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by Lorenzo Burlon, Alberto Locarno, Alessandro Notarpietro
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PUBLIC INVESTMENT AND MONETARY POLICY STANCE IN THE EURO AREA

by Lorenzo Burlon*, Alberto Locarno*, Alessandro Notarpietro* and Massimiliano Pisani*

Abstract

This paper evaluates the macroeconomic impact of a programme for public infrastructure spending in the euro area (EA) under alternative assumptions about funding sources and the monetary policy stance. The quantitative assessment is made by simulating a dynamic general equilibrium model of a monetary union with region-specific fiscal policy. The main results are the following. First, EA-wide stimuli are more effective than unilateral (region-specific) stimuli. Second, under EA-wide stimulus, the fiscal multiplier is close to 2 if the forward guidance (FG) on the short-term policy rate holds. Third, if the monetary authority keeps down both the policy rates (with FG) and the long-term interest rates (with quantitative easing), the fiscal multiplier exceeds 3 at peak and investment spending is self-financing. Fourth, the financing method is relevant: debt financing, particularly under an accommodative monetary policy stance and if the sovereign spreads do not increase, is more growth-friendly than tax financing in the short-term (but not in the long-term). Fifth, the effectiveness of the fiscal stimulus is larger if government spending is directed towards productive goods and its implementation occurs efficiently and without delays.

JEL Classification: E52, E62, F41, F42.
Keywords: public investment, fiscal policy, monetary policy, euro area.

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Common action is urgently needed to sustain public investment in the euro area, which has fallen by a quarter in four years.

Ignazio Visco, Governor of the Bank of Italy.[1]

In parallel, it may be useful to have a discussion on the overall fiscal stance of the euro area with the view to raising public investment where there is fiscal space to do so.

Mario Draghi, President of the European Central Bank.[2]

1 Introduction[3]

Weak aggregate demand and very low inflation have characterized the euro area (EA) economy since the Great Recession and notwithstanding an extremely accommodative monetary stance. In addition, by reducing the pace of capital accumulation and increasing the duration of unemployment, they have negatively affected potential output growth, contributing to make the recession to last longer and the recovery more subdued.

As proposed by policy-makers and commentators, one way to address these concerns and at the same time exploit the exceptionally low level of borrowing costs is to increase public spending in infrastructures.[4] This measure is viewed as beneficial and effective for several reasons. First, it would be implemented after years of reductions in public investment spending and after a prolonged decline in the stock of public capital-to-GDP ratio.[5] Second, it would stimulate aggregate demand in the short term and boost supply capacity in the long run. Third, it could be self-financing, if the impact on economic activity is large enough. The institutional and policy framework of the EA would provide an even more friendly environment for public infrastructure

[1] See Visco (2014).

[2] See Draghi (2014).

[3] We thank Bartosz Mackowiak and participants at the Eurosystem Working Group on Econometric Modelling (May 2017), European Central Bank workshop "Euro area business investment in a global context – the role of cyclical and structural factors and frictions" (June 2017), Computing in Economics and Finance (June 2017), 5th Workshop in Macro Banking and Finance (September 2017). The views expressed in this paper are those of the authors alone and should not be attributed to the Bank of Italy or the Eurosystem. Any remaining errors are the sole responsibility of the authors.

[4] See International Monetary Fund (2014b), European Commission (2015), In 't Veld (2016), and OECD (2016).

[5] The International Monetary Fund, in Chapter 3 of the April 2014 World Economic Outlook, suggests that aging infrastructure and insufficient maintenance and investment may be affecting the quality of the existing infrastructure stock. See International Monetary Fund (2014a).

investment. Given that the fiscal policy is managed at the level of Member States, which mostly trade with each other, cross-country coordination in the form of simultaneous fiscal stimuli would favor bilateral exports (and, thus, limit the size of trade leakages associated with a fiscal stimulus implemented by a single Member State). Moreover, the stance of the common monetary policy, if expansionary as currently, would favour the crowding-in of households' and firms' spending, by capping the increase in short- and long-term interest rates that arises in correspondence of a fiscal stimulus financed by issuing public debt.

The ongoing debate usually acknowledges that there are also arguments against the use of infrastructure spending for demand management purposes. The most often quoted reasons are: (i) the lack of fiscal space, (ii) decision and implementation delays, (iii) disparities between the amounts spent and the actual value of the works realized, and (iv) distorted political incentives.[6] First, the current debt levels are at historical highs in several countries and ambitious spending plans could backfire if debt sustainability concerns triggered an increase in sovereign risk premia. Second, the length of the political decision process and the need to comply with an increasingly complex regulatory environment make it extremely difficult to kick-start infrastructure projects quickly and have them completed in a reasonable amount of time. Infrastructure spending is therefore a poor way to try and manage aggregate demand. Third and fourth, most investment projects are selected not on the basis of a standard cost-benefit analysis, but rather with the aim of either favouring specific constituencies or in the hope of promoting the economic prospects of disadvantaged areas. If these areas are in a process of long-term economic decline, public investment will likely yield poor returns.

This paper evaluates the macroeconomic impact on the EA economy of the increase in public investment in infrastructures under alternative assumptions about the monetary policy response. The assessment is based on simulations of a calibrated three-country large-scale New Keynesian dynamic general equilibrium model, which includes two EA regions (one labelled "Home", calibrated to a relatively small-size economy, and the other assembling the rest of the eurozone, dubbed "REA") and the rest of the world ("RW"). The model is akin to the Eurosystem EAGLE (see Gomes *et al.*, 2010). The EA is a monetary union, so Home and REA share the same monetary policy and nominal exchange rate. The inclusion of the RW allows for a full characterization

[6] See Banca d'Italia (2012).

of trade flows. The model features country-specific fiscal policies; the public-sector budget exhibits, on the expenditure side, lump-sum transfers, public consumption, and public investment in infrastructures. On the revenue side, there are distortionary taxes on labor income, capital income, and consumption. Public debt is stabilized through a fiscal rule adjusting lump-sum transfers to achieve the desired debt target. Public capital enters the production function of domestic goods jointly with private capital and labor. As the speed at which spending occurs is crucial for short-run stimulative effects, we also allow for delays in the implementation of spending plans in infrastructures (time-to-build assumption). The monetary authority can resort to both standard and non-standard monetary policies, the latter including forward guidance (FG) and quantitative easing (QE).

The second novel feature of the model is financial segmentation à la Chen *et al.* (2012), which allows us to relax the well-known "Wallace neutrality" and make financial assets imperfect substitute so that sovereign bonds' purchases by the monetary authority have real effects in our model. In each EA region there are two types of households, "restricted" and "unrestricted". Restricted households can invest only in domestic long-term sovereign bond market and, because they are owner of domestic private capital producers (joint with domestic unrestricted households), in physical capital. The purchase of long-term government bonds by the monetary authority reduces long-term interest rates and therefore induces restricted households to increase consumption and investment via the standard intertemporal substitution effect.

In all exercises, we simulate an increase in public investment spending equal to 1% of before-shock (steady-state) GDP. The fiscal stimulus lasts for five years and thereafter gradually fades out.

We initially consider the case of an increase in public investment implemented by the Home country in isolation under standard monetary policy (i.e., the short-term interest rate is set according to a Taylor rule that reacts to EA-wide inflation and output growth); we also consider a scenario in which the EA monetary authority promises to keep, in a credible way, the short-term interest rate at its baseline level for the initial eight quarters ("Forward Guidance" on the monetary policy rate, FG). Public investment is financed by issuing government bonds; the fiscal rule ensuring debt stabilisation becomes active after five years from the beginning of the

simulation.

We consider several variants, among which is the case of an EA-wide increase in public investment (i.e., an increase that takes place simultaneously in both the home country and in the rest of the monetary union) under both a standard monetary response and, alternatively, under the combination of (1) two-year FG and (2) QE. The latter aims at stimulating economic activity by lowering the interest rates on EA long-term sovereign bonds and its size is set equal to that of the public sector purchase programme (PSPP) announced by the ECB in January 2015, consisting in monthly purchases of €60 billion for nineteen months (i.e., covering seven quarters in our quarterly model). To highlight the relevance of the interaction between fiscal and monetary policies, we also evaluate the effectiveness of the stimulus when the public investment increase is, alternatively, (i) financed by issuing debt and, simultaneously, the sovereign spread increases, (ii) financed by distortionary taxation, and (iii) matched with a corresponding increase in the balance sheet of the monetary authority.

In the final section we present the outcome of the sensitivity analysis. We report how results change under alternative assumptions on (i) the efficiency of public spending (public spending is pure waste and does not contribute to public capital accumulation), (ii) the implementation delays associated with the administrative procedures for planning, bidding, and contracting (time-to-build assumption).[7]

All simulations are run under the assumption of perfect foresight. Accordingly, (i) the increase in public investment and the monetary policy stance are fully credible; (ii) there is no uncertainty, and (iii) households and firms correctly anticipate the paths of the policy variables.

The main results are the following. First, EA-wide stimuli are more effective than unilateral (region-specific) stimuli. Second, under EA-wide stimulus, the fiscal multiplier is close to 2 if the forward guidance (FG) on the short-term policy rate holds. Third, if the monetary authority keeps lower both the policy rates (with FG) and the long-term interest rates (with quantitative easing), the fiscal multiplier exceeds 3 at peak and investment spending is self-financing. Fourth, the financing method is relevant. Debt financing, in particular under an accommodative

[7]See Kydland and Prescott (1982) and, more recently, Bouakez et al. (2017).

monetary stance and if the sovereign spreads do not increase, is more growth-friendly than tax financing in the short run (but not in the long run).[8] Fifth, the effectiveness of the fiscal stimulus is larger if government spending is directed towards productive goods and its implementation occurs efficiently and without delays.

Our paper is related to several contributions in the literature. Coenen *et al.* (2013) evaluates the impact on EA GDP of the European Economic Recovery Plan (EERP), enacted in response to the financial crisis of 2008–2009 and including, among the several measures, public investment. Elekdag and Muir (2014) evaluates the macroeconomic impact of public investment in infrastructure in the EA and in Germany. Blanchard *et al.* (2014) assesses the effects of fiscal expansions in European core economies on GDP in non-core countries. Abiad *et al.* (2016) stress that the effectiveness of public investment depends on its efficiency and on whether it is financed by debt issuance. De Jong *et al.* (2017) analyse the sensitivity of the effect of an increase in public investment in the EU to alternative assumptions regarding the structure of the economy and other policy provisions. Differently from the mentioned contributions, we focus on the interaction between fiscal policy and standard and non-standard monetary policy measures.

The paper is organized as follows. Section 2 reports the key equations and the calibration of the model. Section 3 illustrates the design of the exercises. Section 4 shows the results of the simulations. Section 5 presents evidence coming from the sensitivity analysis. Section 6 concludes.

2 The model

We first report an overview of the model. Subsequently, we describe its key features, i.e., households, capital producers, public capital and public investment, the fiscal authority budget constraint and fiscal rule, the EA monetary authority, and the definition of general equilibrium. Finally, we show the calibration.

[8] See International Monetary Fund (2015) for potentially adverse effects of debt-financing when sovereign risk-premia respond to announcements of fiscal stimulus, especially for countries with a high level of initial debt.

2.1 Overview

The model is New Keynesian and represents a world economy composed of three regions, i.e., Home, REA (Home+REA=EA), and RW. The size of the world economy is normalized to 1. Home, REA, and RW have sizes equal to n, n^*, and $(1-n-n^*)$, with $n > 0$, $n^* > 0$, and $n + n^* < 1$.[9] Home and REA share the currency and the monetary authority. The latter sets the nominal interest rate according to EA-wide variables (a standard Taylor rule holds) when it does not deliberately enact non-standard monetary policy measures. The presence of the RW outside the EA allows to assess the role of the nominal exchange rate and extra-EA trade for the transmission of the EA shocks.

The first crucial feature of the model is that the EA firms can sell the final investment goods not only to domestic households but also to the domestic public sector. The former exploits investment goods to accumulate "private" physical capital, the latter to accumulate "public" capital. The public investment decision is an exogenous variable set by the fiscal authority. Crucially, domestic public capital enters the production of intermediate tradable and non-tradable goods joint with capital and labor supplied by domestic households. Public capital is common to both sectors. Firms take public capital as given when choosing their optimal demand for private capital and labor. The public capital does not provide any pecuniary return, but increases productivity of the private inputs and, thus, their returns.

The second novel feature of the model is financial segmentation à la Chen *et al.* (2012), which allows us to relax the well-known "Wallace neutrality" and make financial assets imperfect substitute so that sovereign bonds' purchases by the monetary authority have real effects in our model. In each EA region there are two types of households, "restricted" and "unrestricted". Restricted households can invest only in domestic long-term sovereign bond market and, because they are owner of domestic capital producers (joint with domestic unrestricted households), in domestic private physical capital. The purchase of long-term government bonds by the monetary authority reduces long-term interest rates and therefore induces restricted households to increase consumption and investment via the standard intertemporal substitution effect.

[9] For each region, size refers to the overall population, to the number of firms operating in each sector and, in the case of each EA region, the number of capital producers.

Unrestricted households (1) have access to the domestic short-term private bond and long-term sovereign bond markets, (2) trade a riskless private bond with RW households, and (3) invest in physical capital because they own domestic capital producers.

The latter accumulate private physical capital by demanding final investment goods subject to quadratic adjustment costs on investment change. They rent out capital to the domestic firms producing intermediate goods. They maximize profits with respect to capital and investment taking prices as given, and evaluate returns according to a weighted average of restricted and unrestricted households' stochastic discount factors (where the weights reflect the corresponding population shares). The (net) revenues are rebated in a lump-sum way to domestic restricted and unrestricted households according to their corresponding shares.

Households consume a final good which is a composite of intermediate non-tradable and tradable goods. The latter are domestically produced or imported. All households supply differentiated labor services to domestic firms and act as wage setters in monopolistically competitive labor markets by charging a mark-up over their marginal rate of substitution between consumption and leisure.

On the production side, there are perfectly competitive firms that produce two final goods (consumption and investment goods) and monopolistic firms that produce intermediate goods (firms are owned by domestic unrestricted households). The two final goods are sold domestically and are produced combining all available intermediate goods using a constant-elasticity-of-substitution (CES) production function. The two resulting bundles can have different compositions. Intermediate tradable and non-tradable goods are produced combining domestic public capital, private capital, and labor. The latter two production factors are assumed to be mobile across sectors. Intermediate tradable goods can be sold domestically and abroad. Since intermediate goods are differentiated, firms have market power and restrict output to create excess profits. We also assume that markets for tradable goods are segmented, so that firms can set a different price for each of the three markets. In line with other dynamic general equilibrium models of the EA (see, among the others, Christoffel *et al.* 2008 and Gomes *et al.* 2010), we include adjustment costs on real and nominal variables ensuring that consumption, production, and prices react in a gradual way to a shock. On the real side, habits and quadratic costs prolong the

adjustment of consumption and investment, respectively. On the nominal side, quadratic costs make wages and prices sticky.[10]

2.2 Restricted households

There exists a continuum of restricted households j', with $j' \in (0, n\lambda_R]$, where $0 \leq \lambda_R \leq 1$. Their preferences are additively separable in consumption and labor effort. The generic restricted household j' receives utility from consumption $C_R(j')$ and disutility from labor $L_R(j')$. Following common practice in the New Keynesian literature, the assumption of cashless economy holds in the model. The household's expected lifetime utility is

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta_R^t \left[\frac{\left(C_{R,t}\left(j'\right) - hC_{R,t-1}\right)^{1-\sigma}}{(1-\sigma)} - \frac{L_{R,t}\left(j'\right)^{1+\tau}}{1+\tau} \right] \right\}, \tag{1}$$

where E_0 denotes the expectation conditional on information set at date 0, β_R is the discount factor ($0 < \beta_R < 1$), $1/\sigma$ is the elasticity of intertemporal substitution ($\sigma > 0$), and $1/\tau$ is the labor Frisch elasticity ($\tau > 0$). The parameter h ($0 < h < 1$) represents external habit formation in consumption.

Restricted households have access only to the market of long-term sovereign bonds. The budget constraint is

$$\begin{aligned} & P_t^L B_{R,t}^L\left(j'\right) - \sum_{s=1}^{\infty} \kappa^{s-1} B_{R,t-s}^L\left(j'\right) \\ = \; & \Pi_t^{prof}\left(j'\right) + \left(1-\tau_t^{\ell}\right) W_{R,t}\left(j'\right) L_{R,t}\left(j'\right) \\ & -P_t\left(1+\tau_t^c\right) C_{R,t}\left(j'\right) - AC_{R,t}^W\left(j'\right), \end{aligned} \tag{2}$$

where $B_{R,t}^L$ is the amount of long-term sovereign bonds, Π_t^{prof} is profit from ownership of the Home capital producers, $0 \leq \tau_t^c \leq 1$ is the tax rate on consumption. The long-term sovereign bonds have price $P_{L,t}$ and are formalized as perpetuities paying an exponentially decaying coupon $\kappa \in (0, 1]$, following Woodford (2001). Finally, households act as wage setters in a monopolistic competitive labor market. Each household j' supplies one particular type of labor services which is an imperfect substitute to services supplied by other households. It sets its nominal wage

[10] See Rotemberg (1982).

$W_{R,t}$ taking into account of the labor income tax rate $0 \leq \tau_t^{\ell} \leq 1$, labor demand, and quadratic adjustment costs AC_R^W à la Rotemberg on the nominal wage $W_R(j')$:

$$AC_{R,t}^W(j') \equiv \frac{\kappa_W}{2}\left(\frac{W_{R,t}(j')/W_{R,t-1}(j')}{\Pi_{t-1}^{\alpha_W}\bar{\Pi}_{EA}^{1-\alpha_W}} - 1\right)^2 W_{R,t}L_{R,t}, \tag{3}$$

where $\kappa_W > 0$ and $0 \leq \alpha_W \leq 1$ are parameters regulating wage stickiness, the variable $\Pi_t \equiv P_{C,t}/P_{C,t-1}$ is the consumer price inflation rate, and $\bar{\Pi}_{EA}$ is the long-run inflation target of the EA monetary authority (assumed to be constant). The adjustment costs are proportional to the per-capita wage bill of restricted households, $W_{R,t}L_{R,t}$.[11]

Restricted households are crucial for the PSPP to have real effects in our model. As they cannot arbitrage between short-term and long-term bonds, their consumption decisions depend only upon the long-term interest rate. Therefore, the monetary policy authority can affect their consumption and saving decisions by directly intervening in the secondary long-term sovereign bond market to change the long-term interest rate.

2.3 Unrestricted households

There exists a continuum of unrestricted households, indexed by j, with $j \in (n\lambda_R, n]$. These households have the same preferences as restricted households, thus they consume and supply labor. The only difference is the discount factor, β_U, which can be different from that of restricted households.

Home unrestricted households have access to multiple financial assets (all denominated in euro terms): the short-term (one-period) sovereign bond B^G, exchanged with the domestic government; the short-term private bond B^P, exchanged with REA unrestricted and RW households and paying the interest rate R^P; the long-term sovereign bond B_U^L, exchanged with the domestic restricted households, domestic government and, because of the PSPP, the EA monetary authority. Thus, they have several opportunities to smooth consumption when facing a shock. The

[11] As the implied first order conditions are rather standard we do not report them to save on space. They are available upon request.

budget constraint of the generic unrestricted household j is

$$\begin{aligned}
&B_t^G(j) - B_{t-1}^G(j) R_{t-1} \\
&+B_t^P(j) - B_{t-1}^P(j) R_{t-1}^P(1-\phi_{t-1}) \\
&+P_t^L B_{U,t}^L(j) - \sum_{s=1}^{\infty} \kappa^{s-1} B_{U,t-s}^L(j) = \\
&\left(1-\tau_t^{\ell}\right) W_{U,t}(j) L_{U,t}(j) + \Pi_t^P(j) + \Pi_t^{prof}(j) - P_t\left(1+\tau_t^c\right) C_{U,t}(j) \\
&+TR_t(j) - AC_{U,t}^W(j) - AC_{U,t}^B(j),
\end{aligned} \tag{4}$$

where the short-term government bond B_t^G pays the EA monetary policy rate R_t. The dividends $\Pi_t^P(j)$ are from ownership of domestic monopolistic firms (claims to firms' profits are not internationally tradable). The term ϕ_t represents an exponential adjustment costs, needed to stabilize the position in the internationally traded bond.[12] The variable Π_t^{prof} is profit from ownership of the Home capital producers. The term TR_t represents lump-sum transfers from the government. Unrestricted households supply labor services under monopolistic competition and face quadratic adjustment costs $AC_{U,t}^W$ when setting nominal wages (the cost is similar to the one paid by restricted households, see eq. 3). They also pay adjustment costs $AC_{U,t}^B$ on long-term sovereign bond holdings.[13]

First order conditions imply no-arbitrage conditions for the unrestricted households.[14] Thus, in equilibrium the interest rates paid by the different bonds are equal to the monetary policy rate R_t, net of the spreads induced by the longer maturity and the adjustment costs.[15]

[12] The adjustment cost is defined as

$$\phi_{B,t} \equiv \phi_{b1} \frac{\exp\left(\phi_{b2}\left(B_t^P - \bar{B}^P\right)\right) - 1}{\exp\left(\phi_{b2}\left(B_t^P - \bar{B}^P\right)\right) + 1}, \text{ with } \phi_{b1}, \phi_{b2} > 0$$

where B_t^P and $\bar{B}^P$ are the period-by-period and steady-state positions of the representative Home unrestricted household, respectively. Both are taken as given in the maximization problem. A similar cost holds for the RW household.

[13] We assume a standard quadratic form for the adjustment cost, that is,

$$AC_{U,t}^B(j) \equiv \frac{\phi_{bL}}{2}\left(P_t^L B_{U,t}^L(j) - \bar{P}^L \bar{B}_U^L\right)^2, \text{ with } \phi_{bL} > 0,$$

where $\bar{P}^L \bar{B}_U^L$ is the (symmetric) steady-state value of the long-term sovereign bond. The adjustment cost guarantees that the bond holdings follow a stationary process and that the economy converges to the steady state.

[14] As the implied first order conditions are rather standard we do not report them to save on space. They are available upon request.

[15] See Chen *et al.* (2012) for the details. Our calibration implies that households can modify their financial positions without facing relevant adjustment costs.

2.4 Capital producers

There exists a continuum of mass $0 \leq n \leq 1$ of firms e that produce private physical capital. They optimally choose capital K_t and investment I_t to maximize profits subject to the law of capital accumulation, the adjustment costs on investment, and taking prices as given. The law of motion of capital accumulation is

$$K_t(e) = (1-\delta) K_{t-1}(e) + \left(1 - AC_t^I(e)\right) I_t(e),$$

where $0 < \delta < 1$ is the depreciation rate. The adjustment cost on investment AC_t^I is

$$AC_t^I(e) \equiv \frac{\phi_I}{2}\left(\frac{I_t(e)}{I_{t-1}(e)} - 1\right)^2, \text{ with } \phi_I > 0.$$

Capital producers rent existing physical capital stock $K_{t-1}(e)$ at the nominal rate R_t^K (on which they pay the tax rate $0 \leq \tau_t^k \leq 1$) to domestic firms producing intermediate tradable and non-tradable goods. Investment is a final non-tradable good, composed of intermediate tradable (domestic and imported) and non-tradable intermediate goods. Capital producers buy it in the corresponding market at price P_I.[16] Because of the adjustment costs on investment, a "Tobin's Q" holds.

When maximizing profits with respect to capital and investment, capital producers discount profits using the stochastic discount rates of restricted and unrestricted households, aggregated according to the corresponding population shares.

2.5 Public capital and firms' decisions

The production function of the generic firm i in the Home intermediate tradable sector is

$$Y_{T,t}(i) = K_{T,t}^P(i)^{\alpha_{1T}} L_{T,t}^U(i)^{\alpha_{2T}} L_{T,t}^R(i)^{\alpha_{3T}} \left(K_{G,t-1}\right)^{1-\alpha_{1T}-\alpha_{2T}-\alpha_{3T}},$$

[16] As for the consumption basket, the investment bundle is a composite of tradable and non-tradable goods. The composition of consumption and investment goods can be different.

where $K_{T,t}^{P}(i)$ is private capital, which is supplied by the domestic capital producers, $L_{T,t}^{R}(i)$ and $L_{T,t}^{U}(i)$ represent labor supplied by, respectively, domestic restricted and unrestricted households, $K_{G,t-1}$ is public capital, accumulated by the domestic public sector, . The parameters $0 < \alpha_{iT} < 1$ $(i = 1, 2, 3)$, $\alpha_{1T} + \alpha_{2T} + \alpha_{3T} < 1$, are the weights on private capital, unrestricted households' labor, and restricted households labor, respectively.

The firm optimally chooses demand for private capital and labor taking prices and the amount of public capital as given. Thus, firms do not demand public capital and there is no price or tariff paid for its use.

A similar production function holds for the generic firm i producing the intermediate non-tradable good:

$$Y_{N,t}(i) = K_{N,t}^{P}(i)^{\alpha_{1N}} L_{N,t}^{U}(i)^{\alpha_{2N}} L_{N,t}^{R}(i)^{\alpha_{3N}} (K_{G,t-1})^{1-\alpha_{1N}-\alpha_{2N}-\alpha_{3N}}.$$

For public capital projects, we follow Leeper *et al.* (2010) and in some simulations assume "time-to-build" (Kydland and Prescott, 1982): there is a delay between the authorization of a government spending plan and the completion of an investment project. The possibility of several periods of time-to-build in public capital implies that the government initiates investment projects that take N periods until they become productive and augment the public capital stock. Thus, the public capital is accumulated by the public sector according to

$$K_{G,t-1} = (1 - \delta_G) K_{G,t-2} + A_{I_G,t-1-N},$$

where $0 < \delta_G < 1$ is the depreciation rate, and $A_{I_G,t-1-N}$, with $N \geq 1$, is authorized government investment in period $t-1-N$. The time-to-build lags capture the idea that it takes time before a public investment is finished and, hence, can be effectively included in the public capital stock and affect the supply side of the economy. A "classic" example is the government that authorizes funding at time (quarter) $t-8$ for a highway that takes two years to build ($N = 8$). Then the highway cannot be considered as a part of the stock of public capital until quarter t ($K_{G,t-1}$ is used to produce goods in period t).

To capture the idea that spending outlays typically occur over time, we introduce the sequence

$\{b_0, b_1, b_2, ..., b_{N-1}\}$ of the spending rates from the date the funding is authorized (date $t-8$) to the period before project completion (date $N-1$). For example, the highway may not be usable for two years but government investment increases during this time as construction of the highway takes place. Therefore, government investment actually implemented at time t is then given by

$$I_{G,t} = \sum_{n=0}^{N-1} b_n A_{I_G,t-n}, \tag{5}$$

$$\sum_{n=0}^{N-1} b_n = 1. \tag{6}$$

where the rate at which the construction takes place is parameterized by the b's. In the case of a one-period time-to-build technology (as assumed for private investment), public investment outlaid in period t becomes productive in period $t+1$, i.e. $N=1$ and $I_{G,t} = A_{I_G,t}$.

2.6 Fiscal sector

Fiscal policy is set at the regional level. The government budget constraint is

$$B^S_{G,t} - B^S_{G,t-1}R_{t-1} + P_{L,t}B^L_{G,t} - \sum_{s=1}^{\infty} \kappa^{s-1} B^L_{G,t-s} \leq P_{N,t}C_{G,t} + P_{I_G,t}I_{G,t} + TR_t - T_t, \tag{7}$$

where $B^S_{G,t}$, $B^L_{G,t}$ are short-term and long-term nominal sovereign bonds, respectively ($B^S_{G,t}, B^L_{G,t} > 0$ is public debt). The short-term bond is a one-period nominal bond issued in the domestic bond market that pays the (gross) monetary policy interest rate R_t. The implied gross yield to maturity at time t on the long-term bond is defined as

$$R^L_t = \frac{1}{P^L_t} + \kappa. \tag{8}$$

The variable $C_{G,t}$ represents government purchases of goods and services, $Tr_t > 0$ (< 0) are lump-sum transfers (lump-sum taxes) to households. Consistent with the empirical evidence, $C_{G,t}$ is fully biased towards the intermediate non-tradable good. Therefore, it is multiplied by the corresponding price index $P_{N,t}$.[17] Given that the public investment has its own composition,

[17] See Corsetti and Mueller (2006).

it is pre-multiplied by the public investment price deflator $P_{I_G,t}$. The investment in public capital $I_{G,t}$ is assumed, in line with empirical evidence, to have a composition that is more biased towards domestic goods. Thus, we assume that it has the same composition as the private consumption good. The same tax rates apply to every domestic household and capital producer (the latter pays the tax rate $0 \leq \tau_t^k \leq 1$ on return R_t^k on capital K_{t-1}). Total government revenues T_t from distortionary taxation are given by the identity

$$\begin{aligned} T_t \equiv & \int_0^{n\lambda_R} \tau_t^{\ell} W_t\left(j'\right) L_t\left(j'\right) dj' \\ & + \int_{n\lambda_R}^{n} \tau_t^{\ell} W_t\left(j\right) L_t\left(j\right) dj \\ & + \int_0^{n} \tau_t^{k} R_t^k K_{t-1}\left(e\right) de \\ & + \int_0^{n\lambda_R} \tau_t^{c} P_t C_t\left(j'\right) dj' \\ & + \int_{n\lambda_R}^{n} \tau_t^{c} P_t C_t\left(j\right) dj. \end{aligned} \tag{9}$$

The government follows a fiscal rule defined on lump-sum transfers to bring the short-term public debt as a percentage of domestic GDP, $b_G^s > 0$, in line with its long-run (steady-state) target $\bar{b}_G^s$.[18] The rule is

$$\frac{TR_t}{TR_{t-1}} = \left(\frac{b_{G,t}^s}{\bar{b}_G^s}\right)^{-\phi_1}, \tag{11}$$

where the parameter $-\phi_1$ is lower than zero ($\phi_1 > 0$), calling for a reduction (increase) in lump-sum transfer whenever the current-period short-term public debt (as a ratio to GDP) is above (below) the target. We choose lump-sum transfers to stabilize public finance as they are non-distortionary and, thus, allow a "clean" evaluation of the macroeconomic effects of public investment.

For long-term public debt, it is assumed for simplicity that its rate of change is the same as

[18] The definition of nominal GDP is

$$GDP_t = P_t C_t + P_t^I I_t + P_t^{I_G} I_{G,t} + P_{N,t} C_{G,t} + P_t^{EXP} EXP_t - P_t^{IMP} IMP_t, \tag{10}$$

where P_t, P_t^I, $P_t^{I_G}$, $P_{N,t}$, P_t^{EXP}, P_t^{IMP} are prices of private consumption, private investment, public investment, public consumption (given the assumption of fully biased composition towards intermediate non-tradable goods), exports, and imports, respectively.

that of the short-term public debt, so that the maturity composition of the overall public debt does not change.

Fiscal items other than (i) public deficit, (ii) public debt, (iii) lump-sum transfers, and (iv) public investment are kept at their corresponding initial (steady-state) levels when simulating the model.

2.7 Monetary authority

The EA monetary authority sets the (short-term) policy rate R_t according to a Taylor rule of the form

$$\left(\frac{R_t}{\bar{R}}\right)^4 = \left(\frac{R_{t-1}}{\bar{R}}\right)^{4\rho_R} \left(\frac{\Pi_{EA,t,t-3}}{\bar{\Pi}^4}\right)^{(1-\rho_R)\rho_\pi} \left(\frac{GDP_{EA,t}}{GDP_{EA,t-1}}\right)^{(1-\rho_R)\rho_{GDP}}. \tag{12}$$

The parameter ρ_R ($0 < \rho_R < 1$) captures inertia in interest-rate setting, while the term $\bar{R}$ represents the steady-state gross nominal policy rate. The parameters ρ_π and ρ_{GDP} are respectively the weights of yearly EA CPI inflation rate $\Pi_{EA,t,t-3} \equiv P_{C,t}/P_{C,t-4}$ (in deviation from the long-run steady-state target $\bar{\Pi}^4$) and the GDP gross growth rate ($GDP_{EA,t}/GDP_{EA,t-1}$). The CPI inflation rate is a geometric average of Home and REA inflation rates, with weights equal to the corresponding (steady-state) regional GDP (as a share of the steady-state EA GDP). EA GDP is the sum of Home and REA GDP. A similar equation describes monetary policy in the RW region.

In some simulations, the central bank resorts to non-standard measures, namely FG and QE. In the first case, the monetary authority credibly commits to keep the policy rate constant at its baseline (steady-state) level for a prolonged period of time and, thereafter, returns to follow the Taylor rule; in the second case, the central bank purchases long-term (domestic) sovereign bonds in the secondary markets to affect the long-term interest rates and hence the real side of the economy. The so called Wallace neutrality[19] is relaxed by making short- and long-term sovereign bonds imperfect substitute in households' portfolios.[20] Specifically, we allow for preferred habitat investors: in each EA region some agents do not have access to short-term bonds and invest in

[19] See Wallace (1981).
[20] See for instance Chen *et al.* (2012)

physical capital and domestic long-term sovereign bonds: the monetary authority, by buying long-term sovereign bonds, lowers their yields and induces households to substitute investment in physical capital for sovereign bonds.[21]

The market clearing condition for the long-term sovereign bonds of the Home region is

$$\int_0^{n\lambda_R} B^L_{R,t}(j')dj' + \int_{n\lambda_R}^{n} B^L_{U,t}(j)dj + B^L_{PSPP,t} = B^L_{G,t},$$

where $B^L_{PSPP,t}$ are the central bank purchases. A similar condition holds for the REA region.

Finally, we also consider the case of the monetary authority permanently increasing its balance sheet through a QE that is directly proportional to the increase in public investment. We compare this policy measure with the distortionary tax-based financing of the public investment.

2.8 Equilibrium

In each country the initial asset positions, preferences, technologies, and budget constraints are the same for households belonging to the same type and firms belonging to the same sector. Moreover, profits from ownership of domestic monopolistically competitive firms are equally shared among unrestricted households. Profits from ownership of domestic capital producers are distributed to restricted and unrestricted households according to the corresponding population shares, and are equally shared within each type. Thus, we consider the representative household for each household type (restricted and unrestricted). Moreover, we consider the representative firm for each sector (final non-tradable, intermediate tradable, and intermediate non-tradable) and the representative capital producer. The implied symmetric equilibrium is a sequence of allocations and prices such that, given initial conditions and considered shocks, households and firms satisfy their corresponding first order conditions, the monetary rules, the fiscal rules, and the government budget constraints hold, and all markets clear.

[21] There is empirical evidence that supports the preferred habitat theory in the case of the EA (see Blattner and Joyce 2016 and Altavilla *et al.* 2015): the Eurosystem purchases create a scarcity in some bonds considered special by private investors, leading investors to push up prices and lower yields if these securities cannot easily be replaced with other securities featuring similar characteristics.

2.9 Calibration

The model is calibrated at quarterly frequency. We set some parameter values so that steady-state ratios are consistent with average EA national account data. For remaining parameters we resort to previous studies and estimates available in the literature.[22]

Table 1 contains parameters for preferences and technology. Parameters with "$*$" and "$**$" are related to the REA and the RW, respectively. We assume perfect symmetry between the REA and the RW unless differently specified. The discount factor of EA unrestricted households is set to 0.9994, so that the steady-state short-term interest rate is equal to 0.25% on an annual basis. The discount factor of RW households is also set to 0.9994. The discount factor of restricted households determines the steady-state value of the long-term interest rate and is set to 0.995, so that in steady state the spread between short- and long-term bond is equal to 1.8pp. We set the intertemporal elasticity of substitution to 1, the Frisch elasticity of labor supply to 1/2, and the depreciation rate of private and public capital to 0.025, as customary in the literature. The habit motive for consumption implies a persistence of consumption patterns equal to 0.8. We set the elasticity of output to public capital to 0.1, in line with common practice (see Elekdag and Muir 2014 and De Jong *et al.* 2017) and with ample empirical evidence provided by Bom and Ligthart (2014).

In each EA region the share of restricted households is set to 0.25. Given the lack of micro-evidence on this share, we set it to get a response of investment to the (benchmark) PSPP around four times as large as the response of consumption, in line with standard business cycle facts, and at the same time to calibrate the adjustment cost on investment to a rather standard value (i.e., 7.50, as reported in Table 3), in line with Smets and Wouters (2003).[23]

Tables 2, 3, and 4 report gross mark-up, adjustment costs, and parameters of the monetary and fiscal rules, respectively.

The parameter regulating the adjustment costs paid by the unrestricted household on deviations of long-term sovereign bond positions from steady-state levels, ϕ_{b^L}, is set to 0.00047

[22] See the New Area Wide Model (NAWM, Christoffel *et al.* 2008) and Euro Area and Global Economy Model (EAGLE, Gomes *et al.* 2010), and the Global Economy Model (GEM, Pesenti 2008).

[23] We run robustness analysis. To save on space we do not include it in the paper. Specifically, when we reduce the share of restricted households to 0.15; the peak effect on EA GDP and inflation roughly halves. Qualitatively, results do not change.

and to 0.0008 in Home and REA, respectively. The parameters regulating the adjustment cost on private bond position, paid by Home unrestricted households and RW households, are set to 0.0015 and 0.003. These parameters have been calibrated following two criteria. First, they should not greatly affect the model dynamics and yet help to stabilize it. Second, the response of the interest rate on long-term sovereign bonds to the benchmark PSPP should be in line with existing evidence for the EA.[24]

Table 4 reports the parametrization of the systematic feedback rules followed by the fiscal and monetary authorities. It is always lump-sum transfers to adjust to ensure stability of the debt-to-GDP ratio. The corresponding parameter of the fiscal rule is set to 1.01. The central bank of the EA targets the contemporaneous EA-wide consumer price inflation (the corresponding parameter is set to 1.7) and the output growth (the parameter is set to 0.1). Interest rate is set in an inertial way and hence its previous-period value enters the rule with a weight equal to 0.92. The values are identical for the corresponding parameters of the Taylor rule in the RW.

Table 5 reports the great ratios, which are matched by the model steady state under our baseline calibration. We assume a zero steady-state net foreign asset position of each region. The sizes of Home and REA GDPs as shares of world GDP are set to 2.5% and to 19.1%, respectively. So the Home GDP is around 12% of EA GDP.

Short-term public debt (ratio to yearly GDP) is set to 13% for Home and 8% for the REA, respectively. Long-term public debt is set to 121% and 93% of (yearly) GDP for Home and the REA. Thus, total public debt as a share of GDP is 134% in Home and 101% in REA. We assume that in each country long-term sovereign bond holdings are equally shared between unrestricted and restricted households. The parameter κ is calibrated to match the average duration of the representative long-term EA sovereign bond, which is equal to 8 years.

Variables of the RW are set to values equal to those of corresponding REA variables.

The chosen calibration yields impulse response functions to a standard monetary policy shock (+0.25 basis points) for GDP and inflation in each EA region that are in line with the workhorse estimated models of the EA in the literature.[25]

[24] See Altavilla *et al.* (2015).
[25] See, for example, Gomes *et al.* (2010).

3 Simulated scenarios

In the first scenario the Home government increases public investment by 1% of the before-shock (steady-state) GDP for five years and, thereafter, gradually decreases it to the baseline level (the public investment follows an AR(1) process with a quarterly decay rate of 0.9). During the first five years, the fiscal rule (eq. 11) is not active; it start operating from the beginning of the sixth year, when lump-sum transfers to households endogenously adjust to stabilize the public debt-to-GDP ratio. The EA monetary policy rate follows the Taylor rule (12); alternatively, the policy rate remains constant for eight quarters at its baseline level and the Taylor rule becomes operative only thereafter (FG assumption). The comparison between the two alternative monetary policy responses allows to assess to what extent a more accommodative stance can increase the fiscal multiplier and mitigate the impact on the debt and the deficit ratios of the rise in government spending.

We compare the previous scenarios with those in which the increase (equal to 1% of the before-shock GDP) in public investment is simultaneously implemented in the Home and REA blocs; the assumptions on monetary policy are the same as above: in one case the short-term rate is determined by the Taylor rule; in another it is kept fixed for eight quarters; in the final case the stimulus coming from the low and fixed policy rate is reinforced by QE (the so-called Public Sector Purchase Programme, PSPP for short). Under the PSPP the central bank commits to purchase €180 billion per period for seven quarters (€60 billion in the first quarter), as was the case for the PSPP announced in January 2015 (long-term sovereign bond purchases in Home and REA are proportional to the size of the corresponding region, measured as a share of the size of the EA).

We also analyze how the form of financing affects the impact on the economy of the increase in public investment by comparing the benchmark case of debt-financing with a hike in distortionary taxation. Moreover, we assess the role of the increase in sovereign spread when the stimulus is financed by issuing public debt.

Finally, we consider a case where the monetary authority buys and rolls over an amount of sovereign bonds equal to the increase in public investment. In this way, the monetary authority keeps low both the policy rates (with forward guidance) and the long-term interest rates (with

the accommodative monetary stance).

We also perform a sensitivity analysis to assess the relationship between macroeconomic effectiveness and implementation efficiency of the investment programme, where the lack of efficiency is associated with low and slow accumulation of public investment and, thus, reduced impact on the supply side of the economy.

All simulations are run under perfect foresight, with households and firms considering fully credible the policy announcement.

4 Results

We initially describe the results for the case of a single-country increase in public investment. Subsequently, we report results for the case of a joint public investment boost in both EA regions.

4.1 Home-country increase in public investment

Figure 1 shows the quarterly responses of the main Home variables when only the domestic fiscal authority increases public investment (the REA public investment is constant at its baseline level). We consider both the case when the policy interest rate is set according to the Taylor rule (No FG) and the case when the interest rate is kept constant for the first eight quarters (FG). Economic activity in the Home country expands in both scenarios. Aggregate demand rises following the increase in public investment. Consumption is roughly constant, while private investment slightly decreases during the first five years, due to the increase in the long-term interest rate. Spending in infrastructures stimulates not only aggregate demand but also supply, via the accumulation of public capital, which enters the production function: a higher stock of public capital fosters labour productivity and boosts labor supply. The implied reduction in firms' current and expected marginal costs lowers the price of domestic goods and thus CPI inflation. The public sector deficit as a share of output increases, as the GDP gain does not generate tax revenues large enough to compensate for the higher expenditures. The deficit reduction starts from the sixth year, when the fiscal stimulus stops and the fiscal rule becomes active again. The public debt-to-annualized GDP ratio falls on impact. Thereafter, and crucially,

rises and remains persistently above its baseline value, implying that the fiscal stimulus is not self-financing.[26] The euro slightly appreciates vis-à-vis the RW currency: the reason is that the EA monetary authority raises the policy rate more than the RW central bank does.[27]

The expansionary effects are slightly larger in the FG scenario; the reason of so small a difference is that the standard Taylor rule in the No-FG scenario does not command a large increase in the policy rate in response to the fiscal stimulus, because the Home country is a relatively small part of the monetary union and its spillovers on inflation and economic activity in the REA are positive but contained (see Figure 2). Not surprisingly, the spillovers are slightly amplified by the accommodative monetary policy stance: the increase in REA inflation induces a decrease in the REA ex-ante real interest rate, which stimulates REA consumption and investment. The euro slightly depreciates vis-à-vis the RW currency, because the RW monetary authority raises the policy rate more than the EA authority. The deficit- and debt-to-GDP ratios are basically the same as those observed when monetary policy follows a Taylor rule.

Table 6, columns "Home increase"and "Home increase+FG", reports the first-, second-, and tenth-year (long run, LR) responses (they are averages of the corresponding quarterly responses). The single-country fiscal stimulus has long-lasting expansionary effects. Domestic consumption and investment benefit from the supply-side expansion and the associated increase in permanent income; exports rise because of price-competitiveness gains following the depreciation of the exchange in real terms. Imports increase as well, due to the increase in domestic demand.

To summarize, an increase in public investment occurring only in one country is expansionary. It basically has no effects on the rest of the monetary union if monetary policy responds to the improved business cycle conditions; it increases output and inflation slightly more at home and in the REA if instead the central bank keeps short-term interest rate constant.

[26]The ratio of public debt to GDP can fall on impact even though the deficit over GDP increases because of a "valuation effect"associated with the dynamics of the sovereign bond prices. The increase in long-term interest rate connected with the public investment programme leads to a decrease in the market price of sovereign bonds. Given that we model the long-term bonds as perpetuities, the value of the *overall* stock of public debt as a ratio to GDP decreases more than the increase in volume of the debt itself. As remarked also in the main text, this is an effect that benefits public debt only in the initial period of the simulation.

[27]The nominal exchange rate dynamics is dictated by the uncovered interest parity condition, which links the EA and RW policy rates differential to the expected nominal exchange rate depreciation.

4.2 EA increase in public investment

Figure 3 shows the responses of the Home variables to an increase in public investment in both regions of the EA.

In a standard monetary policy regime (No FG), Home GDP benefits from the spillovers due to the fiscal boost in the REA and increases more than when infrastructure spending is raised only in the Home country. Exports increase, as they benefit from the expansion in REA consumption and investment (see Figure 4). The additional boost provided by foreign demand more than offsets the increase in supply and, thus, causes Home inflation to increase, unlike the case analysed in the previous subsection, where the rise in aggregate demand is not large enough to absorb the increase in supply. The public debt-to-GDP ratio initially decreases but then starts deteriorating and, in the long term (i.e., 10 years after the fiscal stimulus), it is higher than in the baseline.

Under FG the expansionary effects of the joint stimulus are further enhanced by the more accommodative monetary policy, as the nominal interest rate is kept constant at its baseline level for the first two years after the shock. For a given increase in inflation, the real interest rate decreases more than in the No-FG case, fueling a stronger expansion of consumption and (private) investment. Home Inflation steps up more as well, because of the large depreciation of the euro vis-à-vis the RW currency: the RW monetary authority, which faces expansionary spillovers from the EA, raises its policy rate more than the EA authority does, because the latter is committed to FG. The fiscal multiplier turns out to be slightly above 2 in both the short and in the long run.

The improvement in public finances is more pronounced and longer-lasting in the FG than in the No-FG scenario, because the fiscal stimulus is amplified by the accommodative stance of monetary policy and, thus, induces a larger increase in Home GDP. Ten years after the shock the public debt-to-GDP ratio is still lower than in the baseline, implying that the increase in public investment, in this case, is self-financing.

Figure 4 reports results for the REA variables. They are similar, qualitatively and quantitatively, to the results for the Home region. The effects of higher REA public spending on REA GDP are expansionary. The REA international relative prices (not reported) deteriorate,

consistent with the excess aggregate supply that has to be absorbed by lowering the price of REA-produced goods.

Table 6 (columns "EA increase"and "EA increase+FG") contains the average values of the first, second, and tenth year (long run, LR) responses. Consistent with the results reported in the charts, the monetary stance does matter for the short-run macroeconomic effectiveness of the public investment increase. In the case of FG, the Home public debt-to-GDP ratio decreases in the short and, to some extent, in the long run. The corresponding ratio in the REA slightly increases in the long run. The ratio decreases in the Home region because Home tax rates are calibrated (and kept constant) to higher steady-state values than REA rates. This implies that, for a given increase in economic activity, fiscal revenues as a ratio to GDP increase to a larger extent in the Home region than in the REA.

Overall, we find that the EA-wide public investment increase has expansionary effects on the EA economy, and the Home region benefits from the expansionary spillovers associated with the increase in REA economic activity. The short-run expansionary effects are larger and the improvement in public finances is greater if the stance of monetary policy is accommodative.

4.3 EA-wide public investment increase and non-standard monetary policy measures: Beyond FG

In the model the non-standard monetary policy measures have real effects: the Wallace neutrality does not hold and short- and long-term bonds are imperfect substitutes. Thus, the monetary authority, by buying long-term sovereign bonds in the secondary market, is able to affect the long-term interest rate and to induce restricted households to substitute investment in physical capital for investment in sovereign bonds.

Figures 5 and 6 respectively show the macroeconomic effects on Home and REA regions of implementing the EA-wide stimulus when the EA monetary authority implements the two-year FG on short-term interest rates (as in previous simulations) or, alternatively, the FG joint with the PSPP. The monetary authority buys long-term sovereign bonds and holds them up to maturity, after eight years. At the beginning of the ninth year, the monetary authority newly buys the same amount of bonds, so that its balance sheet does not change. Thereafter, the

central bank holds the newly-bought bounds to maturity. The sovereign bond prices increase and consistently the long-term interest rates decrease (see eq. 8). Thus, households and firms have a larger incentive to substitute consumption and investment in physical capital for sovereign bond holdings. In both Home and REA regions the expansionary macroeconomic effects are larger than those under the assumption of implementing only the FG. The public deficit- and public debt-to-GDP ratios decrease favored by the large increase in GDP.

Table 7 reports the results for the first, second year, and tenth year (long run, LR) responses. The results are reported under standard monetary policy (No FG), FG only, and FG and PSPP. The PSPP strengthens the short- and long-run macroeconomic effectiveness of the public investment increase by persistently keeping the long-term interest rate below the baseline. The fiscal multiplier exceeds 3 and in the long run the public debt-to-GDP ratio turns out to be well below the baseline.

Overall, the PSPP reduces the long-term interest rates to a larger extent than the FG on short-term interest rates does, magnifying the macroeconomic impact of the increase in public investment. This is due to the fact that the expectations hypothesis, which makes short- and long-term bonds perfect substitutes (and, thus, non-standard monetary policy measures neutral) holds only for unrestricted households, that have access to both short- and long-term bonds. It does not hold for restricted households, that have access only to long-term sovereign bonds (preferred habitat assumption). The FG alone affects only the choices of unrestricted households, that are able to arbitrage away its impact on their portfolio choices. The PSPP instead affects also restricted households that do not have the same diversification opportunities as unrestricted households, thus magnifying the impact on the real variables. If there was no FG under the PSPP, its effectiveness would be great diminished due to residual arbitrage opportunities of unrestricted households.[28]

4.4 EA-wide public investment financed with distortionary taxation

In the previous exercises it was assumed that the increase in public investment was initially financed by issuing public debt and, from the sixth year onwards, lump-sum taxes were allowed

[28] See Burlon *et al.* (2017) for an analysis of the effectiveness of the PSPP with different durations of the FG.

to rise to stabilise the debt-to-GDP ratio. To investigate how alternative funding sources bear upon the macroeconomic effectiveness of public investment spending, we look at the effects of the stimulus when it is paid by levying distortionary taxes. We consider an increase in distortionary taxation on consumption, labor and capital income. The FG assumption is maintained.

Distortionary tax rates are levied so as to obtain the same revenue - 1/3 of the increase in public investment (1% of initial GDP) - from each source: consumption, capital and labour income. The Home (REA) tax rates rise from $\tau^l = 0.426$ ($\tau^{l*} = 0.346$) to $\tau^l_t = 0.432$ ($\tau^{l*}_t = 0.352$), from $\tau^k = 0.349$ ($\tau^{k*} = 0.259$) to $\tau^k_t = 0.363$ ($\tau^{k*}_t = 0.273$), and from $\tau^c = 0.168$ ($\tau^{c*} = 0.203$) to $\tau^c_t = 0.173$ ($\tau^{c*}_t = 0.209$). The tax rates exogenously rise for five years, i.e., for the whole duration of the increase in public investment; thereafter lump-sum taxes are used to control debt developments.

Table 8 reports the simulation results. Compared with the benchmark scenario (column "EA increase+FG"), financing the increase in public investment through higher distortionary taxes leads to milder expansionary and inflationary effects in the first years. Higher distortionary taxation has negative income and substitution effects, inducing, *ceteris paribus*, households to reduce consumption, decrease the supply of labor, and invest less in physical capital. Thus, distortionary taxes attenuate the expansionary effects of the increase in productive capacity associated with a larger stock of public capital. With a notable exception, in the longer term the differences with respect to the benchmark scenario vanish, as the hike in distortionary taxation is temporary. The exception is represented by public finances: higher fiscal revenues decrease public deficit in the initial years, reducing public debt in the long run by more than in the benchmark case.

4.5 Increase in sovereign spread

The previous section suggests that in the short run the stimulus is more expansionary if financed by issuing debt. However, if the fiscal authority cannot credibly commit to the stabilization of public finances or if non-fundamental shocks can shift the demand for sovereign bonds, the sovereign risk premia may well rise in response to the announcement of a large program of fiscal stimulus, especially in countries with a high initial level of public debt. Considerably higher

long-term interest rates connected with high risk premia can easily undo the expansionary effect of a debt-financed fiscal stimulus, worsening the future level of public deficits through lower fiscal revenues and potentially triggering a further deterioration of sovereign risk premia.

In this section we evaluate how the macroeconomic effectiveness of increasing Home public investment is affected by an increase in Home sovereign spread. We assume that the higher public investment is financed by issuing new debt and that the Home sovereign default risk affects Home consumption and investment decisions by creating a wedge between the risk-free rate and the government bonds yield. The spreads on both policy and long-term interest rates is assumed to increase by around 0.75 (annualized) bp during the first five years, in line with the empirical regularities between sovereign spread and public debt as documented in Corsetti et al. (2012).[29]

Figure 7 reports the results. We assume that there is no FG and, thus, that the Taylor rule always holds. The case of spread increase (labeled "No FG & spread") is compared with the one in which the spread does not increase (labeled "No FG"). The latter is the same scenario as the one reported in Figure 1. The increase in Home spread and, thus, Home interest rates counterbalances the stimulating effect of the increase in Home public investment. Higher interest rates induce Home households and firms to reduce consumption and investment. Home GDP increases to a lower extent in the short run. Public deficit and public debt increase to a larger extent, because of the increase in interest spending and the lower increase in GDP (which reduces the increase in tax revenues).

Overall, the simulation suggests that public investment becomes a viable tool to stimulate the economy only when its increase is part of a plan that guarantees the stability of public finances and the sustainability of public debt.

[29] We do not consider here the ex-post consequences of an actual default. As in Corsetti et al. (2012), the model does not allow for a strategic default, that would result from an explicit decision of the policymaker, comparing costs and benefits of the default. Thus, the premium is not microfounded. This is a deliberate choice, to make the model tractable. The link between sovereign risk premium and the expected path of public debt is imposed, (1) building on the result (from the literature on strategic default) that in equilibrium the probability of default increases in the level of debt, and (2) implicitly assuming that there are limits to credible commitment on the part of fiscal policymakers. Equivalently, as in Corsetti et al. (2012), we assume that the government can make use of non-distortionary taxation (lump-sum transfers) so that, in case of a sovereign default, government bond holders would be compensated for their loss. Hence, while actual ex-post default is neutral, the ex-ante probability of default is crucial for the pricing of government debt and has real effects.

4.6 EA-wide public investment under monetary accommodation

We consider now a case where the monetary authority keeps low both the policy rates (with forward guidance) and the long-term interest rates. Different from the PSPP, the expansion of the balance sheet of the central bank is proportional to cost of the investment plan and is permanent. The monetary authority buys sovereign bonds to the extent that they are issued to finance the public investment and rolls them over to expand its balance sheet. The interest rates thus remain at a relatively low level despite the onset of the public investment program.

The last column of Table 8 reports the simulation results. Compared with the benchmark scenario (column "EA increase+FG"), an increase in public investment associated with an accommodative monetary policy stance leads to a more expansionary stimulus as it avoids the increase in interest rates both in the short end and in the long end of the yield curve. Its effects are also larger than those of the benchmark scenario, where the issuance of sovereign bonds partially crowds out consumption and investment because of the step-up in long-term interest rates. In the case of the monetary accommodation, there is no increase in long-term interest rates, which on the contrary slightly decrease as households invest part of their additional savings in sovereign bonds. The public debt-to-GDP ratio decreases substantially due to the increase in the GDP, and, in the short and medium run, slightly more than in the case of distortionary taxation. This is due to the fact that the initial increase in distortionary taxes reduces the GDP increase in the short and medium run, because households and firms are induced to postpone consumption, investment, and labor demand, to periods in which the tax rates return to their baseline levels. Consistent with that, the increase in GDP is less front-loaded in the case of increasing taxes. Thus, the long-run decrease in the public debt-to-GDP ratio is slightly larger when tax rates are increased.

Overall, results suggest that coordination between fiscal and monetary authority, as when the budget expansion is associated with an accommodative monetary policy stance, enhances the GDP response to the stimulus.

5 Sensitivity analysis

The results presented in the previous section rest on the assumptions that public capital enters the production function and the investment programme is implemented efficiently. We now evaluate the effects of a EA-wide increase in public investment and PSPP implementation when: i) the increase in public investment affects aggregate demand but has no impact on aggregate supply (i.e., we do not allow public investment expenditures to contribute to public capital accumulation); ii) investment increases the stock of public capital only with a lag (time-to-build), i.e., we assume that it takes five years for the new capital goods to be delivered and become fully productive (in terms of eq. (5) it implies that in every quarter, a fraction equal to 5% of the authorized outlays does actually occur; thus, parameters $\{b_i\}_{i=1}^{N-1}$ are set to 1/20, and N is set to 20).[30] In both scenarios, the EA short-term interest rate is kept constant at the baseline level during the first eight quarters.

Table 9 reports the simulation results. The effects on GDP and the aggregate demand components are lower than in the benchmark scenario. As public spending does not affect capital accumulation, the long-run impact is negligible and entirely dependent on the response of households' labor supply; the short-run effects are modest as well: households and firms anticipate a subdued increase in permanent income and accordingly consume less. Similarly, in the time-to-build case, the GDP gain is lower in the short run, as it takes time to accumulate public capital. In both scenarios, public debt in the home country decreases less in both the short and the long run, as a consequence of the lower increase in GDP.

The results presented in Table 9 confirm that the benefits accruing from increasing government capital expenditure depend on (i) what goods are actually purchased (i.e. productive or unproductive goods) and on (ii) whether the investment plan is implemented efficiently (i.e. with no undue delays).

[30] In this way we capture implementation delays associated with the administrative procedures needed for planning, bidding, and contracting.

6 Conclusions

We have evaluated the macroeconomic impact of increasing spending in infrastructures in the EA under alternative assumptions about its financing.

Results suggests that the EA-wide fiscal stimulus can be rather effective in supporting economic activity in both the short and the long run. First, EA-wide stimuli are more effective than unilateral (region-specific) stimuli. Second, under EA-wide stimulus, the fiscal multiplier is close to 2 if the forward guidance (FG) on the short-term policy rate holds. Third, if the monetary authority keeps lower both the policy rates (with FG) and the long-term interest rates (with quantitative easing), the fiscal multiplier exceeds 3 at peak and investment spending is self-financing. Fourth, the financing method is relevant. Debt financing, in particular under an accommodative monetary stance and if the sovereign spreads do not increase, is more growth-friendly than tax financing in the short run (but not in the long run). Fifth, the effectiveness of the fiscal stimulus is larger if government spending is directed towards productive goods and its implementation occurs efficiently and without delays.

Our paper supports the view that spending on public capital can promote growth and provide benefits to society. It is therefore consistent with a large part of the recent literature, which includes the analysis presented in International Monetary Fund (2014a). There are however studies that reach opposite conclusions. Garin (2016) studies the impact of the American Recovery and Reinvestment Act's highway spending on county-level employment and finds basically zero effect four years after the start of the recession: some jobs were created in the counties of the contractors but not in those where the highways were built. The Japanese experience of the 1990s may also be considered as a cautionary tale: it certainly produced engineering marvels, but no material contribution to the economic recovery. The long-run beneficial impact of public capital accumulation is far from certain either. Warner (2014) examines whether big infrastructure and public capital spending programmes have succeeded in accelerating economic growth in low-income countries. The evidence he collects shows only a weak positive association between investment spending and growth, with no long-term impact. Pritchett (2000) argues that vast anecdotal experience suggests that many governments' investment efforts are much less productive than private ones.

The available evidence is also not easy to interpret, due to the presence of reverse causality: not only might public investment stimulate growth, higher growth may also lead to higher demand for infrastructures. Moreover, the macroeconomic impact is dependent on conditions related to its implementation (e.g., the quantity and quality of the capital stock already in place; whether spending aims at alleviating bottlenecks; whether the project are politically viable at the local level), which explains why the effects of public investment differ across countries, regions, and sectors. It is therefore not surprising that the literature contains a relatively wide range of conflicting estimates, as described for instance by the review conducted by Sturm *et al.* (1998), who note that there are studies claiming that the marginal product of public capital is much higher than that of private capital, others suggesting that it is roughly equal, and still others finding that it is well below that of private capital and, in some cases, even negative.

The evidence presented in the paper is mostly based on the response of economic activity to the fiscal stimulus. No attempt is made to assess its welfare implications. The analysis of the welfare implications is left for future research.

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Table 1: Parameterization.

Parameter	H	REA	RW
Discount factor $\beta_U, \beta_U^*, \beta^{**}$	0.9994	0.9994	0.9994
Discount factor β_R, β_R^*	0.995	0.995	–
Intertemporal elasticity of substitution $1/\sigma$	1.0	1.0	1.0
Share of restricted households λ_R	0.25	0.25	–
Inverse of Frisch Elasticity of Labor Supply τ	2.0	2.0	2.0
Habit h	0.8	0.8	0.8
Depreciation rate of (private and public) capital δ	0.025	0.025	0.025
Tradable Intermediate Goods			
Substitution between factors of production $\xi_T, \xi_T^*, \xi_T^{**}$	0.90	0.90	0.90
Share of private capital $\alpha_{1T}, \alpha_{1T}^*, \alpha_{1T}^{**}$	0.3	0.3	0.3
Share of unrestricted HH's labor $\alpha_{2T}, \alpha_{2T}^*, \alpha_{2T}^{**}$	0.5	0.5	0.7
Share of restricted HH's labor $\alpha_{3T}, \alpha_{3T}^*$	0.1	0.1	–
Share of public capital $1-\alpha_{1T}-\alpha_{2T}-\alpha_{3T}, 1-\alpha_{1T}^*-\alpha_{2T}^*-\alpha_{3T}^*$	0.1	0.1	–
Non tradable Intermediate Goods			
Substitution between factors of production $\xi_N, \xi_N^*, \xi_N^{**}$	0.90	0.90	0.90
Share of private capital $\alpha_{1N}, \alpha_{1N}^*, \alpha_{1N}^{**}$	0.3	0.3	0.3
Share of unrestricted HH's labor $\alpha_{2N}, \alpha_{2N}^*, \alpha_{2N}^{**}$	0.5	0.5	0.7
Share of restricted HH's labor $\alpha_{3N}, \alpha_{3N}^*$	0.1	0.1	–
Share of public capital $1-\alpha_{1N}-\alpha_{2N}-\alpha_{3N}, 1-\alpha_{1N}^*-\alpha_{2N}^*-\alpha_{3N}^*$	0.1	0.1	–
Final consumption goods			
Subst. btw. dom. and imported goods $\phi_A, \phi_A^*, \phi_A^{**}$	1.50	1.50	1.50
Bias towards domestic tradable goods a_H, a_F^*, a_G^{**}	0.68	0.59	0.90
Subst. btw. tradables and nontradables $\rho_A, \rho_A^*, \rho_A^{**}$	0.50	0.50	0.50
Bias towards tradable goods a_T, a_T^*, a_T^{**}	0.68	0.50	0.50
Final private investment goods			
Subst. btw. dom. and imported goods $\phi_E, \phi_E^*, \phi_E^{**}$	1.50	1.50	1.50
Bias towards domestic tradable goods $\upsilon_H, \upsilon_F^*, \upsilon_G^{**}$	0.50	0.49	0.90
Subst. btw. tradables and nontradables $\rho_E, \rho_E^*, \rho_E^{**}$	0.50	0.50	0.50
Bias towards tradable goods $\upsilon_T, \upsilon_T^*, \upsilon_T^{**}$	0.78	0.70	0.70
Final public investment goods			
Subst. btw. dom. and imported goods ϕ_A, ϕ_A^*	1.50	1.50	–
Bias towards domestic tradable goods a_H, a_F^*	0.68	0.59	–
Subst. btw. tradables and nontradables ρ_A, ρ_A^*	0.50	0.50	–
Bias towards tradable goods a_T, a_T^*	0.68	0.50	–
Tax rates			
Labor tax τ^l, τ^{l*}	0.426	0.346	0.346
Capital tax τ^k, τ^{k*}	0.349	0.259	0.259
Consumption tax τ^c, τ^{c*}	0.168	0.203	0.203

Note: H=Home;REA=rest of the euro area; RW= rest of the world. "*" refers to REA, "**" to RW

Table 2: Gross Mark-ups.

	Mark-ups and Elasticities of Substitution		
	Tradables	nontradables	Wages
H	1.08 ($\theta_T = 13.32$)	1.29 ($\theta_N = 4.44$)	1.60 ($\psi = 2.65$)
REA	1.11 ($\theta_T^* = 10.15$)	1.24 ($\theta_N^* = 5.19$)	1.33 ($\psi^* = 4$)
RW	1.11 ($\theta_T^{**} = 10.15$)	1.24 ($\theta_N^{**} = 5.19$)	1.33 ($\psi^{**} = 4$)

Note: H=Home; REA=rest of the euro area; RW= rest of the world. "*" refers to REA, "**" to RW

Table 3: Real and Nominal Adjustment Costs.

Parameter	H	REA	RW
Real Adjustment Costs			
Investment ϕ_I, ϕ_I^*,ϕ_I^{**}	7.50	7.50	7.50
Adjustment Costs on bonds			
Households' long-term bond positions ϕ_{b^L}, $\phi_{b^L}^*$	0.00047	0.0008	–
Households' short-term private bond positions			
ϕ_{b1}, ϕ_{b1}^{**}	0.0015	–	0.0015
ϕ_{b2}, ϕ_{b2}^{**}	0.003	–	0.003
Nominal Adjustment Costs			
Wages κ_W, κ_W^*, κ_W^{**}	400	400	400
Home produced tradables κ_H, k_H^* k_H^{**}	400	400	50
REA produced tradables κ_H, k_H^* k_H^{**}	400	400	50
RW produced tradables κ_H, k_H^* k_H^{**}	50	50	400
Non-tradables κ_N, κ_N^*, κ_N^{**}	600	600	600

Note: H=Home; REA=rest of the euro area; RW= rest of the world. "* " refers to REA, "** " to RW

Table 4: Fiscal and Monetary Policy Rules.

Parameter	H	REA	EA	RW
Fiscal policy rule				
$\phi_1, \phi_1^*, \phi_1^{**}$	1.01	1.01	-	1.01
Common monetary policy rule	-	-		
Lagged interest rate ρ_R, ρ_R^{**}	-	-	0.92	0.92
Inflation ρ_Π, ρ_Π^{**}	-	-	1.70	1.70
GDP growth $\rho_{GDP}, \rho_{GDP}^{**}$	-	-	0.10	0.10

Note: H=Home; REA=rest of the euro area; RW= rest of the world. "* " refers to REA, "** " to RW

Table 5: Main macroeconomic variables (ratio to GDP).

	H	REA	RW
Macroeconomic variables			
Private consumption	63.3	60.7	60.2
Public consumption	20.0	20.0	20.0
Private investment	14.1	16.8	17.2
Public investment	3.0	3.0	0.0
Imports	27.2	19.1	4.8
Net Foreign Asset Position	0.0	0.0	0.0
GDP (share of world GDP)	2.5	19.1	78.4
Short-term public debt (ratio to annual GDP)	13.2	8.0	–
Long-term public debt (ratio to annual GDP)	121.3	93.3	–

Note: H=Home; REA=rest of the euro area; RW= rest of the world.

Table 6: Public investment increase and FG.

	Home increase			Home increase+FG			EA increase			EA increase+FG		
	1st	2nd	LR	1st	2nd	LR	1st	2nd	LR	1st	2nd	LR
Home												
GDP	0.68	0.80	1.54	0.73	0.85	1.54	0.94	1.04	1.70	1.94	2.20	1.84
Inflation	-0.07	-0.16	0.04	-0.03	-0.13	0.04	0.19	0.09	-0.04	1.13	0.79	-0.04
Short-term interest rate	0.01	0.01	0.00	0.00	0.00	0.00	0.11	0.18	-0.09	0.00	0.00	-0.09
Long-term interest rate	0.13	0.15	0.07	0.13	0.14	0.06	0.14	0.14	-0.02	0.02	0.03	-0.06
Consumption	-0.07	-0.06	1.00	-0.03	-0.01	1.01	0.12	0.20	1.38	0.97	1.28	1.53
Investment	-0.55	-1.06	1.76	-0.44	-0.90	1.75	-0.28	-0.63	2.63	1.90	2.54	2.47
Export	-0.02	0.35	1.97	0.03	0.39	1.98	0.46	0.66	2.21	1.59	1.52	2.43
Import	1.17	0.90	0.31	1.21	0.95	0.31	1.32	1.20	1.16	2.09	2.31	1.15
Labor	0.69	0.35	0.15	0.77	0.43	0.15	1.12	0.74	0.17	2.75	2.47	0.16
Real wage	0.14	0.35	1.03	0.14	0.36	1.03	0.15	0.41	1.33	0.10	0.46	1.45
Real exch. rate Home-REA	0.01	0.03	0.18	0.01	0.04	0.18	0.00	0.01	0.04	0.02	0.05	0.05
Real exch. rate Home-RW	0.01	0.05	0.31	0.04	0.07	0.31	0.11	0.11	0.39	0.70	0.38	0.44
Public deficit	1.00	1.08	-0.44	0.97	1.05	-0.43	0.89	0.95	-0.50	0.34	0.28	-0.25
Public debt	-1.53	-0.49	3.80	-1.59	-0.64	3.63	-2.17	-1.47	2.38	-3.43	-4.59	-0.89
REA												
GDP	0.01	-0.00	0.01	0.06	0.05	0.01	0.86	0.91	1.52	1.84	1.93	1.62
Inflation	0.00	0.00	0.00	0.05	0.04	0.00	0.24	0.13	-0.05	1.32	0.87	-0.05
Long-term interest rate	0.00	0.00	-0.00	0.00	0.00	-0.00	0.14	0.15	-0.02	0.04	0.05	-0.05
Real exch. rate REA-RW	-0.03	-0.01	0.02	0.11	0.04	0.03	0.53	0.47	1.68	3.43	1.54	1.84
Public deficit	0.01	0.01	-0.00	-0.01	-0.00	0.00	0.92	0.98	-0.49	0.44	0.41	-0.29
Public debt	-0.04	-0.02	-0.04	-0.10	-0.14	-0.10	-1.51	-0.72	2.78	-2.63	-3.33	0.37

Note: Home increase is 1% (of Home steady-state GDP) increase in the Home public investment. EA increase is a 1% (of steady-state EA GDP) increase in EA-wide public investment. FG represents a EA monetary policy rate kept at its baseline level during the first two years. Average values are reported. 1st= 1st year; 2nd= 2nd year; LR=long run (10 year). REA=rest of the EA. All variables are % dev. from steady state; inflation, interest rate, public deficit/GDP and public debt/(4*GDP) as % point dev. from steady state. For real exchange rates, +=depreciation.

Table 7: EA public investment, FG, and PSPP.

	EA increase			EA increase+FG			FG and PSPP		
	1st	2nd	LR	1st	2nd	LR	1st	2nd	LR
Home									
GDP	0.94	1.04	1.70	1.94	2.20	1.84	3.03	3.55	2.63
Inflation	0.19	0.09	-0.04	1.13	0.79	-0.04	2.14	1.65	-0.06
Short-term interest rate	0.11	0.18	-0.09	0.00	0.00	-0.09	0.00	0.00	-0.04
Long-term interest rate	0.14	0.14	-0.02	0.02	0.03	-0.06	-0.45	-0.45	-0.34
Consumption	0.12	0.20	1.38	0.97	1.28	1.53	1.96	2.59	2.09
Investment	-0.28	-0.63	2.63	1.90	2.54	2.47	5.40	8.63	4.45
Export	0.46	0.66	2.21	1.59	1.52	2.43	2.53	2.11	3.46
Import	1.32	1.20	1.16	2.09	2.31	1.15	3.40	4.43	1.72
Labor	1.12	0.74	0.17	2.75	2.47	0.16	4.56	4.50	0.33
Real wage	0.15	0.41	1.33	0.10	0.46	1.45	0.09	0.57	1.99
Real exch. rate Home-REA	0.00	0.01	0.04	0.02	0.05	0.05	0.04	0.09	0.06
Real exch. rate Home-RW	0.11	0.11	0.39	0.70	0.38	0.44	1.17	0.53	0.64
Public deficit	0.89	0.95	-0.50	0.34	0.28	-0.25	-0.61	-0.83	-0.08
Public debt	-2.17	-1.47	2.38	-3.43	-4.59	-0.89	-1.67	-5.32	-6.68
REA									
GDP	0.86	0.91	1.52	1.84	1.93	1.62	2.92	3.15	2.34
Inflation	0.24	0.13	-0.05	1.32	0.87	-0.05	2.49	1.80	-0.07
Long-term interest rate	0.14	0.15	-0.02	0.04	0.05	-0.05	-0.42	-0.41	-0.32
Real exch. rate REA-RW	0.53	0.47	1.68	3.43	1.54	1.84	5.68	1.96	2.71
Public deficit	0.92	0.98	-0.49	0.44	0.41	-0.29	-0.37	-0.51	-0.14
Public debt	-1.51	-0.72	2.78	-2.63	-3.33	0.37	-1.45	-4.20	-4.11

Note: EA public investment increase is a 1% (of EA steady-state GDP) increase in EA-wide public investment. FG represents a EA monetary policy rate kept at its baseline level during the first two years. PSPP is the implementation of the Public Sector Purchase Programme. Average values are reported. 1st= 1st year; 2nd= 2nd year; LR=long run (10 year). REA=rest of the EA. All variables as % dev. from steady state; inflation, interest rate, public deficit/GDP and public debt/(4*GDP) as % point dev. from steady state. For real exchange rates, +=depreciation.

Table 8: EA public investment with distortionary taxes and monetary accommodation.

	EA increase+FG			Tax increase			Monetary accommodation		
	1st	2nd	LR	1st	2nd	LR	1st	2nd	LR
Home									
GDP	1.94	2.20	1.84	1.60	1.71	1.88	2.30	2.65	2.13
Inflation	1.13	0.79	-0.04	0.91	0.64	-0.05	1.47	1.09	-0.02
Short-term interest rate	0.00	0.00	-0.09	0.00	0.00	-0.08	0.00	0.00	-0.05
Long-term interest rate	0.02	0.03	-0.06	-0.06	-0.07	-0.10	-0.15	-0.15	-0.22
Consumption	0.97	1.28	1.53	0.72	0.92	1.53	1.35	1.80	1.81
Investment	1.90	2.54	2.47	0.74	0.76	3.07	3.12	4.72	3.40
Export	1.59	1.52	2.43	1.21	1.06	2.44	1.84	1.61	2.69
Import	2.09	2.31	1.15	1.73	1.77	1.32	2.59	3.16	1.52
Labor	2.75	2.47	0.16	2.21	1.78	0.18	3.36	3.18	0.25
Real wage	0.10	0.46	1.45	0.15	0.53	1.48	0.09	0.49	1.63
Real exch. rate Home-REA	0.02	0.05	0.05	0.02	0.04	0.04	0.03	0.06	0.05
Real exch. rate Home-RW	0.70	0.38	0.44	0.56	0.29	0.43	0.83	0.40	0.47
Public deficit	0.34	0.28	-0.25	-0.63	-0.68	-0.00	-0.00	-0.16	-0.30
Public debt	-3.43	-4.59	-0.89	-2.63	-4.29	-3.67	-2.79	-4.75	-3.62
REA									
GDP	1.84	1.93	1.62	1.50	1.48	1.69	2.19	2.34	1.90
Inflation	1.32	0.87	-0.05	1.07	0.71	-0.06	1.71	1.20	-0.04
Long-term interest rate	0.04	0.05	-0.05	-0.05	-0.05	-0.09	-0.12	-0.13	-0.21
Real exch. rate REA-RW	3.43	1.54	1.84	2.71	1.13	1.84	4.03	1.52	1.98
Public deficit	0.44	0.41	-0.29	-0.53	-0.55	-0.02	0.15	0.05	-0.32
Public debt	-2.63	-3.33	0.37	-2.11	-3.44	-2.43	-2.18	-3.56	-1.90

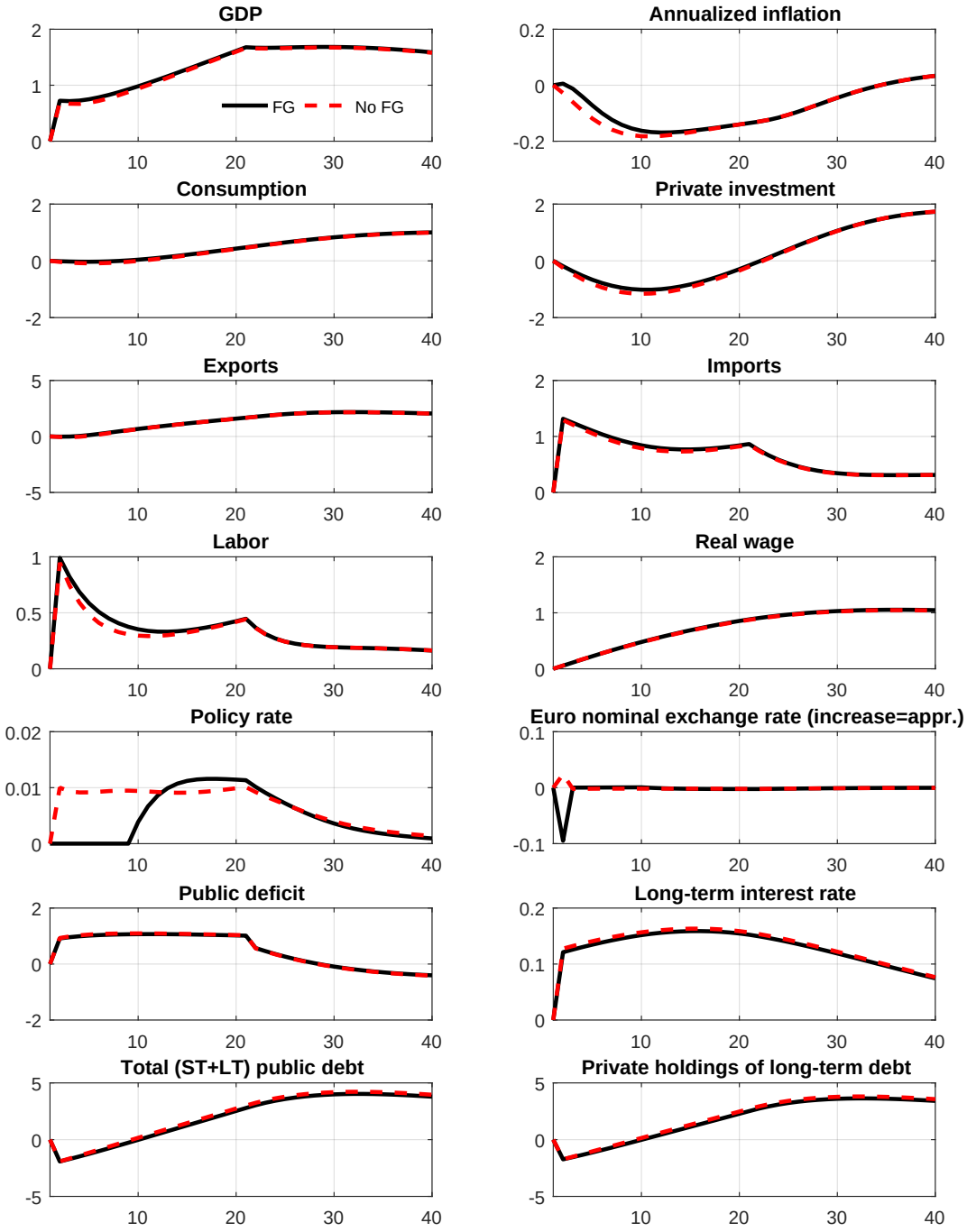
Note: EA public investment increase is a 1% (of EA steady-state GDP) increase in EA-wide public investment. FG represents a EA monetary policy rate kept at its baseline level during the first two years. Tax increase is a symmetric increase of labor, capital, and consumption tax rates whose combined fiscal revenue corresponds to 1% of initial GDP. Monetary policy accommodation is the permanent roll-over of purchases of sovereign bonds by the central bank capable of maintaining the balance sheet of the central bank equal to the total increase in public investment; interest income received by the central bank is transferred back to the government. Average values are reported. 1st= 1st year; 2nd= 2nd year; LR=long run (10 year). REA=rest of the EA. All variables as % dev. from steady state; inflation, interest rate, public deficit/GDP and public debt/(4*GDP) as % point dev. from steady state. For real exchange rates, +=depreciation.

Table 9: EA public investment and PSPP: no-public capital accumulation and time-to-build.

	FG and PSPP			No-public capital acc.			Time-to-build		
	1st	2nd	LR	1st	2nd	LR	1st	2nd	LR
Home									
GDP	3.03	3.55	2.63	1.89	1.94	0.54	1.53	1.86	2.22
Inflation	2.14	1.65	-0.06	1.32	1.12	-0.02	1.51	1.34	-0.15
Short-term interest rate	0.00	0.00	-0.04	-0.00	-0.00	0.06	0.00	0.00	0.10
Long-term interest rate	-0.45	-0.45	-0.34	-0.35	-0.34	-0.19	-0.36	-0.35	-0.24
Consumption	1.96	2.59	2.09	0.92	1.04	0.21	1.29	1.61	1.37
Investment	5.40	8.63	4.45	3.78	5.93	1.17	4.26	6.55	3.76
Export	2.53	2.11	3.46	1.14	0.46	0.73	1.35	0.74	2.92
Import	3.40	4.43	1.72	2.66	3.32	0.33	1.73	2.81	1.54
Labor	4.56	4.50	0.33	3.06	2.91	0.13	2.50	2.78	0.35
Real wage	0.09	0.57	1.99	-0.04	0.10	0.36	-0.03	0.16	1.55
Real exch. rate Home-REA	0.04	0.09	0.06	0.02	0.04	0.02	0.02	0.05	0.05
Real exch. rate Home-RW	1.17	0.53	0.64	0.54	0.13	0.15	0.70	0.22	0.53
Public deficit	-0.61	-0.83	-0.08	-0.09	-0.13	-0.04	-0.89	-0.88	0.08
Public debt	-1.67	-5.32	-6.68	-0.25	-2.11	-1.54	-0.29	-3.59	-3.74
REA									
GDP	2.92	3.15	2.34	1.82	1.71	0.48	1.50	1.66	2.06
Inflation	2.49	1.80	-0.07	1.49	1.19	-0.02	1.70	1.40	-0.12
Long-term interest rate	-0.42	-0.41	-0.32	-0.32	-0.31	-0.18	-0.33	-0.32	-0.23
Real exch. rate REA-RW	5.68	1.96	2.71	2.59	0.28	0.62	3.42	0.73	2.35
Public deficit	-0.37	-0.51	-0.14	0.10	0.09	-0.11	-0.74	-0.66	0.01
Public debt	-1.45	-4.20	-4.11	-0.25	-1.55	-0.06	-0.48	-3.05	-1.79

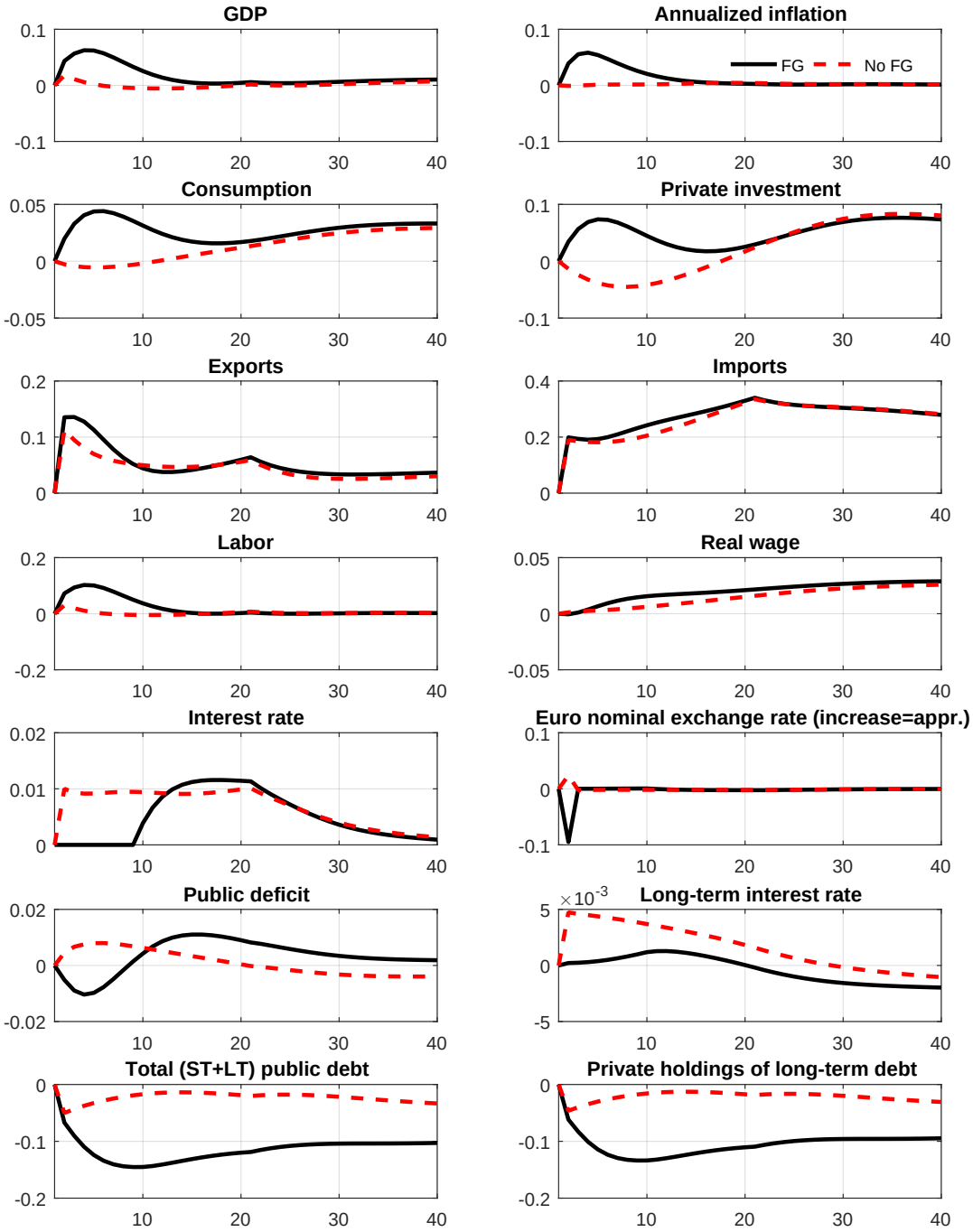
Note: EA public investment increase is a 1% (of EA steady-state GDP) increase in EA-wide public investment. FG is a EA monetary policy rate kept at its baseline level during the first two years. PSPP is the implementation of the Public Sector Purchase Programme. No-public capital accumulation is an increase in public spending without the corresponding accumulation of public capital. Time-to-build is a delay of five years before the transformation of public investment into accumulation of public capital. Average values are reported. 1st= 1st year; 2nd= 2nd year; LR=long run (10 year). REA=rest of the EA. All variables as % dev. from steady state; inflation, interest rate, public deficit/GDP and public debt/(4*GDP) as % point dev. from steady state. For real exchange rates, +=depreciation.

Figure 1: Home public investment and FG. Home variables



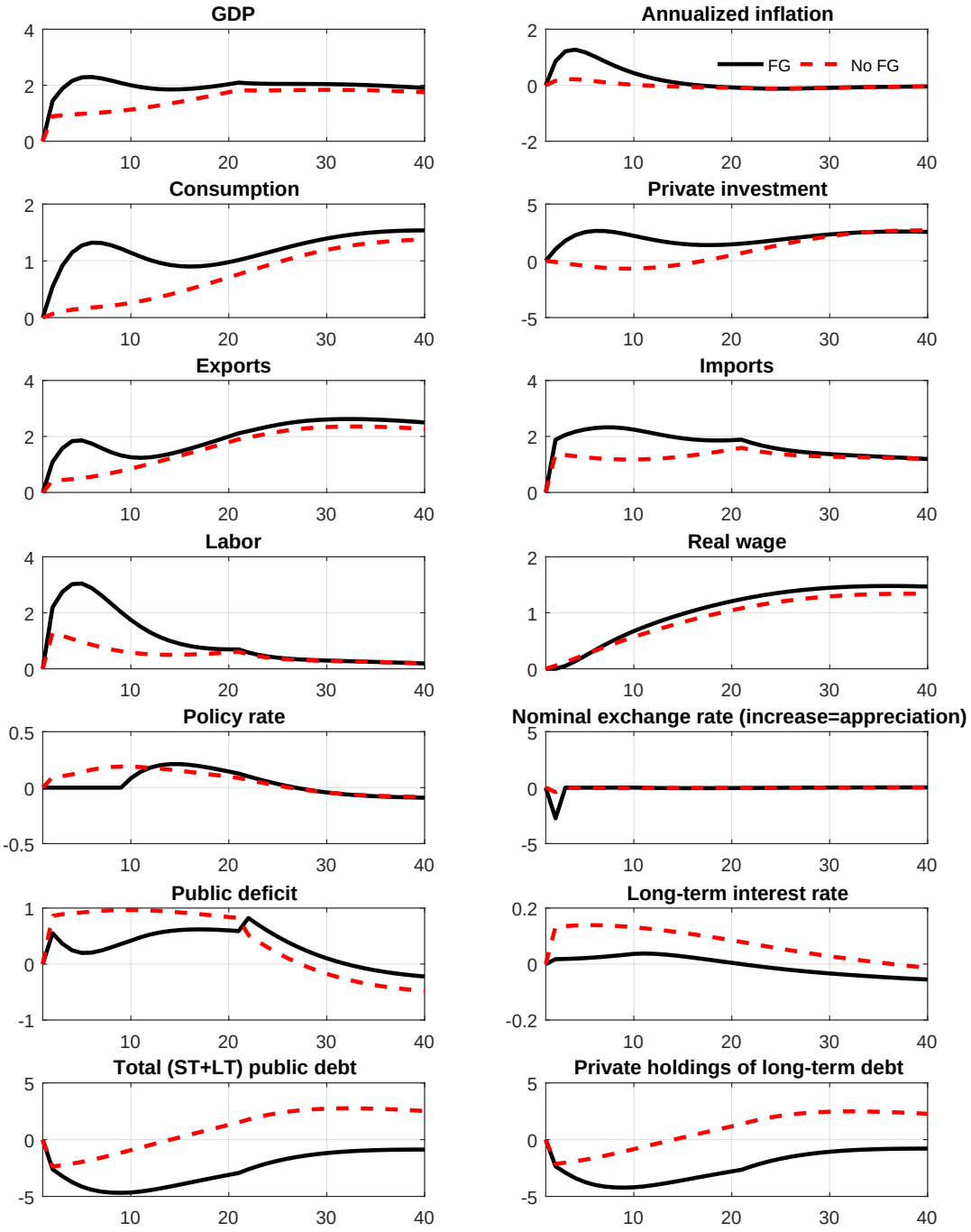
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline. GDP and its components are both evaluated at constant (steady-state) prices. Inflation and interest rates are reported in annualized p.p., public deficit as ratio to GDP, public debt as a ratio to annualized GDP (all as deviations from the baseline).

Figure 2: Home public investment and FG. REA variables.



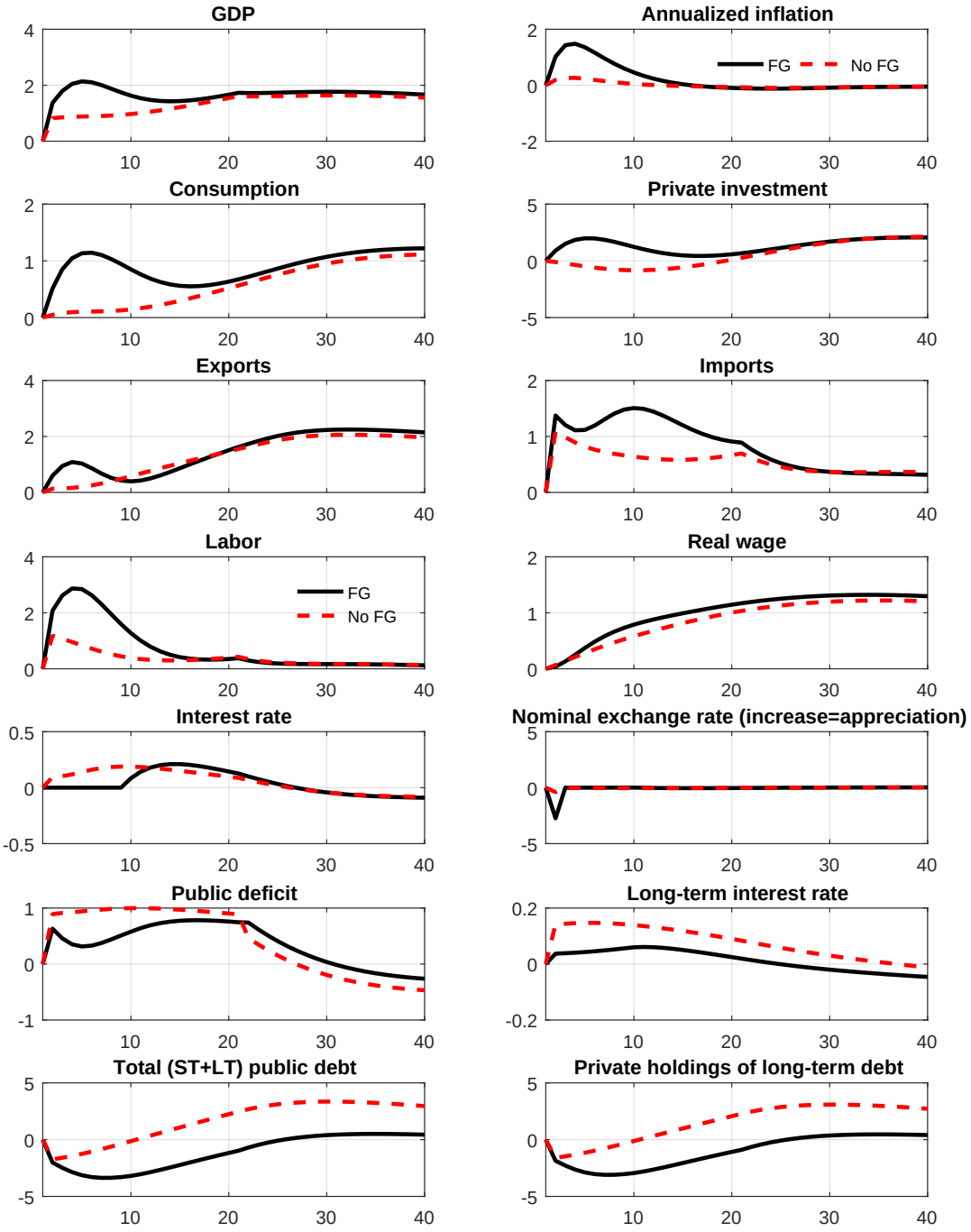
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline. GDP and its components are both evaluated at constant (steady-state) prices. Inflation and interest rates are reported in annualized p.p., public deficit as ratio to GDP, public debt as a ratio to annualized GDP (all as deviations from the baseline).

Figure 3: EA public investment and FG. Home variables.



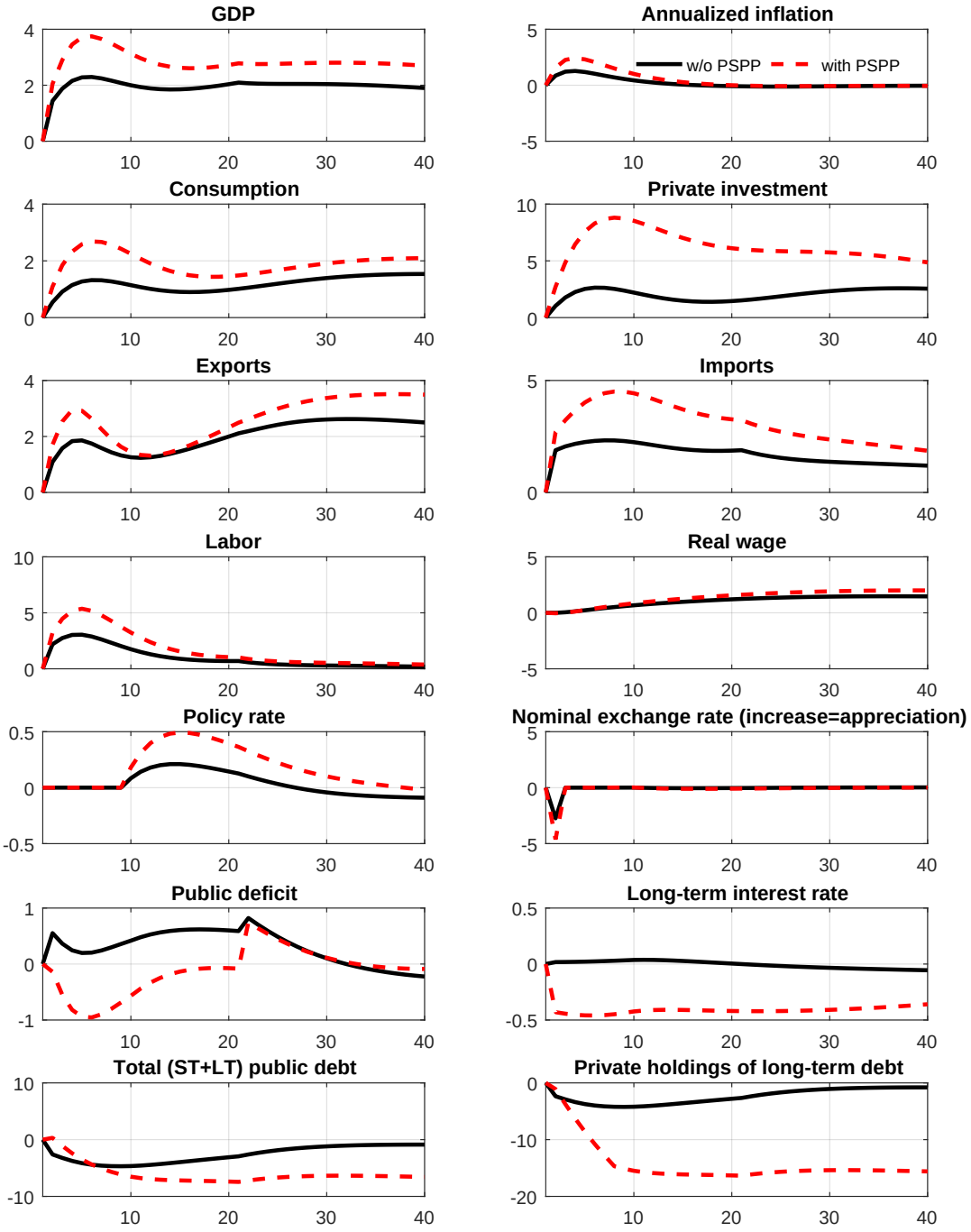
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline. GDP and its components are both evaluated at constant (steady-state) prices. Inflation and interest rates are reported in annualized p.p., public deficit as ratio to GDP, public debt as a ratio to annualized GDP (all as deviations from the baseline).

Figure 4: EA public investment and FG. REA variables.



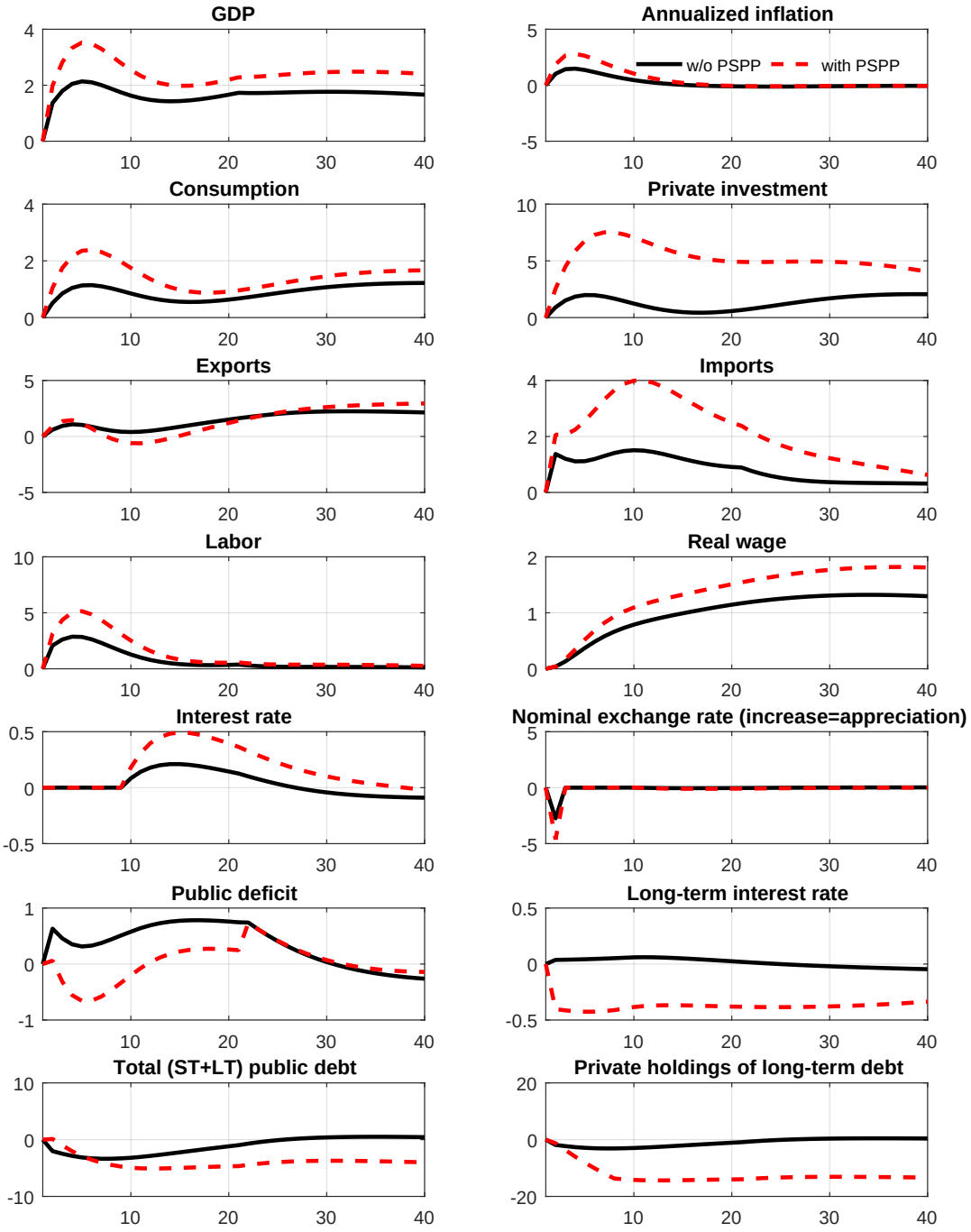
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline. GDP and its components are both evaluated at constant (steady-state) prices. Inflation and interest rates are reported in annualized p.p., public deficit as ratio to GDP, public debt as a ratio to annualized GDP (all as deviations from the baseline).

Figure 5: EA public investment, FG and PSPP. Home variables.



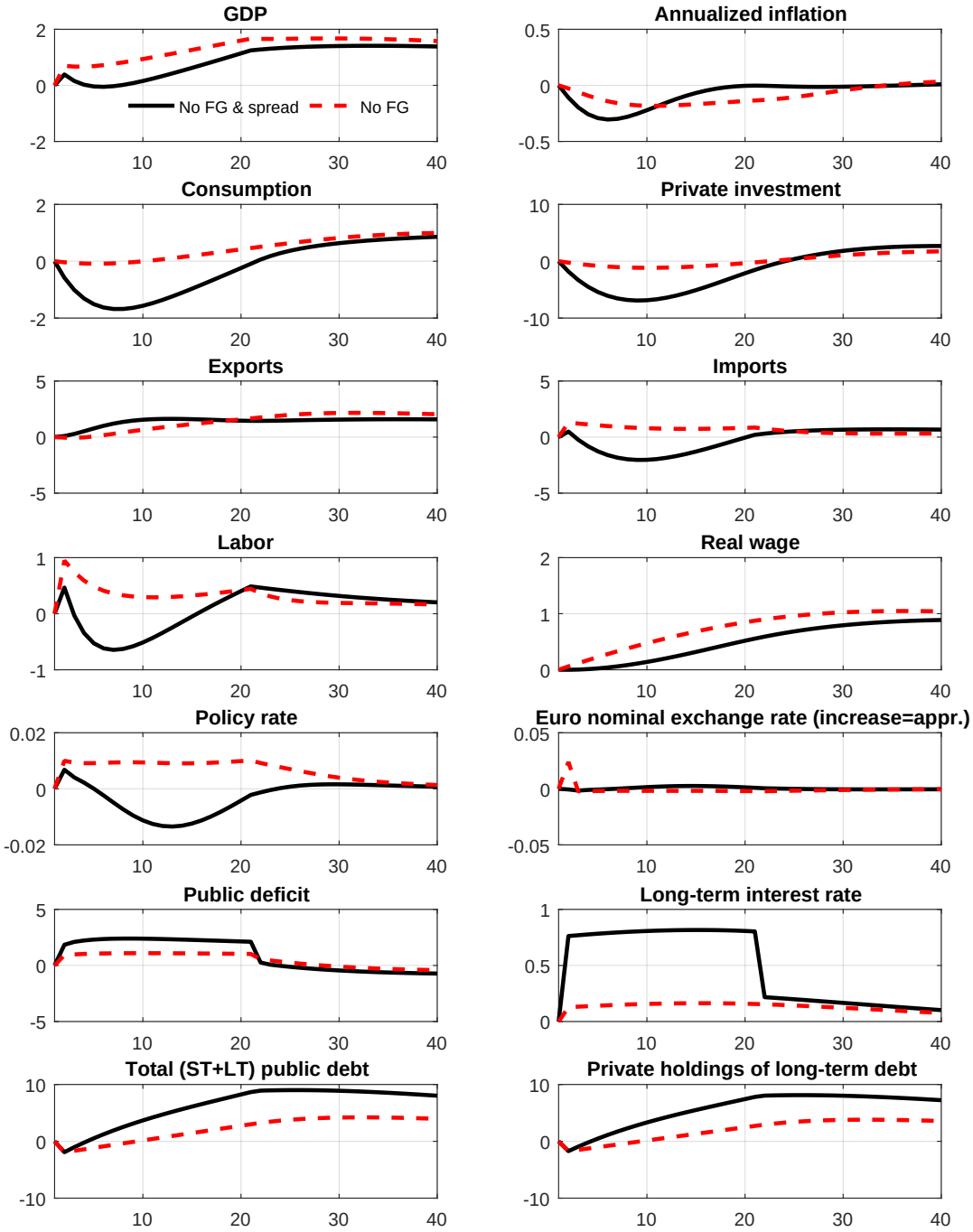
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline. GDP and its components are both evaluated at constant (steady-state) prices. Inflation and interest rates are reported in annualized p.p., public deficit as ratio to GDP, public debt as a ratio to annualized GDP (all as deviations from the baseline).

Figure 6: EA public investment, FG and PSPP. REA variables.



Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline. GDP and its components are both evaluated at constant (steady-state) prices. Inflation and interest rates are reported in annualized p.p., public deficit as ratio to GDP, public debt as a ratio to annualized GDP (all as deviations from the baseline).

Figure 7: Home public investment and spread. Home variables.



Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline. GDP and its components are both evaluated at constant (steady-state) prices. Inflation and interest rates are reported in annualized p.p., public deficit as ratio to GDP, public debt as a ratio to annualized GDP (all as deviations from the baseline).

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