Government Consumption, Government Investment, and Public Debt in a Heterogeneous-Agent New Keynesian (HANK) Model*

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February 29, 2024

Abstract

The paper analyses the interaction of government investment spending and the fiscal rule with monetary policy in a heterogeneous-agent New Keynesian (HANK) model. It shows that an increase in government investment can be expansionary in the short run and recessionary and deflationary in the medium run when monetary policy is passive and an increase in productive public capital crowds out private labour. This holds under both tax and debt-financing, time-to-build and under temporarily suspended fiscal rule, as long as there is sufficient amount of government bonds for households to partially self-insure. When this is restricted, such as in the case of no initial public debt, financing of government investment with taxes is recessionary and deflationary, while financing with debt is expansionary and inflationary. Active monetary policy response stimulates aggregate demand to counter deflationary pressure from productive public capital over the medium to longer term, with little cost in terms of inflation.

JEL Classification: E21, E31, E32, E52, E62

Keywords: *Government investment, Public capital, Monetary policy, Heterogeneous agents*

*The author would like to thank.....

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1 Introduction

The role of fiscal policy in managing business cycles has begun attracting more attention since the Great Financial Crisis (Ramey (2021), Kopiec (2022)). Government investment in particular has garnered interest, for at least two reasons. First, it was the easiest government spending item that could be reduced, especially in European countries during the sovereign debt crisis.[1] Second, because public capital has a supply-side element that can increase potential output in the medium to longer run. This second property is particularly interesting in HANK models, because its implications are not a priori clear. An increase in demand due to an increase in government investment has expansionary effects in a New Keynesian framework, but the supply-side effect from more public capital is similar to a productivity shock and could be recessionary in the medium run. It is not clear which of the effects prevails, under what conditions this happens, and whether monetary policy plays a role. These are the questions this paper attempts to analyse.

Government spending, either for consumption or investment purposes, has been the subject of numerous analyses in standard representative-agent New Keynesian (RANK) models, and the properties of such policies are relatively well known. However, the emergence of heterogeneous-agent models, where distributional issues, household income, and income risk give much more prominence to Keynesian demand elements than in the standard RANK models, warrants re-visiting some of the issues. One reason is that there are several new transmission channels in HANK models, and also standard and well-known transmission channels may work differently, for instance just because the marginal propensity to consume in HANK models is larger.

A concrete example of a different or modified transmission mechanism is public debt. In a standard RANK model, public debt is an intertemporal transfer of income between government and households and has no direct benefit for households. In a HANK model, public debt has an additional role in that it serves as a saving vehicle - households can use it to save and therefore self-insure against idiosyncratic income risk. More public debt, therefore, facilitates self-insurance of households in a HANK model, which has an effect on their consumption and

[1] For empirical evidence that European countries reduced government investment by more than government consumption during the sovereign debt crisis in Europe, see Banbura et al. (2018).

saving decisions.

Similarly, government investment that increases productive public capital has been shown to increase wages and employment in a standard RANK model over a medium to longer term. Part of the reason for this is that the benefits of higher productivity of public capital are shared among the households. In a HANK model, this is not necessarily the case, because more (and more productive) public capital could crowd-out labour, as the same amount of goods could be produced using less labour if public capital has increased. Less labour in turn means lower labour income for at least some households, which can reduce rather than increase their consumption.

The aim of this paper is to investigate the new or modified transmission channels, in particular with respect to public debt, its cyclicality, to the crowding-out of labour by productive public capital, and the role monetary policy can play in this setting. This is done in two ways. The issue of the effect of public debt as a saving vehicle for self-insurance is investigated by assuming that government spending (either wasteful consumption or non-wasteful investment) is financed either by lump-sum taxes, so that public debt does not increase, or by allowing public debt to temporarily increase. The issue of productive public capital crowding-out labour is investigated by simulating an increase of government investment at different levels of productivity of public capital. Importantly, the model incorporates realistic features regarding the cyclicality and distribution of incomes, in particular that the vast majority of households receive procyclical wage income, except the richest ones (who also receive dividends, which are calibrated to be small). This avoids some of the unrealistic effects of countercyclical dividends on labour supply in a typical HANK model with sticky prices and flexible wages, as pointed out specifically in the context of fiscal policy by Broer et al. (2023).

The main finding is that government investment, when public capital is productive, reduces firms' demand for household labour in the medium run. This implies that, after the initial stimulus from government is over, wages and labour demand fall, resulting in a loss of income for households. Because households have relatively high marginal propensities to consume compared to a RANK model, this leads to a reduction in private consumption in the medium run. These results hold regardless whether government investment is financed by issuing debt, by reducing government consumption spending, or by taxes. The finding also holds for various modifications

in terms of timing of how government investment affects public capital (time-to-build) or by various modifications of the fiscal rule. One exception is when the stock of the saving vehicle that households can use to self-insure (government bonds) is very small to start with. In this case, an increase in government investment that is financed by issuing debt has expansionary and inflationary effects in the short and medium run. However, if it is financed by taxes, it is contractionary and deflationary even in the short run.

Monetary policy reaction to government investment increase materially affects the above results. The reduction in interest rates in response to lower inflation stimulates consumption of households that can to some extent smooth consumption. This increases aggregate demand in the short to medium run and therefore increases firms' demand for labour. This fills-in the gap of "missing demand" for labour that occurs because firms can produce more with less labour due to the increase in productive public capital. Because the demand for labour falls less, consumption of relatively poor households - who are more dependent on labour income - also increases. This leads to the amplification of aggregate demand and inflation, so that we observe the standard responses to a government investment increase in equilibrium - an increase in output, aggregate consumption, and inflation. Active response of monetary policy is crucial for this outcome. Moreover, the response of monetary policy interacts with the productivity of public capital and this interaction has implications for consumption inequality. In particular, when public capital is more productive and monetary policy responds to inflation and output developments, consumption of households at different levels of income tends to co-move, which is not the case when monetary policy just keeps the real interest rate constant. Importantly, aggregate consumption and output stay higher over an extended period of time when monetary policy is active and public capital is productive, and this comes with little cost in terms of inflation in the short run, and no cost in the medium run.

The paper is related to the literature that examines the role of government investment for business cycles, which dates back to at least Baxter and King (1993), and has been revived in a number of papers such as Leeper et al. (2010), and more recently in various contexts such as the zero lower bound (Bouakez et al. (2017) and Bouakez et al. (2020)), small open economy in a monetary union (Clancy et al. (2016) and Hickey et al. (2020)), and numerous papers

that investigate various combinations of fiscal policies that can include government investment spending (Coenen et al. (2012a), Coenen et al. (2012b), Kilponen et al. (2019), and many others).

While there has been some investigation of fiscal multipliers in the HANK literature, the papers have mostly focussed on government consumption spending (see e.g. Kopiec (2022) and Broer et al. (2023)) or on allocations that can be achieved by a combination of taxation and conventional fiscal policy (Seidl and Seyrich (2023)). There has been less focus on government investment in the HANK literature, which has mostly focussed on the role of monetary policy and its transmission mechanisms (see e.g. McKay and Reis (2016), McKay et al. (2016), Kaplan et al. (2018), Auclert (2019), and many others, with the list is again not doing justice to the growing literature). An excellent recent overview of the issues regarding the effects of government investment in the standard RBC and New Keynesian models, along with the review of the empirical evidence can be found in Ramey (2021).

The paper is structured as follows. Section 2 describes the model, Section 3 explains the calibration, Section 4 describes the main results and discusses several robustness checks and additional experiments, and Section 5 concludes.

2 Model

To analyse the effects of government consumption and investment spending policies, we start from the simplest possible HANK model along the lines of McKay et al. (2016), to which we add the two types of government spending to the aggregate demand, public capital to production, and time-varying public debt. This section describes the main model blocs and discusses where the new elements enter the model.

Households. There is a unit continuum of ex-ante identical households indexed by h, who face idiosyncratic income risk and a borrowing constraint. Markets are incomplete, so households are not able to fully insure against adverse income shocks. They can partially insure themselves by saving in government bonds, which are in positive net supply. Household preferences are given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_{h,t}^{1-\gamma} - 1}{1-\gamma} - \psi_1 \frac{l_{h,t}^{1+\psi_2}}{1+\psi_2} \right], \tag{1}$$

where $c_{h,t}$ is consumption of household h at time t, $l_{h,t}$ is labour supply, γ is the inverse of the intertemporal elasticity of substitution, ψ_1 is the relative weight of labour in the utility function, and ψ_2 is the inverse of the Frisch elasticity of labour supply.

Each household has a budget constraint and a borrowing constraint:

$$c_{h,t} + \frac{b_{h,t+1}}{1+r_t} = b_{h,t} + w_t z_{h,t} l_{h,t} - \tau_t \bar{\tau}\left(z_{h,t}\right) + D_t \bar{d}\left(z_{h,t}\right), \tag{2}$$

$$b_{h,t} > \bar{b}, \tag{3}$$

where r_t is the real interest rate on riskless government bonds, $b_{h,t}$, $z_{h,t}$ is the idiosyncratic level of productivity that determines a household's labour income, w_t is wage level, $\tau_t \bar{\tau}\left(z_{h,t}\right)$ is the lump-sum tax that depends on household's level of labour income, and $D_t \bar{d}\left(z_{h,t}\right)$ are dividends received by each household, again depending on their respective labour productivity. $\bar{b}$ determines the borrowing constraint (we assume $\bar{b} = 0$). A household's productivity follows a Markov chain with transition probabilities $Pr\left(z_{h,t+1}|z_{h,t}\right)$, so that labour income received by a household is $w_t z_{h,t} l_{h,t}$.

The decision problem of the household can then be written as

$$V_t\left(b_{h,t}, z_{h,t}\right) = \max_{\{c_{h,t}, b_{h,t}, l_{h,t}\}} \left[\frac{c_{h,t}^{1-\gamma} - 1}{1-\gamma} - \psi_1 \frac{l_{h,t}^{1+\psi_2}}{1+\psi_2} + \beta \sum_{z_{h,t+1}} \Pr\left(z_{h,t+1}|z_{h,t}\right) V_{t+1}\left(b_{h,t+1}, z_{h,t+1}\right) \right] \tag{4}$$

subject to the budget constraint (2) and the borrowing constraint (3).

The optimality conditions, subject to the aforementioned constraints, are the standard Euler equation,

$$c_{h,t}^{-\gamma} \leq \beta \sum_{z_{h,t+1}} \Pr\left(z_{h,t+1}|z_{h,t}\right) c_{h,t+1}^{-\gamma}, \tag{5}$$

which holds with equality if the household is away from the constraint, and the labour supply condition

$$c_{h,t}^{-\gamma} z_{h,t} w_t = \psi_1 l_{h,t}^{\psi_2}. \tag{6}$$

Government and central bank. The government in this model has two instruments on the spending side, government consumption, $G_{C,t}$, which is assumed to be wasteful (government buys goods and consumes them), and government investment, $G_{I,t}$, which accumulates as public capital, $K_{G,t}$. The government also issues discount bonds B_t and collects lump-sum taxes. These taxes depend on the cross-section of of idiosyncratic productivities $\Gamma^z(z)$, and the speed at which the government collects taxes depends on how quickly it wants to return the debt to its target level. The government budget constraint is:

$$\frac{B_t}{1+r_t} + G_{C,t} + G_{I,t} + \sum_z \Gamma^z(z)\, \tau_t \bar{\tau}\left(z_{h,t}\right) = B_{t-1}. \tag{7}$$

Public capital accumulates according tot he following law of motion, where δ_G is the rate of depreciation of public capital.

$$K_{G,t} = (1-\delta_G) K_{G,t-1} + G_{I,t}. \tag{8}$$

Government bonds serve as a saving vehicle for the households and are not in zero net supply. Households can trade in government bonds (but not in equity), so that in case of an adverse wage shock they can sell (part of) their government bond holdings to help maintain their level of consumption. The amount of available government bonds varies according to the following fiscal rule, which is specified in terms of lump-sum taxes. To simplify notation, define $\tau_t^e \equiv \sum_z \Gamma^z(z)\, \tau_t \bar{\tau}\left(z_{h,t}\right)$ as an effective tax (collected across households).[2] The fiscal rule is then

[2]Unless otherwise stated, we will assume that all lump-sum taxes are levied only on the households with the highest wage income.

$$\tau_t^e = \overline{\tau^e} + \frac{B_t - \overline{B}}{1 + r_t} + \phi_B(B_t - \overline{B}), \tag{9}$$

where bars over a variable denote their steady-state values, and $\overline{\tau^e} \equiv \overline{G_C} + \overline{G_I} + \frac{\overline{B}}{1+\overline{r}}$ is the level of effective taxes needed to finance government consumption, government investment, and all interest payments on government debt in the steady state. Fiscal rule (9) assumes that taxes are adjusted so that they fully cover the additional interest rate payments from new debt (the second term on the right-hand side), plus a reduction of debt towards the target level by a fraction ϕ_B. For instance, if $\phi_B = 1$, the fiscal rule implies a balanced budget and constant debt.

The role of the central bank is to set the interest rates for government bonds. We follow McKay et al. (2016) and assume that the central bank can, due to nominal price stickiness, set real rates directly. It does this by manipulating the nominal interest rate, observing the relationship between the nominal and the real interest rate given by the Fisher equation:

$$1 + r_t = \frac{1 + i_t}{1 + \pi_{t+1}}, \tag{10}$$

where π_{t+1} denotes the expected rate of inflation.

Intermediate goods firms. There is a continuum of monopolistically competitive intermediate goods firms, who produce output $y_{j,t}$ using labour $n_{j,t}$ and services provided by public capital:

$$y_{j,t} = K_{G,t}^{\alpha_G} n_{j,t} - \psi_F, \tag{11}$$

where the parameter α_G determines the productivity of public capital. The higher the α_G, the more productive is public capital. Note that when $\alpha_G = 0$, we obtain the standard case where public capital plays no role in production. The parameter ψ_F is a fixed cost that ensures profit to be zero, guaranteeing no entry of new firms in the steady state.[3]

The presence of public capital drives a wedge between the real wage paid to the workers and

[3]This does not ensure that profits are zero outside of the steady state, but it has the added benefit that cyclical movements of dividends, which are countercyclical in New Keynesian models with sticky prices and flexible wages, do not have a material effect on the model's properties (see Werning (2015)). In addition, we assume that all dividends are received by the highest-income households.

the real marginal cost, mc_t, which is defined as:

$$mc_t = \frac{w_t}{K_{G,t}^{\alpha_G}}. \tag{12}$$

We assume, following Calvo (1983), intermediate goods firms can only set the optimal price p_t^* occasionally, which occurs with the probability θ. This implies that the pricing problem of intermediate goods firms is:

$$\max_{p_t^*, \{y_{j,s}, n_{j,s}\}_{s=t}^{\infty}} \sum_{s=t}^{\infty} \beta^{s-t} (1-\theta)^{s-t} \left(\frac{p_t^*}{P_s} y_{j,s} - mc_s n_{j,s} \right), \tag{13}$$

subject to satisfying aggregate demand

$$y_{j,s} = \left(\frac{p_t^*}{P_s} \right)^{\mu/(1-\mu)} Y_s, \tag{14}$$

where μ is the markup related to elasticity of demand.

The solution to the pricing problem is:

$$\frac{p_t^*}{P_t} = \frac{\sum_{s=t}^{\infty} \beta^{s-t} (1-\theta)^{s-t} \left(\frac{P_t}{P_s} \right)^{\mu/(1-\mu)} Y_s \mu mc_s}{\sum_{s=t}^{\infty} \beta^{s-t} (1-\theta)^{s-t} \left(\frac{P_t}{P_s} \right)^{1/(1-\mu)} Y_s}. \tag{15}$$

The above expression can be written recursively by defining two auxiliary variables F_t and G_t as follows:

$$F_t = \mu mc_t Y_t + \beta(1-\theta) \pi_{t+1}^{\frac{\mu}{\mu-1}} F_{t+1}, \tag{16}$$

$$G_t = Y_t + \beta(1-\theta) \pi_{t+1}^{\frac{1}{\mu-1}} G_{t+1}, \tag{17}$$

and finally

$$\frac{p_t^*}{P_t} = \frac{F_t}{G_t}. \tag{18}$$

Equation 18 defines the (relative) price chosen by the intermediate goods firms that get the opportunity to reset the price.

Final goods firms. Final goods firms are competitive and purchase intermediate goods as inputs and bundle them to final goods, which are bought by households and government. They do this using the following production technology:

$$Y_t = \left(\int_0^1 y_{j,t}^{\frac{1}{\mu}} \mathrm{d}j \right)^{\mu}. \tag{19}$$

The maximization problem of final goods producers is:

$$\max_{y_{j,t}} P_t Y_t - \int_0^1 p_{j,t} y_{j,t} \mathrm{d}j, \tag{20}$$

which yields the demand for intermediate goods that was used as a constraint for intermediate goods optimization:

$$y_{j,t} = \left(\frac{p_{j,t}}{P_t} \right)^{\mu/(1-\mu)} Y_t. \tag{21}$$

It can be shown that the aggregate price P_t index is:

$$P_t = \left(\int_0^1 p_{j,t}^{(1/(1-\mu))} \mathrm{d}j \right)^{1-\mu}. \tag{22}$$

Using the Calvo assumption, aggregate price level is a weighted average of the newly set prices and prices that have remained unchanged from the previous period. Using this in the definition of the aggregate price index gives us the following expression for inflation:

$$1 + \pi_t = \left(\frac{1-\theta}{1 - \theta \left(\frac{p_t^*}{P_t} \right)^{\frac{1}{1-\mu}}} \right)^{1-\mu}. \tag{23}$$

Market clearing. To compute market clearing, we first require the law of motion for the wealth distribution. Denoting by $\Gamma_t(b_t, z_t)$ the distribution of households in terms of their government bond holdings b over the idiosyncratic labour productivity state z at time t, we

have the following law of motion for the wealth distribution:

$$\Gamma_{t+1}\left(\mathcal{B}, z_{t+1}\right) = \int_{\{(b_t,z_t):g_t(b_t,z_t)\in\mathcal{B}\}} Pr\left(z_{t+1}|z_t\right) d\Gamma_t(b_t, z_t), \tag{24}$$

where $g_t(b_t, z_t)$ is households' decision rule for their bond holdings.

Bond market clearing means that all the bonds issued by the government have to be held by the households:

$$B_t = \int g_t(b_t, z_t) d\Gamma_t(b, z). \tag{25}$$

If households' decision rule for their labour supply is $l_t(b, z)$, then the total labour supply in the economy, L_t, is

$$L_t = z \int l_t(b_t, z_t) d\Gamma_t(b_t, z_t), \tag{26}$$

which in equilibrium has to be equal to the total labour demand from intermediate goods firms, N_t:

$$L_t = N_t. \tag{27}$$

Given marginal costs, the total dividends paid intermediate goods firms are:

$$D_t = Y_t - mc_t N_t - \psi_F, \tag{28}$$

where, as explained above, the parameter ψ_F is chosen such that dividends are zero in the steady state.

If we denote households' consumption decision rule by $c_t(b_t, z_t)$, then we can write aggregate consumption as

$$C_t \equiv \int c_t(b, z) d\Gamma_t(b, z). \tag{29}$$

The supply-side of the economy consists of aggregate production, which, using $y_{j,t} = K_{G,t}^{\alpha_G} n_{j,t}$, is defined as

$$N_t K_{G,t}^{\alpha_G} = S_t Y_t, \tag{30}$$

where S_t is the efficiency loss resulting from price dispersion due to nominal rigidities. It is

defined as

$$S_t \equiv \int_0^1 \left(\frac{p_{j,t}}{P_t}\right) dj \tag{31}$$

and has the following law of motion:

$$S_{t+1} = (1-\theta) S_t (1+\pi_{t+1})^{\frac{-\mu}{1-\mu}} + \theta \left(\frac{p^*_{t+1}}{P_{t+1}}\right)^{\frac{\mu}{1-\mu}}. \tag{32}$$

Aggregate resource constraint of the economy is

$$K_{G,t}^{\alpha_G} N_t - \psi_F = C_t + G_{C,t} + G_{I,t}, \tag{33}$$

which states that total production has to be equal to consumption of households, government spending on consumption, and government spending on investment.

3 Calibration

Calibration of the model, except for the new features, follows the calibration in McKay et al. (2016). The main reason for this is that the calibration is well-known and well-tested, and at the same time fairly realistic. The values of the parameters used are provided in Table 1. An important departure from McKay et al. (2016) is that the model here assumes that (1) there are fixed costs so that profits are zero in the steady state (but not outside the steady sate), which ensures that dividends are a relatively small proportion of household income (zero in the steady state), and (2) all dividends are received by households with the highest labour productivity.[4] The other departures from this calibration relate mainly to the newly-added model features and are discussed below.

The key new parameter in the model is the productivity of the public capital, α_G. The benchmark value of 0.03 has been chosen because this is a conservative estimate in line with the literature (close to Leeper et al. (2010)), but alternative values are also considered, in particular a higher value of 0.08 based on the meta-study by Bom and Ligthart (2014).

The shares of government investment and consumption spending are also based on the stan-

[4]Dividends are countercyclical in New Keynesian models with sticky prices and flexible wages, and they can have a material effect on the model's properties (see Werning (2015) and Broer et al. (2023)).

TABLE 1. Calibration

Parameter	Value
(Inverse of) Intertemporal elasticity of substitution, σ	2
Weight of labour in the utility f., ψ_1	1
Inverse Frisch labour supply elast., ψ_2	2
Markup, μ	1.2
Frequency of price adjustment, θ	0.15
Bonds to quarterly GDP, $\frac{B}{Y}$	5.5
Steady-state real rate (annualised), r	2%

Notes: All values are taken from McKay et al. (2016).

dard values from the literature, in particular, it is assumed that the share of government consumption is 20% of GDP, which is in line with most of the policy models (see, e.g., Coenen et al. (2012a) or Kilponen et al. (2019)), and we used rounded values from Coenen et al. (2012a). The share of government investment expenditure is calibrated to be at 3% of GDP, which is in line with the empirical estimates after the Great financial crisis (see e.g. Leeper et al. (2010) or Clancy et al. (2016)). Depreciation of public capital, δ_G, has been set to be equal to the standard estimates for the depreciation of private capital, 0.025 per quarter. Finally, the fixed cost in the production function, ψ_F, has been chosen such that the steady-state level of firm profits is zero. Table 2 gives an overview of the newly-introduced parameters.

TABLE 2. Calibration

Parameter	Value	Source/Target
Share of government consumption in GDP, $\frac{G_C}{Y}$	0.2	Coenen et al. (2012a)
Share of government investment in GDP, $\frac{G_I}{Y}$	0.03	Coenen et al. (2012a)
Productivity of public capital, α_G	0.03	Based on Clancy et al. (2016)
Fixed cost in production, ψ_F	0.2	Zero steady-state profit
Depreciation of public capital, δ_G	0.025	10% per year

In addition to the above new model features, this paper departs from McKay et al. (2016) in the features of the fiscal rule. There, the parameter ϕ_B determines how quickly the government will return the debt to its initial level. The paper assumes that in every quarter, the government will reduce 20% of debt that exceeds its steady-state level, i.e., $\phi_B = 0.2$.

Finally, this paper assumes that all firm profits are received by the households with the highest labour income.

4 Results

4.1 The effects of an increase in government spending

To analyse the effects of an increase in government spending, we follow the standard practice in the literature and increase government investment or consumption spending by 1 p.p. of steady-state quarterly GDP (see Coenen et al. (2012a) and Kilponen et al. (2019)), and we do so for four quarters (equivalent to 1 p.p. of annual GDP increase).

Figure 1 shows the aggregate responses and Figure 2 shows the responses of labour and consumption by households, grouped by their labour productivity levels. Three different cases are plotted, differentiated by the level of productivity of government spending, measured by the parameter α_G, which determines how much of an effect government (investment) spending will have on production. The value of this parameter is somewhat uncertain, and various levels have been used in the literature. Here we use as a benchmark the value of $\alpha_G = 0.03$, which is a somewhat conservative value, but close to the lower value used in Leeper et al. (2010). The alternative is $\alpha_G = 0.03$, which comes from the midpoint estimate of the meta study of Bom and Ligthart (2014). Finally, we use also a value of $\alpha_G = 0$, because in this case government spending on investment is equivalent to government spending on (wasteful) consumption, which is what is typically assumed in the standard models about government consumption.[5]

In all three cases, the top right panel of Figure 1 shows that the impact multiplier is slightly higher than 1. The reason for this is that aggregate consumption *increases* while the government stimulus is active, and only decreases afterwards. The more productive the public capital, the lower is the initial increase in private consumption and the stronger its decline after the fiscal stimulus is over. Similarly, inflation increases initially only in the case of government consumption spending, but not in the case of government investment spending, and the fall in inflation is stronger when public capital is more productive.

These findings are perhaps somewhat surprising, but they should not be once one notes that productive public capital is akin to an increase in aggregate productivity, and this has an important effect at medium-run horizon, as discussed below. In the short run, while government

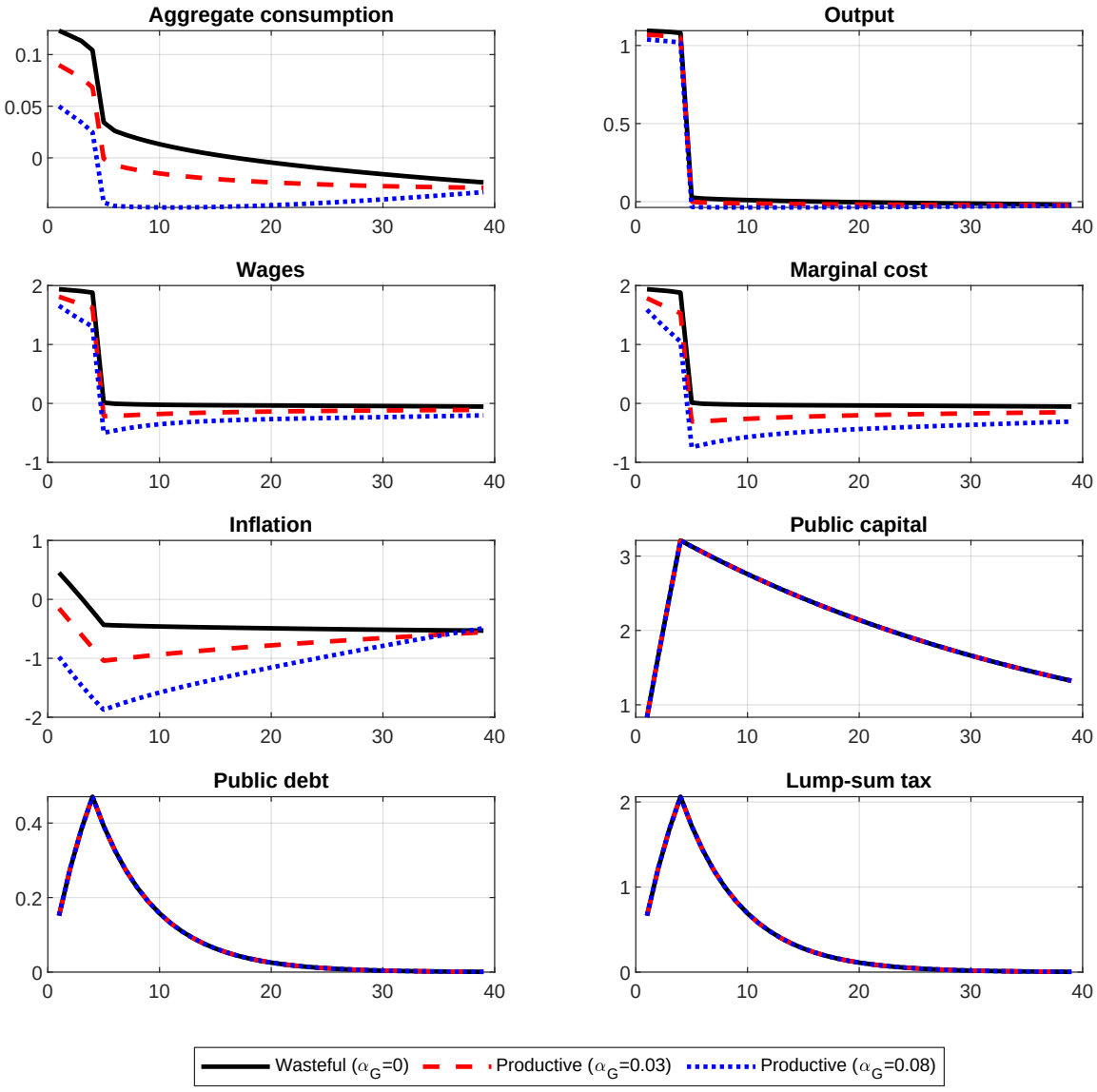
[5]To see the equivalence, note that when $\alpha_G = 0$, then $K_{G,t}^{\alpha_G} = 1$, so that the level of public capital has no effect on production. In this case, any spending on government investment is identical to spending for government consumption, as it only has temporary demand effects.

spending stimulus is active, aggregate demand is higher because of this stimulus. Wages and marginal costs increase during this period, and so do households' incomes, because in addition to receiving higher wages, they also work more (see the right-hand panels of Figure 2). In a HANK model, households have in general higher marginal propensities to consume out of current income, and in particular households with lower wage incomes that are closer to the borrowing constraint. Their consumption increases because they receive higher labour income. The households with the highest wage income pay taxes, so they will ultimately have to pay for government borrowing and this is the reason why consumption of these households decreases (see the left-hand panels of Figure 2). Overall, the consumption increase of the low- and medium-wage dominates, and this is the main reason for the increase in the aggregate consumption.[6]

When the government spending stimulus is over, the aggregate demand falls because the government spending returns to its initial value. What remains is higher level of public capital, higher level of government debt (and therefore more availability of a vehicle in which households can self-insure, the role of which we discuss in detail in Section 4.5), and temporarily higher taxes (see lower-right panels in Figure 1). In addition, the distribution of wealth across households has changed. These factors all influence the dynamics of the economy in the medium run, and the most important of these is the stock of public capital.

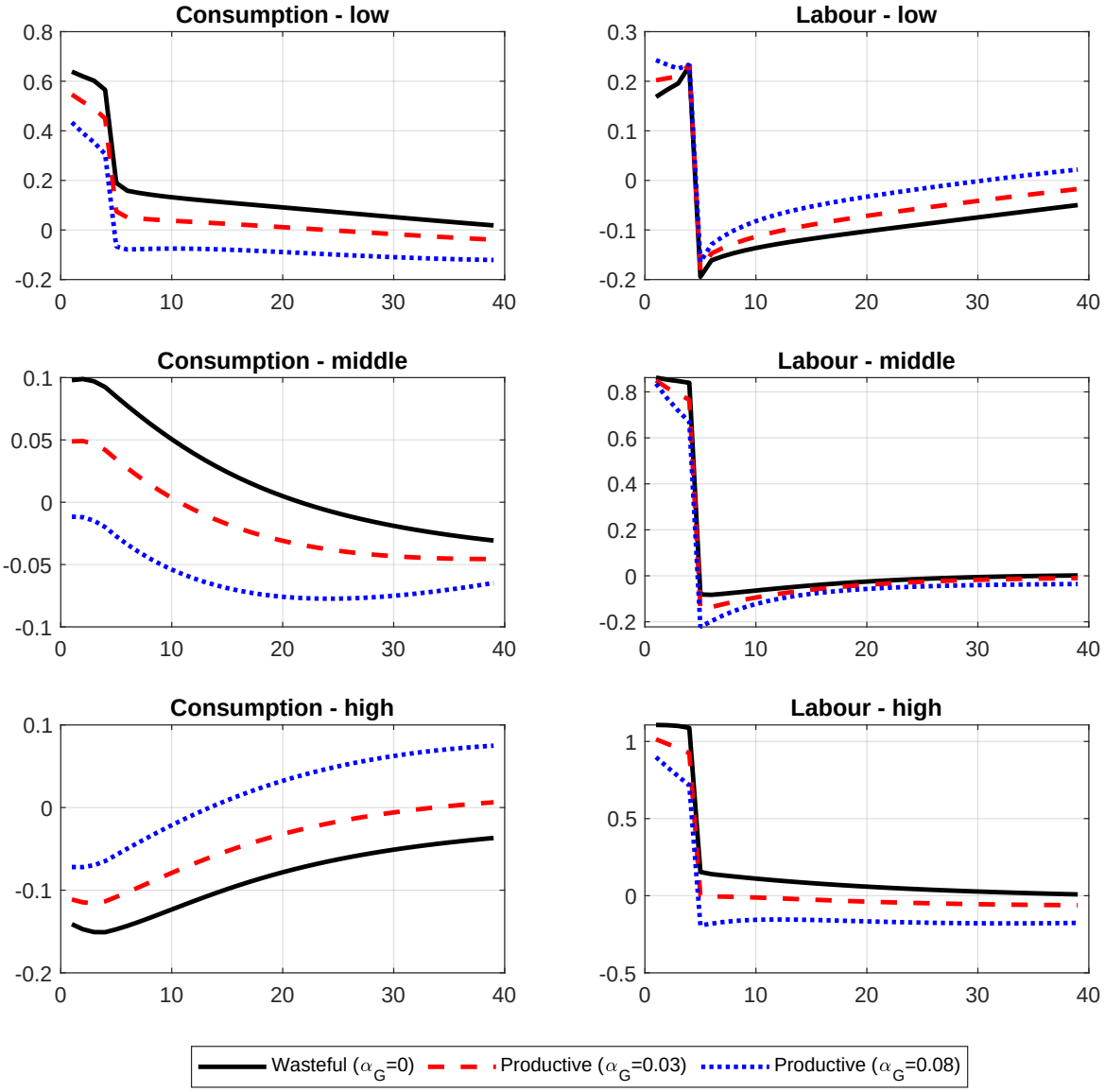
[6]The increase in aggregate consumption is in part also due to the fact that during the simulation the central bank keeps the real interest rate constant. With a standard Taylor rule, the real interest rate would have actually decreased in cases where government investment expenditure is productive, so that the fall in consumption of the high-wage households would have been smaller and the increase in aggregate consumption higher.

FIGURE 1. Government investment expansion - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and public debt-to-GDP (percentage point deviations from annual GDP). All variables are in real terms.

FIGURE 2. Government investment expansion - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

The more productive the public capital is, the less labour is needed to produce a given amount of goods (see equation 11). In a New Keynesian model, where output is demand-determined and prices are sticky, this implies that there will be a drop in labour demand after the government spending stimulus is over, stemming from (1) a drop in demand due to the return of government spending to initial levels and (2) persistently higher stock of productive public capital, which means that given demand can be met by employing less workers. This can clearly be seen in the

right-hand panels of Figure 2, where labour falls across the board after five periods, and where the fall is more pronounced in the case where public capital is more productive. The fall in labour demand also means that wages fall (and with them marginal costs, with the latter falling even more because of productive public capital drives a wedge between wages and marginal costs). This is the main reason why inflation decreases in the medium run when public capital is productive, resulting in a situation where we can have a non-inflationary fiscal expansion.

To illustrate and isolate the mechanism discussed, it is useful to consider the following experiment. Suppose we attempt to neutralise initial demand stimulus from the government, and in addition also the tax and debt-related effects of government investment spending. This can be done by simulating an ex-ante budget-neutral reshuffling of government spending, away from (wasteful) consumption and towards the (productive) government investment - concretely, by assuming a 4-quarter 1 p.p. increase in government investment financed by a 4-quarter 1 p.p. decrease in government consumption.[7] Figures 3 and 4 show the effects of such experiment. The key thing to note is the decrease in aggregate labour that exceeds the decrease in aggregate output in Figure 3. The reason is that the increase in productive public capital has driven a wedge between output and labour and has therefore crowded-out labour. In addition, because this has happened through the reduction in labour demand, wages have fallen, which compounded the loss of income for the households and resulted in the fall in aggregate consumption.[8] Households with the lowest level of wage income, who are the closest to the borrowing constraint and have the highest marginal propensity to consume reduce their consumption by the most. This has an effect on their labour supply, which increases as they have become poorer, and this is why we see a mild increase in their labour even though in the aggregate labour falls (see Figure 4).

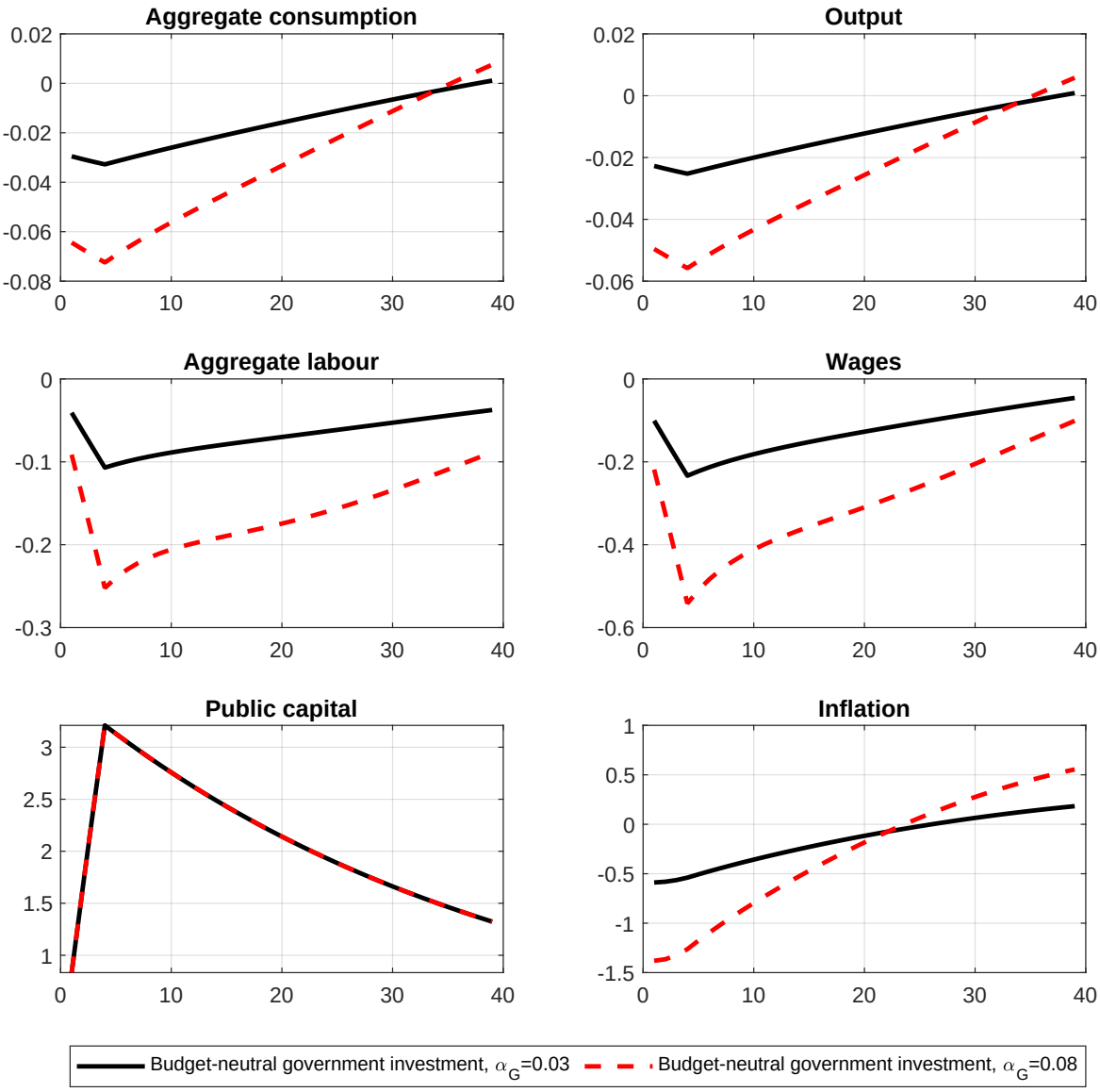
Overall, however, Figure 3 shows that, without the aggregate demand stimulus, an increase in productive government investment is mildly recessionary and deflationary in the short run, and only expansionary and inflationary after a long delay. The main reason is the crowding-out of labour, which reduces households' labour incomes, which in turn interacts with their marginal

[7]To the best of my knowledge, this has first been analysed by Clancy et al. (2016) in a representative-agent and open-economy model, but is particularly useful in this simple HANK setting because it results in negligible movements in taxes and debt.

[8]Only the high-income households increase their consumption, which they can do because they receive dividends - the latter increase because wages fall.

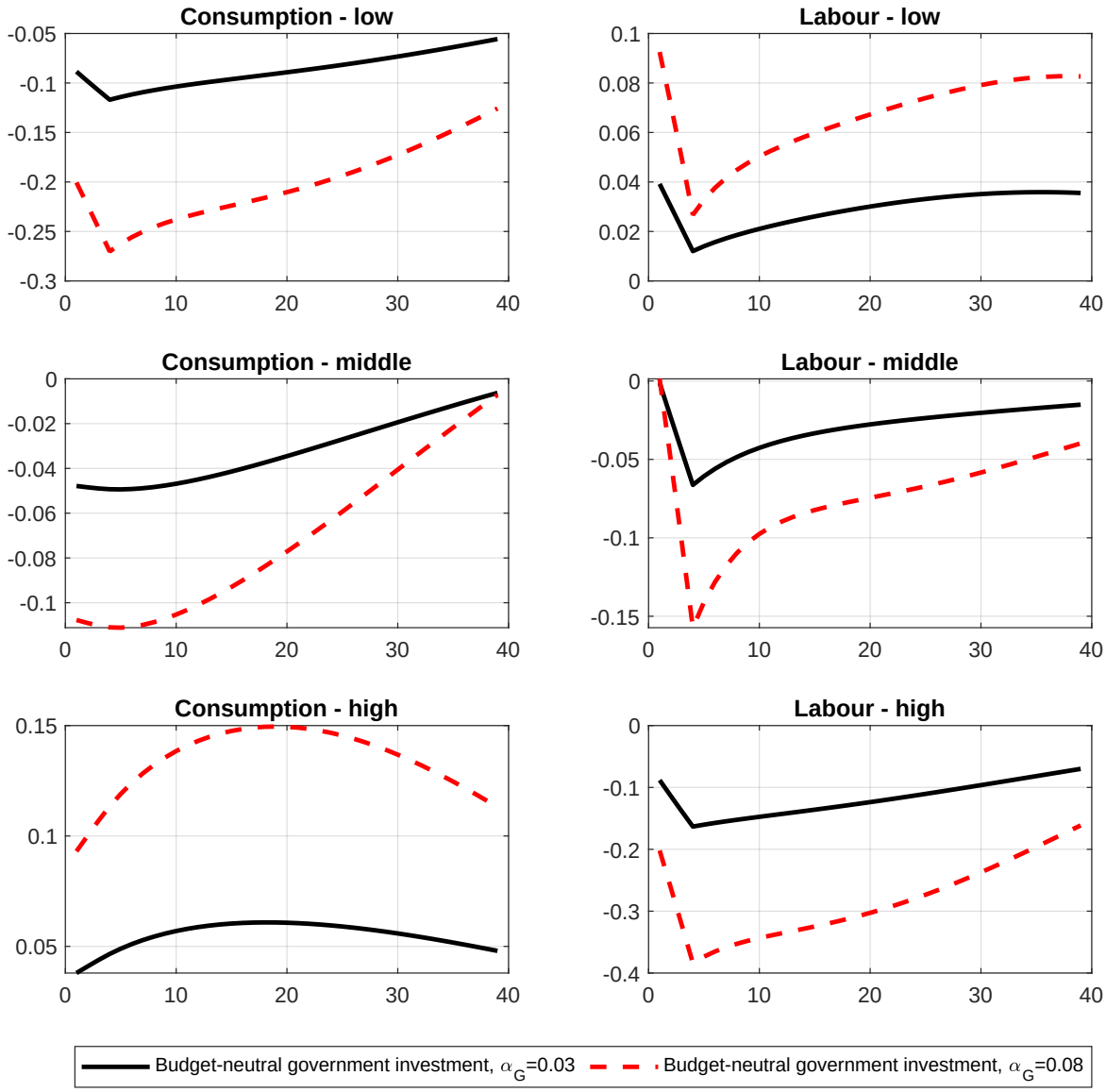
propensities to consume and results in the persistent decline in aggregate consumption.

FIGURE 3. Budget-neutral government investment expansion - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations). All variables are in real terms.

FIGURE 4. Budget-neutral government investment expansion - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

4.2 The role of monetary policy

In the results reported above, monetary policy was passive in the sense that the central bank kept the *real* interest rate constant (recall that because prices are sticky, the central bank can set the real interest rate to any value by changing the nominal interest rate). In this benchmark case, the model showed crowding-out of labour by productive public capital, because aggregate demand could be met by using less labour in production. At the same time, more productive

public capital lowered marginal costs and caused a fall in inflation. This section looks at what happens if the central bank actively reacts to inflation and output according to the Taylor rule.

We first change the monetary policy reaction function in equation 10 to follow the standard Taylor rule with the response to the (deviation of) inflation and output from their steady-state values:

$$(1 + r_t) = (1 + \overline{r}) \left(\frac{(1 + \pi_t)}{(1 + \overline{\pi})} \right)^{\phi_\pi} \left(\frac{Y_t}{\overline{Y}} \right)^{\phi_Y}, \tag{34}$$

where bars over variables indicate their steady-state values, and where ϕ_π and ϕ_Y are the coefficients that govern how much does the real rate respond to inflation and output. We pick $\phi_\pi = 0.3$ and $\phi_Y = 0.1$, so that the real rate increases when inflation increases and increases mildly when output increases, as estimated in e.g. Christiano et al. (2016).

Figures 5 and 6 show the benchmark simulation where the central bank keeps the real rate constant (full black lines) and the alternative where it follows the Taylor rule in equation 34, both cases with balanced budget (tax financing) and with the benchmark public capital productivity ($\alpha_G = 0.03$). When the central bank follows the Taylor rule, it raises the interest rates in the short run in response to the increase in output and inflation, and lowers them in the medium run in response to falling marginal costs. Higher interest rates in the short run mean that taxes have to increase by more than in the benchmark case, because the debt service has become more expensive.

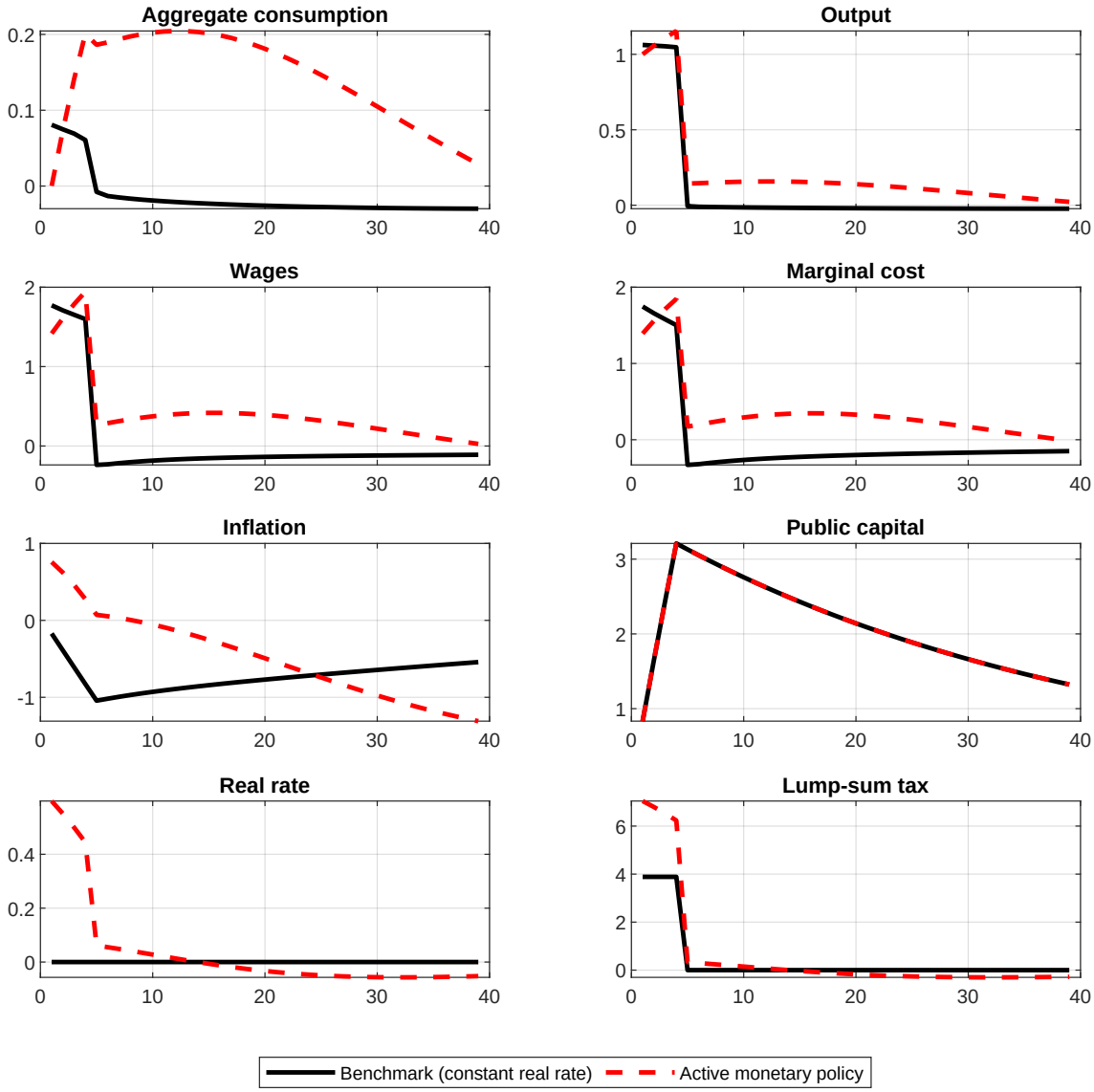
However, lower interest rates in the medium to longer run have several distributional consequences and also stimulate current aggregate consumption. This increase in aggregate consumption comes mainly from low- and medium-income households (Figure 6), and is the result of the combined intertemporal consumption smoothing and income effects. Medium-income households, because they have sufficient assets that enables them some intertemporal consumption smoothing, increase their current consumption in response to lower interest rates in the future. Unlike high-income households, they are not subject to higher taxes, so they can afford to do so (but note that in the medium run also high-income households increase their consumption). These households are many - half of the population in the steady state - and their consumption level is not small. More consumption of these households in the short and medium run means

higher aggregate demand exactly at the time when accumulated productive public capital is contributing towards the reduction in marginal costs. These increase less than wages, and higher aggregate demand increases the demand for labour, which implies that labour income rises for low-income households, who have the least wealth and are the most dependent on labour income. This causes them to increase their consumption, which further amplifies the increase in aggregate consumption in the medium run in the aggregate.

Note that Debortoli and Galí (2024) made the point that changes in consumption (in their case due to the change in idiosyncratic income risk) of a small group of households with relatively low consumption have little bearing on aggregate fluctuations. In the case discussed here, the idiosyncratic risk is constant, but the aggregate fiscal shock and the reaction of monetary policy affect households with various levels of incomes (and therefore different wealth and MPCs) in a different way, so that the incidence of income (who gets additional income) differs. The share of affected households is not small and the distributional consequences lead to an amplification of aggregate consumption and output responses over the medium run.

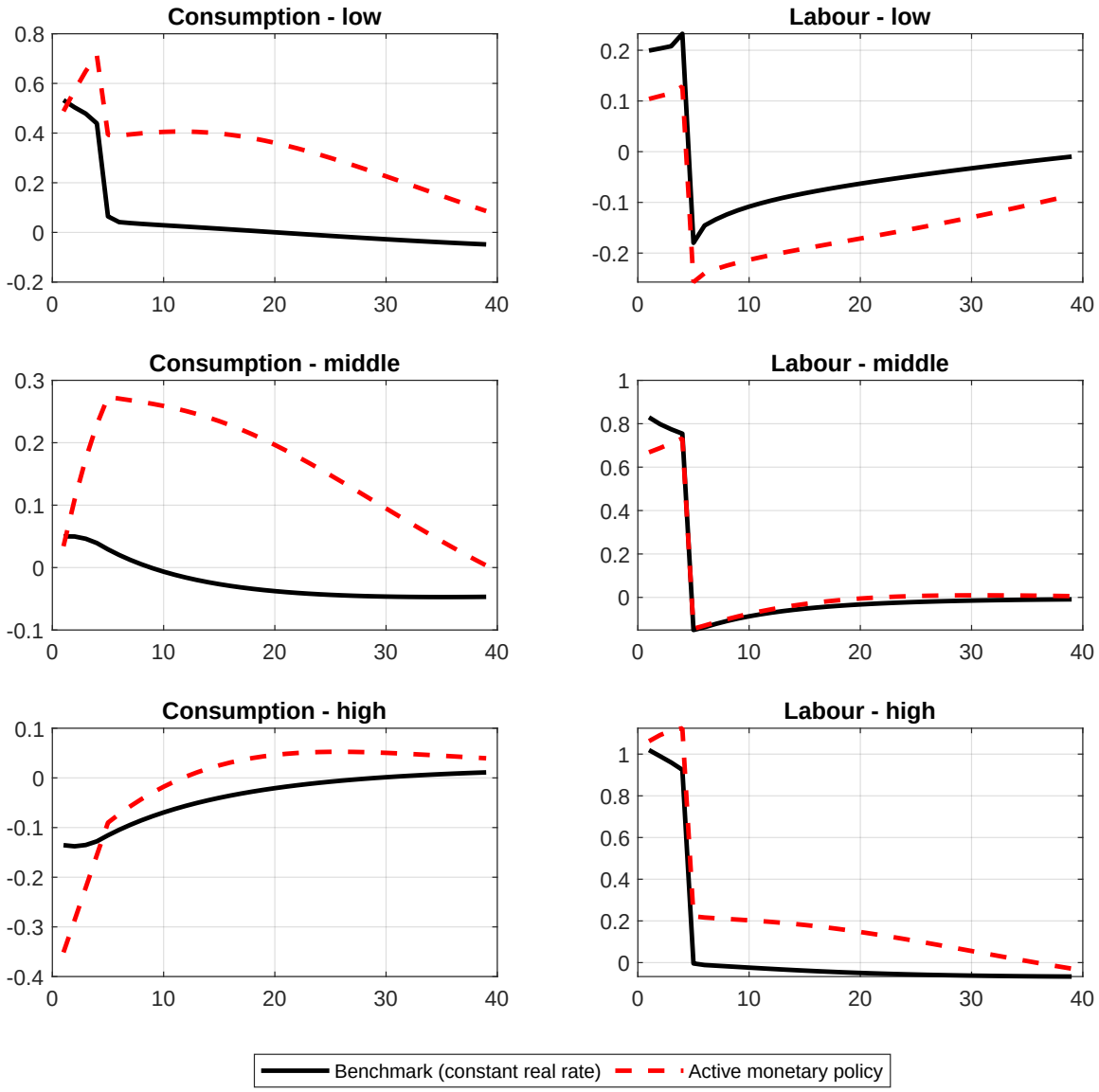
Importantly, aggregate consumption and output stay higher over an extended period of time when monetary policy is active, and this comes with little cost in terms of inflation in the short run, and no cost in the medium run.

FIGURE 5. Active monetary policy and tax-financed government investment - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and the real interest rate (percentage point deviations, annualised). All variables are in real terms.

FIGURE 6. Active monetary policy and tax-financed government investment - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

The responses to an increase in government investment with debt financing are reported in Appendix C, as they are not materially different from the responses with tax financing of government investment discussed above. The key conclusions are the same - there is an increase in aggregate consumption over the medium run that stimulates aggregate demand and demand for labour over the longer to medium-run, with little cost in terms of inflation. Also, there is the same redistributional effect that consumption of low and middle-income households increases by

more relative to the benchmark case where monetary policy is passive.

4.2.1 Public capital productivity and distributional consequences of active monetary policy

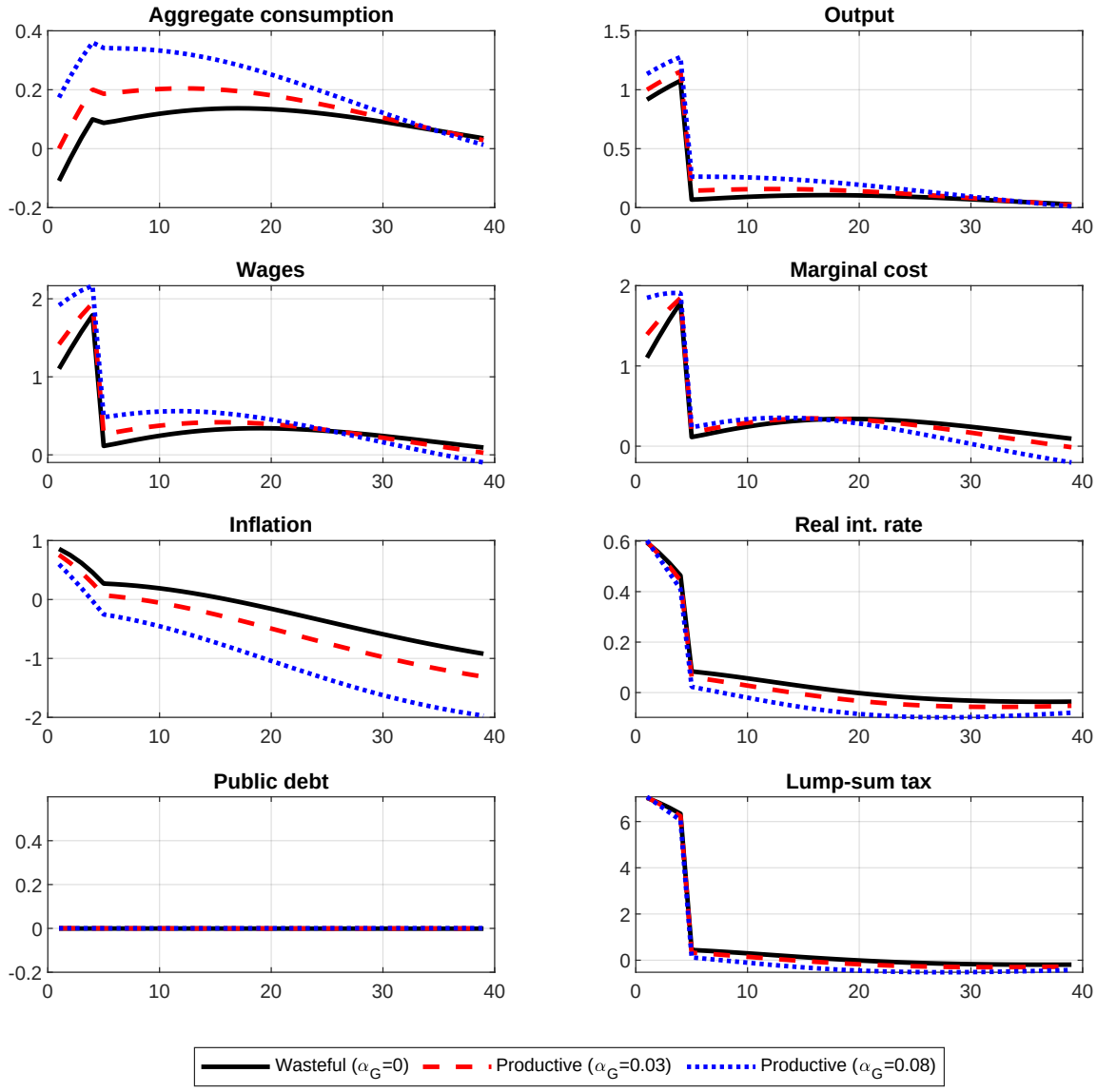
Given that active monetary policy interacts with public investment in a way that affects the incidence of income increases, a question arises whether more productive public capital, which reduces marginal costs and therefore inflation by more, also interacts more strongly with monetary policy.

Figure 7 shows the responses to a tax-financed increase in government investment for three different productivity types. The only way the simulation differs from the benchmark simulation in Figure 1 is that here monetary policy is active in the sense that it does not only keep the real interest rate constant, but actively varies it in response to output and inflation changes. There are quite a few differences. First, aggregate consumption increases by more, the more productive is public capital, unlike in the benchmark case where aggregate consumption increased the least when public capital was the most productive. The reason for this difference is that the more productive public capital is, the more it will lower marginal costs and inflation in the future, to which the central bank will react by reducing interest rates more. As explained above, the interest rate reduction in the future stimulates consumption of wealthy and middle-income households, and increases aggregate demand, which increases demand for labour and wages. The combined effect of more employment and more wages increases labour income and consumption of the low-income households, who have the highest marginal propensity to consume.

The aggregate response described above happens mainly because of the distributional effects that are induced by the interaction of monetary policy and public capital productivity. These can clearly be seen if one compares the responses of consumption by income groups of households in the benchmark case (Figure 2) with the case where monetary policy reacts to output and inflation, shown in Figure 8. In high-productivity benchmark case consumption of low-income households increased in the short run and decreased afterwards, consumption of the middle-income households stayed roughly unchanged, and consumption of high-income households first decreased and then increased. Consumption inequality has therefore increased. In the case where

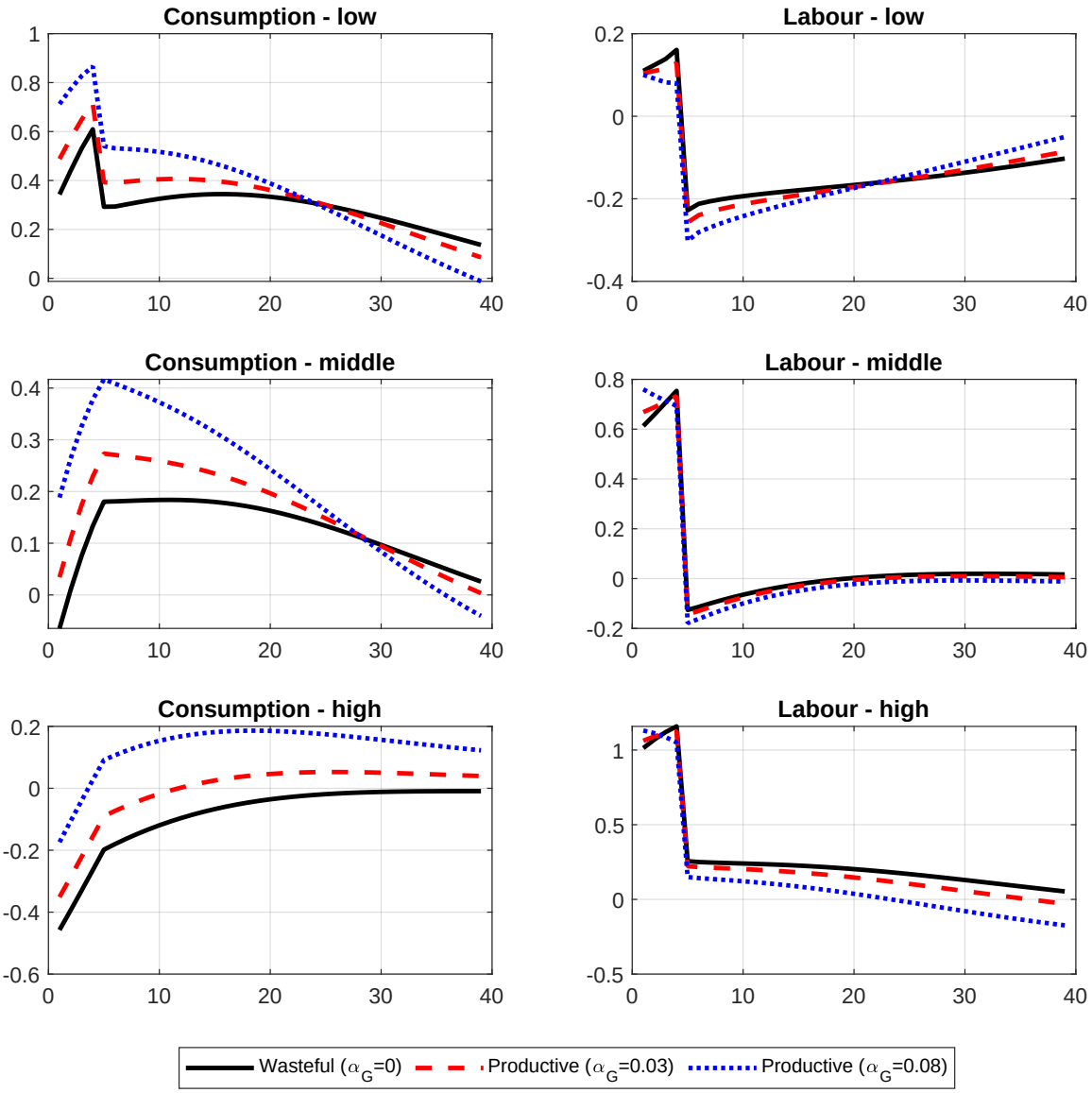
monetary policy is active and public capital is productive, the responses are much more uniform, as consumption of all three types of households increases (except in the first few quarters for the high-income households). Moreover, the responses of consumption are stronger for all three income levels of households when public capital is more productive (unlike in the benchmark case, where they tended to be the weakest). Labour is still crowded-out in the medium run by productive public capital, but higher consumption also reduces labour supply, which prevails and causes higher wages. These more than compensate the shortfall of labour income due to the fall in labour, allowing households that hold less assets to increase their consumption based on higher labour income.

FIGURE 7. Productivity of tax-financed government investment and monetary policy - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and the real interest rate (percentage point deviations, annualised). All variables are in real terms.

FIGURE 8. Productivity of tax-financed government investment and monetary policy - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

Very similar mechanisms as described above operate when government investment is financed in part by issuing debt (see Appendix C).

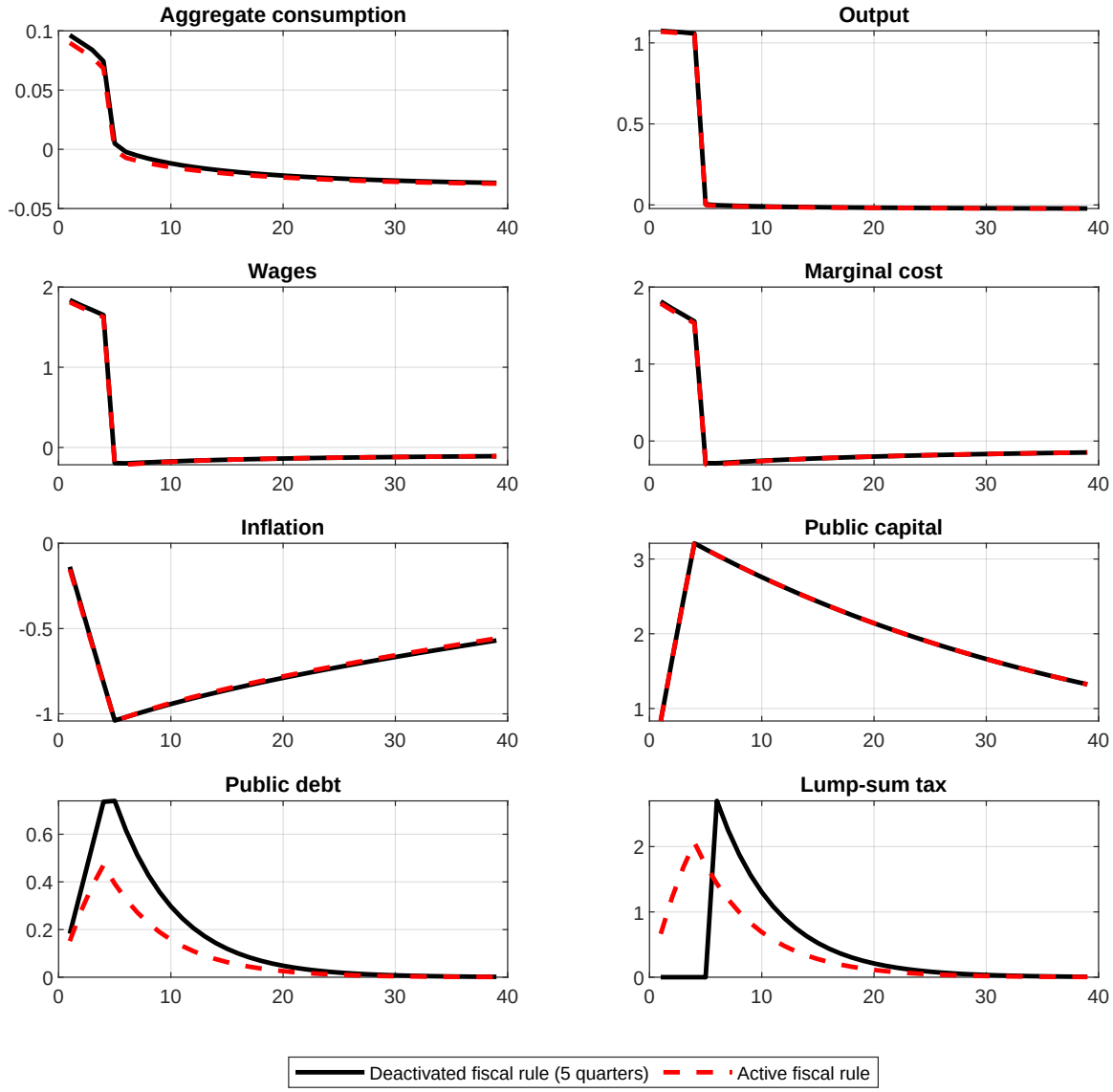
4.3 The role of fiscal rule

One of the questions that arises is whether a temporarily deactivated fiscal rule would make a material difference in the responses of the economy to a government investment increase. In this

subsection, the fiscal rule is deactivated for the period of five quarters, in the sense that taxes do not increase during this period to cover either additional interest expenditures or (part of) additional debt. The results are reported in Figures 9 and 10, which compare the benchmark case of $\alpha_G = 0.03$ with active fiscal rule (dashed red line) and the temporarily deactivated fiscal rule (full black line).

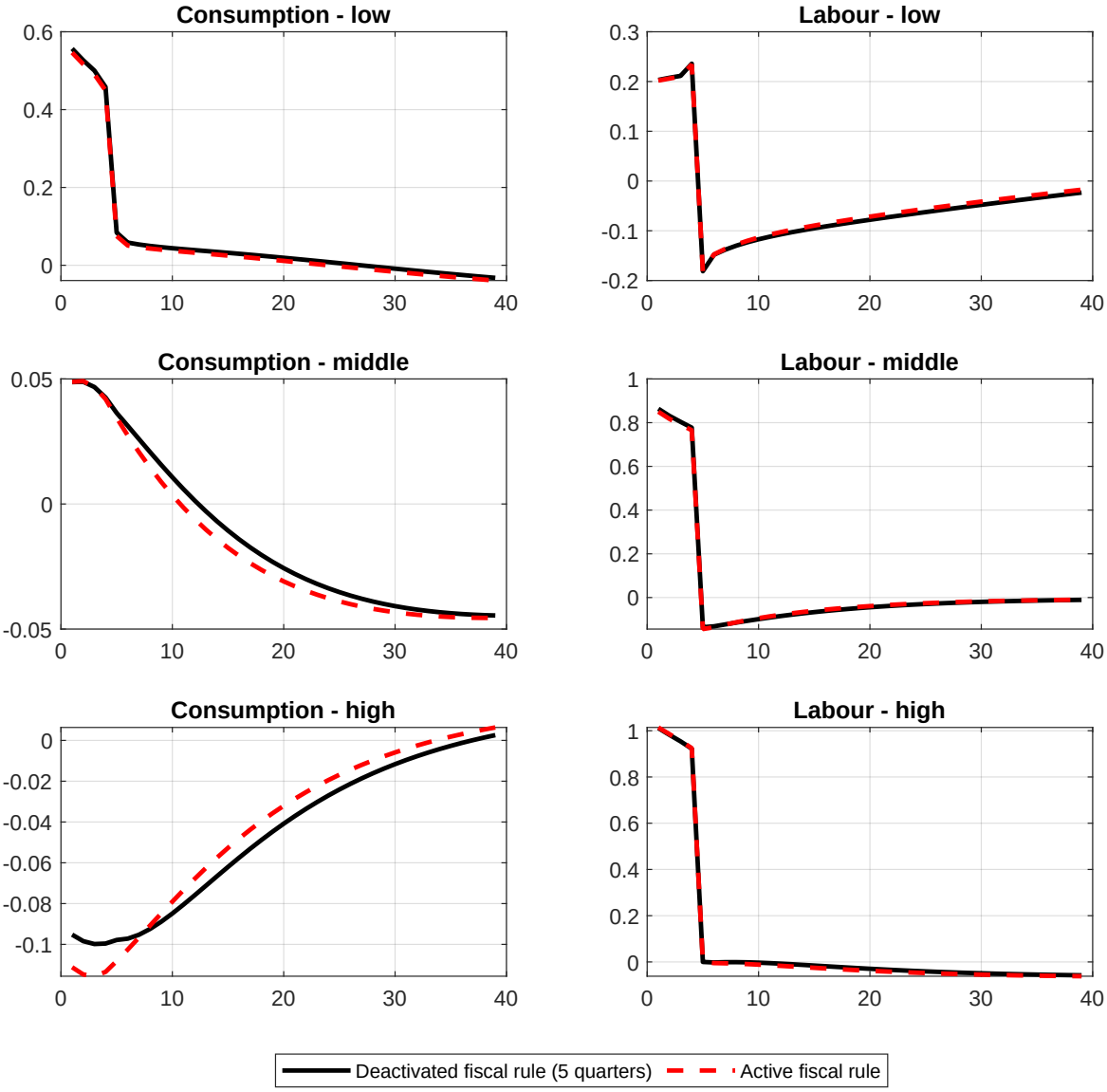
The deactivation of the fiscal rule makes almost no difference, apart from temporarily higher public debt and a modest amplification in the initial response of aggregate consumption (Figure 9). The latter is due to the high-income households, who reduce their consumption by less on impact, because they do not have to pay taxes yet (see the bottom-left panel of Figure 10).

FIGURE 9. Government investment expansion and fiscal rule - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations). All variables are in real terms.

FIGURE 10. Government investment expansion and fiscal rule - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

4.4 Time to build

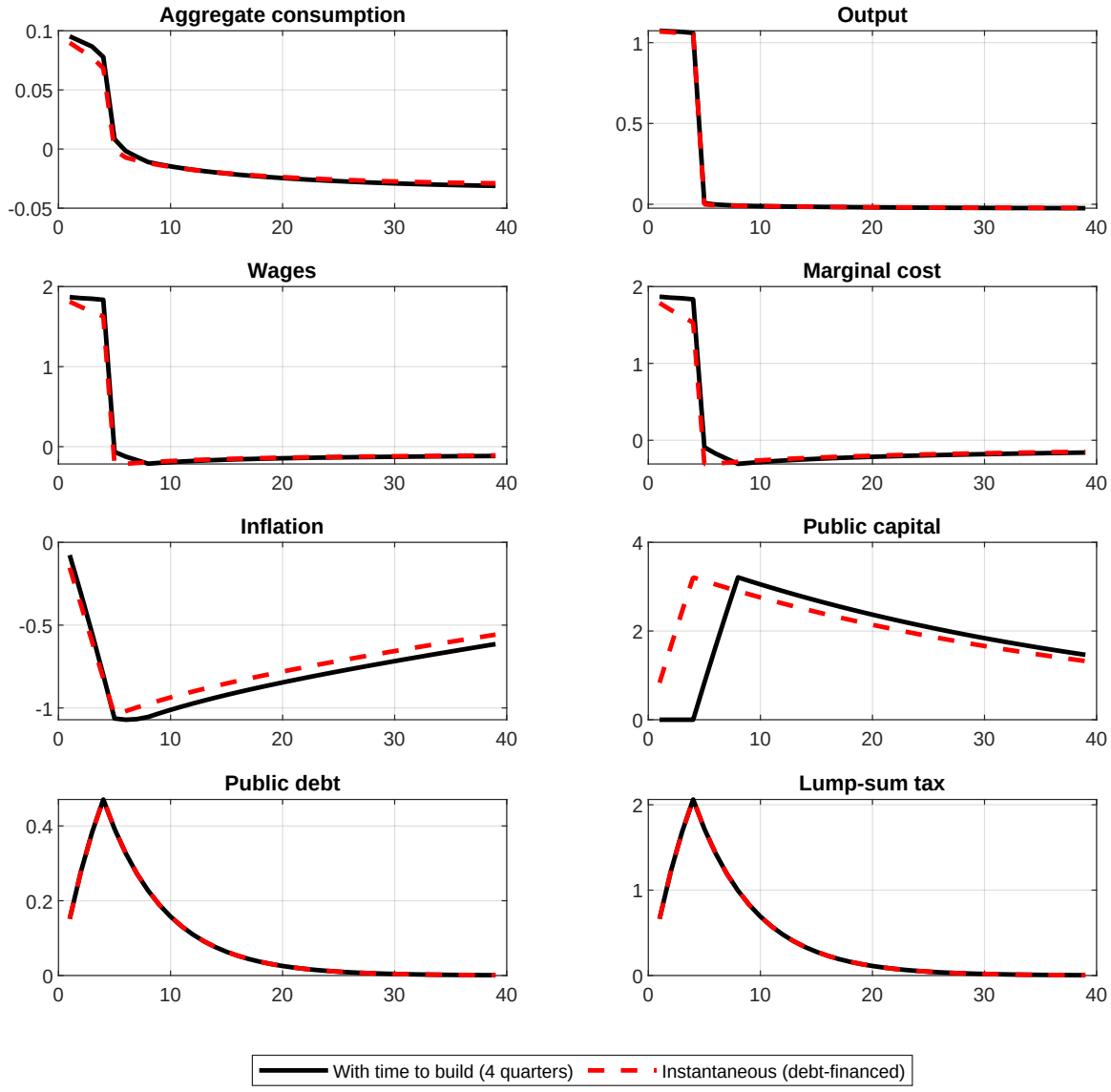
A typical characteristic of government investment is that it may not increase public capital instantaneously, but that there is some time delay before it can increase public capital. This time-to-build delay implies that any benefits from higher public capital also come with a delay. This section investigates whether the delay matters for the dynamics of the economy's responses to government investment increase and for the distributional aspects.

Figures 11 and 12 show the responses for the case where time-to-build lasts four quarters (black line) compared to the benchmark case without time-to-build (dashed red line). In both cases we assume the productivity of public capital $\alpha_G = 0.03$ and that government investment is financed in part with taxes and in part with public debt.[9]

A delay in time to build has somewhat more expansionary effects, which are manifested in a somewhat stronger increase in consumption and lower initial decline in inflation (which later becomes stronger). The reason is that with time-to-build, the productivity of public capital kicks in later, so that wages and marginal costs do not decline from the outset. Higher wages stimulate consumption for low- and middle-income households (see Figure 12), who have higher marginal propensities to consume out of income, which amplifies the increase in aggregate consumption. Higher wages and marginal costs are the reason for lower decline in inflation in the initial periods. However, once the delay in building public capital is over, the now higher public capital takes longer to depreciate and therefore lowers marginal costs for a longer period of time (the effect is very small, but also very persistent), which is why inflation falls by more after the time-to-build delay is over.

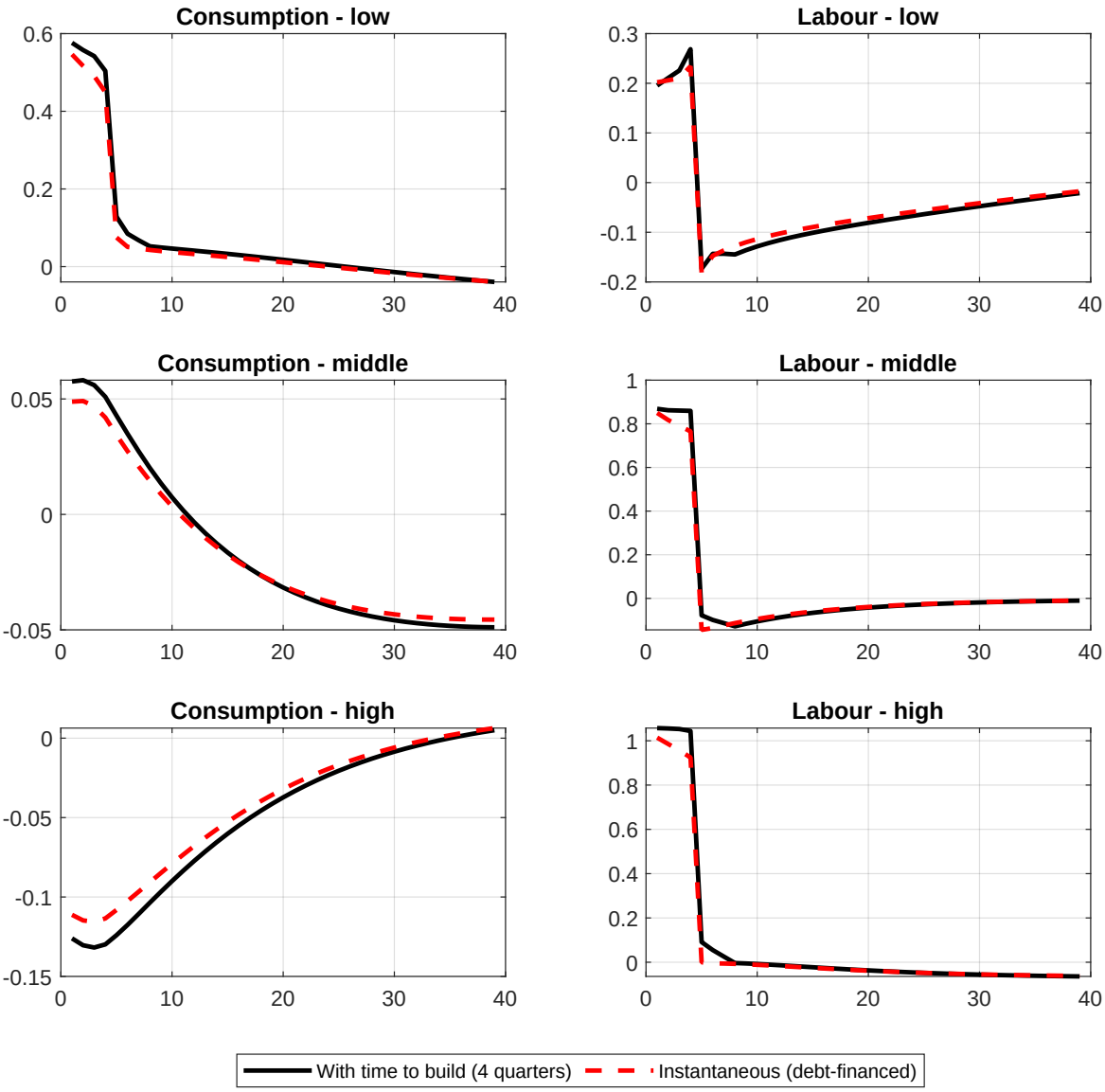
[9]Appendix A shows that there is practically no difference between debt-financed and tax-financed cases for investment with time-to-build.

FIGURE 11. Investment and time-to-build - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and public debt-to-GDP (percentage point deviations from annual GDP). All variables are in real terms.

FIGURE 12. Investment and time-to-build - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

4.5 Financing of government investment and the role of the saving vehicle

This section investigates the role of the availability of the saving vehicle and the financing of government investment.[10] To see why the availability of the saving vehicle is important, consider the case where there is no government bonds in the steady state, so that households

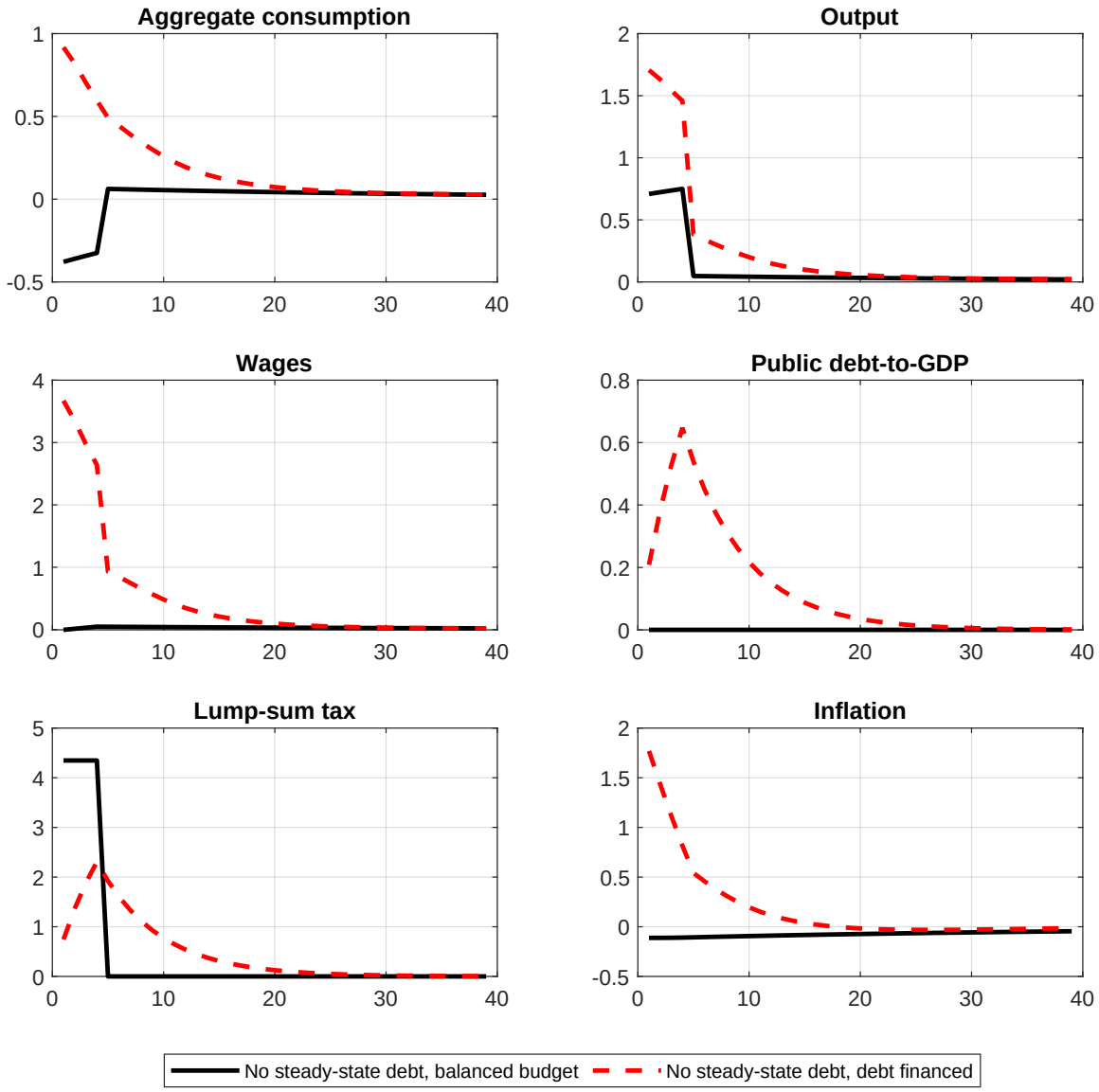
[10]While the focus here is on government investment, essentially the same findings apply to financing of government consumption. To see this, consider the fact that if public capital is completely unproductive ($\alpha_G = 0$), then government investment that increases such public capital is equivalent to (wasteful) government consumption.

have no savings in the steady state, which in turn means that they cannot self-insure against adverse shocks. In this situation, it will be very important whether the government finances its investment spending with taxes or by issuing bonds, as will be shown below.

Figure 13 shows the responses of aggregate variables and Figure 14 shows the responses by groups of households in an economy where there is no public debt to start with. The figure considers two cases, one where government investment is fully financed by lump-sum taxes levied on the households with the highest income (full black line), and one where government investment is financed in part by the same taxes and in part by issuing public debt (red dashed line). The differences are material, as responses of consumption and inflation have different signs, and the response of output differs by a factor of two. To understand the reasons behind this difference, consider first the case with tax-financed government investment. In this case the government raises taxes to finance investment expenditure, and the tax directly affects the households with the highest current incomes. These households have no savings (because the only available means of saving - public debt - is zero in the steady state), so they reduce their consumption and increase their labour supply in order not to have to reduce consumption too much. The reduction in consumption affects aggregate consumption, which in turn affects aggregate labour demand, so that even those households that are not taxed do not receive additional income, as labour demand does not increase. Moreover, wages increase only by a small amount, which provides almost no additional income and therefore no improvement of aggregate demand to counter the reduction in high-income household consumption.

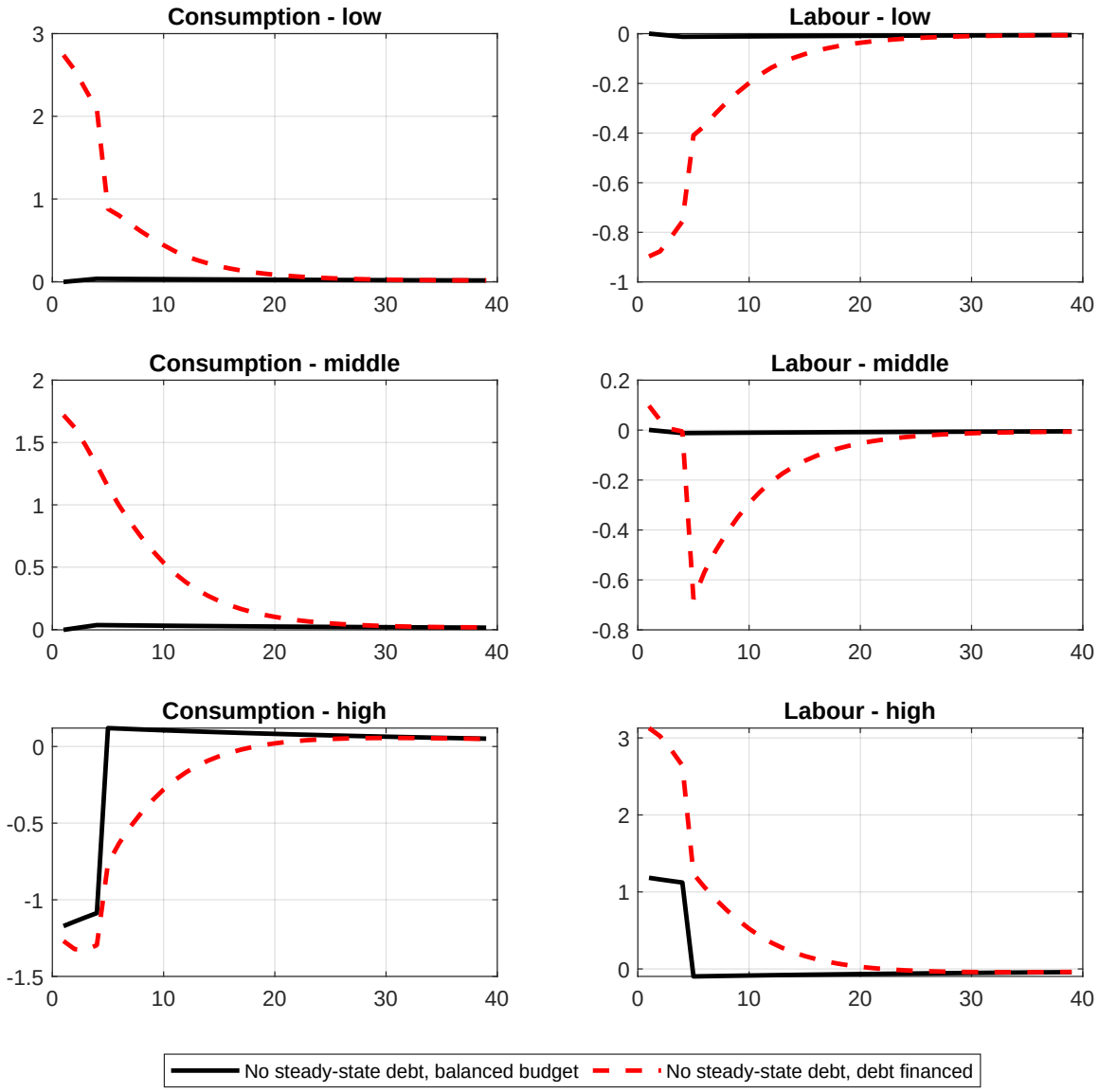
Inflation decreases because of the fall in aggregate consumption that dampens the aggregate demand increase due to government investment spending, and also because an increase in public capital makes production in the medium run more efficient by reducing marginal costs. Forward-looking firms take this into account and reduce their prices, which causes mild deflation. Note that this happens despite the expansionary fiscal policy.

FIGURE 13. Financing government investment with no steady-state debt - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and public debt-to-GDP (percentage point deviations from annual GDP). All variables are in real terms.

FIGURE 14. Financing government investment with no steady-state debt - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

When there is no public debt in the steady state, but the government finances part of government investment spending by issuing public debt (dashed red line in Figures 13 and Figure 14), consumption and inflation increase rather than decrease, and output increases by about twice as much as in the tax-financed case. Note that the government investment is only *partially* financed by debt, and still partially financed by taxes (lump-sum taxes still increase, and do so for a longer period of time than in the tax-financed case). The reason why we get so different

responses in this case is the increase in the availability of the saving and therefore insurance vehicle, and the lower initial increase in taxes. First, the middle-income households, who are not subject to tax and have labour incomes high enough so that they can afford saving, increase their savings in the now newly available saving vehicle (government bond). At the same time, they can also increase consumption. The latter becomes possible through the general equilibrium effect, because the increase in their consumption leads to an increase in aggregate consumption and therefore in labour demand from firms. Higher labour demand from firms also substantially increases wages, leading to a further increase in income. The increase in wages is strong enough to cause a (small) reduction of labour supply among the low- and middle-income households, which happens because the wealth effect from the increase in consumption reduces labour supply of these households. Together, this is sufficient to finance an increase in consumption and savings of middle-income households and in consumption of low-income households, while consumption of high-income households declines because they are taxed now (and also know that they will be taxed in the future when debt will be repaid).[11] Overall, the increase in consumption of middle- and low-income households dominates, leading to the increase in aggregate consumption and therefore output. Inflation increases because of the strong increase in wages, which prevails over the relatively small negative effect of the increase of productive public capital on marginal cost.

It is important to stress that these differences between debt-financed and tax-financed government investment spending occur only if there is a scarcity of the means in which households can save. If there are sufficient government bonds for the households to self-insure, then tax-financed and debt-financed government spending have very similar effects, which are close to those for the debt-financed case discussed above, just more attenuated. The responses are shown in Appendix B, where the figures show the responses to exactly the same shock in the economy where the steady-state debt is 5.5-times its quarterly GDP. [12] The reason for the attenuation of responses is that with high public debt in the steady state, many households have savings and are therefore away from the borrowing constraint, which implies that their marginal propensities

[11] Low-income and high-income households also increase their bond holdings, but by a very small amount. Low-income households do so because their income is not high enough to afford saving, while high-income households cannot afford it because they are taxed.

[12] The number is taken from McKay et al. (2016) and can be thought as illustrative for European countries with relatively high public debt.

to consume are smaller, which is why the reaction of consumption tot he shock is smaller.

5 Conclusion

This paper investigated the new or modified transmission channels, in particular with respect to public investment and the productivity of public capital, in a structural HANK model.

The main finding of the paper is that government investment, when public capital is productive, reduces firms' demand for households' labour in the medium run. This implies that, after the initial stimulus from government is over, wages and labour demand fall, resulting in a loss of income for households. Because households have relatively high marginal propensities to consume compared to a RANK model, this leads to a reduction in private consumption in the medium run. These results hold regardless whether government investment is financed by issuing debt, by reducing government consumption spending, or by taxes. The finding also holds for various modifications in terms of timing of how government investment affects public capital (time-to-build) or by various modifications of the fiscal rule. The only exception is when the stock of the saving vehicle that households can use to self-insure (government bonds) is very small to start with. In this case, an increase in government investment that is financed by issuing debt has expansionary and inflationary effects in the short and medium run. However, if it is financed by taxes, it is contractionary and deflationary even in the short run.

The reaction of monetary policy to government investment stimulus is crucial as it can prevent deflation in the medium run and can extent the time period during which government investment leads to economic expansion, without much cost in terms of inflation.

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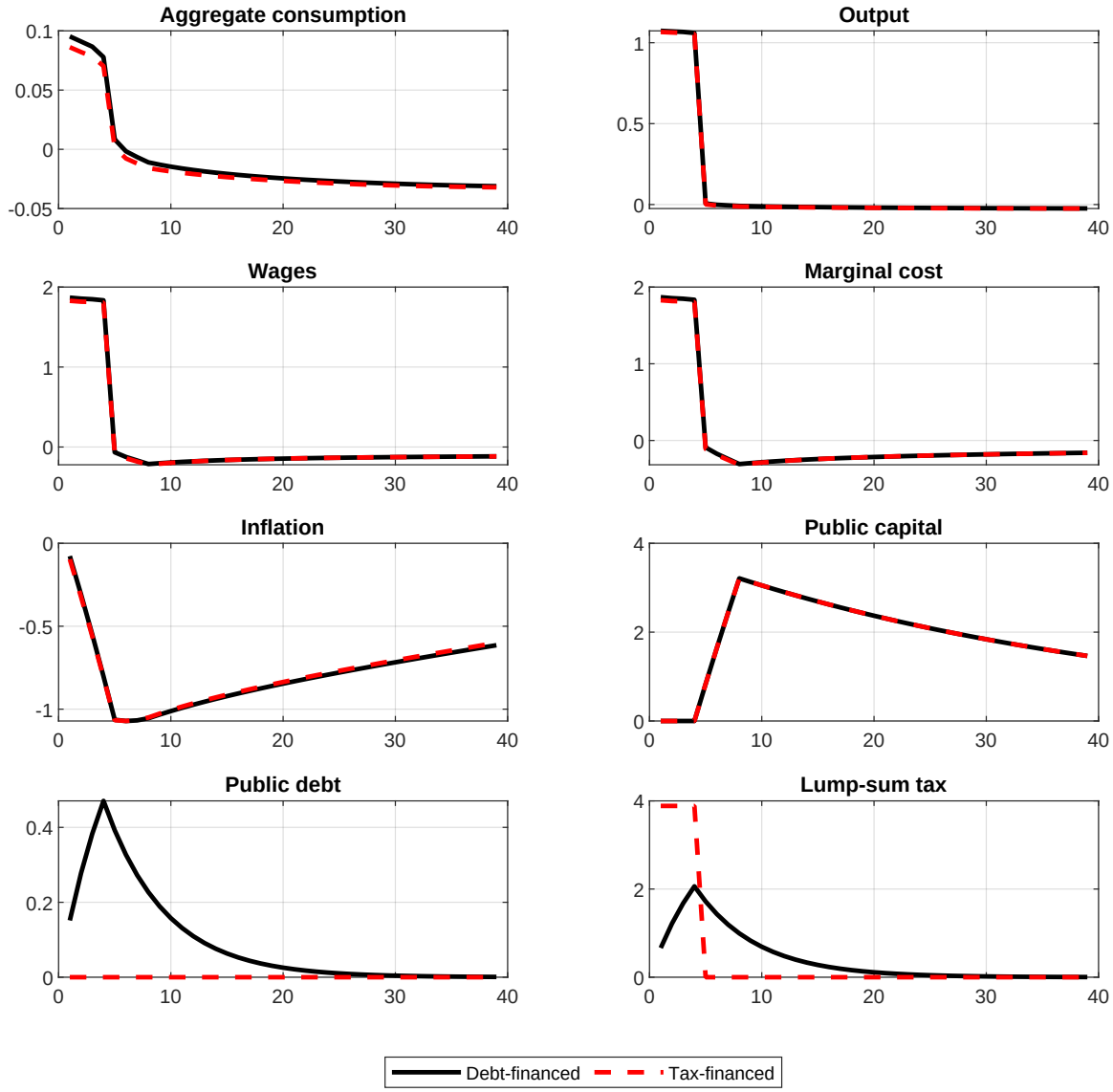
A Time to build with tax and debt financing

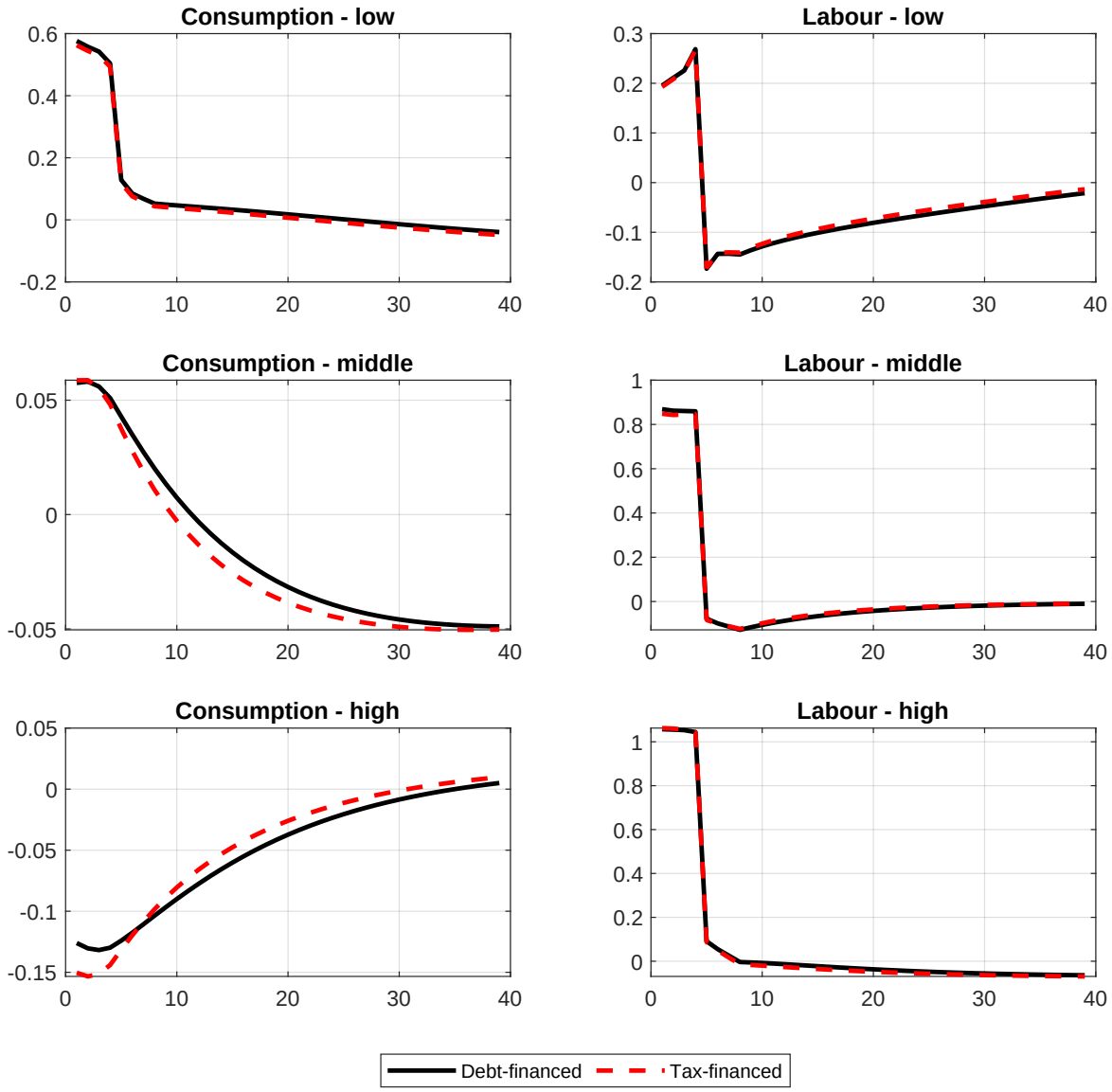
Figures 15 and 16 compare the cases with time-to-build, where in one case government investment is financed with taxes (red dashed line), and the other case where it is financed in part by issuing debt (full black line). As can be seen from the figures, there is almost no difference in aggregate responses, with the exception of aggregate consumption, where in the debt-financed case the increase is slightly stronger. This is mainly due to the lower fall in consumption of the high-income households (see the bottom-left panel in Figure 16), who are in the case of taxes subject to a stronger initial tax increase.

FIGURE 15. Investment financing and time-to-build - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and public debt-to-GDP (percentage point deviations from annual GDP). All variables are in real terms.

FIGURE 16. Investment financing and time-to-build - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

B Financing government investment with high initial debt

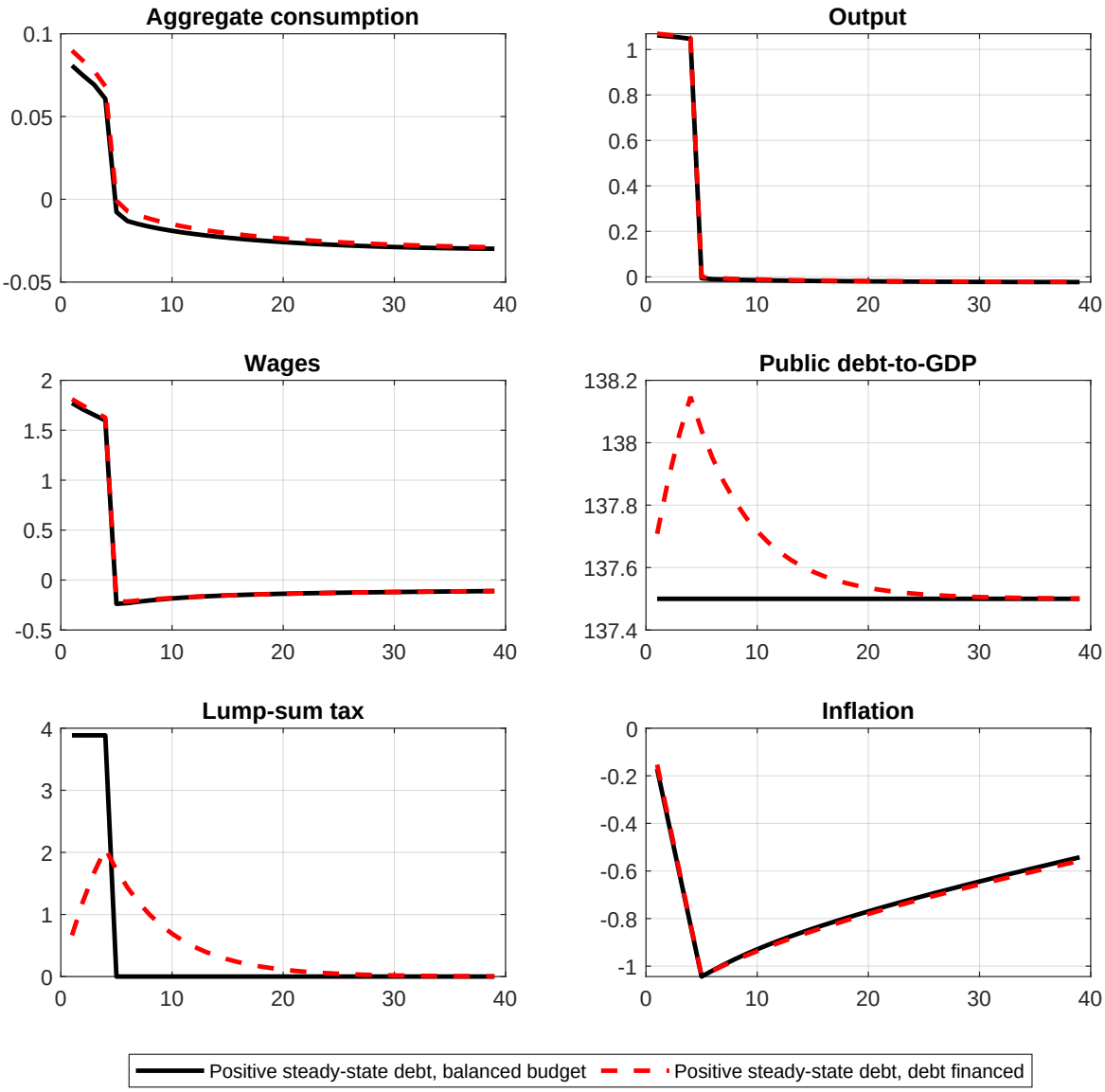
While the main text examined the case of financing government investment with taxes or in part by issuing debt in an economy with no means in which the households are able to save (zero steady-state public debt), this appendix shows the responses to the same government investment spending shock, just that this time the initial stock of public debt is high (5.5

times the steady-state quarterly output). In this case, the means for households to save is abundant and households are relatively well self-insured against adverse shocks.[13] In this case, as Figures 17 and 18 show, there is little difference between tax-financed and debt-financed government investment spending. It is still the case that debt-financed spending has somewhat more expansionary effects, but the differences are quite small.

What is more interesting is that the aggregate effects are quantitatively much smaller than in the debt-financed case in Figures 13 and 14. The reason is that with zero debt, marginal propensities to consume are relatively high for all households, as they are all at the constraint because there are no assets in which to save in the steady state. With high public debt there are a lot of assets to save in, which means that many households have accumulated enough savings to move away from the borrowing constraint, which implies that their marginal propensities to consume are smaller. This is the main reason for the attenuation of the responses seen in Figures 17 18 compared to the debt-financed case in Figures 13 and 14 in the main text.

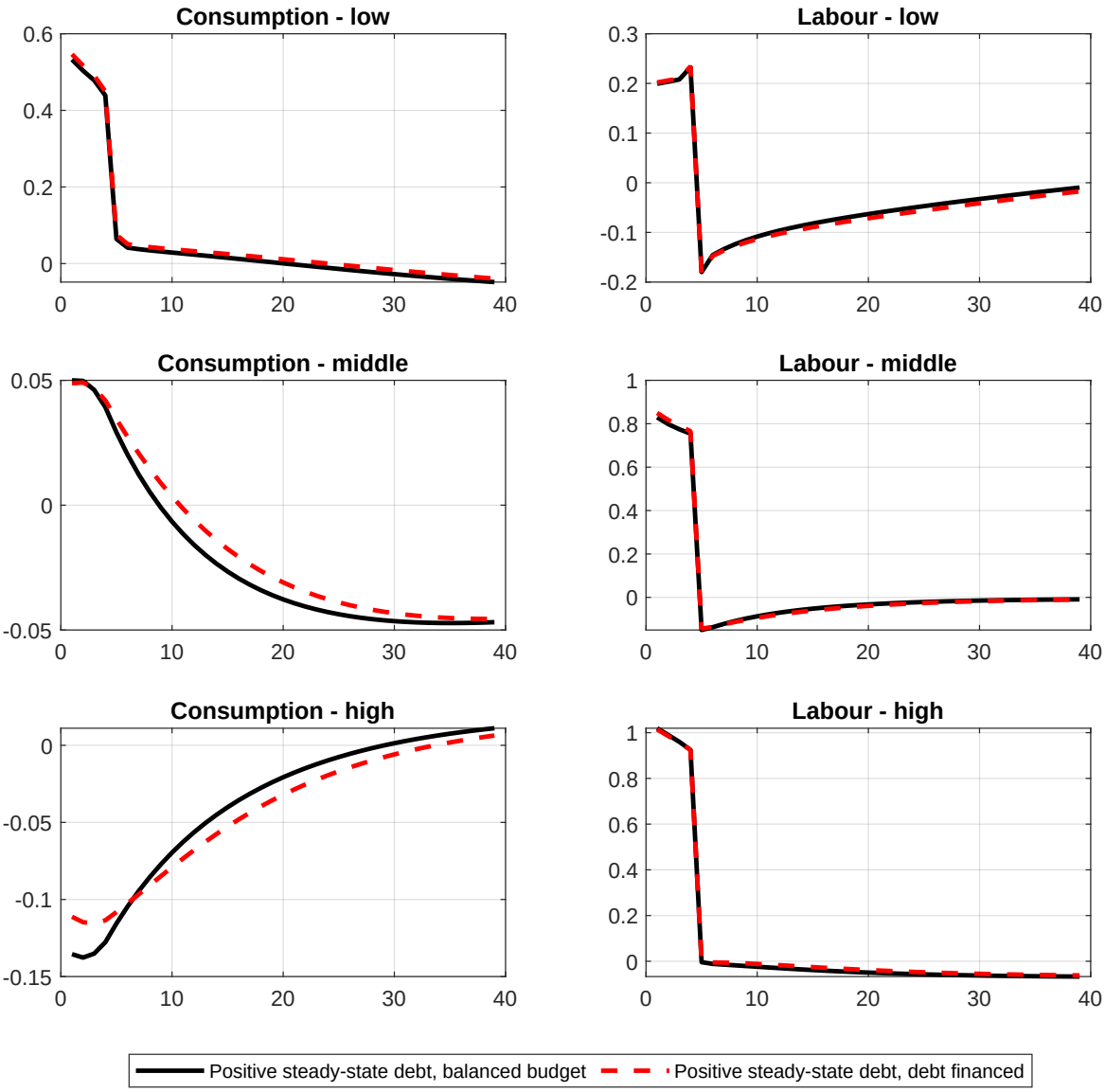
[13]There is still a substantial proportion of households (about 15%) with no assets, but the remaining households tend to have at least some government bonds of savings.

FIGURE 17. Financing government investment with high steady-state debt - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and public debt-to-GDP (percentage point deviations from annual GDP). All variables are in real terms.

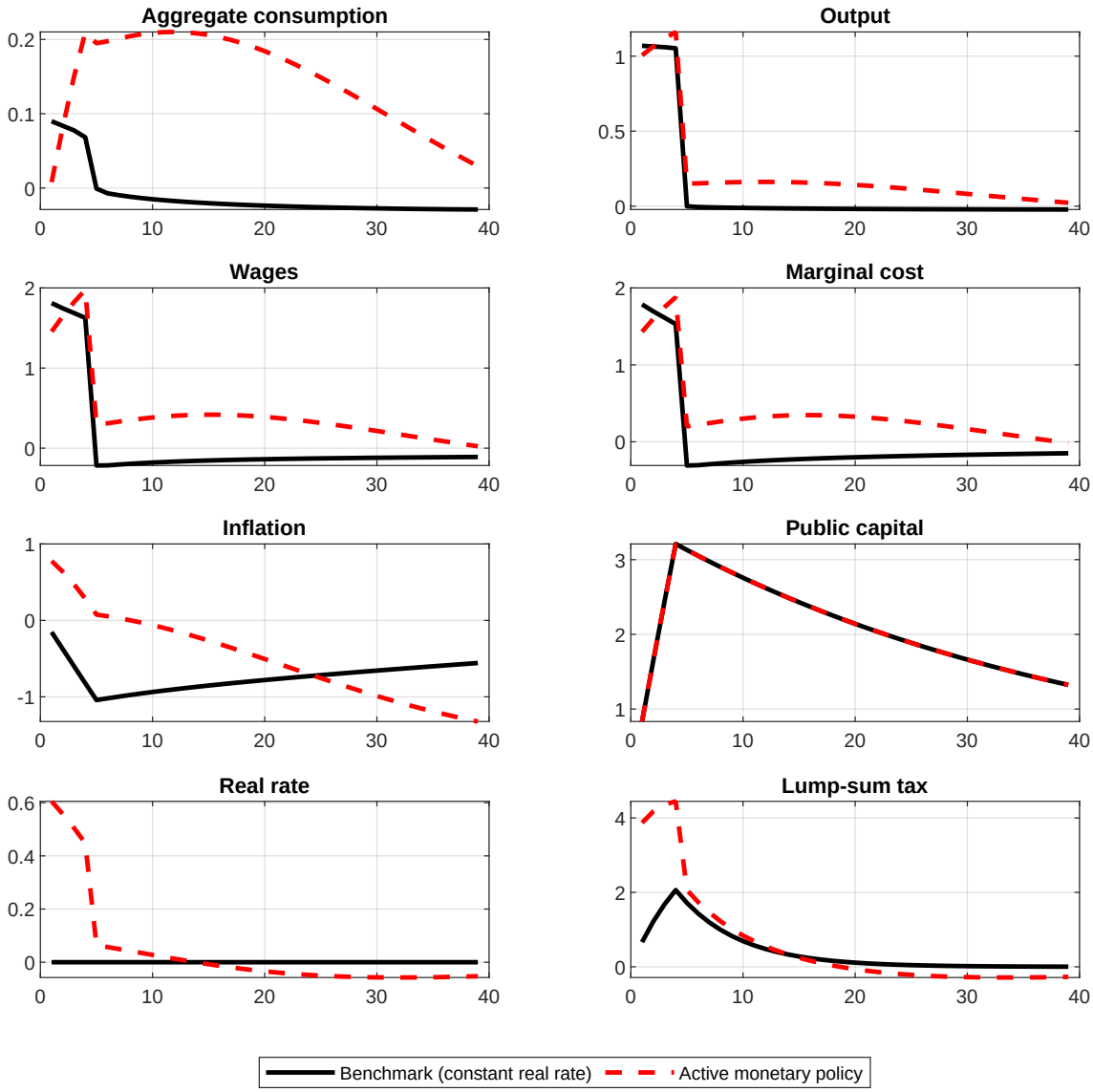
FIGURE 18. Financing government investment with high steady-state debt - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

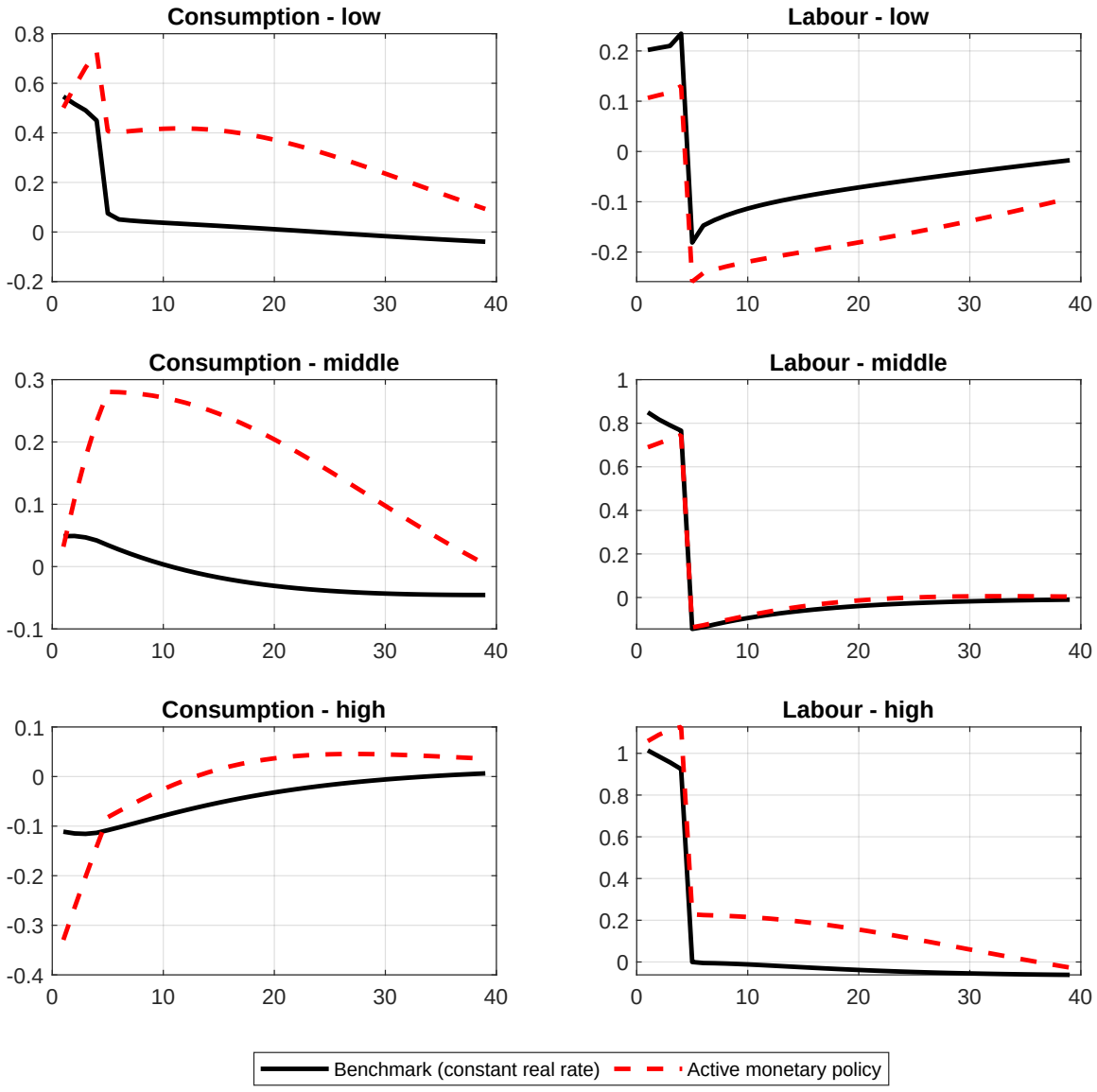
C Active monetary policy with debt financing

FIGURE 19. Active monetary policy and tax-financed government investment - aggregate variables



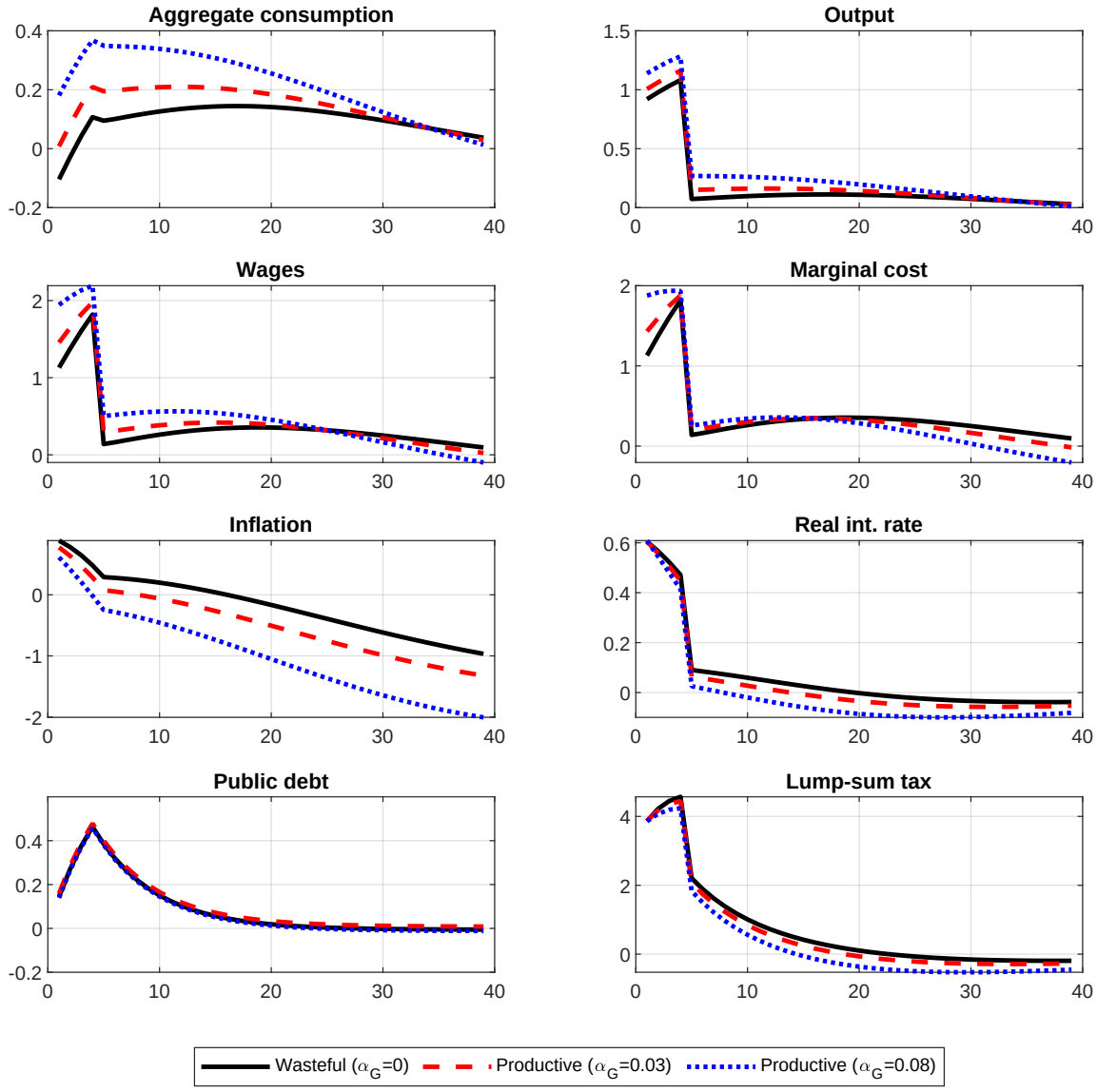
Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and public debt-to-GDP (percentage point deviations from annual GDP). All variables are in real terms.

FIGURE 20. Active monetary policy and tax-financed government investment - responses by groups



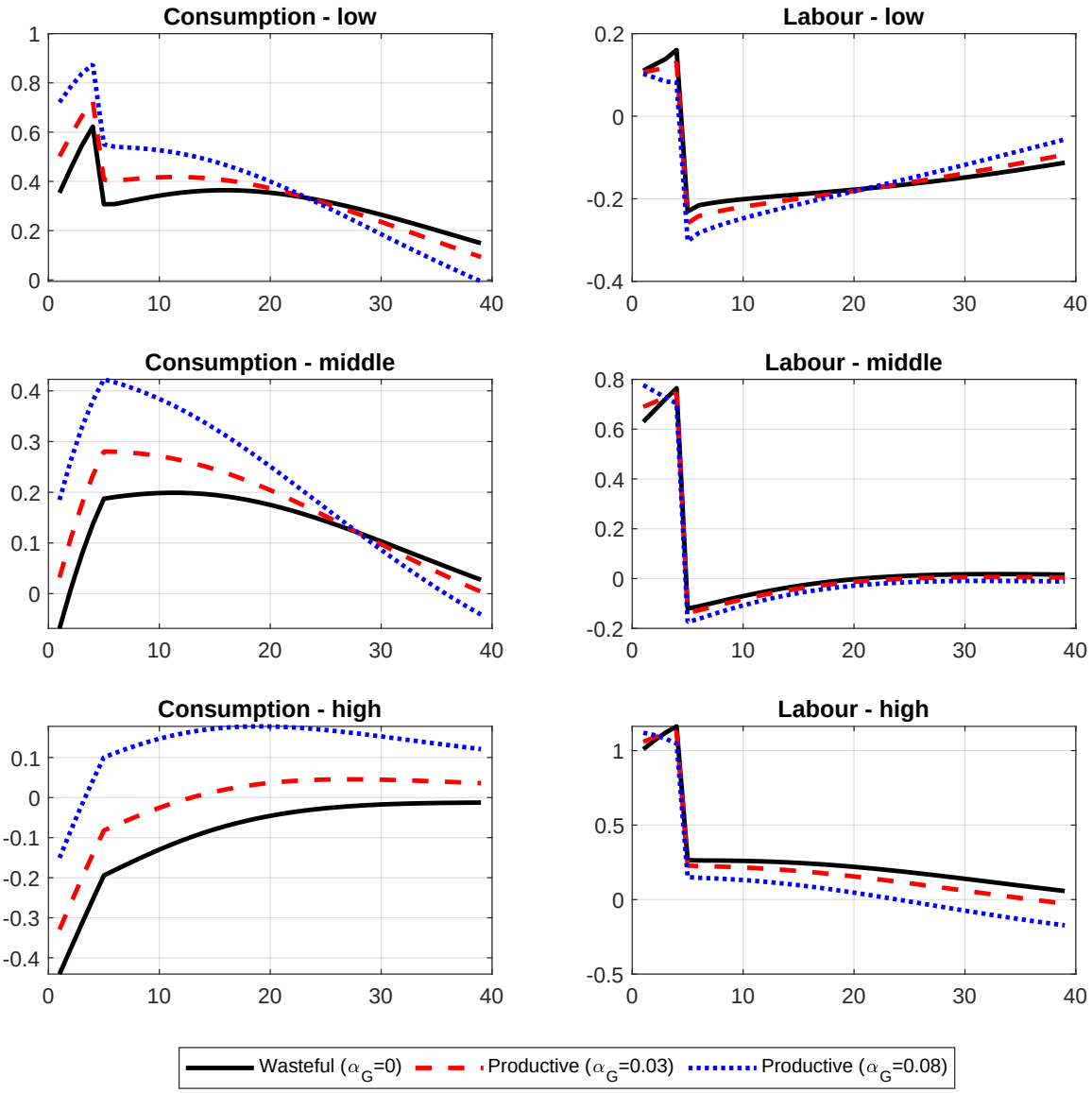
Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.

FIGURE 21. Productivity of debt-financed government investment and monetary policy - aggregate variables



Horizontal axes: quarters; vertical axes: percent deviations from the steady state, except inflation (annualised percentage-point deviations) and the real interest rate (percentage point deviations, annualised). All variables are in real terms.

FIGURE 22. Productivity of debt-financed government investment and monetary policy - responses by groups



Horizontal axes: quarters; vertical axes: percent deviations from the steady state. All variables are in real terms.