# Department of Economics

# Athens University of Economics and Business

## WORKING PAPER no. 02-2025

# Assessing Downside Public Debt Risks in an Environment of Negative Interest Rates Growth Differentials

Yiannis Dendramis, Georgios Dimitrakopoulos

and Elias Tzavalis

February 2025

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303-5. E-mail: econ@aueb.gr / www.aueb.gr
76, Patission Street, Athens 104 34 Greece. Tel.: (+30) 210 8203303-5

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303-5. E-mail: econ@aueb.gr / www.aueb.gr
76, Patission Street, Athens 104 34 Greece. Tel.: (+30) 210 8203303-5

# Assessing Downside Public Debt Risks in an Environment of Negative Interest Rates Growth Differentials

Yiannis Dendramis, Georgios Dimitrakopoulos and Elias Tzavalis*

February 1, 2025

**Abstract**

In this paper, we suggest using structural policy scenario analysis to assess downside risks of public debt (implying debt accumulation) arising from alternative counterfactual policy scenarios. Our analysis considers the following scenarios: the abandonment of a fiscal policy rule responding to debt-GDP ratio, a change of the interest rate growth differential (IRGD) from a negative to positive value and a slowdown in real economic activity. We provide clear cut evidence that the most important downside risk of public debt comes from the slowdown of real economic activity. This happens because this slowdown has also important effects on the other determinants of the debt-GDP ratio, i.e., the primary balance and IRGD. The benefits of negative IRGDs on public debt decumulation is not without risk. The debt-GDP levels can escalate if the IRGD value turns positive. This happens with higher probability if government relaxes fiscal discipline and relies solely on negative IRGDs for debt refinancing.

JEL Classification: C32, C53, H63, H60 and H68.

*Keywords*: dynamic debt equation, structural VAR (SVAR), generalized impulse response analysis, structural policy scenario analysis, forecasting, bootstrap simulations.

The authors would like to thank Nikolaos Charalampidis, Ioannis Kospentaris, Apostolis Philippopoulos, John Tsoukalas, Petros Varthalitis, and participants at the AMEF 2024 conference for useful comments and suggestions on a previous version of the paper.

*Department of Economics, Athens University of Economics & Business, Athens 104 34, GR

emails: ydendramis@aueb.gr, dimitrakopgeorg@aueb.gr and e.tzavalis@aueb.gr

# 1 Introduction

Public debt stabilization (or decumulation) is one of the main objectives of fiscal policy authorities. Apart from primary surpluses, it can be achieved by sustained negative values of the differential between the average interest rate paid on government debt and the positive growth rate of the economy (known as interest rate-growth differential, or shortly IRGD). Note that this can happen even in the presence of budget primary deficits. As shown in a series of recent papers (see, e.g., Blanchard (2019), and Mauro and Zhou (2020)), IRGDs can be negative over long periods of time for both advanced and emerging economies. In fact, negative IRGDs are often observed during periods of overheating of the economy, closed to zero interest rates and hyperinflation, financial repression and stagnation (see, Turner and Spinelli (2011), Escollano et al (2017) and Checherita-Westphal and Semeano (2020), inter alia).

Although negative IRGDs offer the opportunity to governments to reduce public debt at lower fiscal costs, they imply important risks for stabilizing debt. As noted in recent studies (see, e.g., Blanchard (2019) and Rogoff (2020)), there is the distinct risk that negative values of IRGDs can quickly reverse to positive, which can quickly add to public debt. This can increase sovereign risk premia and, eventually, lead to a debt crisis, especially for countries with high debt levels. Thus, it can limit the benefits of negative IRGDs on public debt servicing (see also Barrett (2018)). In addition to the above source of risk, there is always the risk that governments, driven by political factors, rely on heterodox policies to deal with public debt decumulation (e.g., negative IRGDs), thereby abandoning fiscal discipline and accelerating public debt accumulation. Even during periods of negative, or zero, IRGDs, running surpluses may be critical for achieving substantial reductions in the dept-GDP ratio. As shown by Hall and Sargent (2011), negative IRGDs have contributed far less than primary surpluses to the reduction of this ratio for the US economy.

In this paper, we contribute to the above debate in two ways. Firstly, we propose a formal framework to identify the structural economic shocks determining the future paths of the debt-GDP ratio and then evaluate the effects of these shocks on public debt downside risk (implying public debt accumulation). Secondly, apart from IRGDs and primary balance sources of downside risks, we also consider risks coming from other determinants of the debt-GDP ratio, particularly a slowdown (or a downturn) in real economic activity. This can directly and/or indirectly (i.e., throughout primary balance and IRGD) affect future paths of the debt-GDP ratio. A slowdown in economic activity can be caused by various factors, such as supply shocks, financial crises, global economy shocks, natural disasters (like pandemics), political uncertainty etc.

To address the above questions, we proposed using structural policy scenario analysis (denoted as SPS) for the debt-GDP ratio.[1] According to this analysis, we can identify the structural shocks affecting the dynamic paths of the debt-GDP ratio based on a structural vector autoregression (SVAR) model consisting of the endogenous variables determining the debt-GDP ratio. The values of some of these shocks (known as driving shocks) are adjusted to reflect alternative counterfactual policy scenarios that

[1] This approach has been recently suggested in the empirical macroeconomic literature by Bernanke et al (1997), Hamilton and Herrera (2004), and Diaz et al (2021), inter alia, with the aim of appraising the impact of structural policy changes on the economy.

increase downside risks for public debt. The downside risks are measured based on the frequency distribution of the debt-GDP ratio's future paths which are generated by means of stochastic simulations of the SVAR model.

The SPS analysis can provide a more realistic approach of assessing and economically interpreting the downside risks of public debt, compared to deterministic methods such as bound-testing and stress testing (see, e.g., Diaz et al (2021)). Under this analysis, we can assess downside risks of public debt by taking into account the actual comovements among all the covariates and/or their associated structural shocks determining the dynamics of the debt-GDP ratio and the sample distribution features of these covariances. Ignoring these features may lead to implausible and not particularly informative debt paths. To our knowledge, this is the first paper to employ SPS analysis to appraise downside risks for public debt.

The specification of the reduced form VAR model assumed in our analysis is an extension of Favero's and Giavazzi's (2007, 2009) model. It includes all the macroeconomic variables determining the debt dynamics as endogenous variables, namely the IRGD, primary balance, real output growth rate and inflation rate. It also allows for debt-GDP feedback effects by treating the lagged debt-GDP ratio as a predetermined variable. Another interesting feature of the suggested framework of the SPS analysis is that the dynamic debt-GDP accumulation equation is not treated as a linear regression, but as a nonlinear identity (as is actually defined). This equation complements the VAR system of equations for the endogenous variables. We use forecasts of the endogenous variables of the VAR model to provide dynamic forecasts of the future paths of the debt-GDP ratio, based on the dynamic debt equation. Due to the nonlinearity of this equation, we rely on the generalized method suggested by Koop et al (1996) to carry out impulse response function analysis (IRF) for the structural shocks determining future paths of the debt-GDP ratio and its covariates. To generate these paths, we use a bootstrap sampling method. This method can generate shocks which are consistent with the empirical distribution features of the covariates determining the debt-GDP ratio.

In our empirical analysis, we employ data from the Greek economy over the last two decades, since joining the Eurozone. This constitutes a rich data set which covers a range of events, offering the opportunity to better identify the dynamic effects of structural economic shocks and/or fiscal policy reactions on the debt-GDP ratio. During the sample period, the Greek economy was severely affected by the global financial crisis of 2008. The public debt of the country became unsastainable and fiscal policy turn contractionary as an effort of the fiscal authorities (governments) to restrict primary deficit and stabilize public debt. Another external event that hit the Greek economy was the covid-19 pandemic. To tackle the rapid downturn of the economy and its socioeconomic consequences triggered by this pandemic, the government and the ECB adopted fiscal stimulus and easy monetary policies, which eventually led to negative IRGDs.[2]

The paper provides a number of interesting results, which have important policy implications. First, it shows that negative IRGDs can help accelerate debt decumulation and reduce the debt-GDP ratio.

[2]Due to this rich range of events, many studies in the literature use these data to study aspects of debt sustainability (see, e.g., Bournakis et al (2017), Papageorgiou and Vourvachaki (2017), Economides et al (2021), Dimakopoulou et al (2022) and Chodorow-Reich et al (2023)).

However, this benefit can be quickly lost if negative values of the IRGDs turn positive and fiscal authorities become more relaxed and abandon fiscal policy rules. In this case, we show that the public debt downside risk is very high, even for short horizons ahead, and the debt-GDP ratio escalates rapidly, with a probability approaching to one. Second, the paper demonstrates that, among the structural shocks determining future paths of the debt-GDP ratio, the highest downside risk arises from those reflecting a slowdown in real economic growth. This source of risk can directly increase the debt-GDP ratio very quickly, even under negative IRGDs. We find that this occurs because a shock in real economic growth has also sizable and pervasive effects on two other determinants of public debt, namely primary balance and IRGDs.

The paper is organized as follows. Section 2 presents the dynamic dept-GDP equation and discusses the downside risks of public debt, particularly those related to a reversal of IRDGs from negative to positive values and/or a relaxation of fiscal discipline. Section 3 presents the econometric methodology employed to carry out impulse response analysis for the debt-GDP ratio. This section also discusses some econometric issues of employing the debt-GDP ratio equation for forecasting purposes which are due to the nonlinear nature of this equation and it suggests a method to overcome these issues. Section 4 presents the results of the SVAR analysis. Section 5 presents the results of the SPS analysis for the debt-GDP ratio. Finally, Section 6 concludes the paper.

## 2 The economic model

The accumulation of public debt is given by the following dynamic equation:

$$D_t = (1 + i_t)D_{t-1} - PB_t + DB_t, \tag{1}$$

where $D_t$ is the nominal domestic debt at the end of time $t$, $i_t$ is the average nominal interest rate paid on debt $D_{t-1}$ (covering the period from $t-1$ to $t$), $PB_t$ is the primary government balance (given as $PB_t = T_t - G_t$ where $G_t$ stands for government expenditures, excluding interest rate payments and $T_t$ stands for tax revenues) and, finally, $DB_t$ presents deficit-debt adjustments (known as flow-stock adjustments). Dividing the above equation with the nominal GDP and assuming a nominal GDP growth rate $g_t$, equation (1) yields the following dynamic debt-GDP ratio equation:

$$d_t = \left(1 + \frac{i_t - g_t}{1 + g_t}\right) d_{t-1} - pb_t + db_t, \tag{2}$$

where the lowercase letters denote ratios of the above variables to the nominal GDP (*e.g.*, $d_t = \frac{D_t}{GDP_t}$) and $i_t - g_t$ is the nominal *IRGD*. For analytic convenience, in what follows we will assume that $db_t = 0$.

As shown by Bonn (1998), relationship (2) satisfies the intertemporal budget constraint and the no-ponzi game (NPG) condition under a fiscal policy rule (reaction function) like the following reduced-form relationship:[3]

$$pb_t = c_t + \beta d_{t-1}, \quad \beta > 0, \tag{3}$$

where $d_{t-1}$ plays the role of feedback variable, $c_t$ stands for cyclical components of primary balance.[4] A strictly positive value of $\beta$ means that, in order to achieve fiscal sustainability and solvency, policy makers take action to reduce $d_t$ either by cutting off public spending or raising taxes. Substituting (3) into (2) yields the following form of the debt-GDP dynamic equation:

$$d_t = \lambda_t d_{t-1} + c_t, \text{ with } \lambda_t = 1 + \frac{i_t - g_t}{1 + g_t} - \beta \tag{4}$$

This is a nonlinear equation, with a time-varying slope coefficient given as $\lambda_t = 1 + \frac{i_t - g_t}{1+g_t} - \beta$ (or $\lambda_t = \frac{1+i_t}{1+g_t} - \beta$). Assuming that $c_t$ constitutes a stationary (cyclical) component, the last equation shows that $d_t$ is stable if $\lambda_t < 1$ (meaning that $\frac{i_t - g_t}{1+g_t} - \beta < 0$), otherwise it becomes explosive.[5] As shown by Canzoneri (2001), stability on $d_t$ requires that limsup($\lambda_t$)<1, which permits the values of $\lambda_t$ to exceed unity only for a finite number of periods.

Equations (2) and/or (4) can be used to study the sources of the downside risks of debt. These risks are critically determined by the sign of $i_t - g_t$ and the size of the fiscal response coefficient $\beta$, when (3) holds. The growth rate $g_t$ itself also plays a significant role in determining these risks since it affects the magnitude of ratio $\frac{i_t - g_t}{1+g_t}$ relative to $\beta$, by dividing $i_t - g_t$ with $(1 + g_t)$. The effect of $i_t - g_t$ on the debt-GDP ratio $d_t$ is known in the literature as the snow-ball effect. The sign of $i_t - g_t$ plays a critical role for the existence of a sustainable debt. If $i_t - g_t$ is positive, then quite large substantial fiscal reactions to the current level of $d_t$ (requiring $\beta > \frac{i_t - g_t}{1+g_t}$) are needed so that debt becomes stable and reaches a steady state level.[6]

If $i_t - g_t = 0$, then the dynamics of $d_t$ depend entirely on the value of $\beta$. Finally, if $i_t - g_t < 0$, $d_t$ converges faster to its steady state level, when $\beta > 0$.[7] However, note that, when $i_t - g_t < 0$, equation (4) implies that $d_t$ converges to its steady state level even if $\beta = 0$. In this case, governments can reduce the debt-GDP ratio, or can maintain a sustainable level of debt by adopting debt rollover policies (i.e., financing debt by issuing new debt) without having to raise taxes.

Although negative values of $i_t - g_t$ appear to make fiscal policies less costly and stabilize public debt even in the presence of primary deficits, there exists the risk of reversal of a value of $i_t - g_t$ from negative to positive which can add quickly to the public debt. This can increase sovereign risk premia and, eventually, lead to a debt crisis, especially for countries with high debt levels, as noted in

[3] As recently noted by Dimakopoulou et al (2022), another reason why a fiscal policy rule is necessary is that allays fears of government default leading to an increase in the IRGD due to risk premia effects. Evidence that higher levels of debt imply larger increases in interest rates are provided by Lian et al (2020).

[4] $c_t$ can include lagged values of $g_t$,$pb_t$ etc. and an error term.

[5] Note that $\lambda_t < 1$ is a debt-stabilizing condition which is stricter than the NPG condition (see, e.g., Daniel and Shiamptanis (2013)). The NPG condition is a minimum requirement for fiscal sustainability. It states that, if $d_t$ is rising, it will eventually reach a limit which depends on the level of the future primary surpluses that governments can run.

[6] Note that the case that $i_t - g_t > 0$ is predicted by economic growth theory, which requires higher interest rates than the GDP growth rate $g_t$ (which equals the capital stock growth rate) to compensate investors for giving up consumption today to cover the depreciation of capital stock and support consumption in future.

[7] Theoretically, negative values of $i_t - g_t$ are allowed for some OLG models with non-diversifiable uncertainty and co-exist with competitive equilibria or models with rational bubbles (see, e.g., D'Erasmo et al. (2016) and Blanchard (2019)), for a review. In models with rational bubbles, they are consistent with an economy which is dynamically efficient, as the bubbles can enhance liquidity in the presence of severe constraints (see Martin and Ventura (2012)).

the introduction. Negative values of $i_t - g_t$ can reverse to positive ones for a number of reasons, e.g., high levels of debt-dgp ratios, primary deficits, economic contraction and high-inflation rates, etc (see Checherita-Westphal and Semeano (2020), for a more recent study). How quickly this reversion can happen will depend on the interaction of $i_t - g_t$ with the other macroeconomic variables determining $d_t$. Using a large sample of advanced and emerging economies, Lian et al (2020) found that high levels of debt can lead to adverse future dynamics of $i_t - g_t$ and shorter duration of negative IRGD episodes.

Summing up, the above analysis highlights that the benefits of negative IRGDs in stabilizing debt may be less than expected and can be lost quickly. Thus, fiscal policies aiming to stabilize debt based solely on negative IRGD strategies alone should be seen with caution. The abandonment of a fiscal policy rule, such as (3), may pose important downside risks to public debt and lead to self-fulling prophecies. To appraise qualitatively and quantitatively the above sources of risk as well as others, such as a slowdown in economic activity, which also affects $d_t$, we suggest a new empirical methodology in the next section. This methodology focuses on the economic identification and interpretation of the structural shocks causing downside risks for public debt. It is based on a structural vector autoregression (SVAR) framework of the covariates determining the debt-GDP dynamics.

# 3 The SVAR empirical framework

Our SVAR analysis relies on the reduced form VAR model with debt-GDP feedback effects, suggested by Favero and Giavazzi (2007, 2009). This model augments a standard VAR model with the dynamic debt-GDP equation (2) which is used as an identity equation, i.e.,

$$
\begin{aligned}
Y_t &= A_0 + \sum\nolimits_{i=1}^{p} A_i Y_{t-i} + \sum\nolimits_{i=1}^{s} \beta_i d_{t-i} + e_t \qquad (5)\\
d_t &= \left(1 + \frac{i_t - g_t}{1 + g_t}\right) d_{t-1} - pb_t, \qquad (6)
\end{aligned}
$$

where $Y_t$ denotes the vector of the endogenous variables of the model, $s$ denotes lag structure and $e_t$ is the vector of reduced form error terms (known as innovations). We assume that vector $Y_t$ consists of the key endogenous variables driving the debt-GDP ratio dynamics. That is, $Y_t$ is defined as follows: $Y_t = (\gamma_t, \pi_t, pb_t, i_t - g_t)'$, where $\gamma_t$ denotes the real GDP growth rate and $\pi_t$ is the inflation rate. The remaining variables of $Y_t$ are defined in the previous section. The augmented VAR model, given by equations (5)-(6), captures the dynamic linkages among all the macroeconomic fundamental variables determining debt, namely $pb_t$, $g_t$ and $i_t - g_t$, while treating the debt-GDP variable, $d_t$, as a predetermined variable. This framework can produce dynamic forecasts of $d_{t+h}$ for one-period ahead (i.e., $h = 1$) by feeding the dynamic debt equation (2) with the forecasts of $Y_t$, for $Y_{t+1}$. The obtained forecasts for $d_{t+1}$ can then be used to obtain future forecasts of $Y_t$ for period $t + 2$, and so on. The two variables $\gamma_t$ and $\pi_t$ of vector $Y_t$ constitute the components of the nominal growth rate $g_t$, which enters equation (2). By considering them separately in the VAR analysis, we can evaluate the relative effects of real GDP growth and inflation dynamics on the future paths of $d_t$.

Some of the interesting properties of employing the above VAR model in studying the debt-GDP dynamics and evaluating its downside risks are as follows: First, by treating $d_{t-1}$ as a predetermined variable in (5), we can capture feedback effects on $Y_t$ from $d_{t-1}$ which can reflect, for instance, debt stabilizing effects on $pb_t$, risk premium effects on $i_t - g_t$ and debt-burden effects on real economic growth rate $\gamma_t$ (see, e.g., Kumar and Woo (2010) and Baldacci and Kumar (2010), for recent surveys). Capturing these effects can obviously improve the fit of the VAR model (5) to the data and improve its predictive ability for both $Y_t$ and $d_t$. Secondly, the use of the dynamic debt equation (2) as an identity accounts for the nonlinear and time-varying pattern of its slope coefficient, given as $1 + \frac{i_t - g_t}{1+g_t}$, which is affected by variables $i_t - g_t$ and $g_t$ (see equation (4)). Ignoring this pattern may lead to biased forecasts of $d_t$, which invalidate the SVAR analysis.

The ordering of the variables in vector $Y_t$ implies a recursive causation scheme where primary balance innovations respond to real economic growth and inflation rates structural shocks. These shocks can reflect cyclical changes in the economy (see equation (3)) and/or exogenous events, such as global financial crises, natural disasters (like the covid pandemic), supply chain effects etc, which affect tax revenues and primary balances. The inclusion of variable $i_t - g_t$ in vector $Y_t$ directly measure the snow-ball effects on $d_t$. As in Canzoneri et al (2001), we assume that a structural shock in $i_t - g_t$ affects the remaining variables in $Y_t$ with a time lag.

The above ordering of the variables means that we can employ the Cholesky decomposition of the variance-covariance matrix of the VAR innovation terms, collected in vector $e_t = (e_{t,\gamma}, e_{t,\pi}, e_{t,pb}, e_{t,i-g})'$, to identify the vector of structural economic errors (shocks), denoted as $u_t = (u_{t,\gamma}, u_{t,\pi}, u_{t,pb}, u_{t,i-g})'$. This decomposition implies that the vectors of $e_t$ and $u_t$ are related through the following relationship:

$$e_t = \Theta u_t, \tag{7}$$

implying $u_t = \Theta^{-1} e_t$, where $\Theta$ is a lower triangular matrix. The impulse response functions ($IRFs$) of the variables in vector $Y_{t+h}$, for $h = 1, 2, 3, ...$, horizons ahead, to the structural shocks in vector $u_t$ are obtained as follows:

$$IRFs(h) = \frac{\partial Y_{t+h}}{\partial u_t'} = A^h \Theta \tag{8}$$

The estimates of $IRFs(h)$, given by (8), will help us understand the structural interactions among the variables of vector $Y_{t+h}$ determining future paths of $d_{t+h}$ and provide an economic interpretation about the structural sources of the downside risk of public debt. To measure the effects of structural errors $u_{t,j}$, $j = \{\gamma, \pi, pb, i-g\}$, collected in vector $u_t$, on $d_{t+h}$, we will rely on the generalized impulse response function (GIRF) analysis, suggested by Koop et al (1996). This is because $d_t$ is nonlinearly related to variables $g_t$ and $i_t - g_t$, which determine the slope coefficient of the dynamic debt-GDP equation (6). In addition to this analysis, we will also present estimates of the generalized variance decomposition functions (VDFs) of the forecast errors of $d_{t+h}$. These functions indicate the relative importance of shocks $u_{t,j}$ in explaining the forecast error variance of $d_{t+h}$, over $h$.

More specifically, for a structural shock $u_{t,j}$ the generalized $IRF_j(h)$, denoted as $GIRF_j(h)$, $j = \{\gamma, \pi, pb, i-g\}$, is calculated as the difference of the following conditional expectation terms: $E[d_{t+h}|u_{t,j}, I_t]$

and $E[d_{t+h}|I_t]$, i.e.,

$$GIRF_j(h) = E[d_{t+h}|u_{t,j}, I_t] - E[d_{t+h}|I_t], \quad j = \{\gamma, \pi, pb, i-g\}, \tag{9}$$

where $I_t$ denotes the information set, at time $t$. The difference between the above two expectation terms reflects the effects of a specific path of shock $u_{t,j}$, on $d_{t+h}$, compared to the case where no particular path is assumed. This is done by taking into account the covariance structure among the structural shocks collected in $u_t$. The effects of the $j$-$th$ structural shock, i.e., $u_{t,j}$, on $d_{t+h}$ can be obtained by integrating out the effects of the remaining structural shocks $u_{t,k}$, for $k \neq j$, on $d_{t+h}$. To calculate the above expectation terms, we will rely on a bootstrapping procedure resampling from the vector of structural shocks $u_t$ identified by the Cholesky decomposition of the variance of $e_t$, based on equation (7). The use of structural shocks $u_{t,j}$, $j = \{\gamma, \pi, pb, i-g\}$, instead of innovation terms $e_{t,j}$, in calculating $GIRF_j(h)$ provides an economic interpretation of the shocks affecting the future paths of $d_t$, $d_{t+h}$, consistent with the interpretation given by the IRFs analysis presented earlier.

Given $GIRF_j(h)$, the generalized VDF, denoted as $GVDF_j(h)$, can be calculated as follows:

$$GVDF_j(h) = \frac{\sum_{l=1}^{h} GIRF_j(l)^2}{\sum_{j=1}^{4}\sum_{l=1}^{h} GIRF_j(l)^2}, \text{ for } j = \{pb, \gamma, \pi, i-g\}, \tag{10}$$

see Lanne and Nyberg (2016). In the last relationship, the denominator measures the aggregate cumulative effect of all the structural shocks, while the numerator captures the cumulative effect of the $j$-th structural shock, $u_{jt}$. The value of $GVDF_j(h)$, for all $j$, lies between 0 and 1, and it can be easily interpreted as reflecting the contribution of shock $u_{t,j}$ in explaining the forecast error variance of $d_{t+h}$.

One econometric issue in forecasting $d_{t+h}$ and estimating $GIRF_j(h)$ (and $GVDF_j(h)$) arises from the nonlinearity of the dynamic debt-GDP equation (6), particularly due to the time-varying nature of its slope coefficient, given by the ratio $\frac{i_{t+h}-g_{t+h}}{1+g_{t+h}}$. Forecasting future paths of $d_{t+h}$, based on expectation terms $E[d_{t+h}|u_{t,j}, I_t]$ and $E[d_{t+h}|I_t]$, requires unbiased forecasts of the ratio $\frac{i_{t+h}-g_{t+h}}{1+g_{t+h}}$ conditional on $I_t$. Substituting, naively, point forecasts of $i_{t+h} - g_{t+h}$ and $g_{t+h}$ in $\frac{i_{t+h}-g_{t+h}}{1+g_{t+h}}$, based on forecasts of VAR model (5), and then obtaining forecasts of $d_{t+h}$ in a recursive manner (known as skeleton forecasts, see, e.g., Granger and Terasvirta (1993)) can lead to biased estimates of $E[d_{t+h}|u_{t,j}, I_t]$ and $E[d_{t+h}|I_t]$. This happens because $\frac{i_{t+h}-g_{t+h}}{1+g_{t+h}}$ is the ratio of two random variables and its conditional expectation has not always an analytic form. To address this issue, we suggest a bootstrap resampling method along the lines of the multi-step ahead forecasts for nonlinear models suggested by Granger and Terasvirta (1993) - see, also Lundbergh and Terasvirta (2004). This suggested method will be also applied to obtain forecasts of vector $Y_{t+h}$, which depend on the paths of $d_{t+h-1}$. The benefits of applying this method for forecasting $d_{t+h}$, compared to the method of skeleton forecasts, are highlighted in the empirical section of the paper.

To present the method in more detail, define vector $Z_t = (Y_t', d_t)'$ and write the system of equations (5) and (6) in a more general form as $Z_t = F(Z_{t-1}, u_t; \vartheta)$, where $\vartheta$ denotes the parameter vector of the system. Then, an unbiased estimate of $E(Z_{t+h}|I_t)$, which constitutes an optimal forecast of $Z_{t+h}$

(denoted as $\hat{Z}_{t+h|t}$), can be derived by the following general ($h$-step ahead) forecast equation:

$$\begin{aligned}\hat{Z}_{t+h|t} &= E(Z^{(b)}_{t+h}|I_t) = E\left(F(\hat{Z}^{(b)}_{t+h-1}, u^{(b)}_{t+h}; \vartheta)\right) \\ &= \frac{1}{B}\sum_{b=1}^{B} F(\hat{Z}^{(b)}_{t+h-1}, u^{(b)}_{t+h}; \vartheta),\end{aligned} \tag{11}$$

where $b = 1, 2, ...B$ denotes the bootstrap iterations and $u^{(b)}_{t+h}$ are randomly drawn (with replacement) from the distribution of the estimates of the structural errors of VAR model (5), based on the relationship $u_t = \Theta^{-1}e_t$. The above procedure generates a distribution of point forecasts of $Z_{t+h}$ around its conditional mean $E(Z^{(b)}_{t+h}|I_t)$. This distribution can be also employed to obtain bootstrapped confidence intervals for $GIRF_j(h)$.

# 4 Empirical analysis: Estimates of the IRFs and GIRFs

Our empirical analysis has the following order. Firstly, we estimate the VAR model (5) and evaluate its forecasting performance for $d_t$. Next, based on the estimates of the structural form of the model, we carry out IRF analysis and calculate the GIRFs for the debt-GDP ratio based on equation (9).

## 4.1 The data

In our empirical analysis, we use quarterly data from the Greek economy over the period 2000:Q1-2024:Q2. Figure 1 graphically presents the series of variables employed in our analysis (namely, $\gamma_t$, $\pi_t$, $pb_t$, $i_t - g_t$ and $d_t$). These series are calculated year-over-year for each quarter. Note that, in order to calculate inflation rate, we rely on values of the consumer price index (CPI). Our sample covers a range of events which can help to better identify the dynamic effects of structural shocks on the dynamics of $d_t$. During the sample period, the Greek economy faced a sovereign debt crisis in the aftermath of the global financial crisis of 2007–2008. After 2008:Q4, the values of $i_t - g_t$ turned positive for the first time since this economy joined the Eurozone in year 2001. The recession triggered by the global financial crisis weakened the country's tax revenues and worsened its primary balance. By early 2010, the fiscal situation of Greece was unsastainable and the government sought bailout funding, which was received under austere fiscal consolidation programs aimed at achieving a budget surplus and maintaining debt sustainable. These programs led to a severe GDP drop and an increase in the Greek debt-GDP ratio from 127% in 2009 to 181% in 2019. The debt-GDP ratio further rose to 207% by the end of 2020, as a result of the severe downturn of the economic activity of the country caused by the covid-19 pandemic.

As can be seen from Figure 1, the structural changes that began in the Greek economy after 2008 and the covid-19 pandemic lockdown years of 2020 and 2021 are clearly reflected in all the series, especially in the real growth rate $\gamma_t$, $pb_t$ and $i_t - g_t$. The quite large negative values of $pb_t$ and $i_t - g_t$, during the pandemic years (from 2020 to 2022) are due to the simultaneous loosening of monetary and fiscal policies allowed by EU authorities to shore up the economy and tackle the socioeconomic consequences of the pandemic.

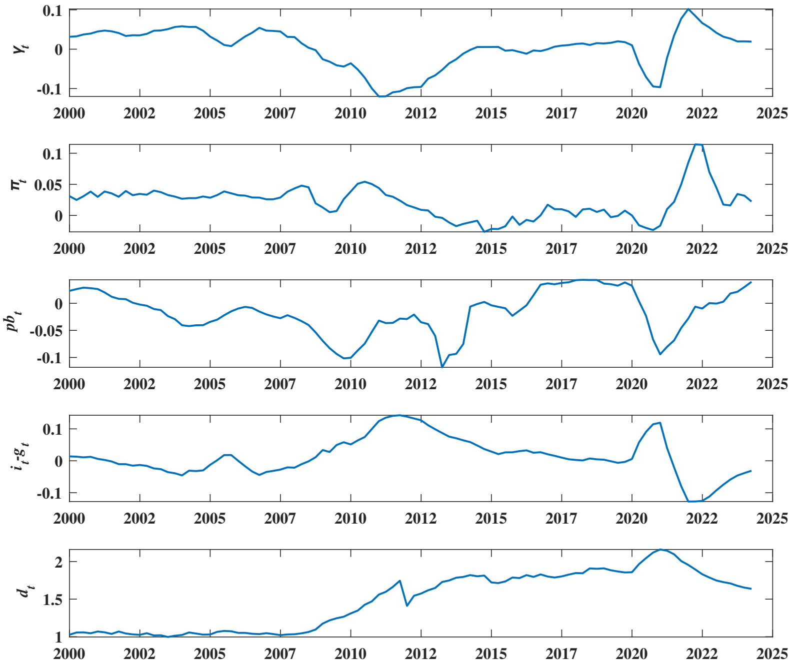



Fig. 1: Graphs of variables (2000:Q1-2024:Q2)

## 4.2 Estimates of the VAR model and impulse response analysis

*(a) Estimates of the VAR model*

In Table 1, we present least squares (LS) estimates of the coefficients of the VAR model (see equation (5)), for a lag structure $s = 1$. This lag structure is chosen based on the values of the Bayesian and Akaike Information Criteria, reported in the table. Note that the Akaike criterion is corrected for small sample bias (see Burnham and Anderson (2004)). The reported estimates satisfy the stabilities conditions of the VAR model.

To evaluate the forecasting performance of the augmented VAR model for the debt-GDP ratio $d_{t+h}$, in Figure 2 we present out-of-sample (OOS) forecasts of $d_{t+h}$, for $h = 1$ quarter ahead, against its actual values. To obtain these forecasts, we rely on the suggested bootstrap method described by equation (11). This is done using an expanding window approach, starting with the data sample from 2000:Q1 to 2014:Q1 as the initial window. For each OOS period, we obtain dynamic forecasts of $d_{t+h}$, based on the debt-GDP dynamic equation (6) and the forecasts for vector $Y_{t+h}$. Then, we add to the sample window the next quarter of observations, re-estimate the model and obtain new forecasts for $d_{t+h}$.This procedure is sequentially repeated until the end of the sample (i.e., 2024:Q2), resulting in an out-of-sample interval of 41 observations used for the evaluation of the forecasting performance of the model for $d_{t+h}$. In this way, we maintain a good balance between having a significantly large initial sample to accurately estimate the VAR model while also keeping a reasonable period for OOS testing (see Diebold, 2015).

**Table 1**: Estimates of the VAR model

| | | | | | | | $R^2$ |
|---|---|---|---|---|---|---|---|
| $\gamma_t$ | $-0.02$ | $+1.2\gamma_{t-1}$ | $-0.08\pi_{t-1}$ | $-0.13pb_{t-1}$ | $+0.14(i_{t-1}-g_{t-1})$ | $+0.01d_{t-1}$ | 0.90 |
| | (0.01) | (0.10) | (0.08) | (0.05) | (0.07) | (0.006) | |
| $\pi_t$ | $-0.01$ | $+0.25\gamma_{t-1}$ | $+0.90\pi_{t-1}$ | $-0.11pb_{t-1}$ | $+0.13(i_{t-1}-g_{t-1})$ | $+0.01d_{t-1}$ | 0.85 |
| | (0.01) | (0.10) | (0.07) | (0.04) | (0.08) | (0.005) | |
| $pb_t$ | $-0.04$ | $+0.36\gamma_{t-1}$ | $+0.15\pi_{t-1}$ | $+0.87pb_{t-1}$ | $+0.21(i_{t-1}-g_{t-1})$ | $0.02d_{t-1}$ | 0.90 |
| | (0.01) | (0.12) | (0.07) | (0.04) | (0.08) | (0.004) | |
| $i_t-g_t$ | 0.04 | $-0.43\gamma_{t-1}$ | $-0.04\pi_{t-1}$ | $+0.13pb_{t-1}$ | $+0.69(i_{t-1}-g_{t-1})$ | $-0.02d_{t-1}$ | 0.93 |
| | (0.01) | (0.11) | (0.08) | (0.06) | (0.08) | (0.007) | |
| $AICc(p)$ : | $AICc(1)=-2431.2, AICc(2)=-2420.8, AICc(3)=-2290$ | | | | | | |
| $BIC(p)$ : | $BIC(1)=-2385.8, BIC(2)=-2375.7, BIC(3)=-2302.7$ | | | | | | |

**Notes**: The table presents LS estimates of the VAR model (5) of lag order one. In parentheses, we present estimates of standard errors based on Newey-West method using one lag. $R^2$ is the coefficient of determination. $AICc(p)$ is the Akaike Information Criterion corrected for small sample bias. Both of the criteria are calculated for lag order p = {1,2,3}.

The results of Table 1 clearly indicate that, first, there is a significant reaction by fiscal authorities to a higher level of the debt-GDP ratio $d_{t-1}$, one-period back. The estimate of the slope coefficient of $d_{t-1}$ in the primary balance equation of the VAR model (henceforth referred to as *pb*-equation) is positive (approximately given by 0.02) and significant, at the 5% level. This result is in accordance to the predictions of the fiscal policy reduced form relationship (3). It can be obviously attributed to the efforts of fiscal authorities for sustainable and solvent fiscal policies, since the Greek sovereign debt crisis began. As was expected, the primary balance $pb_t$ is also found to be positively related to real growth rate $\gamma_{t-1}$ and inflation rate $\pi_{t-1}$, one-period back. As discussed earlier, both of these variables independently capture real and nominal economic activity effects on budgetary policies, particularly on the side of tax revenues. Another interesting finding of the *pb*-equation estimates is that $pb_t$ is positively and significantly related to $i_{t-1}-g_{t-1}$. This relationship may interpreted as a reaction of fiscal police authorities to higher values of $i_{t-1}-g_{t-1}$ making public debt financing more expensive. Economides et al (2025) have recently argued that such a relationship is a necessity for public debt stability and fiscal sustainability, in addition to the fiscal policy rule given by equation (3).

Second, there is strong evidence of fiscal consolidation effects on economic activity. As can be seen from the estimates of the slope coefficients of the VAR equations concerning variables $\gamma_t$ and $\pi_t$, there are strong negative and significant primary balance effects on economic activity due to an increase in $pb_{t-1}$, one-period back. Notably, both variables $\gamma_t$ and $\pi_t$ tend to fall together when an increase to $pb_{t-1}$ happens. These results are the consequences of the austere fiscal contraction programs adopted by the Greek governments in response to the sovereign debt crisis. This will be more rigorously examined in the next section by presenting IRFs of $\gamma_t$ and $\pi_t$ with respect to primary balance structural shock $u_{t,pb}$.

Third, the results indicate that we can successfully predict changes in the values of the IRGD variable $i_t-g_t$ and their sign based on lagged values of most variables in vector $Y_t$ one-period back, including $i_{t-1}-g_{t-1}$. The reported estimates of the VAR equation for $i_t-g_t$ (henceforth referred to as $(i-g)$-equation) show that the predictive power of this equation is very high (see the coefficient of determination, $R^2$= 0.93). According to these estimates, a fall in $\gamma_{t-1}$ and an increase in $pb_{t-1}$ can predict changes in the sign of $i_t-g_t$ from negative to positive. Another interesting finding for $(i-g)$-equation is that the autoregressive coefficient for $i_t - g_t$ is approximately 0.69. This is considerably lower than the autoregressive coefficients of the other endogenous variables in vector $Y_t$, namely $pb_t$, $\gamma_t$ and $\pi_t$. This result may be interpreted as evidence that negative values of $i_t - g_t$ reverse to positive ones much more frequently than the other variables determining $d_t$. It also suggests that the snow ball dynamic effects of $i_t - g_t$ on $d_t$ may be less persistent than commonly believed. This will be more formally answered by the results of our GIRFs analysis, reported in a next subsection, which identifies the structural error associated with $i_t - g_t$.

Finally, the inspection of Figure 2 indicates that our VAR model, given by equations (5)-(6), can successfully predict future paths of $d_{t+h}$. The OOS forecasts produced by the model,based on the bootstrap approach suggested by equation (11), closely follow the actual values of $d_{t+h}$ reported in the figure. This holds true even for the covid-19 pandemic period, where $d_t$ fluctuates most substantially. To assess whether the above method of forecasting $d_{t+h}$ outperforms the method of skeleton forecasts often used in practice, we calculated the Diebold-Mariano test statistic for the out-of-sample (OOS) forecasts for the two methods over different horizons $h = \{1, 4, 8, 12\}$. This is done based on the mean squared proportional error (MSPE) loss function which is more robust to possible heteroscedasticity in series $d_t$. The estimates of this statistic are given below:

| $h$ | 1 | 4 | 8 | 12 |
|---|---|---|---|---|
| $DM$ | -1.49 | -1.14 | -1.57 | -4.15 |
| $p$-value | 0.071 | 0.129 | 0.052 | 0.000 |

where $DM$ denotes the statistic, $p$-value is the type I error of rejecting the null hypothesis that the two methods have the same forecasting performance against the alternative hypothesis assuming that the method skeleton forecasts is worse. The results of the above test clearly indicate that there exist substantial benefits in forecasting $d_{t+h}$ based on the bootstrap approach compared to the method of skeleton forecasts. The $p$-values reported reject the null hypothesis and accept the alternative at low significance levels. Furthermore, the rejections of the null hypothesis become more strong with $h$, implying higher forecasting benefits for the bootstrap approach as $h$ increases.

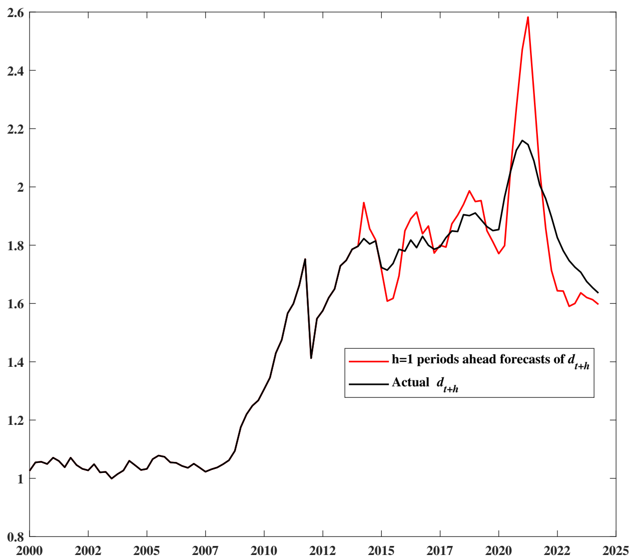



Fig. 2: Out-of-Sample (OOS) forecasts of $d_{t+h}$ for the period 2014:Q2 to 2024:Q2

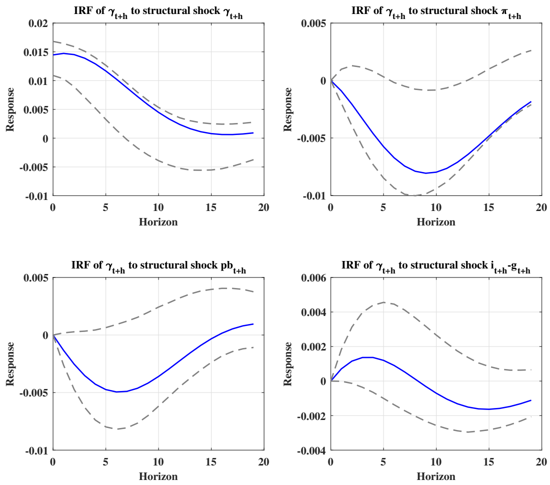
*(b) IRFs analysis*

The results of our IRFs analysis, based on the estimates of the VAR model presented in Table 1, are reported in Figure 3. The figure graphically presents estimates of $IRFs(h)$, for $h = 1, 2, ..., 20$ quarters ahead, together with their 90% confidence intervals for all the endogenous variables of the VAR model, i.e., $\gamma_t$, $\pi_t$, $pb_t$ and $i_t - g_t$. See Plots A, B, C and D of the figure, respectively. The reported estimates present responses of these variables to positive structural shocks $u_{t,j}$, $j = \{\gamma, \pi, pb, i-g\}$, of one standard deviation magnitude. These estimates are obtained using the Cholesky decomposition of the variance-covariance matrix of the vector of innovation terms $e_t = (e_{t,\gamma}, e_{t,\pi}, e_{t,pb}, e_{t,i-g})'$, see equation (7). The confidence intervals ($CIs$) reported in the plots are calculated using the bootstrap method with 10.000 iterations. Bootstrap estimates of $CIs$, instead of asymptotic approximations, are more appropriate when there are substantial asymmetries in the distributions of $IRFs(h)$, as can be confirmed by the reported values of $CIs$.

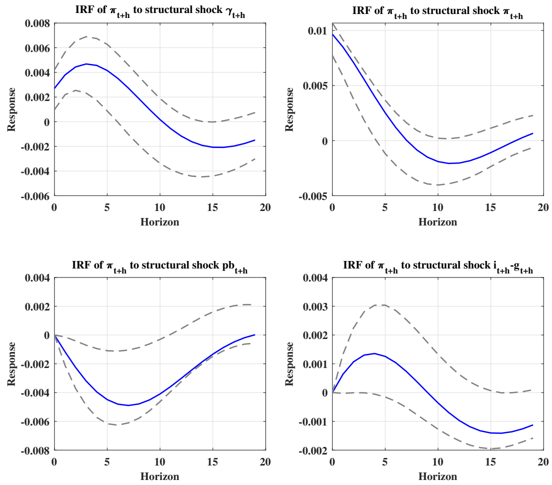
The inspection of the plots of the $IRFs(h)$ leads to several interesting conclusions about the dynamic and cross-section interactions among the covariates determining the debt-GDP ratio dynamics. These are very useful in interpreting the GIRFs of $d_{t+h}$ with respect to structural shocks $u_{t,j}$, presented in the next section. First, the estimates of $IRFs(h)$ show that the own effects of the structural shocks (captured by $IRF_{j,j}(h) = \frac{\partial Y_{t+h,j}}{\partial u_{t,j}}$) are persistent and significant for most endogenous variables of the VAR model. The only exception is the IRGD structural shock $u_{t,i-g}$ whose effects on $i_{t+h} - g_{t+h}$ appear significant only for a few quarters ahead, as indicated by the reported estimates of $CIs$. These results are consistent with the estimates of the autoregressive coefficients of the endogenous variables of the VAR model, reported in Table 2.

Second, regarding the cross-sectional covariate effects of structural shocks $u_{t,j}$ (captured by $IRF_{i,j}(h) = \frac{\partial Y_{t+h,i}}{\partial u_{t,j}}$, for all $i \neq j$), the results in the figure indicate that the signs of these effects are consistent with the theory. However, their degree of persistency differs across the shocks. The most important, both in terms of magnitude and persistency, of these effects is found to be that caused by structural shock $u_{t,\gamma}$, capturing structural real economic growth changes. Apart from its own effects, this shock has significant and persistent effects on the future paths of the other endogenous variables the VAR model (i.e., $\pi_t$, $pb_t$ and $i_t - g_t$). As was expected, a positive value of $u_{t,\gamma}$ causes positive changes in $pb_{t+h}$ and $\pi_{t+h}$, and negative in $i_{t+h} - g_{t+h}$.

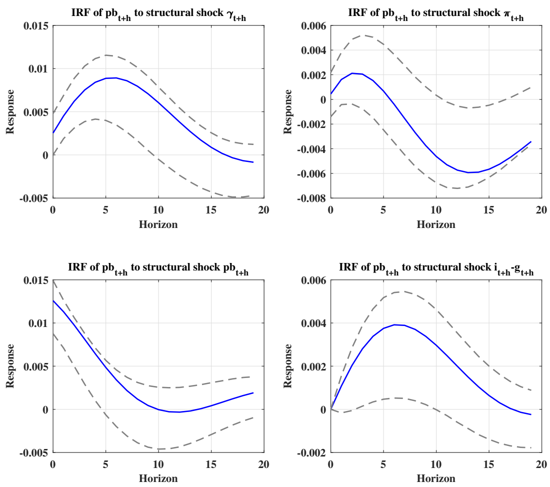
The remaining structural shocks (i.e., $u_{t,\pi}$,$u_{t,pb}$ and $u_{t,i-g}$) are found to have smaller in magnitude and less pervasive cross-section covariate effects than $u_{t,\gamma}$. Regarding their sign, these effects align with the slope coefficients of the VAR model, discussed in the previous section. A positive value of $u_{t,pb}$ is found to have negative effect on $\pi_{t+h}$ and $\gamma_{t+h}$, reflecting fiscal policy consolidation effects. A positive value of $u_{t,\pi}$ leads to an increase in $pb_{t+h}$, as it increases tax revenues. Finally, a positive value of $u_{t,i-g}$ causes a positive effect in $pb_{t+h}$. As mentioned earlier, this can be interpreted as a reaction of fiscal policy authorities to the higher cost of refinancing public debt.



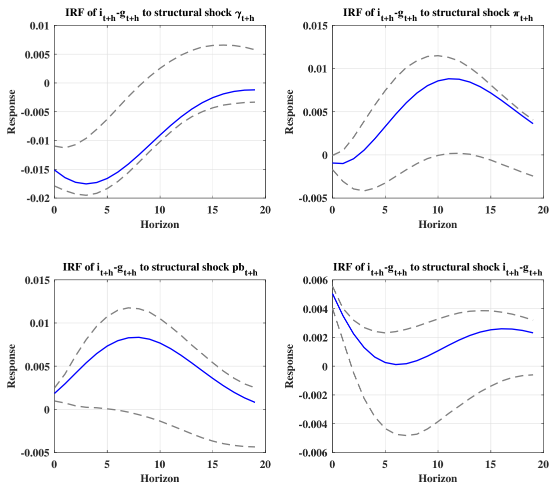

(A) IRFs of $\gamma_{t+h}$ to structural shocks




(B) IRFs of $\pi_{t+h}$ to structural shocks




(C) IRFs of $pb_{t+h}$ to structural shocks




(D) IRFs of $i_{t+h} - g_{t+h}$ to structural shocks

Fig. 3: Impulse Response Functions (IRFs) of endogenous variables to structural shocks.

*(c) GIRFs analysis for the debt-GDP ratio*

The direct effects of the structural shocks on the future paths of debt-GDP ratio $d_{t+h}$ can be discussed with the help of Figure 4 and Table 2. Figure 4 graphically presents estimates of the $GIRF_j(h)$ for $d_{t+h}$ to one-standard-deviation positive change in all shocks $u_{t,j}$, $j = \{\gamma, \pi, pb, i-g\}$ together with their 90% $CIs$. Table 2 presents estimates of $GVDF_j(h)$, for $h = \{1, 4, ..., 20\}$ quarters ahead, for all $u_{t,j}$. Both set of estimates, reported in the figure and the table, are obtained based on the bootstrap method presented in the previous section (see equations (9) and (11)) using 10.000 iterations.

A number of useful conclusions can be drawn from the estimates of $GIRF_j(h)$ and $GVDF_j(h)$, for all $j$. Firstly, a general conclusion is that the sign of both the impact (current $t$-time) and dynamic effects of all structural shocks $u_{t,j}$ considered on $d_{t+h}$ is consistent with the predictions of the debt dynamic equation (2). The debt-GDP ratio $d_{t+h}$ responds negatively to a positive value of structural shocks $u_{t,\gamma}$, $u_{t,\pi}$ and $u_{t,pb}$, and positively to a positive value of $u_{t,i-g}$, which increases the financing cost of the debt. The opposite effects hold for a negative value of $u_{t,j}$. In this case, $u_{t,i-g}$ reduces the level of $d_{t+h}$, thus highlighting the benefits of negative IRGDs for the debt stabilization.

Secondly, the real output structural shock $u_{t,\gamma}$ has the highest in magnitude and persistency effects on $d_{t+h}$ of all the shocks considered. In particular, the impact of $u_{t,\gamma}$ on $d_{t+h}$, for $h = 0$, has size which is almost four times bigger than the other structural shocks, while its dynamic effects on $d_{t+h}$ last for more than twenty quarters ahead (see the $CIs$ values, reported in the figure). On the contrary, the dynamic effects of the other structural shocks on $d_{t+h}$ (including the IRGD shock $u_{t,i-g}$) are much shorter, lasting between three and five quarters ahead. These results are not surprising given the estimates of the IRFs analysis, presented in the previous section. Apart from its own effects, the prolonged effects of $u_{t,\gamma}$ on $d_{t+h}$ can be also attributed to its cross-section effects on the remaining covariates determining the debt-GDP ratio dynamics. These are found to be important, both in terms of size and persistency. The less pervasive effects of the IRGD shock $u_{t,i-g}$ on $d_{t+h}$ can be attributed to its lower degree of persistency and its cross-section effect on primary balance. As shown by the estimates of $IRF_j(h)$ for this shock, a negative value of $u_{t,i-g}$ implies a decrease in $pb_{t+h}$ for a some quarters ahead, which leads to public debt accumulation.

Third, the above results are also consistent with the estimates of $GVDF_j(h)$, reported in Table 2. The results of this table indicate that the shock $u_{t,\gamma}$ explains most of the variance of the forecast error of $d_{t+h}$. The contribution of $u_{t,\gamma}$ to $GVDF_j(h)$ ranges from 0.77 to 0.94. This is the highest contribution of all structural shocks either for short ($h = 1$) or long ($h = 20$) horizons. On the contrary, the contribution of the shock $u_{t,i-g}$ to $GVDF_j(h)$ is relatively small (i.e., 0.06) and concerns only the short horizon $h = 1$. A similar conclusion can be drawn for the primary balance shock $u_{t,pb}$. Finally, note that the contribution of the inflation shock $u_{t,\pi}$ mainly concerns the long end of $GVDF_j(h)$ (i.e., $h = 20$) and it is low relative to $u_{t,\gamma}$.

Summing up, the results of the IRFs and GIRFs analysis imply that, although a negative value of the IRGD structural shock $u_{t,i-g}$ has stabilizing effects on public debt, these effects are temporary and of lower magnitude compared to those of a positive real output structural shock $u_{t,\gamma}$. The latter can stabilize the debt-GDP ratio considerably, as it also significantly affects the IRDG and primary balance.

Table 2: Generalized Variance Decomposition Function

| *horizon* | 1 | 4 | 8 | 16 | 20 |
|---|---|---|---|---|---|
| $u_{t,\gamma}$ | 0.80 | 0.95 | 0.98 | 0.81 | 0.77 |
| $u_{t,\pi}$ | 0.01 | 0.01 | 0.01 | 0.13 | 0.17 |
| $u_{t,pb}$ | 0.12 | 0.03 | 0.01 | 0.06 | 0.06 |
| $u_{t,i-g}$ | 0.07 | 0.01 | 0.00 | 0.00 | 0.00 |

Notes: The table presents estimates of the $GVDF_j(h)$ of $d_{t+h}$ for the vector of structural shocks $u_t = (u_{t,\gamma},\, u_{t,\pi},\, u_{t,pb},\, u_{t,i-g})$.

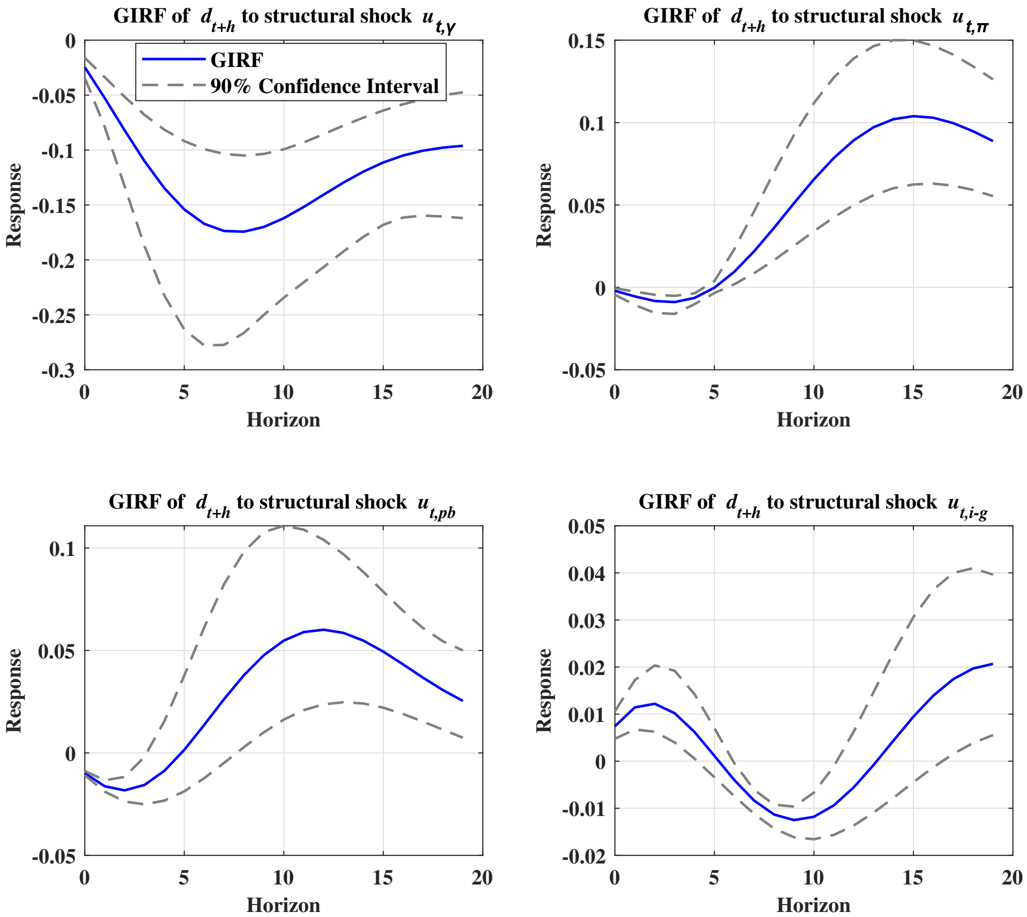



Fig. 4: GIRFs of $d_{t+h}$ to structural shocks

# 5 Assessing downside risks of public debt under different structural policy scenarios

The results of the previous section imply that downside risks of public debt (implying debt accumulation) can be attributed to different structural economic shocks. In this section, based on structural policy scenario (SPS) analysis, we evaluate both qualitatively and quantitatively the downside risks of public debt associated with three of the structural shocks driving the debt-GDP ratio dynamics presented by the SVAR analysis.[8] These shocks are taken to reflect alternative counterfactual policy scenarios which occur $h = 1, 2, ...$ periods after the end of the sample, at time $T$ (i.e., over period $T + h$).

The first scenario considers a primary balance structural shock, denoted as $u^*_{T+h,pb}$, which offsets the effects of fiscal policy rule (3) on $pb_{T+h}$. This means the abandonment of the fiscal policy rule given by the reduced form equation (3). The second scenario considers an IRGD structural shock, denoted as $u^*_{t,i-g}$, which turns the value of $i_{T+h} - g_{T+h}$ from negative to positive, implying that there are no benefits of refinancing public debt at negative IRGDs. This shock sets $i_{T+h} - g_{T+h} = 2\%$, for all $h$. Finally, the third scenario assumes a structural shock, denoted as $u^*_{T+h,\gamma}$, which causes a fall in real output growth by 1%. The first two sources of risks (due to shocks $u^*_{T+h,pb}$ and $u^*_{T+h,i-g}$) have an immediate fiscal policy interest. They primarily concern government decisions on financing public debt, either by higher taxes or further borrowing. The third source (due to shock $u^*_{T+h,\gamma}$) has a broader economic policy interest, given also our findings that $u_{t,\gamma}$ causes large and persistent deviations of $d_{t+h}$ from its long run levels.

To appraise the above risks, we will rely on the estimates of the structural VAR (SVAR) model, given by equations (5), (6) and (7), reported in the previous section. Based on these estimates, we will examine the impact of structural shocks $u^*_{T+h,pb}$, $u^*_{T+h,i-g}$ and $u^*_{T+h,\gamma}$, defined above, on the future path of $d_{T+h}$ by means of stochastic simulations. The adjusted stocks $u^*_{T+h,pb}$, $u^*_{T+h,i-g}$ and $u^*_{T+h,\gamma}$, reflecting the above alternative policy scenarios, are known in the literature as driving shocks. These shocks, for each scenario considered, are assumed to deviate from their unconditional distribution, over period $T + h$, in contrast to the remaining structural shocks (known as non-driving) which retain their unconditional distribution features. One merit of the SPS analysis in assessing downside risks for $d_{t+h}$ is that it takes into account the actual interactions among the covariates determining $d_{t+h}$ and their associated structural shocks identified by the data, as well as the empirical distribution of these shocks. This is expected to provide more empirically plausible distributions of the future paths of $d_{t+h}$ and, hence, estimates of the downside risks for $d_{t+h}$.

The results of our SPS analysis are presented in Figures 5 and 6. The figures presents fan charts of $d_{T+h}$, for $h = \{1, 2, 3, 4\}$ quarters ahead. This is done for the baseline scenario of the SPS analysis (denoted as $\text{SPS}_0$), which does not consider any counterfactual policy scenario (see Figure 5), and for the cases of the alternative counterfactual policy scenarios described above (see Figure 6). The fan charts, reported by the figure, present frequency distributions of the possible future paths of $d_{T+h}$, for all $h$, which correspond to the alternative policy scenarios. These distributions will be used to calculate public debt downside risks. To obtain these charts, we rely on a bootstrap stochastic simulation method which generates paths of $Y_{T+h}$ and $d_{T+h}$ based on the relationship $Z_{T+h} = F(Z_{T+h-1}, e_{T+h}, u^*_{j,T+h}; \vartheta)$, defined in equation (11), where $Z_{T+h} = (Y'_{T+h}, d_{T+h})'$, $e_{T+h} = \Theta u_{T+h}$ (see equation (7)) and $u^*_{j,T+h}$, $j = \{pb, i - g, \gamma\}$. According to this method, the paths of $Y_{T+h}$ and $d_{T+h}$ are generated by randomly drawing (with replacement) from the distribution of the vector of innovation terms $e_{T+h}$ given by $e_{T+h} =$

[8] We have also considered the case of a structural shock in inflation, but we have found that it does not change the main conclusions of our analysis. This is not surprising, given the results of Table 2, which show that the contribution of the shock $u_{t,\pi}$ to $GVDF_j(h)$ is relatively low compared to $u_{t,\gamma}$. These results are not reported due to space limitations.

$\Theta u_{T+h}$ where the structural shocks $u^*_{j,T+h}$ are replaced by their corresponding driving shocks $u^*_{j,T+h}$, as defined under the alternative policy scenarios. The remaining (non-driving) structural shocks are left unrestricted; these take values from their sample distribution estimates, based on the SVAR estimates.

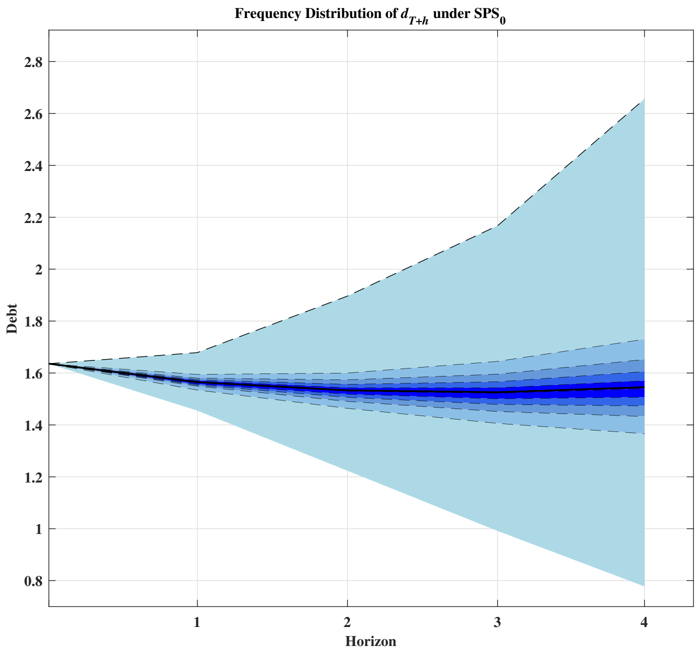
More analytically, for the structural policy scenario assuming the abandonment of the fiscal policy rule (3), over $T+h$, denoted as SPS$_1$, the structural equation between $e_{T+h,pb}$ and $u^*_{T+h,pb}$ is given as: $e_{T+h,pb} = \theta_{31}e_{T+h,\gamma} + \theta_{32}e_{T+h,\pi} + u^*_{T+h,pb}$, for all $h$, where $u^*_{T+h,pb} = u_{T+h,pb} - 0.02d_{T+h-1}$. This equation is used to generate future paths of $d_{T+h}$, by drawing from the sample distributions of $e_{T+h,\gamma}$, $e_{T+h,\pi}$ and $u^*_{T+h,pb}$. By doing so, we take into account the causal relationships between the structural shocks and innovation terms assumed by structural relationship (7)), which gives economic interpretation to structural shocks $u_{t,j}$.

For the structural policy scenario which sets IRGD $i_{T+h} - g_{T+h}$ to 2%, denoted as SPS$_2$, the structural equation between $e_{T+h,i-g}$ and $u^*_{T+h,i-g}$ used to generate paths of $d_{T+h}$ is given as $e_{T+h,i-g} = \theta_{41}e_{T+h,\gamma} + \theta_{42}e_{T+h,\pi} + \theta_{43}e_{T+h,pb} + u^*_{T+h,i-g}$, where $u^*_{T+h,i-g} = u_{T+h,i-g} - (i_{T+h} - g_{T+h}) + 0.02$. Note that, since $i_{T+h} - g_{T+h}$ is not observable at time $T+h$, it is replaced by its VAR forecast. Finally, for the structural policy scenario that reduces the real growth rate $\gamma_{T+h}$ by 1%, denoted as SPS$_3$, the structural equation between $e_{T+h,\gamma}$ and $u^*_{T+h,\gamma}$ is given as $e_{T+h,\gamma} = u^*_{T+h,\gamma}$, where $u^*_{T+h,\gamma} = e_{T+h,\gamma} - 0.01$. In addition to the above scenarios, we also consider a fourth scenario (denoted SPS$_{1,2}$) which combines both SPS$_1$ and SPS$_2$. This scenario can appraise the downside risk of public debt when fiscal authorities abandon the fiscal policy rule and focus more on the negative IRGDs for public debt stabilization.

To obtain a quantitative assessment of the public debt downside risks caused by the above scenarios, in Table 3 (see Panel A) we present the probabilities that $d_{T+h}$ raises above its end of sample level, i.e., $d_T = 163.5\%$, for $h = \{1, 2, 3, 4\}$ quarters ahead, defined as $\Pr[d_{T+h} \geqslant d_T]$. This is done for all the alternative policy scenarios considered in our SPS analysis. The values of $\Pr[d_{T+h} \geqslant d_T]$, presented in the table, are calculated based on the fan charts, reported by Figure 5. For comparison, in the table (see Panel B) we also present values of $\Pr[d_{T+h} \geqslant d_T]$ for all the above scenarios under the stress testing approach (STA). These cases are denoted as STA$_1$, STA$_2$, STA$_3$ and STA$_{1,2}$. For a more fair comparison to the SPS method, we consider a probabilistic version of the STA based on the reduced version of our VAR specification to generate paths of $Y_{T+h}$ and $d_{T+h}$. The fan charts of these scenarios are not provided for reasons of space. Instead of placing restrictions on structural shocks, the STA restricts the future paths of the variables determining $d_{T+h}$, over $T+h$, to take certain values under the assumptions of the alternative scenarios considered and leaves the future paths (projections) of the remaining covariates unchanged.[9] The distribution of the future paths of these covariates, over $T+h$, is obtained by drawing random samples (with replacement) from the empirical distributions of the estimates of their innovation terms $e_{t,j}$. The difference between the SPS analysis and the probabilistic STA is due to the fact that the STA does not take into account the structural relationship between $e_{T+h}$ and $u_{T+h}$, given by $e_{T+h} = \Theta u_{T+h}$, in drawing samples of $e_{T+h}$. Ignoring this relationship (capturing structural

[9] In particular, the future paths of $Y_{T+h}$ and $d_{T+h}$ are generated from the relationship $Z_{T+h} = F(Z_{T+h-1}, e_{T+h}; \vartheta)$, where $e_{T+h,j}$ $(j = \{\gamma, pb, i-g\})$ are restricted accordingly to the alternative policy scenarios. That is, $pb_{T+h} = pb_{T+h} - 0.02d_{T+h-1}$ for STA$_1$, $i_{T+h} - g_{T+h} = 0.02$ for STA$_2$ and $\gamma_{T+h} = \gamma_{T+h} - 0.01$ for STA$_3$, where $pb_{T+h}$, $i_{T+h} - g_{T+h}$ and $\gamma_{T+h}$ are replaced by their VAR forecasts.

Fig. 5: Fan Chart of $d_{T+h}$ under no counterfactual policy analysis ($SPS_0$)



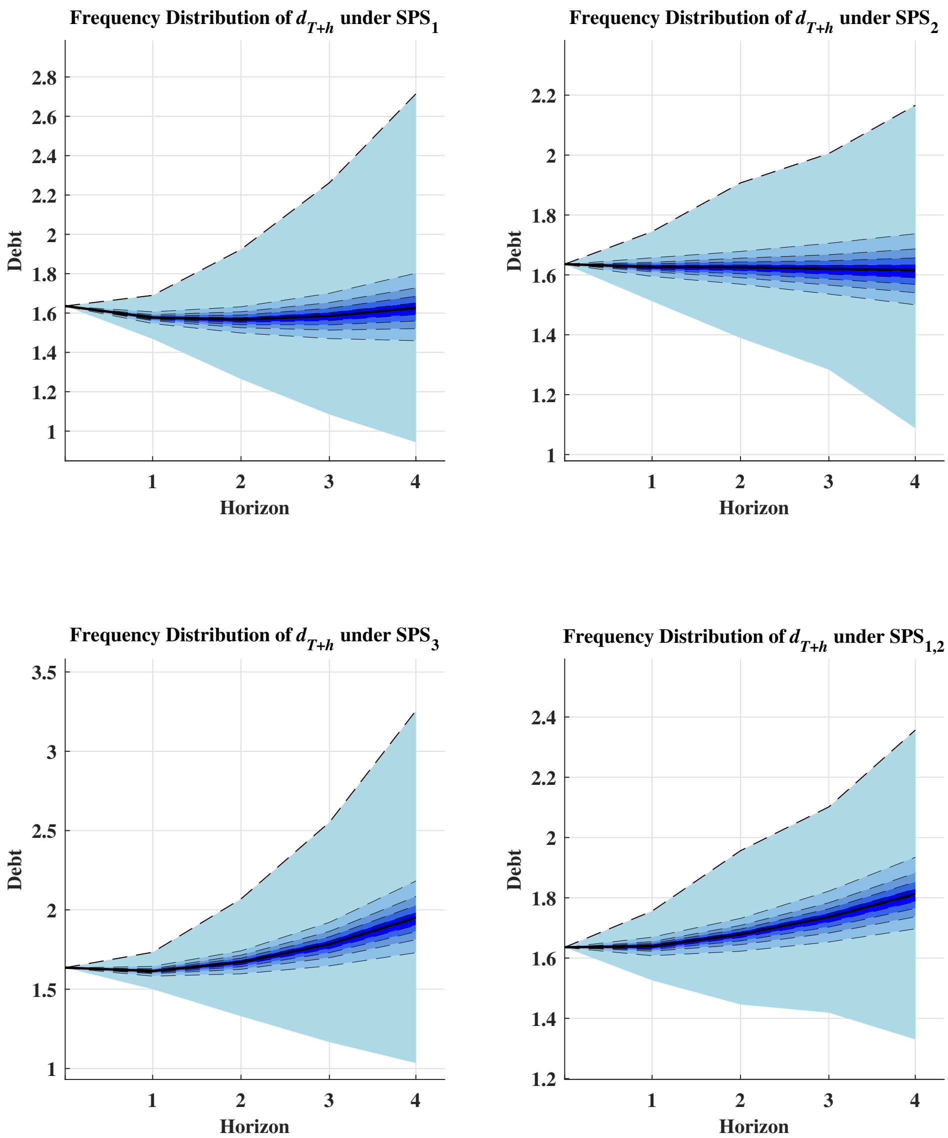




Fig. 6: Fan Charts of $d_{T+h}$ under counterfactual policy scenarios ($SPS_1$, $SPS_2$, $SPS_3$, and $SPS_{1,2}$)

interactions among the covariates determining future paths $d_{T+h}$) may not produce empirically plausible paths of $d_{t+T}$, over $T+h$ (see also Diaz et al (2021)). Yet, it can not provide downside risks for public debt which are be economically interpretable (i.e., driven by identified structural shocks).

A number of useful conclusions can be drawn from the inspection of the fan charts of Figure 5 and the results of Table 3. First, the fan chart estimates show a downward trend in $d_{T+h}$, for all $h$, under the baseline scenario $\text{SPS}_0$. The probabilities (risk) of reversing this trend, reported in the table, are relatively low, compared to the cases of $\text{SPS}_i$ ($i = 1, 2, 3$) considered. Second, the highest risk of reversing this trend is under $\text{SPS}_3$, which assumes a fall in real output growth. This risk escalates with $h$, quickly, and it is important even under negative IRGDs, observed over the last years of our sample. This is not surprising, given the estimates of the IRFs and GIRFs (presented in the previous section), which show that the structural shock to real growth growth rate causes the largest magnitude and most persistent deviations of the debt-GDP ratio from its long run level among all the structural shocks considered.

The downside risk of the IRGD turning from a negative value to positive (see $\text{SPS}_2$) is found to be important even for short horizons (e.g., $h = \{1, 2\}$ quarters ahead). This risk exacebrates quickly, with a probability approaching to one as $h$ increases, if it is combined with the downside risk of the abandonment of the fiscal policy rule (see $\text{SPS}_{1,2}$). In this case, the level of the downside risk exceeds that of the economic growth slowdown policy scenario, for all $h$. This result emphasizes the high downside risk of relaxing fiscal discipline and relying on negative IRGDs to stabilize public debt. The abandonment of the fiscal policy rule (see $\text{SPS}_1$) affects the downside risk at horizons longer than $h = 2$.

A final conclusion that can be drawn from our results is that the levels of the downside risk predicted under the STA differ substantially from those based on the SPS method in two out of the three scenarios considered. In particular, these levels are much bigger under the SPS method than the STA for $\text{SPS}_3$, for all $h$. The opposite result holds for $\text{SPS}_1$. Following our previous discussion, these results can be attributed to the fact that, in obtaining future paths of $d_{T+h}$, the SPS analysis accounts for possible interactions among all structural shocks determining the dynamics of $d_{T+h}$. The smaller levels of the downside risk estimated under the $\text{SPS}_1$, compared to the $\text{STA}_1$, can be explained by the fact that, apart from its own structural shock, $pb_{T+h}$ is strongly influenced by the structural shock $u_{T+h,\gamma}$ (see our IRFs analysis).

# 6 Conclusions

The aim of this paper was to examine whether negative values of the interest rates growth differential (IRGD) can be thought of as a viable source of public debt stabilization and to appraise its downside risks compared to other determinants of public debt, such as primary balances and economic activity. To this end, we focus on the following sources of public debt downside risks: the abandonment of a fiscal policy rule responding to debt-GDP ratio, a reversal of IRGD from negative to positive value and a slowdown of the real output growth by 1%. These risks have immediate interest to economic policymakers, particularly fiscal authorities. To assess them, we rely on a structural policy scenario (SPS) analysis. This analysis enables us to identify structural shocks associated with the above sources of risk and to generate future

Table 3: Estimates of the downside risk (probabilities) $\Pr[d_{T+h} \geq d_T]$

| | **Panel A: Under the SSP approach** | | | | | **Panel B: Under the stress testing approach** | | | |
|---|---|---|---|---|---|---|---|---|---|
| h | $SPS_0$ | $SPS_1$ | $SPS_2$ | $SPS_3$ | $SPS_{1,2}$ | $STA_1$ | $STA_2$ | $STA_3$ | $STA_{1,2}$ |
| 1 | 2.94% | 3.19% | 32.82% | 15.21% | 53.72% | 5.13% | 32.89% | 3.08% | 60.50% |
| 2 | 4.73% | 9.82% | 37.87% | 75.07% | 84.75% | 29.06% | 38.03% | 5.88% | 88.42% |
| 3 | 11.36% | 26.74% | 37.18% | 91.55% | 93.67% | 57.85% | 37.49% | 20.96% | 95.22% |
| 4 | 23.08% | 46% | 38.76% | 95.28% | 96.77% | 73.80% | 39.05% | 50.3% | 97.53% |

**Notes:** The table presents estimates of the probabilities $\Pr[d_{T+h} \geqslant d_T]$, for $h = 1, 2, 3, 4$, periods ahead based on the values of $d_T$, at the end of the sample. This is done under $SPS_0$ (no counterfactual scenario), and for the following SPS cases: $SPS_1$, $SPS_2$, $SPS_3$ and $SPS_{1,2}$ (see Panel A of the table), as well as their corresponding cases $STA_1$, $STA_2$, $STA_3$ and $STA_{1,2}$, considered under the stress testing approach.

paths of the debt-GDP ratio, allowing us to quantitatively and qualitatively appraise the above risks by means of stochastic simulation. This is achieved within a unified econometric framework which accounts for the dependence structure among all covariates determining the debt dynamics and their empirical distribution properties.

In our empirical analysis, we consider a vector autoregression (VAR) model of the data which consists of the fundamental economic variables driving the debt-GDP ratio dynamics and also allows for feedback effects from the debt-GDP ratio to these variables. Following a research stream in economic literature, we treat the dynamic equation of the debt-GDP ratio as an identity. This equation complements our VAR model specification. Due to the nonlinearity of this equation, we suggest a bootstrap sampling procedure to obtain unbiased forecasts of the debt-GDP ratio based on forecasts of its covariates obtained by the VAR model. In our empirical analysis, we use data from the Greek economy since joining European Union (EU). This sample period covers a range of significant events (i.e., a sovereign debt crisis, fiscal consolidation programs and the covid-19 pandemic) that occurred in this economy, which help to better identify the structural shocks driving the debt-GDP ratio dynamics and to assess the magnitude of public debt downside risks.

The results of the paper lead to several conclusions which have important fiscal policy implications. Firstly, they demonstrate that negative IRGDs can indeed help accelerate public debt decumulation. However, this benefit is temporary and not without risk. The debt-GDP ratio levels can quickly escalate if the IRGD values turn positive. This risk is exacerbated if fiscal authorities (governments) become more relaxed and pursue primary balance deficits, focusing solely on negative IRGDs to stabilize public debt. The paper clearly shows that abandoning a fiscal policy rule reacting to debt-GDP levels implies a high risk of accelerating public debt even in an environment of negative IRGDs. Secondly, the findings of the paper indicate that, both in terms of size and persistency, the most important public debt downside risk of all covariates determining the debt-GDP ratio comes from a structural shock reducing real economic activity. This shock not only directly increases the debt-GDP ratio levels but also leads to sizable and permanent increases in the IRGD and primary balances, which, in turn, can substantially increase public debt levels.

## References


Baldacci, E. and M. Kumar (2010), 'Fiscal Deficits, Public Debt, and Sovereign Bond Yields," IMF working paper 10/184.

Barrett, P. (2018), "Interest-growth differential and debt limits in advanced economies", IMF Working Paper, WP/18/82

Bernanke, B.S., M. Gertler, and M. Watson (1997), "Systematic Monetary Policy and the Effects of Oil Price Shocks." Brookings Papers on Economic Activity, 91-142.

Blanchard, O. (2019), "Public Debt and Low Interest Rates," American Economic Review, 109(4), pages 1197-1229.

Bohn, H. (1998), 'The behaviour of US public debt and deficits', Quarterly Journal Economics, 113(3), 949–963.

Bournakis I, C. Tsoukis, D.K. Christopoulos, and T. Palivos T (2017), Political economy perspectives on the Greek crisis. Palgrave Macmillan.

Burnham, K.P. & D.R. Anderson (2004), Multimodel inference: understanding AIC and BIC in model selection. Sociological Methods and Research, 33, 261–304

Canzoneri, M. B., R. E. Cumby and B. T. Diba (2001), "Is the Price Level Determined by the Needs of Fiscal Solvency?," American Economic Review, 91 (5), 1221–1238.

Checherita-Westphal, C. and J.D. Semeano (2020), "Interest rate-growth differentials on government debt: an empirical investigation for the euro area", ECB, WP, No 2486/2020.

Chodorow-Reich G., L. Karabarbounis and R. Kekre (2023), "The macroeconomics of the Greek depression", American Economic Review, 113 (9), 2411-2457.

D' Erasmo P., E. Mendoza and J. Zhang (2016), "What is a Sustainable Public Debt?", Handbook of Macroeconomics, Volume 2B, 2557-2588.

Daniel, B.C. and C. Shiamptanis (2013), " Pushing the limit? Fiscal policy in the European Monetary Union", Journal of Economic Dynamics & Control, 37, 2307-2321.

Diaz, J.A., I. Petrella and J.F. Rubio-Ramirez (2021), "Structural scenario analysis with SVARs", Journal of Monetary Economics, 117, 798–815.

Diebold, F.X. (2015) Comparing Predictive Accuracy, Twenty Years Later: A Personal Perspective on the Use and Abuse of Diebold-Mariano Tests. Journal of Business & Economic Statistics, 33, 1.

Dimakopoulou, V., G. Economides and A. Philippopoulos (2022), " The ECB's policy, the Recovery Fund and the importance of trust and fiscal corrections: The case of Greece", Economic Modelling, 112, 1-14.

Economides G., D. Papageorgiou and A. Philippopoulos (2021), " Austerity, assistance and institutions: Lessons from the Greek sovereign debt crisis, Open Economies Review, 32, 435-478.

Economides G., G. Koliousid, N. Miaoulid and A. Philippopoulos (2025), "From debt arithmetic to fiscal sustainability and fiscal rules: Taking stock and policy lessons", Journal of Economic Asymmetries (forthcoming).

Escolano, J., A. Shabunina and J. Woo (2017), "The Puzzle of Persistently Negative Interest-Rate–Growth Differentials: Financial Repression or Income Catch-Up?", IMF Fiscal Studies, 38(2), 179–217

Favero, C. and F. Giavazzi (2007), "Debt and the Effects of Fiscal Policy," NBER working paper 12822.

Favero, C. and F. Giavazzi (2009), "How Large Are the Effects of Tax Changes," NBER working paper 15303.

Granger, C. and T. Terasvirta (1993), Modelling Nonlinear Economic Relationships, Oxford University Press, USA.

Hall, G.T., and T.J. Sargent (2011), "Interest Rate Risk and Other Determinants of Post-WWII US Government Debt/GDP Dynamics", American Economic Journal: Macroeconomics, 3, 192–214.

Hamilton, J.D., and A.M. Herrera (2004), "Oil Shocks and Aggregate Economic Behavior: The Role of Monetary Policy: Comment", Journal of Money, Credit, and Banking, 36 (2), 265-286

Koop, G., M.H. Pesaran amd S.M. Potter (1996), "Impulse response analysis in non linear multivariate models", Journal of Econometrics, 74 (1), 119–147

Kumar, M. and J. Woo (2010), "Public Debt and Growth," IMF working paper 10/174.

Lanne, M. and H. Nyberg (2016), "Generalized Forecast Error Variance Decomposition for Linear and Nonlinear Multivariate Models", Oxford Bulletin of Economics and Statistics, 78 (4), 595-603.

Lian, W., A.F. Presbitero and U. Wiriadinata (2020), "Public Debt and r - g at Risk", IMF working paper 20/137.

Lundbergh, S. and T. Terasvirta (2004), "Forecasting with Smooth Transition Autoregressive Models", In M. P. Clements and D. F. Hendry (Eds.), A Companion to Economic Forecasting, 485–509. Blackwell Publishing

Martin, A. and J. Ventura (2012), "Economic Growth with Bubbles", American Economic Review, 102(6), 3033-3058.

Mauro, P. and J. Zhou (2020), "r-g<0: Can We Sleep More Soundly?", IMF Working paper, WP/20/52, Washington DC.

Papageorgiou D. and E. Vourvachaki (2017), "Macroeconomic effects of structural reforms and fiscal consolidation: trade-offs and complementarities", European Journal of Political Economy, 48, 54–73.

Rogoff, K. S. (2020), "Falling real interest rates, rising debt: A free lunch?", Journal of Policy Modeling, 42 (4), 778–790.

# Department of Economics
# Athens University of Economics and Business

## List of Recent Working Papers

**2023**

01-23 Real interest rate and monetary policy in the post Bretton Woods United States, George C. Bitros and Mara Vidali
02-23 Debt targets and fiscal consolidation in a two-country HANK model: the case of Euro Area, Xiaoshan Chen, Spyridon Lazarakis and Petros Varthalitis
03-23 Central bank digital currencies: Foundational issues and prospects looking forward, George C. Bitros and Anastasios G. Malliaris
04-23 The State and the Economy of Modern Greece. Key Drivers from 1821 to the Present, George Alogoskoufis
05-23 Sparse spanning portfolios and under-diversification with second-order stochastic dominance, Stelios Arvanitis, Olivier Scaillet, Nikolas Topaloglou
06-23 What makes for survival? Key characteristics of Greek incubated early-stage startup(per)s during the Crisis: a multivariate and machine learning approach, Ioannis Besis, Ioanna Sapfo Pepelasis and Spiros Paraskevas
07-23 The Twin Deficits, Monetary Instability and Debt Crises in the History of Modern Greece, George Alogoskoufis
08-23 Dealing with endogenous regressors using copulas; on the problem of near multicollinearity, Dimitris Christopoulos, Dimitris Smyrnakis and Elias Tzavalis
09-23 A machine learning approach to construct quarterly data on intangible investment for Eurozone, Angelos Alexopoulos and Petros Varthalitis
10-23 Asymmetries in Post-War Monetary Arrangements in Europe: From Bretton Woods to the Euro Area, George Alogoskoufis, Konstantinos Gravas and Laurent Jacque
11-23 Unanticipated Inflation, Unemployment Persistence and the New Keynesian Phillips Curve, George Alogoskoufis and Stelios Giannoulakis
12-23 Threshold Endogeneity in Threshold VARs: An Application to Monetary State Dependence, Dimitris Christopoulos, Peter McAdam and Elias Tzavalis
13-23 A DSGE Model for the European Unemployment Persistence, Konstantinos Giakas
14-23 Binary public decisions with a status quo: undominated mechanisms without coercion, Efthymios Athanasiou and Giacomo Valletta
15-23 Does Agents' learning explain deviations in the Euro Area between the Core and the Periphery? George Economides, Konstantinos Mavrigiannakis and Vanghelis Vassilatos
16-23 Mild Explocivity, Persistent Homology and Cryptocurrencies' Bubbles: An Empirical Exercise, Stelios Arvanitis and Michalis Detsis
17-23 A network and machine learning approach to detect Value Added Tax fraud, Angelos Alexopoulos, Petros Dellaportas, Stanley Gyoshev, Christos Kotsogiannis, Sofia C. Olhede, Trifon Pavkov
18-23 Time Varying Three Pass Regression Filter, Yiannis Dendramis, George Kapetanios, Massimiliano Marcellino
19-23 From debt arithmetic to fiscal sustainability and fiscal rules: Taking stock, George Economides, Natasha Miouli and Apostolis Philippopoulos

**20-23** **Stochastic Arbitrage Opportunities: Set Estimation and Statistical Testing, Stelios Arvanitis and Thierry Post**
**21-23** **Behavioral Personae, Stochastic Dominance, and the Cryptocurrency Market, Stelios Arvanitis, Nikolas Topaloglou, and Georgios Tsomidis**
**22-23** **Block Empirical Likelihood Inference for Stochastic Bounding: Large Deviations Asymptotics Under *m*-Dependence, Stelios Arvanitis and Nikolas Topaloglou**
**23-23** **A Consolidation of the Neoclassical Macroeconomic Competitive General Equilibrium Theory via Keynesianism (Part 1 and Part 2), Angelos Angelopoulos**
**24-23** **Limit Theory for Martingale Transforms with Heavy-Tailed Noise, Stelios Arvanitis and Alexandros Louka**

## 2024

**01-24** **Market Timing & Predictive Complexity, Stelios Arvanitis, Foteini Kyriazi, Dimitrios Thomakos**
**02-24** **Multi-Objective Frequentistic Model Averaging with an Application to Economic Growth, Stelios Arvanitis, Mehmet Pinar, Thanasis Stengos, Nikolas Topaloglou**
**03-24** **State dependent fiscal multipliers in a Small Open Economy, Xiaoshan Chen, Jilei Huang, Petros Varthalitis**
**04-24** **Public debt consolidation: Aggregate and distributional implications in a small open economy of the Euro Area, Eleftherios-Theodoros Roumpanis**
**05-24** **Intangible investment during the Global Financial Crisis in the EU, Vassiliki Dimakopoulou, Stelios Sakkas and Petros Varthalitis**
**06-24** **Time will tell! Towards the construction of instantaneous indicators of different agent-types, Iordanis Kalaitzoglou, Stelios Arvanitis**
**07-24** **Norm Constrained Empirical Portfolio Optimization with Stochastic Dominance: Robust Optimization Non-Asymptotics, Stelios Arvanitis**
**08-24** **Asymptotics of a QLR-type test for optimal predictive ability, Stelios Arvanitis**
**09-24** **Strongly Equitable General Equilibrium Allocations, Angelos Angelopoulos**
**10-24** **The Greek macroeconomy: A note on the current situation and future outlook, Apostolis Philippopoulos**
**11-24** **Evolution of Greek Tax System, A Survey of Legislated Tax Changes from 1974 to 2018, Panagiotis Asimakopoulos**
**12-24** **Macroeconomic Impact of Tax Changes, The case of Greece from 1974 to 2018, Panagiotis Asimakopoulos**
**13-24** **`Pareto, Edgeworth, Walras, Shapley' Equivalence in a Small Economy, Angelos Angelopoulos**
**14-24** **Stimulating long-term growth and welfare in the U.S, James Malley and Apostolis Philippopoulos**
**15-24** **Distributionally Conservative Stochastic Dominance via Subsampling, Stelios Arvanitis**
**16-24** **Before and After the Political Transition of 1974. Institutions, Politics, and the Economy of Post-War Greece, George Alogoskoufis**
**17-24** **Gaussian Stochastic Volatility, Misspecified Volatility Filters and Indirect Inference Estimation, Stelios Arvanitis, Antonis Demos**
**18-24** **Endogenous Realtor Intermediation and Housing Market Liquidity, Miroslav Gabrovski, Ioannis Kospentaris, Victor Ortego-Marti**
**19-24** **Universal Choice Spaces and Expected Utility: A Banach-type Functorial Fixed Point, Stelios Arvanitis, Pantelis Argyropoulos, Spyros Vassilakis**
**20-24** **Government Expenditures and Tax Policy Framework after the Political Transition, The Case of Greece, Panagiotis Asimakopoulos**

**2025**

01-25 **Democracy, redistribution, and economic growth: Some evidence from post-1974 Greece, George C. Bitros**

02-25 **Assessing Downside Public Debt Risks in an Environment of Negative Interest Rates Growth Differentials, Yiannis Dendramis, Georgios Dimitrakopoulos and Elias Tzavalis**

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303-5. E-mail: econ@aueb.gr / www.aueb.gr
76, Patission Street, Athens 104 34 Greece. Tel.: (+30) 210 8203303-5

ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS
ΣΧΟΛΗ ΟΙΚΟΝΟΜΙΚΩΝ ΕΠΙΣΤΗΜΩΝ
SCHOOL OF ECONOMIC SCIENCES
ΤΜΗΜΑ ΟΙΚΟΝΟΜΙΚΗΣ ΕΠΙΣΤΗΜΗΣ
DEPARTMENT OF ECONOMICS

**Department of Economics**
**Athens University of Economics and Business**

The Department is the oldest Department of Economics in Greece with a pioneering role in organising postgraduate studies in Economics since 1978. Its priority has always been to bring together highly qualified academics and top quality students. Faculty members specialize in a wide range of topics in economics, with teaching and research experience in world-class universities and publications in top academic journals.

The Department constantly strives to maintain its high level of research and teaching standards. It covers a wide range of economic studies in micro-and macroeconomic analysis, banking and finance, public and monetary economics, international and rural economics, labour economics, industrial organization and strategy, economics of the environment and natural resources, economic history and relevant quantitative tools of mathematics, statistics and econometrics.

Its undergraduate program attracts high quality students who, after successful completion of their studies, have excellent prospects for employment in the private and public sector, including areas such as business, banking, finance and advisory services. Also, graduates of the program have solid foundations in economics and related tools and are regularly admitted to top graduate programs internationally. Three specializations are offered:1. Economic Theory and Policy, 2. Business Economics and Finance and 3. International and European Economics. The postgraduate programs of the Department (M.Sc and Ph.D) are highly regarded and attract a large number of quality candidates every year.

For more information:

https://www.dept.aueb.gr/en/econ/