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Deficit Aversion as a Path to Higher Debt: Sovereign Debt Dynamics in a Stock-Flow Consistent Model with Public Capital

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ABSTRACT

I develop a stock-flow consistent model that incorporates public sector into economy and offers a novel framework to evaluate the long-term economic consequences of government budgetary decisions. In this model, both government consumption and investment enter the aggregate income; however, public investment adds up to the public capital stock. The productivity of the private capital depends on the public capital stock due to congestion effects. The composition of public spending, however, depends on fiscal rules. I simulate two scenarios: a balanced budget fiscal rule and a 'golden rule of public investment'. The investment-friendly fiscal rule requires public deficits, but it induces a higher growth rate, a higher capacity utilisation, and, eventually, a lower debt-to-output ratio than the balanced budget rule. I conclude that a policy that boosts productivity is more effective for fiscal sustainability than focusing on reducing the public deficit.

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1. Introduction

There is a well-grounded case for risky innovation projects, research and development as well as investment-intensive infrastructure to be financed by the state (Mazzucato and Semieniuk 2017). A readily available example is an enormous investment requirement of the looming socio-ecological transformation. The estimates of the necessary additional green investment to achieve the 2030 climate and energy targets in Europe range from 260 billion Euro per year (European Commission 2020) up to 855 billion Euro annually (Wildauer, Leitch, and Kapeller 2020). A notable portion of this sum falls onto the public sector. However, the capacity of the state to provide public investment has often been limited by financial constraints in recent decades. First, the leeway of the state to finance investment has diminished due to the possibility of adverse 'markets' reactions'. Indeed, interest rates on government bonds can be subject to negative market sentiments disconnected from the underlying economic indicators (De Grauwe and Ji 2013). Also, institutions, such as fiscal rules, have been increasingly implemented in most developed countries to restrict the government's autonomy in decisions of public finance.

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In this way, a modern state is increasingly being charged with facilitating structural change, which requires massive public investment, while being confronted with uncertainty on the financing side resulting from restrictions on public spending. It remains unclear if there will be sufficient room for government-financed projects under the political constraints on public spending and debt during the next decades. However, can a restrictive fiscal policy achieve its goal of bringing down the debt-to-GDP ratio in the long run, if public investment is crucial to enable economic stability and growth? To shed some light on this matter, this paper examines the dynamics of public investment and sovereign debt under two different fiscal rules scenarios with the help of a stock-flow consistent (SFC) macroeconomic model which allows to model complex interactions between sectors of the economy and integrate the real and financial sides of all economic activity (Godley and Lavoie 2012; Nikiforos and Zezza 2017).

I employ a simple SFC model à la Dafermos and Nikolaidi (2019) with private households, firms, and the government. The model is demand-led where private investment depends on profit rate, capacity utilisation rate, and leverage. The novelty of this paper is to explicitly introduce public investment into the SFC framework to analyse the dynamics of public investment and debt under spending constraints. Importantly, I make use of the assumption that public capital stock, such as mass transport, water and electricity infrastructure, streets, airports, but also educational and healthcare facilities and workers, is a crucial factor for productivity. I follow Tavani and Zamparelli (2016) and assume that the productivity coefficient of capital stock is variable and depends on the supply of public capital. A weak provision of public capital results in a lower productivity of the private capital stock due to congestion effects. Therefore, on the one hand, public investment can induce growth of potential output and lead to a reduction of the debt burden in the future. On the other hand, debt-financing also piles up the outstanding liabilities in the short term and is thus subject to regulations regarding government budget and debt.

The public investment decision is accounted for in a set of fiscal rules. The first fiscal policy scenario is designed as a 'Maastricht-like' fiscal rule where the government aims at achieving a balanced budget. Since government consumption is difficult to cut down in the short run due to fixed obligations, public investment must adjust to accommodate the spending ceiling in case of a shock. The second scenario implements a so-called 'golden rule of public investment'. In this way, government investment is growing at a given rate, whereas deficit spending must increase to accommodate it.

The modelled economy extended by the fiscal authority is then calibrated to the Euro area. Dynamic adjustments of the model are computed to investigate the development of the fiscal policy composition and the resulting path of the output growth and the debt accumulation under various fiscal scenarios. Indeed, the analysis shows that insufficient provision of public capital is a detriment to growth since expansion of the supply side is necessary for the output growth in the model. Since the growth rate is endogenous in the model, the two scenarios illustrate two distinct fiscal outcomes of the debt sustainability condition. First, increased public investment induces a growth rate above the net interest rate on government bonds and allows for a negative budget balance in the long run. Second, the frugal fiscal scenario results in a growth rate below the net interest rate on bonds so that the surplus is needed for the stability of the debt-to-output ratio. So, despite the association with higher public deficits, the golden rule of public investment results in lower debt-to-GDP ratios due to stronger growth and accelerated capital accumulation. The balanced budget scenario results in a higher debt-to-GDP ratio, although the government runs a fiscal surplus. In addition, the balanced budget rule induces economic instability, characterized by increased capital productivity volatility, preventing the model from fully converging to steady state within the simulation period.

Therefore, I conclude that deficit aversion does not necessarily lead to debt reduction. Restrictive fiscal policies may not be the most effective path to achieving long-term debt sustainability, especially when public investment is pivotal to enhancing growth. Aligning government policies solely with short-term fiscal indicators, such as the budget balance, becomes problematic. A more effective policy approach would involve evaluating the economic impacts of different spending categories and prioritising investments that promote productivity growth.

The remainder of this paper is structured as follows. Section Two offers a comprehensive review of the economic literature on productive public investment. Section Three describes the model. Section Four presents baseline results of simulations as well as sensitivity tests. Section Five concludes.

2. Literature Review

This section reviews the literature on modelling productive public investment which includes applied research as well as theoretical models of neoclassical and heterodox flavours, with a focus on public finance outcomes. First, I will give a brief overview on econometric findings regarding the productivity of public investment and a short summary of insights from the mainstream modelling approaches. Then, I will discuss Post-Keynesian and especially SFC literature dealing with productive public investment and contrast my contribution to the established findings.

Seminal empirical research on the productivity of public investment was contributed by Aschauer (1989a, 1989b) who finds a high elasticity of output to public capital of 0.39 and presents evidence that the net effect of public investment on private investment is positive. His estimate of the elasticity of output to public capital was confirmed by Munnell (1990). In line with their research, Fernald (1999) shows that productivity of automobile-intensive industries in the US depends positively on road-building.[1]

Pereira and Flores de Frutos (1999) and Pereira (2000) show a large long-run elasticity of output to public capital and a long-run multiplier of public investment of 4.5. Positive effects on growth have been confirmed for developing countries (Easterly and Rebelo 1993) as well as for an international panel, while addressing non-stationarity, reverse causality and country-heterogeneity (Calderón, Moral-Benito, and Servén 2015), and specifically for the energy sector (Deleidi, Mazzucato, and Semieniuk 2020). Finally, Bom and Ligthart (2014) performed a meta-regression analysis of empirical literature on the productivity of public capital. Their estimate for the elasticity of output to public capital amounts to approximately 0.08 in the short run and 0.12 in the long run, and it is twice as high for the core infrastructure on the local level.[2]

[1]See Gramlich (1994) for a survey of the early literature on the productivity of US infrastructure.
[2]See Ramey (2020) for an extensive review of research on the productivity of public investment.

Coming to the neoclassical theoretical literature, Arrow and Kurz (1970) formulated an optimal public investment policy as an optimization over time while keeping the private saving rate constant. In their model, the initial debt level is important since it determines the level of interest payments and, thus, how much can be spent on investment. If the initial level of debt is low enough, financing public debt with borrowing is optimal. Baxter and King (1993) investigated public spending effects on the output in a neoclassical real business cycle model. Concerning the long-run effect, they suggest that if the labour is fixed, the direct expenditure effect of public investment is larger than the supply side effect. However, if the labour is variable, the multiplier associated with expanding the private productive capacity is higher than the immediate spending effect. Also, Barro (1990) and Barro and Sala-i Martin (1990) find that, if social returns on investment exceed private returns, tax-financed productive public spending policy may be optimal. In contrast to them, Futagami, Morita, and Shibata (1993) argue that capital stock, such as the available infrastructure and the level of public education, is more relevant to the productivity of the economy than the current expenditure. Fisher and Turnovsky (1998) analyse the role of congestion of public capital in private capital formation. In the absence of congestion, public infrastructure only leads to a higher private accumulation rate if they are complements. By modelling congestion, they show how public and private capital can have a degree of substitutability, and still, an increase in public capital stock induces an expansion of private capital, at least in the long run.

Also, neoclassical models highlight that debt-financed public investment can increase the growth rate, although there is a threshold of the government borrowing after which the positive effect on growth is offset by the detrimental effect of the higher interest payments (Greiner and Semmler 2000); optimal public investment policy depends on the chosen budgetary stance (Ghosh and Mourmouras 2004); and initial stock of public debt matters (Teles and Mussolini 2014; Yakita 2008). Furthermore, this strand of literature explores a possibility of multiple equilibria (Futagami, Iwaisako, and Ohdoi 2008), analyses government expenditure composition (Agénor 2008; Groneck 2010; Gupta and Barman 2010; Minea and Villieu 2009) and introduces a time-to-build delay (Bouakez, Guillard, and Roulleau-Pasdeloup 2017; Gallen and Winston 2021; Leeper, Walker, and Yang 2010).

Having considered mainstream literature, I focus on the Post-Keynesian approach instead and on the SFC modelling in particular. A major notion of this school of thought is the endogenous money assumption and the path dependency of the modelling outcomes instead of the optimal inter-temporal allocation of resources (Lavoie 2014). For this reason, this class of models is much more in line with the reality of economic behaviour and monetary systems in practice. Especially SFC modelling is a very helpful approach when it comes to account for complex interactions between the monetary and the real sides of the economy (Godley and Lavoie 2012).

Taking account of Post-Keynesian literature, it is important to note that government expenditure generally plays a crucial role for growth in this paradigm. The reason is that aggregate demand is central to growth in Post-Keynesian, or Kaleckian, models. See Allain (2015) for an overview of the strand of literature and for his neo-Kaleckian growth model with autonomous demand components and private investment subject to Harrodian instability (Harrod 1939). In his model, the long-term growth rate of the economy converges to the exogenous growth rate of autonomous public spending. In addition, autonomous government spending, under certain conditions, is able to stabilize the growth expectations of firms, thus solving the Harrodian knife-edge problem.

Moving further to models with productive government expenditure, Dutt (2013) develops a model with government spending on consumption and investment. His model shows several mechanisms how government investment spending can increase growth. Besides a generally positive effect on aggregate demand, public investment also crowds in private investment and promotes technological change, thus raising the natural rate of growth. In this framework, the debt-to-output ratio can be stable even if one allows for labour shortage problems and a financial crowding-out effect. Parui (2021) extends Dutt (2013) by introducing the dependence of private investment on the profit rate, workers' savings, and differentiation between investment categories. He is able to show that, while both public consumption and investment enhance growth, an optimal composition of public spending is determined by the (wage-led or profit-led) demand regime and the effect of public investment on labour productivity. Similarly, in a neo-Kaleckian model with government investment in human capital (Lima, Carvalho, and Serra 2021), demand regime determines the optimal tax rate and thus the optimal human capital accumulation rate. Skott (2021) investigates the differences between developing and mature economies and argues that appropriate fiscal policies are different in one and the other case. Whereas a permanent fiscal stimulus could be helpful in mature economies where the natural growth rate is low, creating the right conditions for investment to accumulate a necessary capital stock is necessary in dual economies, thus, fiscal policy should focus on the level and the composition of aggregate demand.

Tavani and Zamparelli (2016) develop a Post-Keynesian model with two types of government expenditure: transfers and investment. They compare a fixed wage closure of the model, which allows for endogenous growth, and a fixed labour supply closure where growth is exogenously given. In the first case, the chosen tax rate does not only determine the wage and the profit share, but also the growth rate; whereas in the second scenario, the government sector can only influence income redistribution. Tavani and Zamparelli (2017a) extend this analysis with government debt. They find that public debt has no impact on the growth rate in their model; however, in order to sustain the equilibrium, the growth rate of the economy must exceed the interest rate on government bonds.[3]

Deleidi and Mazzucato (2019) make a strong case for public investment in a Sraffian Supermultiplier model. This model utilises the notion of autonomous demand components and makes use of a private investment function dependent on the aggregate demand. Extending this framework by consumptive and 'industrial policies' government spending, they are able to show that both types of public spending induce a crowding-in effect and result in a higher growth rate through the multiplier-accelerator mechanism. However, productive ('mission-oriented') government spending generates the largest effect on output, private investment, and productivity growth. They test their model on the US time series data and, indeed, find a very large long-run multiplier of the 'mission-oriented' public spending (Deleidi and Mazzucato 2021). Skott, Santos, and da Costa Oreiro (2022) compare a supermultiplier solution and an active fiscal policy

[3] Also, see their overview of heterodox growth models with and without public investment (Tavani and Zamparelli 2017b).

guided by principles of functional finance and conclude that the latter framework delivers superior outcomes in terms of stabilization and capacity utilisation rates.

Finally and centrally, relevant SFC literature will be discussed here. A large range of SFC contributions considered active fiscal policy. For a comprehensive overview refer to Caverzasi and Godin (2014) who provide classification of the SFC literature along several dimensions, such as methodological differences and main topics of research. Also, Nikiforos and Zezza (2017) revise a variety of SFC models and summarize their distinctive characteristics as well as advantages and disadvantages compared to mainstream models. All in all, SFC modelling seems to be a particularly appropriate framework to analyse the connection between fiscal regimes and public finance dynamics.

In an early work, Schlicht (2006) argues that the stock-flow consistency allows for an important insight. In SFC models, public debt plays a major role in establishing equilibrium in a closed economy since it it allocates output between private and public spending. Fiscal rules that put bounds on public debt can therefore undermine macroeconomic equilibrium. Godley and Lavoie (2007) show that even with interest rates higher than the growth rate of the economy, the ratio of real deficit to output as well the ratio of real debt to output both converge to stable values as long as public expenditure is sufficient to ensure full employment. Also, Ryoo and Skott (2013) highlight the necessity of sufficient government spending for full employment and argue that variations in public debt are the instrument to smooth out fluctuations in the private sector.

Furthermore, Brochier and Macedo e Silva (2018) analyse whether the standard results of a supermultiplier model hold in an SFC setting where the 'non-capacity creating' autonomous expenditure is endogenous and depends on households' wealth. They show that changes in distribution and propensity to save will permanently affect the growth rate through the supermultiplier. For a comparison of neo-Kaleckian and Supermultiplier closures in SFC context, see Brochier and Freitas (2023). Spinato Morlin (2022) develops an open-economy model where exports and government expenditure compose autonomous demand. In this case, domestic fiscal policy plays a major role in keeping the economy from hitting the external constraint to growth.

Caiani, Catullo, and Gallegati (2018) employ an agent based SFC (AB-SFC) model of a currency union, where technological change is endogenous, and simulate various policy experiments. In their model, increased fiscal spending leads to higher labour productivity as well as higher GDP and employment. They illustrate how an austerity event can result in growing average debt-to-output ratios and exacerbate the volatility of main economic aggregates in a monetary union. Another relevant AB-SFC contribution is provided by Teglio et al. (2019) who model economic dynamics under the European fiscal framework. They also come to conclusion that debt or deficit fiscal rules lead to instability and fail to achieve their ultimate goal. In recessions, counter-cyclical fiscal policies prove to be more effective in stabilizing the economy and public finances. Dafermos (2018) employs a Godley–Minsky cyclical model with a government sector. He tests two types of fiscal rules and concludes that a strict Maastricht-like debt rule exacerbates the cyclical dynamics in the model, whereas a countercyclical fiscal rule stabilizes the output and, importantly, also the government debt-to-GDP ratio.

In addition, Bibi (2023) develops an SFC model with productive public investment. Namely, public investment adds to the capital stock and thus enhances the productivity of the labour force, increasing potential output. The author tests various fiscal policy scenarios as a reaction to an exogenous fall in private investment and concludes that a balanced budget fiscal scenario fails to reduce the debt-to-GDP level. Instead, the proactive government scenario, where the fiscal policy mix is chosen to support the macroeconomy, results in the smoother recovery path, a lower debt-to-output ratio, and less interclass inequality. Kappes, Milan, and Morrone (2022) employ an SFC model to compare macroeconomic outcomes under a variety of fiscal rule scenarios. They show that an expenditure rule results in higher inflation, less unemployment, lower firms' leverage, but a higher debt-to-output ratio, than a debt rule, independent of the target values. Ioannou (2018) explores institutional actors influencing government's ability to finance its' deficit and the role of the credit rating agencies in the context of an SFC model and illustrates how a recession, followed by downgrading, can result in a fiscal crisis.

To mention SFC models extended with the environmental sector, Dafermos and Nikolaidi (2019) analysed the government's role in socio-economic transition via direct public investment or subsidies for green investment. They provide an insight that more spending on green investment reduces government debt, because green investment stimulates growth and reduces the climate change damage in their framework. Also, Naqvi and Stockhammer (2018) develop an ecological SFC model with directed technological change. They show that a mix of tax increases and fine-tuned public spending to boost demand and private investment are necessary to achieve a structural shift towards greener technologies.

Last but not least, Post-Keynesian literature highlights the centrality of human capital accumulation in the context of growth models with public sector. More precisely, the productivity benefits of public capital are not solely derived from physical assets but also from the effective provision of essential services, especially in sectors like health and education. Including human capital into the framework reconciles central aspects of growth modelling, such as the relationship between distribution and growth and the supply and demand link (Setterfield 2023). Furthermore, the inclusion of social services into the macroeconomic setup shows how public spending affects gender disparities by, first, providing public facilities for care work and, second, improving employment chances for women (Onaran, Oyvat, and Fotopoulou 2022). These authors also demonstrate that investment in public social infrastructure significantly enhances output and productivity as well as gender equality in both wages and employment opportunities (Onaran, Oyvat, and Fotopoulou 2023).

This paper connects to the above SFC literature for it follows the same modelling structures and the behavioural assumptions established in the Post-Keynesian tradition. In particular, this work builds on the model developed in Dafermos and Nikolaidi (2019) but introduces a supply side to the economy and analyses the role of government investment for maintaining and enlarging the productive capacity. Through this extension, the contribution of this paper is to augment the SFC literature with the analysis of the composition of public expenditure and its' effects on public deficit and debt dynamics.

For simplicity, I refrain from modelling productive public consumption along the lines of Onaran, Oyvat, and Fotopoulou (2022) or Setterfield (2023). However, public investment in this paper is defined broadly to encompass not only physical infrastructure, but also investments in human capital, including expenditures that enhance the quality and availability of essential public services like education and healthcare. While abstracting from explicitly distinguishing between physical capital formation and investment in the human capital of public servants, it is still implied that both are necessary for sustained growth. Consequently, public consumption is defined as government expenditures that do not directly contribute to the production process or to the formation of public capital, such as administrative costs and transfers.

3. Model

3.1. Stock-Flow Consistent Model of Public Investment

3.1.1. The Macroeconomic Setup

I employ a simple SFC model along the lines of Dafermos and Nikolaidi (2019) with private households, firms, and the government. The model is cast in real terms, so I refrain from modelling prices. My central innovation to the model is an explicit formulation of the production function (PF) that includes public capital. This allows us to model the demand-side and supply-side effects of public investment. Indeed, public investment enters the demand side of the economy as government expenditure, which creates more demand for investment goods, and therefore induces an increase in production and income. Although this channel can also have long-lasting repercussions through increased private investment, as in Deleidi and Mazzucato (2019), I regard it as temporary. Instead, I model a long-term supply side effect of government investment which takes place by building up public capital stock.

First of all, public capital is itself a productive input, next to private capital. In addition, since public capital comprises major infrastructure, it determines the productivity of the private capital stock. In more detail, there is a need for adequate infrastructure, which is provided on the public level, i.e., roads, bridges, energy grid, water supply, public institutions, etc., for the economy to function efficiently and to avoid congestion. Therefore, for the same level of the private capital stock, it can be more productive if the provision of public capital is higher.

However, treating public investment too narrowly, as formation of physical capital, would underestimate the full spectrum of government contributions to productivity, especially in knowledge-based economies where human capital is often the primary productivity driver. In sectors like education and health, the distinction between investment and consumption is blurred. Productivity-enhancing expenditure may occur through both capital formation and through spending categories which might be typically classified as consumption but are in fact investment in human capital. Therefore, public capital in this model is defined broadly and includes not only physical infrastructure such as roads and buildings, but also human capital. Public consumption will be, consequently, defined as non-productive expenditure categories, such as administrative costs and transfers.

To model the supply side of the economy, I start conventionally with a Leontief PF of the form:

$$Y = \min\{aN, vK\} \tag{1}$$

where N denotes available workforce and K stands for capital stock. Per simplifying assumption, labour does not constitute a binding constraint on output in our model. Full employment is never reached and there is a reserve army that can supply more labour, so that $Y = vK$. I follow Tavani and Zamparelli (2016) and assume that the public capital stock KG is a productive input next to the private capital stock Kpr and that they are imperfect substitutes, settling upon the following equation for the potential output:

$$Y_t^* = v_t Kpr_t^{(1-\rho)} KG_t^{\rho} \tag{2}$$

The functional form is justified by the empirically observed considerable substitutability between private and public capital (for example, private vs. public schools; private vs. public highways). Also, this PF specification implies constant returns to scale, but diminishing returns to each input factor separately, since $0 < \rho < 1$.[4] Constant returns to scale is a rather conservative assumption since neoclassical literature sometimes assumes that the sum of exponents in the Cobb-Douglas PF with productive public capital exceeds unity (Baxter and King 1993).

Furthermore, I assume that the productivity coefficient of the private capital stock v_t is variable and depends on the supply of public capital, in accordance with Tavani and Zamparelli (2016). The intuition behind this, as discussed above, is that better public infrastructure increases the productivity of the private capital stock through decreased congestion. This is also similar to the literature on congestion of public infrastructure (Barro and Sala-i Martin 1990; Fisher and Turnovsky 1998) which offers several options for modelling congestion, for example, as a share of public services to output or a ratio of public capital to private capital. I opt for the latter version, assuming that the accumulated stock of public capital, and not the flow variable of public spending, determines the productivity of private capital:

$$v_t = \left(\frac{KG_t}{Kpr_t}\right)^{(1-\sigma)} \tag{3}$$

where σ determines the degree of rivalry and excludability of public infrastructure. So, if $\sigma = 1$, there is no congestion at all, and in case $\sigma = 0$, public capital stock must increase in direct proportion to private capital stock, for private capital to maintain the same productivity. I assume partial congestion, i.e., $\sigma = 0.5$, since public infrastructure, such as roads and railways, but also social infrastructure, such as child-care facilities, is a non-excludable and, to a large extent, rival good.

Importantly, explicit modelling of the supply side of the economy poses a particular challenge for the stock-flow consistency of the model since the production and the aggregate spending are determined by different factors and do not always coincide. Aggregate demand equals the overall spending of the private and public sector in our economy:

$$Z_t = C_t + I_t + G_t \tag{4}$$

In most periods, demand does not exceed potential output or $Z_t \leq Y_t^*$ and, thus, the overall income equals the aggregate spending in the economy:

$$Y_t = Z_t \tag{5}$$

However, in some periods of the simulation, aggregate demand might exceed potential output $Z_t > Y_t^*$, since it is possible to create loans and issue government bonds endogenously, and spending is not limited to current income. In this case, the excess demand

[4] I use the estimate of Bom and Ligthart (2014) of 0.12.

must be satisfied with inventories Θ that firms maintain, where this share of the aggregate supply is defined as:

$$\theta_t = Z_t - Y_t^* \tag{6}$$

3.1.2. Firms

Since the model assumes that the wage share ω is constant, the wages are determined straightforwardly as a fraction of the aggregate income:

$$W_t = \omega Y_t \tag{7}$$

As established in canonical Post-Keynesian models (Dutt 1984; Taylor 1985), firms decide how much to invest based on the profit rate and utilisation of the productive capacity. I proceed with a private investment function of this tradition extended by a simple rule to prevent unlimited expansion of credit taking similar to Brochier and Freitas (2023):

$$I_{Kt} = (\alpha_1 r_{t-1} + \alpha_2 u_{t-1} + \alpha_3 lev_{t-1})Kpr_{t-1} \tag{8}$$

assuming $\alpha_1 > 0$, $\alpha_2 > 0$, $\alpha_3 < 0$, whereas the profit rate r_t, the capacity utilisation rate u_t and the leverage ratio lev_t are specified as:

$$r_t = TP_t/Kpr_t \tag{9}$$

$$u_t = Y_t/Y_t^* \tag{10}$$

$$lev_t = L_t/Kpr_t \tag{11}$$

Also, following Godley and Lavoie (2012), firms prefer to maintain a certain amount of inventories Θ at the desired target level Θ^T, which is a fraction β of the overall sales in the previous period, to avoid frustrating customers with supply constraints:

$$\Theta_t^T = \beta Z_{t-1} \tag{12}$$

so that investment in inventories at any t equals:

$$I_{\theta t} = \Theta_t^T - \Theta_{t-1} \tag{13}$$

conditioned on its non-negativity, otherwise $I_{\theta t} = 0$. The overall private investment is determined as:

$$I_t = I_{Kt} + I_{\theta t} \tag{14}$$

Stock of inventories in each period declines by the amount of excess demand and increases by investment in inventories:

$$\Theta_t = \Theta_{t-1} - (Z_t - Y_t^*) + I_{\theta t} \tag{15}$$

In addition, private capital stock is subject to depreciation at rate δ_{Kpr}, so that it develops according to:

$$Kpr_t = (1 - \delta_{Kpr})Kpr_{t-1} + I_{Kt} \tag{16}$$

and its growth rate equals:

$$g_{Kprt} = \frac{Kpr_t - Kpr_{t-1}}{Kpr_{t-1}} \tag{17}$$

Also, firms borrow to finance investment in addition to retained profits and pay a fixed interest rate on the outstanding loans. The loans dynamics are described as follows, where investment can partly stem from inventories (for stock-flow consistency):

$$L_t = L_{t-1} + (I_t - \theta_t) - RP_t \tag{18}$$

Therefore, firms' total profits TP equal to the profit share less interest rate expenses of the firms, where a fraction RP is retained to repay the loans:

$$TP_t = (1 - \omega)Y_t - int_L L_{t-1} \tag{19}$$

$$RP_t = s_F TP_t \tag{20}$$

and a fraction of profits can be transferred to firms' cash accounts V_O where they can neither be taxed nor consumed at a tax avoidance rate λ_P:

$$\Delta V_{Ot} = \lambda_P (TP_t - RP_t) \tag{21}$$

$$V_{Ot} = V_{Ot-1} + \Delta V_{Ot} \tag{22}$$

and the rest DP is distributed to the households:

$$DP_t = (1 - \lambda_P)(TP_t - RP_t) \tag{23}$$

3.1.3. Banks

Money is endogenous, and there are no restrictions on the amount of credit to the firms as well as the government, so the banking sector only performs the function of credit supply in my model, and banks fully redistribute the profits they make by giving out loans and holding government bonds, after paying interest on deposits, to the households:

$$BP_t = int_L L_{t-1} + int_B B_{t-1} - int_V V_{Ht-1} \tag{24}$$

3.1.4. Households and Government

Coming to the households and public finance, since the government taxes all income from wages, profits and capital gains at a fixed tax rate τ, disposable income of the household is:

$$Y_{Ht} = (1 - \tau)(W_t + DP_t + BP_t + int_V V_{Ht-1}) \tag{25}$$

while government tax revenue is determined by:

$$T_t = \tau(W_t + DP_t + BP_t + int_V V_{Ht-1}) \tag{26}$$

Private consumption is a fraction of disposable income and deposits:

$$C_t = c_1 Y_{Ht-1} + c_2 V_{Ht-1} \tag{27}$$

where deposits develop according to:

$$V_{Ht} = V_{Ht-1} - C_t + Y_{Ht} \tag{28}$$

Government consumption is a fixed proportion of the aggregate income in the previous period:

$$CG_t = \gamma_{CG} Y_{t-1} \tag{29}$$

In addition, government investment is determined by:

$$IG_t = T_{t-1} - CG_t + \gamma_{IG} KG_{t-1} \tag{30}$$

where γ_{IG} is specified by a fiscal rule which is the central part of modelling public finance dynamics. I run simulations with two alternative fiscal rules. The first one corresponds to a rule where the government pursues a balanced budget, meaning $G_t = T_{t-1}$ and, correspondingly, $\gamma_{IG} = 0$. The second scenario is defined as an investment-friendly fiscal rule where public investment is determined by the exogenous public capital accumulation rate $\gamma_{IG} > 0$, thus allowing for non-zero fiscal deficits.

In total, government expenditure is the sum of government consumption and investment:

$$G_t = CG_t + IG_t \tag{31}$$

Public capital stock is determined as:

$$KG_t = (1 - \delta_{KG})KG_{t-1} + IG_t \tag{32}$$

where δ_{KG} is the depreciation rate of the public capital stock; and the growth rate of the public capital stock equals to:

$$g_{KGt} = \frac{KG_t - KG_{t-1}}{KG_{t-1}} \tag{33}$$

The stock of outstanding government bonds develops according to the following equation, where the interest payments are serviced by issuing new bonds:

$$B_t = B_{t-1} + G_t - T_t + int_B B_{t-1} \tag{34}$$

The stock-flow consistency of the model implies that the financial flows add up in each given period, according to:

$$\Delta V_{Ht} + \Delta V_{Ot} = \Delta B_t + \Delta L_t \tag{35}$$

and the bank accounts balance:

$$V_{Ht} + V_{Ot} = B_t + L_t \tag{36}$$

Tables 1 and 2 represent the balance sheet and the transaction matrices of the modelled economy.

3.2. Steady State Implications

Due to the complexity of the model's supply side, only a few things can be said about the long-term dynamics in the model. Since private investment depends on the capacity

Table 1. Balance sheet matrix.

	Households	Firms	Commercial banks	Government	Total
Deposits	$+V_H$		$-V_H$		0
Loans		$-L$	$+L$		0
Treasury bills			$+B$	$-B$	0
Tax haven accounts		$+V_O$	$-V_O$		0
Capital		$+K_{pr}$		$+K_g$	$+K$
Inventories		$+\Theta$			$+\Theta$
Total (net worth)	$+V_H$	$+V_f$	0	$+V_g$	$+V$

utilisation rate (equation 10), output and potential output must increase at the same rate in the steady state:

$$g_Y = g_{Y^*} \tag{37}$$

From the functional form of the PF (equations 2 and 3) it follows that the productivity of capital must be constant in the long run. It implies that the steady state conditions of the model are given when the growth rate of output, private capital stock, and public capital stock are all equal:

$$g_Y = g_{Kpr} = g_{KG} \tag{38}$$

Equating the growth rates of private and public capital yields:

$$\frac{I_{Kt}}{Kpr_{t-1}} - \delta_{Kpr} = \frac{IG_t}{KG_{t-1}} - \delta_{KG} \tag{39}$$

Rearranging, the ratio of private capital investment to private capital stock must exceed the ratio of public investment to public capital to cover the difference in the depreciation rates:

$$\frac{I_{Kt}}{Kpr_{t-1}} - \frac{IG_t}{KG_{t-1}} = \delta_{Kpr} - \delta_{KG} \tag{40}$$

Table 2. Transaction matrix.

		Firms		Commercial banks			
	Households	Current	Capital	Current	Capital	Government	Total
Pr. investment in capital		$+I_K$	$-I_K$				0
Pr. investment in inventories		$+\Delta\Theta$	$-I_\theta + \theta_t$				0
Pr. consumption	$-C_{pr}$	$+C_{pr}$					0
Gov. investment		$+I_g$				$-I_g$	0
Gov. consumption		$+C_g$				$-C_g$	0
Gov. revenue	$-T$					$+T$	0
Wage bill	$+W$	$-W$					0
Interest on deposits	$+int_v V_{Ht-1}$			$-int_v V_{Ht-1}$			0
Interest on loans		$-int_l L_{t-1}$		$+int_l L_{t-1}$			0
Interest on treasury bills				$+int_b B_{t-1}$		$-int_b B_{t-1}$	0
Firms' profits	$+DP$	$-TP$	$+RP$				
			$+\Delta V_O$		$-\Delta V_O$		0
Com. banks profits	$+BP$			$-BP$			0
Change in deposits	$+\Delta V_H$				$-\Delta V_H$		0
Change in loans			$-\Delta L$		$+\Delta L$		0
Change in treasury bills					$+\Delta B$	$-\Delta B$	0
Total	0	0	0	0	0	0	0

Writing out equations 8 and 16 and finding the equilibrium value for capacity utilisation:

$$u^* = \frac{1}{\alpha_2}\left(g_{Kpr} + \delta_{Kpr} - \alpha_1 r^* - \alpha_3 lev^*\right) \tag{41}$$

where r^*, lev^* are equilibrium values of the profit rate and the private leverage rate. Plugging the rest of equations 9, 10, 11, 30 into equation 39 yields:

$$\left(\alpha_1 \frac{TP_{t-1}}{Kpr_{t-1}} + \alpha_2 \frac{Y_{t-1}}{v_{t-1} Kpr_{t-1}^{(1-\rho)} KG_{t-1}^{\rho}} + \alpha_3 \frac{L_{t-1}}{Kpr_{t-1}}\right) - \delta_{Kpr} = \frac{(T_{t-1} - \gamma_{CG} Y_{t-1})}{KG_{t-1}} + \gamma_{IG} - \delta_{KG} \tag{42}$$

Due to the expression for the supply side of the model, which enters this equation, the condition for the growth rates in the steady state cannot be usefully simplified to deduce a concise formulation for the equilibrium values of the key variables. However, a crucial observation can be made that the growth rates go up with the parameter of the fiscal rule γ_{IG}.

Considering the dynamics of public debt, it follows from equation 34:

$$B_t = (1 + int_B)B_{t-1} + G_t - T_t \tag{43}$$

Dividing by Y_t, we get the debt to output ratio $debt_t = B_t/Y_t$, and assuming the growth rate constant in the long run:

$$\frac{B_t}{Y_t} = \frac{1 + int_B}{1 + g_Y}\frac{B_{t-1}}{Y_{t-1}} + \frac{G_t}{Y_t} - \frac{T_t}{Y_t} \tag{44}$$

It is important to take into consideration that the interest rate payments to the bondholders are subject to tax and, thus, enter the tax revenue T_t. As Pedrosa, Brochier, and Freitas (2023) show, the financial component of the changes in the government debt ratio is reduced by the share of taxed debt service. Inserting equations 24 and 26 and rearranging, we come to the following expression for the government debt ratio:

$$\frac{B_t}{Y_t} = \frac{1 + (1-\tau)int_B}{1 + g_Y}\frac{B_{t-1}}{Y_{t-1}} + \phi_{1t} - \phi_{2t} \tag{45}$$

where $\phi_{1t} = \frac{G_t}{Y_t}$ is the government expenditure to output ratio, and $\phi_{2t} = \frac{\tau(W_t + DP_t + int_L L_{t-1})}{Y_t}$ is the tax revenue from wages, profits and interest payments on private loans in relation to output.

In the long run:

$$\frac{B_{t+n}}{Y_{t+n}} = \left(\frac{1 + (1-\tau)int_B}{1 + g_Y}\right)^{n+1}\frac{B_{t-1}}{Y_{t-1}} + \sum_{s=0}^{n-1}\left(\frac{1 + (1-\tau)int_B}{1 + g_Y}\right)^{n-s-1}(\phi_{1t} - \phi_{2t}) \tag{46}$$

Thus, for non-explosive dynamics due to compounding:

$$(1-\tau)int_B < g_Y \tag{47}$$

This is a modification of the known Domar debt sustainability condition that requires that the growth rate of the economy is larger than the interest rate on government debt (Domar 1944). Similar to Domar's original work, for the government debt ratio to be stable in the stock-flow consistent model, the interest rate on government bonds *net of tax rate on capital income* must not exceed the steady state growth rate of output.

Furthermore, rewriting the equation in terms of the change in debt ratio $\frac{B_t}{Y_t} - \frac{B_{t-1}}{Y_{t-1}}$ yields:

$$\Delta debt_t = \frac{(1-\tau)int_B - g_Y}{1+g_Y} debt_{t-1} + (\phi_{1t} - \phi_{2t}) \tag{48}$$

Defining deficit as the difference of tax revenue from wages, profits and interest payments on private loans and public expenditure in relation to output: $deficit_t = \phi_{2t} - \phi_{1t}$, a constant debt-to-GDP ratio then implies that the deficit equals the public debt to output ratio scaled by the relationship between the interest rate on government bonds net of tax rate and the growth rate of output:

$$deficit = \frac{(1-\tau)int_B - g_Y}{1+g_Y} debt \tag{49}$$

It follows that a stable positive debt-to-GDP ratio is possible in two cases: First, if there is budget deficit (government spending exceeds tax revenue), then it is necessary that the growth rate of output is higher than the interest rate on government bonds net of tax rate. Vice versa, if the net interest rate is above the growth rate, the government needs to run a surplus to keep the debt-to-GDP ratio stable. This result is in line with Tavani and Zamparelli (2017a).

Also, the growth rate of output is not exogenous to the interest rate on government bonds in the model, since interest payments on government bonds enter the disposable income and thus private consumption, as it follows from equations 24, 25 and 27, which in the following periods affects other categories of aggregate spending. Thus, whether the debt dynamics are stable in the model will also depend on the effect of the interest rate on growth:

$$\frac{\partial g_Y}{\partial int_B} = \partial \frac{(C_t - C_{t-1} + I_t - I_{t-1} + G_t - G_{t-1})}{Y_{t-1}} / \partial int_B \neq 0 \tag{50}$$

Due to the limited analytical conclusions from the model, I follow the simulation practice in the SFC literature (Caverzasi and Godin 2014) and proceed with numerical experiments with calibrated parameter values in order to analyse the development of the main variables in the model. Two fiscal policy scenarios will be simulated to explore the dynamics of the growth rates, the capacity utilisation rate, and the debt-to-GDP ratio. Centrally, the experiments allow us to show not only the long-run outcomes but also the adjustment path. In addition, the simulations will investigate the implications of the modified Domar condition. By varying the degree to which the service payments on government bonds are redistributed, the effect of the interest rate on the growth rates and the public debt ratio will be explored.

3.3. Calibration of Parameters

In the course of the following numerical simulations, the parameters of the model are calibrated to the Euro area. Table A1 (in Appendix) lists the parameters and the initial values of the main variables. Initial variables are normalized to $Y_1 = 1$. This section will briefly describe the parametrisation. First, I use the main national accounts data from Eurostat (2023a) to determine the propensity to consume out of disposable income. For the value of the propensity to consume out of deposits, I turn to the literature (Dafermos and Nikolaidi 2019). I use a long-term value for the wage share (ECB 2023a) and the recent increased interest rate values from the ECB database (ECB 2023b, 2023e).

I calibrated the saving rate out of profits, although somewhat lower than the empirically observed, to prevent a negative private leverage value under the chosen set of parameters. This is necessary since the firms in my model retain profits to invest and pay off the loans, which is not the same in real business practice. Also, the parameter of the firms' profits transferred to tax haven accounts λ_P is assumed to be rather low and induces a tax revenue loss of below 0.5 per cent of GDP in the model, whereas the recent estimate for Europe of tax revenue loss through tax havens is at 0.82 per cent (Tax Justice Network 2023).

As mentioned earlier, I opt for the median long-term value of ρ found in the meta-regression analysis (Bom and Ligthart 2014). The values for the depreciation rate of the public and private capital are empirical estimates for high-income economies (IMF 2015). The desired level of inventories is set to be 5 per cent of demand. The tax rate is calibrated to fit the data for the tax revenue in percent of output (Eurostat 2023b). The set of the private investment function parameters α_1, α_2, α_3 were chosen to induce a plausible multiplier. The parameter of the government consumption share is calculated to fit the initial values of public consumption and investment. Last but not least, the parameter of the fiscal rule, i.e., the public investment target parameter γ_{IG}, is determined by the fiscal rule scenario.

Coming to the initial values of the main variables, I use the data from Eurostat (2023a) for the aggregate output and spending. Potential output is calculated from equation 2, and our economy is assumed to start from operating below full capacity. Private investment is taken from the main national accounts (Eurostat 2023a), and private consumption is calculated as a residual component of the aggregate spending (next to private investment and government spending). The values of public and private capital stock are taken from the IMF Capital Stock Dataset (IMF 2021), and the productivity parameter of the private capital stock is determined by their relationship as indicated earlier. The factors affecting the private investment, that is the profit rate, the capacity utilisation rate, and the private leverage, are calculated according to equations 9–11. Again, tax revenue is provided by Eurostat (2023b). Government expenditure is assumed to be equal to the tax receipts since I start from a balanced budget in the first period of the simulation. Therefore, the initial value of the public deficit is, per assumption, equal to zero. Government consumption is calculated according to equation 29, and government investment is obtained by equation 30. Lastly, I consult the ECB databases (ECB 2023c, 2023d) to determine the value of outstanding loans and government securities as well as the current debt-to-GDP ratio. The value of the deposits in the first period is calculated as a residual from equation 36.

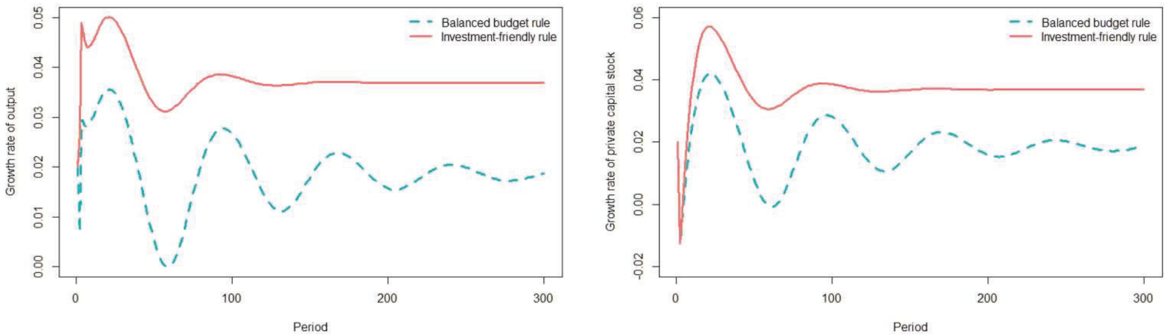
4. Results

4.1. Baseline Results

I begin with a simulation of the model, as described above, over 300 periods. This section presents the baseline simulation results of two fiscal rule scenarios, a balanced budget rule, where $\gamma_{IG} = 0$, and an investment-friendly 'golden' rule with $\gamma_{IG} = 0.02$. Figure 1 displays the growth rates of output and of private capital stock under the two chosen fiscal rule scenarios. The yearly growth rates peak at 5 per cent after 20 periods in the case of the investment-friendly fiscal rule and gradually converge to approximately 3.7 per cent in the long run. However, growth remains much lower than that until the end of the simulation exercise in the case of the balanced budget fiscal rule, only reaching a maximum of 3.6 per cent and fluctuating around 1.7 per cent over the long term. This is the first central observation in the simulation exercise.

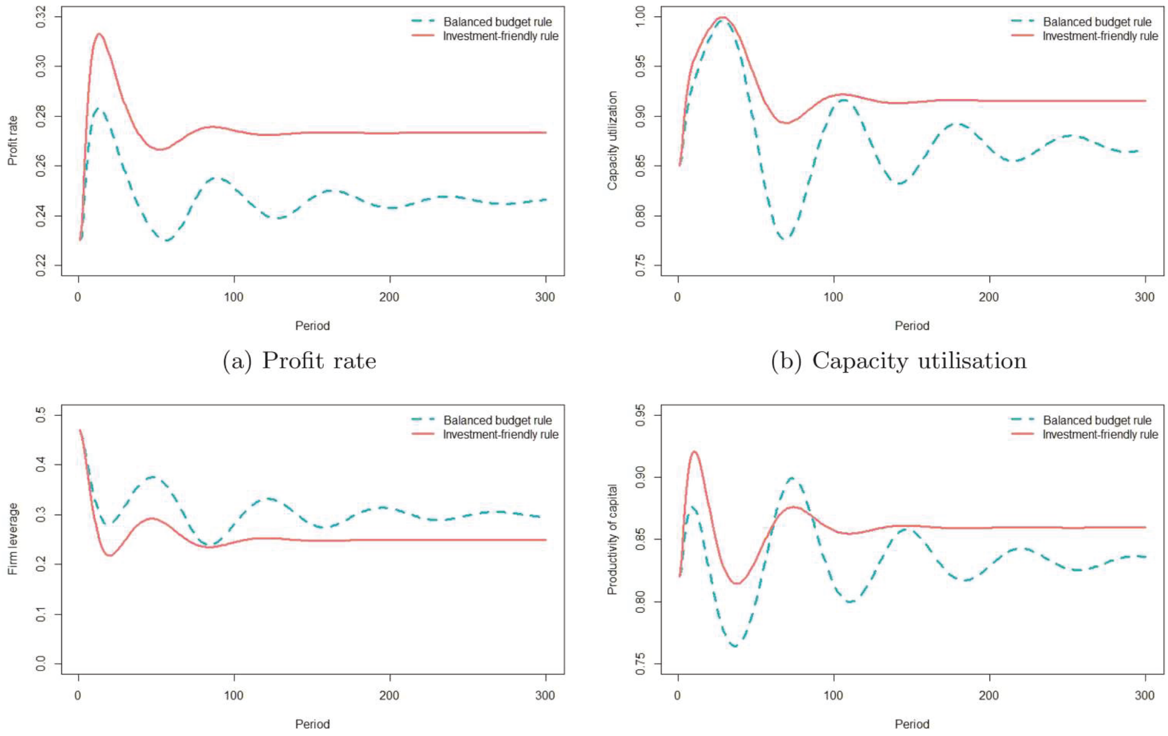
The second crucial result here is the difference in volatility of the growth rates under the two scenarios. Indeed, in the case of the investment-friendly fiscal rule, the variance of the growth rate is significantly lower, and it is converging to the long-term value much sooner than under the balanced budget fiscal rule. Under the scenario where the government is primarily focused on balancing the budget, the volatility of the growth rates is large and persistent, with periods of low economic growth, and the convergence to the long-term growth rate values is not completed within the simulation period. Thus, not only growth, but also economic stability is lower under the balanced budget scenario.

The higher growth rates, as well as their lower volatility under the scenario where public investment is exempt from the spending ceiling, are explained by the factors determining the accumulation of private capital in the model, i.e., profit rate, capacity utilisation, and firms' leverage. These variables, after a short adjustment period, converge to their long-term values in the case of the investment-friendly fiscal rule (see Figure 2). The profit rate increases significantly from the initial level to about 27.3 per cent, whereas it fluctuates around a lower level of about 24.5 per cent under the balanced budget fiscal rule (Figure 2(a)).



(a) Output (b) Private capital

Figure 1. Growth rates. (a) Output and (b) Private capital.



(a) Profit rate

(b) Capacity utilisation

(c) Loans to private capital ratio

(d) Productivity coefficient v

Figure 2. Private investment determinants and capacity utilisation. (a) Profit rate, (b) Capacity utilisation, (c) Loans to private capital ratio and (d) Productivity coefficient v.

Furthermore, the rate of capacity utilisation, after a temporary increase, falls significantly and then oscillates around the initial level under the restrictive fiscal policy scenario. On the contrary, it converges to a higher long-term level of about 91.5 per cent in the golden rule scenario (Figure 2(b)). Thus, the scenario of the investment-friendly fiscal policy results not only in higher growth of private capital, but also in a more intensive usage of productive capacity. A higher and more stable capacity utilisation implies a higher and more stable employment under the golden rule scenario. Moreover, a larger increase in profits under the investment-friendly fiscal rule allows firms to reduce their leverage a bit further, notwithstanding an accelerated investment activity (Figure 2(c)). To conclude, all three factors determining the investment rate of the private firms are more favourable under the investment-friendly fiscal rule, resulting in a faster private capital accumulation and output growth.

The dynamics of the productivity of the capital stock v_t is crucial for the results of the simulation (Figure 2(d)). Since public capital stock is subject to depreciation, the productivity of capital is lower under the balanced budget rule, and it exhibits a more volatile behaviour. On the contrary, the productivity coefficient converges to a higher value under the investment-friendly rule and is more stable, since sufficient government investment is undertaken to maintain the public capital stock. To sum up, public investment ensures a faster and more stable growth of the supply side which is necessary for the overall growth in the model.

To provide an economic interpretation for this result, the balanced budget scenario would depict an empirically observed phenomenon that private capital cannot be highly productive when public infrastructure is in a state of deterioration. Importantly, public infrastructure in this framework includes not only physical infrastructure but also investments in human capital that improve the quality and accessibility of essential public services like education and healthcare. Vice versa, the investment-friendly fiscal rule scenario illustrates how barriers to private economic activity can be reduced by increasing the productivity of private capital through improved infrastructure. A stable productivity coefficient lowers the uncertainty for firms, thus creating more favourable business conditions. As a result, private investment activity is accelerating.

Figure 3 depicts the fiscal multiplier defined as the change of output in relation to the change in public spending:

$$M_t = \frac{Y_t - Y_{t-1}}{G_t - G_{t-1}} \tag{51}$$

The fiscal multiplier ranges between 0 and 2.9. The multiplier is marginally higher in the long run under the balanced budget rule since the growth rate is lower. So, the dynamics and the magnitude of the fiscal multiplier are roughly in line with empirical evidence (Gechert and Rannenberg 2018).

Finally, Figure 4 presents the development of the key public finance variables. First, government runs deficits in the scenario of the golden rule, amounting to roughly 1.2 per cent of GDP in the long run, whereas the debt-to-output ratio converges to about 56.7 per cent of GDP. In the balanced budget scenario, the primary balance fluctuates around zero for the major part of the simulation period. However, as a consequence of low growth, the debt-to-output ratio, after an initial decline, when it sinks below the level of the golden rule scenario, goes up again. Eventually, when the growth rates reach the long-term value and stabilize there, the public debt ratio fluctuates at about 69 per cent of output. It is thus considerably higher than under the investment-friendly fiscal rule and also much more volatile. In conclusion, aiming to achieve a balanced budget does not result in a lower debt-to-GDP ratio.

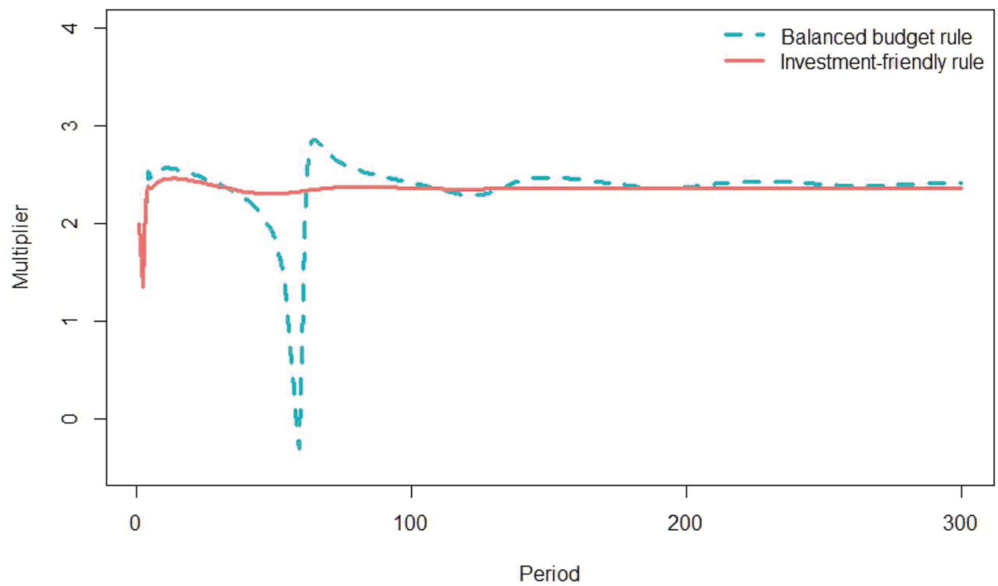
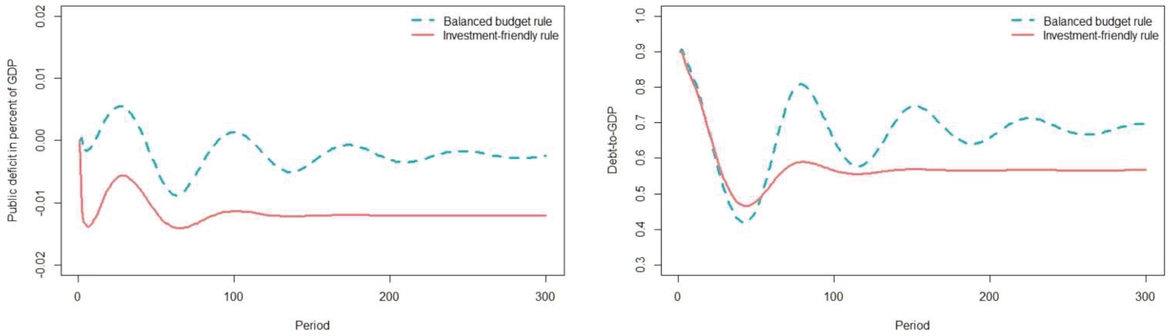


Figure 3. Fiscal multiplier.



(a) Public deficit (b) Public debt

Figure 4. Public finance. (a) Public deficit and (b) Public debt.

Indeed, as equation 49 indicates, the debt ratio converges to a stable positive value in two cases: Given there is budgetary deficit, the debt-to-output ratio is stable if the growth rate is higher than the interest rate on government bonds net of tax rate; otherwise, if the net interest rate is above the growth rate, the government needs to run a surplus to keep the debt-to-GDP ratio constant. Since the growth rate is endogenous to public spending in the model, the simulated scenarios correspond to these two opposite outcomes. The fiscal policy of increased public investment induces a higher growth rate which allows for a negative budget balance, while the public debt ratio remains low in the long run. Whereas the frugal fiscal scenario results in the growth rate being below the net interest rate on government bonds over prolonged periods, so that the surplus is needed for the stability of the debt-to-output ratio.

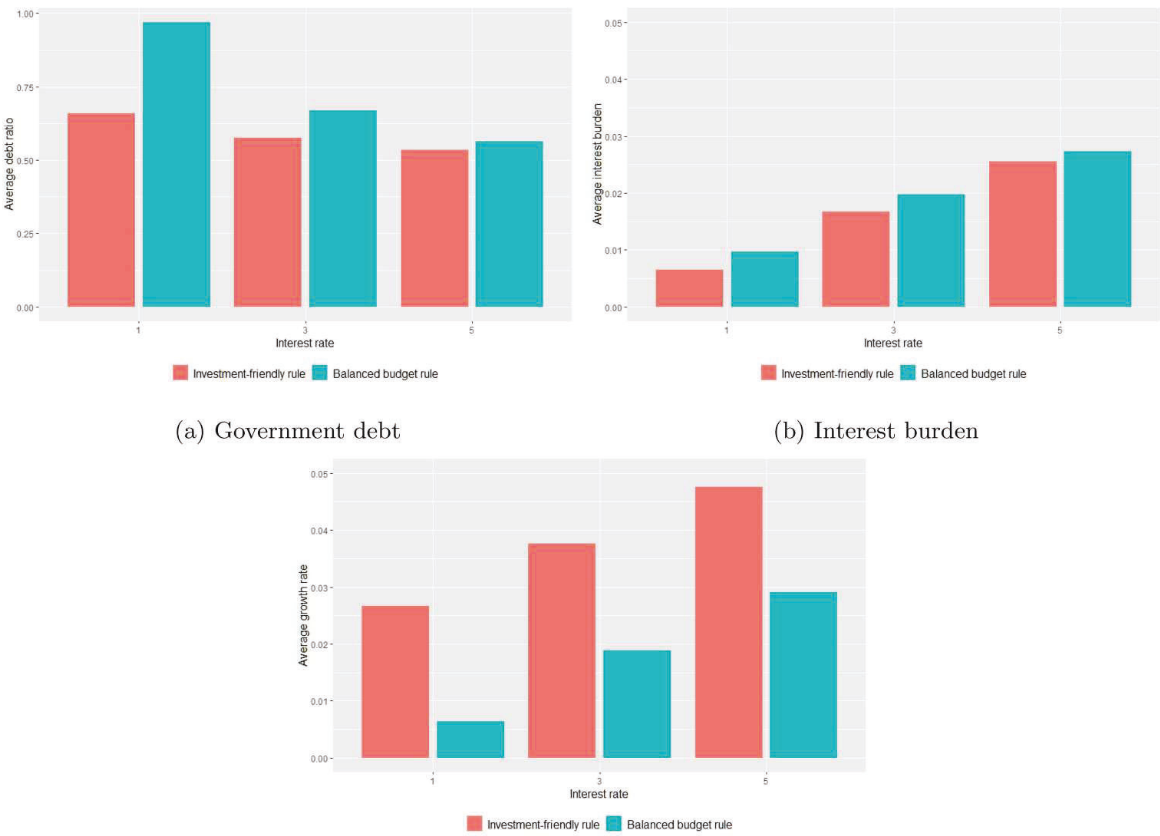
To conclude, the balanced budget rule scenario demonstrates lower growth rates of output as well as public and private capital. This scenario exhibits a lower profitability and a lower capacity utilisation rate, a somewhat higher firms' leverage and a persistently lower productivity of capital stock. Notwithstanding a budget surplus in some periods or an insignificant deficit in other periods, the balanced budget rule scenario results in a public debt-to-GDP ratio which stays significantly higher than under the investment-friendly rule in the long run, thus missing the objective of fiscal sustainability. In addition, it induces economic instability since the macroeconomic variables show much more volatile dynamics under the balanced budget rule. On the contrary, higher growth rates and accelerated capital accumulation under the golden rule of public investment, although associated with public deficits, result in a lower debt-to-output ratio.

4.2. Interest Rate on Bonds and the Domar Condition

In this section, I investigate the sensitivity of the results to the interest rate on government bonds. In the baseline scenario, the interest rate on government bonds amounted to 3 per cent. Now I simulate the model for the interest rate values of 1 per cent and 5 per cent. Crucially, debt service payments are modelled as a transfer from the government to the population since interest payments enter the bank profits which are directly distributed as income to the households. Therefore, a higher interest rate will induce an increase in this transfer and, thus, an increase in disposable income and government revenue.

Figure 5 presents the results of the interest rate simulations. Figure 5(a) displays the debt-to-GDP averages under the different fiscal rules and the values for the interest rate. The debt-to-output ratio is higher with a lower interest rate, especially so for the balanced budget scenario. At first, this might seem at odds with the Domar debt sustainability condition (Domar 1944). However, the analysis in Domar's original work assumed that the growth rate is exogenously given and does not depend on the interest rate. This is different in the model outlined in this paper. The growth rate is endogenous to the interest rate due to the stock-flow consistency of the model. Also, the modelled economy is closed so that the debt service flows enter the disposable income of households in their entirety. By consulting the graphs for the interest burden and the growth rate (Figure 5(b,c)), it becomes obvious that, although the interest burden is predictably larger with an increased interest rate, the growth rates are, however, also higher. This is due to the increased disposable income, tax revenue, and thus also aggregate spending. The effect on the growth rate is more than proportional to the change in interest rate, so the sustainability of debt improves with a higher (and worsens with a lower) interest rate.

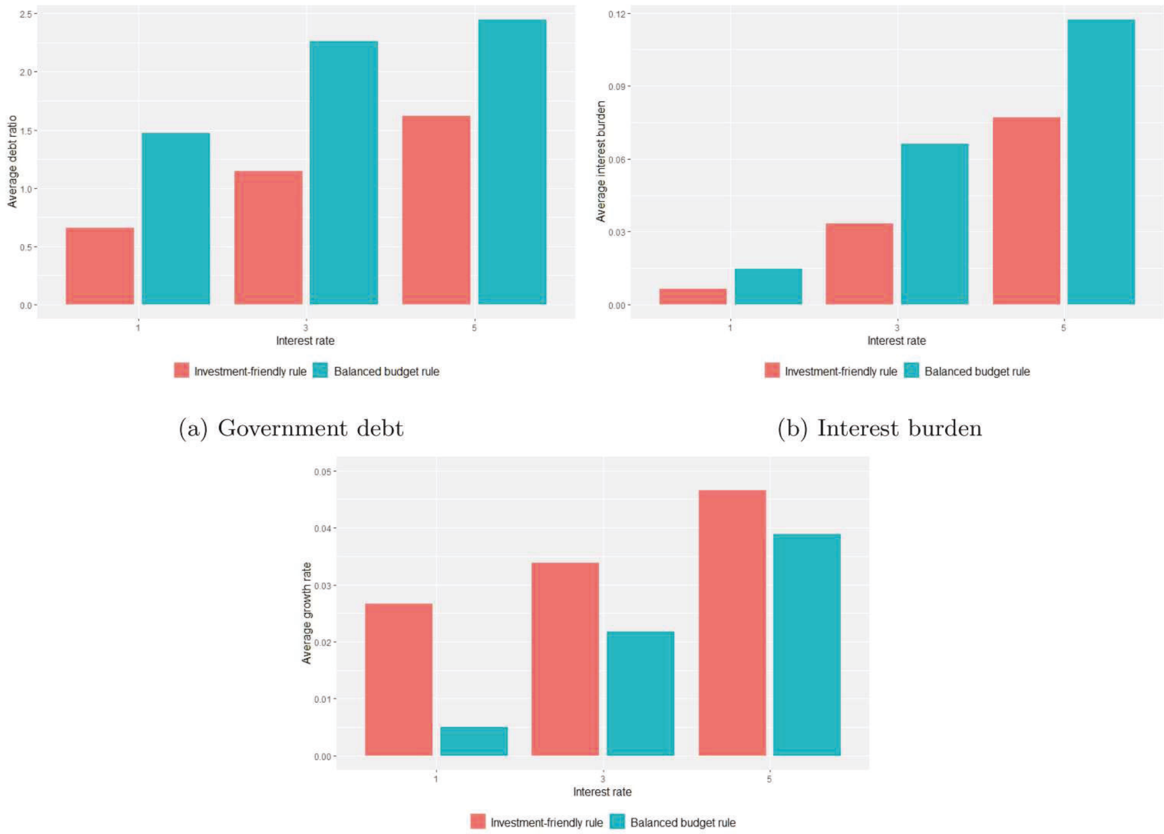
The assumption that interest payments flow to disposable income and tax revenue can be relaxed to contrast its effect on debt sustainability. In what follows, I assume that debt service payments are not spent in their entirety. Instead, bondholders transfer a share of



(a) Government debt (b) Interest burden

(c) Growth rate

Figure 5. Sensitivity to interest rate on government bonds. (a) Government debt. (b) Interest burden and (c) Growth rate.



(c) Growth rate

Figure 6. Sensitivity to interest rate on government bonds under alternative assumptions. (a) Government debt. (b) Interest burden and (c) Growth rate.

interest payments to tax haven accounts, instead of firms that distribute their entire profits to households.[5] Formally:[6]

$$\Delta V_{Ot} = \lambda_B(int_B B_{t-1}) \tag{52}$$

$$BP_t = int_L L_{t-1} + (1 - \lambda_B)int_B B_{t-1} - int_V Vh_{t-1} \tag{53}$$

$$DP_t = TP_t - RP_t \tag{54}$$

Figure 6 presents the results of the simulation under these alternative assumptions. Higher debt service still results in stronger growth. However, the additional interest burden is much larger in relation to output. As a result, the public debt ratio is higher for scenarios with a higher interest rate, because the increase in debt service is larger than the effect on growth. This would be in line with the original Domar condition. In conclusion, the stock-flow consistency and the closed nature of the modelled economy allow for an illustration of the interaction between the monetary and real variables in the context of the Domar condition: Higher interest rates on bonds lead to an increase in the debt-to-GDP ratio only if the positive effect of interest payments on the aggregate demand does not outweigh the increase in interest burden.

[5]Please note that this reclassifies V_O as a bank asset instead of firms asset.
[6]$\lambda_B = 0.75$. Note that λ_B equal to 1 would mean that the interest payments are entirely saved in tax havens. For example, in case public debt is held by foreign investors, a higher interest rate does not increase domestic demand.

4.3. Sensitivity of Results to Parameters

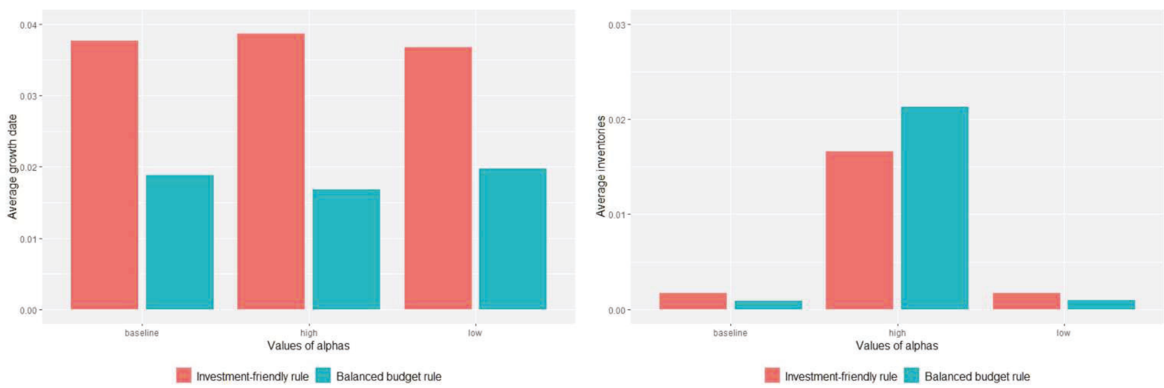
The results of the baseline simulations possibly depend on the parameters of the key equations, such as the private investment and the capital stock accumulation. The parameters have been set exogenously, based on the available data and theoretical arguments. However, values of these parameters as well as assumptions can significantly influence the outcomes of the simulations. Therefore, this section will investigate the sensitivity of results to variation in these factors.

4.3.1. Parameters of the Private Investment Function

In this section, I test the robustness of the results to the parametrisation of the private investment function. I specified private investment as a function of the profit rate, the capacity utilisation and the leverage (see equation 8). The elasticities of the private investment to these factors (correspondingly, α_1, α_2 and α_3) were chosen in order to induce plausible multipliers and growth rates in a reasonable range, since reliable empirical estimates for them are not available.

Figure 7 examines the sensitivity of results to the size of alphas. The baseline scenario corresponds to $\alpha_1 = 0.15$, $\alpha_2 = 0.15$ and $\alpha_3 = -0.15$. The simulations with these values result in an average growth rate amounting to about 3.7 per cent under the investment-friendly fiscal rule and 1.7 per cent under the balanced budget rule. Also, in this case, the simulations deliver average private capacity utilisation rates of a magnitude between 75 per cent and 95 per cent and a large but reasonable fiscal multiplier of 2.4. Now I test two alternative sets of alphas: 'low' and 'high'. Namely, the low alphas scenario is a set of parameters 10 per cent lower than the baseline scenario ($\alpha_1 = 0.135$, $\alpha_2 = 0.135$ and $\alpha_3 = -0.135$), and the high alphas scenario tests a set of parameters 10 per cent larger than the baseline ($\alpha_1 = 0.165$, $\alpha_2 = 0.165$ and $\alpha_3 = -0.165$).

The alternative sets of alphas induce similar growth rates to the baseline (Figure 7(a)). However, in the scenario of larger alphas, private investment is greater than in the baseline. Expanded private investment brings the economy to its capacity limit where aggregate demand exceeds potential output. Firms start to invest in inventories at a much higher rate, on average more than 1.5–2 per cent of GDP each period (Figure 7(b)). Further increasing the alphas induces explosive dynamics in the model. Contrarily, the



(a) Average growth rate (b) Average investment in inventories

Figure 7. Sensitivity to parameters of the private investment function. (a) Average growth rate and (b) Average investment in inventories.

low alphas scenario differs from the baseline scenario in a significantly lower private investment activity. Private sector leverage falls to smaller values. Further decreasing alphas turns firms into net lenders since retained earnings exceed investment expenditure. All in all, both alternative scenarios do not seem to be plausible in the long run.

Figure 8 shows the average debt-to-GDP ratios under the alternative sets of alphas. The debt ratio proves to be sensitive to the parametrisation of the private investment function. Indeed, the debt ratio is smaller (larger) in the case of higher (lower) alphas. Still, in all cases, it holds that the fiscal rule that allows for additional public investment induces a lower debt ratio than the balanced budget rule. All things considered, the findings in this section confirm the plausibility of the initial set of alphas for the baseline scenario since it delivered the most moderate result. Centrally, the baseline results remained stable under the alternative specifications of the model.

4.3.2. Sensitivity to Depreciation Rates

Due to the centrality of public as well as private capital accumulation in the model, the assumption of capital stock depreciation plays an important role in the analysis. This section will explore the sensitivity of results to the chosen values of the depreciation rates. The baseline depreciation rates correspond to the empirical estimates for high-income countries in the study conducted by IMF (2015) and amount to 0.1041 for private and 0.0459 for public capital. I run additional simulations using depreciation rates representative of middle-income and low-income countries, consistent with the values reported in the report (IMF 2015), which correspond to the following values: 0.081 and 0.0351 for middle-income economies and 0.0425 as well as 0.025 for low-income countries, for private and public capital, respectively. The values for richer countries, as well as for private capital compared to public capital, are higher, since more technologically sophisticated assets have shorter life spans.

Figures 9 and 10 show the simulation results for two key variables: public debt-to-output ratio and the growth rate of private capital. Although the average debt-to-GDP ratio is lower for all the alternative depreciation rate scenarios, the difference is marginal for the balanced budget rule (Figure 9). This result is explained by the growth

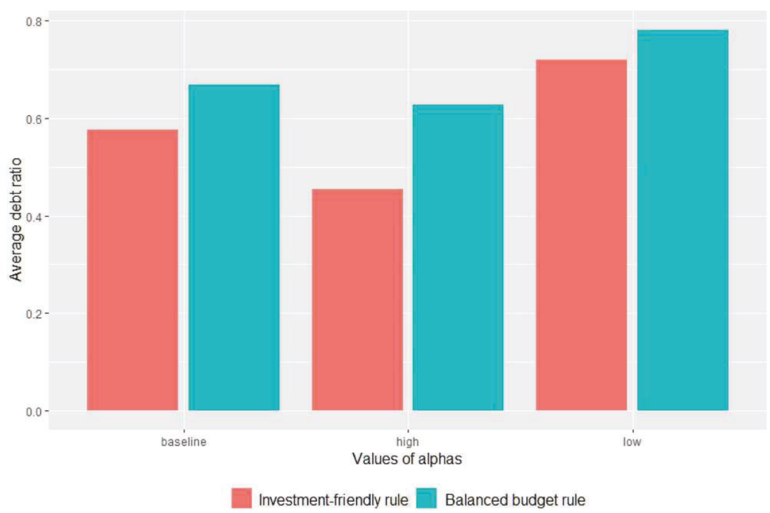


Figure 8. Sensitivity of public debt to parameters of the private investment function.

Figure 9. Sensitivity of public debt to depreciation rates.

rate of private capital (Figure 10) which remains about the same for the budget balance scenario under the lower capital depreciation rates. Indeed, the growth rate of private capital is driven by the profit rate, the capacity utilisation rate, and the leverage rate. Under the balanced budget rule, these variables do not improve compared to the baseline simulation, even though the depreciation rates are lower. Au contraire, the boost to the private investment activity of the additional investment in public infrastructure under the golden rule proves to be stronger under lower depreciation rates.

To wrap up, while slower depreciation improves the efficiency of public capital accumulation, it also enhances the crowding-in effect of public investment through the positive impact on the determinants of private investment in this framework. A last, but not least, important observation to be mentioned is that the main result of the model holds: The debt-to-output ratio is lower for the investment-friendly fiscal rule, than for the balanced budget rule, also under the alternative sets of depreciation rates.

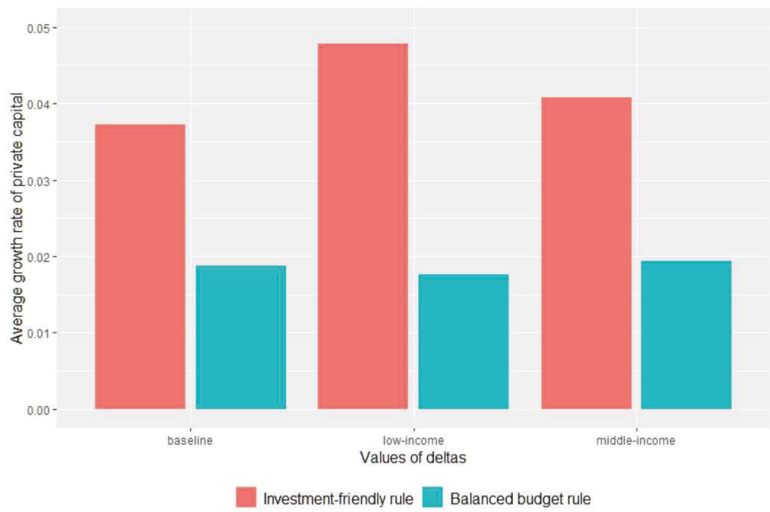


Figure 10. Sensitivity of private capital growth rate to depreciation rates.

5. Conclusion

I develop a macroeconomic SFC model that incorporates public sector in the economy. In this model, government can consume and invest; both spending categories enter the aggregate income, however, government investment adds up to the public capital stock which is defined broadly and includes public and social infrastructure. The productivity of the private capital depends on the public capital stock due to congestion effects. The composition of public spending, in turn, depends on the fiscal rules. Two fiscal scenarios are then simulated: the one where the government is aiming to attain a balanced budget and the one where the government invests at a constant rate.

Baseline results show that the investment-friendly fiscal rule induces a higher profitability of private capital, a more intensive capacity utilisation, a lower firms' leverage, and, as a consequence, stronger growth. The higher growth rates and accelerated capital accumulation under the golden rule of public investment, although associated with higher public deficits, result in a lower debt-to-output ratio. The balanced budget scenario results in a higher debt-to-GDP ratio, although the government runs a fiscal surplus. In addition, the balanced budget rule induces economic instability due to a high volatility of the productivity of capital so that the model does not converge to the steady state within the simulation time span. Furthermore, the stock-flow consistent nature of the model facilitates an investigation of the Domar condition under the premise that the growth rate is endogenous to the interest rate. Finally, sensitivity tests confirm that the results are fairly robust to parametrisations of the private investment and the capital accumulation equations.

To conclude, deficit aversion does not necessarily bring about a reduction in debt. A restrictive fiscal policy does not seem to be the most efficient way to achieve long-term debt sustainability if public investment is crucial for productivity. Moreover, not only the economic, but also the ecological and political dimensions of society may become more and more fragile in the current multi-crisis, leaving less time and room for manoeuvre. Therefore, aligning government policy to the short-term indicators of public finance, such as the deficit, and neglecting the long-term outcomes becomes problematic. A more effective policy would include looking at the economic effects of various spending categories and prioritising projects that boost productivity.

Lastly, the model can be extended in a variety of ways to delve into further topics, for example, by implementing additional fiscal regime scenarios or alternative sets of fiscal rules. Moreover, interest rates on government bonds can be hinged on a set of variables, such as the debt-to-output ratio, the growth rate, and others. This would make the model suitable to investigate some behavioural reactions in financial markets discussed in the literature. Furthermore, the model could make an appropriate tool to analyse the dynamics of the green transition by introducing carbon emissions and climate-relevant investment to the developed framework. Last but not least, a useful extension to the model could be implementing 'delays to build'. Imposing lags on the adjustment of these variables would mimic the time needed for the construction work. This would enable simulation of the temporal discrepancy between the fiscal policy and the real economy effects of infrastructure, potentially invoking insightful dynamics.

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Appendix

Table A1. Parameters and initial values of variables.

Parameter	Definition	Value	Source
c_1	Propensity to consume out of disposable income	0.88	Main national accounts (Eurostat 2023a)
c_2	Propensity to consume out of deposits	0.05	Dafermos and Nikolaidi (2019)
ω	Wage share	0.624	Long-term value (ECB 2023a)
int_V	Interest rate on deposits	0.02	Bank interest rates (ECB 2023b)
int_B	Interest rate on government bonds	0.03	Yield curves (ECB 2023e)
int_L	Interest rate on loans	0.05	Bank interest rates (ECB 2023b)
s_F	Saving rate out of profits	0.47	Calculated to fit lev_t
λ_P	Rate of tax avoidance	0.025	Tax Justice Network (2023)
ρ	Output elasticity of public capital	0.12	Bom and Ligthart (2014)
$1-\rho$	Output elasticity of private capital	0.88	Calculated from $1-\rho$
δ_{Kpr}	Depreciation rate of private capital	0.1041	Estimated from data (IMF 2015)
δ_{KG}	Depreciation rate of public capital	0.0459	Estimated from data (IMF 2015)
β	Desired inventories level	0.05	Per assumption
τ	Tax rate	0.5	Calculated to fit T_1
α_1	Investment function coefficient of profit rate	0.15	Selected from a plausible range
α_2	Investment function coefficient of cap. utilisation	0.15	Selected from a plausible range
α_3	Investment function coefficient of firms' leverage	−0.15	Selected from a plausible range
γ_{CG}	Consumption spending coefficient of government	0.36	Calculated to fit CG_1
γ_{IG}	Government investment target	0/0.02	Determined by fiscal rules
Variable	**Definition**	**Initial value**	
Y_1	Aggregate output	1	Main national accounts (Eurostat 2023a)
Y_1^*	Potential output	1.18	Calculated from equation 2
Z_1	Aggregate spending	1	Main national accounts (Eurostat 2023a)
I_1	Total private investment	0.14	Main national accounts (Eurostat 2023a)
C_1	Private consumption	0.44	Calculated to fit Z_1
KG_1	Public capital stock	1	IMF Capital Stock Dataset (IMF 2021)
Kpr_1	Private capital stock	1.5	IMF Capital Stock Dataset (IMF 2021)
v_1	Productivity coefficient of capital stock	0.82	Calculated from equation 3
r_1	Profit rate	0.23	Calculated from equation 9
u_1	Capacity utilisation	0.85	Calculated from equation 10
T_1	Tax revenue	0.42	Total receipts from taxes (Eurostat 2023b)
G_1	Government expenditure	0.42	Calculated to fit $deficit_1$
CG_1	Government consumption	0.36	Calculated from equation 29
IG_1	Government investment	0.06	Calculated from equation 30
L_1	Loans	0.7	Sector accounts (ECB 2023d)
lev_1	Leverage	0.47	Calculated from equation 11
V_{H_1}	Households' deposits	1.6	Calculated from equation 36
V_{O_1}	Firms' tax haven deposits	0	No estimate
Θ_1	Stock of inventories	0.05	Per assumption
B_1	Bonds outstanding	0.9	Government debt (ECB 2023c)
$debt_1$	Debt-to-GDP ratio	0.9	Government debt (ECB 2023c)
$deficit_1$	Government deficit	0	Determined by fiscal rules