On the estimation of panel fiscal reaction functions: Heterogeneity or fiscal fatigue?

by Gerdie Everaert and Stijn Jansen

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Abstract

This paper investigates whether fiscal fatigue is a robust characteristic of the fiscal reaction function in a panel of OECD countries over the period 1970-2014 or merely an artifact of ignoring important aspects of the panel dimension of the data. More specifically, we test whether the quadratic and cubic debt-to-GDP terms remain significant once dynamics, heterogeneous slopes and an asymmetric reaction to the business cycle are allowed for. The results show a significant heterogeneous reaction of the primary balance to lagged debt with fiscal fatigue not being a general characteristic of the fiscal reaction function shared by all countries in our panel. In line with the literature, we further find that fiscal balances tend to deteriorate in contractions without correspondingly improving during expansions. Explorative stochastic debt simulations show that debt forecasts crucially depend on the specification of the fiscal reaction function.

JEL Classifications: E62, H62, H63, H68

Keywords: Fiscal reaction function, dynamics, non-linearities, fiscal fatigue, debt sustainability analysis

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TABLE OF CONTENTS

1 Introduction

The European sovereign debt crisis, rising age-related public expenditures and the secular stagnation of output growth have put renewed emphasis on questions about the sustainability of fiscal policy. In a series of papers, Bohn (1995, 1998) developed a stochastic general equilibrium model to evaluate the sustainability question. He argues that plausible indicators such as the average budget deficit and the realized path of the debt-to-GDP ratio can be quite misleading as fiscal sustainability also depends on future economic growth and interest rates. Although historically a growth dividend has covered the entire interest bill on U.S. debt, neither a stable debt-to-GDP ratio nor a balanced primary budget (i.e. the overall government budget net of interest payments on debt) guaranties sustainability when there is a positive probability that future economic growth falls below the interest rate. He further shows that a positive reaction of the primary budget to lagged debt, in contrast, is a sufficient condition for the government to satisfy its intertemporal budget constraint and hence fiscal policy to be sustainable. The essence of Bohn's sustainability test is to estimate a fiscal reaction function (FRF) to determine whether a build-up of the public debt-to-GDP ratio elicits an increase in the primary balance, controlling for other determinants (the business cycle, inflation, external deficits, etc.). Based on FRF estimates, Bohn (1998) concludes that U.S. fiscal policy has historically been sustainable. Mendoza and Ostry (2008) extend this evidence of fiscal solvency to a large panel of developed and emerging economies.

Contemporary debt sustainability analysis has evolved from estimating FRFs to using these estimates for stochastic debt simulations. To this end, a reduced form vector autoregressive (VAR) model is estimated to obtain the joint distribution of shocks to a standard set of macroeconomic variables (e.g. output growth, real interest rates and inflation) affecting debt dynamics. Repeatedly drawing shocks from this distribution, letting the primary balance react through the FRF and calculating the implied change in debt then generates stochastic debt trajectories, which are typically summarized by plotting fan charts (see e.g. Celasun et al., 2007; Medeiros, 2012).

With the FRF at the center of debt sustainability analysis, it is essential that it is correctly specified and estimated. A first key question is whether the FRF is *linear or non-linear* in the debt-to-GDP ratio. The most simple rule that ensures sustainability is a linear one. However, in an attempt to stabilize the debt-to-GDP ratio at a reasonable level, fiscal policy may respond more when debt is high and/or rising while being less responsive at lower debt levels. Bohn (1998) indeed shows that U.S. fiscal policy over the period 1916-1995 was unresponsive at low levels of debt but significantly active at higher levels. Ghosh et al. (2013) further argue that it cannot literally be true that the primary balance would always increase with debt because, at sufficiently high levels of debt, this would require primary balances that exceed GDP. Using a panel of 23 advanced countries over the period 1970-2007, they find strong support for the existence of a non-linear FRF that exhibits this alleged 'fiscal fatigue' characteristic. Specifically, the FRF is well approximated by a cubic function where at low levels of debt there is no relationship between the primary balance and debt while as debt rises, the primary balance increases but the responsiveness eventually weakens and then actually decreases at very high levels of debt. This implies that there is a debt level above which the debt dynamics become explosive and the government will necessarily default. A similar result can be found in Mendoza and Ostry (2008) and Ostry et al. (2010) and is now widely accepted as an important characteristic of FRFs and used by different policy institutions to calculate fiscal space, as the difference between this debt limit and the observed debt-to-GDP ratio, or embedded in their stochastic debt simulations (see e.g. Fournier and Fall, 2015; Berti et al., 2016).

A second important topic is the *dynamic specification* of the FRF. The highly politicized nature of government budgeting makes it hard to react immediately to changes in debt and other economic conditions. As a result, the primary balance turns out to be a highly persistent series. Ghosh et al. (2013) and Mendoza and Ostry (2008) both consider a static FRF, though, dealing with the resulting strong autocorrelation in the error terms using a somewhat mechanical Generalized Least Squares (GLS) correction. In fact, the underlying assumption of an autoregressive (AR) pattern in the error terms implies that the persistence in the primary balance is assumed to stem from autocorrelation in exogenous shocks that hit the primary balance. This precludes a slow reaction in response to changes in the debt-to-GDP ratio or other economic conditions and potential non-linearities induced by fiscal plans. Although there are plenty of studies that model slow adjustment by adding the lagged primary balance as an explanatory variable (see e.g. Égert, 2012; Fatás and Mihov, 2012, for recent work), studies combining a dynamic model with non-linearities are rare. One exception is Ostry et al. (2010) who combine a dynamic specification with a non-linear (cubic) reaction in the debt-GDP ratio as a robustness test in their appendix.

A third specification issue is potential *slope heterogeneity*. Because debt-to-GDP ratios often show only small variation over time within countries, most of the current literature estimating FRFs relies on panel datasets. Adding a cross-sectional dimension and using a homogeneous panel specification ensures that there is sufficient information in debt-to-GDP ratios - ranging from low levels in countries like Australia, New-Zealand, Denmark, Norway and Sweden to very high levels in countries like Belgium, Greece, Italy and Japan - to identify non-linearities in the FRF. However, the significant fiscal fatigue identified by e.g. Ghosh et al. (2013) and Mendoza and Ostry (2008) may very well be induced by slope heterogeneity. If some countries react weaker to debt than others (i.e. they have a smaller coefficient on the debt-to-GDP ratio in their FRF), these countries will over time end up with a higher debt level. When estimating a homogeneous FRF, high debt will coincide with a weak reaction in the primary balance not because of fiscal fatigue but because of unmodeled slope heterogeneity in the FRF across countries.

A further specification matter is that an adequate analysis of debt sustainability requires an appropriate modeling of the *link between fiscal policy and the business cycle.* There is quite some literature on this complex link, but it is somewhat detached from the literature on debt sustainability. Gali and Perotti (2003) and Fatás and Mihov (2012) emphasize the role played by automatic stabilizers and discretionary fiscal policy. The degree of automatic stabilization depends on the size of the government and the progressiveness of the tax system, implying that the automatic reaction of fiscal policy to the business cycle is heterogeneous across countries. Large cross-sectional variation in the use of discretionary policy further adds to this heterogeneity. Moreover, there is growing evidence that fiscal variables react asymmetrically to cyclical conditions, i.e. fiscal balances tend to deteriorate in contractions without correspondingly improving in expansions (Égert, 2012; Balassone et al., 2010). When this asymmetry is not taken into account, the risk of debt increases may be underestimated (Celasun et al., 2007).

The objective of this paper is to design an appropriately specified panel FRF. More specifically, we will investigate whether fiscal fatigue is a robust characteristic in a panel of OECD countries over the period 1970-2014 or merely an artifact of ignoring important aspects of the panel dimension of the data. Hence, we will test whether the quadratic and cubic debt-to-GDP terms remain significant once dynamics are adequately modeled and heterogeneous slopes and an asymmetric reaction to the business cycle are allowed for. The results show a significantly heterogeneous reaction of the primary balance to lagged debt with fiscal fatigue not being a general characteristic of the FRF shared by all countries in our panel. In line with the literature, we further find that fiscal balances tend to deteriorate in contractions without correspondingly improving during expansions. Explorative stochastic debt simulations show that debt forecasts crucially depend on the specification of the FRF. Especially for some of the countries with relatively high debt levels, debt trajectories are more favorable when based on a FRF figuring fiscal fatigue. This is due to the fact that our coefficient estimates for the fiscal fatigue specification imply that the response of the primary balance is at its maximum when the debt-to-GDP ratio is around 100%, which may be much more favorable for simulated debt trajectories than those based on the country-specific coefficient estimates.

The remainder of this paper is organized as follows. Section 2 outlines our empirical specification and estimation methodology. Section 3 presents the estimation results. Section 4 illustrates to what extent the specification of the fiscal reaction function influences the outcome of stochastic debt simulations. Section 5 concludes.

2 Empirical specification and estimation methodology

In this section we outline our empirical specification of the FRF and the econometric methodology to estimate it. We start with the baseline specification as outlined in Ghosh et al. (2013) and next extend it to allow for persistence in the primary balance, a heterogeneous response to lagged debt and a heterogeneous and asymmetric reaction to the business cycle.

2.1 Baseline specification

Our starting point is the static homogeneous non-linear panel FRF proposed by Ghosh et al. (2013)

$$pb_{it} = \alpha_i + \beta_1 d_{i,t-1} + \beta_2 d_{i,t-1}^2 + \beta_3 d_{i,t-1}^3 + \phi gap_{it} + Z_{it}\omega + \varepsilon_{it}, \tag{1}$$

for $i = 1, \ldots, N$ and $t = 1, \ldots, T$ and where pb_{it} denotes the primary balance of country i in period t, $d_{i,t-1}$ the one period lagged debt-to-GDP ratio and gap_{it} the output gap. Following the literature (see e.g. Gali and Perotti, 2003; Mendoza and Ostry, 2008; Ostry et al., 2010; Ghosh et al., 2013), we add a vector of control variables Z_{it} including inflation ($infl_{it}$), the implicit interest rate on government debt (iir_{it}), the current account balance as a percentage of GDP ($curac_{it}$), trade openness ($open_{it}$), the ratio of elderly (old_{it}), the future ratio of elderly ($Fold_{it}$) and three dummy variables capturing whether a country is part of the Euro area in a specific year (D_{it}^{euro}), whether elections where held in a certain year (D_{it}^{elec}) and whether a country adopted some type of fiscal rule (D_{it}^{fisc}). Country-fixed effects α_i are included to account for country-specific time-invariant factors not included in Z_{it} that affect the primary balance.

Since unmodeled persistence in the error terms of equation (1) would cause the lagged debt-to-GDP ratio $d_{i,t-1}$ and its powers to be endogenous and hence induce inconsistency, ε_{it} is modeled as an AR(1) process

$$\varepsilon_{it} = \rho\varepsilon_{i,t-1} + \mu_{it}. \tag{2}$$

The model in equations (1)-(2) is typically estimated using the (iterated) Prais-Winsten Generalised Least Squares (GLS) estimator (see e.g. Ostry et al., 2010; Ghosh et al., 2013).

As fiscal policy, and hence the primary balance pb_{it}, is expected to have an impact on the state of the economy, the output gap gap_{it} is most likely an endogenous variable in equation (1). We will therefore use an instrumental variables estimator using the first and the second lag of gap_{it} (in line with Gali and Perotti, 2003) and a (trade share) weighted average of foreign countries' output gaps gap_{it}^{f} (in line with Pesaran et al., 2004; Jaimovich et al., 2007) as instruments. Both instruments are expected to be correlated with the output gap while at the same time being predetermined/exogenous. Besides the output gap, also the current account and implicit interest rate on government debt are potentially endogenous. The twin-deficit hypothesis states that a fiscal deficit (due to e.g. a tax reduction) may lead to an income boost and hence a current account deterioration. We instrument the current account and the implicit interest rate by their own first and second lag.[1]

The fiscal fatigue proposition of a positive but eventually slowing response of the primary balance to rising debt should show up as a $\beta_3 < 0$ (in a cubic specification) or $\beta_2 < 0$ and $\beta_3 = 0$ (in a quadratic specification). Using a panel of 23 advanced economies over the period 1970-2007, Ghosh et al. (2013) find $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 < 0$. Their coefficient estimates imply that the marginal response of the primary balance to lagged debt is at its maximum for a debt-to-GDP ratio of around 100% of GDP, starts to decline beyond that level and becomes negative for very high debt-to-GDP ratios (exceeding 140%). As a result, the response of the primary balance is at its maximum for a debt-to-GDP ratio of around 140%. However, Table 1 shows that this downward sloping segment of the FRF is identified mainly from the behavior of Japan, and to a lesser extent Belgium and Italy, as over the period 1970-2007 only these countries have episodes where the debt-to-GDP ratio is well above 100%. Hence, it is not obvious that this empirical result can be generalized to fiscal fatigue being present in all individual countries.

[1] The instruments were found to be sufficiently strong, with a first step adjusted R^2 of 67.2, 83.3 and 98.7 for the output gap, the current account and the implicit interest rate respectively. As each of these variables has strong persistence, especially their first lag serves as a valuable instrument.

Table 1: Evolution of debt-to-GDP ratio

	70-79	80-89	90-99	00-07	08-14
Australia	25.6	21.2	26.5	13.4	23.8
Austria	23.0	47.9	62.5	64.5	71.1
Belgium	60.1	108.3	125.8	96.8	97.1
Canada	48.4	61.8	92.8	75.4	84.8
Denmark	8.4	53.8	67.6	42.6	41.5
Finland	6.1	14.7	45.1	41.6	49.3
France	17.8	28.6	49.7	62.1	85.1
Germany	22.7	38.9	51.3	64.1	77.5
Greece	24.8	41.6	90.7	103.2	149.2
Ireland	46.1	90.4	78.3	30.2	92.9
Italy	51.3	75.9	112.5	105.5	122.3
Japan	23.5	64.8	92.5	171.3	226.6
Korea	15.2	17.9	10.1	24.0	34.5
Netherlands	41.8	63.3	73.0	50.5	66.2
New Zealand	51.3	59.8	48.5	24.8	32.6
Norway	39.8	31.5	32.3	47.4	53.3
Portugal	20.8	47.6	54.3	57.7	104.3
Spain	13.3	25.2	55.0	47.6	71.2
Sweden	20.1	50.8	62.1	49.8	40.2
UK	55.3	48.0	45.0	40.8	77.2
US	44.0	52.6	67.7	59.2	94.9

Sources: see Table 5 in Appendix A.

2.2 Extended specification

To investigate the robustness of the fiscal fatigue proposition, we alter and extend the baseline specification of the panel FRF in equation (1) to

$$pb_{it} = \alpha_i + \delta_t + \gamma pb_{i,t-1} + \beta_{1i} d_{i,t-1} + \beta_{2i} d^2_{i,t-1} + \beta_{3i} d^3_{i,t-1} + \phi_{it} gap_{it} + Z_{it}\omega + \varepsilon_{it}. \quad (3)$$

By allowing the coefficient β_{1i} to be *heterogeneous across countries*, equation (3) makes it possible to discriminate between the fiscal fatigue proposition that the response of the primary balance eventually decreases at high levels of debt ($\beta_3 < 0$ or $\beta_2 < 0$, $\beta_3 = 0$) in all countries and the proposition that the response to debt is heterogeneous (β_{1i} is significantly different) across countries.

Adequately discriminating between these two propositions requires sufficiently rich data, i.e. the panel should contain enough countries with considerable variation in their debt-to-GDP ratio over time. The recent sovereign debt crisis entails interesting new information in this respect as there was a widespread increase in debt levels, with additional countries moving into the area where fiscal fatigue may set in or moved from relatively low to high levels of debt. Table 1 shows that this was especially the case for Ireland, Greece and Portugal and to a lesser extent for France, Spain, the UK and the US. The sovereign debt crisis thus makes it possible to analyze the behavior of countries' fiscal policy over a wider range of debt levels. We will further test whether there is a heterogeneous non-linear reaction to lagged debt by also allowing β_{2i} or β_{3i} to differ across countries.

Our extended specification (3) nests three further generalizations. First, the use of an AR(1) process for the error terms ε_{it} in equation (1) implies that persistence in the baseline specification stems exclusively from autocorrelation in shocks hitting the primary balance. Hence, it disregards the slow political process underlying budget formation. To allow for sluggishness in the response of fiscal policy to economic conditions we add the *lagged primary balance* $pb_{i,t-1}$ as an explanatory variable to the model. The extension from a static to a dynamic panel data model may complicate estimation. Dynamic panel data models with country fixed effects suffer from the well-known Nickell (1981) bias for finite T and $N \to \infty$. The current literature provides numerous methods for avoiding this bias such as the difference and system generalized method of moment estimators of Arellano and Bover (1995) and Blundell and Bond (1998) or the bias-corrected fixed effects estimators proposed by Kiviet (1995) or Everaert and Pozzi (2007). However, due to our sufficiently long time dimension ($T = 45 > 30$), this bias is expected to be negligibly small (see Judson and Owen, 1999). Experimenting with these alternative estimation methods (results not reported) showed that this is indeed the case.

Second, global economic trends and common economic shocks (e.g. the recent financial crisis) can cause cross-sectional dependence and are potentially also an additional source of persistence in the error terms. We account for this by adding *time-fixed effects* δ_t to the model. We also implemented the more general Common Correlated Effects estimator suggested by Pesaran (2006), but given the fairly large number of explanatory variables too many degrees of freedom were lost (i.e. up to 15 country-specific coefficients need to be estimated) to obtain accurate estimates. Moreover, the results presented below show that the time-fixed effects are sufficient to remove the positive cross-sectional dependence in the error terms.

Third, borrowing from the literature analyzing the cyclical behavior of fiscal policy, we allow for a *flexible reaction to business cycle fluctuations* by modeling ϕ_{it} as a parameter that can vary both over countries and time. Heterogeneity over countries is added as both the degree of automatic stabilization and discretionary policy vary substantially internationally (Fatás and Mihov, 2012). Time variation in ϕ_{it} should capture the potential asymmetric reaction to positive and negative cyclical conditions (Égert et al., 2010). This can be modeled by letting ϕ_{it} take on two different values, i.e. ϕ_{i1} when the economy of country i is in a downturn ($gap_{it} < 0$) and ϕ_{i2} in case of an upturn ($gap_{it} > 0$). This allows for a different reaction of the primary balance towards the output gap depending on the state of the economy.

3 Estimation results

Our dataset comprises an unbalanced panel of yearly data for 21 OECD countries over the period 1970-2014.[2] A more detailed description of the included variables and the data sources used can be found in Table 5 in Appendix A. We start with discussing the results for the baseline specification and subsequently extend the specification along the lines suggested in Section 2.2. Although our main focus is on the robustness of the fiscal fatigue proposition, we will also briefly discuss the impact of the control variables on the primary balance.

3.1 Baseline specification

The results of estimating the baseline specification (1) suggested by Ghosh et al. (2013) using our extended dataset are presented in column (1) of Table 2. In line with their findings, the estimated coefficients on the debt terms imply fiscal fatigue. The marginal response of the primary balance to lagged debt even starts to decline at somewhat lower debt levels of around 100% of GDP and becomes negative when the debt-to-GDP ratio exceeds 170%.

3.2 Dynamics and structure in the error terms

As the baseline specification is a static model, estimated using GLS to correct for autocorrelation in the error terms, it does not explicitly allow for a sluggish response of the primary balance to debt and its determinants. As a first extension we therefore transform the static model to a dynamic one. Estimates for the dynamic specification are reported in column (2) of Table 2.[3] The coefficient on the lagged primary balance is 0.731 and highly significantly, showing considerable persistence in

[2] Compared to Ghosh et al. (2013), due to data availability our dataset does not include Iceland and Israel. See Table 3 for the included countries and individual sample periods.

[3] When comparing the results from the static and dynamic regressions, note that in the latter the long-run effect of each variable equals $\beta_{LR} = \frac{\beta}{1-\gamma}$.

Table 2: Fiscal policy reaction function: homogeneous and mean-group estimation results

Dependent variable: pb_{it} — Sample period: 1970-2014, 21 countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$pb_{i,t-1}$		0.731***	0.735***	0.664***	0.620***	0.665***	0.656***	0.662***
		(0.053)	(0.058)	(0.060)	(0.056)	(0.059)	(0.059)	(0.054)
$d_{i,t-1}$	−0.066**	0.011	−0.005	**0.006**	**−0.065**	**0.027*** **	**0.026*** **	**0.041*** **
	(0.030)	(0.015)	(0.014)	**(0.006)**	**(0.181)**	**(0.006)**	**(0.006)**	**(0.011)**
$d^2_{i,t-1}$	1.5e-3***	4.1e-4**	4.3e-4**	2.4e-4	**−9.1e-4**			
	(3.4e-4)	(1.8e-4)	(1.7e-4)	(3.0e-4)	**(4.7e-3)**			
$d^3_{i,t-1}$	−5.1e-6***	−1.8e-6***	−1.7e-6***	−6.5e-7	**3.8e-5**			
	(1.1e-6)	(5.7e-7)	(5.5e-7)	(7.5e-7)	**(6.1e-5)**			
gap_{it}	0.447***	0.158***	0.066**	0.122***	0.115***	0.119***		
	(0.041)	(0.032)	(0.028)	(0.033)	(0.035)	(0.033)		
$gap_{it} < 0$							0.233***	**0.372** **
							(0.052)	**(0.147)**
$gap_{it} > 0$							0.012	**−0.081**
							(0.046)	**(0.127)**
$infl_{it}$	0.012	0.017	0.070**	0.130***	0.167***	0.133***	0.128***	0.150***
	(0.029)	(0.026)	(0.027)	(0.031)	(0.036)	(0.032)	(0.032)	(0.034)
iir_{it}	0.134***	0.081***	0.044*	0.013	−0.015	0.021	0.030	−0.026
	(0.046)	(0.024)	(0.026)	(0.039)	(0.046)	(0.034)	(0.035)	(0.038)
$curac_{it}$	0.165***	0.115***	0.082***	0.113***	0.127***	0.098***	0.123***	0.093***
	(0.037)	(0.025)	(0.022)	(0.021)	(0.021)	(0.021)	(0.021)	(0.024)
$open_{it}$	0.055***	0.026***	0.011	0.007	0.022	0.008	0.004	−0.006
	(0.013)	(0.009)	(0.010)	(0.011)	(0.014)	(0.012)	(0.012)	(0.015)
D^{euro}_{it}	−0.323	−0.471**	−0.173	−0.165	−0.440	−0.230	−0.124	0.062
	(0.408)	(0.234)	(0.222)	(0.254)	(0.354)	(0.255)	(0.254)	(0.305)
D^{elec}_{it}	−0.184**	−0.154	−0.230**	−0.212*	−0.211*	−0.230**	−0.225**	−0.260**
	(0.087)	(0.130)	(0.122)	(0.114)	(0.109)	(0.114)	(0.114)	(0.110)
D^{fisc}_{it}	0.494*	0.590***	0.580***	0.424**	0.358*	0.440**	0.419**	0.411*
	(0.291)	(0.191)	(0.205)	(0.218)	(0.221)	(0.219)	(0.218)	(0.219)
old_{it}	−0.347**	−0.132	−0.045	0.147	0.266	0.134	0.116	0.139
	(0.153)	(0.083)	(0.078)	(0.108)	(0.164)	(0.104)	(0.106)	(0.112)
$Fold_{it}$	−0.044	−0.087**	−0.025	−0.048	−0.136*	−0.048	−0.042	−0.065
	(0.093)	(0.043)	(0.047)	(0.051)	(0.080)	(0.053)	(0.053)	(0.058)
Observations	811	809	809	809	809	809	809	809
Cross-sectional corr.	0.150	0.243	−0.048	−0.047	−0.047	−0.046	−0.046	−0.046
Time fixed effects	no	no	yes	yes	yes	yes	yes	yes
CH AR(1) test χ^2	414.422***	8.391***	0.028	0.064	0.153	0.051	0.131	1.294
GLS	yes	no	no	no	no	no	no	no
Hetero coefs on $d_{i,t-1}$	no	no	no	yes	yes	yes	yes	yes
Wald hetero test				65.16***	166.24***	83.72***	81.74***	78.73***
Hetero coefs on gap_{it}	no	no	no	no	no	no	no	yes
Wald hetero test								160.20***

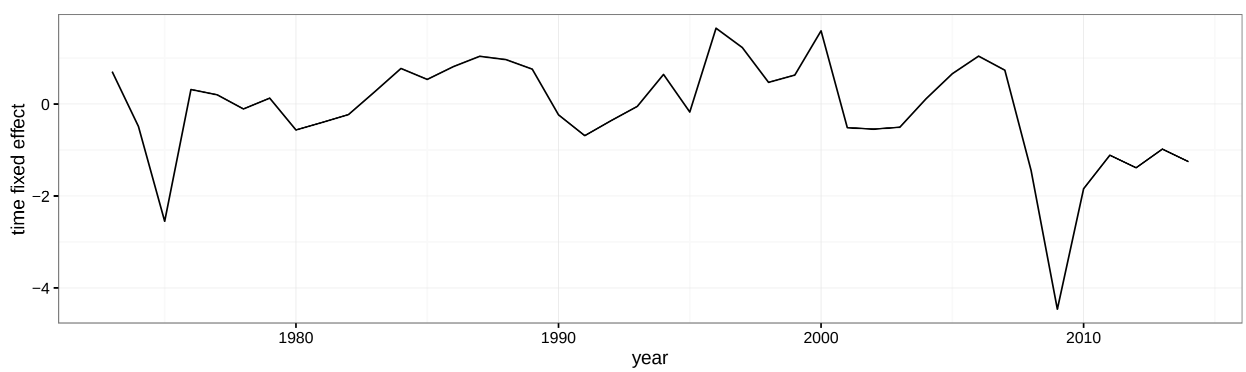
Notes: The dependent variable is the primary balance pb_{it} as a % of GDP. The GLS estimator corrects for an AR(1) autocorrelation structure and cross-sectional heteroskedasticity in the error terms. When GLS is not used, we report White robust standard errors for the homogeneous coefficients. For the heterogeneous coefficients we report (in bold) mean group estimates as defined in equation (4) with standard errors calculated using equation (5). Statistical significance at the 10%, 5% and 1% level is indicated using *, ** and *** respectively.

The output gap is instrumented by using its first and second lag and a weighted average of foreign countries' output gaps. The current account and implicit interest rate are instrumented by their first and second lags.

The cross-sectional correlation coefficient is calculated as the average of the country-by-country cross-correlation in the estimated error terms. CH AR(1) is the Cumby and Huizinga (1992) test for first-order serial correlation in the error terms. This test is robust to heteroscedasticity and applicable when the regression has been estimated using instrumental variables. It is calculated from regressions results without applying the Prais-Winsten GLS correction, which is only implemented when significant autocorrelation is detected. 'Wald hetero' tests the null hypothesis that the heterogeneous slopes are actually homogeneous across countries. It uses a covariance matrix that is robust to heteroscedasticity.

the formation of the government budget. Note that the test for autocorrelation in the error terms reported in the bottom of Table 2 shows that even in the dynamic specification there is significant autocorrelation left. Moreover, the average pairwise correlation coefficients reported in the bottom of Table 2 show that there is cross-sectional correlation in the error terms of specifications (1) and (2). To allow and correct for common shocks hitting all countries in the panel, in specification (3) we therefore add time-fixed effects to the model. Looking at the pairwise correlation coefficient, this reduces the cross-sectional correlation in the error terms to a negligibly small number. Interestingly, it also removes the autocorrelation in the error terms, suggesting that this was induced by persistence in shocks common to all countries. The estimated time-fixed effects plotted in Figure 1 indeed show considerable persistence (the first-order autocorrelation coefficient is 0.69). The two deep dips that can be observed coincide with the first oil crisis in the mid 1970s and the recent financial crisis.

Figure 1: Evolution in the time-fixed effects



Note: Based on the column (3) in Table 2 with 1972 as the reference year.

3.3 Fiscal fatigue versus slope heterogeneity

We further extend the specification by allowing the coefficient on lagged debt $d_{i,t-1}$ to vary across countries. Using the heterogeneous coefficients $\widehat{\beta}_i$ we calculate Mean Group (MG) estimates

$$\widehat{\beta}_{MG} = \frac{1}{N} \sum_{i=1}^{N} \widehat{\beta}_i, \tag{4}$$

with standard errors calculated in a non-parametric way (see Pesaran, 2006, equation (58) for the asymptotic covariance matrix) as

$$se\left(\widehat{\beta}_{MG}\right) = \sqrt{\left(\frac{1}{(N-1)N} \sum_{i=1}^{N} (\widehat{\beta}_i - \widehat{\beta}_{MG})(\widehat{\beta}_i - \widehat{\beta}_{MG})\right)}. \tag{5}$$

Results are reported in column (4) of Table 2. First, although the MG estimate for the reaction of the primary balance to lagged debt of 0.006 is not significant, cross-country heterogeneity is highly significant (Wald test statistic = 65.16; $p = 0.00$). Moreover, it also renders the homogeneous coefficients on the non-linear debt terms $d^2_{i,t-1}$ and $d^3_{i,t-1}$ individually insignificant, which is confirmed by a joint significance test (Wald test statistic = 0.79; p= 0.67). In column (5), we further allow for heterogeneous coefficients on the quadratic and cubic debt terms. Despite significant heterogeneity, as indicated by the Wald test, non of the MG estimates is significant. The heterogeneous coefficients reported in Table 3 below imply that only Denmark, Portugal and Japan show significant fiscal fatigue. For Denmark and Portugal this is due to β_3 being significantly smaller than zero. The coefficient estimates imply that the marginal response of the primary balance to lagged debt becomes negative at debt levels of around 70% and 100% of GDP, respectively, in these countries. Japan is a special case as we obtain $\beta_2 < 0$ and $\beta_3 > 0$ sch that the primary balance will ultimately show an increasingly positive response as debt becomes sufficiently high. However, the coefficient estimates imply that this response only becomes positive when the debt-to-GDP ratio exceeds 260%. Over the historically relevant range of debt-to-GDP ratios up to 250%, Japan shows very strong fiscal fatigue. Note that also in Austria, Canada and the UK we obtain significant $\beta_2 < 0$ and $\beta_3 > 0$, but the specific coefficient values do not imply any relevant fiscal fatigue in these countries.

Taking stock, only a few countries show signs of fiscal fatigue and this non-linear feature of the FRF is not clearly linked to the level of debt as some highly indebted countries (like Belgium and Italy) seem to have a linear FRF while Denmark has a cubic FRF despite its low debt level. All of this suggests that the response to debt is heterogeneous over countries and that the general finding of fiscal fatigue is an artifact of imposing homogeneity. This is further confirmed by column (6) of Table 2 where we report regression results for removing $d^2_{i,t-1}$ and $d^3_{i,t-1}$ from the model. The heterogeneity is still significant (Wald test statistic = 83.72; p= 0.00) with the average reaction to lagged debt now being positive and highly significant. The estimates of the heterogeneous reactions reported in Table 3 reveal that most countries show a positive response to lagged debt, with Japan being the only country with a significantly negative reaction. The countries with the biggest positive response are Greece, Ireland, Italy, Norway, Portugal and Sweden. Interestingly, except for Norway and Sweden, these are also the countries with a very high debt rate, close to or even strongly exceeding 100% of GDP at the end of the sample and, hence, in the range where fiscal fatigue may be observed. Moreover, out of the five other countries with a significantly positive reaction, four (Belgium, Canada, Spain and the UK) also have a relatively high debt rate (between 70% and 100% at the end of the sample). These results suggest that the fiscal fatigue result obtained in the homogeneous specifications is largely due to the highest indebted country, Japan, showing the worst reaction to lagged debt and not a general feature shared by other highly indebted countries in our sample.[4]

[4] Note that over the post-global financial crisis period several eurozone countries (e.g. Ireland, Greece, and Portugal) experienced a sovereign debt crisis and had to rely on EU-IMF program financing that required tightening of fiscal policies and a reduction in fiscal deficits. This may explain their strong positive reaction to debt. Similarly, the positive responsiveness in Belgium and Italy likely reflects the massive fiscal adjustment that these countries undertook in the mid to late 1990s to meet the Maastricht Treaty criteria of budgets deficits no greater than 3% of GDP. While one may argue that these are not 'normal' times, it nevertheless shows that there are mechanisms that prevent fiscal fatigue to be a general characteristic of the FRFs of the countries in our sample.

Table 3: Fiscal policy reaction function: heterogeneous coefficient estimates

	Specification (4)		Specification (5)					Specification (6)	
	α_i	$d_{i,t-1}$	α_i	$d_{i,t-1}$	$d_{i,t-1}^2$	$d_{i,t-1}^3$	Wald	α_i	$d_{i,t-1}$
Australia	−3.001	0.034	−12.199	1.490	−0.074	0.001	4.16	−3.188	0.049
(1970-2014)	(2.044)	(0.040)	(9.610)	(1.243)	(0.061)	(0.001)		(2.018)	(0.038)
Austria	−2.145	−0.027	−8.549	0.504**	−0.014***	1.2*e*-4***	13.77***	−2.323	−0.007
(1971-2013)	(2.247)	(0.024)	(5.279)	(0.211)	(0.005)	(4.0*e*-5)		(2.203)	(0.013)
Belgium	−4.122	−0.007	21.872	−0.901	0.010	−3.2*e*-5	1.32	−5.112**	0.022*
(1975-2014)	(2.695)	(0.045)	(26.618)	(0.832)	(0.009)	(3.0*e*-5)		(2.529)	(0.012)
Canada	−2.232	0.003	−23.082	1.038*	−0.016*	8.2*e*-5**	13.78***	−2.970*	0.023**
(1970-2014)	(1.873)	(0.038)	(22.648)	(0.610)	(0.009)	(4.0*e*-5)		(1.718)	(0.011)
Denmark	−3.497	0.015	−0.625	−0.350***	0.009***	−6.3*e*-5***	14.77***	−3.718*	0.034**
(1975-2012)	(2.253)	(0.029)	(3.296)	(0.114)	(0.003)	(2.0*e*-5)		(2.221)	(0.014)
Finland	−1.244	−0.034	0.268	−0.264	0.007	−5.8*e*-5	10.23**	−1.278	−0.018
(1970-2014)	(1.952)	(0.021)	(2.664)	(0.170)	(0.006)	(5.7*e*-5)		(1.902)	(0.014)
France	−3.179	−0.010	−0.665	−0.195*	0.003	−8.6*e*-6	30.26***	−3.326*	0.009
(1973-2014)	(2.035)	(0.024)	(3.442)	(0.111)	(0.002)	(1.3*e*-5)		(1.979)	(0.008)
Germany	−2.961	−0.014	−6.835	0.293	−0.008	5.7*e*-5*	6.56*	−3.209	0.008
(1992-2013)	(2.216)	(0.030)	(5.340)	(0.244)	(0.005)	(3.2*e*-5)		(2.162)	(0.011)
Greece	−7.515***	0.028	−0.337	−0.318	0.004	−1.5*e*-5	27.17***	−8.246***	0.054***
(1995-2013)	(2.372)	(0.036)	(6.358)	(0.248)	(0.003)	(9.8*e*-6)		(2.260)	(0.017)
Ireland	−5.956***	0.030	10.221*	−0.873	0.013	−5.2*e*-5	10.62**	−6.383***	0.053***
(1990-2013)	(2.209)	(0.037)	(5.266)	(0.625)	(0.009)	(3.9*e*-5)		(2.159)	(0.018)
Italy	−6.770***	0.021	1.748	−0.276	0.003	−8.6*e*-6	22.99***	−7.590***	0.049***
(1970-2014)	(2.245)	(0.043)	(12.818)	(0.292)	(0.004)	(1.3*e*-5)		(2.084)	(0.011)
Japan	−0.621	−0.042	−2.257	0.057*	−8.7*e*-4***	2.4*e*-6***	10.54**	−1.124	−0.016**
(1970-2013)	(1.832)	(0.041)	(2.043)	(0.035)	(3.2*e*-4)	(8.7*e*-7)		(1.761)	(0.007)
Korea	−1.736	0.028	0.463	−0.394	0.019	−2.4*e*-4	3.27	−1.762	0.037
(2001-2014)	(1.215)	(0.034)	(4.287)	(0.478)	(0.025)	(4.0*e*-4)		(1.176)	(0.035)
Netherlands	−2.151	−0.027	25.713	−1.411	0.021	−1.0*e*-4	7.86**	−2.643	−0.002
(1970-2014)	(2.177)	(0.037)	(31.543)	(1.063)	(0.019)	(1.1*e*-4)		(2.111)	(0.021)
New Zealand	−0.990	−0.031	1.218	−0.229	0.005	−3.2*e*-5	3.44	−1.385	−0.011
(1972-2013)	(1.956)	(0.032)	(6.173)	(0.386)	(0.010)	(7.4*e*-5)		(1.908)	(0.019)
Norway	−3.489	0.060	2.861	−0.523	0.014	−1.1*e*-4	10.25**	−3.584	0.078**
(1975-2014)	(2.506)	(0.040)	(22.543)	(1.607)	(0.038)	(2.9*e*-4)		(2.452)	(0.034)
Portugal	−4.975**	0.020	4.657	−0.573***	0.010***	−4.6*e*-5***	22.62***	−5.613***	0.046***
(1975-2014)	(2.136)	(0.034)	(4.787)	(0.220)	(0.004)	(1.7*e*-5)		(2.044)	(0.013)
Spain	−3.842**	0.014	−4.878*	0.085	−0.002	1.8*e*-5	11.16**	−3.980**	0.031***
(1975-2014)	(1.935)	(0.022)	(2.649)	(0.099)	(0.002)	(1.5*e*-5)		(1.881)	(0.010)
Sweden	−6.657***	0.053*	−0.820	−0.487	0.013	−8.9*e*-5	21.24***	−6.925***	0.074***
(1975-2011)	(2.412)	(0.030)	(7.774)	(0.406)	(0.009)	(6.6*e*-5)		(2.367)	(0.014)
United Kingdom	−5.101**	0.018	−49.054**	2.259***	−0.038***	2.0*e*-4***	29.50***	−5.337**	0.036**
(1970-2014)	(2.326)	(0.027)	(21.245)	(0.815)	(0.014)	(7.8*e*-5)		(2.253)	(0.017)
United States	−2.542	−0.011	4.620	−0.307	0.004	−1.3*e*-5	7.03*	−2.975	0.011
(1970-2013)	(2.004)	(0.030)	(17.156)	(0.534)	(0.008)	(3.6*e*-5)		(1.892)	(0.013)

Notes: Specifications (4), (5), (6), (7) and (8) refer to the respective columns in Table 2 in the main paper. The Wald test is for the joint significance of the three debt terms. White robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated using *, ** and *** respectively. See Table 2 for further notes.

Table 3: Fiscal policy reaction function: heterogeneous coefficient estimates (cont.)

	Specification (7)		Specification (8)			
	$d_{i,t-1}$	Fixed effect	$d_{i,t-1}$	$gap_{it} < 0$	$gap_{it} > 0$	Fixed effect
Australia	0.043	−2.655	0.041	0.056	−0.755	−1.439
(1970-2014)	(0.038)	(2.039)	(0.037)	(0.229)	(0.424)	(2.227)
Austria	−0.007	−1.794	0.004	−0.197	0.654**	−1.882
(1971-2013)	(0.013)	(2.223)	(0.016)	(0.259)	(0.257)	(2.605)
Belgium	0.022*	−4.357*	0.026	−0.293	0.311	−3.548
(1975-2014)	(0.012)	(2.557)	(0.017)	(0.512)	(0.363)	(3.207)
Canada	0.022*	−2.204	0.017	0.589***	−0.185	−0.021
(1970-2014)	(0.011)	(1.773)	(0.013)	(0.109)	(0.142)	(2.472)
Denmark	0.025	−2.536	0.022	1.039***	0.004	−0.451
(1975-2012)	(0.015)	(2.327)	(0.022)	(0.291)	(0.111)	(3.129)
Finland	−0.018	−0.637	−0.009	0.374***	0.248***	0.055
(1975-2014)	(0.014)	(1.932)	(0.014)	(0.094)	(0.087)	(2.151)
France	0.009	−2.909	0.009	−0.202	0.332	−2.612
(1973-2014)	(0.008)	(1.992)	(0.010)	(0.209)	(0.233)	(2.278)
Germany	0.008	−2.688	0.025*	−0.293*	0.637**	−3.464
(1992-2013)	(0.011)	(2.182)	(0.014)	(0.170)	(0.323)	(2.470)
Greece	0.065***	−8.111***	0.065***	0.160	−0.184*	−7.412***
(1995-2013)	(0.017)	(2.262)	(0.018)	(0.308)	(0.103)	(2.566)
Ireland	0.052***	−5.251**	0.229**	2.491**	0.332	−9.921***
(1990-2013)	(0.018)	(2.235)	(0.092)	(1.107)	(0.331)	(2.875)
Italy	0.051***	−7.240***	0.047***	−0.042	−0.067	−6.202***
(1970-2014)	(0.011)	(2.089)	(0.011)	(0.140)	(0.142)	(2.413)
Japan	−0.015**	−0.772	−0.013	−0.408**	0.580*	−1.584
(1970-2013)	(0.007)	(1.770)	(0.008)	(0.198)	(0.338)	(2.162)
Korea	0.031	−1.197	0.066*	0.140	−0.828***	−0.177
(2001-2014)	(0.034)	(1.213)	(0.039)	(0.222)	(0.312)	(1.569)
Netherlands	−0.001	−2.132	−0.001	0.081	0.021	−0.579
(1970-2014)	(0.020)	(2.127)	(0.024)	(0.215)	(0.236)	(2.710)
New Zealand	−0.010	−0.809	0.008	1.083*	−1.652***	1.114
(1972-2013)	(0.019)	(1.933)	(0.024)	(0.556)	(0.596)	(2.167)
Norway	0.069**	−2.722	0.060	0.720	−0.584**	−0.516
(1975-2014)	(0.033)	(2.498)	(0.038)	(0.442)	(0.268)	(2.874)
Portugal	0.047***	−4.899**	0.067***	0.503***	0.044	−4.776**
(1975-2014)	(0.013)	(2.076)	(0.016)	(0.173)	(0.179)	(2.366)
Spain	0.030***	−3.241	0.041***	0.184*	−0.155	−3.115
(1975-2014)	(0.010)	(1.924)	(0.012)	(0.102)	(0.339)	(2.207)
Sweden	0.068***	−5.966**	0.067***	0.364**	0.160	−4.471
(1975-2011)	(0.014)	(2.443)	(0.017)	(0.160)	(0.189)	(3.114)
United Kingdom	0.037**	−4.748**	0.060***	1.262***	−0.905***	−3.367
(1970-2014)	(0.017)	(2.283)	(0.019)	(0.264)	(0.194)	(2.613)
United States	0.012	−2.540	0.027**	0.205**	0.285***	−3.285
(1970-2013)	(0.013)	(1.920)	(0.013)	(0.083)	(0.101)	(2.205)

3.4 Heterogeneity and asymmetry in response to business cycle fluctuations

Finally, we test whether there is cross-country heterogeneity and asymmetry in the reaction of fiscal policy towards business cycle fluctuations. To this end regression (7) in Table 2 allows the reaction of the primary balance to the output gap to be different when the economy is in an upturn ($gap_{it} > 0$) or in a downturn ($gap_{it} < 0$). The results confirm the findings of Balassone et al. (2010) and Égert (2012) that fiscal balances tend to deteriorate in contractions without correspondingly improving in expansions. This difference is found to be statistically significant (Wald test statistic = 11.38; p=0.00). Regression (8) further allows the reaction to the business cycle to be heterogeneous across countries.[5] The asymmetric counter-cyclical reaction to the business cycle shows up significantly in ten of the individual country estimates, most pronounced in Denmark, Ireland, New Zealand and the UK. Eight countries show a more symmetric (or no) reaction to the business cycle, while in three countries (Austria, Germany and Japan) the primary balance improves more in expansions than it deteriorates during recessions.

3.5 The effect of control variables

Inflation, as measured by the GDP-deflator, always has a positive impact on the primary balance and is significant most of the time. The most common explanation given in the literature is the bracket creep effect (see e.g. Saez, 2003), referring to the phenomenon that in a progressive tax system government revenues will rise faster than inflation when there is no automatic indexation of the tax brackets. An increase in seigniorage revenues is an alternative but less likely explanation, given that the (change in the) amount of central bank profits is quite limited. A higher *implicit interest rate* on debt should urge governments to improve their primary balance in order to offset the negative effect on the overall balance. The coefficient on the implicit interest rate is indeed positive, but only significant in the fully homogeneous specifications (1)-(3). Each regression further confirms the twin-deficit hypothesis by showing a positive and significant coefficient. *Trade openness* is included to control for the possibility that countries that are more sensitive to unforeseen international economic shocks may follow a more prudent fiscal policy as a buffer against these shocks. Although the coefficient is always positive, it is only significant in regressions (1)-(2).

The *euro area* dummy should capture the potential difference in fiscal policy after a country lost control of its monetary policy. The results show that euro area membership does not significantly affect the primary balance. The *election year* dummy shows up with a negative coefficient and

[5] This heterogeneity is found to be significant (Wald test statistic = 160.20; $p = 0.00$).

is significant in the majority of models. This supports the electoral business cycle hypothesis (see e.g. Alesina et al., 1993) that governments tend to realize a larger deficit/lower surplus in election years. The idea is that ruling politicians make use of their power position to manipulate the current economic situation with more spending in order to increase their chance of reelection. The implementation of a *fiscal rule*, in contrast, has a significantly positive impact on the primary balance in all of the regressions reported in Table 2.

Turning to the *ratio of elderly*, we expect that a higher ratio of old people has a negative impact on the primary balance due to higher social security expenditures while a higher ratio of future old people, in contrast, should stimulate forward-looking governments to improve the current primary balances in order to buffer for future age-related costs. However, this is not confirmed by the data. The expected negative effect of the current ratio of elderly is present in the first 3 regressions but is only significant in the first. The future ratio of elderly even has an unexpected negative (although mostly insignificant) impact.

4 Debt sustainability analysis

In this section we look into debt sustainability analysis. Next to Bohn (1998)'s original sustainability test, we present stochastic debt simulations to illustrate the sensitivity of future debt trajectories to the specification of the FRF. These simulations are to a large extent explorative and should therefore not be taken as full-fledged predictions of future debt evolutions.

4.1 Sustainability tests based on the FRF estimates

Bohn (1998)'s original sustainability test checks whether a rise in a country's debt-to-GDP ratio elicits an increase in its primary balance. In practice, this comes down to estimating the coefficient on $d_{i,t-1}$ in a linear but heterogeneous FRF. Table 3 reports the country-specific coefficient estimates for the various specifications in Table 2. Focusing on the most general specification (8), fiscal policy is sustainable in Germany, Greece, Ireland, Italy, Korea, Portugal, Spain, Sweden, the UK and the US as these countries show a significantly positive response of the primary balance to the lagged debt-to-GDP ratio.

Although a positive reaction of the primary balance to lagged debt is a sufficient condition for the government to satisfy its intertemporal budget constraint, it does not rule out a further increase in the debt-to-GDP ratio. This can be seen by looking at a standard debt dynamics equation

$$\Delta d_{it} = \frac{r_{it} - g_{it}}{1 + g_{it}} d_{i,t-1} - pb_{it} \approx (r_{it} - g_{it})\, d_{i,t-1} - pb_{it}, \quad (6)$$

where r_{it} is the real interest rateand g_{it} is the growth rate of real GDP. Equation (6) shows that the debt-to-GDP ratio will increase when the reaction of the primary balance to lagged debt is smaller than the interest-growth rate differential. Hence Bohn's condition does not exclude an ever increasing debt-to-GDP ratio and is therefore labeled a weak sustainability criterion.

Ghosh et al. (2013) adopt the stricter sustainability criterion that government debt should converge to some finite proportion of GDP. When the FRF is linear in the lagged government debt-to-GDP ratio, this condition is met when the reaction of the primary balance is greater than the interest-growth rate differential. Ghosh et al. (2013) further argue that due to fiscal fatigue the responsiveness of the primary balance will fall below the interest-growth rate differential as debt rises, resulting in a debt limit beyond which fiscal policy is unsustainable. A country's fiscal space can then be defined as the difference between this debt limit and the actually observed debt level. Although fiscal space is an attractive and intuitive way to evaluate debt sustainability, we will not use it as we have shown that fiscal fatigue is a characteristic of FRFs that disappears once a heterogeneous response to lagged debt is allowed for.

4.2 Stochastic debt simulations

The above sustainability criteria do not take into account the uncertainties surrounding debt dynamics induced by macroeconomic shocks. In this section we therefore present results from stochastic debt simulations. By simulating macroeconomic shocks and feeding them into the FRF and dynamic debt equation, we are able to simulate future debt paths. Note that these simulations are only included here to demonstrate the effect of alternative specifications of the FRF and the uncertainty surrounding future debt trajectories. For this purpose, we deliberately adopt a rather simple simulation algorithm based on Celasun et al. (2007) and Medeiros (2012). This raises the comparability with existing simulations but also means that we inherit their drawbacks. For example, there is no channel in which fiscal policy influences the economy, we do not make projections for the future evolution of the control variables, future shocks may be different from past shocks, fiscal policy may change over time, etc. Hence, our simulation results should not be taken as full-fledged predictions of debt evolutions. More elaborate simulations are left for future research.

Stochastic debt simulations start from the dynamic debt equation (6) to construct future debt-to-GDP ratios $d_{i,t+\tau}$, with τ indicating the forecasting horizon, complemented with (i) a VAR model to generate future economic shocks and (ii) a fiscal reaction function to model the response of the primary balance $pb_{i,t+\tau}$ to the lagged debt-to-GDP ratio and economic shocks as generated by the VAR.

More specifically, we first estimate country-specific unrestricted quarterly VAR models using data including the (unweighted) average of the long and short term real interest rate, real GDP growth and inflation (see Table 6 in Appendix A for data sources). The latter was added to separate the different feedback channels of the shocks (see Burger et al., 2012). We select the maximum lag order of each VAR in a similar fashion as Medeiros (2012). This means that the Schwarz information criterion is used for sample sizes lower than 120 observations and the Hannan-Quinn criterion for the countries with a longer sample. The estimated VAR model is then used to construct future interest rate, growth and inflation trajectories by generating innovations to each of these variables and feeding them through the VAR dynamics. As the Jarque-Bera test rejected the null hypothesis that the VAR error terms are normally distributed for each country and variable, these innovations are not taken from a normal distribution but obtained by randomly drawing (with replacement) from the estimated reduced form VAR error terms. The cross-correlation structure is maintained by jointly sampling from the reduced form error terms in each period.

Second, the FRF estimates from Section 3 are used to infer the reaction of the primary balance. We will use the estimation results from 5 different FRFs reported in Table 2, corresponding to the fiscal fatigue and dynamic fiscal fatigue specifications in columns (1) and (2), the heterogeneous linear model in column (6) and the heterogeneous linear models with asymmetric response to the output gap in column (7) and (8). Besides lagged debt, FRFs typically include a list of control variables. The evolution of inflation and the output gap are simulated using the VAR model.[6] For the other control variables we don't have predictions readily available.[7] Following Celasun et al. (2007), we therefore fix each of these control variables to stay constant at their last observed value over the forecasting period.[8] We further add country-specific shocks when simulating the primary balance to account for uncertainty in the reaction of fiscal policy. These shocks are randomly drawn

[6]To obtain the output gap, we apply a Hodrick-Prescott filter ($\lambda = 1600$) to the simulated real GDP growth series. The end-period problem is avoided by extending the predicted period of GDP growth by 4 quarters.

[7]Note that the VAR includes market interest rates rather than the implicit interest rate on government debt as we don't have any quarterly data available for the latter. As a result, we have to fix the implicit interest rate over the forecasting horizon.

[8]We checked the robustness of this assumption by using the average over the previous 5 years of each control variable. This does not have a big impact on the results.

(with replacement) from the estimated FRF error terms.

Third, given the simulated interest and growth rates and the reaction of the primary balance, we can calculate government debt using equation (6). In order to obtain a fan chart of different possible outcomes, we simulate 2000 debt trajectories over a five year horizon starting from the last available observation T_i. Given the unbalancedness of the data, T_i varies over countries and hence the forecasting horizon ranges from 2012-2016 to 2015-2019.

Fan charts of the debt trajectories for the 21 considered countries and each of the 5 alternative FRF specifications are reported in Appendix B. As a summary of the results, Table 4 reports the simulated five years ahead mean debt-to-GDP ratio together with the probability that it increases over the forecasting horizon.

Table 4: Summary results stochastic debt simulations over alternative FRF specifications

		$E(d_{i,T_i+5})$					$P(d_{i,T_i+5} > d_{i,T_i})$				
		(1)	(2)	(6)	(7)	(8)	(1)	(2)	(6)	(7)	(8)
1	Australia	47.7	62.9	54.0	55.2	55.0	99.9	100.0	100.0	100.0	100.0
2	Austria	51.5	65.7	79.0	78.5	79.5	0.0	8.6	98.0	97.2	95.6
3	Belgium	99.7	101.0	104.9	103.9	115.1	43.3	50.6	63.9	61.0	91.0
4	Canada	86.6	81.9	76.8	75.7	75.4	32.8	14.0	3.7	3.1	3.4
5	Denmark	40.6	30.3	30.0	27.9	24.5	19.2	0.9	0.5	0.6	0.2
6	Finland	41.6	47.9	52.9	51.7	45.8	0.0	1.2	11.1	7.5	0.4
7	France	85.0	98.8	108.0	105.1	115.5	4.3	60.9	92.1	85.8	98.9
8	Germany	73.8	82.4	82.2	82.6	80.2	12.8	66.1	66.4	68.7	52.4
9	Greece	138.0	171.7	142.5	132.4	138.7	12.3	44.6	14.3	8.2	10.9
10	Ireland	66.9	150.9	143.3	138.7	88.9	0.1	99.2	97.1	93.8	3.0
11	Italy	143.8	141.7	124.9	121.8	132.8	92.2	82.3	1.8	0.7	25.5
12	Japan	306.6	299.4	282.6	284.0	273.0	100.0	100.0	100.0	100.0	99.4
13	Korea	31.1	23.0	20.8	20.7	28.3	5.2	0.9	0.3	0.3	0.4
14	Netherlands	49.7	66.3	65.5	62.8	73.3	0.0	5.5	4.4	0.9	54.0
15	New Zealand	63.9	77.5	74.6	73.5	56.5	100.0	100.0	100.0	100.0	90.7
16	Norway	18.7	−9.5	0.2	−0.8	3.0	0.0	0.0	0.0	0.0	0.0
17	Portugal	132.2	142.4	132.6	128.4	117.6	73.6	95.9	74.3	55.5	14.2
18	Spain	92.9	123.5	116.0	111.7	114.8	22.8	100.0	99.3	95.1	98.5
19	Sweden	53.2	44.3	40.5	40.4	39.0	99.9	95.6	76.5	73.7	62.1
20	United Kingdom	87.0	121.6	117.9	118.0	111.6	30.8	100.0	100.0	100.0	100.0
21	United States	94.5	108.3	114.8	113.9	116.4	2.0	55.0	86.2	82.2	92.7

Notes: The specifications numbers (1), (2), (5), (6) and (7) refer to the respective columns in Table 2, with (1) and (2) being the fiscal fatigue and dynamic fiscal fatigue specifications, (5) the heterogeneous linear model and (6) and (7) the heterogeneous linear models with asymmetric response to the output gap.

$E(d_{i,T_i+5})$ is the mean of the simulated five years ahead debt-to-GDP ratio, while $P(d_{i,T_i+5} > d_{i,T_i})$ is the simulated probability that the debt-to-GDP ratio increases over the forecasting horizon.

Also see Table 2 for further notes.

The simulation results show that the debt trajectories are very sensitive to the specification of the FRF. First, somewhat counter intuitively, for some of the relatively highly indebted countries the stochastic debt simulations based on the fiscal fatigue specifications (1) and (2) generate more favorable outcomes than the other 3 FRFs. This is due to the fact that our coefficient estimates of the fiscal fatigue specification imply that the response of the primary balance is at its maximum when the debt-to-GDP ratio is around 100%. As a result, in Belgium, France and the US the response based on the fiscal fatigue specifications (1)-(2) is more favorable than the heterogeneous response in the linear specifications (6)-(8). Although Canada, Ireland, Italy and Portugal also have debt-to-GDP levels in the proximity of 100%, their heterogeneous reaction in specifications (6)-(8) implies an even more favorable response. When debt is very high, as in Greece and Japan, fiscal fatigue sets in implying a less favorable response.

Second, the asymmetric response towards the output gap in specification (7), with the primary balance deteriorating in bad times but not improving in good times, should in principle imply less favorable debt trajectories. Overall, this doesn't show up in the simulation results, though. This is due to the fact that when going from specification (6) to (7) the fixed effect improve for all countries, while some countries also show a stronger reaction to lagged debt (e.g. Greece), both of which leading to more favorable debt trajectories and hence counterbalancing the negative impact of the asymmetric response towards the output gap. A similar outcome can be observed when allowing for a heterogeneous asymmetric response to the output gap, i.e. going from specification (7) to (8). Ireland, for instance, shows a very strong counter-cyclical reaction during downturns but its reaction to lagged debt is much stronger implying a much more favorable debt trajectory under specification (8). The same holds for New Zealand and the United Kingdom, where next to a somewhat stronger reaction to lagged debt also the fixed effect improves considerably.

5 Conclusion

This paper has investigated whether fiscal fatigue is a robust characteristic of the fiscal reaction function in a panel of OECD countries over the period 1970-2014 or merely an artifact of ignoring important aspects of the panel dimension of the data. We find that the quadratic and cubic debt-to-GDP terms that imply fiscal fatigue become insignificant once a heterogeneous reaction to lagged debt is allowed for. The results further show that the primary balance deteriorates in bad times but is largely unresponsive in good times. Explorative stochastic debt simulations show that debt forecasts crucially depend on the specification of the fiscal reaction function.

Our main finding that fiscal fatigue is not an ubiquitous feature of the fiscal reaction function, at least not over the debt levels observed in our sample, implies that the nowadays popular fiscal space concept, calculated at many national and international policy institutions, may be an erroneous debt sustainability measure. To gain further insight in the sustainability of fiscal policy, further research should look into the determinants of the heterogeneous response. Also the role played by other type of non-linearities like fiscal plans and consolidation periods is worth investigating.

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A Data sources

Table 5: Variables used in the FRF regressions (21 countries, 1970-2014, yearly data)

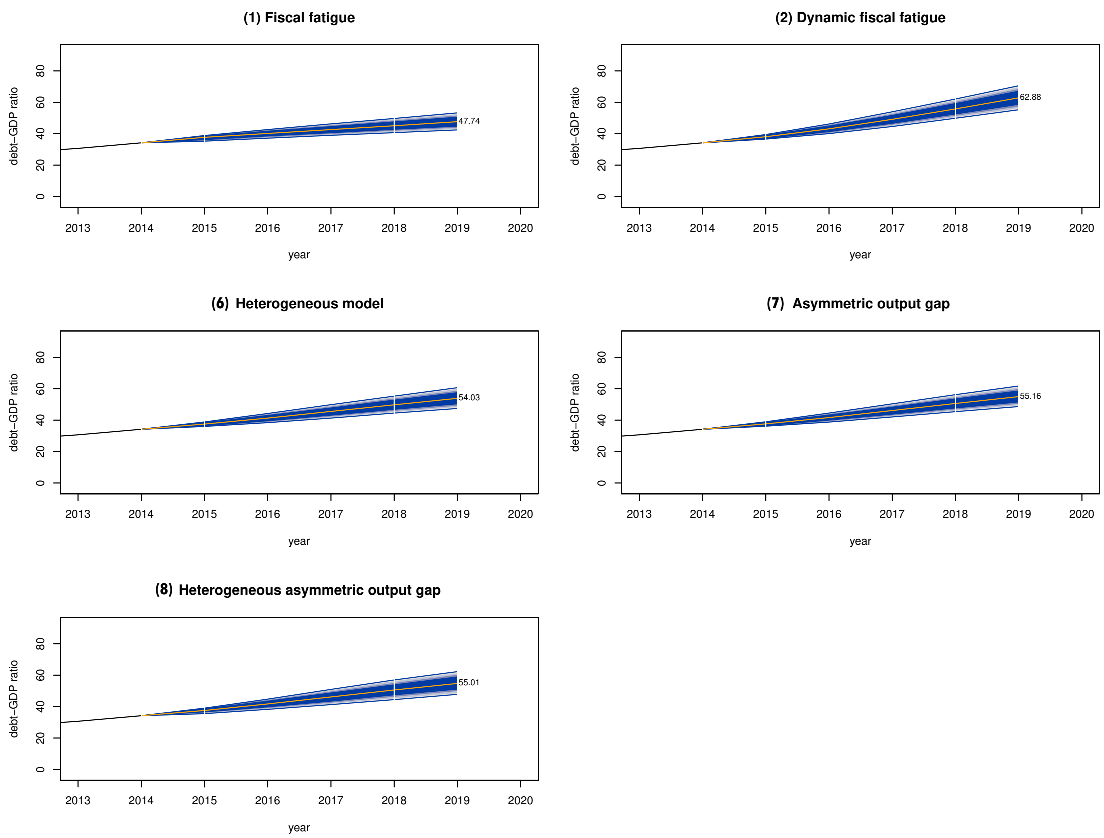
Variable	Description	Source
Primary Balance	Primary balance as % of GDP	Data up to 2011 based on Mauro et al. (2015) from which we selected the relevant countries and updated these with more recent data (2012-2014) using the OECD Economic Outlook database
Debt	Gross public debt as % of GDP	Data up to 2011 based on Mauro et al. (2015) from which we selected the relevant countries and updated these with more recent data (2012-2014) using the IMF World Economic Outlook database
Output Gap	Output gap in % of potential GDP	IMF World Economic Outlook database
Inflation	Growth rate GDP deflator (in %)	World Bank and OECD National Accounts data
Implied interest rate	Gross interest payments as a ratio of total gross debt	Mauro et al. (2015)
Current account balance	External sectors, trade and payments: Current account balance, as a % of GDP	OECD Economic Outlook (International Monetary Fund, Balance of Payments Statistic for Greece)
Trade Openness	Sum of exports and imports of goods and services, as a % of GDP	World bank, World Development indicators
Euro area	Dummy that is 1 for countries belonging to the Euro area, 0 otherwise	http://ec.europa.eu/economy_finance/euro/index_en.htm
Election year	Dummy that is 1 when an election (legislative or presidential) was held in a certain year, 0 otherwise	World Bank, database of Political Institutions
Fiscal Program	Dummy that is 1 if a fiscal program was in place in a certain year, 0 otherwise	Budina et al. (2012); Bova et al. (2015); Dong-won et al. (2011) and Shyn (2013) for Korea
(Future) old	Percentage of the total population older than 60, current or in 20 years	United Nations, Population by age, sex and urban/rural residence

Table 6: Variables used in the VAR estimation (21 countries, 1970-2014, quarterly data)

Variable	Description	Source
Real GDP growth	Year-on-year growth in real GDP, seasonally adjusted	OECD, National Accounts (quarterly)
Real interest rate	Unweighted average of short- and long-term real interest rates, % per annum	OECD, Monetary and Financial Statistics (monthly)
Inflation	Year-on-year growth in the consumer prices index (all items)	OECD, Main Economic Indicators (quarterly)

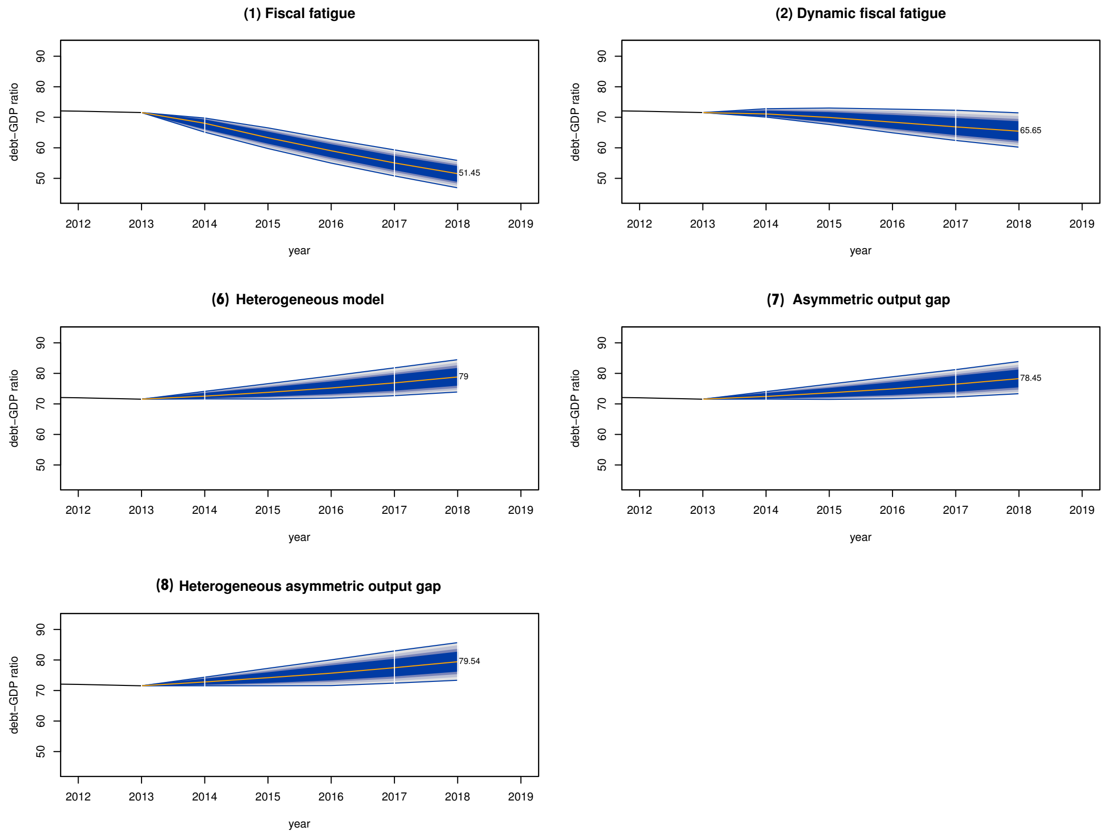
B Country-specific simulated debt trajectories

Figure 2: Results stochastic debt simulations for Australia



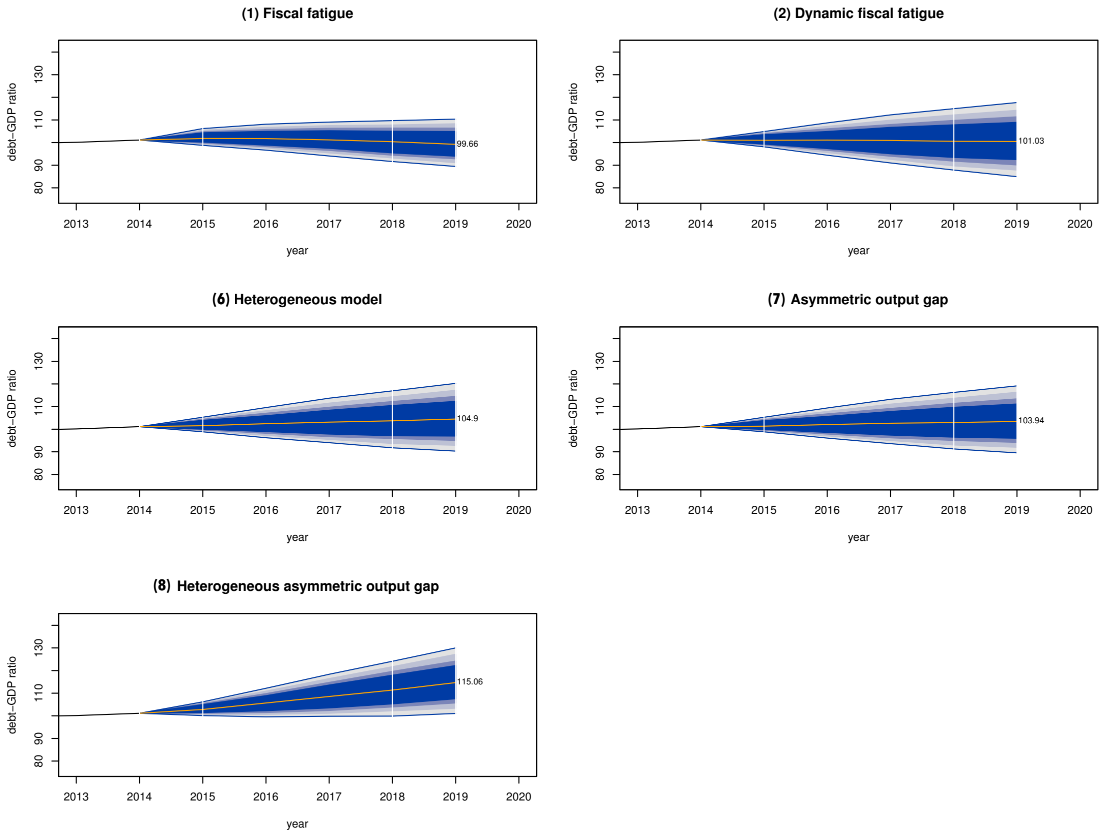
Note: Different colors present deciles in the distributions of debt ratios, with the zone in dark blue representing a 50 percent confidence interval around the median projection and the full colored area a confidence interval of 80 percent.

Figure 3: Results stochastic debt simulations for Austria



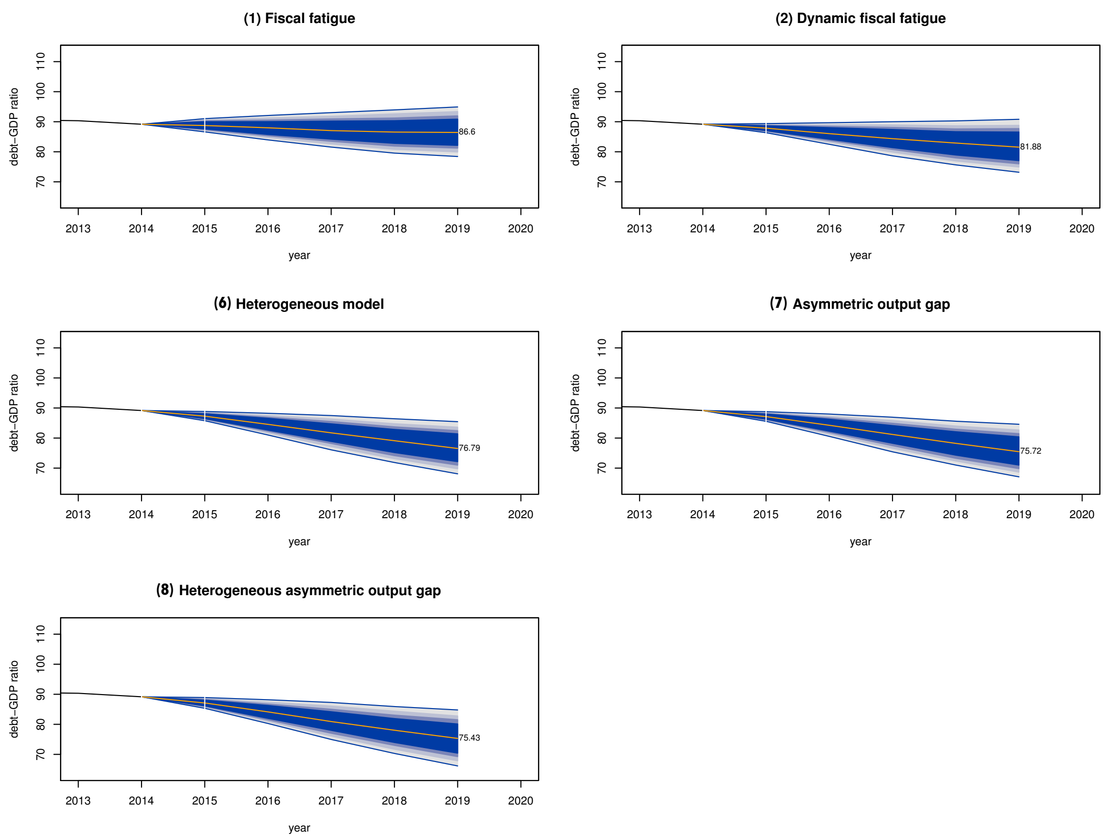
Note: see Figure 2.

Figure 4: Results stochastic debt simulations for Belgium



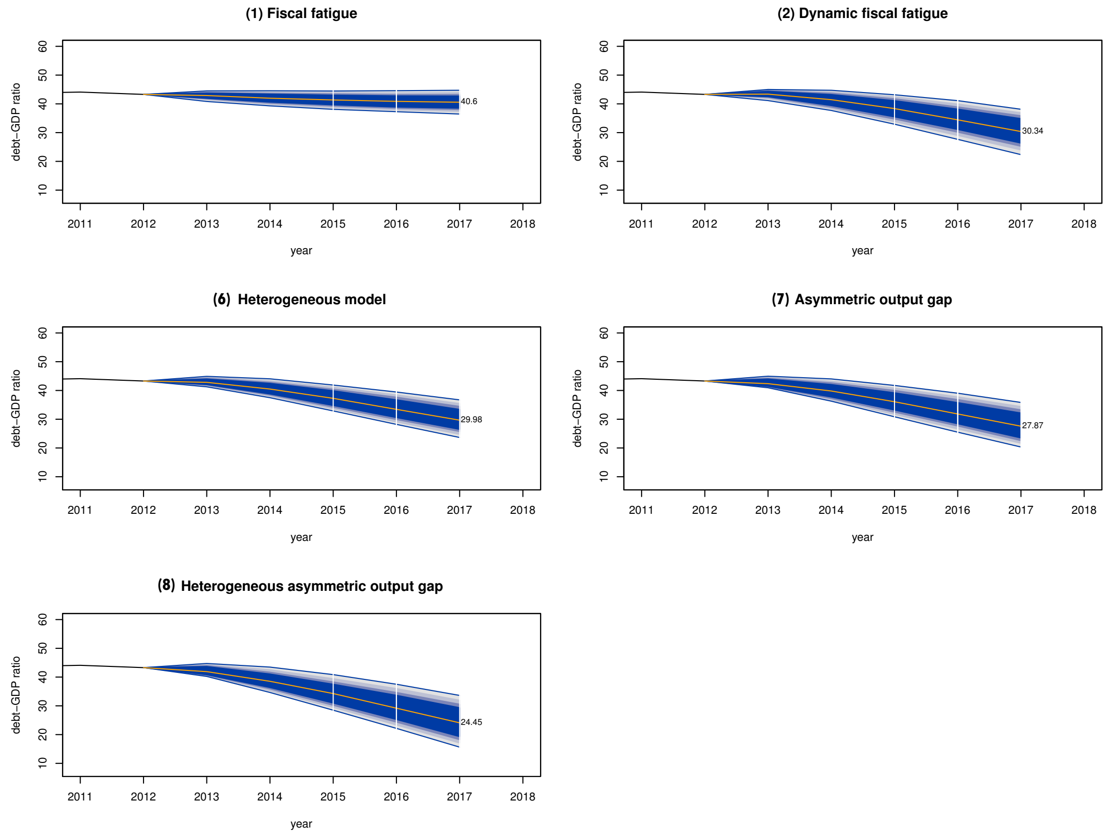
Note: see Figure 2.

Figure 5: Results stochastic debt simulations for Canada



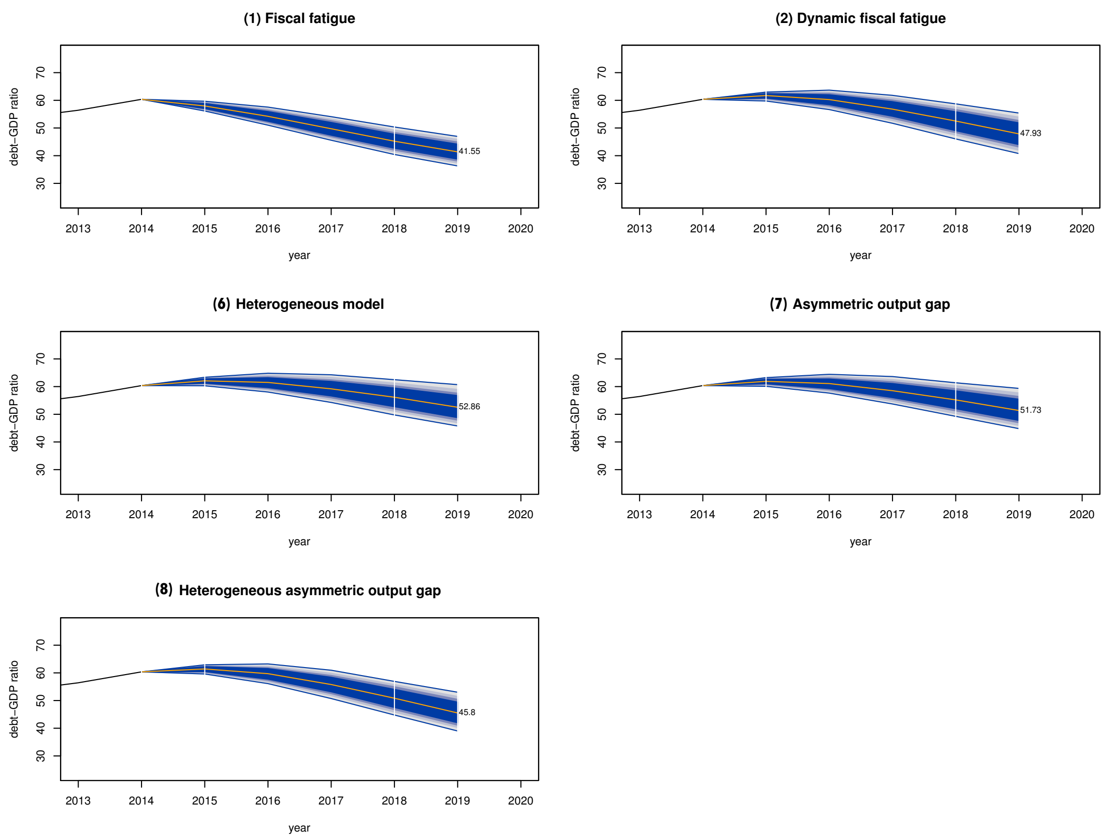
Note: see Figure 2.

Figure 6: Results stochastic debt simulations for Denmark



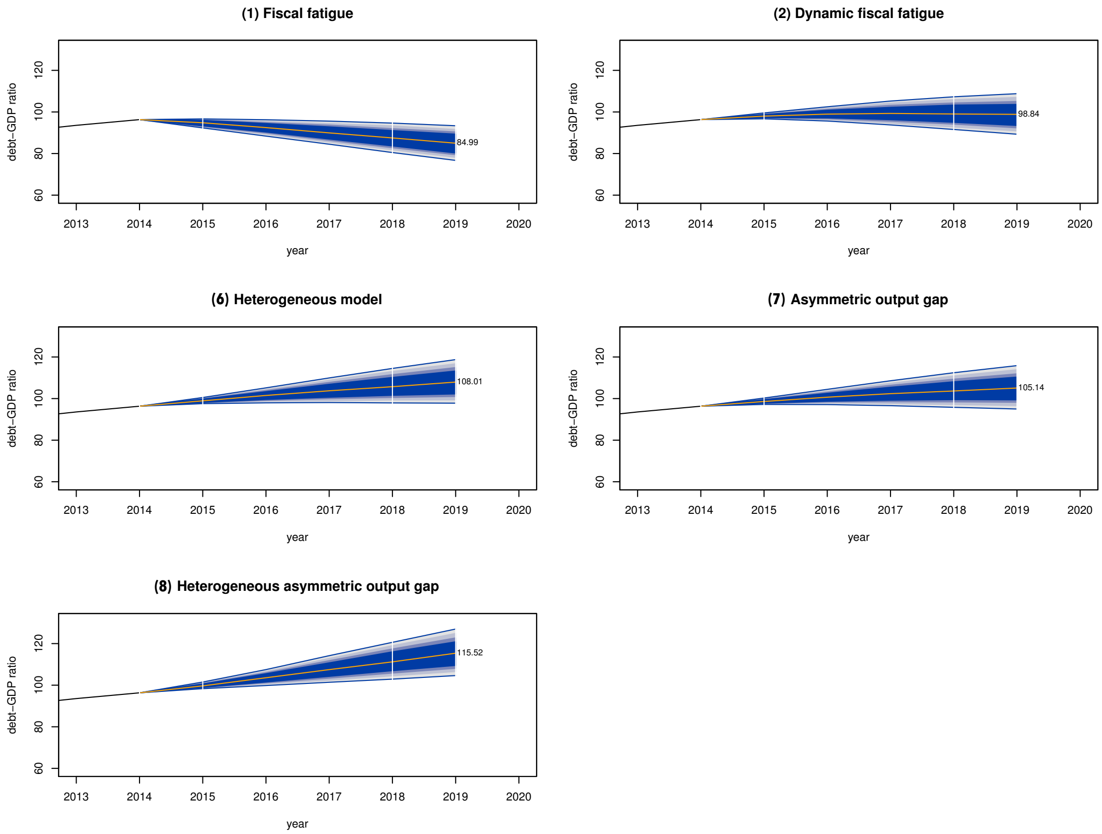
Note: see Figure 2.

Figure 7: Results stochastic debt simulations for Finland



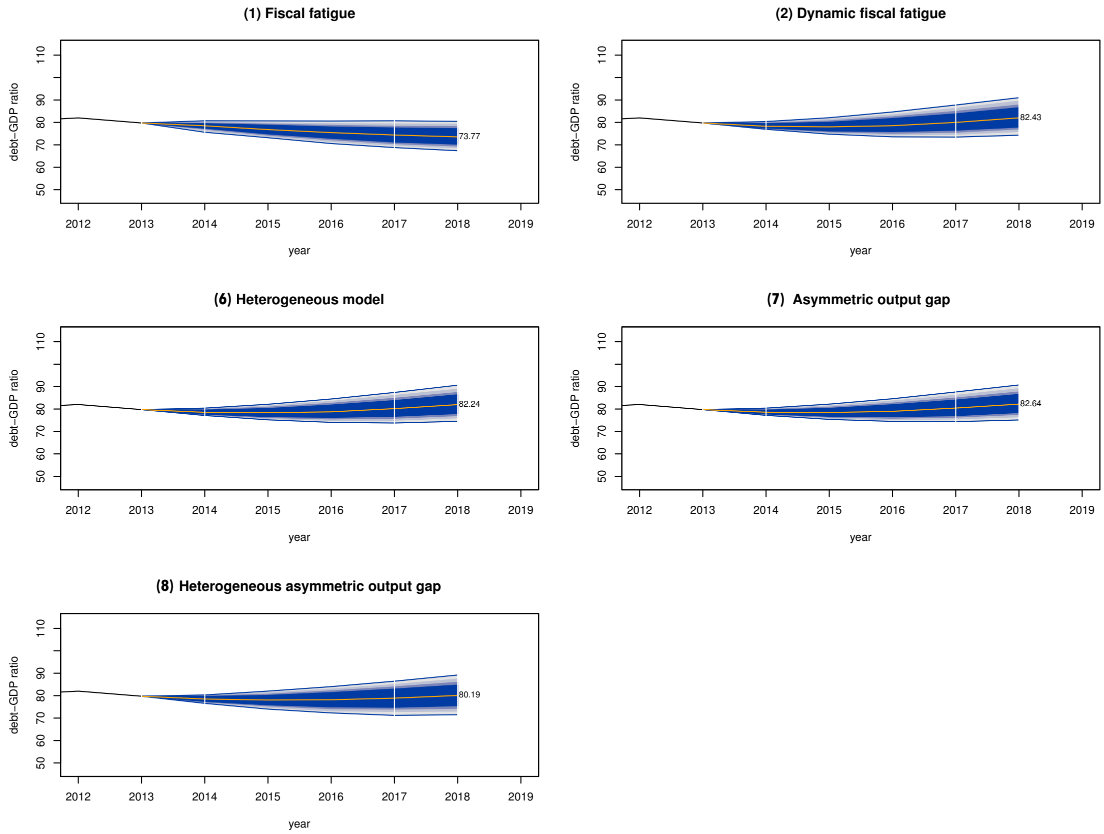
Note: see Figure 2.

Figure 8: Results stochastic debt simulations for France



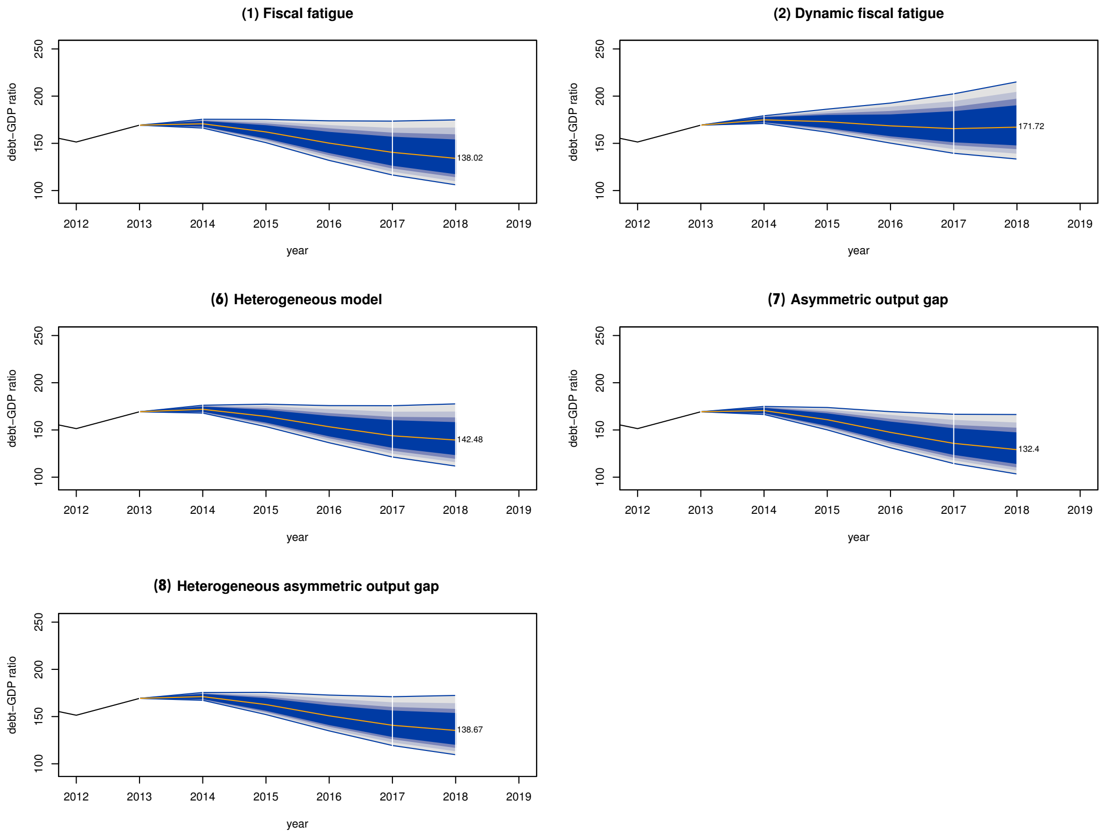
Note: see Figure 2.

Figure 9: Results stochastic debt simulations for Germany



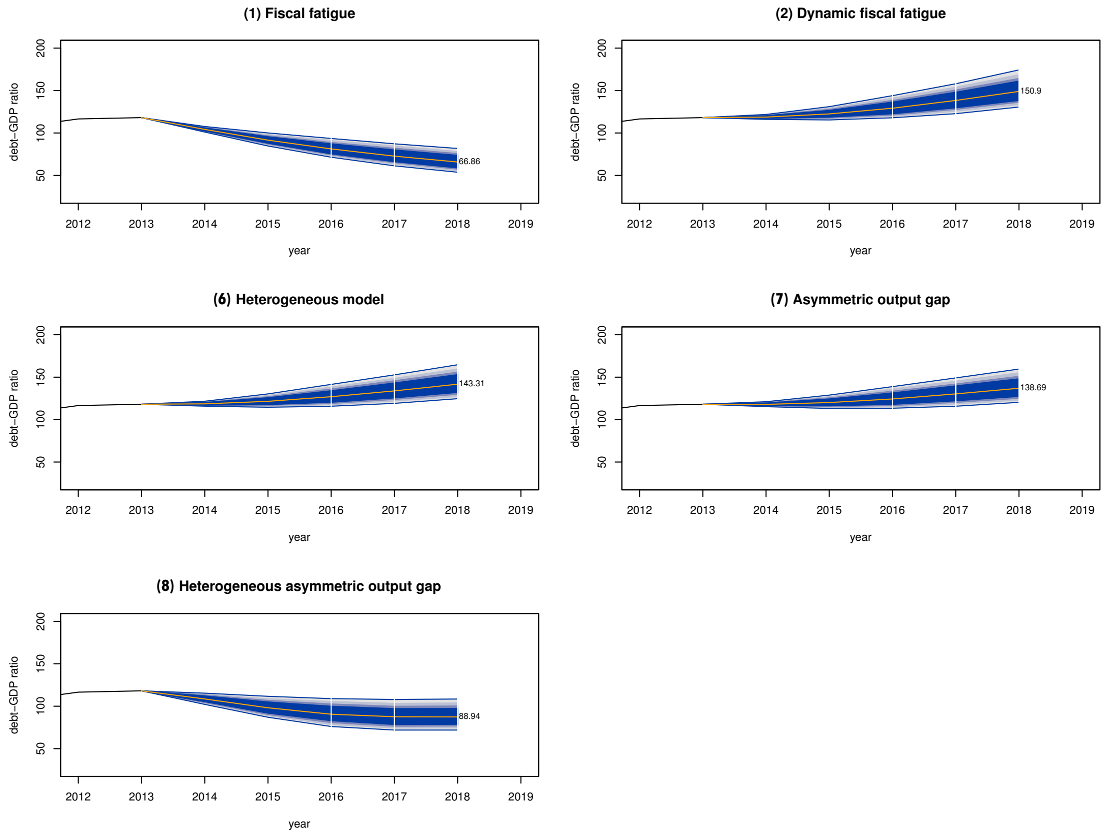
Note: see Figure 2.

Figure 10: Results stochastic debt simulations for Greece



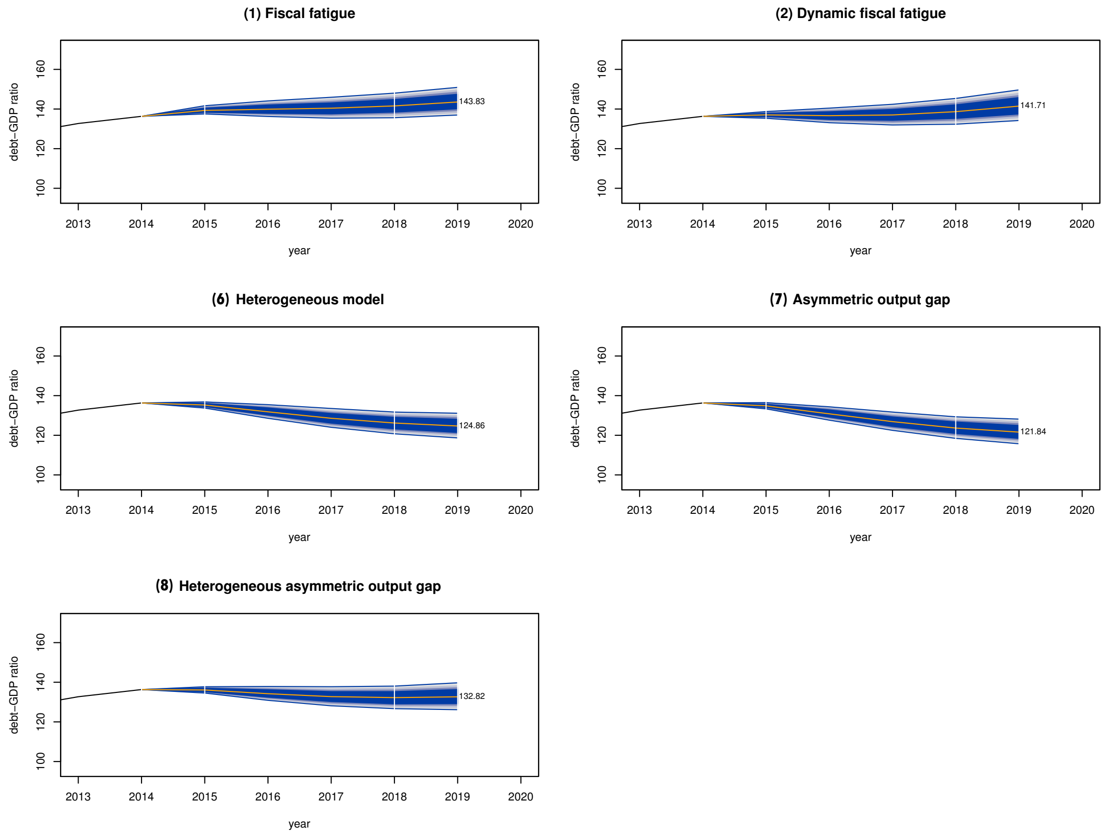
Note: see Figure 2.

Figure 11: Results stochastic debt simulations for Ireland



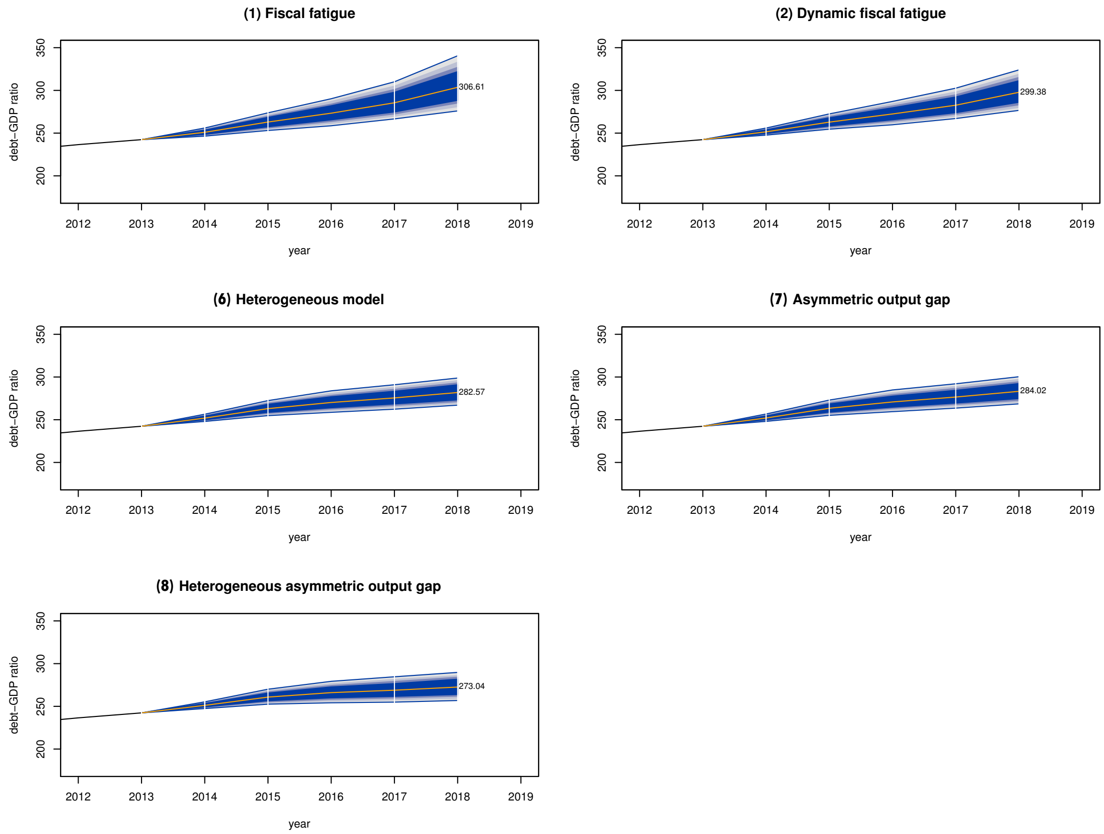
Note: see Figure 2.

Figure 12: Results stochastic debt simulations for Italy



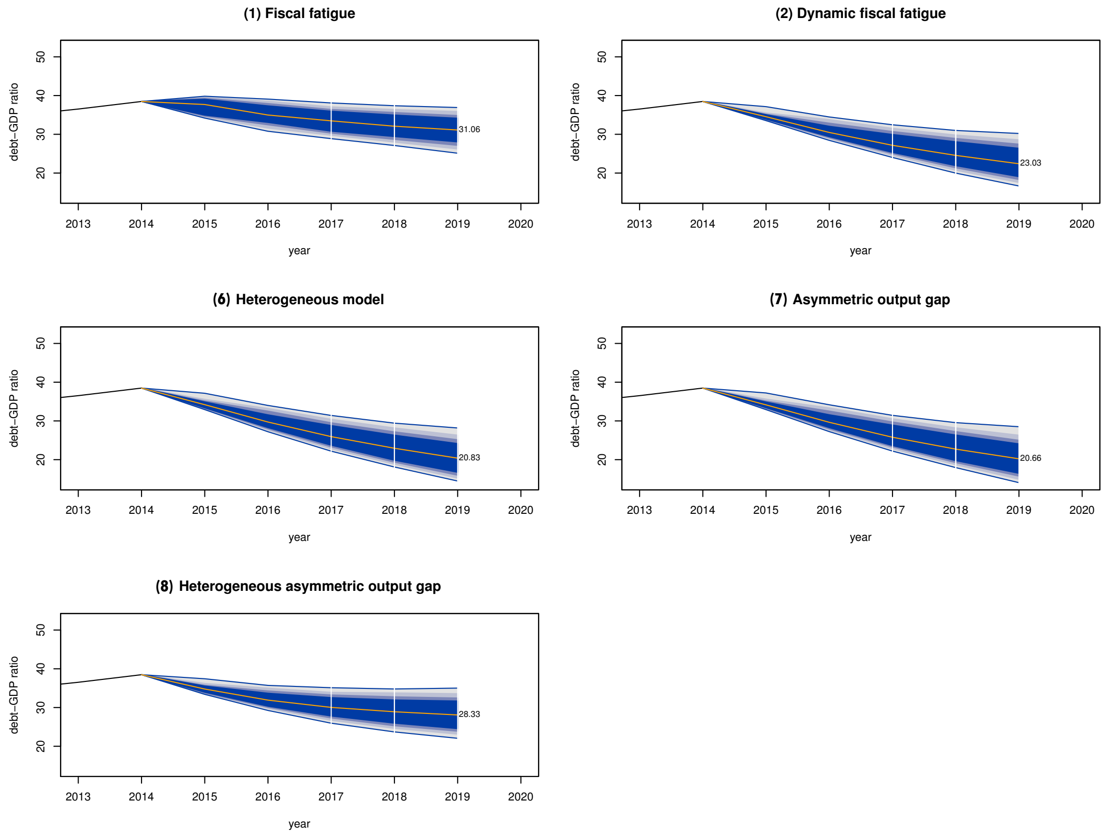
Note: see Figure 2.

Figure 13: Results stochastic debt simulations for Japan



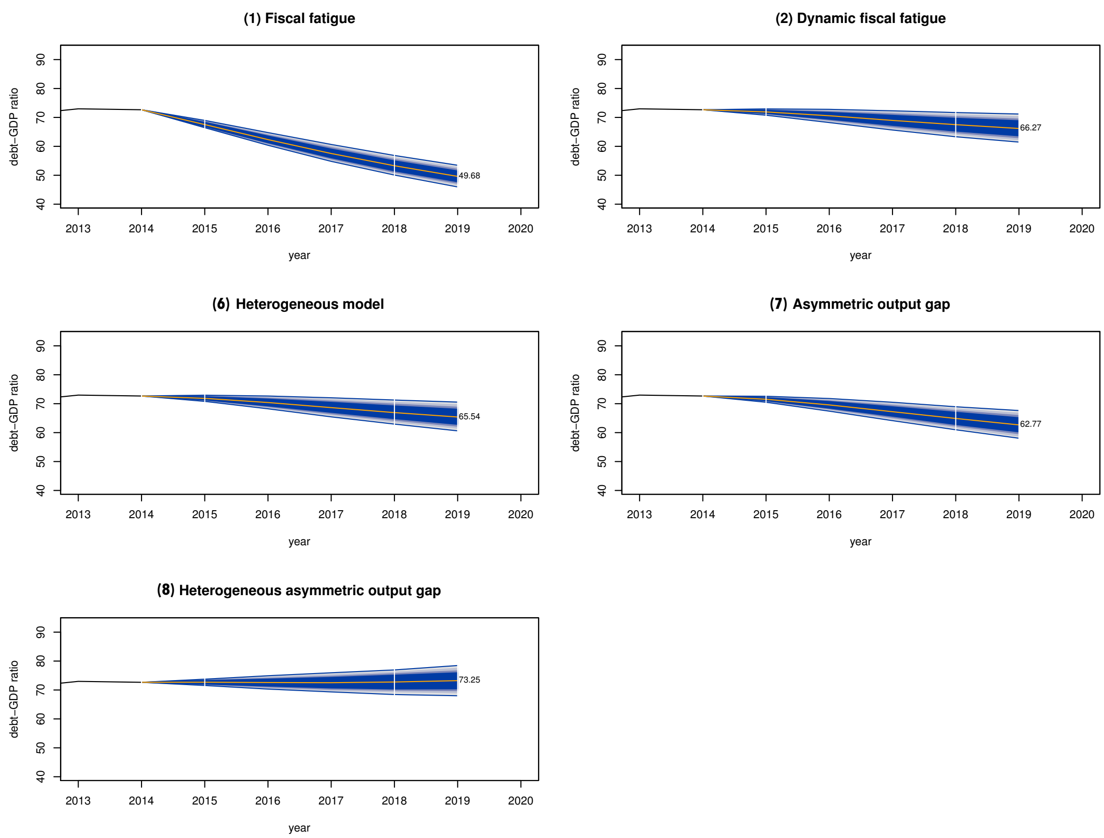
Note: see Figure 2.

Figure 14: Results stochastic debt simulations for Korea



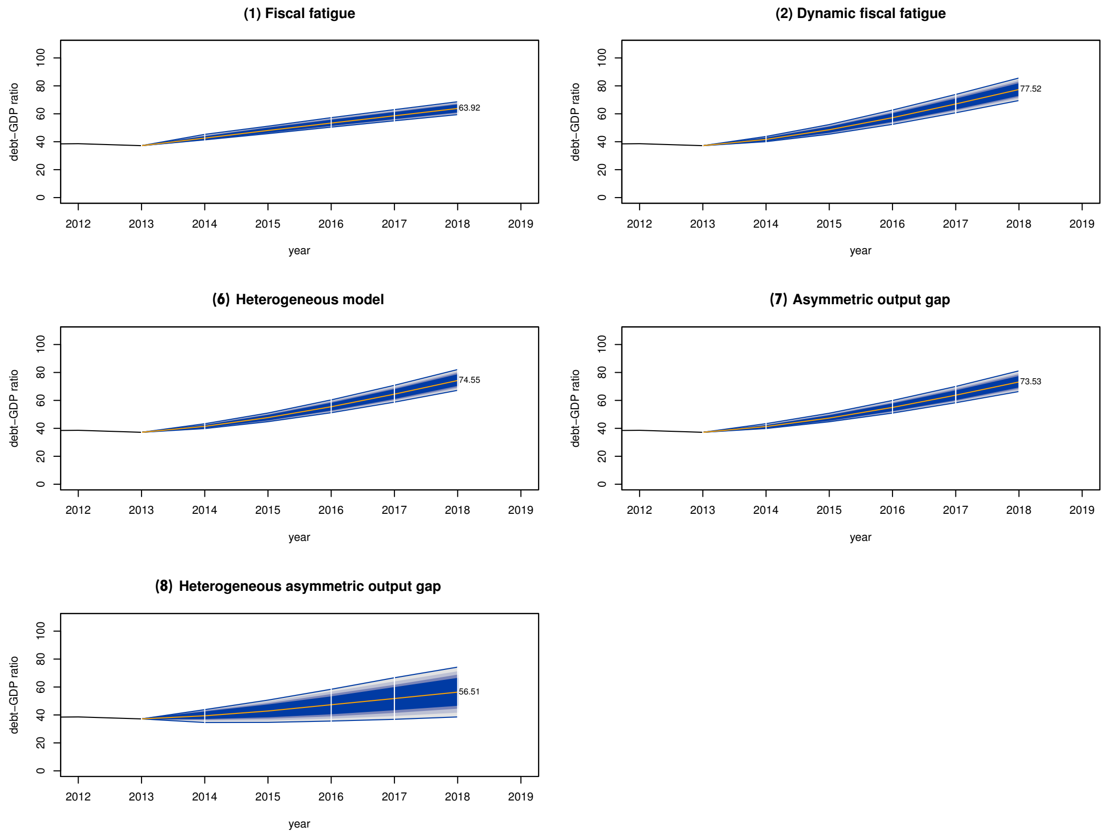
Note: see Figure 2.

Figure 15: Results stochastic debt simulations for Netherlands



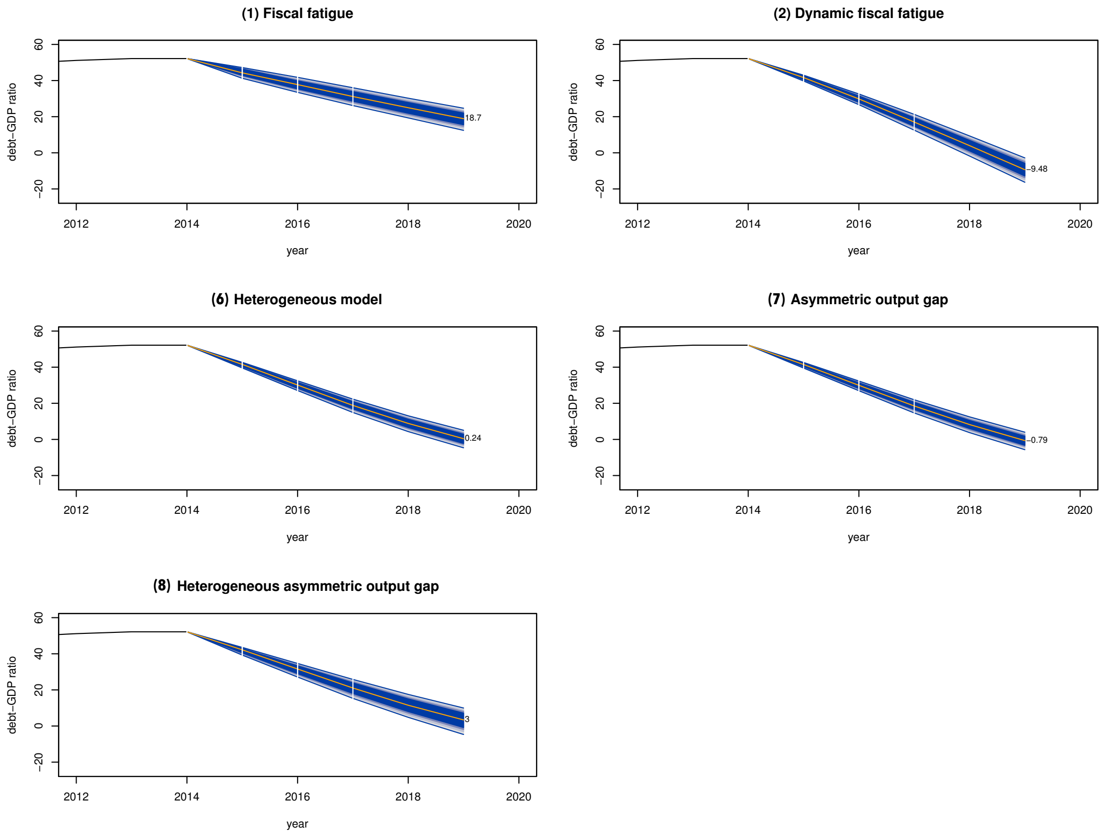
Note: see Figure 2.

Figure 16: Results stochastic debt simulations for New Zealand



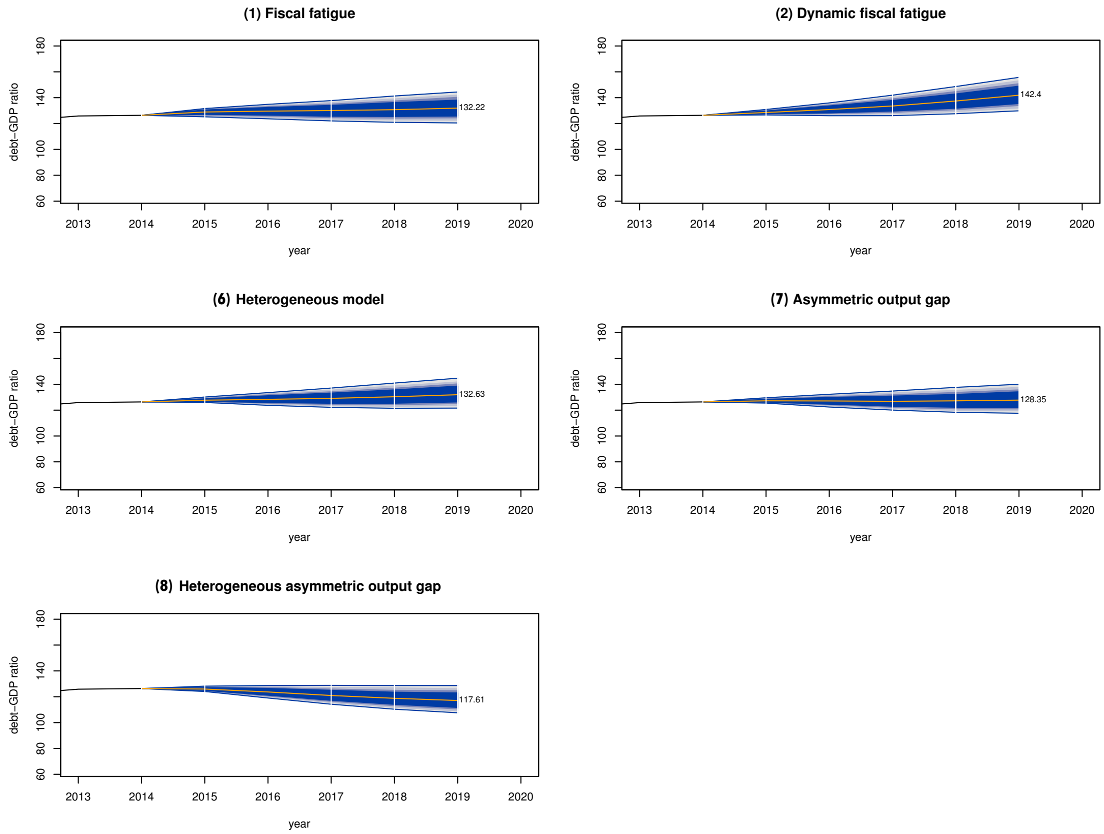
Note: see Figure 2.

Figure 17: Results stochastic debt simulations for Norway



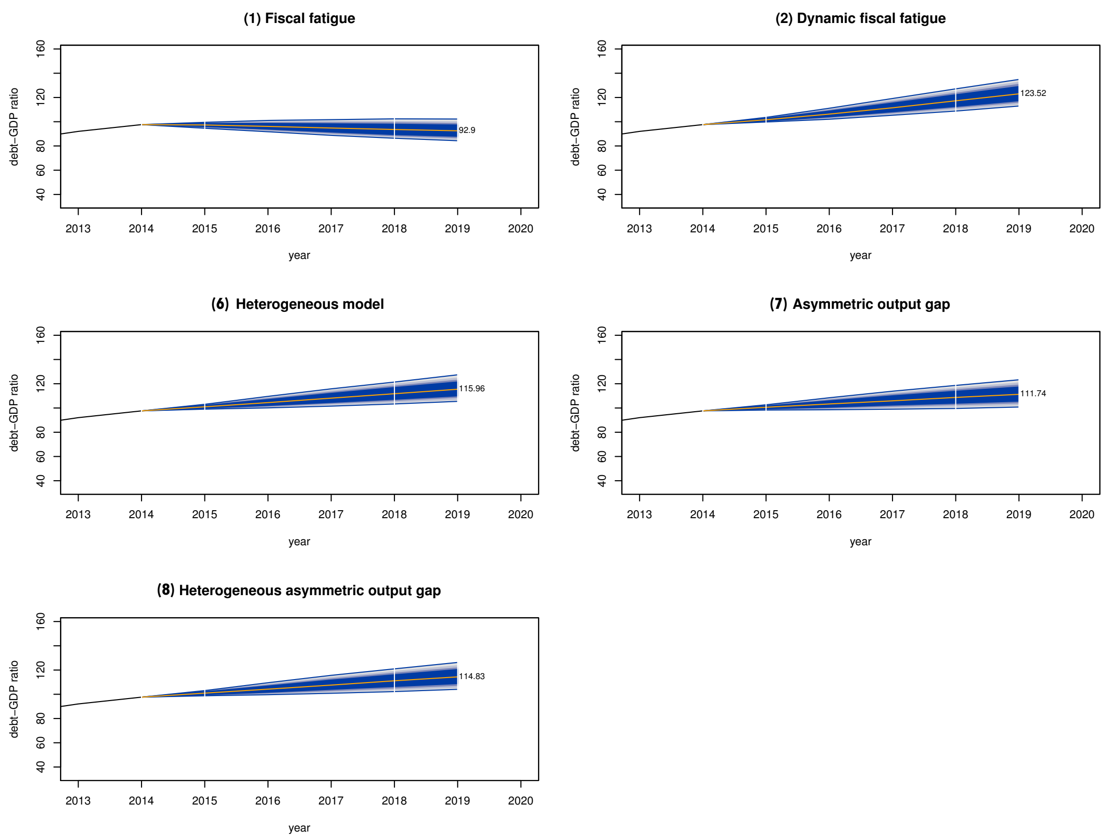
Note: see Figure 2.

Figure 18: Results stochastic debt simulations for Portugal



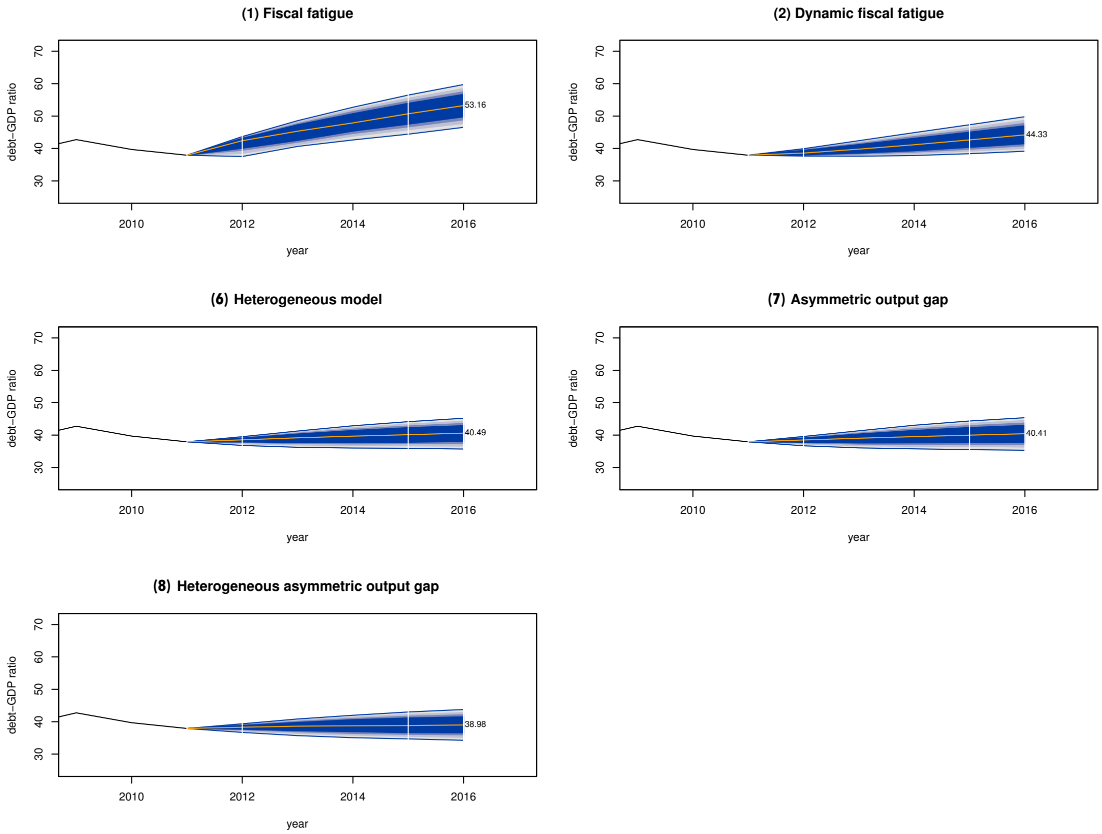
Note: see Figure 2.

Figure 19: Results stochastic debt simulations for Spain



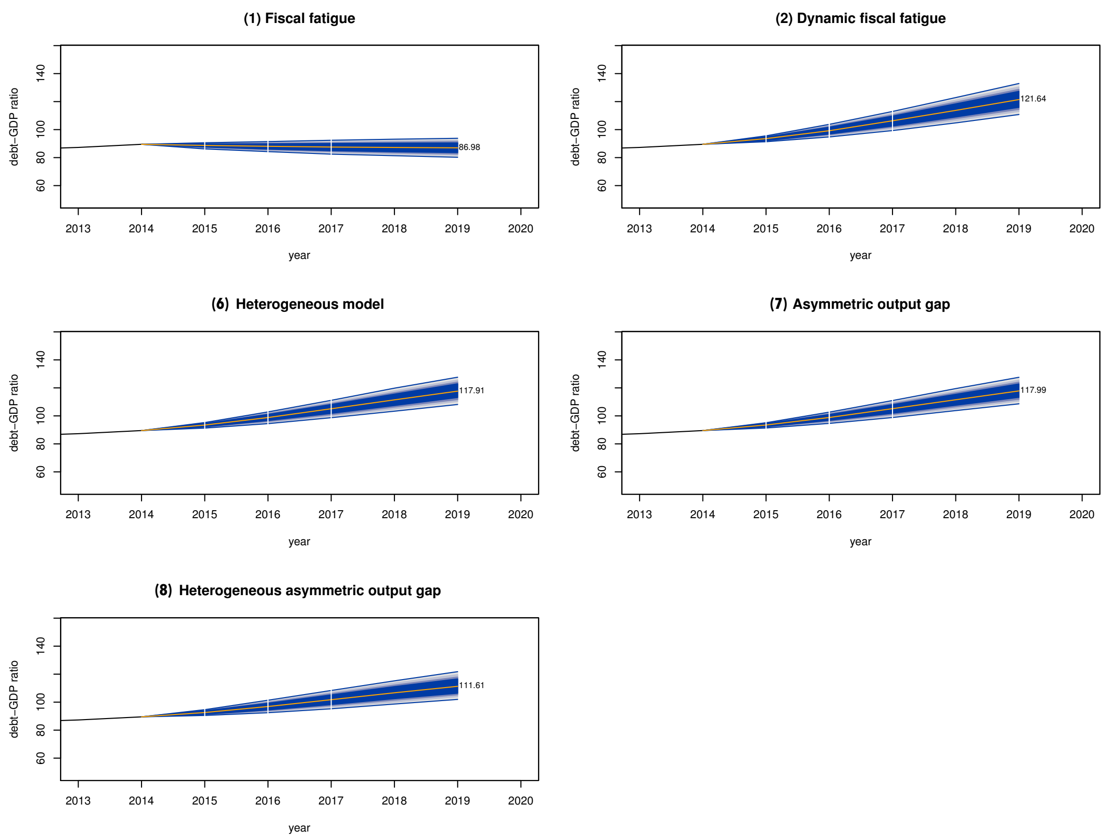
Note: see Figure 2.

Figure 20: Results stochastic debt simulations for Sweden



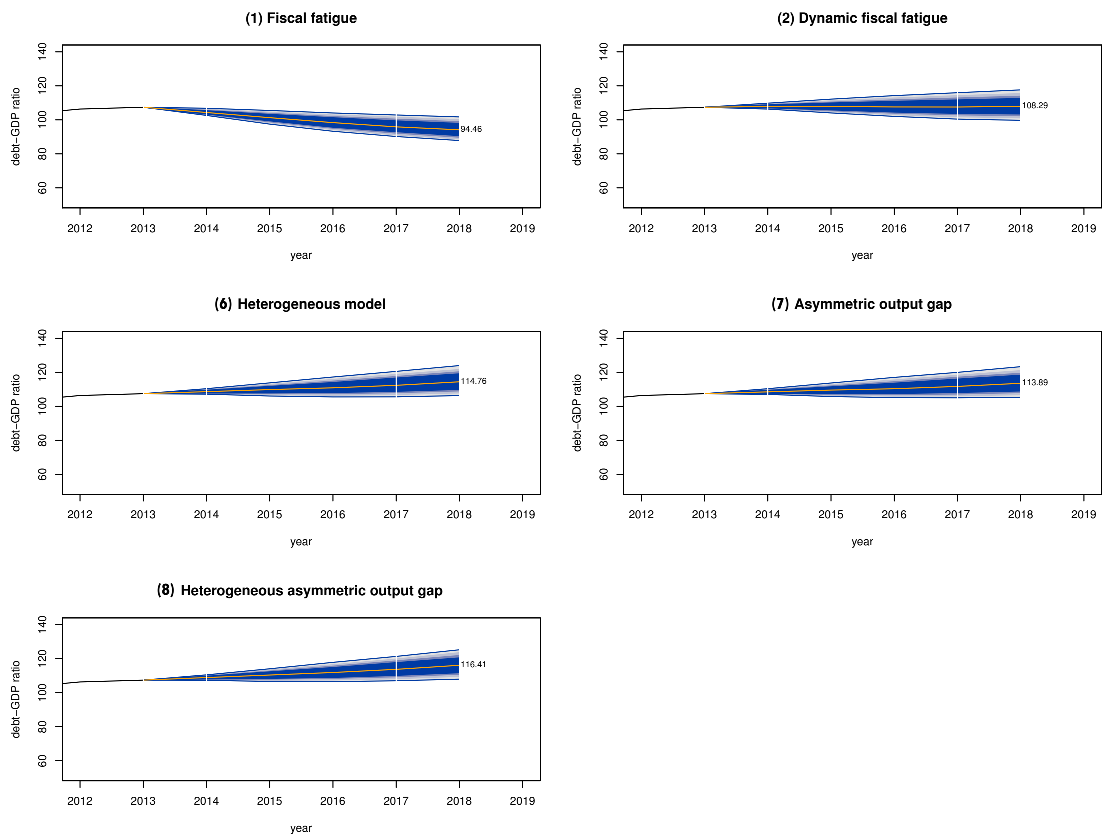
Note: see Figure 2.

Figure 21: Results stochastic debt simulations for United Kingdom



Note: see Figure 2.

Figure 22: Results stochastic debt simulations for United States



Note: see Figure 2.

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