Short-term interest rate	0.55*** [0.037]	0.52*** [0.052]	0.55*** [0.037]	0.58*** [0.029]		0.58*** [0.031]
Short-term real interest rate					0.63*** [0.039]	
Lag (Real growth)	-0.081*** [0.022]	-0.062** [0.026]	-0.088*** [0.022]		-0.084*** [0.024]	-0.072*** [0.022]
Lag (Potential growth)				-0.32*** [0.12]		
Lag (Public debt)	0.0064 [0.0044]	0.0098** [0.0049]	0.013** [0.0053]	0.0049 [0.0044]	0.020*** [0.0048]	0.0037 [0.0043]
EMU	-1.95*** [0.70]	-0.025*** [0.0087]	-0.28 [0.31]	-1.85*** [0.60]	-1.65** [0.76]	-2.15*** [0.69]
Lag(Public debt) * EMU	0.023** [0.0095]	0.038*** [0.014]		0.022** [0.0091]	0.025** [0.0097]	0.023** [0.0093]
EMU.size		0.11* [0.059]				
Lag(Public debt) * EMU.size		-0.24*** [0.091]				
Sample	1985-2013	1985-2013	1985-2013	1985-2013	1985-2013	1985-2013
Year fixed effects	no	no	no	no	no	no
Country fixed effects	yes	yes	yes	yes	yes	yes
N	624	533	624	621	672	676
Rho	0.55	0.50	0.53	0.59	0.59	0.55
R2	0.680	0.638	0.676	0.723	0.487	0.682

Note: Panel regression with AR(1) Prais-Winsten correction and panel heteroskedasticity-robust standard errors. Standard errors are in parenthesis.

39. The coefficient that links debt to the interest rate is extracted from these estimates (Table 5, Column 1), and combined with the long-run interest rate r_{it}^l anticipated in the Long-Term Baseline scenario in 2030 and with the corresponding debt D_{it} to build the following linear approximation:⁴

$$r_t^l(d) = r_{it}^l + (\beta_{4,4} + \beta_{4,5} \text{emu}_{it})(d - D_{it})$$

40. This interest rate already includes a risk premium, and hence the debt limit is calculated as the highest debt level at which the primary balance can compensate the accumulation dynamic:

$$\underbrace{(r(d^*) - g)d^*}_{\text{accumulation of past debt}} = \underbrace{(\mu + f(d^*))}_{\text{primary balance}}$$

4.2. Country-specific debt limits

41. Results are reported in Table 6, with either the fiscal reaction function estimated above, or with the assumption that the government's fiscal surplus effort is equal to 4% of GDP, which is a larger surplus than that achieved in the past for most countries. The absence of a debt stabilising solution in several countries means that past behaviour does not suffice to keep debt stable, reflecting a tendency to generate primary deficits in the past. In particular, euro area countries that face a higher sensitivity of the interest rate to debt need a higher primary surplus to stabilise debt (Figure 6).

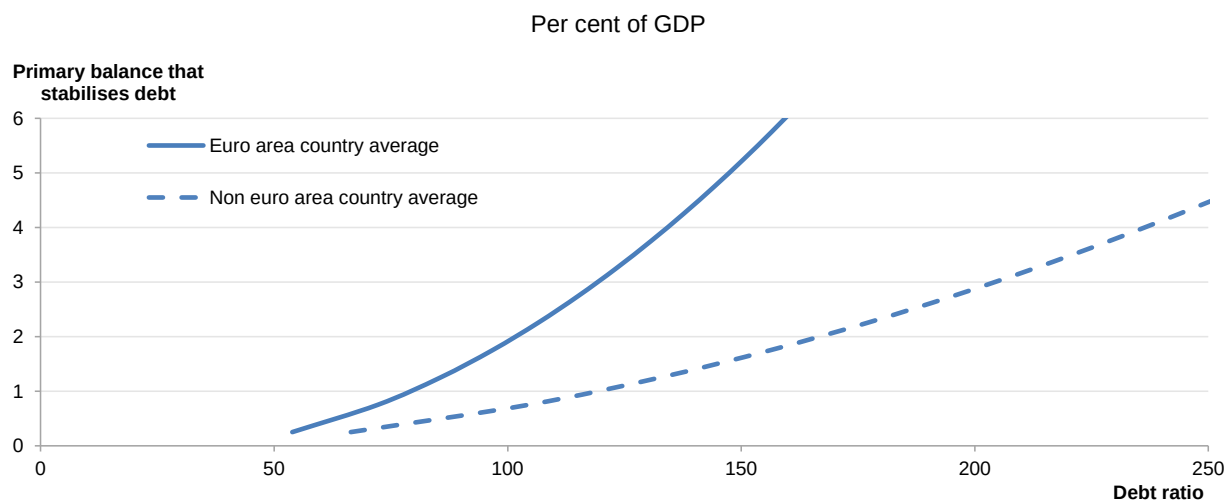
4. Replacing this 2030 reference point by the low levels of interest rates observed in the current period would lead, in this approach, to unrealistically high debt limits in many countries, reflecting the role of unconventional monetary policies.

Table 6. Debt limits with an estimated reaction of the interest rate to debt

Government behaviour	Per cent of GDP					
	Pre-crisis		Current		Long-term prospects	
	Estimated	Surplus = 4%	Estimated	Surplus = 4%	Estimated	Surplus = 4%
Year	2007	2007	2014	2014	2030	2030
AUS	196	204	187	202	191	193
AUT	149	156	94	148	105	152
BEL	184	161	174	143	182	159
CAN	213	328	191	258	196	256
CHE	198	303	195	284	191	269
CZE	190	369	n.s.	173	n.s.	171
DEU	106	133	94	128	99	125
DNK	213	268	202	224	220	306
ESP	173	176	n.s.	128	100	149
FIN	183	172	114	138	170	143
FRA	n.s.	136	n.s.	132	n.s.	141
GBR	179	209	n.s.	190	179	198
GRC	172	172	n.s.	113	52	137
HUN	222	>300	193	225	205	281
IRL	189	226	n.s.	135	173	166
ISL	220	349	n.s.	108	183	157
ISR	n.a.	n.a.	193	>300	n.a.	n.a.
ITA	76	128	n.s.	112	94	140
JPN	n.s.	291	n.s.	237	n.s.	275
KOR	245	474	227	>300	206	225
LUX	204	205	171	142	178	138
NLD	168	148	165	142	174	154
NOR	>300	>300	>300	>300	>300	>300
NZL	199	173	192	166	196	157
POL	221	>300	181	259	n.s.	178
PRT	n.s.	138	n.s.	115	n.s.	159
SVK	205	293	n.s.	165	n.s.	146
SVN	n.a.	n.a.	n.s.	137	n.a.	n.a.
SWE	214	>300	203	285	199	248
USA	190	294	184	286	186	272

Note: n.s. = no solution (no finite interest rate solution, if past fiscal behaviour prevails). n.a. = not available. Pre-crisis debt limits are calculated with the 2007 interest rate and the average potential growth rate between 2004 and 2007. Current debt limits are the baseline debt limits reported in Table 2. Long-term prospect debt limits are calculated with the Long-term Baseline interest rate and potential growth rate projected in 2030. In the model based interest rate calculations, the interest rate includes a modelled risk premium, which increases with debt. The model-based debt limit corresponds to the market interest rate in 2007, 2014 and 2030.

Source: OECD calculations.

Figure 6. Euro area countries have to generate a higher surplus to keep debt sustainable

Note: This chart shows the primary balance surplus that stabilises the debt level, assuming that the interest rate is more sensitive to the debt level in the euro area. The growth rate is set at the average potential growth rate between 2014 and 2017.

Source: OECD calculations.

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