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Government Investment, Its Financing and the Public Capital Stock: A Small Open Economy Perspective*

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Abstract

Expenditure reductions played a key role in many small open economies during the fiscal consolidation between 2008 to 2013, especially for public investment. This led to lower public capital stock and affected competitiveness of these countries. After the crisis, many governments consider increasing government investment to replenish the public capital stock, but have limited resources to do so. This paper shows that budget-neutral investment spending can generate the long-term benefits of a higher public capital stock while at the same time limiting the risks of overheating and negative consequences for public finances and trade balance. The least harmful way of financing government investment, which preserves both fiscal and external balances, is by reducing other government spending, even if it is valued by households. Financing government investment with debt worsens fiscal and external balances. Financing investment with labour taxes reduces the external balance, while financing with VAT only does so in the very short run.

JEL classification: F16, F41, F42, F45, F47.

Keywords: DSGE models, government investment, public finances, monetary union, open-economy macroeconomics.

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Non-technical summary

During the recent crisis, many European countries, especially those that were more severely affected by the sovereign debt crisis, resorted to reductions in government investment. Such a measure is relatively easier to implement during downturns compared to other types of government spending. However, if such measures last for a long period of time, they result in depleted public capital stock, with tangible implications such as deteriorated or outdated infrastructure. This can increase costs for the industry and reduce competitiveness of the economy. Governments can replenish public capital by either borrowing, or in a budget-neutral way, by either restructuring government expenditure or by increasing various types of taxes. This paper examines which of these options is preferable.

The paper first describes the developments in government investment spending in Ireland, putting recent developments in the context of what happened prior to, and during the, financial crisis. We show the impact that these long-lasting government investment spending reductions have had on the public capital stock. The paper then takes a forward-looking approach, using the concrete example of Irish government investment projections. While this requires assumptions on depreciation, it appears that the level of public capital will increase by a sizeable margin in the years ahead. We then use the Global Dynamic General Equilibrium model of Ireland in a monetary union, and examine how different ways of financing government investment affect the key macroeconomic variables, in particular, how do different options affect the economy's fiscal and external balance.

We find that no matter how government investment is financed, the increase of productive public capital stimulates output in the medium and longer term. However, we find that where the increase in government investment is financed by redirecting other government spending toward investment seems to be the most beneficial in terms of achieving output growth, fiscal balance, and an improvement in the trade balance. Interestingly, over the medium run this has similar effects as a fiscal devaluation, just that it is achieved using fiscal policy variables on the expenditure side rather than on the revenue side. Pure debt financing increases public debt, and financing with labour taxes increases marginal costs and reduces the external competitiveness of the economy, leading to a worsening of the trade balance. While the financing of government investment with VAT depresses private consumption, it also leads to a lesser deterioration and faster improvement of the trade balance compared to the case when government investment is financed by labour taxes. Importantly, in all cases, an increase in even moderately productive public capital has sufficiently strong effects on output that offsets the negative effects of higher taxes in the short run. This implies that timing of government investment is important, as there may be some short-run costs, while the benefits will accrue over the medium and longer run. Our findings are robust to a number of assumptions, such as time-to-build, permanent shocks, different fiscal rules, and the non-wastefulness of government consumption.

1 Introduction

Many European countries that were affected by the sovereign debt crisis resorted to reductions in government investment as the most readily available measure to decrease government spending (ECB, 2018). This is a more general phenomenon, as most countries find it easier to lower government investment during downturns rather than other types of government spending (Bachmann and Sims, 2012). The reduction in public investment persisted and went so far that in 2016, the share of gross investment by the general government in GDP reached its lowest point in 20 years in the EU (EIB 2017).

If downturns are protracted so that the reduction in government investment persists, such policies result in a depleted public capital stock, with tangible implications such as deteriorated or outdated infrastructure. This gives rise to pressure to resume investment in public capital. Governments can invest by either borrowing, or in a budget-neutral way, by either restructuring government expenditure or by increasing various types of taxes to raise funds for public investment. This paper examines which of these options is preferable, and for which type of government investment.

For concreteness, we illustrate the issue at stake by first describing the developments in government investment spending in Ireland, putting recent developments in the context of what happened prior to, and during the, financial crisis, where adjustment in government investment expenditure played an important role in the stabilisation of public finances. Importantly, the Irish example is not an isolated one, as reductions in investment expenditure were a key component of adjustment in economies receiving financial support, with the decline experienced in Ireland similar to that in Spain, Greece and Portugal. We also consider the impact that these long-lasting government investment spending reductions have had on the public capital stock.

The paper then takes a forward-looking approach, using the concrete example Irish government investment projections in the 2018 Stability Programme Update (Department of Finance, 2018) on the public capital stock. While this requires assumptions on depreciation, it appears that the level of public capital will increase by a sizeable margin in the years ahead. To assess the macroeconomic effects of this government investment plan, we use the Global Dynamic General Equilibrium model of Ireland in a monetary union, and examine how different ways of financing government investment affect the key macroeconomic variables.

The model is based on Gomes et al. (2012), and extended to allow for government investment and public capital (Clancy et al., 2016). In this setting, we investigate various possibilities of financing government investment, including debt financing and three ways of budget-neutral financing (by reducing government consumption, by using labour taxes, and VAT). For all these cases, we examine the effects for two levels of productivity of public capital.[1] The focus is on a small open economy that is a member of a monetary union. We analyse how different options impact on the economy's fiscal balance and on external balance. We do so because these two balances are of particular importance for a small open economy that has to abide by the fiscal rules in the European Monetary Union. We emphasise that we take Ireland as an example for concreteness, but the analysis is

[1]The productivity of public capital measures how much does the public capital improve the productivity of the private sector. A standard assumption that this is small, but positive, so that more public capital always improves private sector productivity, albeit only by a little bit.

more broadly applicable and the mechanisms analysed in the paper apply to government investment and the role of public capital stock in all small open economies.

Our main findings are that no matter how government investment is financed, the build-up of productive public capital increases output in the medium and longer term. However, we find that the way public investment is financed has a significant impact on the structure of output in the short and medium run. In particular, the case where the increase in government investment is financed by redirecting other government spending toward investment seems to be the most beneficial in terms of achieving output growth, fiscal balance, and an improvement in the trade balance, a factor that is particularly important for small open economies. Interestingly, over the medium run this case has similar effects as fiscal devaluation (see Gomes et al., 2016), just that it is achieved using fiscal policy variables on the expenditure side rather than taxes.

Pure debt financing increases public debt, and financing with labour taxes increases marginal costs and reduces the external competitiveness of the economy, leading to a worsening of the trade balance. Financing of government investment with VAT depresses private consumption, but also quickly improves the trade balance. Importantly, in all cases, an increase in even moderately productive public capital has sufficiently strong effects on output that offsets the negative effects of higher taxes in the short run. If the productivity of public capital is higher, then beneficial output effects over the medium and longer term are even stronger. In all these cases, the open economy aspect is important, as productive public capital contributes to lowering the marginal costs and therefore improves the competitiveness of the home economy.[2] Timing of government investment is important, as the costs associated with the fiscal stimulus due to higher investment are front-loaded, while the benefits accrue over the medium to longer run.

We also investigate the robustness of our results to a number of assumptions, such as time-to-build, permanent shocks, different fiscal rules, and the non-wastefulness of government consumption. Overall, our main results hold.

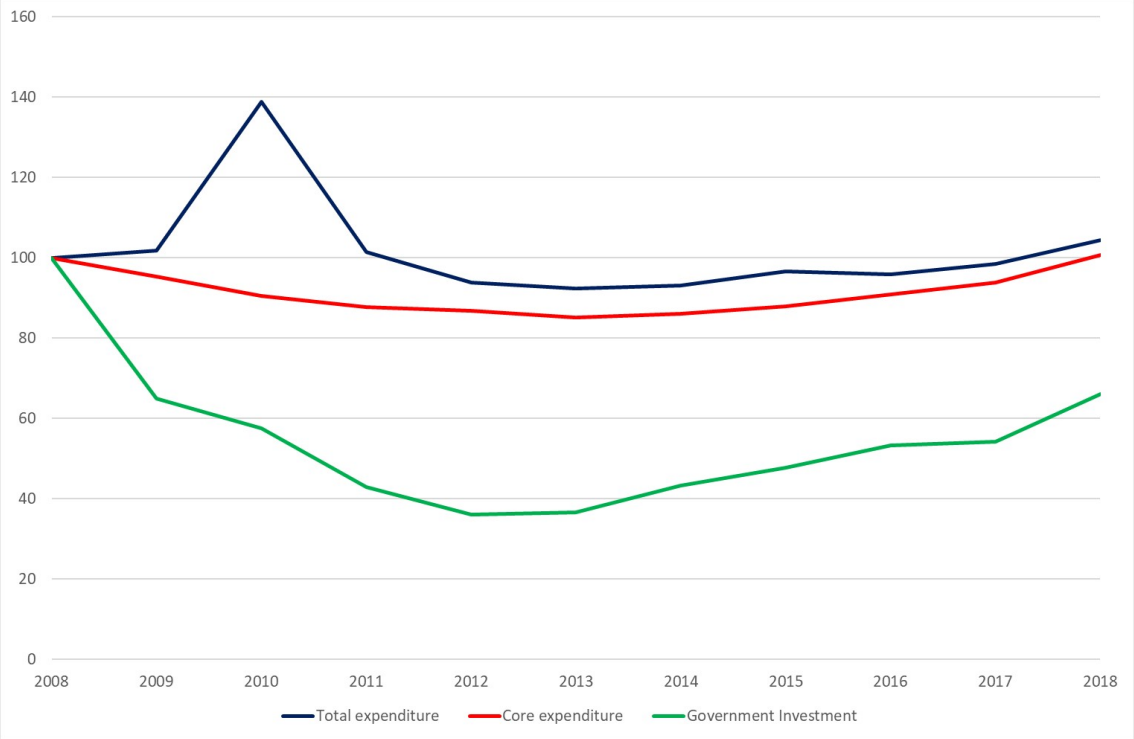
The paper is structured as follows. Section 2 describes the evolution of government investment and the public capital stock in Ireland. Section 3 describes the main model components, Section 4 reports the main results, and Section 5 examines the effects of alternative assumptions. Section 6 concludes.

2 Government investment and the public capital stock in Ireland

Following very strong growth prior to the financial crisis, the Irish economy has experienced a prolonged period of subdued government investment spending. This reflects the important role that expenditure reductions played in bringing the public finances back to sustainable levels and, within that, the large role that investment spending played. For example, government investment spending recorded a peak to

[2] Overall, our ranking of different budget-neutral options to finance government investment is in line with the findings regarding fiscal consolidations (see, e.g., in 't Veld, 2013). However, our focus is not on fiscal consolidations but rather on the ex-ante budget-neutral financing of government investment. In our setting, the positive effects of higher public capital can make higher government investment self-financing.

FIGURE 1. Government expenditure



trough decline of 65 per cent between 2008 and 2013. Reflecting the Department of Finance's (2011) view that spending led adjustments would be more successful in reducing deficits and stabilising debt ratios, approximately two-thirds of the Government's adjustment measures came via reductions in government expenditure (see Figure 1). This followed rapid growth in the years prior to the crisis; in nominal terms spending increased by 57 per cent in the five years to 2007, compared to an increase of 20 per cent for the Euro area as a whole. Abstracting from the spike in government spending in 2010 related to banking related measures, there was a peak to trough decline of 8 per cent in spending between 2008 and 2013, before spending gradually picked up. Changes in total expenditure is not an ideal measure of spending adjustments, however, due to the impact of capital transfers to the financial sector and higher interest costs. What we call 'core' government spending – excluding these two components - provides a more accurate picture of the measures taken by successive governments in order to bring the public finances back to more sustainable levels. Relative to 2008, 'core' government spending reached a peak decline of 15 per cent in 2013 and the gradual nature of its subsequent recovery meant it only returned to the pre-crisis peak in 2018, five years after the conclusion of the Economic Adjustment Programme.

Figure 1 also highlights the significant role that government investment spending played in reducing total expenditure with the former declining by two-thirds between 2008 and 2013. As a result, and despite its small relative weight in total expenditure (capital spending represented 12 per cent of core spending in 2008), it accounted for just over half of the nominal core spending reduction that took place between 2008 and 2013 (EUR 6.2 billion out of a total reduction of EUR 11.1 billion). Note that government investment only returned to two-thirds of its pre-crisis peak in 2018.

FIGURE 2. Government investment and depreciation as percent of GNI*

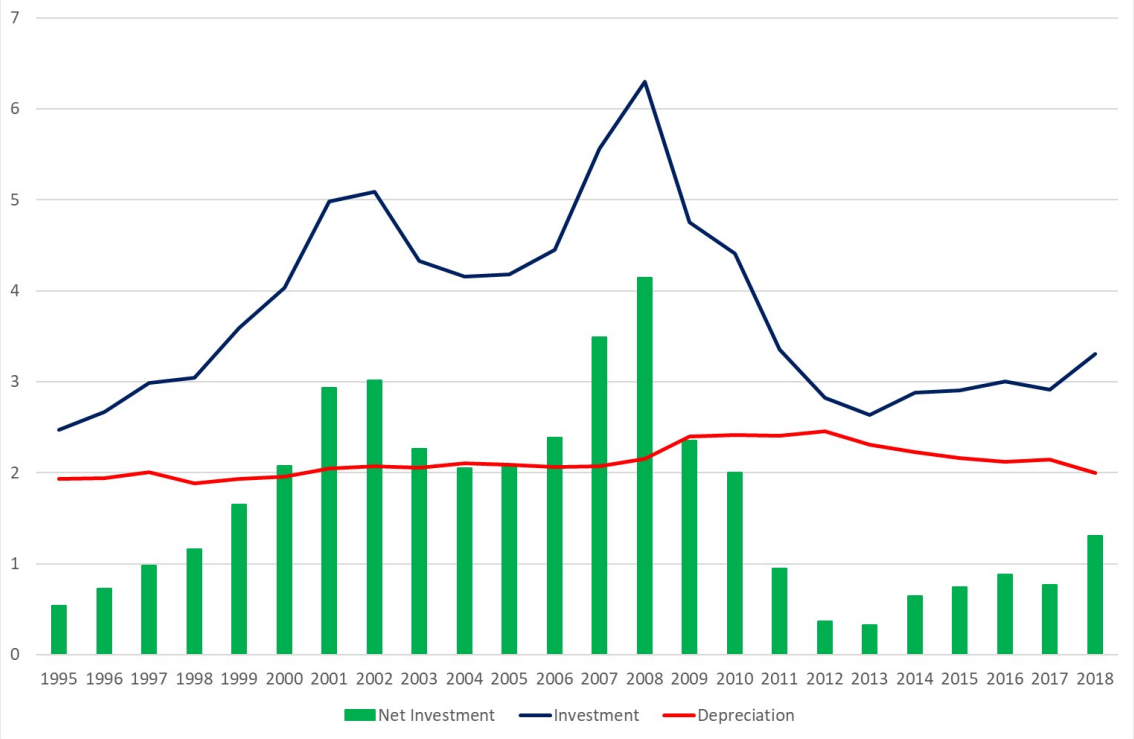


Figure 2 shows government investment spending as a percentage of GNI* over a longer time frame.[3] In common with broader government expenditure, this highlights the very strong increases recorded in investment spending prior to the crisis (reaching a peak of 6.1 per cent of GNI* in 2008). Spending growth was particularly marked in the period 2006 to 2008, increasing by 40 per cent in those two years alone. This spending was primarily driven by increases in the broad areas of transport and housing related investments.

Government investment may have been expected to fall back once key capital projects had been delivered, and reflecting the phase of the cycle. The close relationship between public investment spending and economic activity is well established. Looking at the cyclical behaviour of fiscal policy in OECD countries, Lane (2003) finds that investment is the most pro-cyclical component of public spending, with a particularly strong pro-cyclical relationship identified in Ireland. The subsequent decline was very large; in 2013 investment spending had declined to levels not seen since the mid 1990s (2.5 per cent of GNI*) and the improvement since has been gradual. The Figure also outlines depreciation in the government sector. This allows us to highlight the sharp fall in net investment (investment less depreciation) that also occurred, both in an absolute sense and relative to pre-crisis levels. Annual net investment spending averaged just 0.5 per cent of GNI* in the 5-year period to 2017, compared to an average rate of over 3 per cent in the years immediately prior to the crisis. There was a slightly stronger pick-up in 2018, but it remained well below the levels seen in the early 2000s. Furthermore, the

[3]GNI* is a measure of the Irish GDP that excludes most of the activities that have little or nothing to do with the domestic Irish economic developments. These are mainly the activities pertaining to foreign multinational firms, mostly related to intellectual property rights.

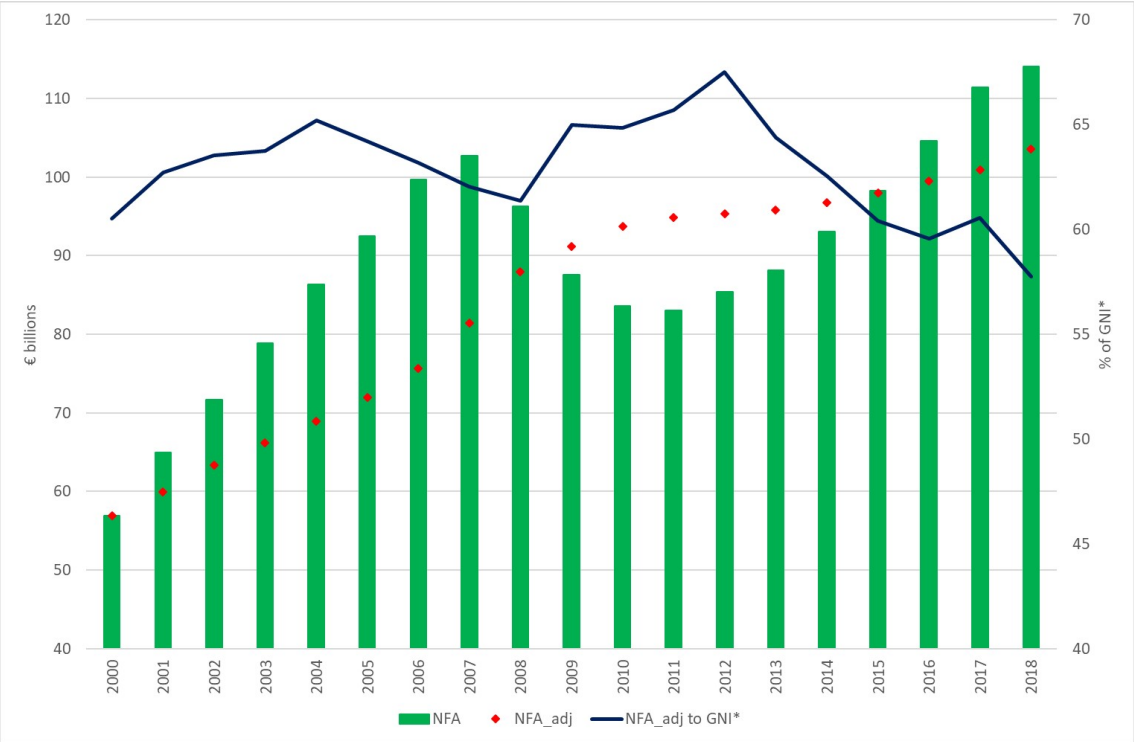
announced capital expenditure adjustments between 2008 and 2013 could also have understated the actual level of adjustment borne by capital in the event that certain projects were delayed or postponed.

Reductions in investment spending were an important part of fiscal consolidation in each of the euro area countries that accessed financial assistance programmes following the financial crisis. Peak to trough declines in investment spending ranged from 37 per cent to 71 per cent in these six economies, but when Latvia – which was in a balance of payments programme – is excluded, that range narrows from 55 per cent (Cyprus) to 71 per cent (Portugal). As mentioned above the Irish peak to trough decline in investment spending was close to two-thirds, very similar to that in Greece and Spain. Most of these countries saw growth boosted by unsustainable macroeconomic imbalances prior to the financial crisis. Ireland, Greece, Spain and Portugal were, according to the European Commission's Macro Imbalance Procedure (MIP) scoreboard, the only euro area members that had at least five indicators breaching MIP thresholds in 2007, with these breaches broad based across internal and external indicators. This supported sharp increases in total expenditure and the investment component in particular. Investment spending was well above the Euro area average in these four economies, but experienced a sharp decline around the end of the decade. The fact that government investment was commonly used in consolidation programmes could partly reflect the strength of spending in preceding years. However, Bedogni and Scott (2017) have noted that a possible anti-investment bias may exist when reducing expenditure. Given the lack of an intertemporal dimension in metrics of fiscal performance, they point to a greater incentive to maintain current expenditure, reductions of which can be more politically sensitive.

Government investment differs from government consumption spending because it contributes to the stock of public capital, which can have a longer lasting impact on the economy. While estimates of the effect of public capital on growth vary - and depend on factors such as the composition and efficiency of spending - the literature typically finds a positive relationship between the two (de Jong et al. (2017)). The effects of public investment spending tend to be stronger when the spending is more effective and productive. This highlights the need for rigorous assessment and appraisal of planned investment projects. The literature on the impact of public capital on output is mixed, with a range of estimates on output elasticities. In general, core infrastructure investments (roads, transport, telecommunications) have higher output effects. In an Irish context, FitzGerald et al., (2003) found that returns to investment in physical infrastructure, in particular roads, were high.

The marked reductions in investment spending across the EU following the financial crisis has raised concerns in relation to longer-term growth implications (see OECD (2015), ECB (2016) and European Commission (2017)). The IMF (2014) noted 'sharp continued cuts in public investment may need to be reversed to avoid a depletion of public capital stocks and potentially adverse effects on long term growth'. While data are available for economy-wide capital stock levels, estimating the government's share is problematic due to data related issues (see IMF (2014), ECB (2016) and Kennedy (2016)). In order to assess the impact that recent spending developments have had in Ireland, we use the CSO's 'Non-Financial Assets of General Government' (NFA) data series to produce an estimate of the Irish public capital stock. This is shown in Figure 3. The data includes a wide range of physical assets owned by government such as dwellings, buildings, stocks and equipment. In nominal terms, the stock of the

FIGURE 3. Public capital in levels and compared to domestic economic activity



Government's NFA is estimated to have declined sharply between 2007 and 2010 (by EUR 19 billion), but subsequently recovered by to reach EUR 115 billion in 2018.

One problem with using the NFA data is that annual movements reflect both the 'net acquisition of assets' (net investment) and 'other changes'. The latter includes changes in the valuations of existing assets, driven in turn by factors such as market sentiment and cyclical conditions. These valuation changes have driven most of the movements in NFA in recent years, with only one-third of the increase since 2010 reflecting net investment. They are also not particularly relevant when it comes to determining the impact that the public capital stock will have on future growth. Accordingly, we construct an alternative stock of NFA – 'adjusted NFA'. We do this by taking the stock of NFA in 2000 as a base year and extrapolating this series forward based on the level of net government investment. This illustrative series (red dotted series in Figure 3) highlights solid and sustained growth in the stock of assets to 2008 (average annual growth of 5.5 per cent from 2001 to 2008) followed by stagnation or very modest increases to 2017 (average growth 1.5 per cent), with a slight pick-up in 2018. Compared to total economic activity, however, the level of public capital relative to domestic economic activity fell sharply over the recent years, as the solid blue line in Figure 3 shows.

In view of these developments, a new National Development Plan (NDP), announced in February 2018, commits to increase public capital investment to approximately 4 per cent of GNI* by 2025 – up from 2.7 per cent in 2017 – and to maintain it at that level thereafter. This figure includes central government investment and other spending. A sharp increase in the level of government investment is envisaged (by more than 50 per cent), from EUR 5.4 billion in 2017 to EUR 8.3 billion (3.7 per cent of GNI*) in 2021. We estimate that higher government net investment spending should result in a sizeable increase in the stock of public capital. Based on current plans, the stock of public capital

could increase by close to 16 per cent in the 4-year period to 2021. This compares to an increase of 5 per cent in the most immediate 4-year period.

The remainder of this paper attempts to analyse the effects of an increase in government investment, with a particular emphasis on how it is financed. The central scenario in the model assumes that government investment spending increases in line with the 2018 Stability Program Update projections out to 2021, after which it returns to close to its long-run average. Whilst the model necessarily simplifies some real world behaviour, it provides useful insights into channels through which public investment spending affects the wider economy.

3 The model

This section briefly describes the model setup and the main equations used. The model used is a variant of a global DSGE model of the euro area, the EAGLE (see Gomes et al. (2012) for details), which is adapted to distinguish between government investment and government consumption spending. Importantly, the model also accounts for the fact that in a small open economy, some government spending (either investment or consumption) is imported, as in Clancy et al. (2016).[4]

The model assumes the world economy consists of four regions (US, the rest of the world - RW, Home country, and the REA - rest of the euro area), two of which (Home and the REA) constitute a monetary union (EA). Each region is an open economy, following the Smets-Wouters (2003) model. The various regions are modelled symmetrically and linked with each other through bilateral trade relations. The model has a proportion of non-Ricardian households and a number of real and nominal rigidities, such as habit formation, adjustment costs for investment and imports, rigid prices of final goods and rigid wages, with partial indexation. Final goods are aggregates of nontradable and tradable goods, with tradable goods themselves an aggregate of domestically-produced and imported goods. We use a version of the EAGLE that permits an import content of exports.[5]

The government generates revenue by levying distortionary and lump-sum taxes, and seigniorage earned on outstanding money balances. Debt is held in the form of government bonds, with a long-term target debt level in line with the Maastricht Treaty achieved via a smooth adjustment in lump-sum taxes.

The two EA blocs share a monetary authority (interest rate) and the exchange rate vis-a-vis the remaining two blocs of the model. All other regions have their own monetary authorities. All regions follow a Taylor-type interest rate rule, specified in terms of deviations of consumer price inflation and output gap from their target levels and allows for interest rate smoothing. Crucially, in the monetary union the interest rate reacts only to the EA-wide developments. This implies that, for all practical purposes, the EA-wide interest rate remains almost unchanged in response to Ireland-specific fiscal measures.

To permit government spending on imported goods, we assume that the government purchases a composite final good. This is produced by firms that assemble the final government consumption and investment bundles, $Q_t^{G_C}$ and $Q_t^{G_I}$ respectively, using

[4] This section is based on the model description in Clancy et al. (2016).

[5] See Brzoza-Brzezina et al. (2010), for details.

intermediate tradable and non-tradable goods as inputs.[6] Final government investment goods are assembled according to a constant elasticity of substitution (CES) technology, using tradable goods, $TT_t^{G_I}$, and non-tradable goods, $NT_t^{G_I}$:

$$Q_t^{G_I} = \left[\nu_{G_I}^{\frac{1}{\mu_{G_I}}} \left(TT_t^{G_I} \right)^{\frac{\mu_{G_I}-1}{\mu_{G_I}}} + (1-\nu_{G_I})^{\frac{1}{\mu_{G_I}}} \left(NT_t^{G_I} \right)^{\frac{\mu_{G_I}-1}{\mu_{G_I}}} \right]^{\frac{\mu_{G_I}}{\mu_{G_I}-1}}. \tag{1}$$

Government demand for non-tradable goods is therefore:

$$NT_t^{G_I} = (1-\nu_{G_I}) \left(\frac{P_{NT,t}}{P_{G_I,t}} \right)^{-\mu_{G_I}} Q_t^{G_I}, \tag{2}$$

and analogously for government tradable goods. $P_{NT,t}$ is the price of non-tradable goods and $P_{G_I,t}$ is the price of final government goods. ν_{G_I} governs the share of each good in the bundle and μ_{G_I} is the elasticity of substitution between these goods. The tradable good consumed by the government is a bundle of home-produced tradable goods, $HT_t^{G_I}$, and imported goods, $IM_t^{G_I}$:

$$TT_t^{G_I} = \left[\nu_{TG_I}^{\frac{1}{\mu_{TG_I}}} \left(HT_t^{G_I} \right)^{\frac{\mu_{TG_I}-1}{\mu_{TG_I}}} + (1-\nu_{TG_I})^{\frac{1}{\mu_{TG_I}}} \left(IM_t^{G_I} \right)^{\frac{\mu_{TG_I}-1}{\mu_{TG_I}}} \right]^{\frac{\mu_{TG_I}}{\mu_{TG_I}-1}}. \tag{3}$$

Government demand for home-produced tradable goods is then:

$$HT_t^{G_I} = \nu_{TG_I} \left(\frac{P_{HT,t}}{P_{TTG_I,t}} \right)^{-\mu_{TG_I}} TT_t^{G_I}. \tag{4}$$

As above, ν_{TG_I} determines the share of each good in the bundle and μ_{TG_I} the elasticity of substitution between them. $P_{HT,t}$ is the price of home tradable goods and $P_{TTG_I,t}$ is the price of government-consumed tradable goods.

Imports of government consumption goods, $IM_t^{G_I}$, consist of a bundle of (bilateral) imports of tradable goods, $IM_t^{G_I,CO}$, produced in all other regions:

$$IM_t^{G_I} = \left[\sum_{CO \neq H} \left(\nu_{MG_I}^{H,CO} \right)^{\frac{1}{\mu_{MG_I}}} \left(IM_t^{G_I,CO} \right)^{\frac{\mu_{MG_I}-1}{\mu_{MG_I}}} \right]^{\frac{\mu_{MG_I}}{\mu_{MG_I}-1}}, \tag{5}$$

where

$$\sum \nu_{MG_I}^{H,CO} = 1.$$

Government demand for imports from bloc CO is

$$IM_t^{G_I,CO} = \nu_{MG_I}^{H,CO} \left(\frac{P_{IM,t}}{P_{IMG_I,t}} \right)^{-\mu_{MG_I}} IM_t^{G_I}. \tag{6}$$

The superscript H indicates the home country and the superscript CO the bloc from which the good is imported. Again, $\nu_{MG_I}^{H,CO}$ is the share of goods from each bloc, μ_{MG_I} is the elasticity of substitution between them, $P_{IM,t}$ is the price of imported goods and $P_{IMG_I,t}$ is the price of government consumption imports.

[6] The equations are identical for the government consumption and investment goods, so we describe only equations for investment.

Prices are defined by equations which correspond to the CES-aggregated goods bundles. Prices of government consumption good, $P_{G_I,t}$, government tradable consumption good, $P_{TTG_I,t}$, and government imported consumption good, $P_{IMG_I,t}$, respectively are:

$$P_{G_I,t} = \left[\nu_{G_I}(P_{TTG_I,t})^{1-\mu_{G_I}} + (1-\nu_{G_I})(P_{NT,t})^{1-\mu_{G_I}}\right]^{\frac{1}{1-\mu_{G_I}}}, \tag{7}$$

$$P_{TTG_I,t} = \left[\nu_{TG_I}(P_{HT,t})^{1-\mu_{TG_I}} + (1-\nu_{TG_I})(P_{IMG_I,t})^{1-\mu_{TG_I}}\right]^{\frac{1}{1-\mu_{TG_I}}}, \tag{8}$$

and

$$P_{IMG_I,t} = \left[\sum_{CO\neq H} \nu_{MG_I}^{H,CO}\left(P_{IM,t}^{CO}\right)^{1-\mu_{MG_I}}\right]^{\frac{1}{1-\mu_{MG_I}}}, \tag{9}$$

where $P_{IM,t}^{CO}$ is the price of imports from bloc CO.

The equations for government consumption are analogous, but, importantly, in this paper we depart from Clancy et al. (2016) in that we assume that government consumption is *not* complementary to private consumption.

The extended model explicitly accounts for the fact that government investment, $G_{I,t}$ contributes to public capital, $K_{G,t}$:

$$K_{G,t+1} = (1-\delta_G)K_{G,t} + G_{I,t}, \tag{10}$$

where δ_G is the depreciation rate. $K_{G,t}$ enters the private sector's production functions of tradable and non-tradable sectors in a non-rival way:

$$Y_{T,t}^S = z_{T,t}K_{G,t}^{\alpha_G}(K_{T,t}^D)^{\alpha_T}(N_{T,t}^D)^{1-\alpha_T} - \psi_T \tag{11}$$

and analogously for the non-tradable sector.[7]

Government capital enhances the productivity of private capital in a similar manner as technological progress. This means that an increase in government capital will reduce marginal costs, $MC_{T,t}$, of the intermediate goods' sector:

$$MC_{T,t} = \frac{1}{z_{T,t}K_{G,t}^{\alpha_G}(\alpha_T)^{\alpha_T}(1-\alpha_T)^{1-\alpha_T}}\left(R_t^K\right)^{\alpha_T}\left((1+\tau_t^{W_f})W_t\right)^{1-\alpha_T}. \tag{12}$$

The same holds for non-tradable goods.[8] For the corresponding market clearing conditions, see Clancy et al. (2016). Note that the setup used here is somewhat different from the setup for Ireland used in Varthalitis (2019), where private-sector productivity is affected by *all* public-sector services, not only public capital.

[7] Here, $Y_{T,t}^S$ is output, $z_{T,t}$ is the level of productivity, α_G determines the productivity of public capital, $K_{T,t}^D$ is private capital rented, $N_{T,t}^D$ is labour hired, α_T is the capital share in the tradable sector and ψ_T fixed cost.

[8] The parameter $\tau_t^{W_f}$ accounts for labour taxes paid by firms, W_t are wages and R_t^K is the rental cost of capital.

Calibration

We calibrate our model to Ireland. The main steady-state ratios (the Great Ratios) are calibrated based on the mix of national accounts data (for the volume of trade) and input-output tables (for the composition, consumption or investment, of traded goods and the bilateral component of trade). The remaining parameters in the model are either based on country specific empirical evidence, where available, or kept consistent with the original EAGLE model. The values of the calibrated parameters and steady-state ratios are reported in Tables 1 to 3. The relative size of the home bloc is recalibrated to reflect the GDP share in the world economy.

We opt for a calibration of government goods with a low elasticity of substitution between non-tradable and tradable goods, but with relatively high substitution between tradable goods and imported goods from the different blocs. The quasi-share of imported government consumption goods is calibrated to achieve a 2 percent of GDP government consumption that is spent directly on imports in the steady state. This amounts to about 15 percent of government consumption in Ireland. We assume that the share of imported government investment goods is higher, as investment goods tend to be very specific and less likely to be produced domestically in a SOE. We therefore calibrate the quasi-share of imported government investment goods to achieve a 25 percent share of government investment spending.[9] Finally, we assume that the dynamic adjustment of government consumption and investment goods is not subject to adjustment costs.

The calibration of the other blocs of the model follows Gomes et al. (2012) and is in line with the calibration of models such as the GEM (Laxton and Pesenti, 2003, Pesenti, 2008) and the NAWM (Christoffel et al., 2008).

An important part of calibration is how the productivity of public capital, α_G, is set. The larger the value of this parameter, the stronger is the contribution of public capital to the productivity of the private sector. This parameter has no universally-agreed value (apart that it is small, implying a strongly decreasing returns to scale in the public capital stock), so we present the results for two cases. In the benchmark case, we pick the relatively low level of 0.05, in line with Leeper et al. (2010). As the alternative we consider the estimate from the meta-analysis of Bom and Ligthart (2014), who estimate the productivity of public investment at a higher level, 0.08.

[9] In calibrating the import content of government consumption and investment expenditure we rely on estimates by Corsetti and Müller (2006), in particular on their guideline that home bias is stronger in government expenditure than in private consumption or investment. We used the values reported in their Table 1 and relied on the approximate relation that government expenditure has about half the import content of private expenditure. For the REA, RW, and the US we assumed a 10% import content of government investment, which is consistent with the estimate by Corsetti and Müller, who state 12% as the upper bound for government imports. For the import content of government consumption we use Corsetti and Müller's lower bound of 6% for the REA and the RW, and the exact value of 5.8% for the US. For Ireland we set the import content of government consumption to 12%, the highest value reported by Corsetti and Müller, while for government investment we use a 25% import content. The reason is that Ireland is very open, especially regarding investment goods. Note that these ratios should be modified for policy simulations when governments consider a particular policy action that is known to be more biased towards foreign or domestic goods.

4 Results

In this section we examine the results of the effects of an increase of government investment, financed in four different ways:

- By issuing debt
- By reducing other government consumption
- By increasing labour taxes
- By increasing VAT

In all cases, we assume that the government temporarily raises investment, in line with the Government Investment Plan, by approximately 0.3% GDP per quarter in the first year and 0.4% GDP per quarter during the second, third, and fourth year. Afterwards, government investment returns gradually to the initial level.[10] This scenario implies that the public capital increases by about 5% at the peak.

Except in the debt-financed government investment case, we assume that government investment increase is ex-ante budget-neutral, i.e., that the government offsets the expenditure increase by a tax increase that would, ex-ante, lead to a balanced budget. This implies that the path of the change in the offsetting variable (government consumption, tax rates) is the mirror image of the path of government investment change. Note that ex-post, this may not be budget-neutral, because the tax base changes as a result of government investment and changes in other variables. In the case of debt-financed government investment, we allow government debt to increase in the short and medium run, in line with the fiscal rule that keeps the public debt stable in the long run. This fiscal rule is specified in terms of lump-sum taxes, which increase when public debt increases above the steady state level. However, the benchmark fiscal rule increases lump-sum taxes only by a fraction of the debt increase, which allows debt to increase in the short run. We investigate the effect of alternative assumptions regarding the fiscal rule in a separate section.

For each simulation, we report results for two levels of productivity of public capital, "low" (with $\alpha_G = 0.05$) and "high" (with $\alpha_G = 0.08$).

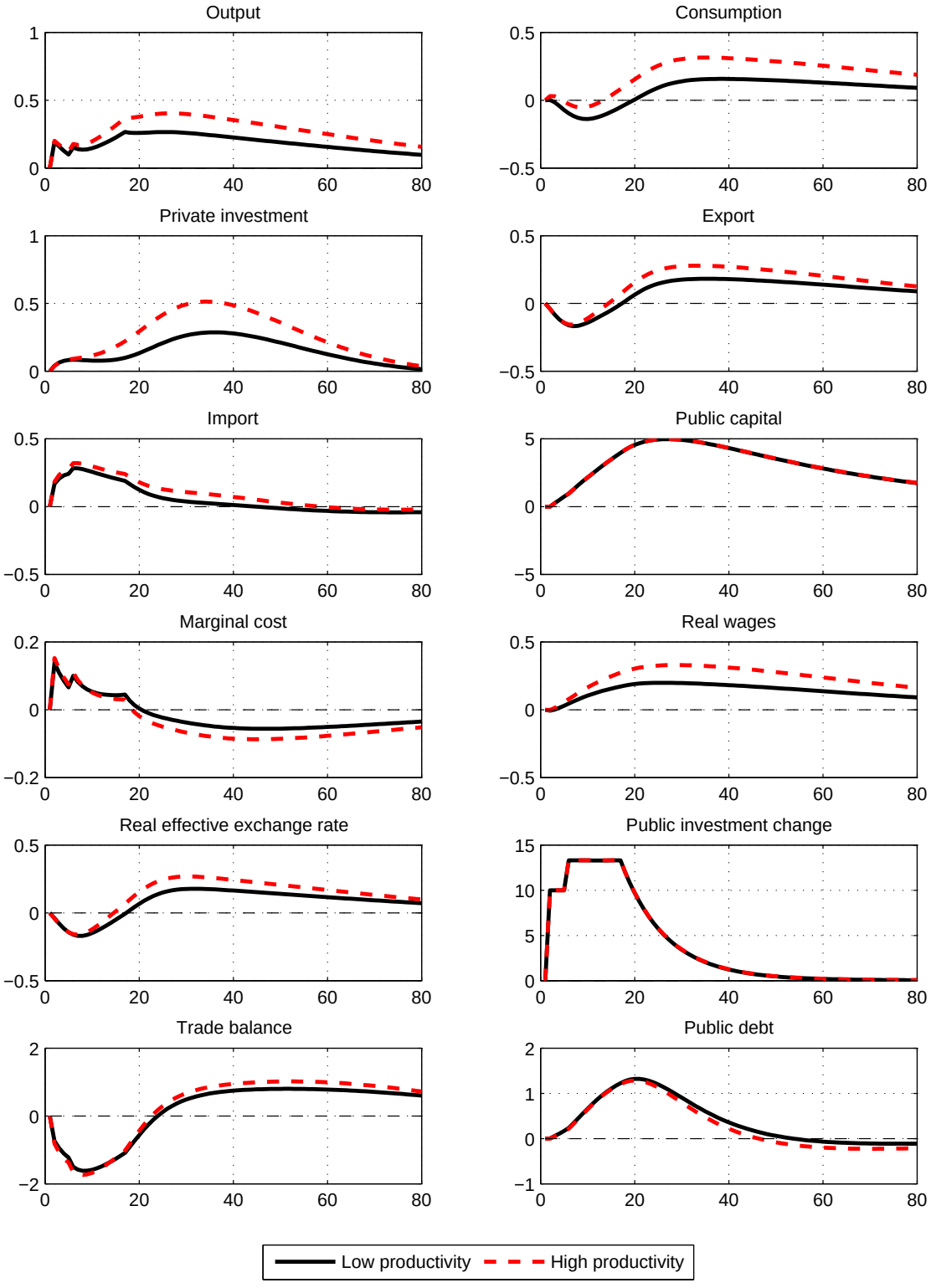
Debt-financed increase in government investment

The first and in many ways simplest case is when government investment is financed by issuing debt. In this case the government decides to increase investment and finances it by issuing debt, with the fiscal rule specified in terms of lump-sum taxes kicking in the long run. The results of this exercise are shown in Figure 4.

During the period when the government is increasing investment, the associated stimulus to aggregate demand directly increases output and marginal costs of firms. During this initial period, government investment has similar effects as the standard debt-funded fiscal stimulus: There is some crowding-out of private consumption, real appreciation in the beginning (note that a decrease in the real effective exchange rate means appreciation), and a decrease in exports due to higher marginal costs and deterioration of external competitiveness. Imports increase because government

[10] The persistence of government investment after the 4th year is 0.9.

FIGURE 4. Debt-financed increase in government investment



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

investment consists in part of imported goods. However, government investment also gradually increases public capital, and the associated increase in productivity starts pushing marginal costs of firms down. More public capital and hence higher productivity allows more goods to be produced, at lower marginal costs despite somewhat higher wages, which improves the external competitiveness (real effective exchange rate depreciates) of the economy and increases exports over the medium and longer run. This is the reason why private investment is not crowded-out in the beginning - in order to benefit from higher public capital in the future, households begin investing immediately.[11]

Overall, over the medium and longer run, the gains from higher public capital stimulate the economy. This, however, comes at the expense of increasing public debt by about 1.5 p.p. over the medium run. In addition, such policy markedly reduces the trade balance in the short run. Because of these side effects, such policy might not be the best during the cyclical upswing or when the country's external balance is weak, at least not in the short run. In the long run, the beneficial effects of productive public capital prevail and trade balance improves, while higher tax revenues (and the fiscal rule) stabilise public debt.

Government-consumption-financed increase in government investment

The second scenario we consider is also the first budget-neutral scenario. In this case, government finances the increase in investment by reducing government consumption. The results of this scenario are shown in Figure 5.

Compared to the debt-financing scenario, there are several marked differences. First, the sharp initial stimulus to output is absent, as government consumption decrease offsets the demand effects of government investment increase. Public debt does not increase initially, and decreases in the medium to long run (the latter is due to the increase in economic activity caused by more public capital, which implies higher tax base). As a result, consumption and private investment are not crowded-out, not even in the short run.

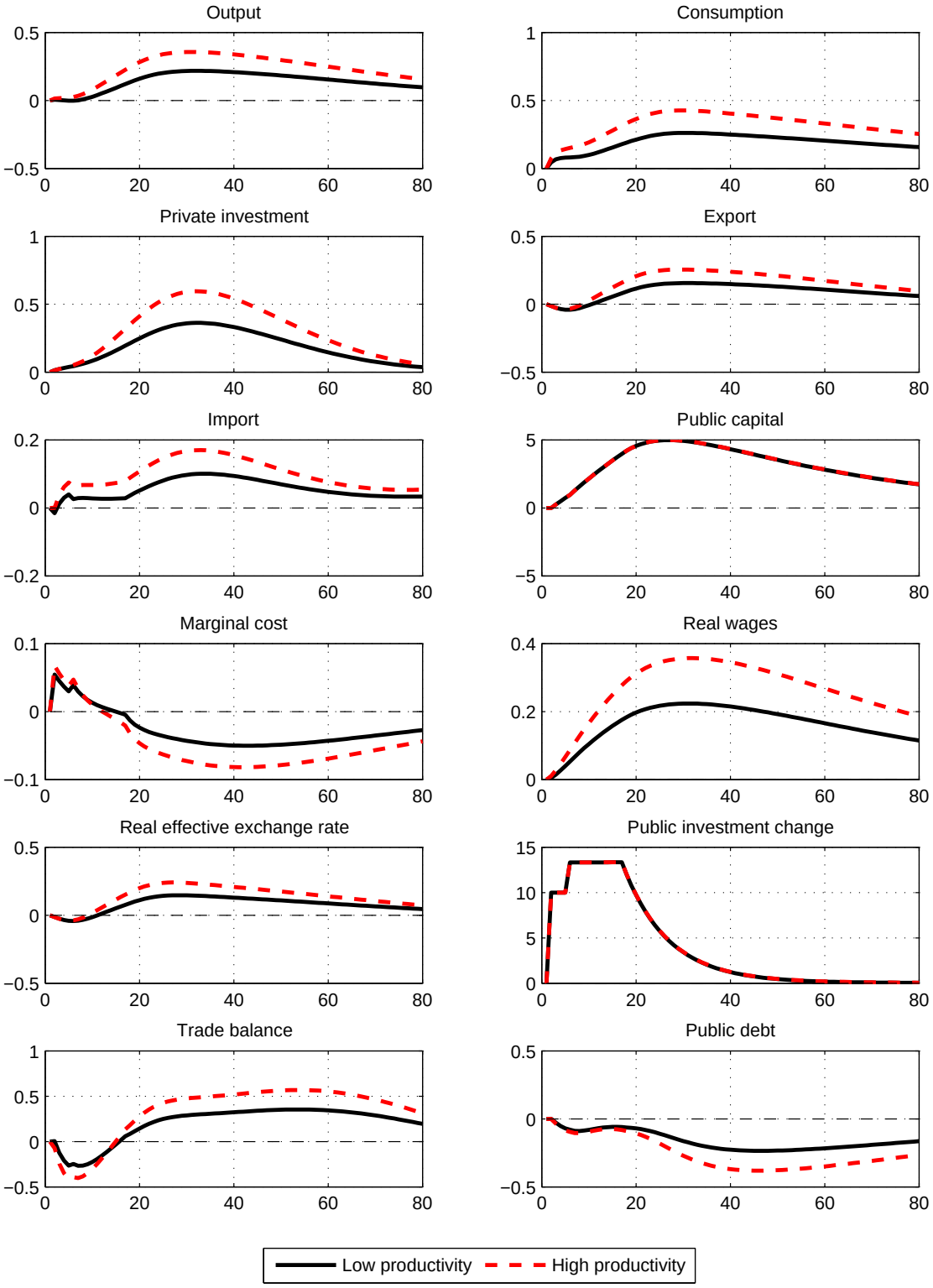
Note that because public debt decreases over the medium and long run, the fact that the fiscal rule is specified in terms of lump-sum taxes implies that our results are on the conservative side. If the fiscal rule was in terms of distortionary taxes, a reduction in public debt levels would imply a reduction in distortionary taxation and therefore more beneficial results.

Lower demand stimulus also implies that marginal costs increase initially substantially less than in the case of debt financing, which preserves the external competitiveness of the economy and does not affect exports as negatively as the debt-financed increase in government investment. Real effective exchange rate does not appreciate initially, exports increase almost immediately and trade balance deteriorates only in the very short run.

In the medium and longer run, beneficial effects of higher public capital reduce marginal costs of firms, which causes real effective exchange rate depreciation (recall that an increase in the real effective exchange rate means depreciation) and higher exports. The latter exceed higher imports, so that the trade balance improves for a long period of time.

[11] Note that there are investment-adjustment costs in the model; if these costs were absent, investment would decrease initially.

FIGURE 5. Other-consumption-financed increase in government investment



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

Note that financing government investment with a reduction in other government consumption is reminiscent of a fiscal devaluation in the medium run. A fiscal devaluation reduces marginal costs and prices (and therefore increases external competitiveness) by lowering labour taxes. At the same time, it offsets the negative effects on fiscal balance by increasing VAT, which is a tax on goods sold within the country and does not affect external competitiveness directly (see Gomes et al., 2016). Financing government investment by redirecting other government consumption expenditure achieves a similar goal, but it does so using fiscal policy variables on the expenditure rather than on the revenue side.

Labour-tax-financed increase in government investment

In this scenario the government finances its investment increase using distortionary labour taxes. The financing is such that ex-ante, the increase in government investment is budget-neutral. The results are shown in Figure 6.

Higher labour taxes reduce labour supply, despite higher wages.[12] Lower labour supply is the main reason why output increases by less than with debt financing or with other government consumption financing (it istill increases sharply on impact because of the short-run stimulus coming from the government investment increase). Moreover, higher labour taxes increase wages, which in turn raise marginal costs of firms, which now increase more persistently then with debt financing.[13] This leads to the worsening of the external competitiveness of the economy (the real effective exchange rate appreciates quite markedly in the first five years) and exports decrease. Combined with the import increase (due to direct import-content of government investment), this markedly reduces the trade balance.

Note that the increase in labour taxes, even though budget-neutral ex-ante, turns out to bring in more revenues because the tax base increases in the short run, so that public debt decreases somewhat.[14] This happens because of the relatively strong wage increase in the initial phases, which is stronger than the labour supply reduction. As a result, this offsets the effect of the lower labour supply on the tax base. As before, the reduction in public debt combined with the fiscal rule in terms of lump-sum taxes implies our results are on the conservative side.

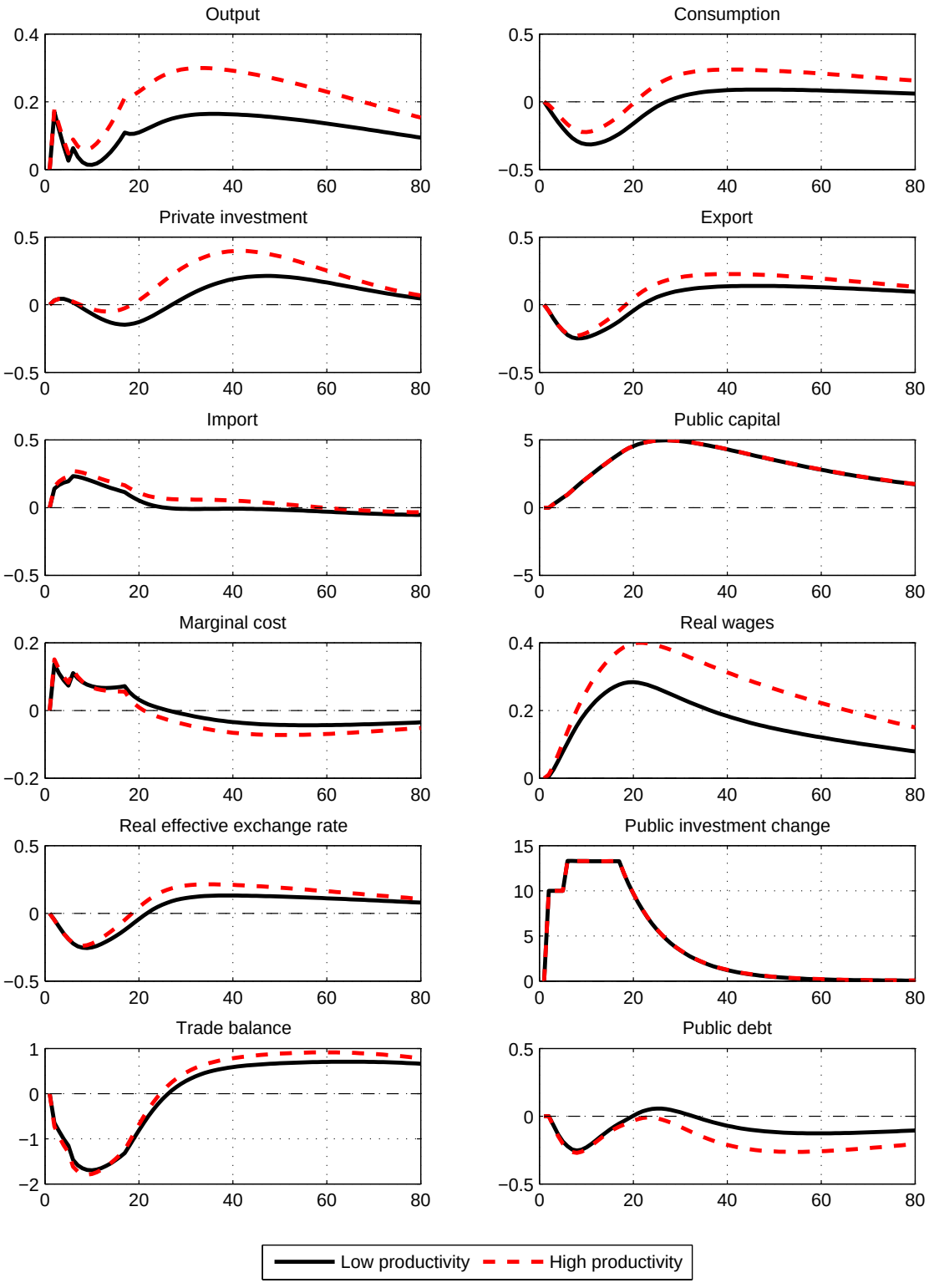
As in all previous cases, benefits from higher public capital begin to kick in the medium and longer run. Marginal costs of firms decrease and the real effective exchange rate depreciates, which stimulates exports in the long run. This results in a persistent improvement of the trade balance. Similarly, the net effect of higher wages and lower labour supply is slightly positive for the tax base in the long run, but the effect from

[12] While the exact extent of labour supply reduction depends on the labour supply elasticity, the decrease is robust to lower labour supply elasticities. Note that our calibration uses the standard value of 2 for the (inverse of) Frisch labour supply elasticity.

[13] Note that if government financed investment using social security contributions borne by firms, then this would increase marginal costs of firms directly and would have even more negative consequences for external competitiveness of the economy.

[14] Note that the path of the tax rate is a mirror image of the path of government investment increase. In other words, if all variables remained at their initial level, the path of the labour tax rate is such that the tax revenues would exactly offset the government investment expenditure in every period.

FIGURE 6. Labour-tax-financed increase in government investment



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

higher consumption on the tax base for the VAT is unambiguously positive, which causes a reduction of public debt in the long run.

VAT-financed increase in government investment

The final scenario we consider is the VAT-financed government investment increase. As before, the VAT increase is ex-ante budget-neutral (even though it may not be ex-post, as the other variables change). The results are shown in Figure 7.

The VAT affects the relative price of consumption and leads to a drop in households' consumption, which falls about twice as much compared to the labour-tax-financed government investment increase. While the reduction in consumption is partly reoriented towards investment (hence the investment increase), this is not sufficient and output does not increase as much as with debt financing.

However, output increases by more than when labour taxes are used to fund investment. Part of the reason is that private consumption is relatively more rigid (there is habit formation) than labour supply. The other reason is related to the open economy setting and can be observed in the responses of wages, marginal costs, and exports. While with labour tax financing wages increase relatively quickly, and in particular already during the phase when government is investing, this worsens external competitiveness substantially. With VAT financing, the wage increase is more delayed and marginal costs do not increase as much (and drop faster). The external competitiveness of the economy is not much affected and exports drop only marginally and for a short period. Trade balance improves quickly after the initial worsening. The lower reduction in foreign demand for Home goods (because prices of Home goods have not increased as much) offsets the main part of consumption decrease, which is why output increases by more than in the case of labour tax financing.

In the medium and longer run, the effects of higher public capital bring similar benefits as in the labour tax case. In particular, productivity gains from higher public capital offset the persistent wage increase, so that trade balance improves persistently. Higher economic activity and eventual increase in consumption increase the tax base and as a result the public debt falls (again, our results are on the conservative side, as the fiscal rule in terms of distortionary taxes would imply that these taxes would have to be reduced).

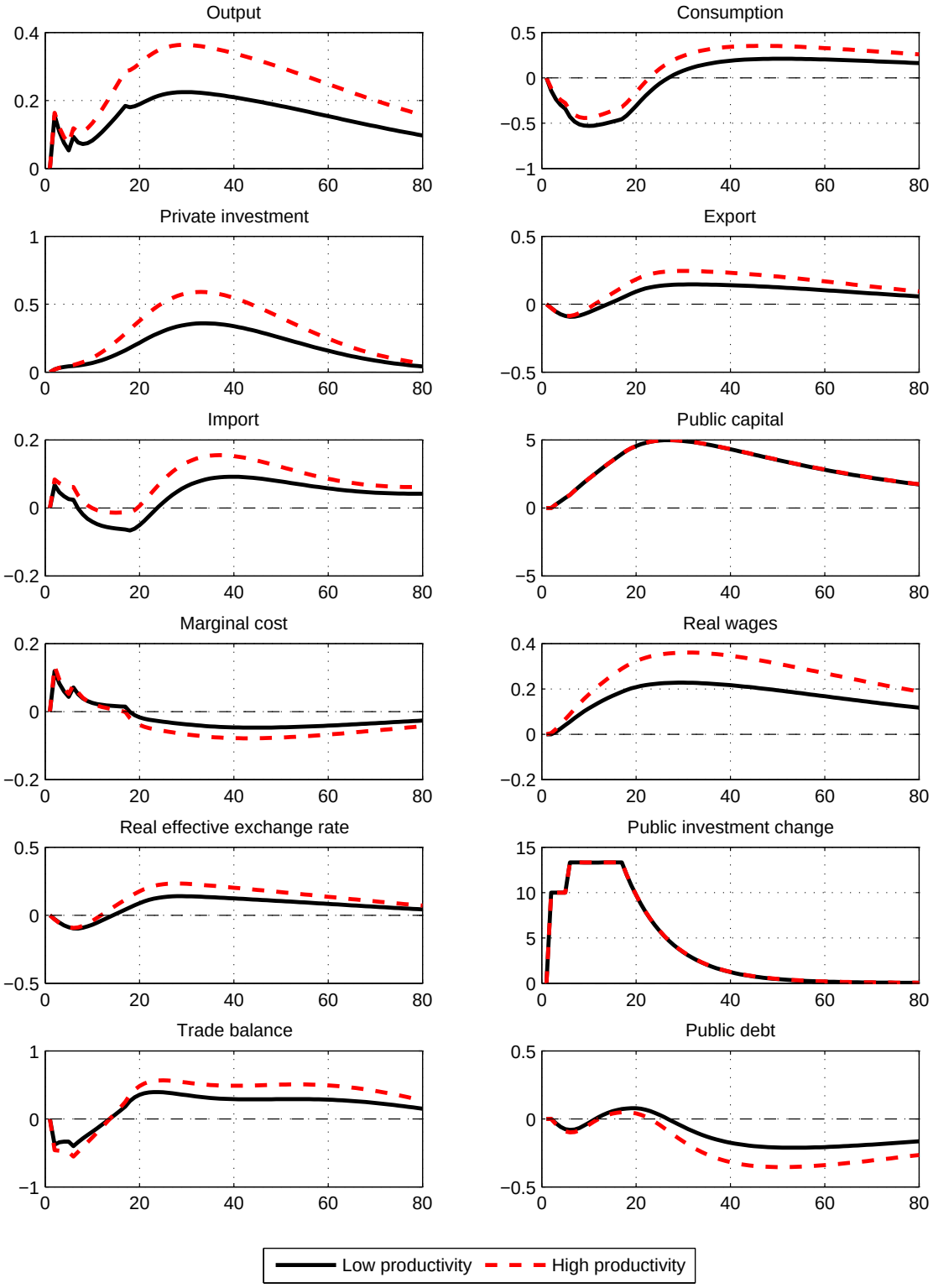
5 Robustness

In this section we examine the robustness of our findings with respect to four cases. First, we investigate the effects of time to build. Second, we analyse the effect of a permanent increase in government investment. Third, we examine the role played by different fiscal rules. Finally, we examine whether financing government investment by redirecting consumption expenditure is still so beneficial when government consumption is valued by households.

Time to build

Government investment, especially in infrastructure, may take time before it can be used by the private sector. We examine how the time to build affects the responses of the economy to government investment by considering three lag lengths: 4, 8, and 12

FIGURE 7. VAT-financed increase in government investment



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

quarters. In all cases we consider the benchmark productivity of public capital ($\alpha_G = 0.05$).

Figure 8 shows the effects of time to build for the case of pure debt-financing of government investment. To save space, we report the case where government investment is financed by redirecting government consumption in Figure 9 and report the plots for the labour tax and VAT financing in Appendix B. The delay due to the time-to-build attenuates the short-term positive responses of output, reduces consumption by more, results in a lower wage increase, and leads to the crowding-out of private investment in the short run. Marginal costs are higher in the short run with time to build. This is due to stronger demand stimulus (and happens despite lower wage increase), resulting in higher prices and stronger appreciation of the real effective exchange rate. There is very little effect on the path of public debt in the short and long run, but in the medium run public debt increases by more with longer time to build. For the external balance, time to build brings a longer-lasting initial deterioration of the trade balance, regardless of the type of financing used. The reason for the adverse short-run effects is that the aggregate demand stimulus increases marginal costs and therefore prices, but that this increase is only offset by the benefits of higher stock of public capital after a delay. The longer the delay, the further in the future are the benefits, and the more adverse are the short-run effects. In the medium and longer run, the differences between the cases with and without time to build become smaller. These results hold qualitatively across all our simulations.

The increasing crowding-out of private investment with longer time to build is of independent interest. Aschauer (1989) and Baxter and King (1993), and Leeper et al. (2010) argue that in theory, productive public investment crowds in private investment. Voss (2002) argues that the crowding in should be stronger in a small open economy that is open to international capital flows, but finds evidence that an increase in government investment crowds out private investment in Canada in the short run. However, and Abiad et al. (2015) find crowding in, and Dreger and Reimes (2016) find that in the Euro Area, private and government investment tend to move together in the longer run. Our model shows that these findings can be reconciled with theory within the same model, and that the short-run crowding out of private investment in a small open economy depends on how long it takes to build public capital.

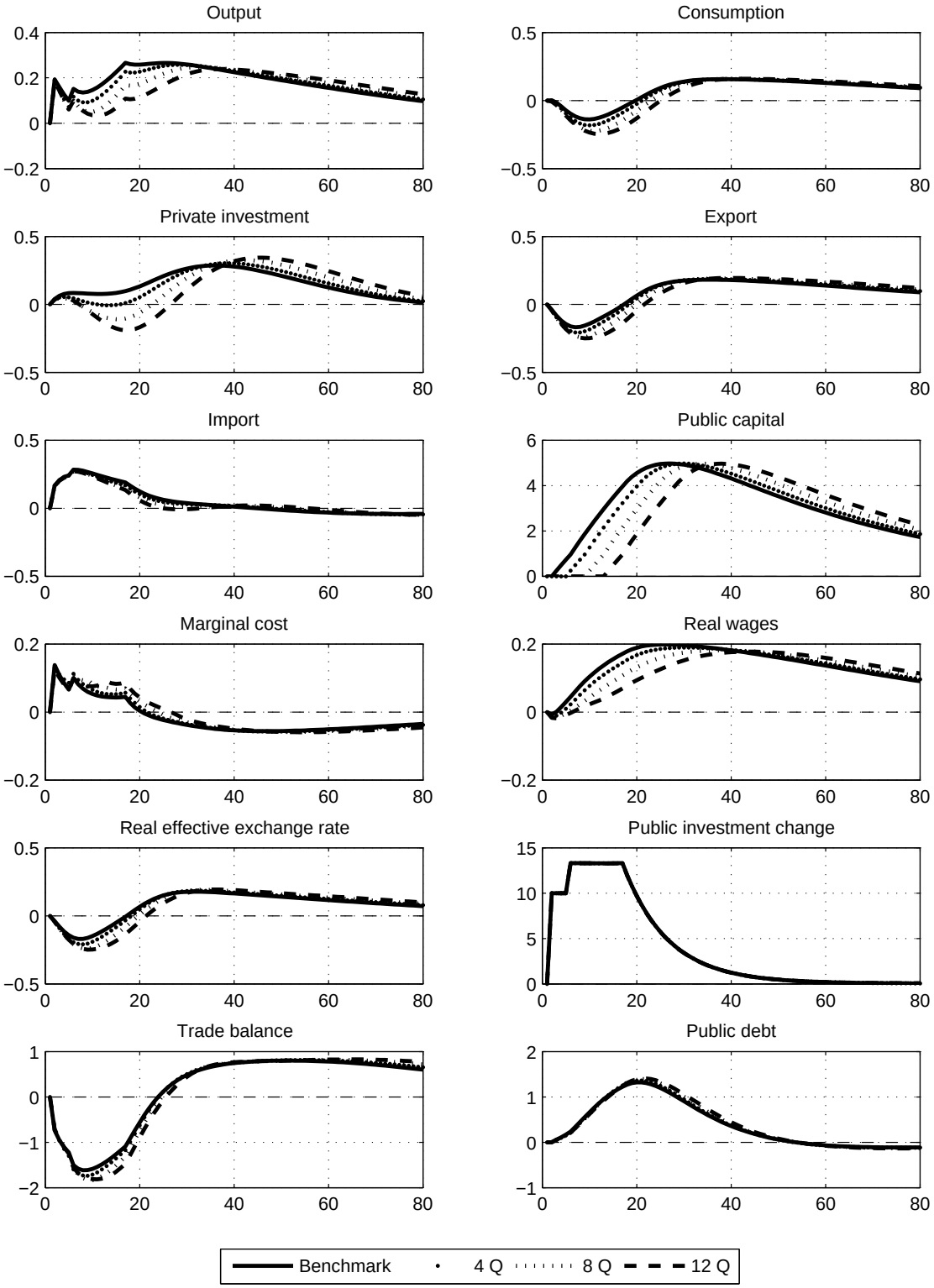
Permanent shocks

In the analysis above, we assumed that government investment gradually returns to the initial levels once the planned increase in public capital is achieved. Here we examine what happens if the government decides to permanently increase the level of public capital and finances this increase by permanently raising taxes.[15] The results are reported in Figure 10.

A permanent increase in government investment implies a much stronger increase in public capital, which is permanent (about 10%, compared to about 5% when the increase in government investment is temporary). The gains from the improved productivity due to higher public capital are therefore both larger and longer-lasting. To benefit from this, private investment increases strongly and permanently, regardless of the type of financing of government investment. Marginal costs decrease after the initial

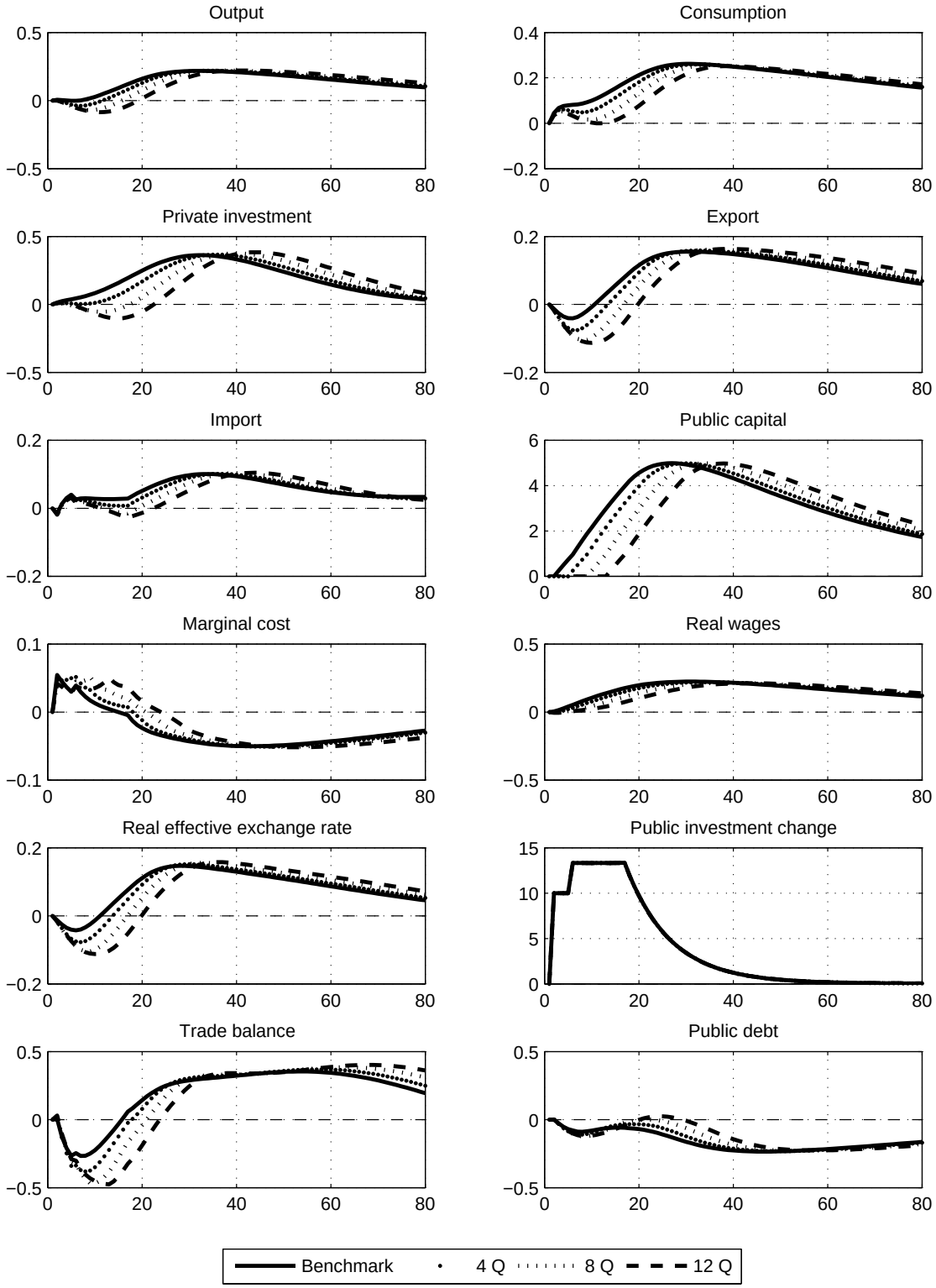
[15] We model this as an extremely persistent increase in government investment and taxes by setting the AR(1) parameter for government investment and tax levels to 0.999.

FIGURE 8. Debt-financed increase in government investment, time to build



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

FIGURE 9. Consumption-financed increase in government investment, time to build



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

increase, and the real exchange rate depreciates after the initial appreciation, leading to an improvement of the trade balance in the long run, again regardless of how government investment is financed. In all cases output increases and more productivity due to higher public capital allows wages to increase in the long run.

There are some differences compared to temporary government investment increase. The most notable is that debt and all tax-based ways of financing government investment lead to stronger crowding-out of private consumption in the short and medium run (even though in the long run, private consumption increases). The reason is that financing with labour taxes or VAT creates a permanent distortion in the household's labour supply condition and tilts the production away from labour towards capital. This hurts labour income of especially non-Ricardian households, whose consumption decreases in the short and medium run. This does not happen when government uses other government consumption to finance the increase in investment. Trade balance now deteriorates in the short run in all cases, and improves in the medium and long run due to the improvement in external competitiveness brought about by lower marginal costs because of higher public capital.

Importantly, public debt decreases ex-post, except when government investment is financed by borrowing. Even in this case, however, the increase in public debt is not excessive. The main reason for the ex-post decrease in public debt is that wages increase. This increases the tax base and allows government investment to be self-financing in the long run. Revenues from ex-post VAT are higher only for the other-consumption-financed increase in government investment, as this is the only case where private consumption increases in the short run (this is reflected in the strongest ex-post decrease in public debt).

Different fiscal rules

In our simulations so far, we have always assumed that the fiscal rule is specified in terms of lump-sum taxes. Here we examine what difference does it make when the fiscal rule is specified in terms of distortionary taxes.

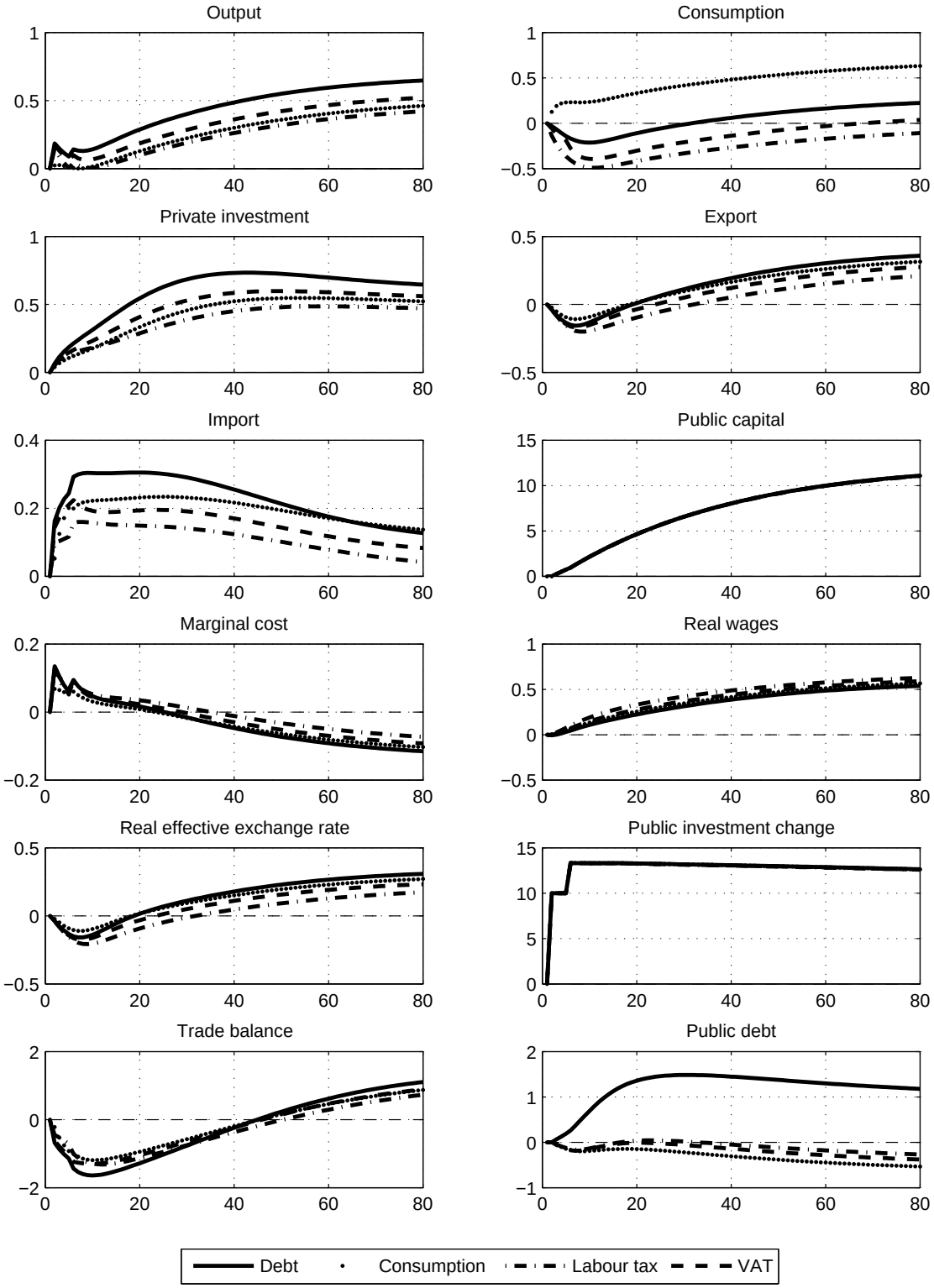
We illustrate the role of different fiscal rules in the case of permanent debt-financed increase in government investment. This is the case where the increase in public debt is strongest, which means that the effects of different fiscal rules will be the most visible.[16] We study the following form of fiscal rules:

$$\tau_t^j = \overline{\tau^j} + \phi_T \left(\frac{b_t}{\overline{PY}} - \overline{BY} \right), \tag{13}$$

where τ_t^j is the time-t tax rate, with $j \in \{T, wh, c\}$ denoting lump-sum, labour, and consumption (VAT) tax rate, respectively. b_t is the public debt level. All variables with a bar above are steady-state values. $\overline{P}$ is the GDP deflator, $\overline{Y}$ is real output, $\overline{BY}$ is the debt-to-GDP target ratio, and ϕ_T is the sensitivity of the tax rule to the deviation of the current debt-to-GDP ratio from its target value. This is a standard form of the fiscal rule that has been used in the literature (see e.g. Gomes et al., 2012, Coenen et al., 2012, and Kilponen et al., 2019). We follow this literature and set $\phi_T = 0.1$ and the target debt-to-GDP ratio $\overline{BY} = 0.6$ on the annual level.

[16] The results apply to all other cases where public debt changes.

FIGURE 10. Permanent increase in government investment



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

The results for the debt-financed permanent increase in government investment for each of the three fiscal rules considered are shown in Figure 11. Now the tax rates increase in line with the increase in public debt, which means that the tax increase is initially more gradual and that the entire path of tax rates now depends on the evolution of public debt. Even though the debt increase is the largest for lump-sum taxes, implying the strongest lump-sum tax increase, this has the least detrimental effects, because these taxes are non-distortionary. They do affect consumption of non-Ricardian households, who are the main culprit for the initial decrease in private consumption. VAT land labour taxes are distortionary and lead to a lower output and private investment increase, and to a stronger drop in private consumption, even though these tax rates increase by less than lump-sum taxes. The drop in consumption in these two cases is mainly due to the drop of consumption of Ricardian households, who become poorer due to the tax increase. In general, however, a different tax rule does not materially affect the results from our benchmark experiment. We emphasise that for all non-debt-financed increases in government investment, the level of public debt does not change materially, so the influence of the fiscal rule on the results would be small.

Non-wasteful government consumption

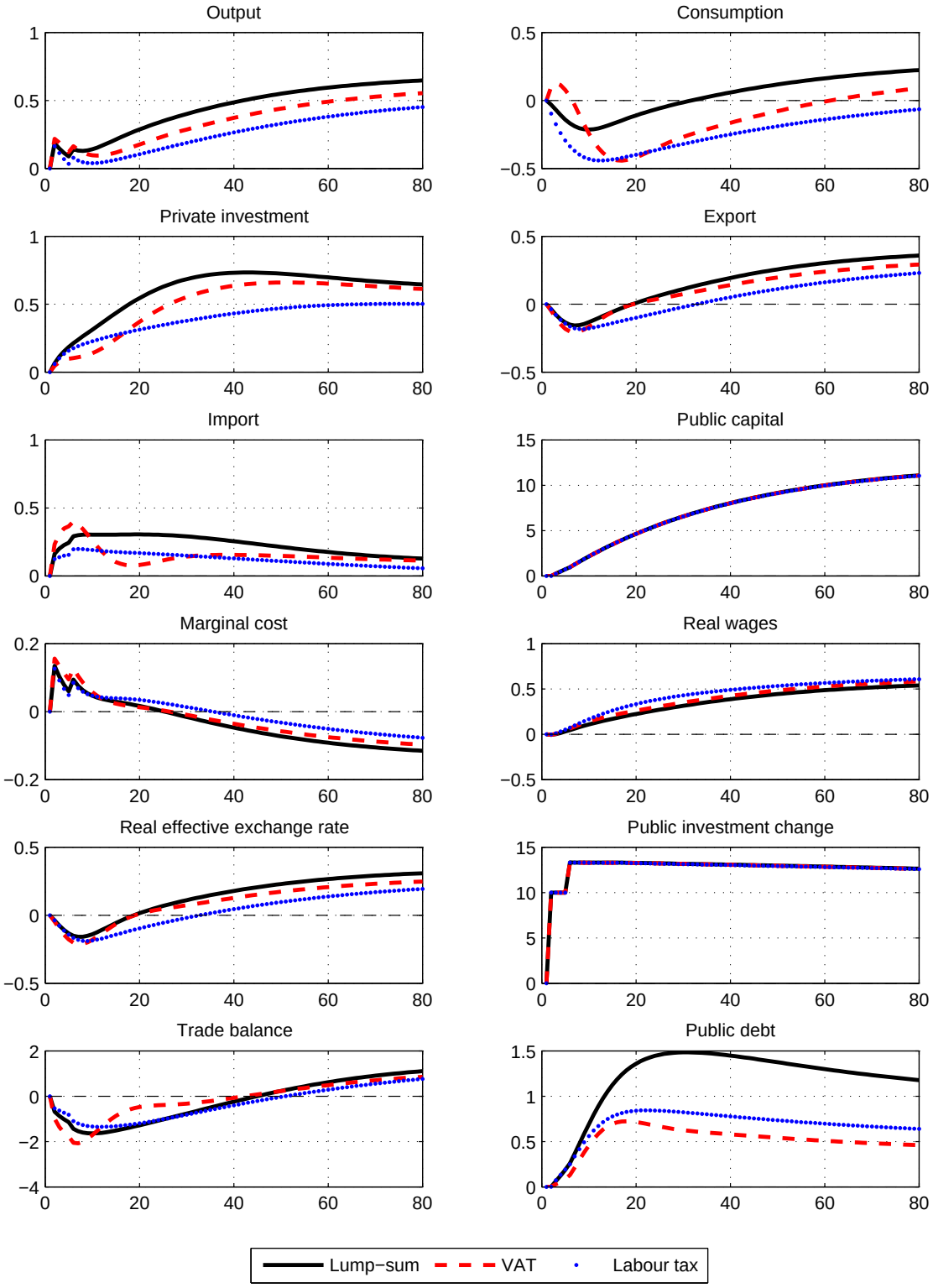
In section 4 we assumed government buys private-sector goods and consumes them, without these goods having an additional utility for the households. In such a setting it is natural that redirecting government spending to an alternative use has immediate positive effects on private consumption, but this may not be always the case, as recently pointed out by Michaillat and Saez (2019). Here we examine what happens if government consumption has a useful component for households. More precisely, we follow Leeper et al. (2010), Coenen et al. (2012), Clancy et al. (2016), and Michaillat and Saez (2019) and assume that households consume a composite of private and government consumption goods, $\tilde{C}$, which is a constant elasticity of substitution aggregate:

$$\tilde{C}_t = \left[\nu_{CCES}^{\frac{1}{\mu_{CCES}}} \left(C_{I,t}\right)^{\frac{\mu_{CCES}-1}{\mu_{CCES}}} + (1-\nu_{CCES})^{\frac{1}{\mu_{CCES}}} \left(G_{C,t}\right)^{\frac{\mu_{CCES}-1}{\mu_{CCES}}} \right]^{\frac{\mu_{CCES}}{\mu_{CCES}-1}} \tag{14}$$

where ν_{CCES} is the quasi-share of private consumption, μ_{CCES} is the elasticity of substitution between private (C_t) and government consumption ($G_{C,t}$) goods. When $\mu_{CCES} \to 0$, private and government consumption become perfect complements, and when $\mu_{CCES} \to \infty$ they become perfect substitutes. When $\mu_{CCES} > 1$, private and government consumption are substitutes and one would expect that a reduction in government consumption increases private consumption, and when $\mu_{CCES} < 1$, one would expect the opposite. We therefore consider two cases of financing of government investment by reducing government consumption. In the first case government and private consumption are near-complements, $\mu_{CCES} = 0.2$, and in the second case they are substitutes, $\mu_{CCES} = 1.5$.

Figure 12 shows the results. In the medium and long run, the results are not very different in the two scenarios and also not compared with the scenario shown in Figure 5, where government consumption does not have additional benefits. This is because in the medium and long run, all the short-run effects tend to dissipate and the only effect that remains is that of the persistent increase in public capital.

FIGURE 11. Permanent increase in government investment, different fiscal rules

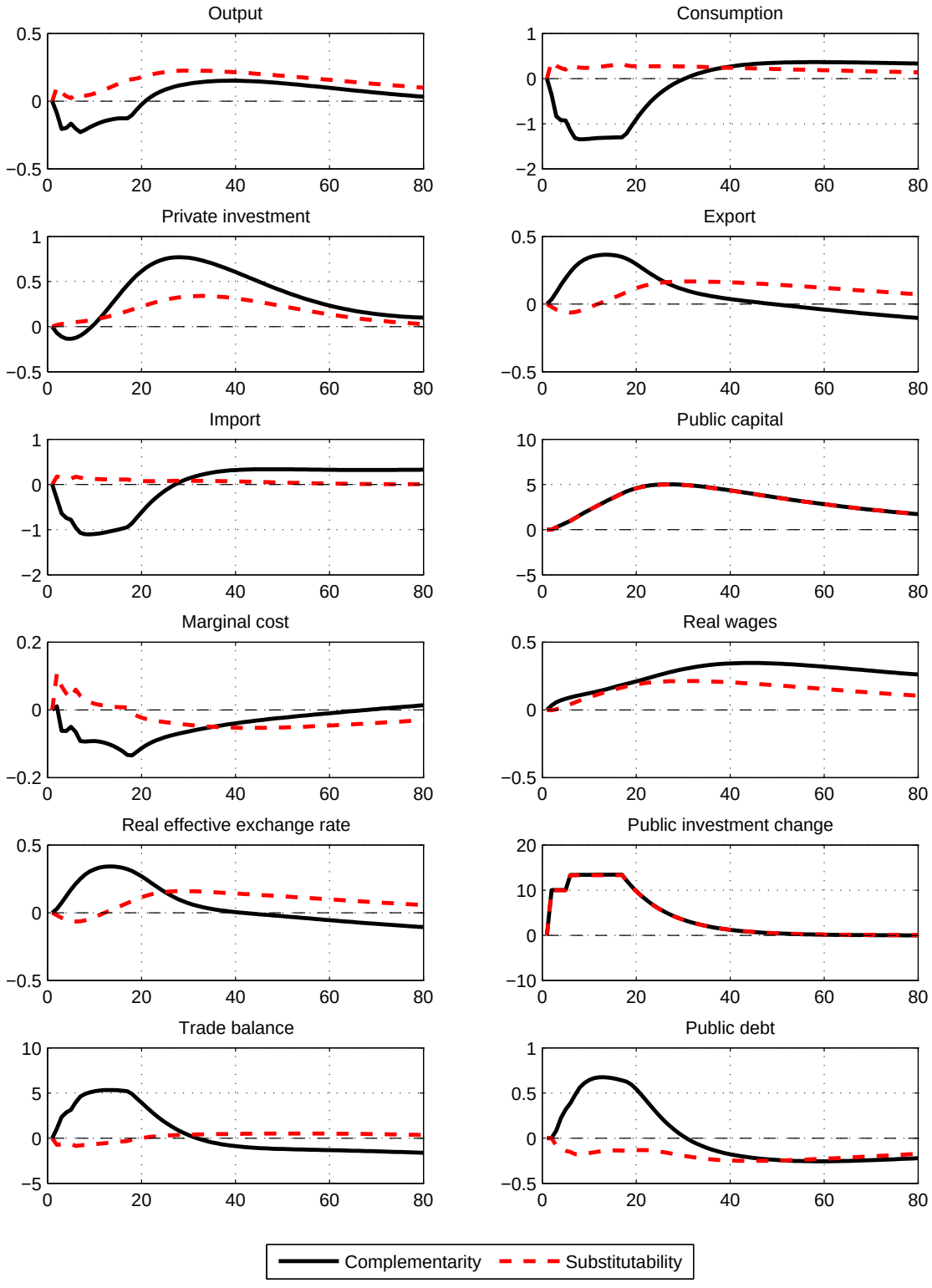


Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

There are however substantial differences between the scenarios in the short run, up to about 20 quarters. When government and private investment are complements (black line in Figure 12), the reduction in government consumption necessary to finance the increase in government investment drags down private consumption and causes a mild recession. This erodes the consumption tax base, resulting in a temporary increase in public debt. An increase in wages is not sufficient to fully offset the drop in the tax base, especially given that hours worked also decrease. Private investment still increases after a short delay. Because of the sharp drop in consumption, domestic prices decrease, causing a strong real effective exchange rate depreciation in the short run and the corresponding strong improvement of the trade balance, both due to the increase in exports and the drop in imports (the latter is also due to the reduction in demand for imported consumption goods). It is this strong improvement in the trade balance that prevents a sharper recession. The strong short-run increase in the trade balance is also the reason why in the medium run trade balance is lower. This happens because the accumulated net foreign assets can be used to finance higher consumption (and private investment) in the medium run.

When private and government consumption are substitutes (dashed red line in Figure 12), private consumption increases when government reduces its consumption. This increases the tax base and public debt does not increase. In addition, the increase in private consumption brings about the increase in marginal costs and prices, although this is mild and short-lived, so that trade balance deteriorates only mildly and recovers quickly.

FIGURE 12. Increase in government investment when government consumption is not wasteful



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

6 Conclusions

Most European countries that were severely affected by the recent crisis and whose public finances have come under stress have responded by strongly decreasing public investment. This has been particularly marked in countries that were in the programme, such as Greece, Ireland, Portugal and Spain. After several years of low government investment, public capital levels in these countries are depleted to a various extent, which may affect the growth potential of these countries. In addition, depleted levels of public capital may also affect their external competitiveness in small open economies. We have examined several possibilities that are at disposal of governments to increase the level of public capital. In particular, pure debt financing and budget-neutral financing using consumption or labour taxes, or other sources of funds. In all cases, we focus on external balance of the economy and on the level of public debt.

Our main findings are that, from the perspective of maintaining fiscal and external balances, the best option to finance government investment is by reducing other government consumption expenditure. Pure debt financing leads to a deterioration of both external and fiscal balances. Financing with labour taxes maintains fiscal balance, but it adversely affects the external balance. Financing investment with the VAT performs only slightly more adversely than financing by reducing other consumption expenditure in terms of both external and fiscal balances.

These results hold if it takes time to build public capital, although in this case the benefits accrue later. The results also hold for permanent shocks, although the differences between budget-neutral options of financing are less pronounced in this case. Different fiscal rules matter less when financing is budget-neutral ex-ante, because public debt does not increase substantially. When it does, as in the case of debt financing, fiscal rule specified in terms of the VAT seems the least damaging in terms of output and consumption loss. When government consumption is valued by households, offsetting an increase in government investment by reducing government consumption induces a mild recession in the short run, which is to some extent mitigated by a strong improvement in the trade balance.

The more productive is public capital, the stronger are the benefits from increasing it, and these benefits are particularly strong for the economy's competitiveness and external balance. Importantly, in the long run, increasing (productive) public capital improves the economy's competitiveness and trade balance, no matter how the government investment is financed.

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A Tables and Figures

TABLE 1. Steady-state Ratios and Trade Matrix (as % of nominal GDP)

	IE
Great Ratios	
Private consumption	0.5791
Private investment	0.1760
Target public debt (% of annual GDP)	0.6000
Trade linkages	
Imports	0.6300
Consumption goods	0.1498
From REA	0.0543
From RW	0.0737
From US	0.0218
Investment goods	0.0972
From REA	0.0343
From RW	0.0465
From US	0.0164
Imports of exports	0.3530
From REA	0.1130
From RW	0.1532
From US	0.0868
Government expenditure	
Consumption expenditure	0.1290
Imports	0.0200
Investment expenditure	0.0400
Imports	0.0100
Country size	
Size (as % of world GDP)	0.03

TABLE 2. Calibration - Households and Firms

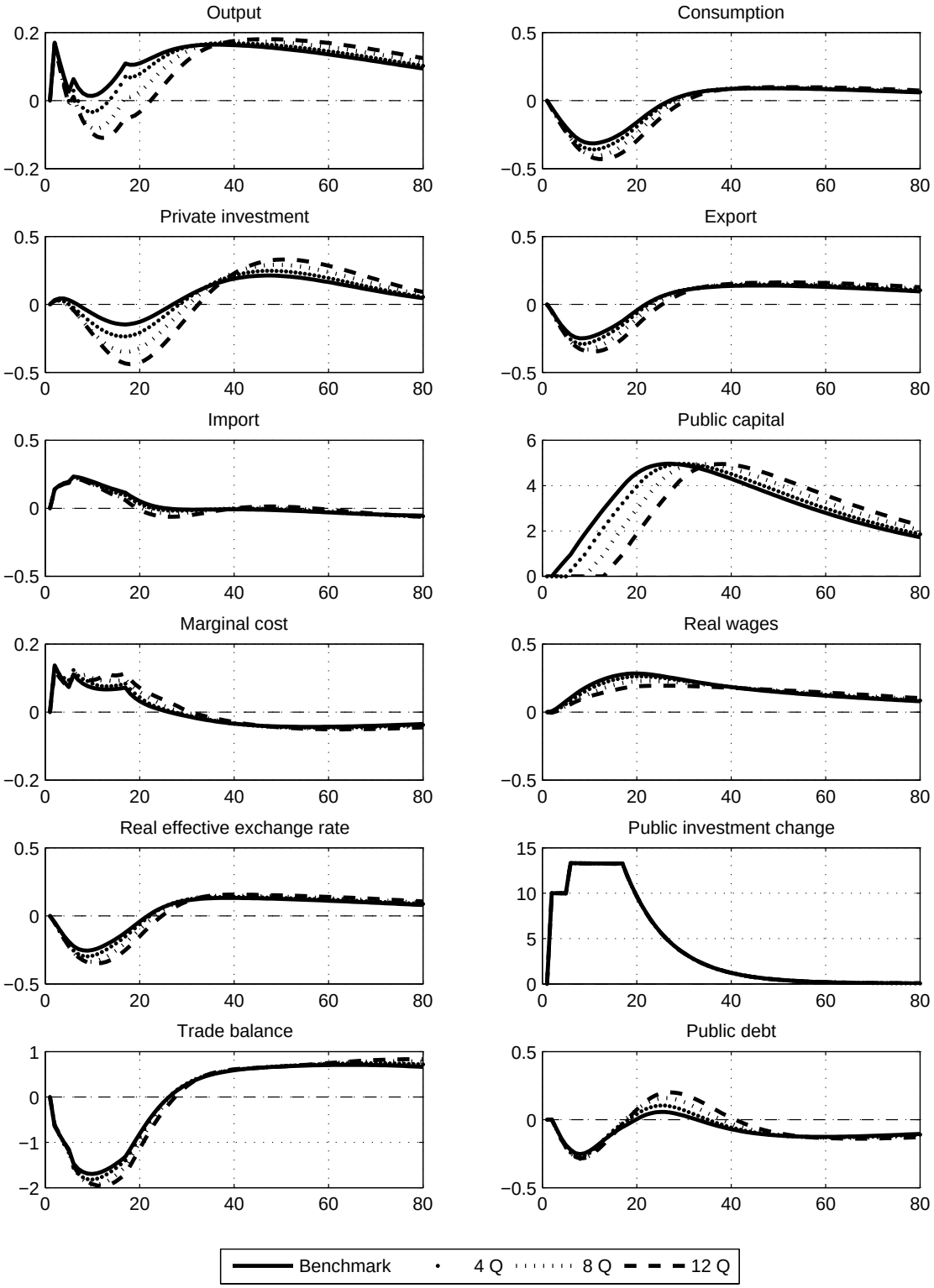
	IE
Households	
Subjective discount factor	$1.03^{\frac{1}{4}}$
Depreciation rate (private capital)	0.025
Depreciation rate (public capital)	0.025
Int. elasticity of substitution	1.00
Habit formation	0.60
Frisch elasticity of labour (inverse)	2.00
Intermediate goods firms	
Tradable - bias toward capital	0.35
Nontradable - bias toward capital	0.30
Final cons. goods	
Subst. btw. domestic and imported	2.50
Subst. imported	2.50
Bias toward domestic tradables	0.3872
Subst. btw. tradable and non-tradable	0.50
Bias toward tradable	0.475
Final inv. goods	
Subst. btw. domestic and imported	1.50
Subst. imported	2.50
Bias toward domestic tradables	0.2336
Subst. btw. tradable and non-tradable	0.50
Bias toward tradable	0.75
Final government cons. goods	
Subst. btw. domestic and imported	2.50
Subst. imported	2.50
Bias toward domestic	0.2084
Subst. btw. tradable and non-tradable	0.50
Bias toward tradable	0.80
Final government inv. goods	
Subst. btw. domestic and imported	2.50
Subst. imported	2.50
Bias toward domestic	0.4252
Subst. btw. tradable and non-tradable	0.50
Bias toward tradable	0.60

TABLE 3. Calibration - Real and Nominal Rigidities, Tax Rates

	IE	REA	US	RW
Real rigidities				
Investment adjustment	6.00	5.00	5.00	5.00
Import adjustment (cons.)	5.00	5.00	5.00	5.00
Import adjustment (inv.)	2.00	2.00	2.00	2.00
Quasi-share of govt cons.	0.25	0.20	0.20	0.20
Complementarity of consumptions	0.20	0.29	0.33	0.33
Nominal rigidities				
Wage stickiness	0.80	0.75	0.75	0.75
Wage indexation	0.75	0.75	0.75	0.75
Price stickiness (domestic)	0.75	0.75	0.75	0.75
Price indexation (domestic)	0.50	0.50	0.50	0.50
Price stickiness (imported)	0.75	0.75	0.75	0.75
Price indexation (imported)	0.50	0.50	0.50	0.50
Price stickiness (services)	0.75	0.75	0.75	0.75
Price indexation (services)	0.50	0.50	0.50	0.50
Tax rates				
Consumption tax	0.1200	0.1830	0.0770	0.0770
Labour income tax	0.1600	0.1220	0.1540	0.1540
Capital tax	0.1000	0.1900	0.1600	0.1600
SSC paid by firms	0.0900	0.2190	0.0710	0.0710
SSC paid by households	0.0700	0.1180	0.0710	0.0710

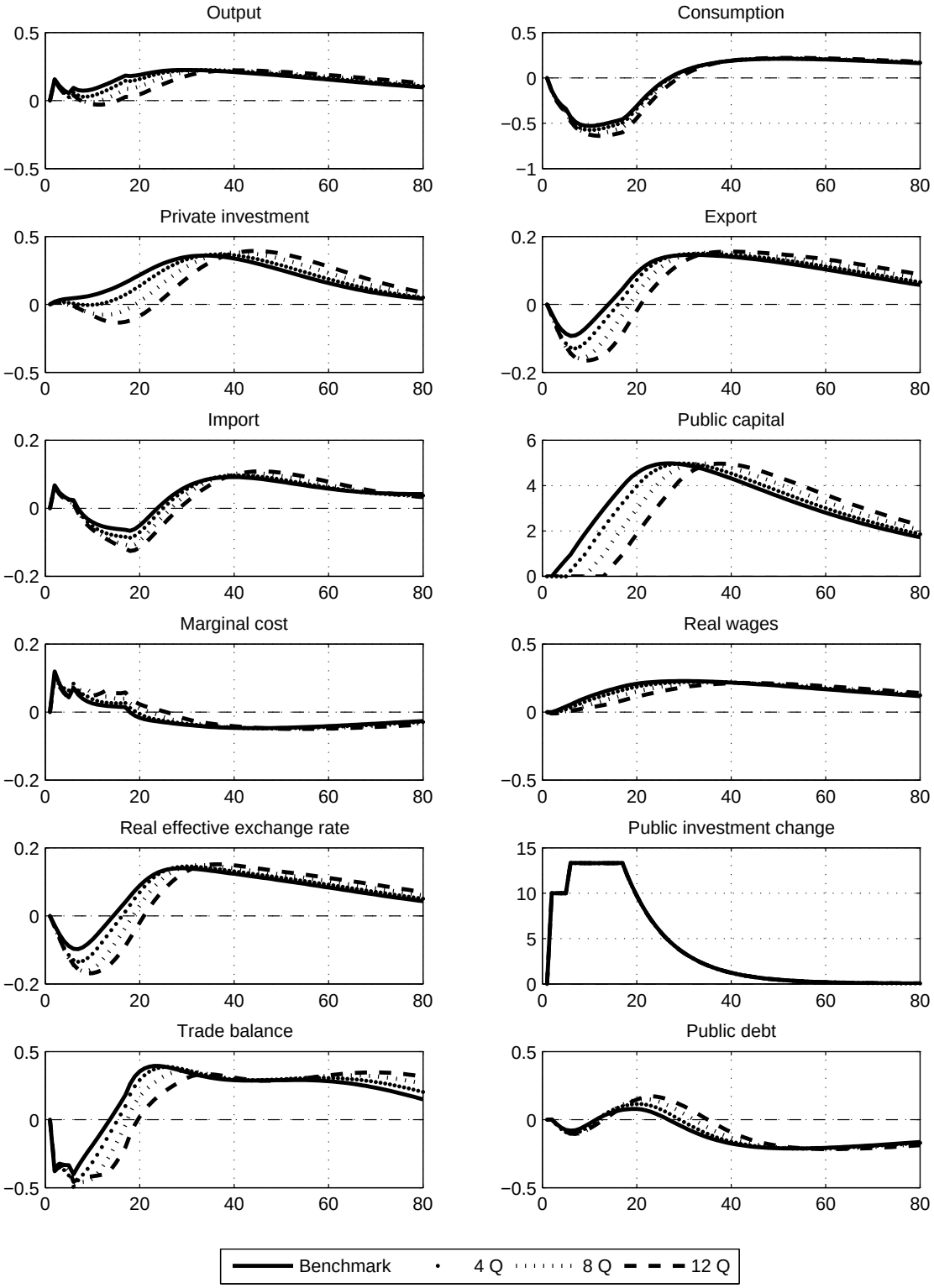
B Time to build - remaining cases

FIGURE 13. Labour-tax-financed increase in government investment, time to build



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.

FIGURE 14. VAT-financed increase in government investment, time to build



Notes: All variables are reported in percent deviations from the steady state. Units on the horizontal axis are quarters.