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Abstract

The paper reviews the economic risks associated with regimes of high public debt through DSGE model simulations. The large public debt build-up following the 2009 global financial and economic crisis acted as a shock absorber for output, while in the recent and more severe COVID19-crisis, an increase in public debt is even more justified given the nature of the crisis. Yet, once the crisis is over and the recovery firmly sets in, keeping debt at high levels over the medium term is a source of vulnerability in itself. Moreover, in the euro area, where monetary policy focuses on the area-wide aggregate, countries with high levels of indebtedness are poorly equipped to withstand future asymmetric shocks. Using three large scale DSGE models, the simulation results suggest that high-debt economies (1) can lose more output in a crisis, (2) may spend more time at the zero-lower bound, (3) are more heavily affected by spillover effects, (4) face a crowding out of private debt in the short and long run, (5) have less scope for counter-cyclical fiscal policy and (6) are adversely affected in terms of potential (long-term) output, with a significant impairment in case of large sovereign risk premia reaction and use of most distortionary type of taxation to finance the additional debt burden in the future. Going forward, reforms at national level, together with currently planned reforms at the EU level, need to be timely implemented to ensure both risk reduction and risk sharing and to enable high debt economies address their vulnerabilities.

Keywords: government debt, interest rates, economic growth, fiscal sustainability.

JEL classification: E62, H63, O40, E43.

Resumen

En este trabajo se analizan los efectos sobre la actividad económica derivados de mantener un nivel elevado de deuda pública por medio de simulaciones realizadas con modelos de equilibrio general dinámico estocástico (DSGE, por sus siglas en inglés). La fuerte acumulación de deuda pública tras la crisis económica y financiera global de 2009 contribuyó a moderar el impacto de la perturbación sobre la actividad. Esta respuesta de política económica está más justificada, si cabe, ante la pandemia de Covid-19, por el marcado carácter transitorio de la perturbación. No obstante, en el medio plazo, una vez se haya superado el impacto inmediato de la pandemia y la recuperación económica esté firmemente asentada, mantener niveles tan elevados de deuda pública puede suponer una fuente de vulnerabilidad para la economía. Esta cuestión es aun más relevante en el caso del área del euro, donde la política monetaria responde al comportamiento de variables agregadas del conjunto del área, de forma que los países con elevados niveles de deuda no cuentan con este instrumento de política para responder a perturbaciones asimétricas. Los resultados de las simulaciones obtenidas a partir de tres modelos DSGE, estimados o calibrados con datos del área del euro, sugieren que las economías con elevada deuda pública: 1) experimentan caídas de la actividad más profundas durante una crisis; 2) pueden pasar más tiempo en la cota inferior de los tipos de interés nominales; 3) muestran efectos *spillover* negativos entre economías más intensos; 4) producen una mayor expulsión de deuda privada en el corto y el largo plazo; 5) presentan una capacidad para realizar una política contracíclica menor, y 6) sufren mayores pérdidas de producto potencial, especialmente cuando la prima de riesgo reacciona significativamente y cuando se financia el coste futuro de la mayor carga de deuda aumentando los impuestos más distorsionadores. De cara al futuro, para facilitar que las economías con elevado nivel de deuda puedan reducir sus vulnerabilidades, resulta necesario implementar reformas estructurales a escala nacional, y que las reformas de la Unión Europea, actualmente en discusión, permitan moderar los riesgos actuales y aumenten el grado de compartición de riesgos entre los miembros de la Unión.

Palabras clave: deuda pública, tipos de interés, crecimiento económico, sostenibilidad fiscal.

Códigos JEL: E62, H63, O40, E43.

Non-technical summary

Debt – public and private – plays an important role in the normal functioning of a market economy. In the private sector, credit is essential to facilitate investment and growth over time. In both the public and private sector, debt can have beneficial effects in terms of smoothing consumption and financing lumpy productive investment. The 2009 global financial and economic crisis left a legacy of historically high levels of public debt in advanced economies, at a scale unseen during modern peace time. Given the extreme severity of the crisis, coined by many as the "great recession", this debt build-up acted as a shock absorber for output. The coronavirus (COVID-19) pandemic is a different type of shock that has dramatically affected global economic activity, including the euro area, since early 2020. Fiscal positions are projected to be strongly hit by the crisis through both automatic stabilisers and discretionary fiscal measures. This substantial support from fiscal policy, together with that of monetary policy, is necessary and should help limit the economic scars of the crisis. Yet, once the crisis is over and the recovery firmly sets in, keeping public debt at high levels over the medium term is a source of vulnerability in itself. A high public debt burden is even more problematic in the euro area, as fiscal policies remain at national level while monetary policy focuses on the aggregate.

The main objective of this paper is to contribute to the stabilisation vs. sustainability debate in the euro area by reviewing through the lens of large scale DSGE models the economic risks associated with regimes of high public debt. The paper argues that a good balance between the two fiscal policy objectives is difficult to achieve when public debt is high. To this end, we first review the theoretical and empirical literature on the role and macroeconomic consequences of public debt. Thereafter, we evaluate the economic consequences of high public debt using simulations with three DSGE models that share the same new-Keynesian framework and feature an enhanced government sector: EAGLE – E(S)CB, GEAR – Bundesbank, and BE – Banco de España.

To our knowledge, this paper is one of the first to systematically assess the macroeconomic implications of high public debt in a global DSGE setup designed for the euro area. By using three different models widely employed for policy simulations in our institutions, we aim at providing a robust and encompassing analysis for the euro area. First, we explicitly account for the heterogeneity within the euro area. The models are calibrated or estimated for different regions/countries, with the euro area being split into either core vs. periphery (for EAGLE and the BE model) or Germany vs. the rest of the EA (for GEAR). Second, and, more crucially, the three models enrich our analysis by bringing alternative perspectives. Hence, the EAGLE model features a more detailed euro area and external block, GEAR includes a sound labour market, while the BE model has a financial block with borrowing constrains and long-term debt. Third, we are able to design a broad range of simulation scenarios, which shed light into various risks associated with regimes of high debt. Hence, we can assess the macroeconomic consequences of an excessive level of debt when the economy is hit by an adverse shock, in normal times or at the zero lower bound (ZLB). In addition, using the BE model, we can examine the specific role played by private deleveraging. Finally, a set of simulations evaluate the long-term costs of a high debt burden.

As indicated in the literature, first, high public debt poses significant economic challenges as it makes the economy less resilient to shocks; second, debt overhangs can exert adverse pressure on the economy through multiple channels over the long-run.

Our DSGE simulations also suggest that high-debt economies (1) can lose more output in a crisis, (2) may spend more time at the zero-lower bound, (3) are more heavily affected by spillover effects, (4) face a crowding out of private debt in the short and long run, (5) have less scope for counter-cyclical fiscal policy and (6) are adversely affected in terms of potential (long-term) output, with a significant impairment in case of large sovereign risk premia reaction and use of most distortionary type of taxation to finance the additional public debt burden in the future. The strength of these results depends on the impact of the level of public debt in these models. Given that the sovereign bond yield spread is the main transmission channel, in the short-run simulations results also depend crucially on the monetary policy implementation.

Going forward, planned reforms at national and EU level to ensure both risk reduction and risk sharing need to be timely implemented to enable high debt economies reduce their vulnerabilities. Once the COVID-19 crisis is over and the economic recovery firmly re-established, further efforts to build fiscal buffers in good times and mitigate fiscal risks over the medium term are needed at the national level. At the EU level, the EU recovery fund currently under negotiation is one important tool that may not only bolster the foundation for sustainable growth in the aftermath of the COVID-crisis, but also support high-debt countries to address their vulnerabilities.

I. Introduction

The 2009 global financial and economic crisis left a legacy of historically high levels of public debt in advanced economies, at a scale unseen during modern peace time. Given the extreme severity of the crisis, coined by many as the “great recession”, this debt build-up acted as a shock absorber for output, through the work of automatic stabilisers, costs incurred in the stabilisation of the financial sector, and fiscal stimulus measures granted at the beginning of the crisis. While debt ratios had generally declined in the euro area countries since that crisis, they still remained at high and very high levels in some countries. The coronavirus (COVID-19) pandemic stroke the global economic activity, including in the euro area, in early 2020, as a more severe and different type of shock. Mainly due to the strict lockdown measures implemented in most euro area countries around mid-March, euro area real GDP registered a record decline of 3.8% in the first quarter of 2020. According to Eurosystem staff’s macroeconomic projections, a further decline in GDP of 13% is expected for the second quarter and what will happen after that is subject to unprecedented uncertainty.[1] Fiscal positions are projected to be strongly hit by the crisis, through both automatic stabilisers and discretionary fiscal measures. This substantial support from fiscal policy, together with that of monetary policy, is necessary and should help limit the economic scars of the crisis.

The general government debt ratio aggregated across euro area (EA) member countries rose from 66% of GDP in 2007 to 95% in 2014, slightly declining afterwards (to 86% by 2019), while total (public and private) debt peaked close to 240% of GDP in 2012 and declined to 223% by end-2018(Chart 1a). Before the COVID-19 crisis hit, two euro area countries had public debt ratios above 120% of GDP at end-2019 (Greece and Italy) and another four countries (Portugal, Belgium, France, Cyprus and Spain) above 90% (Chart 1b). According to the European Commission’s spring 2020 forecast, the euro area debt ratio would increase to 103% of GDP in 2020 and decline to 99% in the next year, while the above mentioned countries will have higher debt ratios, with the largest increases by 2021 projected for Italy and Spain (countries most hard-hit by the pandemic).

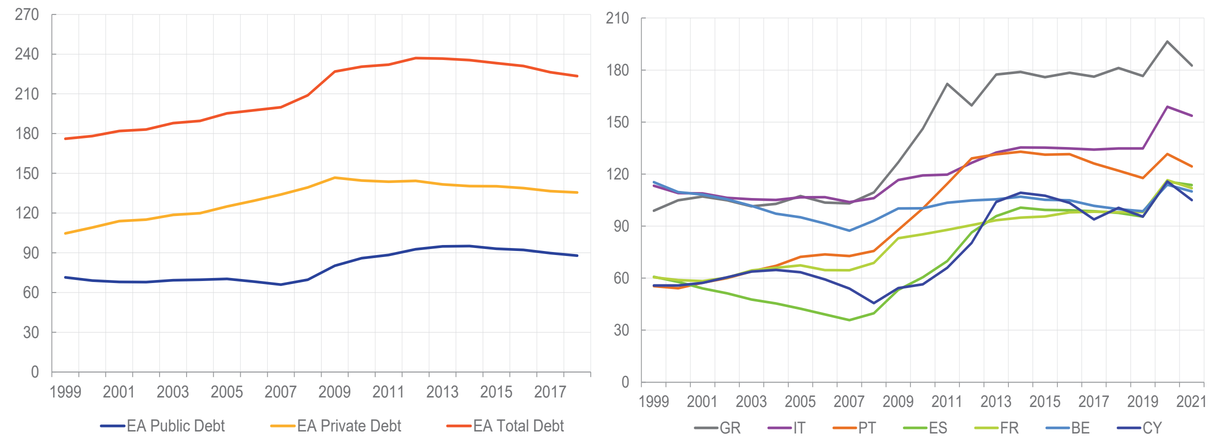
Debt – private and public – is integral to the functioning of a market economy. In the private sector, credit is essential to facilitate productive investment and growth over time. In both the public and private sector, debt can have beneficial effects in terms of smoothing consumption and financing lumpy investment. In most advanced economies, as well as in most macroeconomic models,[2] public debt has been perceived, at least before the 2009 crisis, to be safe (Coeuré 2016). When it carries low credit

[1] See June 2020 Eurosystem staff macroeconomic projections for the euro area.

[2] Assuming a full consolidation between the balance sheet of the central bank and that of the fiscal authority, government debt is considered risk-free in nominal terms. For the euro area, in particular, institutional design like the prohibition of monetary financing and the no bail-out clause (articles 123 and 125 of the EU Treaty) make such models unrealistic.

Chart 1: Public and private debt in the euro area

a) EA aggregate: total, public & private debt (% of GDP) b) The most publicly indebted countries in the EA (% of GDP)



Source: Eurostat, European Commission (Ameco, Spring 2020 forecast) and own calculations.
Notes: Public debt stands for general government gross debt (EDP concept), as defined in the Ameco database. Private debt stands for the stock of liabilities held by the sectors Non-financial corporations and Households and Non-Profit institutions serving households, consolidated data, as per the Macroeconomic Imbalance procedure (MIP) scoreboard for euro area Member States (latest data available for all countries as of end-2018). The EA private debt is calculated as the GDP-weighted average across the Member States. The euro area total debt is calculated as the sum between the EA private debt and public debt.

risk, by providing a relatively safe and liquid asset, also for refinancing operations, public debt plays a vital role for the functioning of the financial system and the transmission of monetary policy. Other contributions conclude that public debt can have positive effects on welfare as long as it provides a safe asset for insurance against both idiosyncratic and aggregate risks.[3]

Yet, when debt is too high, it may become risky for the economy. Essentially, one needs to recognise that government debt even in advanced economies, and especially in those belonging to monetary unions, is not risk free. A high public debt burden is problematic especially in a monetary union like the euro area, in which fiscal policies remain at national level, while member states share a common currency and lack monetary policy autonomy. In this institutional set-up national fiscal policies carry the burden to adjust to asymmetric shocks. However, euro area countries with high levels of public debt are poorly equipped to carry out this stabilisation task. Risks to debt sustainability in a member state can entail risks to the stabilisation of the euro area as a whole.

The main objective of this paper is to contribute to the stabilisation vs. sustainability debate in the euro area[4] by reviewing through the lens of large scale DSGE models the macroeconomic implications of high public debt. The paper argues that a good balance between the two fiscal policy objectives is difficult to achieve when public debt is high.

To our knowledge, this paper is one of the first to systematically assess the macroeconomic implications of high public debt in a global DSGE setup designed for the euro area.[5]

The analysis is based on three different global DSGE models (EAGLE – E(S)CB, GEAR – Bundesbank, and BE - Banco de España) that share the same new-Keynesian framework and feature an enhanced

[3] However, the literature on the relationship between public debt and welfare remains ambiguous, with several studies indicating a negative impact of debt on welfare or optimal debt levels that are either very small or negative (government should accumulate net assets). This is especially the case when welfare (asset holding) is concentrated on a minority of households or when the government seeks to smooth tax distortion over time and thus needs asset buffers to offset adverse shocks. For a review, see Dieppe and Guarda (2015).

[4] See inter alia, ECB (2016b), EC (2016), Bańkowski and Ferdinandusse (2017), IMF (2017). For more details on sustainability, see Boubabdallah et al. (2017).

[5] Andrés et al (2020) assess the role of high debt in a monetary union under an endogenous fiscal limit a la Bi (2012). However, the introduction of this novel feature restricts significantly the number of nominal and real rigidities of the model in comparison to the models used in the current paper.

government sector. By using three different models widely employed for policy simulations in our institutions, we aim at providing a robust and encompassing analysis for the euro area. First, we explicitly account for the heterogeneity within the euro area. The models are calibrated or estimated for different regions/countries, with the euro area being split into either core vs. periphery (for EAGLE and the BE model) or Germany vs. the rest of the EA (for GEAR). Second, and, more crucially, the three models enrich our analysis by bringing alternative perspectives. The EAGLE model features a more detailed euro area (including tradable and non-tradable sectors) and symmetric external block (and as such is very well suited to assess international spillovers), GEAR includes a sound labour market, while the BE model has a financial block with borrowing constrains à la Kiyotaki and Moore (1997) and long-term debt. Third, we are able to design a broad range of simulation scenarios, which shed light into various risks associated with regimes of high debt. Hence, we can assess the macroeconomic consequences of an excessive level of debt when the economy is hit by an adverse shock, in normal times or at the zero lower bound (ZLB). In addition, using the BE model, we can examine the specific role played by private deleveraging. Finally, a set of simulations evaluate the long-term costs of a high debt burden.

The main results of our simulations are the following: (i) A high level of public debt makes the economy more vulnerable to shocks (crises); (ii) High public debt prolongs the time spent at the ZLB; (iii) International spillovers increase the time spent at the ZLB for the high debt economy; (iv) A higher level of public debt crowds-out private debt in the short and long run; (v) High public debt restricts the scope for counter-cyclical fiscal policy; (vi) A high level of public debt affects adversely potential (long-term) output, with a significant impairment in case of large sovereign risk premia reaction and use of most distortionary type of taxation to finance the additional debt burden in the future.

These results show that in the presence of high debt, both the stabilisation and the sustainability objectives of national fiscal policies in the euro area are more difficult to attain in case of a severe idiosyncratic shock. The main explanation relates to the constraint of monetary policy against the backdrop of the euro area institutional design, with the main channel being that of heightened sovereign spreads and uncertainty. These results fit into the broader literature of sovereign vulnerability, according to which higher risk premia and borrowing costs can spill over to other sectors or jurisdictions, especially in integrated economic and monetary unions. Investors may thus more easily question both the sustainability of fiscal policies of a sovereign with high debt burden, particularly when its fiscal track-record and growth prospects are poor, as well as its capacity to effectively implement counter-cyclical fiscal policies and stabilise the economy.

The paper is structured as follows. Section 2 reviews the theoretical and empirical literature on the macroeconomic impact of public debt, with a special focus on the channels through which high debt can ultimately affect growth. Section 3 reports the simulation results and Section 4 concludes.

II. Related literature

The literature on the macroeconomic effects of public debt, in particular the empirical literature, suggests that debt overhangs can exert adverse pressure on the economy through multiple channels.[6]

First, a high debt burden makes the economy more vulnerable to macroeconomic shocks. By restraining the room for counter-cyclical fiscal policy and through spillover effects to the private sector, a public debt overhang can deepen volatility, restrain economic recovery or hurt the economy even in the short-run if aggressive consolidation needs to be implemented in recessions. High government borrowing requirements can make a country more prone to liquidity shocks and defaults. Perceived sovereign vulnerability, reflected in higher risk premia and borrowing costs, can spill over to other sectors or

[6] See also ECB (2016a) for a discussion of risks and vulnerabilities associated with regimes of high debt.

jurisdictions, especially in integrated economic and monetary unions. In particular, the "diabolic loop" between sovereign and bank credit risk through the so-called "balance sheet channel" was considered by many to be the hallmark of the sovereign debt crisis in the periphery of the euro area (Brunnermeier et al., 2016). At the same time, through the country-spillovers channel, the materialisation of risks to sovereign debt sustainability can have adverse implications not only for the country concerned, but also for other members of the monetary union.

Second, and related to the above, the theoretical and empirical literature suggests that high debt burdens can ultimately impede long-term growth.[7] This is particularly the case when debt is contracted to finance unproductive expenses or beyond optimal (growth-maximising) levels of public capital stock (Checherita-Westphal et al., 2014). Moreover, the quality of a country's institutional framework is also likely to affect the relationship between debt and growth, with particularly low growth performance in situations of high debt coupled with poor institutions and conversely, a cushioned impact of high debt in situations of very strong institutions (Masuch et al., 2016). A long string of research tends to conclude that high public debt can adversely affect growth through the channels of sovereign spreads (confidence effects) and sovereign yields,[8] financial intermediation (bank credit),[9] higher future distortionary taxation,[10] future crowding-out of private investment[11] (debt is a deadweight burden on the economy), lower scope for counter-cyclical fiscal policy, including a reduced capacity to finance future public investment,[12] increased uncertainty and catalyser for banking crisis.[13]

The literature also points out that the *level* is not the only relevant dimension in debt-related vulnerabilities. Other characteristics defining its composition, like the maturity structure, financing method and the resulting composition of public debt can also have sizable economic effects.[14] A greater share of short-term debt may make a government more vulnerable during a crisis, because of the need to roll over increased amounts of debt. Moreover, in case a debt crisis mixes elements of illiquidity and insolvency, like the euro area sovereign crisis, the government would be vulnerable to bad news, whose real impact would be amplified by creditors' unwillingness to roll over their claims.

In our paper, we use DSGE model simulations to investigate the two main aspects related to the macroeconomic consequences of high public debt emphasized by the literature: a reduced capacity of high debt economies to withstand shocks and adverse effects on potential (long-term) output. In doing so, we cover topics that belong to various strings of the literature: on sovereign default and nonlinearities between debt and output (Corsetti et al., 2013; Bi and Leeper, 2010), on fiscal multipliers (Coenen et al., 2012), fiscal spillovers (Alloza et al., 2019a, 2019b; Attinasi et al., 2017; Auerbach and Gorodnichenko, 2012), or on the interaction between fiscal and monetary policy, in particular when

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[7] Several empirical studies (spanning all major institutions) find a negative, mostly nonlinear, impact of public debt on growth. Woo and Kumar (2015) find evidence of nonlinearity with higher levels of initial debt (above 90% of GDP) having more significantly negative effects on subsequent growth. For the euro area sample before the crisis, Checherita and Rother (2012) find an inverted U-shape relationship between public debt and growth with a median debt threshold endogenously determined at 90-100% of GDP. Subsequent research for the euro area (Baum et al., 2012) investigates the short-run impact of public debt on GDP growth for a more recent period (1990-2010).The authors find a positive and highly statistically significant effect, which decreases however to around zero and loses significance beyond public debt-to-GDP ratios of around 67%. For high debt-to-GDP ratios (above 95%), additional debt is found to have a negative impact on economic activity. Similar debt thresholds are found in the literature on early signals of sovereign distress. For instance, the current debt sustainability analysis framework of the IMF (in place since 2013) adopts a debt ratio of 85% of GDP to flag fiscal risks in advanced economies along this dimension.

[8] See Codogno et al. (2003), Attinasi et al (2010) and Corsetti et al. (2013) for the effect on spreads and Laubach (2009), Baum et al. (2012) for the effect on long-term sovereign interest rates.

[9] See De Bonis and Stacchini (2013) for the impact on bank credit and Jorda et al. (2016) for the effects in the aftermath of crises. The latter paper explores a historical database on public- and private-sector debt build-ups for advanced countries for the period 1870–2011 and finds that although high public debt build-ups are not correlated with a greater likelihood of financial crisis, a high level of public debt does tend to exacerbate the negative effects of post-crisis financial sector deleveraging.

[10] In line with Barro (1979). This can, in turn, affect precautionary savings and consumption today.

[11] Woo and Kumar (2015), Ostry et al. (2015).

[12] Chalk and Tanzi (2004), Checherita and Rother (2012).

[13] See Hemming et al. (2013); Brunnermeier et al. (2016).

[14] See, for example, Bacchiocchi and Missale (2005), Faraglia et al. (2008), or Hatchondo and Martínez (2013).

nominal interest rates are constrained by an effective lower bound (Bouakeza, et al., 2017; Bletzinger and Lalik, 2017; Arce et al., 2016; Hills and Nakata, 2014). Compared with these papers, ours assesses more systematically the macroeconomic implications of high public debt in a global DSGE setup with three different models designed for the euro area.

We are not covering aspects related to optimal fiscal policy, role of institutions, including changes in euro area institutional design or other debt-related vulnerabilities, such as detailed structure of debt or financial-sovereign interactions. For instance, Smets and Trabandt (2012) examine the implications of high government debt for optimal monetary policy in response to a large recessionary shock at the zero lower bound (ZLB). They show that under optimal policy, the central bank reduces the risk premium on government debt to stabilise the economy. On the role of debt management, also in an optimal policy framework, Cantore et al. (2017) show that the speed of debt consolidation is fast only if the government lacks commitment or if the initial public debt-overhang is very high and the government cannot access official bailout schemes curbing risk premia.[15] As we are using our standard (large-scale) policy models with a very detailed fiscal block and various types of economic agents (Ricardian and non-Ricardian in EAGLE and GEAR, patient and impatient in the BE), any optimal fiscal policy computation or sound welfare analysis cannot be implemented in a straight-forward manner. For obvious computational reasons, such analyses would require a more simplistic model setup.

III. Model simulation results

This section discusses macroeconomic implications of the public debt level in a general equilibrium framework using three global models: EAGLE (ESCB), GEAR (Bundesbank) and the BE model (Banco de España). These models share the same new-Keynesian framework, but have specific features (very detailed international trade linkages, enhanced labour market and private borrowing, respectively), which will be exploited to enrich our set of simulations. The EAGLE model is calibrated for the euro area to periphery (Greece, Italy, Portugal and Spain) vs. core (the rest of the euro area), the rest of the world and the US. BE is a closed monetary union with two countries or regions: the periphery and the core, while GEAR is estimated on German data. See the Appendix for an overview of the main features in the three models.

On the fiscal side, all models feature an enhanced government sector. In the EAGLE and BE models labour income taxation (τ_t^L, in deviation from its steady-state $\bar{\tau}^L$) is assumed to be the main fiscal instrument. It reacts to deviations of the debt-to-GDP ratio (B_t) from target (B^*) with sensitivity (ζ_B) around 0.05 and to the output gap (the last term of equation (1), where Y_t and Y^* represent output and potential output respectively) with sensitivity (ζ_Y) around 0.05. The autoregressive term (ρ) is around 0.8. On the other hand, in the GEAR model all fiscal instruments are active according to the estimated parameters (see Gadatsch et al, 2016). [16] In a more formal way, in the EAGLE and the BE model:

$$\tau_t^L - \bar{\tau}^L = \rho(\tau_{t-1}^L - \bar{\tau}^L) + \zeta_B(B_t/B^* - 1) + \zeta_Y(Y_t/Y^* - 1) \qquad (eq. 1)$$

While in the case of the GEAR mode, for public revenue (considering a generic tax τ_t^x in deviation from its steady state $\bar{\tau}^x$):

$$\log(\tau_t^x/\bar{\tau}^x) = \rho \ \log(\tau_{t-1}^x/\bar{\tau}^x) + \zeta_B^x \ \log(B_t/B^*) + \zeta_Y^x \ \log(Y_t/Y^*) \qquad (eq. 2)$$

[15] Regarding fiscal consolidation strategies, see Kilponen et al. (2015), which provide a comprehensive cross-country comparison using various policy models.

[16] These include labour income, consumption, capital gains and lump-sum taxation on the revenue side, as well as government purchases, public investment and transfers to households on the expenditure side.

and for public spending (considering a generic expenditure X_t in deviation from its steady-state value $\bar{X}$):

$$X_t - \bar{X} = \rho(X_{t-1} - \bar{X}) + \zeta_B^X \log(B_t/B^*) + \zeta_Y^X \log(Y_t/Y^*) \qquad (eq. 3)$$

The introduction of a sovereign risk premium in DSGE models is needed to get a significant impact of the debt level. In standard DSGE models, like the ones currently used for policy simulations, the initial level of debt does not significantly affect the size of multipliers (i.e., output is broadly unaffected by the debt level in case of a shock bringing the economy away from its steady-state). Yet, as pointed out in the literature review (and in various empirical studies used in model calibrations), there is strong evidence that important nonlinearities are at play between debt and output. To capture such effects, we follow Corsetti et al. (2013) and allow for sovereign default as a consequence of government's inability to raise the funds necessary to honour its debt obligations. Consequently, the sovereign risk premium responds to changes in the fiscal outlook of the country and the probability of sovereign default is closely and non-linearly linked to the level of public debt. More specifically, sovereign default is associated with the notion of a fiscal limit in a manner similar to Corsetti et al. (2013) and Bi and Leeper (2010) - whenever the debt level rises above the fiscal limit, a default will occur. The fiscal limit is determined by a stochastic process capturing the uncertainty that surrounds the political process in the context of sovereign default. Specifically, we assume that in each period the limit will be drawn from a specific distribution. Beyond this limit, the probability of default is certain.[17] From a theoretical perspective, the fiscal limit depends on the economy's Laffer curve, which arises from distortionary taxes and constrains the government's ability to service its debt. If the tax rate is on the "slippery" side of the Laffer curve, then the government is unable to raise more tax revenue through higher tax rates (see Trabandt and Uhlig, 2011 and Bi, 2012).

To be more formal (see equation (4)), we assume that there is a positive probability of default that depends on how far away is the actual debt-to-GDP ratio of a country, B_t, from its debt limit, $\bar{B}$. In case the debt-to-GDP ratio hits the debt limit, the country will default with probability one, and the debtor will face a haircut of around 30% (1-χ), thus retrieving only 70% (χ) of full repayment. Following Corsetti et al (2013) and Batini et al (2018), the default probability δ_t is described by a two-parameter distribution function (F):

$$\delta_t = F\left({}^{B_t}/_{\bar{B}}, \alpha_1, \alpha_2\right) \qquad (eq. 4)$$

where α_1 and α_2 determine the slope of the default probability. The more the debt-to-GDP ratio approaches the debt limit, the faster the default probability will rise after an additional increase in public debt. See Table 1 for the distributions assumed in each model, while Chart 2 shows how the probability of sovereign default increases with the government debt to GDP ratio across selected models.[18]

Hence, the Euler equation of a household investing in public debt that has a pre-determined gross interest rate of R_t has to be modified to:

$$\lambda_t = \beta \mathbb{E}_t \left[\frac{R_t}{\pi_{t+1}} \lambda_{t+1}\big(1 - \delta_{t+1}(1 - \chi)\big)\right] \qquad (eq. 5)$$

---

[17] Following Laubach (2009), Attinasi et al (2017) adopt an alternative approach. The public debt risk premium in the euro area countries is assumed to consist of a transitory and a permanent component. The transitory component is country-specific and captures the impact of growth in actual domestic government debt-to-GDP ratio. The permanent component is common to all the members of the monetary union and captures the impact of a level change of the area-wide government debt-to-GDP ratio with respect to the initial level.

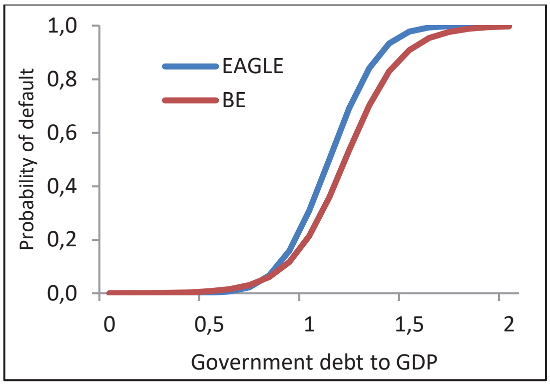
[18] In the case of EAGLE we assume a normal distribution (like Darracq et al. (2016)), in the case of GEAR a beta distribution (like Corsetti et al. (2013)), and in the case of the BE model a logistic distribution (like Bi and Traum (2012)). Parameters determining slope and curvature of the distribution function are calibrated to be in line with Corsetti et al. (2013).

Table 1: Distribution function of default probability

	F	α1	α2	Haircut
EAGLE	Normal	0.4	0.2	37%
GEAR	Beta	3.7	0.54	50%
BE	Logistic	-8.5527	1.8261	30%

Source of the calibration: for EAGLE: Darracq et al. (2016); GEAR: Corsetti et al (2013) and for BE: Batini et al (2018).

Chart 2: Cumulative density function of default probability according to debt level



where λ_t is the household's marginal utility of consumption, π_{t+1} determines (expected) CPI inflation and β beta is the discount factor. It is clear that the interest rate households demand for investing in public debt increases with the default probability. Interest payments in the government budget constraint, hence, must be adjusted accordingly.

Changes in the sovereign risk premium are assumed to affect the cost of financing not only for the government, but in the EAGLE and GEAR models also for the private sector. In the former (public debt channel), the government has to finance higher interest payments and thus to increase distortions in the economy via higher taxes. In the latter (private investment channel), the sovereign risk spills to the private sector. Instead of including a fully- fledged financial sector with explicit lenders and borrowers as in Corsetti (2013), these models assume financial frictions in the private sector, which depend on tensions in the public sector. This is achieved by making the costs of private investment financing in the Tobin's Q an increasing function of the default probability of the public sector. This way, private sector capital investment becomes riskier whenever government default becomes more likely. A rationale for this assumption would be that more projects in the private sector face uncertainty and financing problems and are, therefore, also subject to default. See the flow chart 3 below for a schematic representation of the role of public debt in the short-run transmission channels of shocks, including the above-described effects.[19]

Formally (equation (6)), this is done by modifying the model equations determining the rate of return of physical capital investments. It now holds that

$$R_t^k = \pi_t \left[Q_t(1-\delta^k) + (1-\tau_t^k)\big(1-\varpi\delta_t(1-\chi)\big) + \tau_t^k\delta_t^k \right] / Q_{t-1} - 1 \qquad (eq\ 6)$$

which is, in principle, the standard equation determining the return on private capital investment, R^k_t, in presence of investment adjustment costs, where Q_t is Tobin's Q, δ^k is capital depreciation, τ^k_t the tax rate on capital returns (which implies that capital depreciations are tax exempt) and π_t is CPI inflation.

What is non-standard in this equation is the term $(1-\varpi\delta_t(1-\chi))$. It states that the default probability of the public sector spills over fully to the default probability in the private sector whenever the parameter $\varpi = 1$. This implies that, when the likelihood of a public default increases, this transmits equally to the private sector, and households demand a higher interest rate on private capital investments to be compensated for the (higher) expected potential losses. Below, we also show results of a simulation in which $\varpi < 1$, assuming that

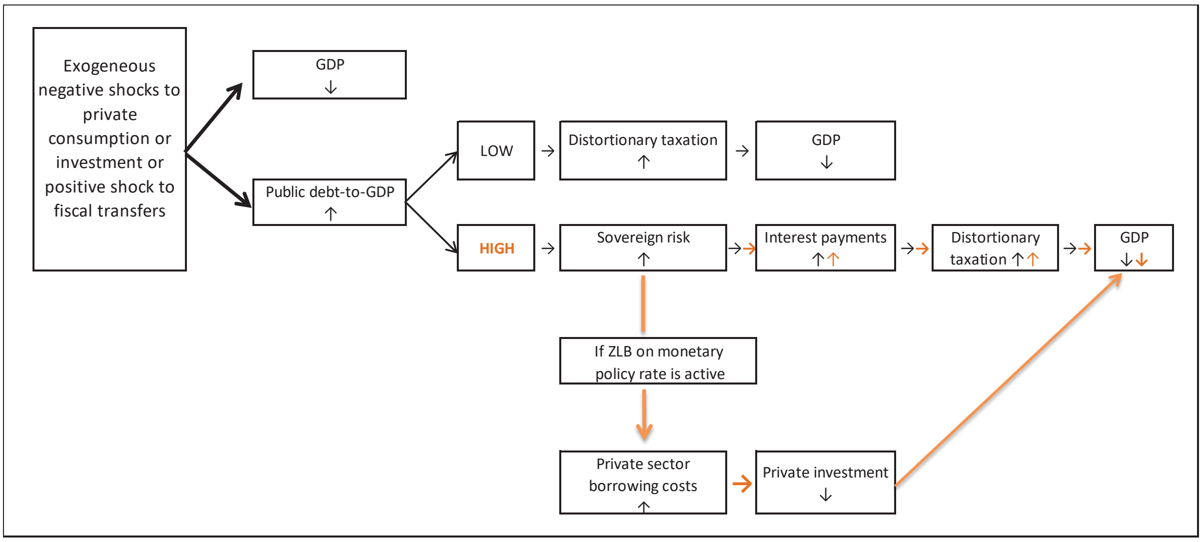
[19] The spill-over of sovereign risk to the firms financing costs has been calibrated in line with Corsetti et al. (2013). Furthermore, Table 1 shows a sensitivity analysis to the degree of spill-overs to the private sector (none, half, full).

default risk in the public sector does not spill over fully to the private sector. This modelling choice can be viewed as a short-cut to modelling a financial sector as in Corsetti et al (2013), where the effects are qualitatively analogous.

The model simulations in this section aim at investigating two broad categories of effects of high debt regimes: (1) short-run effects capturing the resilience of the economy to shocks; (2) long-run effects on output and growth.

Overall, four simulation scenarios are implemented: three on the short run and one on the long run. To assess the impact of the level of public debt on the resilience of the domestic economy in a period of recession with a monetary policy constrained by the ZLB, three sets of simulations are implemented. They have been designed to answer the following questions: (i) What would be the short-term cost in terms of output losses of a very high level of debt (scenario 1)? (ii) What would be the consequence of adverse shocks when the economy is in a liquidity trap (scenario 2)? (iii) What would be the role played by private deleveraging (scenario 3)? In addition, scenario 4 aims at answering the question: (iv) What would be the long-term cost of a high debt burden?

Chart 3: The role of public debt in the short-run transmission channels of shocks



Source: own representation

III.1 Short-run simulations testing the resilience of the economy to shocks in regimes of high debt

The following simulation set-up is used to generate results in this section.

Regimes of debt and types of shock: From a practical modelling perspective, each scenario is computed for low and high-very high levels of debt.[20] In each case, the economy starts at the steady state but with a different initial level of debt.[21] We then shock consumption and/or investment in the private sector to bring the economy into a deep recession. These shocks to demand ensure that both inflation and output decrease, a reflection of the economic developments following the financial crisis. In the model, the shocks are implemented on the discount rate on consumers' preferences and, respectively, on the

[20] The thresholds for the debt-to-GDP ratios are implemented as follows: Low debt: 60% of GDP in EAGLE and GEAR and 25% in the BE model; High/very high debt: 120% in EAGLE, 90% in GEAR and 75% in BE.

[21] Contrary to part of the theoretical literature, standard (large size) DSGE models do not allow multiple regimes with a transition probability of moving from one regime to another. For an example of such models, see Bi and Leeper (2013) applied to questions of fiscal sustainability for Greece and Sweden.

Tobin's Q. In addition to these two real shocks, we implement a compensatory fiscal shock (stimulus) in the form of an increase in public transfers.

Monetary policy: As previously mentioned, in our models, when monetary policy is unconstrained (normal times) it can compensate most of the adverse impact on the (currency area) economy stemming from tensions on sovereign spreads. In this case, simulations show that the additional adverse impact of the shock in regimes of high debt is rather limited. Yet, one salient feature of the crisis is the lower bound on interest rates faced by the monetary authority (scenario of ZLB). However, the constraint on the monetary policy rate can be implemented in DSGE models in different ways, possibly with different policy implications. To account for this, two different scenarios are shown.

In scenario 1, it is assumed that economic agents fully expect that interest rates will be fixed for a given period of two years (the pre-announced or "forward guidance" scenario). In normal times (equation (7)), the Taylor rule is written as follows:

$$R_t = \phi\, R_{t-1} + (1-\phi)\,[\,\overline{R} + \phi_\pi(\pi_t - \pi^*)\,] + \phi_Y\left(\frac{Y_t}{Y_{t-1}} - 1\right) \qquad (eq.7)$$

When the forward guidance applies (equation8)), the extra dummy variable $\mathbb{I}_{FG}$ controls for the duration of fixed nominal interests:

$$R_t = (1-\mathbb{I}_{FG})\left[\phi\, R_{t-1} + (1-\phi)\,[\,\overline{R} + \phi_\pi(\pi_t - \pi^*)\,] + \phi_Y\left(\frac{Y_t}{Y_{t-1}} - 1\right)\right] + \mathbb{I}_{FG}\,\overline{R} \qquad (eq.8)$$

In scenario 2, the length of the ZLB depends on the shocks and is endogenously computed in the model according to the values of output growth and inflation (variables entering the Taylor rule followed by the monetary authority). The ZLB constraint is implemented in the following way (where R_L is the zero lower bound):

$$R_t = \max(R_L, R_t^*) \qquad (eq.9)$$

with

$$R_t^* = \phi\, R_{t-1}^* + (1-\phi)\,[\,\overline{R} + \phi_\pi(\pi_t - \pi^*)\,] + \phi_Y\left(\frac{Y_t}{Y_{t-1}} - 1\right) \qquad (eq.10)$$

In this latter case, the shocks need to bring the economies to the ZLB have to be large enough and global, while in scenario 1 a local shock is sufficient. As regards the simulation period we focus on the shorter term since: (i) the exit from the liquidity trap and the implementation of non-standard policy measures are out of the scope of our analysis, and (ii) our (large otherwise) models do not have all the required features in this respect, such as long-term bonds.[22]

Further sensitivity analysis: The three short-term scenarios presented below are accompanied by sensitivity analyses to assess the robustness of our results to the uncertainty on some key parameters, alternative policy rules or alternative economic environments.

Since the main results of the short-run simulations are qualitatively similar across the three models, we adopt a parsimonious approach and report only the exercises using the EAGLE model, except for scenario 3 where the BE model is used to show the role of private indebtedness.[23]

[22] As mentioned, for alternative models, see Smets and Trabandt (2012) and Cantore et al. (2017).

[23] Baseline simulations with the GEAR model are available upon request.

Scenario 1: Domestic shocks and forward guidance

The objective of this scenario, presented with EAGLE, is to assess the short-term cost in terms of output losses of a very high level of debt. In order to achieve this, two types of shocks to the periphery economy are considered sequentially, each of them lasting one year. The shock to private consumption calibrated to trigger a decrease of GDP of about 6% is implemented to mimic the conditions prevalent during the great recession (implying a 2 percentage point decrease in the consumption share).[24] While the shock to private investment calibrated to trigger a 1% extra GDP loss is considered to replicate the current low investment environment (the investment share decreases by 5 percentage point). During a 2-year period, the nominal interest rate is (exogenously) fixed (as explained above). In addition, we perform several exercises to show the robustness of the results to alternative assumptions.

The results confirm that a higher level of debt makes the periphery economy more vulnerable to shocks.

The impact of an adverse shock on consumption. See Chart 4.a. The green bars show the impact in the periphery of the shock when the debt-to-GDP level is low (60%). In this case, as there are no tensions on sovereign spreads, the spillovers to the private sector are muted. The risk premium channel does not play a significant role. On the contrary, a significant output loss occurs when the debt-to-GDP ratio is high (surpasses 120%, red bars), that is, by around 15% more compared to the initial situation (green bars).[25] The economy is clearly worse off. After an adverse consumption preference shock, households increase their savings which are thus reallocated towards private investment. At the same time, the government needs to increase taxes to finance higher interest payments. Against this background, inflation is pushed further down. As monetary policy cannot be accommodative, real interest rates are slightly higher, which hurts the economy.

The private investment channel deteriorates further the economic activity. See Chart 4.a (dark red bar). The private investment channel takes into account the corporate risk shock, due to the link between the sovereign spread and the cost of financial intermediation. In the absence of tensions (when debt is low), financial markets are not affected and the economy is immunised against this extra source of uncertainty. When the level of debt is high (in periphery), the associated increase in the sovereign risk premium is transmitted to the cost of financing in the economy making investment more vulnerable. In this case, there is an additional drop in private investment, which produces a more significant negative impact on GDP (the extra GDP loss is around 60% compared to the low debt case, green bars) and deteriorates even further the debt-to-GDP ratio. Subsequently, the higher sovereign spreads are translated into higher costs of financing and larger financial uncertainty.

Benefits from higher transfers are largely compensated by the adverse impact of high debt level. See chart 4.b. This last additional shock evaluates the implications in terms of GDP of an increase in lump-sum transfers by 1 percent of nominal GDP aimed at mitigating the adverse impact of the recession on private consumption.[26] Despite the fact that the public transfers mitigate the depth of the recession, the GDP loss in regimes of high debt (red bar), is now about 30% larger than in regimes of low debt. This is due to the fact that the positive gains induced by transfers are more than compensated by the greater burden of debt or, equivalently, that a high debt restricts the scope for counter-cyclical fiscal policy (see also the last simulation of this section).

A prolonged period of constrained monetary policy is more detrimental for a high debt economy. See Chart 4.c. The implementation and the agents' perception of monetary policy are crucial to explain the

[24] For sake of comparison, Gerali et al. (2015) running the same type of exercise for Italy, have generated a 8% drop in GDP after 3 years.

[25] The size of the loss depends obviously on the size of shock and by how much the debt ratio is impacted by the shock.

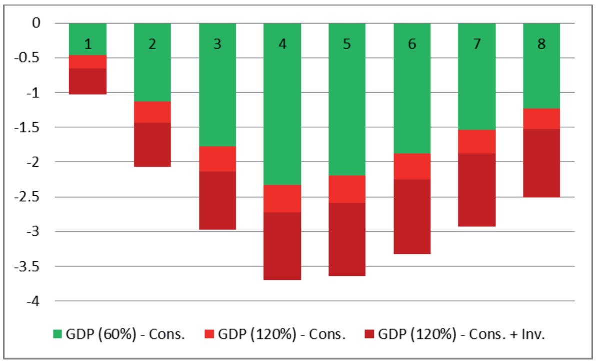
[26] In terms of distributional effects, transfers are targeted to be more favourable to non-Ricardian households (in a proportion of one to three) in line with Coenen et al. (2008).

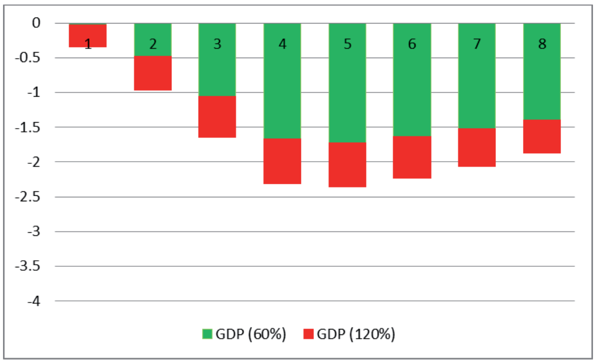
Chart 4: Resilience of the periphery economy to shocks in regimes of high debt: impact on GDP

a) Private consumption shock (benchmark) and investment shock

b) Private consumption shock and compensatory public transfer shock

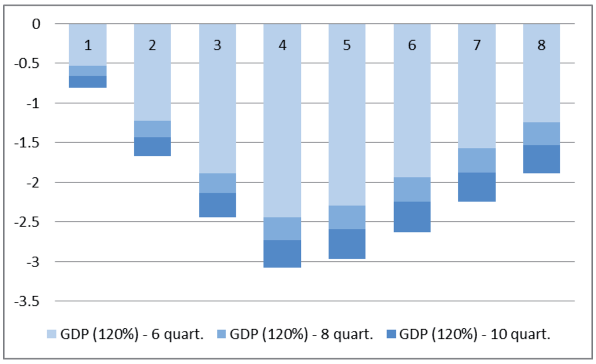
(GDP: % deviation from steady state; Debt ratio: pp deviation from steady state; X-axis: number of quarters)

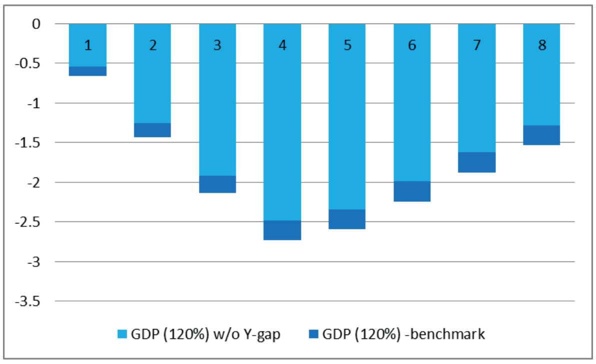




c) Role of monetary policy: length of fixed interest rate period

d) Fiscal policy objective: priority to sustainability in regime of high debt





Source: Authors' calculations
Notes: All panels show impact on GDP (level of debt-to-GDP ratio in parenthesis). The lower panels show sensitivity analysis around the benchmark (private consumption shock) only for regimes of high debt as follows: panel c) - impact of the length of the period monetary policy is constrained and panel d) impact of the fiscal policy rule (switching off the parameter associated with output gap in the fiscal policy rule , see GDP (120%) w/o Y-gap, vs. the benchmark of a standard rule in which fiscal instruments are reacting to both debt stabilisation (sustainability) and output stabilisation.

short-term reaction of the economy to shocks at the ZLB. This question is related to the debate on the size of multipliers in times of crisis (see ECB, 2014, and Kilponen et al., 2015). More specifically, the duration of the fixed interest rate period affects significantly the behaviour of economic agents. In case of large adverse shocks, a longer period of constrained interest rates will further deteriorate the growth prospect. In our benchmark simulations (private consumption shock), we make the assumption that interest rates cannot move for 8 quarters. Against this background,[27] we consider alternative periods of 6 (lighter blue bar) and 10 quarters (darker blue bar) all in regimes of high debt. Chart 4.c highlights two aspects. First, our simulations seem robust to changes in the duration of the ZLB as losses in regimes of high debt remain large. Second, the length of the period during which monetary policy is constrained has an asymmetric impact, reflecting the nonlinearities of the model (implied by the sovereign risk channels). When interest rates are fixed for 6 quarters, the GDP loss compared to the benchmark

[27] As used also in de Jong et al. (2017).

simulation (8 quarters) is 0.25 percentage points lower. When interest rates are fixed for 10 quarters, the extra loss is around 0.35 pp.

A high debt burden reduces the scope for counter-cyclical fiscal policy. See Chart 4.d. In our benchmark simulations fiscal instruments react to both the debt-to-GDP ratio (debt stabilisation, an important component of fiscal sustainability)[28] and output gap (fiscal stabilisation objective). As documented in the Appendix, this benchmark specification is quite standard. In practice, fiscal policy is often used to smooth fluctuations in economic activity, particularly in advanced economies. At the same time, in periods of severe recession, letting automatic stabilisers to operate fully can be counter-productive for a high debt economy under market pressure. Delaying the debt reduction increases the burden of interest payments for the government. In the case of our model, the gain of privileging a debt reduction strategy in regimes of high debt can be assessed by annulling the parameter associated to the output gap in the fiscal rule (lighter blue bar). As shown in Chart 4.d, GDP will decrease on average by 0.25 percentage points less than in the benchmark scenario, confirming the idea that in case of high vulnerability, the consolidation needs to be faster. This scenario suggests, in line with the results shown in Chart 4.b, that a high debt burden constrains the scope for counter-cyclical fiscal policy.

In these policy simulations, the fiscal authority uses the labour income tax (LIT) to stabilize the debt ratio. Alternatively, we could stabilize debt using the VAT tax. Taking the consumption shock as a benchmark, simulations suggest that increasing VAT instead of LIT does not help to mitigate the recessionary impact of the crisis on economic activity. The VAT hike depresses more private consumption bringing HICP further down. In turn, real interest rates are higher, implying a greater loss of GDP. Nevertheless, when the ZLB period is over, the recovery is faster.

Finally, the results of this benchmark scenario are consistent in qualitative terms across the three models considered as also shown in scenario 3 for the BE model.[29] This brings forward two remarks. First, when the level of debt is high, the resilience of the economy to shocks is lower and the scope for counter-cyclical fiscal policy is limited. Second, as already shown in the literature, when the monetary policy is constrained, the size of multipliers is larger.

Scenario 2: Time spent at the ZLB and spillovers

Given the crucial role played by monetary policy in crisis times shown in the previous scenario, we consider now an alternative scenario in which the monetary policy rate is constrained because the recession endogenously reduces the rate below zero. In particular, we assume that the monetary authorities follow a Taylor rule in normal times, i.e. when it delivers a non-negative interest rate, otherwise, the nominal interest rate equals zero.[30] A succession of large unexpected shocks on domestic demand, brings the economy to the ZLB and into the liquidity trap (see Gomes et al., 2015).[31] In practice, the recession is assumed to be worldwide and therefore, shocks hit simultaneously consumption and investment of each block of the model so that the interest rate is at the lower bound for around two years. Agents correctly forecast the impact of each shock as they hit the economy, but are unaware of future shocks.[32]

[28] A comprehensive debt sustainability (DSA) framework should generally consider both debt dynamics (stabilisation) and the level at which debt stabilises, test the resilience of the debt path under various adverse scenarios and account for other relevant indicators. See in this respect Bouabdallah et al. (2017).

[29] To save space, GEAR results are available from the authors upon request.

[30] Technically, we replace the Taylor rule by a function that returns the maximum of the Taylor rule itself or zero.

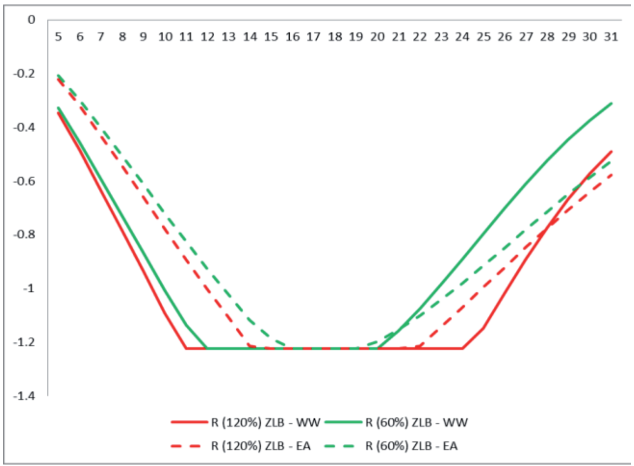
[31] The alternative of having single-period shocks driving the entire episode was rejected because of the sheer size of the shock needed and the extreme reaction of the model, accompanied by numerical problems (see Gomes et al. (2015)).

[32] Alternatively, one could think that the recession and the ZLB were driven by a sequence of shocks affecting agents' confidence, such as bad news regarding the financial health of the banking sector. This behaviour could be simulated in the model as a gradual erosion of consumers and firms' confidence. Nevertheless, the results would be qualitatively similar to scenario 2.

Chart 5

Resilience of the economy to shocks in regimes of high debt –Time spent at the ZLB and spillovers

(Nominal interest rate expressed in pp deviation from steady state; X-axis: number of quarters)



Source: Own calculations. Notes: WW stands for a scenario of worldwide shocks assumed to affect the economy. EA stands for domestic (euro area) shocks.

Chart 5 (solid lines) shows that an economy exposed to a higher level of debt and hit by world-wide (whole EA, the US and rest of the world, WW) shocks will be more vulnerable at the ZLB. The burden of a higher cost of financing and its adverse impact on domestic demand will prolong the time spent in the liquidity trap. At the same time, the more vulnerable economy will enter faster the ZLB. Compared to the low debt case, the high debt economy will stay one year longer at the ZLB. Since the recessionary shock is so severe that the ZLB is binding, higher spreads are translated into higher real interest rates. Consequently, private expenditure and output are falling more when the level of debt is higher. Such results are consistent with Corsetti et al. (2013). A similar result is obtained when instead, the external shocks are limited to the EA, that is, originated in each of the members that form the monetary union (dotted lines). By comparing the world-wide (WW) crisis scenario and the EA-wide scenario, we can assess the importance of international spillovers. Indeed, the globalisation of the crisis is more costly for the economy with a debt problem, making it stay longer (5 quarters more) at the ZLB (compare the differences between the solid and dotted lines in the red versus the green scenario in chart 5).

Scenario 3: The role of private indebtedness

In order to assess the role played by private deleveraging in a high-debt scenario, we repeat the previous exercise with the BE model that includes borrowing constrains in the private sector and long-term private debt. In particular, we would expect a higher level of public debt to exacerbate private sector constraints through the crowding out of private debt.[33]

In addition to the equation explained above determining the sovereign risk premium, the other expressions relevant in the BE model for the impact of high public debt are the borrowing constraints faced by a proportion of households and entrepreneurs and the evolution of agents long term private debt. [34] Constraint private agents can only borrow up to their collateral which is a proportion m_t (the loan-to-value ratio, assumed to be exogenously time-varying) of the expected discounted value of the household's housing stock $(p^h_{t+1}h_t)$

$$b^h_t \leq m_t E_t \frac{p^h_{t+1}h_t}{R_t/\pi_{t+1}} \qquad (eq.11)$$

Therefore, a high level of public debt worsens the private agents borrowing constraints through its effects on the value of the housing stock.

Secondly, debt contracts in the BE model are long-term and require an annual repayment equal to $\gamma \frac{b^h_{t-1}}{\pi_t}$. This imposes a lower bound to private debt, since when the collateral value falls below this value, agents

[33] See Andrés et al (2017) for a detailed description of how private borrowing and deleveraging is introduced in a closed economy version of the model and Arce et al (2016) for the two-region euro area version of the model. Finally, for a detailed description of the public sector in the model see Andrés et al. (2020).

[34] The complexities related to adding private long-term to the BE model reduce significantly the available parameter space, limiting the maximum public debt that can be reached to 75% of GDP.

just repay their debt. As a consequence the borrowing constraint of agents is double and asymmetric, so that the collateral value only determines borrowing when it is greater than the annual debt repayment, while when it falls below agents still repay their debt:

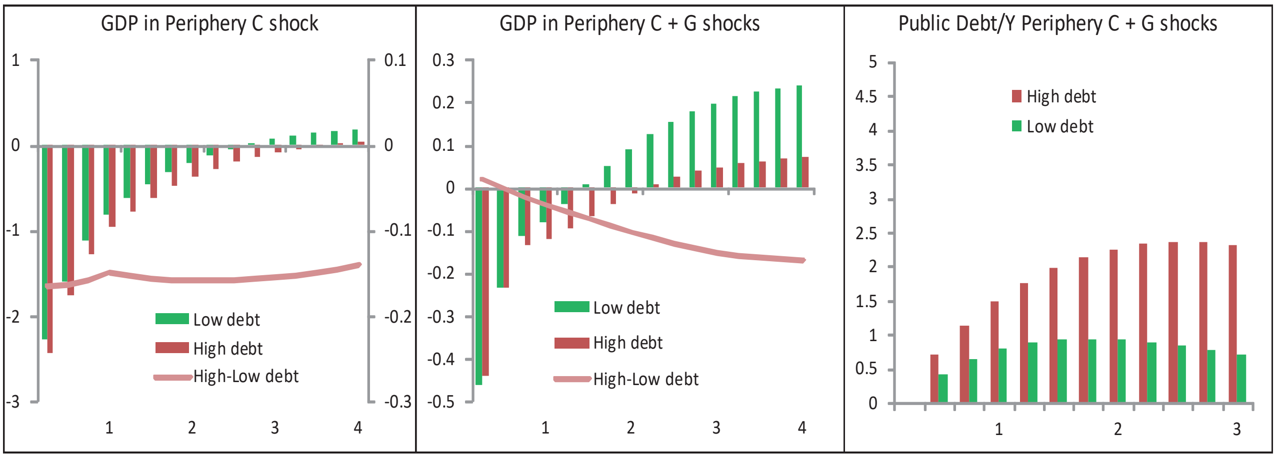
$$b_t^h \le \begin{cases} E_t \dfrac{m_t}{R_t/\pi_{t+1}} p_{t+1}^h h_t & if \;\; E_t \dfrac{m_t}{R_t/\pi_{t+1}} p_{t+1}^h h_t \ge \gamma \dfrac{b_{t-1}^h}{\pi_t} \\ \gamma \dfrac{b_{t-1}^h}{\pi_t} & if \;\; E_t \dfrac{m_t}{R_t/\pi_{t+1}} p_{t+1}^h h_t < \gamma \dfrac{b_{t-1}^h}{\pi_t} \end{cases} \qquad (eq.12)$$

Therefore, long-term debt acts as a buffer in the economy limiting the fall in private credit but at the same time it lengthens the duration of the deleveraging process.

In this case the scenario consists of a large and persistent demand shock (concentrated in private consumption) in the first quarter to bring the economy to the zero lower bound. In addition, we implement a fiscal expansion (increase in government consumption, G), which increases public debt by around 3%.[35] In the left hand side and centre panels of Chart 6, the green bars represent the dynamics of GDP for the periphery (calibrated to Spain) under the low debt steady state calibration, while the red bars capture the effects for the high debt calibration. The line represents the difference between the periphery's GDP under the high and low debt regimes. In the right hand side chart, the bars represent the dynamics of the debt-to-GDP ratio in the periphery under high (red) and low debt (green) steady state calibrations.

Chart 6: Resilience of the economy to shocks in regimes of high debt (BE model) - Rise in public and private indebtedness

(GDP: percentage deviation from steady-state; public debt-to-GDP ratio: percentage point deviation from steady state; X-axis: number of years)



Source: Authors' calculations.
Notes: C shock denotes a negative private consumption shock. G shock denotes a positive government consumption shock.

The scenario shows first that, as in previous exercises, an economy with high debt is less resilient to a demand-based recession (see left hand side chart). The impact of the fall in demand is worsened when public debt is higher because constrained agents (households and entrepreneurs) are even more constrained. First, the value of their collateral, price of housing (p_{t+1}^h), has diminished due to the deeper recession. Second, the higher lump-sum taxes needed to finance the extra public debt reduce the private agents' disposable income and limit their investment in new collateral (housing, h_t). Finally, it prolongs the duration of the ZLB, so that real rates are higher than otherwise (R_t/π_{t+1}), reducing the discounted value of the collateral. That is, the higher public debt exacerbates private sector constraints and crowds out private debt.

35 In BE model high public debt is 75% of GDP and low debt is 25% of GDP.

When there is in addition a fiscal expansion (middle chart), the difference in the output response in regimes of high versus low debt is smaller in the short run (and might even be positive on impact), while it converges to a similar effect in the middle run (three years). The explanation lies in the fact that when public debt is high fiscal policy is more effective on the short run (at least on impact) as it provides additional income to the constrained agents. However, as the high debt economy accumulates even more public debt, the increase in the risk premium and the crowding out of private debt more than compensates the gain from relieving the financially-constrained agents. The differential impact turns negative and increases until both cases converge and the high public debt economy becomes less resilient.

Therefore, there is a trade-off between the short-term gains from an active fiscal policy and the medium-term costs from higher interest payments and the corresponding crowding out of private debt. This trade-off is most pronounced in regimes of high debt, which highlights again the constraint of a debt-burdened economy to implement counter-cyclical fiscal policies.

III.2 Long-term analysis

Scenario 4: Comparative static analysis of the level of debt in the long-run

Finally, in order to assess the long-term losses implied by the level of debt, we conduct a comparative static exercise. In particular, we compute the steady state for different initial values of the public debt-to-GDP ratio–ranging from 60 to 120%–and the output losses relative to the initial steady state where the debt-to-GDP ratio is equal to the lower bound (60%).[36] The amount of the loss will, inter alia, depend on the fiscal instrument used for adjustment.

First of all we use the GEAR model to decompose the long-term impact of a higher level of debt according to the role played by the risk premium (*RP*). More precisely, table 2 includes three cases: (i) a debt increase in the periphery without risk premium ($\delta_t = 0, \forall\, t,$ first column of Table 2), (ii) a debt increase in the periphery with the risk premium only in the public sector ($\varpi = 0$, second column), and (iii) a debt increase in the periphery with spillovers of the risk premium to the private sector. [37] In this case, it is assumed that a higher risk premium in the public sector also augments financing costs in the private sector. The spillovers can be full ($\varpi = 1$, last column of the table) or partial ($\varpi = 0.5$, half pass-through to the private sector; third column). Results are shown for the core and periphery (calibrated in GEAR to Germany and the rest of EA) in percentage points deviation from the initial steady-state values. The initial steady-state debt level of 60% in both regions is increased to 90% in the periphery (whilst it is kept at 60% in the core) and financed with distortionary labour income taxes. .

A large and widely transmitted sovereign risk premium impairs significantly potential output. In the absence of risk premium, the long-term impact on GDP is rather limited. It reflects the mechanical effect of the increased amount of interest-bearing debt that the government has to finance (quantity effect), which results in slightly higher labour income taxes. On the contrary, there are significant effects on the economy when the risk premium has a long-term role: the GDP loss increases from less than 0.1 to 2.6%. In addition to the quantity effect just described, including a risk premium on government bonds now entails a significant price effect, increasing the additional long-run financing needs of the government resulting from higher debt. The tax rate needs to be significantly increased to finance the extra costs. The private consumption deteriorates by 3.6 instead of 0.1% in the previous case. The

[36] Notice that due to different dynamic properties and calibration, it was not possible to run all the models for a 120% debt ratio. We report the highest level supported by our models.

[37] Although the GEAR model is calibrated to Germany and the rest of the EA, for exposition purposes we will name them as the core and the periphery.

Table 2: Long-term impact of higher level of debt (labour income taxes) – GEAR model

	HD (no RP)	HD (RP in public sector)	HD (RP in pub and priv, inter)	HD (RP in pub and priv, full)
…in Germany				
GDP	-0.002	-0.069	-0.079	-0.089
Priv. consumption	-0.003	-0.084	-0.096	-0.109
Priv. investment	-0.003	-0.088	-0.101	-0.114
Unemployment rate	0.001	0.021	0.024	0.027
Real wages	-0.002	-0.068	-0.079	-0.089
…in rest of the Euro Area				
GDP	-0.081	-2.617	-3.024	-3.413
Priv. consumption	-0.111	-3.640	-3.665	-3.706
Priv. investment	-0.091	-2.973	-5.094	-7.111
Unemployment rate	0.049	1.752	1.671	1.597
Real wages	0.039	1.274	0.663	0.085
Labor tax rate	0.451	12.623	12.138	11.690
Debt-to-GDP ratio	90.000	90.000	90.000	90.000

Notes: HD = High debt in Periphery (equal to 90% debt-to-GDP ratio); risk premium as indicated above
Financing instrument: labor taxation (always)

Source: Authors' calculations.

spillovers on the core economy is mechanically larger (-0.069 instead of -0.002) although identical in relative terms (around 0.03 by taking the ratio of the two impacts).[38] When the sovereign risk premium spills over to the private sector, the GDP loss increases by 0.4 relative to the previous simulation due to a larger drop in private investment (from 3 to 5). The subsequent deterioration in firms' prospects induces downward pressures on private wages: real wage growth is now halved (0.66 against 1.27). As a consequence, the unemployment rate does not change significantly (around 1.6 in both cases). When the spillovers from the public to the private sector is full, private investment deteriorates further (by 7 instead of 5), implying a very limited change in private wages (less than 0.1). Compared to the partial effect, full spillovers imply an extra GDP loss of around 0.4 (3.4 vs. 3).

The result of a negative long-run effect of public debt on growth in the periphery is robust to the fiscal instrument used to finance debt. Table 3 presents results for GDP effects under the same simulation set-up, now using alternative fiscal instruments for debt financing, i.e., non-distortionary lump-sum taxes and public expenditures. As expected, when a non-distortionary instrument is used by a government to finance its debt (first column), there is no impact on GDP in the absence of risk premium spillovers to the private sector. The reason is that households who benefit from receiving higher interest payments from holding public debt are also those who need to balance the government budget in the long run by having to pay higher lump-sum taxes. Their permanent income will not be altered (which is, in part, related to Ricardian equivalence).

Table 3

Long-term GDP impact in the periphery of higher level of debt (90%): alternative fiscal instruments – GEAR model

(percentage point deviation from steady state with debt at 60% of GDP)

	Lump-sum taxes	Labour taxes	Public purchases
No risk premium (RP)	0	-0.08	-0.09
RP in public sector	0	-2.62	-2.64
RP in public and private sector (intermediate effect)	-0.62	-3.02	-3.07
RP in public and private sector (full effect)	-1.19	-3.41	-3.48

Source: Own calculations.

Only when the public sector risk premium negatively affects private sector financing, the economy is affected by distortions and GDP falls (by around 0.6% with partial spillovers and twice as much in the presence of full spillovers). Compared to the (benchmark) labour taxes case, the use of public expenditures (third column) produces almost the same quantitative GDP losses as does an increase in the labour tax rate. However, the transmission is slightly different. In the latter case, the cut in public spending depresses aggregate demand in the economy. Yet, because public purchases are assumed to be wasteful (do not increase utility), this cut now

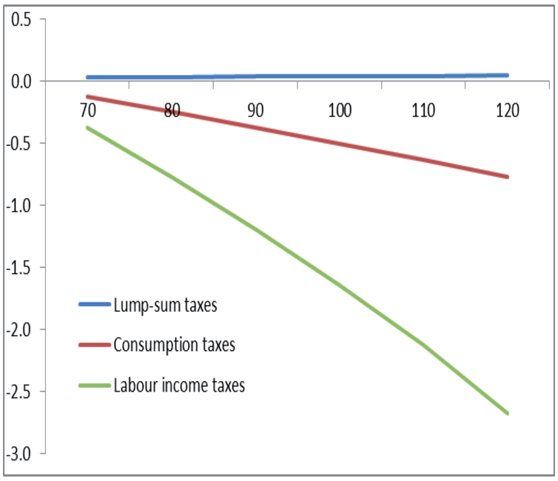
[38] The size of International spillovers depends on trade shares which are not affected in the long run.

crowds-in private consumption. Whether or not this is, in relative terms, more beneficial from the households' perspective depends on how much they evaluate public purchases in utility.[39]

As shown in chart 7, similar results are obtained with the EAGLE model when we increase the periphery's level of public debt gradually from 60% to 120% of GDP.

Chart 7: Long-term GDP impact of higher level of debt: EAGLE model (periphery)

(percentage point deviation from steady state with debt at 60% of GDP)



Source: Own calculations

Table 4: Long-term impact of higher level of debt: BE model

(percentage point deviation from steady state with debt at 60% of GDP)

steady state	change	lump sum taxes Change vs 60% (%)		tax on consumption Change vs 60% (%)	
		80	100	80	100
…in Core					
GDP	%	-0.08	-0.35	-0.08	-0.38
Priv. consumption	%	-0.36	-1.51	-0.37	-1.67
Priv. investment	%	-0.36	-1.51	-0.37	-1.67
employment	%	0.00	0.00	0.00	0.00
real wage	%	-0.37	-1.51	-0.37	-1.67
…in Periphery					
GDP	%	-0.92	-3.76	-1.16	-4.68
Priv. consumption	%	-0.79	-3.38	-1.16	-4.49
Priv. investment	%	-0.38	-1.22	-0.20	-1.16
employment	%	-0.98	-3.99	-1.19	-4.89
real wage	%	0.37	1.51	0.37	1.69
real estate prices	%	-0.16	-0.66	0.16	0.73
Lump-sum taxes to GDP ratio	pp	0.28	0.65	0.00	-0.01
private debt-to-GDP ratio	pp	-6.23	-33.14	-5.55	-31.93
households debt-to-GDP ratio	pp	-6.19	-32.94	-5.45	-31.59
entrepreneurs debt-to-GDP ratio	pp	-0.03	-0.20	-0.09	-0.33
Debt-to-GDP ratio	pp	20	40	20	40

Secondly, to assess the long-term role of public and private deleveraging, we perform a similar steady-state comparative statics exercise with the BE model, so that the debt-to-GDP ratio increases from 60 to 80 to 100%. Two cases are considered: using alternatively a non-distortionary (lump-sum tax) and a distortionary (consumption tax) instrument to close the fiscal rule. The results are presented in Table 4 and show that public debt crowds out private (households) debt. This result is slightly stronger for distortionary taxation than for lump-sum taxes. The rise in public debt increases the probability of default of the government; this increases the risk premium and therefore the interest rate to be paid on public debt. The higher interest payments have to be financed by raising lump-sum taxes (or VAT), which in turn reduces disposable income of all private agents. This is particularly damaging for those households and entrepreneurs that are (endogenously) financially constrained, therefore forcing them to reduce their debt holdings.

The crowding out effect is particularly strong when public debt increases to 100% of GDP since household debt drops by more than 30 percentage points. In addition, all private agents, but especially the constrained ones, reduce their consumption and investment, which reduces GDP.[40] These effects are slightly stronger when the government uses VAT to keep its budget balanced (the model does not have a direct link between the risk premium of public debt and the one of private debt, which would make the crowding out effects much stronger). Furthermore, Table 4 explicitly illustrates the importance of the nonlinearities introduced by the sovereign risk premium between the debt level and GDP: the higher the level of debt, the closer we are to the debt limit and thus the GDP loss increases much more than proportionally.

[39] Furthermore note that, in the GEAR model, public consumption entails a full home bias by assumption. Were the public sector to also purchase goods from foreign economies, spillovers could be larger than in the other simulations.

[40] Notice that differences between the GEAR and BE results (Table 3 and 4 respectively) stem mainly from two sources. First, in the GEAR model there is full spillover of the government risk premium to the private sector financing costs. Second, different distortionary instruments are used in each case (labour taxes vs. VAT).

IV. Conclusions

This paper has evaluated the economic consequences of high debt using simulations with three DSGE models (EAGLE - ESCB, GEAR – Bundesbank, and BE – Banco de España). The economic case for reducing high public debt ratios in the EA is twofold. First, high public debt poses significant economic challenges as it makes the economy less resilient to shocks and reduces the scope for counter-cyclical fiscal policy. Second, debt overhangs can exert adverse pressure on the economy through multiple channels over the long-run. This relationship between debt and growth is bidirectional, with economic, financial and sovereign debt crisis reinforcing each other's detrimental impact on output.

The DSGE simulations also suggest that high-debt economies (1) can lose more output in a crisis, (2) may spend more time at the zero-lower bound, (3) are more heavily affected by spillover effects, (4) face a crowding out of private debt in the short and long run, (5) have less scope for counter-cyclical fiscal policy and (6) are adversely affected in terms of potential (long-term) output, with a significant impairment in case of large sovereign risk premia reaction and use of most distortionary type of taxation to finance the additional debt burden in the future. The strength of these results depends on the impact of the level of public debt in these models. Given that the sovereign spread is the main transmission channel, in the short-run simulations, results also depend crucially on the monetary policy implementation. However, as shown by the empirical literature, other channels, such as agent uncertainty or quality of institutions, as well as complex nonlinearities (more difficult to capture in such large-scale linear DSGE models) are at play. Finally, the transition from a high debt to a low debt regime, including any associated costs, has not been investigated in this paper and remains a topic for further research.

Overall, once the COVID-19 crisis is over and the economic recovery firmly re-established, further efforts to build fiscal buffers in good times and mitigate fiscal risks over the medium term are needed at the national level. Such efforts should be guided by risks to debt sustainability. High debt countries, in particular, should implement a mix of fiscal discipline and wide-ranging growth-enhancing reforms. Policy credibility is in any event essential to reduce sustainability risks. In the context of recent reform proposals at the euro area and EU level, both tools to enhance fiscal stabilisation/risk sharing and market discipline for sound fiscal policies remain essential. In this context, the EU recovery fund[41] currently under negotiation is one of such tools that may not only bolster the foundation for sustainable growth in the aftermath of the COVID-crisis, but also support high-debt countries to address their vulnerabilities.

[41] See “Europe's moment: Repair and prepare for the next generation”, Press release, European Commission, 27 May 2020, Brussels.

Appendix: Short overview of DSGE models used for simulations

Model description and calibration

Models used for the simulation exercises have in common the same theoretical setup, based on Smets and Wouters (2003). This Box sheds some light on their original features: the government sector for EAGLE, the labour market for GEAR and the financial block for the BE model. The latter introduces borrowing constrains as in Kiyotaki and Moore (1997) and long-term debt.

I. EAGLE

EAGLE is an ESCB model developed by a team composed of staff from the Bank of Italy, Bank of Portugal and ECB. The version used in this paper is a fiscal extension of the Euro Area and Global Economy model (Gomes et al. (2010, 2012) and Clancy et al. (2016)), a multi-country dynamic general equilibrium model of the euro area. In EAGLE, the world economy is composed of four blocks. Two of the four blocks are members of the euro area which is formalized as a monetary union. The two countries have a common nominal exchange rate and a common nominal interest rate. Regarding the monetary authority, the central bank sets the domestic short-term nominal interest rate according to a standard Taylor-type rule, by reacting to increases in consumer price index inflation and real activity. Each of the remaining two blocks has its own nominal interest rate and nominal exchange rate. Similarly to the ECB's New Area Wide model (NAWM) and the IMF's Global Economy Model (GEM), EAGLE is micro-founded and features nominal price and wage rigidities, capital accumulation, international trade in goods and bonds. EAGLE is global extension of the NAWM and as such shares the same theoretical setup. The introduction of two sectors (tradable and non-tradable), the fiscal block and the monetary union are the main differences with the original NAWM. Thanks to its sound theoretical foundation and its rich set of fiscal variables, the model facilitates robust fiscal policy analysis under alternative scenarios and economic environment. Given its global dimension, the model is also particularly well suited to assess cross-border spillovers.

Government sector

The fiscal authority in each country sets government consumption expenditures, lump-sum taxes, labour and capital income taxes (labour taxes are split into income taxes paid by households, social contributions paid by employers and by employees), consumption taxes. Government spending on consumption and investment goods is specified as a fraction of steady-state nominal output, as is standard in the literature (Baxter and King (1993); Leeper et al. (2010); Stähler and Thomas (2012)). Moreover, in each country, the public debt is stabilized through a fiscal rule that induces the endogenous adjustment of fiscal instruments.

In many respects, the fiscal sector representation in the EAGLE model is quite standard. The noticeable innovation is the enhancement of the fiscal block which allows for government consumption and investment to play a non-trivial role in affecting the optimal decision-making of the private sector (as in Leeper et al. (2010), Coenen et al. (2013) and Clancy et al. (2016)). More specifically, households are assumed to derive utility from the consumption of a composite good consisting of private and public consumption goods. As a result of the assumed complementarity between private and public consumption goods, changes to public consumption have persistent effects on private consumption. Finally, it is assumed that government capital stock affects the production process. Consequently, variations in public investment have strong and persistent supply-side effects. The government capital evolves by accumulating government investments net of depreciation. The value of the output elasticity determines the productivity of public capital.

Calibration

The EAGLE model is calibrated to Periphery (Greece, Italy, Portugal and Spain) vs. core (the rest of the euro area), for the euro area, the rest of the world and the US. As the calibration is in line with the literature (see Gomes et al. (2010, 2012), Coenen et al. (2008) or Christoffel et al. (2008)) we will focus on the fiscal blocks.

The calibration of parameters that determine the aggregation of private and government consumption expenditure is in line with Coenen et al. (2012). The elasticity of substitution between private and government consumption is set to 0.50, while the quasi-share of government consumption expenditure in the aggregator is set to 0.25. This ensures that the observed responses of consumption to government spending shocks are in line with either country-specific or euro-area empirical evidence (e.g. Kirchner et al., 2010; Coenen et al., 2012b). As such, government and private consumption are strong, but not perfect, complements, consistently with the evidence in Karras (1994) and Fiorito and Kollintzas (2004). On the supply side, the bias towards public capital in the production function of intermediates sectors is equal to 0.10.

As in Coenen et al. (2013) or Gadatsch et al. (2016) the fiscal rules includes an auto-regressive terms and reacts to the deviation of the debt from its target and to the output gap (defined as the deviation from its steady-state level) as well. The term associated to the output gap can be interpreted as an ad-hoc automatic stabilizing component as in Coenen et al. (2013). Following Coenen et al. (2013) AR-terms are set to 0.8 (0.9 respectively) for labour income taxes and public consumption (value added taxes respectively). As suggested by Corsetti et al. (2013), the semi elasticity of revenue with respect to output is set 0.34. Accordingly, the sensitivity to the deviation of the debt from its target is large enough to stabilize the public debt (0.27). Benchmark simulations will use labour income tax (LIT) to stabilize the debt.

Coefficients of the monetary policy rule use standard values from the literature and are in line with the New Area Wide Model (Christoffel et al., 2008) and the original EAGLE (Gomes et al., 2012). The steady-state inflation is equal to the inflation target, set to 2%, while the interest rate inertia is set to 0.87, the sensitivity to inflation gap is set to 1.70 and the sensitivity to output growth is set to 0.10.

Lastly, debt-to-GDP ratio is calibrated to be 60% which corresponds roughly to the average value across time and countries in the pre-crisis period. The level of haircut, in case of sovereign default, is calibrated symmetrically across countries to 0.37, which according to Cruces and Trebesch (2013) corresponds to the median haircut calculated from a sample of sovereign debt re-structuring between 1970 and 2010 (similar to Darracq Pariès et al. (2016)).

II. GEAR

The GEAR model is an estimated New Keynesian DSGE model (see Gadatsch et al, 2016). It consists of three regions: Germany, the Euro Area (without Germany) and the Rest of the world. Each region is inhabited by four types of agents: households, firms, a fiscal and a monetary authority. Within the euro area, there is only one common monetary authority.

Labour market

Households make optimal choices regarding savings in physical capital as well as national and international assets and purchases of consumption and investment goods. Household members also decide whether or not to participate in the labour market. Those who participate may find a job in the private or in the public sector or stay unemployed. Unemployment is modelled in line with Galí (2010) and Galí et al. (2011). Hence, households receive interest and wage payments, unemployment benefits and other fiscal transfers, and they pay taxes. In line with Galí et al. (2007), we also assume that a fraction of households does not participate in asset markets and consumes the entire income each period. Those households have become known in the literature as “rule-of-thumb” (RoT) households; we call the other type of households “optimizers”. Furthermore, households enjoy some monopoly power on the labour market because different types of labour are needed in production, and these are not perfectly substitutable. Wages are, hence, set by a union which takes into account optimizers and RoT households as in Galí et al. (2007). Wage setting is associated with Rotemberg adjustment costs in the sense that changing nominal wages is costly for firms and for workers. This prevents wages from “perfectly” adjusting to the current economic situation which, in the end, induces potentially inefficient wage and employment fluctuations (see Ascari et al., 2011, and Ascari and Rossi, 2011, for a discussion).

Production side

Monopolistic competitors in each region produce a variety of differentiated products and sell these to the home and foreign market. We assume that there is no price discrimination between markets. Firms use labour and private capital as production inputs. Public employment and the public capital stock can be productivity enhancing. However, the provision of these inputs is outside the control of firms and conducted by the fiscal authority. Cost minimization determines the amount of labor and capital input demanded by each firm. Because firms enjoy monopolistic power, they are able to set their nominal price. Price setting is also associated with Rotemberg adjustment costs.

Government sector

The fiscal authority purchases consumption and investment goods produced in the private sector. The latter increases the public capital stock which may, in turn, improve private-sector productivity (for example, because of better infrastructure). The government also employs public-sector workers for whom it has to pay wages. Services provided by these public-sector workers may also affect private-sector productivity positively (for example, because of better governance). Introducing immediate positive spillovers from the public to the private sector follows the idea of Pappa (2009) or Leeper et al. (2010). Furthermore, the fiscal authority pays unemployment benefits and other transfers to private households. To finance the primary expenditure and the interest payments on outstanding debt fiscal authorities rely on distortionary taxes on private consumption, on labour income and on capital returns, lump-sum taxes as well as social security contributions paid by firms. They can also issue new debt.

III. BE (Andrés, Arce, Hurtado and Thomas) model

BE is a closed monetary union with two countries or regions: the periphery and the core. The BE model is an extension of Andrés et al (2017), where a detailed description of how private borrowing and deleveraging is introduced in a closed economy model can be found. However, the version of the model used in this exercise is closer to the two-region euro area version of the model of Arce et al (2016), with a more detailed public sector like in Andrés et al (2020).

Real side of the economy

In each country, households obtain utility from consumption goods and from housing units. Consumption goods are produced using a combination of household labour, commercial real estate, and equipment capital goods. Construction firms build real estate (both for residential and commercial purposes) using labour and consumption goods; the latter are also used as inputs by equipment capital goods producers. Consumption goods and labour markets are both characterized by monopolistic competition and nominal rigidities.

Financial side of the economy

In each country, there are three types of consumers: patient households, impatient households, and (impatient) entrepreneurs. In equilibrium, the latter two borrow from the former and from lenders in the other country. Debt contracts are long term. In periods in which borrowers are able to receive new credit flows, they do so subject to collateral constraints. If the value of their collateral is too low for them to receive new credit flows, they just repay their outstanding debts at a fixed contractual rate. Real estate is the only collateralisable asset. We will henceforth refer to impatient and patient households as "constrained" and "unconstrained" households, respectively. That is, in both areas households and firms borrow long term subject to collateral constraints.

The model has five (endogenous) occasionally binding constraints: on the debt of households and entrepreneurs of each country and on the interest rate (ZLB). However, we never allow for more than three to be binding in the same exercise since we only consider the option of deleveraging in the periphery. Given the number of possible states that this problem generates, it is computationally impossible to solve the model for all three constraints potentially binding in any period. This problem is solved by imposing that all constraints considered in each exercise always bind on impact and then we postulate that the optimal sequence of exit is first the ZLB, then the indebted entrepreneurs and finally the indebted households, and then we check that this order is in fact the optimum. This is why our impulse responses of a specific shock, for example, a fiscal expansion with ZLB and deleveraging, are calculated as the difference between the IRFs in a baseline with a negative demand shock to put the economy in the ZLB and a shock to make the agents deleverage in the periphery and the IRFs in the same economy plus a fiscal expansion.

The model also allows for long-term debt. Unlike in most of the literature, which typically assumes short-term (one-period) debt, we assume that debt contracts are long term. The debt is perpetual and similar to the one proposed by Woodford (2001).

Government sector

The fiscal authority collects taxes on households and entrepreneurs, consumes (with full home bias) and issues non-contingent nominal debt, according to a fiscal rule. Public debt is held by patient agents in both countries. The fiscal rule sets the change in the fiscal instrument as a function of deviations in the government debt to GDP ratio from its long-run target and to changes is this ratio. Holding government debt is subject to sovereign default risk, like in Batini et al (2016). That is, in order to introduce a sovereign risk premium, we assume that government bond contracts are not enforceable. As in Bi and Traum (2012), in each period, a stochastic fiscal limit expressed in terms of government debt-to-GDP ratio is drawn from a distribution, whose cumulative density function is logistical.

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