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Abstract

Rising public investment needs raise the issue of debt sustainability. This paper analyses the implications of public investments for debt dynamics using quantitative model simulations. Without offsetting fiscal adjustments via the primary balance, a temporary increase in public investment implies a lasting increase in the debt-to-GDP ratio. While a significant boost to real GDP can create some backing for the additional public debt, the direct budgetary costs of the stimulus outweigh this denominator effect. In the medium and long run, as these endogenous effects fade, debt dynamics becomes increasingly driven by the long-term r−g differential, which is assumed to be positive in our central scenario, putting debt-to-GDP on an increasing trajectory. In contrast, negative r − g could ensure that debt-to-GDP eventually reverts to its baseline level, even without budgetary adjustments. Alternatively, letting the primary balance adjust beyond the impact of the fiscal shock can provide another mechanism for debt stabilisation. In particular, if non-stimulus spending is fixed in real terms while taxes increase in line with expanding output, debt-to-GDP falls below its baseline in the medium run, even in an economy with positive r−g. However, this constitutes a quasi-consolidation where the resulting higher primary balances reflect the inherent fiscal costs, underlining that public investment is not a "free lunch". Nonetheless, the need for debt-financed public investments to be eventually paid for (in a narrow fiscal sense) does not preclude their potential to be welfare-improving for society, especially if they facilitate the climate transition – a channel our model does not explicitly consider.

JEL Classification: E62, E63, H62, H63.

Keywords: public investment, debt sustainability, fiscal policy, DSGE modelling, interest-growth differential.

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1 INTRODUCTION

Public investment needs are rising in Europe. Estimates suggest that fostering the green and digital transitions requires a significant increase in government investment (European Commission, 2020). This raises the question of how to pay for this spending and whether these policy goals align with fiscal sustainability.

In the public debate, two broad perspectives emerge. One argues that this juncture implies obvious tensions between spending needs and debt sustainability (Blanchard, 2023*b*; Pisani-Ferry, 2023). While negative interest-growth differentials over recent years have kept the fiscal costs of public spending low, these favourable conditions might be more difficult to meet going forward, implying harsher trade-offs faced by policymakers (Adrian, Gaspar and Gourinchas, 2024). Conversely, a more optimistic viewpoint argues (implicitly or explicitly) that by boosting economic growth, increased public investment spending can create (some) funding for itself, either via higher tax bases or beneficial denominator effects.[1] In the extreme, such "self-financing" channels alone might be sufficient to fully stabilise debt ratios, abolishing the need for offsetting fiscal adjustments, even if interest rates are above GDP growth in the long run (Angeletos, Lian and Wolf, 2023). This sort of self-financing would suggest there is a free lunch: that public investments never need to be paid for, as the initial budget deficit ends up financing itself.

Whether this is the case, and under which conditions, becomes also pertinent within the context of the European Union's newly reformed economic governance framework. The framework seeks to incentivize governments to undertake public investment by relaxing fiscal requirements for such Member States.[2] More in general, the question revolves around whether government investments should be encouraged because of their welfare benefits in other policy areas, *in spite of* their fiscal costs (the acknowledgement of which costs warrants the relaxation of fiscal rules in the first place) – or because their potential for self-financing also renders them beneficial for fiscal sustainability itself.

In this article, we contribute to this debate by quantitatively assessing the implications of public investment for debt dynamics. Building on a rich general equilibrium model, we investigate under what conditions and to what extent public investments can contribute to their own funding. Broadly speaking, our analysis breaks down debt-to-GDP dynamics into two key components: the interest-growth differential ("snowball term") and the primary budget balance. A deficit-financed fiscal shock could induce an endogenous decline in the interest-growth differential, reducing the need for subsequent fiscal adjustments through higher primary surpluses. A narrow interpretation of "self-financing" corresponds to the part of debt reduction that is driven by these negative snowball effects.

Our setup incorporates productive public investment and a comprehensive set of expenditure and tax variables. These aspects are intertwined with macroeconomic feedback channels, such as changes in tax bases, inflation or interest rate reactions. In particular, as government investment augments private sector productivity, GDP multipliers can be large in our model: Beyond the Keynesian demand-boosting effects of public spending, they also expand supply capacities and crowd in private investments in the medium term.

Our simulations show that under conventional assumptions, and without offsetting fiscal action, a temporary rise in public investment leads to a sustained increase in the debt-to-GDP ratio. In other words, debt stabilisation would require subsequently higher primary surpluses, implying that public investments must eventually be paid for by fiscal adjustments. This requirement is in spite of a persistent expansion of real GDP that can initially reduce the snowball term, creating some backing for the additional public debt. However, the

[1] See, for example, Krebs and Scheffel (2017) and Abiad et al. (2014).

[2] Member States can be granted an extension of their adjustment period (to reach fiscal targets) from 4 to 7 years if they pursue growth-enhancing investments and reforms.

direct budgetary costs of the stimulus outweigh this denominator effect, which is mitigated further by the deflationary consequences of gradually expanding supply capacities. In the long run, as these *endogenous* effects on the interest-growth differential fade, assumptions about the (exogenous) *steady-state* $r - g$ start dominating the dynamics of the snowball term. In our main scenario, the effect of a positive long-run $r - g$ (a benchmark assumption of established debt sustainability analyses (DSA)) puts public debt on an increasing trajectory.

In contrast, scenarios with a negative long-term $r - g$ suggest that debt-to-GDP could revert to its baseline level, even without budgetary adjustments (Blanchard, 2019). As interest payments accumulate relatively slower, it is possible to outgrow debt independently of the productivity assumptions of public capital. This finding underscores how the steady-state interest-growth differential is highly consequential for the debt-to-GDP ratio's medium and long-run trajectory.

Beyond the snowball term, there might also be endogenous changes within the primary balance that are not the result of *explicit* actions by fiscal policymakers. However, in our central scenario, the primary balance remains essentially unaffected, except for the direct impact of the fiscal shock. On the revenue side, taxes grow roughly in line with GDP, consistent with empirical estimates of budgetary semi-elasticities around zero (Mourre, Poissonnier and Lausegger, 2019). On the spending side, other non-stimulus government expenditures (e.g., pensions and public sector wages) remain stable as a share of GDP, by construction. These features, serving as an initial benchmark, also imply that movements in the primary balance are mostly similar across scenarios with different public investment productivity, despite markedly different effects on output – an outcome that depends crucially on the assumption of non-stimulus spending growing in line with GDP.

Alternatively, keeping non-stimulus spending items fixed in real terms implies a declining expenditure share within a growing GDP. The resulting higher primary balances provide another mechanism for debt stabilisation: in this alternative scenario, debt-to-GDP falls *below* its baseline over the medium to long term. Assumptions on non-stimulus expenditure thus carry significant implications. However, it is essential to recognise that these increased primary balances reflect the inherent fiscal costs needed for debt reduction, challenging the notion of a "free lunch". Instead, this scenario represents a form of fiscal *quasi-consolidation*, as the beneficiaries of fixed public spending items see their income falling behind the rest of the economy. Therefore, the assumption of constant spending in real terms, while often implicitly adopted in short-term analyses, appears less plausible when considering long-term projections.

The fact that public investments need to be paid for in a narrow fiscal sense, via raising subsequent primary surpluses, does not mean that they cannot be welfare-improving for society (e.g. by mitigating climate damages). In addition, financing them via additional debt issuance (instead of in a budgetary-neutral way) might be advisable for tax-smoothing or "pay-as-you-use" generational fairness. However, instead of analysing such normative implications, our exercise restricts itself to pointing out the fiscal implications, i.e. to what extent investment needs to be paid for eventually, but not whether it is welfare-improving.[3]

Similarly, the result of our central scenario, where public investment shocks lead to rising debt-to-GDP, is not to conclude that rising public investment needs are incompatible with fiscal sustainability. It is to point out that, unless $r < g$, they eventually need to be paid for – in spite of their beneficial effects on output. We present a scenario with cuts to unproductive government consumption that offset the cost of the public

[3] This criterion depends, among others, on whether the future return on productive investments in terms of extra output per working hour is larger than the consumption and leisure time sacrifice that has to be made in the present to undertake the investment. This balance also depends on the nature of subsequent fiscal adjustments, as their timing and distribution matter for aggregate demand when Ricardian equivalence does not hold, while their distortionary effects have supply-side consequences. Analysing optimal policy would require a separate analysis beyond the scope of this paper.

investment stimulus in a balanced-budget way. This "spending prioritisation" keeps debt-to-GDP stable, while entailing only moderate sacrifices in terms of real GDP in the short run, and maintaining most of the medium to long-run gains. That said, these aggregate results could hide distributional considerations, implying more challenging trade-offs for policymakers, underscoring the potential costliness of these fiscal adjustments.

Relation to the literature. This paper contributes to a wide literature that explores the interaction of fiscal policy and the interest-growth differential in general, and the magnitude of fiscal multipliers in particular. Regarding the long-run component of $r-g$, Blanchard (2019) demonstrates how interest rates staying persistently below economic growth could eliminate the fiscal costs of stimulus spending: a temporary increase in the deficit need never be paid for.[4] In our model, the steady-state $r-g$ is an exogenous parameter. However, Rachel and Summers (2019) point out the *long-run* endogeneity of $r-g$ to fiscal policy. They show how higher fiscal deficits and larger public debt historically contributed to raising natural real interest rates, mitigating the downward pressure on interest rates from a secular rise in private saving desire and demand for safe assets. Mian, Straub and Sufi (2022) illustrate that if $r-g$ is negative and the endogenous sensitivity of interest rates to public debt is not too large, a modest permanent increase in the deficit can be sustained forever. Reis (2021, 2022) shows how the safety and liquidity services of public debt give rise to a "debt revenue" term, lowering the effective interest rate faced by the government.

The endogenous *short-run* response of the interest-growth differential to a public investment shock is shaped by the effects of fiscal multipliers on real growth, alongside the impacts of inflation and monetary policy reactions. The fiscal theory of the price level (FTPL) describes monetary-fiscal policy regimes where, instead of outright fiscal adjustments, the real value of public debt is stabilised by tolerating *temporarily* higher inflation (Cochrane, 2023; Leeper and Leith, 2016; Sims, 2013). In such a case, deficit-financed government spending would not require a subsequent increase in primary surpluses *ever*, having a flavour close to self-financing (even though bondholders would effectively pay an "inflation tax"). Bianchi, Faccini and Melosi (2023) show how such a policy regime might be realistic, pointing to the role of unfunded transfer shocks in driving inflation in the United States. By contrast, our paper focuses on a policy regime where monetary policy has a price stability objective and satisfies the Taylor principle.

The literature on fiscal multipliers identifies several cases when the GDP impact of public spending can be large. In a liquidity trap environment, where real interest rates remain above their equilibrium level due to the zero lower bound, the usual crowding out effect from fiscal shocks is absent, making fiscal policy a powerful tool for stimulating aggregate demand (Delong and Summers, 2012; Erceg and Lindé, 2014; Farhi and Werning, 2016).[5] In FTPL models, the nominal wealth effect from unbacked public debt breaks Ricardian equivalence even with infinitely lived consumption-smoothing households, leading to large fiscal multipliers on real growth (beyond the inflationary effect), as shown by Jacobson, Leeper and Preston (2019) and Bianchi, Faccini and Melosi (2022).[6] Heterogeneous agent incomplete market models with liquidity-constrained households and precautionary saving motives also violate Ricardian equivalence, amplifying the effect of deficit-financed stimulus via higher marginal propensities to consume (MPC) out of temporary income shocks (Auclert, Rognlie and Straub, 2018; Bayer et al., 2020).[7] This MPC-channel is largely captured by two-agent New Keynesian (TANK) models, like ours, along with Bilbiie (2020); Galí, López-Salido and Vallés (2007) and Cantore and Freund (2021). Beyond the Keynesian demand-side effects, the government investment

[4] Several studies investigate the driving forces behind falling natural real interest rates and persistently weak demand, from rising inequality (Mian, Straub and Sufi, 2021*a*,*b*) to slowing productivity growth and population ageing (Eggertsson, Mehrotra and Robbins, 2019; Cesa-Bianchi, Harrison and Sajedi, 2022).

[5] See also Christiano, Eichenbaum and Rebelo (2011); Woodford (2011); Eggertsson (2011); Coenen et al. (2012).

[6] See also Leeper, Traum and Walker (2017); Davig and Leeper (2011).

[7] See also Hagedorn, Manovskii and Mitman (2019); Broer, Krusell and Öberg (2023).

multiplier in our model is also boosted via persistent productivity effects on the supply side (Pfeiffer, Varga and in 't Veld, 2023).[8] It is, however, noteworthy that empirical studies have found that short-lived government investment shocks yield smaller *short-run* fiscal multipliers compared to government consumption shocks (Boehm, 2020; Klein and Linnemann, 2023). In Appendix D.2, we further explore mechanisms that attenuate the short-run multiplier of public investment.

Whatever their source is, large fiscal multipliers on real growth can lower the snowball term and moderate public debt dynamics. Yet, these self-financing effects are ultimately temporary. When GDP eventually returns to its baseline *level* after the stimulus ends, fiscal adjustments become necessary. By contrast, endogenous technology growth through R&D can deliver a *permanent* level shift in GDP after a stimulus, providing some permanent backing for public debt (Elfsbacka-Schmöller and McClung, 2024).[9] While our simulations do not incorporate these channels, they display very persistent GDP and productivity gains, capturing thereby similar medium-run effects.

Angeletos, Lian and Wolf (2023) present an OLG model where Ricardian equivalence fails due to non-zero death probabilities. This entails stronger discounting of tax hikes that are further in the future, leading to higher fiscal multipliers for deficit-spending if debt-stabilising (explicit) fiscal adjustment is delayed more. In the extreme case of indefinitely postponing explicit fiscal adjustments, the resulting demand boost is so large that the initial deficit is fully paid for via what they refer to as "self-financing" channels: a higher income tax base and (to a lesser extent) higher inflation, eliminating the need to subsequently raise tax *rates* or cut expenditure *levels*. However, this mechanism operates via raising primary surpluses (due to collecting more income taxes), instead of via negative snowball effects. This case corresponds to our fiscal *quasi-consolidation* scenario, as the implicit assumption of a fixed level of pre-stimulus spending implies that the GDP share of those expenditures gets eroded with rising output – while taxes grow in line with GDP. This insight challenges the notion that the deficit "pays for itself" since subsequently higher primary balances reflect the fiscal costs that the stimulus spending entails.

Outline. The rest of the paper is organised as follows. Section 2 presents key features of the model used in our analysis. Section 3 explores the results of our central scenario. Section 4 examines a range of alternative scenarios on key assumptions. Finally, Section 5 concludes.

2 MODEL

We conduct our analysis using a version of the European Commission's QUEST model (Burgert et al., 2020). This quantitative framework incorporates detailed fiscal policy mechanisms. Government investment is treated as productive, contributing directly to the economy's productive capacity (Baxter and King, 1993). Including also government consumption and transfers, the model allows to assess how the reaction of these expenditure items affects public finances. The government finances its expenditures by levying taxes on domestic agents and issuing nominal bonds. The adjustment of the tax bases is endogenous and determined jointly by private and public sector choices.

[8] Sectoral input-output linkages can also amplify government investment multipliers even if investment is concentrated only in a small set of industries (Peri, Rachedi and Varotto, 2023).

[9] One could consider (fully) endogenous growth frameworks, where public investments would permanently raise not only the *level* of real GDP but also the long-term potential *growth rate* g. However, in this case, the equilibrium level of real interest rates r might also rise. As a result, long-run $r - g$ (relevant for debt dynamics) would not be materially affected. Moreover, the data support a semi-endogenous growth model, suggesting that the impact manifests as persistent level effects rather than permanent changes to growth rates (Jones, 2005; Bloom et al., 2020).

Households are infinitely-lived and of two types: liquidity-constrained and "Ricardians". Both consume goods and supply labour, while Ricardians also invest in domestic physical capital, government bonds and international bonds, and receive corporate income. On the production side, monopolistically competitive firms operate in tradeable and non-tradeable sectors and pay social security contributions. Prices and wages are sticky. Public capital raises the productivity of the private capital and labour inputs.

The model version embeds these elements into a three-region setting, consisting of a single Member State, calibrated to Germany, the rest of the monetary union, and the rest of the world.

For brevity, we highlight key model features relevant to the discussion, referring readers to Burgert et al. (2020) for detailed exposition.

2.1. FISCAL POLICY

We first discuss the dynamics of the debt-to-GDP ratio before turning to the assumptions on the government's expenditure and revenue items.

2.1.1. Debt dynamics

Let PB_t denote the primary budget balance at time t, i.e. government revenue minus expenditure excluding interest payments. The nominal government budget constraint can then be written as:

$$B_t = (1 + i^g_{t-1})B_{t-1} - PB_t, \tag{2.1}$$

where B_t denotes the stock of debt with a nominal interest rate of i^g_{t-1}. Dividing by nominal GDP at time t then expresses the debt-to-GDP $d_t = \frac{B_t}{P_t Y_t}$ ratio as

$$\begin{aligned} d_t &= -\,pb_t + \left(\frac{1+i^g_{t-1}}{1+\pi_t}\right)\frac{1}{1+g_t}d_{t-1} \\ &= -\,pb_t + \left(\frac{1+r^g_t}{1+g_t}\right)d_{t-1}, \end{aligned} \tag{2.2}$$

where $pb_t \equiv \frac{PB_t}{P_t Y_t}$ is the primary balance as a percentage of GDP, while $\pi_t \equiv \frac{P_t - P_{t-1}}{P_{t-1}}$ and $g_t \equiv \frac{Y_t - Y_{t-1}}{Y_{t-1}}$ are GDP deflator inflation and real GDP growth rates, respectively. The *ex-post* effective real interest rate $r^g_t \equiv \frac{1+i^g_{t-1}}{1+\pi_t} - 1$ determines the real burden of nominal public debt.

The second line of (2.2) shows how the interest-growth differential $r^g_t - g_t$, in short $r - g$, is a crucial driver of debt dynamics. For a zero primary balance, the debt-to-GDP ratio will rise if $r^g_t > g_t$. If the primary balance remains unchanged, a positive differential generates a *snowball effect* of increased interest payments that compound faster than GDP growth could erode their effect on the debt ratio.

In addition, we include a simple maturity structure of government debt. We assume that the pass-through of current short-term nominal interest rates set by monetary policy authority, i_t, is gradual. In every period, only a share ρ_d of the outstanding debt stock matures and needs to be rolled over at the current interest rates. For the remainder, past nominal effective rates remain locked in:

$$i^g_t = (1-\rho_d)\, i^g_{t-1} + \rho_d \Big[i_t + \Psi_t \Big]. \tag{2.3}$$

This formulation implies that bonds are issued with a maturity of $\frac{1}{\rho_d}$.

We also allow current interest rates to feature a debt-elastic risk premium:

$$\Psi_t = \Psi + \psi\left(d_t - \overline{d}\right). \tag{2.4}$$

For $\psi > 0$, the government risk premium increases if the debt-to-GDP ratio deviates from an exogenous target $\bar{d}$ (set at the steady-state debt ratio). The government also enjoys a constant convenience yield $\Psi < 0$, relative to the private sector, e.g., due to the liquidity services of public debt.

Finally, the nominal primary budget balance PB_t is the difference between the government's nominal revenues REV_t and non-interest nominal expenditures EXP_t:

$$PB_t = REV_t - EXP_t. \tag{2.5}$$

We now turn to our assumptions on the two components.

2.1.2. Primary expenditures

Nominal primary expenditures consist of public investment I_t^G, government consumption G_t, transfers TR_t and unemployment benefits BEN_t (the latter two expressed in nominal terms):

$$EXP_t = P_t^C(I_t^G + G_t) + TR_t + BEN_t, \tag{2.6}$$

where P_t^C denotes the consumption and investment deflator (for simplicity, we assume the same import shares for both goods).

Public capital evolves according to

$$K_t^G = (1 - \delta^g)\, K_{t-1} + I_t^G, \tag{2.7}$$

where δ^g is the depreciation rate of publicly provided capital (K_t^G). Appendix D.2 extends the model with implementation delays (Leeper, Walker and Yang, 2010).

To assess the public finance implications of macroeconomic shocks, we must specify assumptions on the endogenous response (or absence thereof) of expenditure items:

$$G_t = \overline{gs}_t\, \frac{P_t Y_t}{P_t^C} \tag{2.8}$$

$$I_t^G = \overline{igs}_t\, \frac{P_t Y_t}{P_t^C} \tag{2.9}$$

$$TR_t = \overline{trys}_t\, P_t Y_t, \tag{2.10}$$

where the variables $\overline{gs}_t$, $\overline{igs}_t$ and $\overline{trys}_t$ govern the indexation of the respective expenditure items (i.e. their endogenous responses to macroeconomic fluctuations). Keeping these variables constant implies GDP-indexation, yet we explore other rules in Section 4.1.[10]

Total nominal benefits BEN_t provide a constant replacement rate $\overline{benr}$ of current nominal wages W_t for unemployed workers:

$$BEN_t = \overline{benr}\, \underbrace{(1 - L_t)}_{unemp_t}\, W_t. \tag{2.11}$$

2.1.3. Primary revenues and fiscal rule

Nominal tax revenues REV_t are collected through labour (τ_t^L), social security contributions (τ^{ssc}), corporate income taxes (τ^k), consumption taxes (τ^{VAT}) and lump-sum taxes (T_t):

$$REV_t = \tau_t^L\, W_t L_t + \sum_j \tau^{ssc}\, W_t L_t^j + \tau^{VAT} P_t^C C_t + \tau^k \sum_j Pr_t^j + T_t. \tag{2.12}$$

[10] Using a simplified example, Appendix B.2 illustrates how different indexation methods correspond to budgetary expenditure semi-elasticities, governing the shifts in government spending-to-GDP ratios after shocks.

Hours worked (L_t), private consumption (C_t), corporate income net of depreciation (Pr_t^j) and prices are endogenous variables. Hence, the tax bases and revenues adjust to policy shocks. The relative adjustment of the revenue-to-GDP ratio, i.e., the budgetary revenue semi-elasticities, are thus equilibrium outcomes and not fixed parameters.

In addition, $dum_t \in \{0,1\}$ allows to switch on a fiscal feedback rule. For $dum_t = 1$, the labour income tax rate τ_t^L, reacts to deviations of the debt-to-GDP ratio from its target:[11]

$$\tau_t^L = \tau_{t-1}^L + dum_t \left[\phi^d \left(d_t - \overline{d}\right) + \phi^{def} \Delta d_t\right]. \tag{2.13}$$

2.2. PRODUCTION

Two domestic sectors $j \in \{NT, TD\}$ produce non-tradeable and tradeable goods. Domestic value added is produced with a Cobb-Douglas technology using private capital (K_t) and labour (L_t):

$$Y_t^j = A_t^j \left[\left(u_t^j K_t^j\right)^{1-\alpha} \left(L_j^j\right)^{\alpha} \left(K_t^G\right)^{\alpha_g} - fcy\right], \tag{2.14}$$

where A_t^j, u_t^j, and fcy denote total factor productivity, capacity utilisation, and fixed costs, respectively. Value-added producers choose prices, capacity utilisation and factor inputs subject to standard adjustment costs. These frictions reflect technological, regulatory, and market constraints. Informed by model estimations and data on price adjustment frequencies, these features help to capture the economy's dynamic behaviour. Moreover, if public capital is productive ($\alpha_g > 0$), a larger public capital stock raises the marginal product of private factors.

Value-added production is part of a multi-stage process. In the first stage, imperfect substitutable varieties of Y_t^j are assembled into a homogenous good. This imperfect substitutability gives rise to producer market power and mark-up pricing.

The second stage combines this good with intermediates to produce domestic output. In the final stage, perfectly competitive firms combine this output with imported final goods for final use. The open economy matters for fiscal multipliers because cross-border trade and capital flows can generate leakage effects, where some spending increases imports rather than domestic output. The additional distinction between tradable and non-tradable sectors helps capture realistic, real exchange-rate dynamics in response to the public-investment shock.

2.3. OTHER MODEL FEATURES

The remaining model features are standard in quantitative DSGE models. We only sketch them here and refer to (Burgert et al., 2020) for additional details.

2.3.1. Monetary policy

The central bank follows a standard Taylor rule, setting the short-term nominal interest rate i_t^{EA} that reacts to deviations of euro area consumer price inflation $\pi_t^{c,EA}$ and the output gap $\hat{y}_t^{EA}$ with ϕ^π and ϕ^y, respectively:

$$i_t^{EA} = \rho_i\, i_{t-1}^{EA} + (1-\rho_i)\left[r + \pi + \phi^\pi(\pi_t^{c,EA} - \pi) + \phi^y\, \hat{y}_t^{EA}\right], \tag{2.15}$$

[11] This fiscal rule, via sufficiently high coefficients ϕ^d and ϕ^{def}, ensures that rising primary surpluses eventually stabilise the public debt. Thus, in the very long run, fiscal policy is passive, and inflation can be pinned down by monetary policy. However, to carve out the public finance implications of government investment as clearly as possible, we will switch off the fiscal rule for the first 100 years of our simulations.

where $\rho_i \geq 0$ captures interest smoothing. The calibrated policy rule satisfies the Taylor principle of $\phi^\pi > 1$: monetary policy actively manages the *real* interest rate to stabilise inflation around its target π. EA variables are GDP-weighted averages of Germany and the rest of the EA.

2.3.2. Households: TANK

This model version builds on a TANK framework, featuring liquidity-constrained and "Ricardian" households with population shares slc and $(1 - slc)$, respectively. Both consume goods and supply labour subject to consumption and labour taxes. Ricardians also invest in domestic physical capital, government bonds and international bonds, and also receive corporate income subject to taxes. Coupled with inefficiencies in labour and goods markets, the TANK setup leads to stronger responsiveness of consumption to changes in income, thereby producing Keynesian impacts from fiscal stimulus (e.g., Galí, López-Salido and Vallés (2007)).

2.4. CALIBRATION AND SIMULATION APPROACH

Table 2.1 reports the main parameters. Given exogenous TFP and population growth, the real growth rate is set to 1.2% per year. Household savings preferences and liquidity premia (Ψ) imply a real interest rate of 2% for government bonds. Thus, the steady-state interest-growth differential in our central scenario is $r^g - g =$ 0.8%. This positive value aligns with long-run assumptions in the Commission's DSA framework (European Commission, 2023; Darvas, Welslau and Zettelmeyer, 2023). To introduce different channels gradually, our main setting assumes inelastic risk premia on government debt ($\psi = 0$). We explore this feedback mechanism in Appendix D.1. We calibrate the output elasticity of public investment α_g based on the median estimate reported in the meta-study of Bom and Ligthart (2014). Since these parameters are central to the impact of government investment on public finances and the overall economy, alternative scenarios shed light on different model calibrations, including unproductive spending, negative $r - g$ and debt-elastic risk premia.

Table 2.1: Model Calibration: Central assumptions

Parameter	Description	Value
α	Steady-state labour share	0.65
α_g	Output elasticity of public capital	0.12
$\overline{benr}$	Benefit replacement rate	30%
δ_g	Depreciation rate of public capital (ann.)	5 %
$\overline{d}$	Debt-to-GDP ratio	65%
fcy	Fixed costs in production	7.2%
g	Steady-state real growth	1.2%
ϕ^π	Response to inflation EA	1.5
ϕ^y	Response to output gap EA	0.05
ψ	Elasticity of risk premia to gov. debt	0
Ψ	Convenience yield (government bonds)	-1%
ρ_d	Share of maturing debt	1/32
ρ_i	Interest rate smoothing EA	0.82
sig	Share of public investment in steady state	2.2%
slc	Share of liquidity-constrained households	40%
sm	Import share	41%
τ^k	Capital income tax rate	29.8%
τ^L	Steady-state labour tax rate	25.3%
τ^{ssc}	Social security contributions rate	15.3%
τ^{VAT}	Consumption tax rate	24.3%

The calibration of long-run ratios and import shares reflects the characteristics of the German economy. We set the steady-state share of public investment to 2.2%. Tax rates are calibrated based on TAXUD data. Our calibration of ρ_d implies that the government issues bonds with a maturity of eight years. The import share of all goods is set to around 40% (for Germany) based on EUROSTAT's FIGARO database (Remond-Tiedrez et al., 2019).

The shares of bilateral imports are based on the IMF Direction of Trade Statistics (DOTS) for goods trade and on Eurostat, OECD and WTO data sources for services. The calibration of the baseline government-debt-to-GDP ratio of 65% (for Germany) reflects the average ratio observed over the last decade. Behavioural parameters and dynamics adjustment costs are based on model estimations (Ratto, Roeger and in 't Veld, 2009; Albonico et al., 2019).

We solve the model nonlinearly using a perfect-foresight Newton-Raphson algorithm. The initial increase in public investment is unanticipated by all agents but its path perfectly known after the shock.

3 FISCAL EFFECTS OF PUBLIC INVESTMENT

3.1. SIMULATION SETUP

The model simulations consider a 6-year-long increase in public investment of 1% of GDP per year, starting in 2024. While illustrative, it broadly aligns with the volume of Next Generation EU (for the entire EU).[12] The stimulus is fully debt-financed, i.e. explicit fiscal adjustments to stabilise the debt ratio only happen in the very long run, beyond our simulation horizon. To isolate the effects of an investment shock on public finances, we turn off endogenous tax rate adjustments through the fiscal rule by setting $dum_t = 0$ in (2.13) for the first 100 years. This approach allows us to transparently assess the extent to which fiscal actions will be necessary to pay for the stimulus.

3.2. THE TRANSMISSION OF PUBLIC INVESTMENT STIMULUS

Public investment shocks affect debt-to-GDP dynamics via two broad channels: the primary balance pb_t, and the snowball effect. The latter can be further split into an *endogenous response* to the fiscal shock by nominal interest rates i_t^g, real GDP growth g_t and inflation π_t on the one hand, and the contribution of the (exogenous) *steady-state* interest-growth differential $i^g - \mathcal{G} \approx r^g - g$ on the other hand.[13] This can be viewed through the lenses of the following decomposition, which is derived in Appendix A:

$$\hat{d}_t = \sum_{k=1}^{t} \Delta d_k = -\sum_{k=1}^{t} (pb_k - pb) + \sum_{k=1}^{t} \underbrace{\frac{i_{k-1}^g - i^g}{(1+\hat{\pi}_k)(1+\hat{g}_k)(1+\mathcal{G})} d_{k-1}}_{\text{endog. interest effect}} - \sum_{k=1}^{t} \underbrace{\frac{\hat{g}_k}{(1+\hat{\pi}_k)(1+\hat{g}_k)} d_{k-1}}_{\text{endog. real growth effect}} -$$

$$- \sum_{k=1}^{t} \underbrace{\frac{\hat{\pi}_k}{1+\hat{\pi}_k} d_{k-1}}_{\text{endog. infl. erosion}} + \sum_{k=1}^{t} \underbrace{\frac{i^g - \mathcal{G}}{1+\mathcal{G}} \left[\frac{d_{k-1}}{(1+\hat{\pi}_k)(1+\hat{g}_k)} - d \right]}_{\text{"steady-state" r-g}}, \tag{3.1}$$

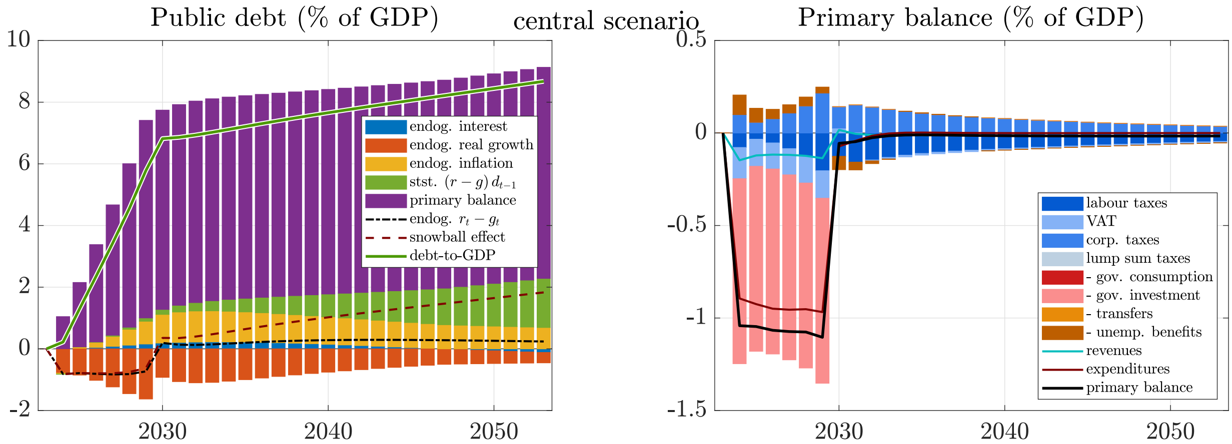
which is a reformulated version of (2.2) in terms of deviation of the debt-to-GDP ratio from its steady state $\hat{d}_t \equiv d_t - d$.[14]

[12] See Pfeiffer, Varga and in 't Veld (2023).

[13] The relationship between the real and nominal formulation of the interest-growth differential is $\frac{i^g - \mathcal{G}}{1+\mathcal{G}} = \frac{r^g - g}{1+g}$, where $\mathcal{G} = (1+g)(1+\pi) - 1$ denotes the trend nominal growth.

[14] The endogenous deviations from trend real GDP growth (g) and trend inflation (π) are $\hat{g}_t = (1+g_t)/(1+g) - 1$ and $\hat{\pi}_t = (1+\pi_t)/(1+\pi) - 1$, respectively.

Figure 3.1: Fiscal effects of a public investment stimulus (central scenario)



Note: The left panel reports pp deviations of public debt-to-GDP from baseline after raising the GDP-share of public investment by 1 pp for six years. Coloured bars depict cumulative contributions to this deviation based on the decomposition shown by (3.1). The endogenous deviation in the interest-growth differential (blue, red, and yellow bars, summing up to the black dash-dotted line) and the term due to the steady-state interest-growth differential (green bars) sum up to the snowball effect (red dashed line). The right panel reports pp deviations of the primary balance-to-GDP ratio from baseline based on (B.1).

Figure 3.1 displays the balance of these various channels on public debt: a temporary increase in government investment, *without offsetting fiscal action*, implies a persistently higher debt-to-GDP ratio on an increasing trajectory.

Primary balance. This result is driven mainly by the cumulative primary deficits that build up while the public investment stimulus lasts (i.e. the purple bars remain large and positive on the left panel of Figure 3.1). Public investment incurs a direct budgetary cost, raising the share of public spending out of GDP (pink bars on the right panel). The impact on other expenditures, such as transfers (e.g. pensions) and government consumption (e.g. public sector wages), hinges on the assumptions about their indexation. In our central scenario, these non-investment expenditures are indexed to output, as detailed in (2.8)-(2.10), implying that their GDP shares stay unchanged (Section 4.1 presents alternative assumptions). While higher growth lowers expenditure on unemployment benefits, this reduction only partly offsets the budgetary costs of the stimulus.

At the same time, total tax revenues (from consumption, labour, and profits) grow roughly in line with GDP, maintaining a relatively stable ratio to GDP, consistent with the budgetary revenue semi-elasticity estimates of close to zero provided by Mourre, Poissonnier and Lausegger (2019) (see also the stylised mapping in Appendix B.2). The tax-to-GDP ratio *declines* slightly only while the stimulus lasts, mainly driven by the VAT channel as the investment share grows at the expense of the consumption share.[15] As a result, the primary balance-to-GDP decreases during the six-year fiscal expansion, and returns very close to its baseline value after the stimulus ends (see right panel of Figure 3.1).

Snowball effects. The snowball term is driven by the interest-growth differential, as interest payments on the outstanding debt stock contribute towards debt accumulation, while higher nominal GDP lowers the debt-to-GDP ratio through a denominator effect. Initially, the snowball term is negative during the public investment stimulus, pulling the debt ratio downwards as higher real GDP reduces the *endogenous component* of the interest-growth differential (red bars in the left panel of Figure 3.1). Real GDP is stimulated directly

[15] Shifts in the tax-to-GDP ratio could also arise from composition effects through varying labour and profit shares to the extent that they are taxed at different rates. This is not the case in the current German calibration of our model (see Table 2.1). Finally, not adjusting the tax brackets of a progressive income tax system along with wage growth could also raise the effective labour tax rate. However, simulations in Motyovszki (2023) indicate that this "fiscal drag effect" is of small quantitative consequence.

(because public investment spending is part of aggregate demand), and indirectly via Keynesian-style multiplier effects on the demand side as well as via persistent productivity effects on the supply side. As public capital enhances the productivity of other production factors, it gradually crowds in private investments, too. This implies a cumulative fiscal investment multiplier of around 1.7 on the 6-year horizon.[16]

However, as supply capacities build up, downward pressures on inflation develop, reversing the initial demand-driven price increase (yellow bars). This effect moderates the rise in nominal GDP, weakening the denominator effect. In addition, monetary policy reacts to the initial inflation in the euro area by raising short-term nominal interest rates. Nonetheless, longer average debt maturities render the rise in the effective government interest rate more gradual and limited (blue bars).[17] As a result, the endogenous component of the snowball term returns to around zero after the stimulus (black dash-dotted line).

In the long run, the positive *steady-state* interest-growth differential $r - g$ becomes the dominant driver of debt-to-GDP (green bars in the left panel of Figure 3.1).[18] As the initial deficits from the stimulus directly raise the debt-to-GDP ratio above its baseline level, long-run interest rates compound faster on this extra debt than trend nominal growth can erode it, putting the overall snowball term on an increasing path (red dashed line).

Overall effects. In sum, while the persistent expansion of real GDP can create some backing for the additional public debt, the direct budgetary costs of the stimulus outweigh this denominator effect. Moreover, as the disinflationary consequences of expanding supply capacities build up, even this denominator effect becomes more muted. In addition, a positive steady-state $r - g$ keeps pushing debt-to-GDP upward, even after the endogenous (and ultimately temporary) effects of the shock on the interest-growth differential fade. Therefore, with insufficient debt stabilisation via the snowball term, public investment stimulus must eventually be paid for by subsequent fiscal adjustments via the primary balance.

Importantly, this result rests on some consequential assumptions, which we will relax in the following section. First, we have a positive steady-state $r-g$. Second, we assume that most non-stimulus public spending grows in line with expanding output, neutralising its effects on the primary balance-to-GDP ratio by construction. This second assumption limits the primary balance's potential endogenous movements following the investment shock. We adopted this approach specifically to isolate the impact of the stimulus on the debt ratio without the confounding effects of fiscal adjustments.

4 ALTERNATIVE SCENARIOS

This section explores alternative scenarios to illuminate key dimensions of fiscal dynamics. Section 4.1 begins by re-evaluating our assumptions regarding the response of the government's non-stimulus expenditure components, which play a crucial role in the dynamics of the primary balance. Sections 4.2 and 4.3 then shed light on the productivity of public capital and steady-state interest-growth differentials, respectively. Finally, Section 4.4 discusses ex-ante budgetary neutral stimulus. In Appendix D, we consider further model extensions, including factors that reduce the short-run multiplier of public investment and scenarios where snowball effects can be driven by debt risk premia.

[16] For the evolution of real GDP under different assumptions for the productivity of investments, see Section 4.2.

[17] Inflation in the rest of the euro area rises due to spillovers from the German stimulus, which boosts demand for imports without enlarging the public capital stock.

[18] The steady-state interest-growth differential ($r - g = 0.8\%$) assumed in our central scenario is the result of a real growth rate of 1.2% and a real interest rate of 2% for gov. bonds, which is consistent with the long-run assumption in the Commission's DSA (European Commission, 2023). Section 4.3 considers alternative assumptions.

4.1. REACTION OF NON-STIMULUS PUBLIC SPENDING

We now consider endogenous changes within the primary balance that are not the result of explicit actions by policymakers, but happen *automatically* in response to the public investment shock. We do this by revisiting our assumptions regarding the reaction of the government's non-stimulus expenditure components. In addition to unemployment benefits, our model features government transfers (e.g. pensions) and government consumption (e.g. public sector wages). Besides our main setting (i), we distinguish two alternative scenarios:

i. **Non-stimulus expenditure items (except unemployment benefits) are linked to GDP** – our central scenario. As GDP grows above baseline after the public investment stimulus, transfers and government consumption increase in line with the additional GDP. Combined with a roughly stable tax-to-GDP ratio, the primary balance does not endogenously adjust much beyond the direct impact of the fiscal shock, in line with the *long-run* assumption in the Commission's DSA of a constant structural primary balance.

ii. **Non-stimulus expenditure components remain constant in real terms** at baseline levels, implying a decline in the government spending share within a growing GDP. While this approach is often used for short-term analysis, it seems more realistic to assume that the fruits of higher GDP would eventually be shared with government employees, pensioners and other transfer recipients in the long run (as in scenario [i.]).

iii. **Mix of the above two scenarios.** Real other expenditures remain constant in the short run while the stimulus lasts, but then gradually catch up to GDP-indexation within 3 years, broadly consistent with established DSA methodologies.[19]

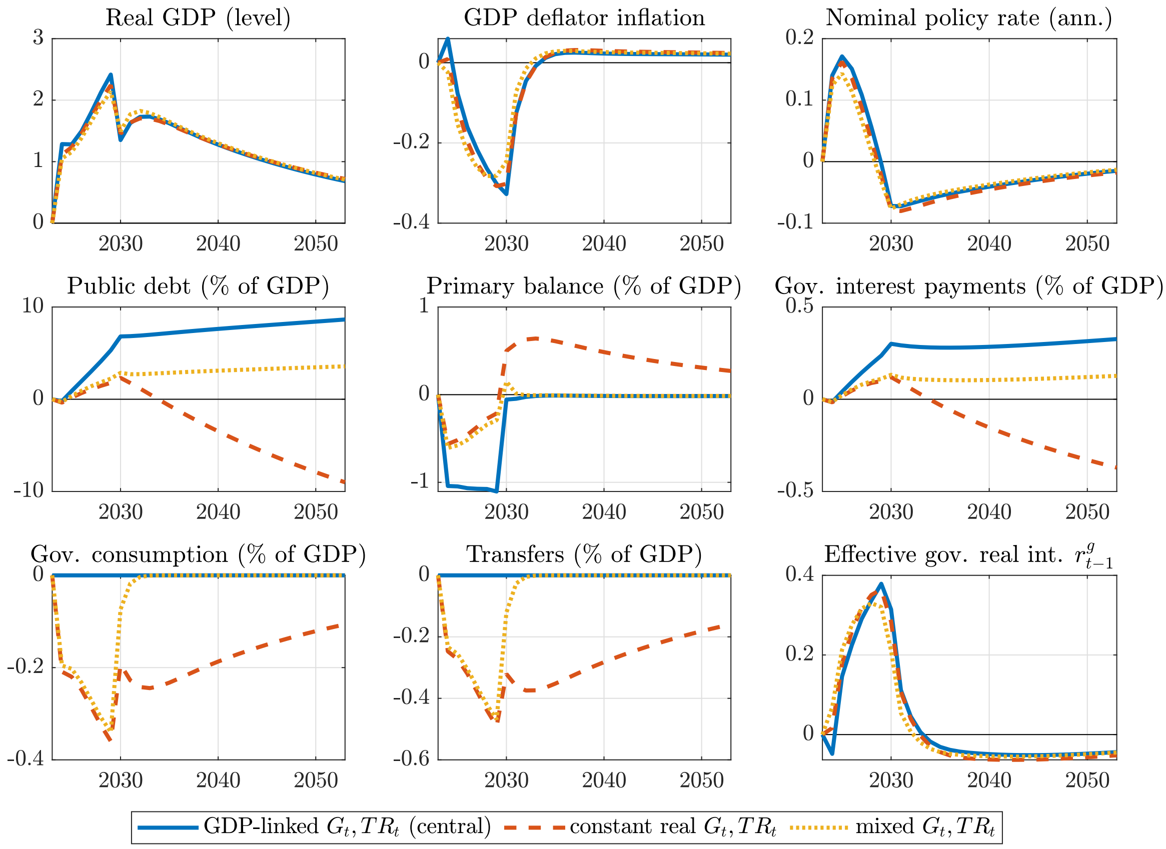
As Figure 4.1 shows, the alternative assumption of constant real spending implies a medium-run reduction in the debt ratio. Compared to the central scenario, the primary balance falls by less during the stimulus phase and rises above baseline once the investment stimulus ends, providing another source of debt stabilisation (red dashed lines). Figure 4.2 illustrates how the decline in debt-to-GDP is driven by the persistently higher primary balance (purple bars on the upper left panel), which in turn is due to government consumption and transfers falling as a share of higher real GDP (red and orange bars in the upper right panel). This indexation thus entails lower budgetary costs relative to our central scenario, where these expenditures grow in line with GDP.

While debt-to-GDP falls below baseline in this alternative scenario, note that this debt reduction results not from negative snowball effects but from increased primary surpluses (achieved by reducing the GDP share of non-stimulus public expenditures). These primary surpluses reflect the fiscal costs needed to reduce debt, underlining that this is not a free lunch. Instead, this scenario represents a fiscal *quasi-consolidation*, marked by a persistent reduction in the GDP share allocated to other spending areas. Consequently, the beneficiaries of these public expenditures, such as pensioners and government employees, see their incomes falling behind the rest of the economy.

This scenario, in effect, corresponds to the implicit assumptions used by Angeletos, Lian and Wolf (2023). Recall that their "self-financing" result relies mainly on a higher income tax base channel, which can pay

[19] In the short run, the European Commission's DSA methodology assumes a positive reaction of the cyclical component of the primary budget balance to a widening positive output gap, mainly driven by the expenditure side (while revenues change roughly in line with GDP), based on the short-run budgetary semi-elasticities reported in (Mourre, Poissonnier and Lausegger, 2019, (Table I.3)). This is consistent with constant expenditures being eroded as a share of GDP in the short run. However, the output gap is assumed to close within 3 years. Therefore, in the long-run, this cyclical component becomes zero by construction, which is broadly in line with our central assumption of GDP-indexed expenditures. Together, the short and long-run elasticities motivate our stylised "mixed" scenario (iii).

Figure 4.1: Indexation of government expenditures ($r - g = 0.8\%, \alpha_g = 0.12$)



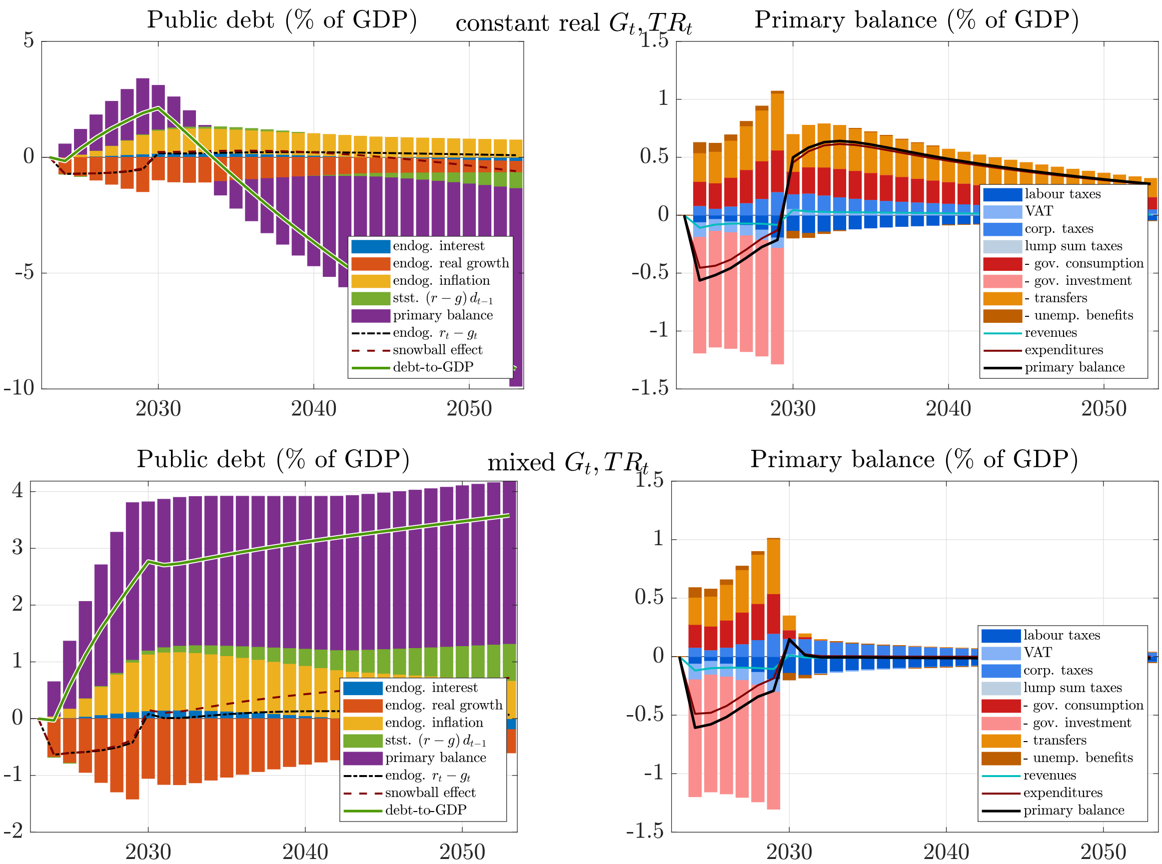
Note: The panels report pp deviations (% deviations for real GDP level) from baseline after raising the GDP-share of public investment by 1 pp for six years. For GDP-linked expenditure (blue), transfers and government consumption grow in line with GDP, while for constant expenditures (red dashed) they are fixed in real terms at their baseline level permanently. The mixed scenario (yellow dotted) keeps these expenditures constant only while the stimulus lasts and then catches up with GDP-indexation within 3 years. All scenarios assume steady-state $r - g = 0.8\%$ and an output elasticity of public capital of $\alpha_g = 0.12$.

for the initial deficit, eliminating the need to subsequently raise tax *rates* or cut expenditure *levels*. But notice how this mechanism operates similarly, via raising primary surpluses (due to collecting more income taxes, while not spending more, in level terms): even if the tax *rate* does not need to be raised (keeping tax-to-GDP constant), the implicit assumption of a fixed level of pre-stimulus spending implies that the GDP-share of those expenditures gets eroded with rising output. So instead of the initial deficit "paying for itself", subsequently higher primary balances reflect the fiscal costs that the stimulus spending entails.

The same argument can be cast equivalently, in *level* terms, which perhaps illustrates the costly nature of this adjustment more intuitively than declining *GDP-shares*. While the level of non-stimulus expenditures remains constant, the level of income taxes increases (as an unchanged tax rate is applied to an expanding tax base), which lowers the *net* income that the private sector receives from the government (transfers and public wages *net* of taxes). Lower net incomes paid by the government reflect the costs associated with the fiscal adjustment.[20] The possibility that private incomes rise even more, offsetting reduced net payouts by the government, does not change the fact that real resources are transferred from the private sector to the fiscal authority. This transfer represents the inherent fiscal cost.

[20]Another perspective is that both tax revenues and expenditures should be assessed in the same terms: either in levels or as a proportion of GDP. One might argue that increased income tax revenues, stemming from higher income without a change in the tax rate, are not inherently costly. However, for consistency, expenditures should then also be accounted for in terms of GDP shares (instead of in level terms). Conversely, one might argue that falling expenditure shares are not inherently costly as long as their real value is preserved, but then taxes, too, should also be considered in level terms, not rates. Both approaches indicate higher primary balances and a costly fiscal adjustment.

Figure 4.2: Fiscal effects of public investment stimulus (different expenditure indexations)



Note: The left panels report pp deviations of public debt-to-GDP from baseline after raising the GDP-share of public investment by 1 pp for six years. Coloured bars depict cumulative contributions to this deviation based on the decompositions shown by (3.1). The endogenous deviation in the interest-growth differential (sum of blue, red and yellow bars, giving the black dash-dotted line) and the term due to the steady-state interest-growth differential (green bars) sum up to the snowball effect (red dashed line). The right panels report pp deviations of the primary balance-to-GDP ratio from baseline based on (B.1). In the upper panels, non-investment public expenditures (transfers and gov. consumption) are assumed to be fixed in real terms. In the lower panels, these expenditures remain constant only while the stimulus lasts, and then catch up with GDP-indexation within 3 years. In all scenarios, the steady-state interest-growth differential is assumed to be $r - g = 0.8\%$. The output elasticity of public capital is our central calibration $\alpha_g = 0.12$.

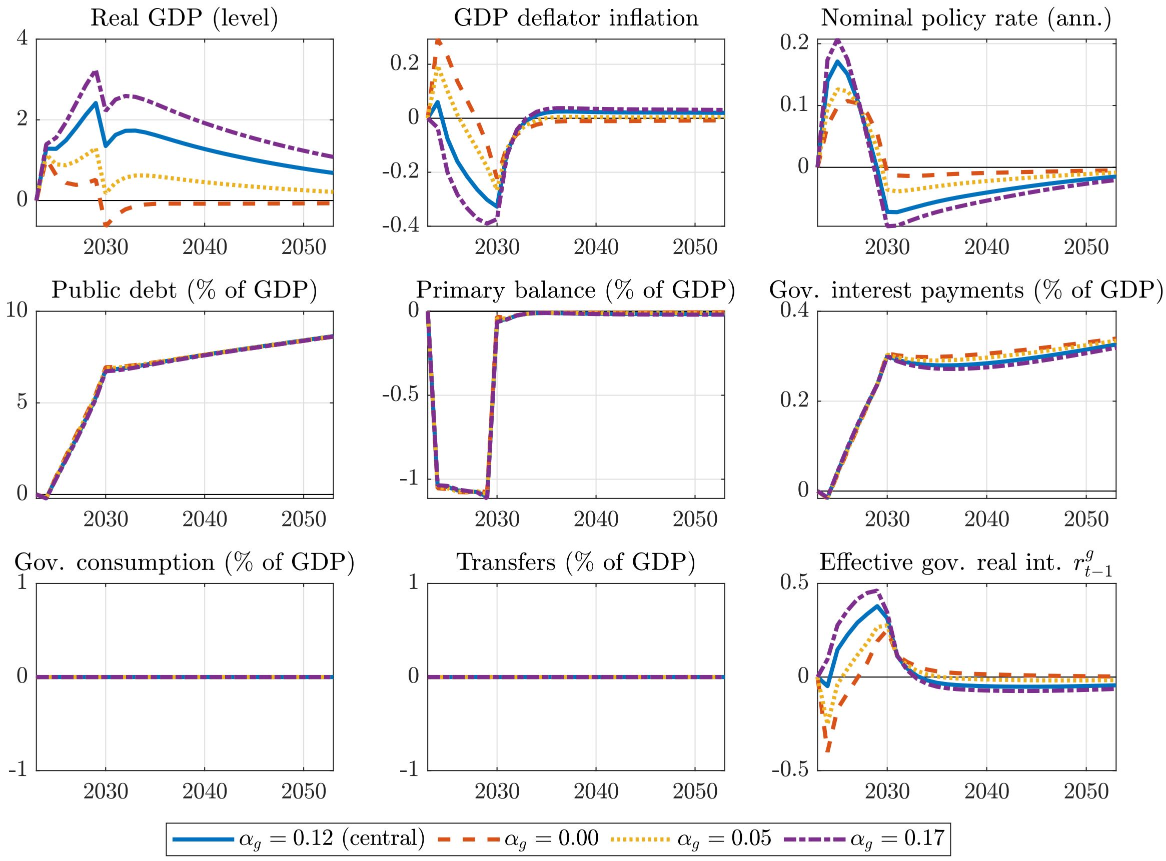
The results from the mixed scenario lie in between the previous two cases. Non-investment public expenditures only gradually catch up to GDP-indexed levels. As a result, the primary balance is initially higher than in the central scenario, limiting the rise in the debt-to-GDP ratio. Over time, however, as public spending catches up with GDP, the primary balance reverts back to our central scenario. As a result the debt ratio remains above the baseline.

4.2. PRODUCTIVITY OF PUBLIC CAPITAL

Since higher GDP is one of the main self-financing channels that could provide backing for the debt arising from the stimulus, this section explores the sensitivity of our results to alternative assumptions about the productivity of public investments. Higher public capital raises output for given inputs (private capital and labour), leading to productivity improvements beyond the demand-side effects of government investments on GDP. As a result, public capital also crowds in private investments, in addition to its direct contribution to expanding supply capacities. Our standard model calibration targets the empirical median estimate (Bom and Ligthart, 2014) for the degree of these productivity improvements, suggesting an output elasticity of public capital, denoted by α_g, of around 0.12.

As Figure 4.3 illustrates, the magnitude and persistence of the output effects are very sensitive to the pro-

Figure 4.3: Productivity of public investments (GDP-linked expenditure, $r - g = 0.8\%$)



Note: The panels report pp deviations (% deviations for real GDP level) from baseline after raising the GDP-share of public investment by 1 pp for six years. Other public expenditure (transfers and government consumption) is assumed to grow in line with GDP. The steady-state interest-growth differential is assumed to be $r - g = 0.8\%$.

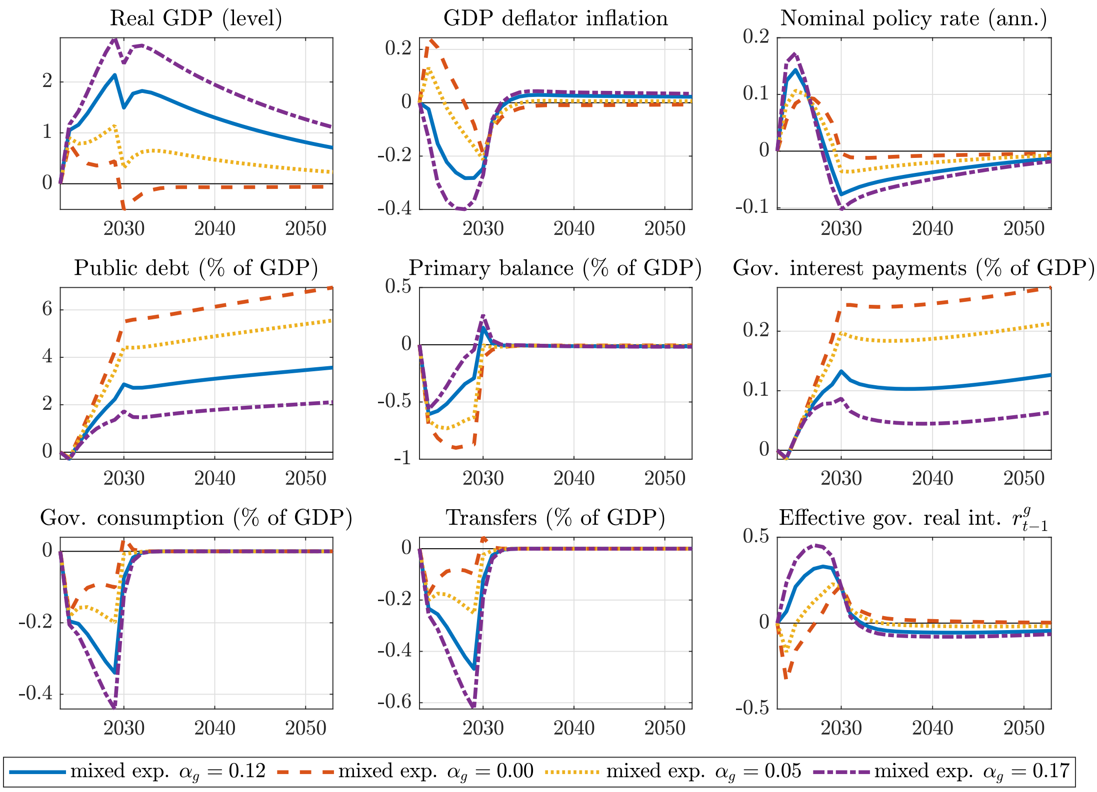
ductivity of public capital. The (undiscounted) cumulative government investment multiplier can range from 0.3 to 5.8 on a 15-year horizon. In the case of unproductive government spending ($\alpha_g = 0$), GDP falls *below* its baseline level immediately after the stimulus ends, as crowding out effects on private consumption and investment persist even after the direct demand boost is gone. In contrast, under our highest productivity scenario ($\alpha_g = 0.17$), GDP gains are still significant even on the 30-year horizon. The exercise also shows that higher productivity leads to more pronounced disinflation via beneficial supply side effects as the productive capacity of the economy expands more.

Despite macroeconomic outcomes being rather different across these scenarios, the implications for fiscal indicators are similar. While significantly higher real GDP in the high-productivity cases pushes the endogenous component of the snowball term downwards, inflation is also lower which offsets most of the gains from higher real growth within the denominator effect. In line with the discussion in Section 3, the primary balance effects are broadly independent of GDP, and therefore similar across these scenarios. While more productive investments can raise corporate income taxes, these are counterbalanced by lower labour income taxes stemming from a declining labour share (the mirror image of rising profit shares). Consequently, the trajectories for debt-to-GDP are almost identical under differing assumptions about investment productivity.

Importantly, this result hinges on assuming that non-stimulus spending grows in line with GDP, as in our central scenario. Under alternative expenditure indexation rules, higher public investment productivity leads to more favourable fiscal outcomes.

Figure 4.4 illustrates the impact of different productivity assumptions when non-stimulus expenditure catches up with output only gradually (scenario (iii.) in Section 4.1). In this case, the primary balance reflects the positive GDP effects of more productive public investments. Specifically, the delayed catch-up of non-stimulus spending results in a declining expenditure share within a growing GDP. With more productive public investments, and correspondingly higher GDP multipliers, this channel is more forceful, pushing the primary balance upwards to a larger extent, and therefore contributing to lower debt-to-GDP ratios.[21] Note that better debt stabilisation, in this case, is driven not by more beneficial snowball effects stemming from higher productivity, but rather by a more pronounced fiscal quasi-consolidation via the primary balance, as higher growth leads to stronger erosion of non-stimulus spending items.

Figure 4.4: Productivity of public investments ("mixed" expenditure, $r - g = 0.8\%$)



Note: The panels report pp deviations (% deviations for real GDP level) from baseline after raising the GDP-share of public investment by 1 pp for six years, for different values of the productivity of public capital. Other public expenditure (transfers and government consumption) is assumed to be constant in real terms while the stimulus lasts, then catch up with GDP indexation within 3 years.

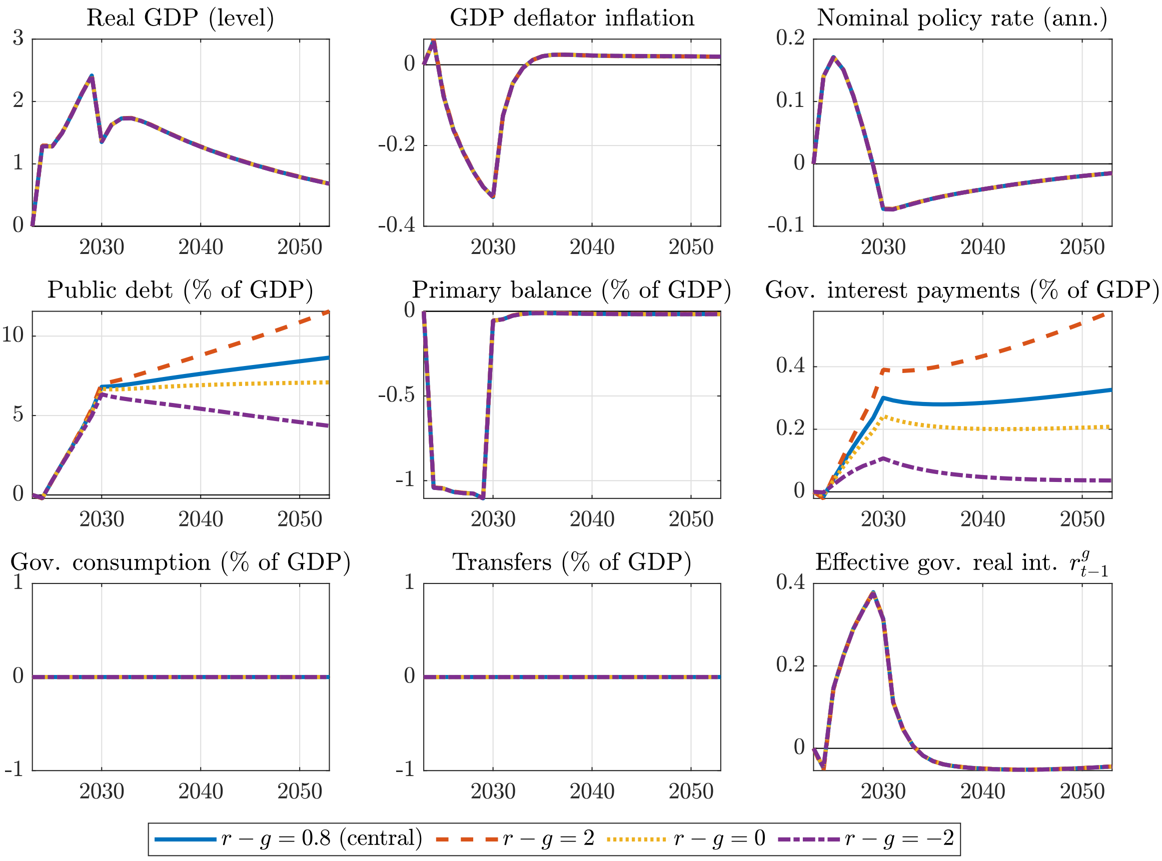
4.3. STEADY-STATE INTEREST-GROWTH DIFFERENTIALS

The steady-state interest-growth differential $(r - g)$ has important fiscal consequences. In recent years, the real growth rate has often exceeded the real interest rate on government debt, opening up the possibility to "outgrow" public debt without raising primary surpluses (Blanchard, 2019). Put differently, the debt ratio tends to revert to its baseline level after a deficit-financed stimulus, even without subsequent fiscal adjustments, if the interest rate paid on government debt is persistently below the trend GDP growth rate.[22] To explore the implications of different long-run interest-growth differentials, we run simulations with alternative assumptions for the steady-state value of $r - g$.

[21] These effects are more substantial if we assume constant non-stimulus expenditure due to the highly persistent quasi-consolidation. See Figure, C.3 in the Appendix.

[22] In terms of (2.2), the debt-to-GDP ratio becomes akin to a stationary AR(1) process with an autoregressive coefficient below unity, which has the mean-reversion property. As a result, and as pointed out by Blanchard (2019), in addition to reverting to its baseline level after a *temporary* increase in the primary deficit $(pb_t - pb)$, debt-to-GDP exhibits similarly stable dynamics even after a *permanent* increase in the primary deficit pb – converging to a stable, although higher, new steady state. Rearranging (2.2), we

Figure 4.5: Steady-state $r - g$ differential (GDP-linked expenditure, $\alpha_g = 0.12$)



Note: The panels report pp deviations (% deviations for real GDP level) from baseline after raising the GDP-share of public investment by 1 pp for six years, for different values of the steady-state interest-growth differential $r - g$. Other public expenditure (transfers and government consumption) is assumed to grow in line with GDP, and the output elasticity of public capital is assumed to be $\alpha_g = 0.12$.

As Figure 4.5 shows, for different values of $r - g$, the trajectories of debt-to-GDP start strongly diverging after the public investment stimulus ends. In contrast, the endogenous response of macroeconomic variables (which primarily reflect *deviations from* steady state) is not affected by varying steady-state $r - g$. Figure 4.6 also makes it clear that the differences are solely due to the steady-state component of the snowball effect (green bars), while the endogenous component of the snowball effect (black dash–dotted line) and the contribution of the primary balance are nearly identical across these scenarios.

A negative steady-state $r - g$ differential leads to a declining debt-to-GDP trajectory after the public investment stimulus ends. As r remains permanently below g, the economy can gradually outgrow the deficit-induced extra debt, which converges back to its pre-stimulus level (purple dash-dotted lines in Figure 4.5). These dynamics result from cumulating negative snowball effects (green bars on the bottom right panel of Figure 4.6): a negative steady-state interest-growth differential enables the economy to "outgrow" the additional debt incurred from the initial stimulus spending. However, while the negative $r - g$ ensures that the debt ratio eventually returns to its baseline, the process unfolds very gradually. As a result, even under the very negative $r - g = -2\%$ assumption, the debt-to-GDP ratio remains still significantly higher after 30 years.

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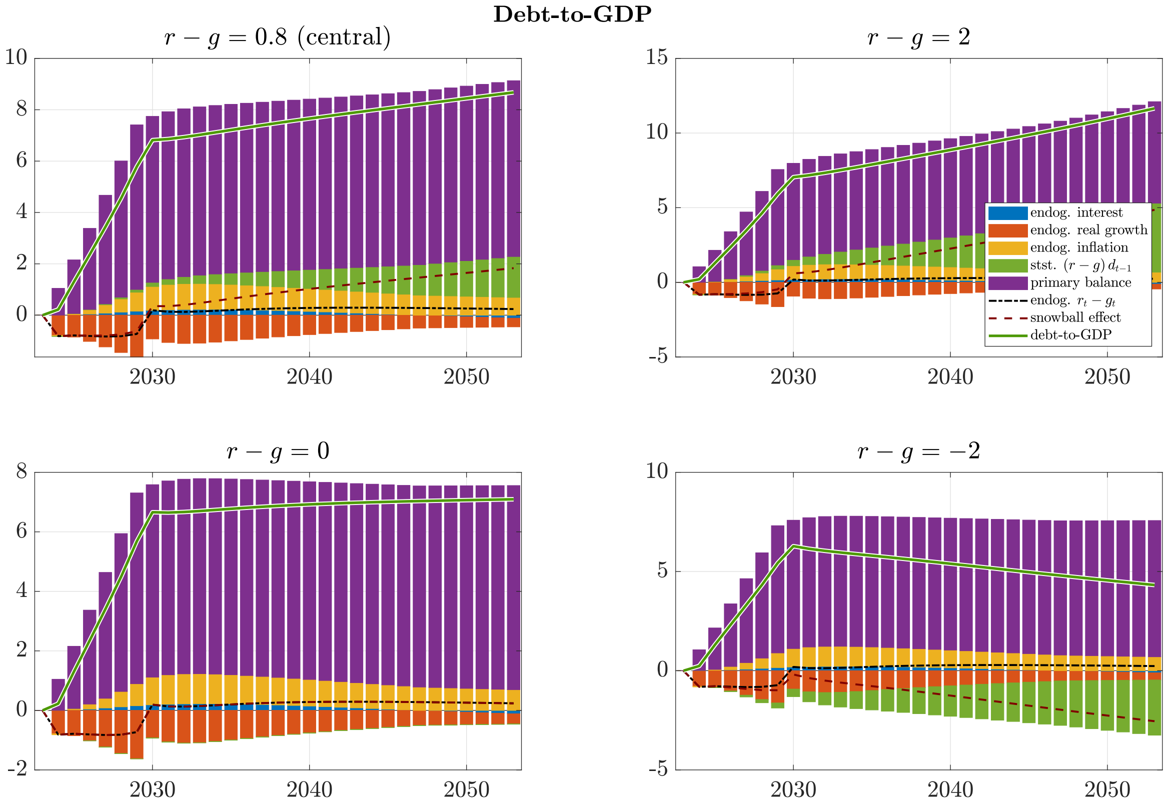
have the familiar AR(1) formulation:

$$d_t = \frac{1+r}{1+g} d_{t-1} + \left(1 - \frac{1+r}{1+g}\right) \underbrace{\frac{pb}{r-g}(1+g)}_{d} - (pb_t - pb)$$

Figure 4.6: Debt-to-GDP after a public investment stimulus (different steady-state $r-g$)



Note: The panels report pp deviations of public debt-to-GDP from baseline after raising the GDP-share of public investment by 1 pp for six years, for different values of the steady-state interest-growth differential $r-g$. The coloured bars represent cumulative contributions to this deviation, based on the decomposition provided in (3.1). The endogenous deviation in the interest-growth differential (sum of blue, red and yellow bars, giving the black dash-dotted line) and the term due to the steady-state interest-growth differential (green bars) sum up to the snowball effect (red dashed line). Other public expenditure (transfers and government consumption) is assumed to grow in line with GDP, and the output elasticity of public capital is assumed to be $\alpha_g = 0.12$.

These effects are mostly independent of the productivity of public investment. With a negative $r-g$ differential, debt-to-GDP would eventually converge back to its baseline level even after completely unproductive spending (see Figure C.1 in Annex C). Here, the debt reduction is achieved not through the endogenous boost to GDP by the fiscal shock, but via a negative steady-state interest-growth differential which operates independently of the stimulus.[23]

The scenario with steady-state $r-g=0$ is instructive as it isolates the effects of the endogenous macroeconomic response after a public investment stimulus. Figure 4.5 shows that, in this case, debt-to-GDP is broadly stable and increases only slightly over the medium run (yellow dotted lines). With the steady-state snowball component set to zero by construction (no green bars in the lower left panel of Figure 4.6), this is entirely due to the endogenous effects of the investment stimulus.[24] However, these effects eventually vanish, and debt-to-GDP remains above its baseline.[25]

[23]Therefore, this mechanism applies not only for unproductive government consumption but also for fiscal measures that do not entail *any* beneficial endogenous reaction in the snowball term (e.g. transfers that are fully saved by households, eliminating any GDP multiplier effect).

[24]For given tax rates, the primary balance remains slightly below the baseline. The snowball term adds a further marginally positive contribution to the debt ratio: Nominal GDP falls slightly *below* baseline due to the disinflationary effects of expanding supply capacities.

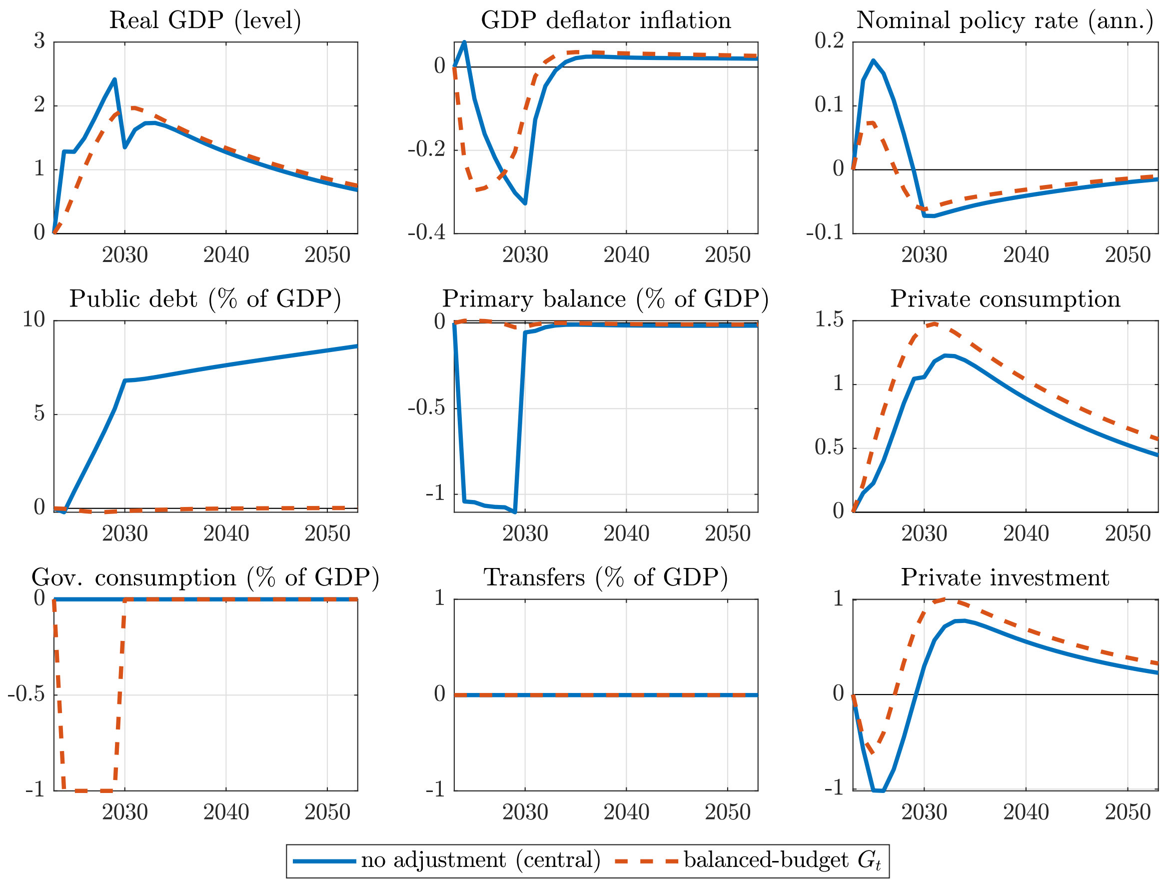
[25]These alternative scenarios illustrate the consequences of various steady-state $r-g$ assumptions in our model. These scenario results are set against a constant steady state which comprises the "no-investment" baseline. However, in reality even this baseline could feature fluctuating interest-growth differentials. For example, interest-growth differentials might be low today, converging slowly to their higher long-run values. Our analysis has not ventured into constructing more intricate or stochastic scenarios to

4.4. EX-ANTE BUDGETARY-NEUTRAL STIMULUS

So far, we have focused on the fiscal costs of debt-financed public investments, with at most *implicit* fiscal adjustments. We now consider an ex-ante budgetary-neutral public investment stimulus. These simulations explore how the macroeconomic effects of public investments would evolve if *explicit* fiscal adjustments are implemented to directly cover the cost of the stimulus and stabilise the debt ratio.

In this scenario, all else equal, a temporary cut in government consumption exactly offsets the costs of the stimulus (1% of GDP). However, after implementation, the different endogenous responses of tax revenues and the broader macroeconomic transmission generate ex-post effects on public finances. All other simulation assumptions (interest-growth differential, productivity of public capital and the endogenous reaction of other expenditure items) remain as in our central scenario.

Figure 4.7: Explicit fiscal adjustments ($r - g = 0.8\%, \alpha_g = 0.12$)



Note: The panels report pp deviations (% deviations for real GDP level) from baseline after raising the GDP-share of public investment by 1 pp for six years. For GDP-linked expenditure (blue), transfers and government consumption grow in line with GDP. Simulations with explicit fiscal adjustments to *ex-ante* cover the cost of the investment stimulus can happen by cutting gov. consumption (red dashed). All scenarios assume that in steady-state $r - g = 0.8\%$ and an output elasticity of public capital of $\alpha_g = 0.12$.

As Figure 4.7 shows, this explicit fiscal adjustment (or spending prioritisation) implies that the debt ratio remains broadly stable (red dashed lines). At the same, this adjustment only entails moderate sacrifices in terms of real GDP in the short run and maintains most of the medium to long-run gains. Private consumption and investment are even higher, due to smaller crowding out effects. In this scenario, the net demand-side effect of the stimulus is zero: without spending more in aggregate terms, the government implements a fiscally neutral shift from unproductive towards productivity-enhancing spending. Therefore, the macroeconomic effects in this scenario isolate the supply-side effects of public investments.

capture this variability.

These results suggest that, while public investments need to be paid for in a fiscal sense, they are compatible with debt sustainability in a way that preserves their growth-enhancing effects. However, a complete assessment of such policies should explicitly consider the qualitative aspects of government consumption, e.g., utility-enhancing services, and address distributional concerns. These considerations imply more challenging trade-offs for policymakers, underscoring the potential costliness of the required fiscal adjustments.

4.5. MODEL EXTENSIONS: DEBT-ELASTIC RISK PREMIA AND IMPLEMENTATION DELAYS

In the Appendix, we extend our analysis along two dimensions. Appendix D.1 analyses debt-elastic risk premia, illustrating how, without fiscal adjustment, increasing interest costs can trigger a self-reinforcing loop of higher debt and risk premia. Yet, given the model calibration and excluding nonlinearities, these effects only build up gradually over time.

Appendix D.2 shows that implementation delays in government investment significantly dampen the short-run multiplier effect, though the long-term fiscal indicators align broadly with those from our central analysis.

5 CONCLUDING REMARKS

The widespread consensus on the need for increased public investment underscores the importance of assessing its implications for public finances. Employing a quantitative structural model that captures rich fiscal dynamics, we analyse the effects of a temporary surge in public investment. Without corresponding fiscal adjustments, such investment leads to a long-lasting rise in the debt-to-GDP ratio, indicating that such investments do not inherently pay for themselves. Apart from scenarios with sustained negative interest-rate growth differentials ($r - g$), which ensure that debt-to-GDP reverts to its baseline level, subsequently higher primary balance adjustments are critical to ensure debt sustainability. We highlight the role of both implicit and explicit fiscal adjustments through different revenue and expenditure components.

Our analysis focuses exclusively on the fiscal consequences of public investment, avoiding normative assessments. The necessity for public investments to be paid for via subsequent primary surpluses does not diminish their potential to enhance societal welfare. This could especially be true for investments that facilitate the green transition and contribute towards avoiding extreme climate scenarios. Ifthe future return on productive investments in terms of extra output per working hour is larger than the consumption and leisure time sacrifice that has to be made in the present to undertake the investment, this would make society better off even if the investments entail a narrowly-defined fiscal cost. Analysing such welfare implications are an important area for further research that the current paper has not ventured into.

In addition, properly accounting for the potential returns on climate investments would require a different framework. Our simulation results are expressed relative to a benign steady state, while in the case of green investments the relevant counterfactual should arguably feature more drastic climate damages. The choice of steady state could affect model dynamics, and hence our results, in a non-linear way. Our current analyis can only capture these additional environmental benefits in a stylised way via varying the productivity of public capital.

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Appendix

A DEBT DYNAMICS AND DECOMPOSITION

The debt-to-GDP ratio $d_t \equiv \frac{B_t}{P_t Y_t}$ follows the dynamic:

$$B_t = -PB_t + (1 + i^g_{t-1})B_{t-1}$$

$$d_t = -pb_t + \underbrace{\left(\frac{1 + i^g_{t-1}}{1 + \pi_t}\right)}_{\equiv 1 + r^g_t} \frac{1}{1 + g_t}\, d_{t-1} \tag{A.1}$$

$$\Delta d_t \equiv d_t - d_{t-1} = -pb_t + \frac{r^g_t - g_t}{1 + g_t}\, d_{t-1} \tag{A.2}$$

where the differential $(r^g_t - g_t)$ drives the **"snowball effect"**. The usual decomposition for the snowball term looks like:

$$\Delta d_t = \underbrace{-pb_t + \underbrace{\frac{i^g_{t-1}}{(1+\pi_t)(1+g_t)}\, d_{t-1}}_{\text{interest costs}}}_{-\text{budget balance-to-GDP}} \underbrace{- \underbrace{\frac{g_t}{(1+\pi_t)(1+g_t)}\, d_{t-1}}_{\text{real growth effect}} - \underbrace{\frac{\pi_t}{1+\pi_t}\, d_{t-1}}_{\text{inflation erosion}}}_{-\frac{\mathcal{G}_t}{1+\mathcal{G}_t} d_{t-1}\text{: denominator effect}} \tag{A.3}$$

$$\hat{d}_t \equiv \sum_{k=1}^{t} \Delta d_k = -\sum_{k=1}^{t} pb_k + \sum_{k=1}^{t} \frac{i^g_{k-1}}{(1+\pi_k)(1+g_k)}\, d_{k-1} - \sum_{k=1}^{t} \frac{g_k}{(1+\pi_k)(1+g_k)}\, d_{k-1} - \sum_{k=1}^{t} \frac{\pi_k}{1+\pi_k}\, d_{k-1} \tag{A.4}$$

Separating the role of **steady state and endogenous movements** in the interest-growth differential:

$$\Delta d_t = d_t - d_{t-1} = -pb_t + \left(\frac{1 + i^g_{t-1}}{(1+\hat{\pi}_t)(1+\hat{g}_t)(1+\mathcal{G})} - 1\right) d_{t-1} =$$

$$= -(pb_t - pb) + \underbrace{\frac{i^g_{t-1} - i^g}{(1+\hat{\pi}_t)(1+\hat{g}_t)(1+\mathcal{G})}\, d_{t-1}}_{\text{endog. interest effect}} - \underbrace{\frac{\hat{g}_t}{(1+\hat{\pi}_t)(1+\hat{g}_t)}\, d_{t-1}}_{\text{endog. real growth effect}} -$$

$$- \underbrace{\frac{\hat{\pi}_t}{1+\hat{\pi}_t}\, d_{t-1}}_{\text{endog. infl. erosion}} + \left[-pb + \underbrace{\frac{i^g - \mathcal{G}}{(1+\hat{\pi}_t)(1+\hat{g}_t)(1+\mathcal{G})}\, d_{t-1}}_{\text{"steady-state" snowball effect}}\right] \tag{A.5}$$

Cumulating (A.5) and writing it in terms of ***deviation from the steady state***, using $\Delta d = -pb + \frac{i^g - \mathcal{G}}{1+\mathcal{G}} d = 0$:

$$\hat{d}_t = \sum_{k=1}^{t} (\Delta d_k - \Delta d) = -\sum_{k=1}^{t} (pb_k - pb) + \sum_{k=1}^{t} \underbrace{\frac{i^g_{k-1} - i^g}{(1+\hat{\pi}_k)(1+\hat{g}_k)(1+\mathcal{G})}\, d_{k-1}}_{\text{endog. interest effect}} - \sum_{k=1}^{t} \underbrace{\frac{\hat{g}_k}{(1+\hat{\pi}_k)(1+\hat{g}_k)}\, d_{k-1}}_{\text{endog. real growth effect}} -$$

$$- \sum_{k=1}^{t} \underbrace{\frac{\hat{\pi}_k}{1+\hat{\pi}_k}\, d_{k-1}}_{\text{endog. infl. erosion}} + \sum_{k=1}^{t} \underbrace{\frac{i^g - \mathcal{G}}{1+\mathcal{G}} \left[\frac{d_{k-1}}{(1+\hat{\pi}_k)(1+\hat{g}_k)} - d\right]}_{\text{"steady-state" r-g}} \tag{A.6}$$

where (A.6) is identical to (3.1) in the main text, and is also the formula used for our debt decomposition charts. The notation is as follows:

- Y_t denotes the level of real GDP, the actual real GDP growth rate being $g_t = \frac{Y_t}{Y_{t-1}} - 1$, while the endogenous deviation from trend growth g is $\hat{g}_t = (1+g_t)/(1+g) - 1$.
- P_t denotes the level of GDP deflator, its actual rate of inflation being $\pi_t = \frac{P_t}{P_{t-1}} - 1$, while the endogenous deviation from trend inflation π is $\hat{\pi}_t = (1+\pi_t)/(1+\pi) - 1$.
- The gross growth rate of actual nominal GDP is $(1+\mathcal{G}_t) = (1+g_t)(1+\pi_t) = (1+\hat{g}_t)(1+\hat{\pi}_t)(1+\mathcal{G})$, where trend nominal growth is $\mathcal{G} = (1+g)(1+\pi) - 1$.
- The effective nominal interest rate on government bonds is $i_t^g = \rho_d i_{t-1}^g + (1-\rho_d)i_t$, where i_t is the short term monetary policy rate, and $\frac{1}{1-\rho_d}$ is the average maturity of public debt.
- Nominal local currency government bonds are denoted by B_t, while $d_t = \frac{B_t}{P_t Y_t}$ denotes the debt-to-GDP ratio, and $\hat{d}_t = d_t - d$ is its deviation from steady state. In the steady-state d is stabilised, so $\Delta d = -pb + \frac{i^g - \mathcal{G}}{1+\mathcal{G}} d = 0$.
- The relationship between the real and nominal formulation of the interest-growth differential is $\frac{i^g - \mathcal{G}}{1+\mathcal{G}} = \frac{r^g - g}{1+g}$.
- The nominal primary balance is PB_t, with $pb_t = \frac{PB_t}{P_t Y_t}$ denoting the primary balance as a share of GDP.

B PRIMARY BALANCE DYNAMICS

B.1. QUEST

The nominal primary budget balance PB_t is the difference between the government's nominal revenues REV_t and non-interest nominal expenditures EXP_t, the GDP share of which is denoted $rev_t = \frac{REV_t}{P_t Y_t}$ and $exp_t = \frac{EXP_t}{P_t Y_t}$:

$$pb_t = rev_t - exp_t \tag{B.1}$$

$$exp_t = \frac{P_t^C (G_t + I_t^G)}{P_t Y_t} + \frac{TR_t}{P_t Y_t} + \frac{BEN_t}{P_t Y_t} \tag{B.2}$$

$$rev_t = \tau_t^L (W_t) \frac{W_t L_t}{P_t Y_t} + \tau_t^{VAT} \frac{P_t^C C_t}{P_t Y_t} + \tau^k \frac{\sum_j profits_t^j}{P_t Y_t} + \frac{T_t}{P_t Y_t} \tag{B.3}$$

which are the equations used for primary balance decomposition charts in the main text, but expressed in terms of deviations from the steady state.

B.2. MULTIPLIERS AND SEMI-ELASTICITIES – MAPPING TO QUEST ASSUMPTIONS

The dynamics of the primary balance-to-GDP ratio depend on the assumptions about the behaviour of individual expenditure and revenue items. These are often captured with "budgetary semi-elasticities". While these are not exogenous input parameters to QUEST, but rather (non-constant) outcomes, we can map certain model assumptions into them. Take the following very stylised example for illustrative purposes.

What is the effect of an increase in government investment on the primary balance to GDP ratio, once endogenous effects on GDP and tax revenues are taken into account?

- the steady-state tax share is $\tau = \frac{T}{Y}$, while the public investment share is $\varphi = \frac{I^G}{Y}$, and for remaining government expenditures $\gamma = \frac{G+TR+BEN}{Y}$
- public investment rises by $\alpha = \frac{\Delta I_t^G}{Y}$ percent of steady-state GDP
- this raises GDP via a multiplier of $\mu = \frac{\Delta Y_t}{\Delta I_t^G}$

- tax revenues rise with GDP governed by $\epsilon = \frac{\Delta T_t}{\Delta Y_t}$
- remaining government expenditures change according to: $\eta = \frac{\Delta(G_t + TR_t + BEN_t)}{\Delta Y_t}$ (for notational brevity, from now on lump them together under the label G_t)
- assume prices are fixed at $P = 1$ (or equivalently, that everything is in real terms)

$$PB_t = \underbrace{T + \overbrace{\epsilon\,\Delta Y_t}^{\Delta T_t}}_{T_t} - \underbrace{\left(G + \overbrace{\eta\,\Delta Y_t}^{\Delta G_t}\right)}_{G_t} - \underbrace{\left(I^G + \Delta I_t^G\right)}_{I_t^G} =$$

$$= \underbrace{T - G - I^G}_{PB} + (\epsilon - \eta)\,\underbrace{\mu\,\Delta I_t^G}_{\Delta Y_t} - \Delta I_t^G =$$

$$\Delta PB_t = PB_t - PB \;=\; \Big[(\epsilon - \eta)\,\mu - 1\Big]\Delta I_t^G \tag{B.4}$$

which shows that *in level terms*, the primary balance improves depending on $\Big[(\epsilon - \eta)\,\mu - 1\Big] > 0$. However, that does not necessarily mean that the primary balance also improves *as a share of GDP*:

$$\Delta pb_t \equiv \frac{PB_t}{Y_t} - \frac{PB}{Y} = \underbrace{\frac{T + \epsilon\,\mu\,\Delta I_t^G}{Y + \underbrace{\mu\,\Delta I_t^G}_{\Delta Y_t}}}_{T_t/Y_t} - \underbrace{\frac{G + \eta\,\mu\,\Delta I_t^G}{Y + \underbrace{\mu\,\Delta I_t^G}_{\Delta Y_t}}}_{G_t/Y_t} - \underbrace{\frac{I^G + \Delta I_t^G}{Y + \underbrace{\mu\,\Delta I_t^G}_{\Delta Y_t}}}_{I_t^G/Y_t} - \underbrace{\left(\frac{T}{Y} - \frac{G}{Y} - \frac{I^G}{Y}\right)}_{\frac{PB}{Y}}$$

$$= \frac{\overbrace{\tau\,Y}^{T} + \epsilon\,\mu\,\overbrace{\alpha\,Y}^{\Delta I_t^G}}{Y + \mu\,\alpha\,Y} - \frac{\overbrace{\gamma\,Y}^{G} + \eta\,\mu\,\overbrace{\alpha\,Y}^{\Delta I_t^G}}{Y + \mu\,\alpha\,Y} - \frac{\overbrace{\varphi\,Y}^{I^G} + \overbrace{\alpha\,Y}^{\Delta I_t^G}}{Y + \mu\,\alpha\,Y} - \Big(\tau - \gamma - \varphi\Big) =$$

$$= \left[\frac{\tau + \epsilon\,\mu\,\alpha}{1 + \mu\,\alpha} - \tau\right] - \left[\frac{\gamma + \eta\,\mu\,\alpha}{1 + \mu\,\alpha} - \tau\right] - \left[\frac{\varphi + \alpha}{1 + \mu\,\alpha} - \varphi\right] =$$

$$= \underbrace{\frac{\alpha}{1 + \mu\,\alpha}\,\mu\Big[\epsilon - \tau\Big]}_{\frac{T_t}{Y_t} - \frac{T}{Y}} - \underbrace{\frac{\alpha}{1 + \mu\,\alpha}\,\mu\Big[\eta - \gamma\Big]}_{\frac{G_t}{Y_t} - \frac{G}{Y}} - \underbrace{\frac{\alpha}{1 + \mu\,\alpha}\Big[1 - \mu\,\varphi\Big]}_{\frac{I_t^G}{Y_t} - \frac{I^G}{Y}} =$$

$$= \frac{\alpha}{1 + \mu\,\alpha}\left(\mu\Big[(\epsilon - \tau) - (\eta - \gamma) + \varphi\Big] - 1\right) \tag{B.5}$$

- (B.5) for the GDP share is a slightly different condition than (B.4) in level terms, and is also somewhat harder to turn positive if we start from a primary surplus $pb = \tau - \gamma - \varphi > 0$:

$$\mu\Big[(\epsilon - \tau) - (\eta - \gamma) + \varphi\Big] - 1 = \Big[\mu\,(\epsilon - \eta) - 1\Big] - \mu\,(\tau - \gamma - \varphi)$$

Note that in QUEST the objects ϵ, η, μ are not exogenous input parameters, but are rather endogenous outcomes that result from the general equilibrium interactions within the model economy, depending on deep structural features and the type of shocks. That said, we can provide an approximate mapping on the main assumptions which drive these outcomes:

- <u>**Tax revenues**</u> stay roughly stable *as a share of GDP* governed by the approximate semi-elasticity $\epsilon - \tau \approx 0$.[26]

[26] The precise revenue semi-elasticity in terms of the above notation is $\frac{T_t/Y_t - T/Y}{(\Delta Y_t)/Y} = \frac{1}{1+\mu\,\alpha}\Big[\epsilon - \tau\Big]$

- For a fully proportional tax system levied only on income (i.e. GDP) we would have exactly $\epsilon = \tau$, so tax revenues would not change as a share of GDP
- In reality $\epsilon \neq \tau$ due to e.g. income tax progressivity. In addition, there might be compositional effects depending on how the labour vs capital/profit share responds, to the extent that labour incomes and profit are taxed at different rates. Furthermore, via the expenditure side, due to consumption taxation (VAT), a change in the consumption share of GDP would also affect the GDP share of tax revenues.
- Ex ante, without knowing the type of shock, $\epsilon \approx \tau$ might be a good approximation, which is also in line with the estimates in Table I.3 of Mourre, Poissonnier and Lausegger (2019), and is also born out by our model simulations presented in the main text: it is *not* the tax revenue share that is the main driver of primary balance-to-GDP fluctuations.

• **Stimulus spending:** The primary balance to GDP ratio is driven more by changes in the spending share. The direct contribution of the public investment stimulus is substantially negative for reasonable multipliers, as governed by $1 - \mu\varphi$.

- The steady-state GDP-share of public investment is around $\varphi \approx 3\%$, so we would need an unrealistically high investment multiplier of $\mu > 30$, which is by far not the case, even in our most optimistic scenarios. The term is therefore substantially positive, contributing to lower the primary balance-to-GDP ratio.
- The multiplier is influenced among others by the productivity of public capital (α_g), by the share of liquidity-constrained households, by crowding out effects depending on the reaction of monetary policy, the starting cyclical position of the economy when the shock hits, or the initial capital-output ratio that affects marginal productivity.
- Our central simulation scenario implies an investment multiplier of around 1.7 on a 6-year horizon, which is already on the optimistic side of other estimates.

• **Other expenditures** as a share of GDP might change substantially depending on the approximate semi-elasticity $\eta - \gamma$. This is also the relevant indicator for the "denominator effects" of higher GDP that persist beyond the stimulus.[27] As shown below, and by our sensitivity analysis in the main text, this is a very consequential assumption for primary balance dynamics.

- Our central simulation scenario, that assumes other expenditures grow in line with GDP, corresponds to $\eta - \gamma = 0$. Therefore, other expenditures do not contribute to changes in the primary balance-to-GDP ratio by design. This assumption seems realistic in the medium to long run.
- Our alternative scenario with other spending held constant, corresponds to $\eta = 0$, resulting in $\eta - \gamma = -\gamma$, meaning that expenditures are eroded as a share of higher GDP which contribute to higher primary balance-to-GDP ratios. This assumption is used in debt sustainability analysis (DSA) for the short term, and is also in line with the estimates reported in Table I.3 of Mourre, Poissonnier and Lausegger (2019). However, this assumption does not seem realistic in the long run (and is not used by the DSA either beyond 3 years[28]), as it would mean that the GDP-share of

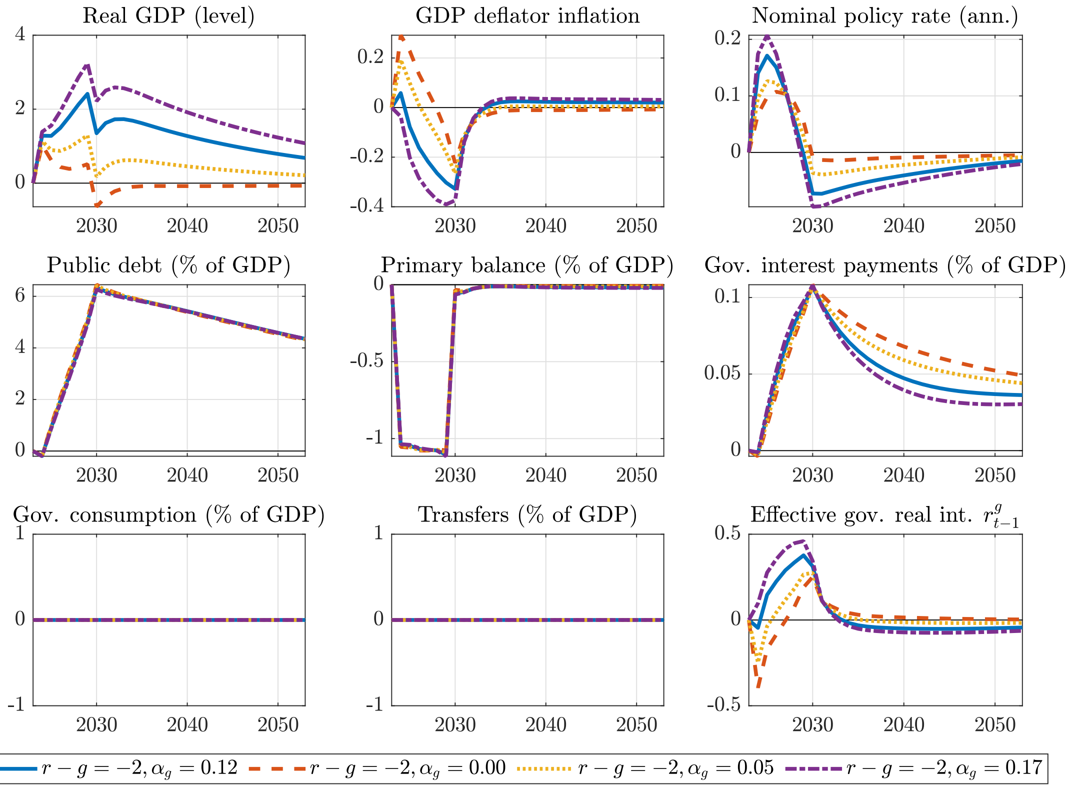
[27] The precise expenditure semi-elasticity in terms of the above notation is $\frac{G_t/Y_t - G/Y}{(\Delta Y_t)/Y} = \frac{1}{1+\mu\,\alpha}\left[\eta - \gamma\right]$, but more in general, for a GDP-deviation of $\beta = \frac{\Delta Y_t}{Y}$, we have $\frac{G_t/Y_t - G/Y}{(\Delta Y_t)/Y} = \frac{1}{1+\beta}\left[\eta - \gamma\right]$.

[28] In the DSA methodology this semi-elasticity is applied to the *output gap*, which in turn is assumed to close within 3 years, so there would not be any effects beyond that horizon.

important spending items (pensions, public sector wages) is persistently eroded, and the recipients of these expenditures would see their income falling behind the rest of the economy.

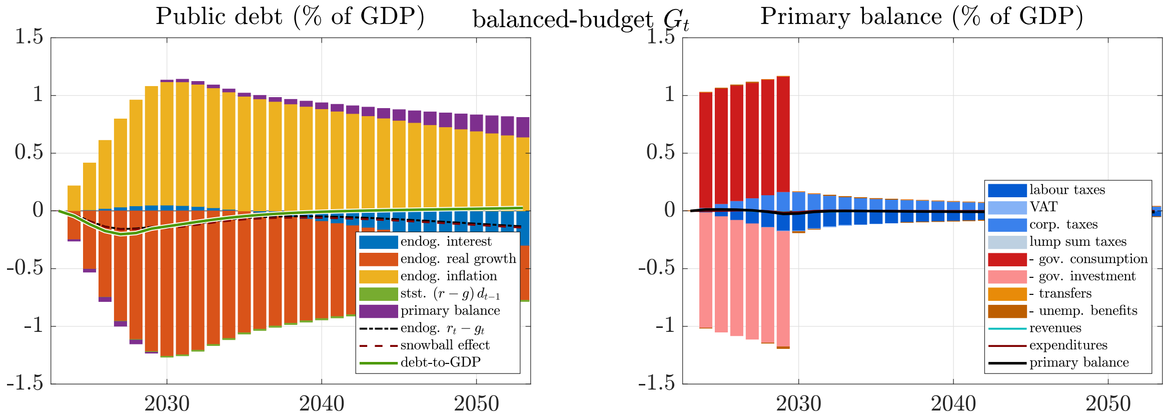
C FURTHER FIGURES

Figure C.1: Productivity of public investments (GDP-linked expenditure, $r - g = -2\%$)



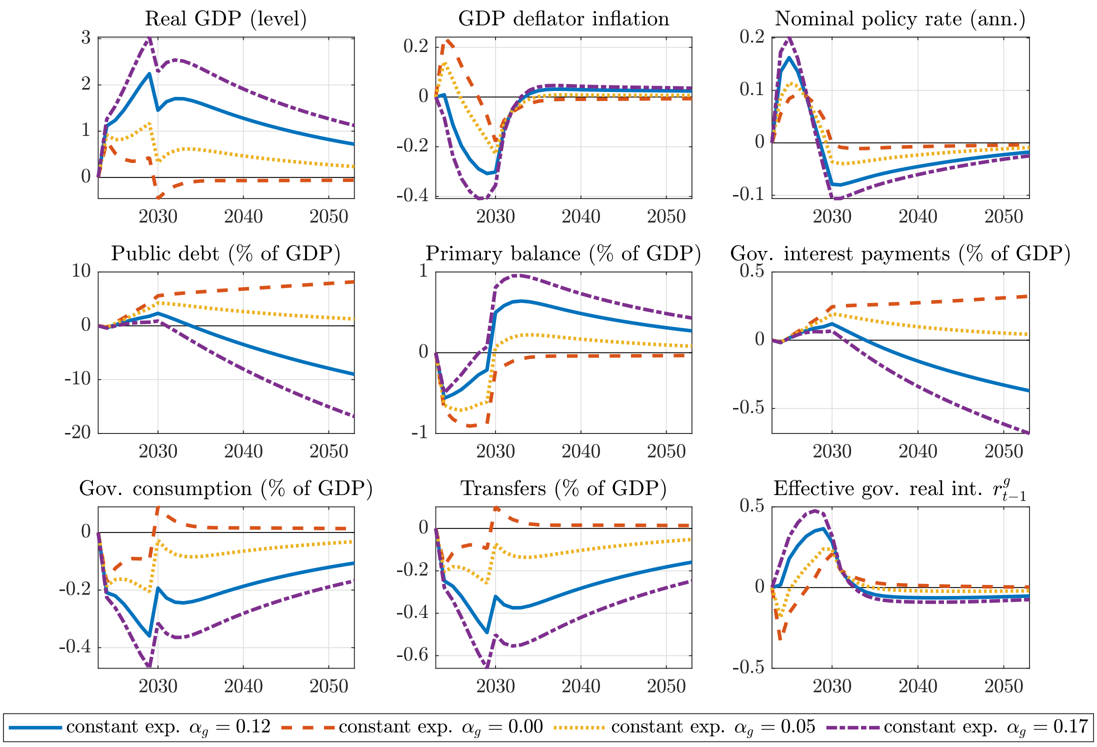
Note: The panels report pp deviations (% deviations for real GDP level) from baseline after raising the GDP-share of public investment by 1 pp for six years, for different values of the productivity of public capital. Other public expenditure (transfers and government consumption) is assumed to grow in line with GDP. The steady-state interest-growth differential is assumed to be negative at $r - g = -2\%$, with a real growth rate of 1.2% and a real interest rate of -0.8% for government bonds.

Figure C.2: Fiscal effects of public investment stimulus (balanced-budget cut in gov. consumption)



Note: The left panels report pp deviations of public debt-to-GDP from baseline after raising the GDP-share of public investment by 1 pp for six years. Coloured bars depict cumulative contributions to this deviation based on the decompositions shown by (3.1). The endogenous deviation in the interest-growth differential (sum of blue, red and yellow bars, giving the black dash-dotted line) and the term due to the steady-state interest-growth differential (green bars) sum up to the snowball effect (red dashed line). The right panels report pp deviations of the primary balance-to-GDP ratio from baseline based on (B.1). Gov. consumption is assumed to be cut in real terms to offset the budgetary cost of higher public investments.

Figure C.3: Productivity of public investments (constant real expenditure, $r - g = 0.8\%$)



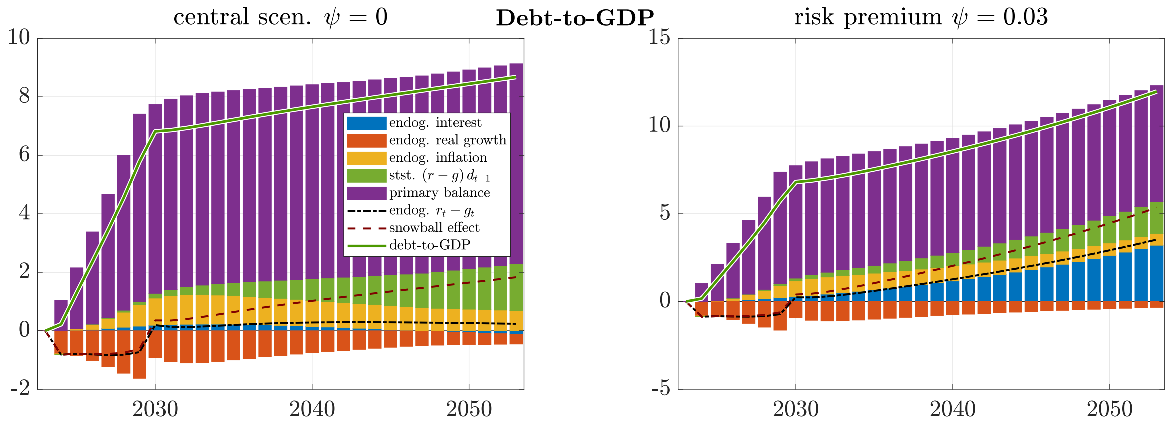
Note: The panels report pp deviations (% deviations for real GDP level) from baseline after raising the GDP-share of public investment by 1 pp for six years, for different values of the productivity of public capital. Other public expenditure (transfers and government consumption) is assumed to be fixed in real terms at their baseline level.

D MODEL EXTENSIONS

D.1. DEBT-ELASTIC RISK PREMIUM

Thus far, the fiscal stimulus considered in our simulations appears to have had only a small impact on the $r-g$ differential. Empirical research, however, suggests that higher government debt (as share of GDP) increases the sovereign risk premium. Our last scenario considers a debt-elastic risk premium by setting $\psi = 0.03$ in (2.4). This calibration implies that funding costs for newly issued debt increase by 3 basis points for every percentage point increase in the debt ratio, which broadly aligns with the estimates of Laubach (2009).[29]

Figure D.1: Debt-to-GDP after a public investment stimulus (different debt-elasticity of risk premium ψ)



Note: The panels report pp deviations of public debt-to-GDP from baseline after raising the GDP-share of public investment by 1 pp for six years, for different values of the debt-elasticity of risk premium ψ in (2.4). Coloured bars depict cumulative contributions to this deviation based on the decomposition shown by (3.1). The endogenous deviation in the interest-growth differential (sum of blue, red and yellow bars, giving the black dash-dotted line) and the term due to the steady-state interest-growth differential (green bars) sum up to the snowball effect (red dashed line). Other public expenditure (transfers and government consumption) is assumed to grow in line with GDP, and the output elasticity of public capital is assumed to be $\alpha_g = 0.12$.

Figure D.1 shows that this feedback generates a self-reinforcing loop of high debt and high risk premia. Without offsetting fiscal adjustment, interest costs (blue bars) introduce a snowball effect that becomes explosive. However, for the specific calibration (e.g., initial debt levels) and excluding nonlinear effects or the transmission of sovereign risk to the private sector, these impacts accumulate only slowly over time.[30]

D.2. IMPLEMENTATION DELAYS

Government investment projects often undergo lengthy stages of planning, contracting, and construction. To shed light on this aspect, our last scenario considers explicitly time-to-spend and time-to-build delays in public investment. Following Leeper, Walker and Yang (2010), we modify the public capital law of motion (2.7)

$$K_t^G = (1 - \delta^g)\, K_{t-1} + AP_{t-N}, \tag{D.1}$$

where AP_{t-N} denotes appropriations to provide funding for spending on government investment. N determines the number of quarters between the decision to investment to the completion of the project. In addition, projects require planning. Such time-to-spend delays (Ramey, 2021) induce lags between authorised

[29] This assumption is also broadly in line with observed spreads in the euro area: For a ten-year bond, the spread between IT and DE is around 130 bps (March 2024), while the gross debt levels are expected to reach 139 and 63% of GDP, respectively (European Commission, DG ECFIN, 2023).

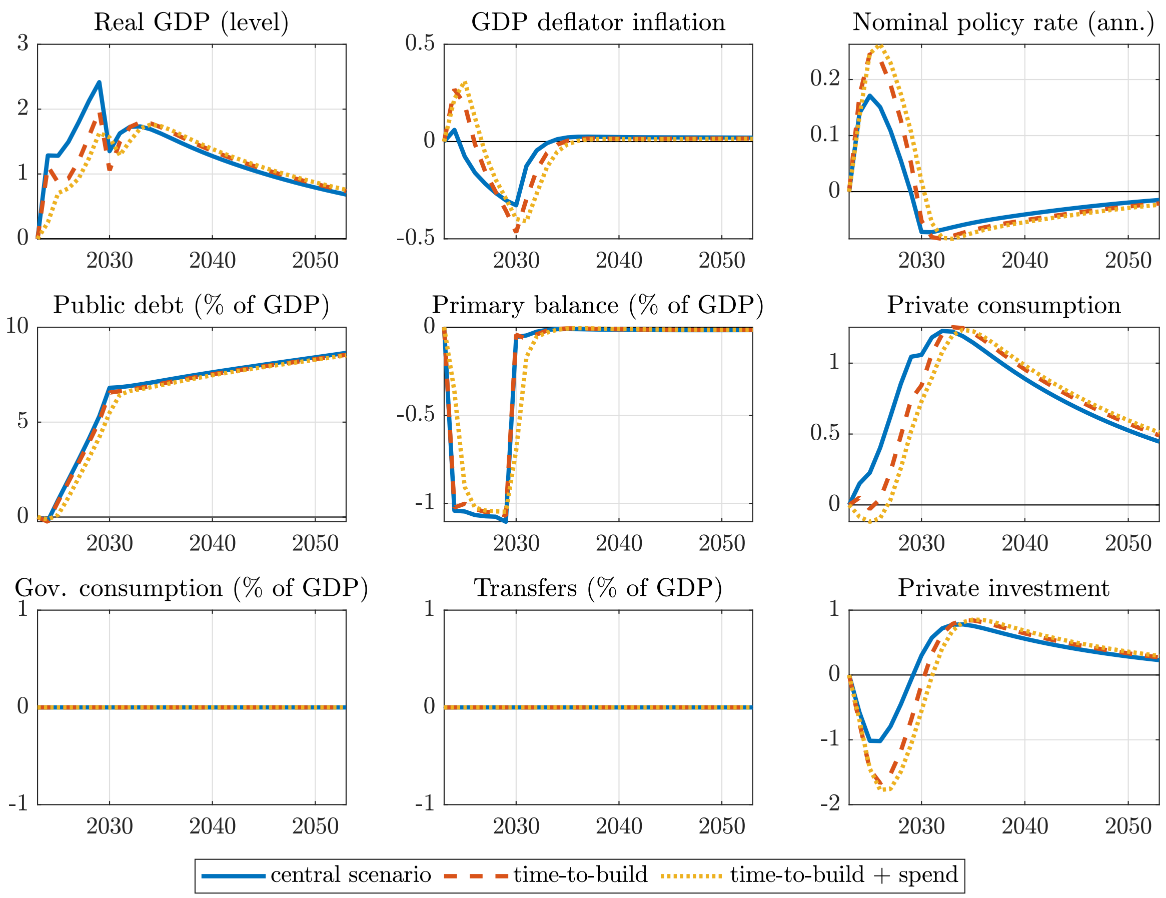
[30] For these aspects, see, e.g., Corsetti et al. (2013), Bocola (2016), and Liu (2023).

investment (appropriations) and implemented government investment, which at time t is is calculated as:

$$I_t^G = \sum_{n=0}^{N-1} \omega_n AP_{t-n}, \tag{D.2}$$

where the different spending rates over time satisfy $\sum_{n=0}^{N-1} \omega_n = 1$. We set $N = 7$ and consider public investment shocks as exogenous changes in authorised investment.

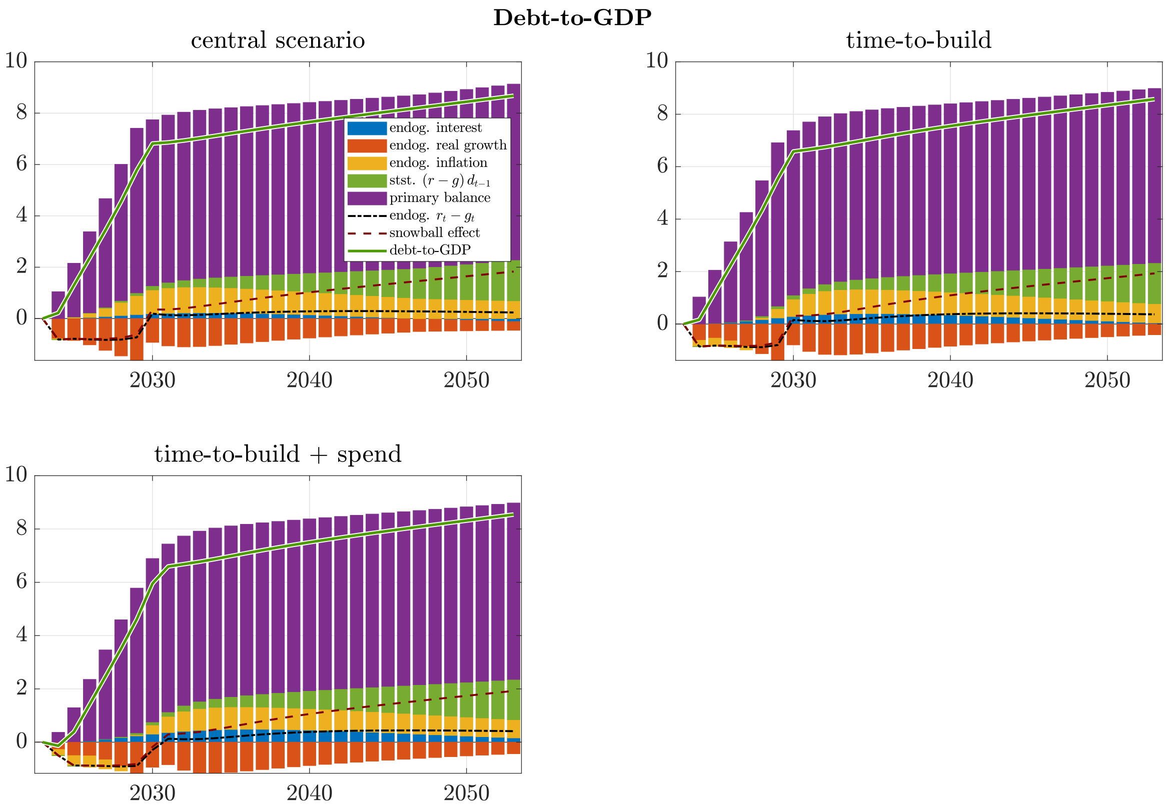
Figure D.2: Implementation delays in public investment



Note: The panels report pp deviations (% deviations for real GDP level) from baseline for the benchmark model (blue), the variants with time-to-build frictions only (red-dashed), and the model with both time-to-build and time-to-spend delays (yellow dotted). All scenarios assume steady-state $r - g = 0.8\%$ and an output elasticity of public capital of $\alpha_g = 0.12$.

Figure D.2 illustrates how time-to-build delays (red lines) diminish the short-run stimulus effects, which is more consistent with empirical findings from Boehm (2020) and Klein and Linnemann (2023). These delays defer the supply-side productivity enhancements, leading to an initial increase in inflation. Additionally, the time-to-spend friction curtails the immediate demand-side stimulus as implemented investment lags authorised investment. Overall, these scenarios show markedly different short-term macroeconomic impacts, while the influence of implementation delays on fiscal indicators appears marginal. The snowball effect sees a trade-off between slower real GDP growth and increased interest costs against the nominal debt reduction from higher inflation. At the same time, the essentially unchanged primary balance (aside from the stimulus) closely mirrors our central scenario, except for the investment's timing, as shown in Figure D.3.

Figure D.3: Debt-to-GDP after a public investment stimulus (implementation delays)



Note: The panels report pp deviations of public debt-to-GDP from baseline after raising the GDP-share of public investment by 1 pp for six years, for different model versions. The coloured bars represent cumulative contributions to this deviation, based on the decomposition provided in (3.1). The endogenous deviation in the interest-growth differential (sum of blue, red and yellow bars, giving the black dash-dotted line) and the term due to the steady-state interest-growth differential (green bars) sum up to the snowball effect (red dashed line). Other public expenditure (transfers and government consumption) is assumed to grow in line with GDP, and the output elasticity of public capital is assumed to be $\alpha_g = 0.12$.

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