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## FISCAL DSGE MODEL FOR LATVIA



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*ABBREVIATIONS*

AOB – alternating-offer bargaining  
AR(1) – auto-regression of order one  
CES – constant elasticity of substitution  
CPI – consumer price index  
DSGE – dynamic stochastic general equilibrium  
EA – euro area  
ECB – European Central Bank  
GDP – gross domestic product  
NAIRU – non-accelerating inflation rate of unemployment  
OECD – Organisation for Economic Co-operation and Development  
pp – percentage point  
SSC – social security contribution  
SVAR – structural vector auto-regression  
vs. – versus

**ABSTRACT**

We develop a fiscal DSGE model tailored to Latvia, a small open economy in a monetary union, for the purposes of policy simulation and scenario analysis. The fiscal sector elements comprise government investment, government consumption, government transfers that are asymmetrically directed to both optimizing and hand-to-mouth households, cyclical unemployment benefits, foreign ownership of government debt, import content in public consumption and investment, and fiscal rules for each fiscal instrument. The model features a search-and-matching labour market friction with pro-cyclical labour costs, a financial accelerator mechanism, and import content in final goods. We estimate the model using Latvian data, study the new channels in the model, and provide a comprehensive analysis on the macroeconomic effects of the fiscal elements. A particular finding is that having foreign-owned government debt generally breaks the Ricardian equivalence paradigm.

**Keywords:** small open economy, fiscal policy, fiscal rules, Bayesian estimation

**JEL codes:** E0, E2, E3, F4, H2, H3, H6

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## 1. INTRODUCTION

In times of monetary policy instruments having been stretched to their extreme, considerations for a more active role of fiscal policy have become increasingly widespread. Specifically, fiscal authorities have to decide on the level of the budget deficit and debt, as well as on the composition and size of budget revenue and expenditure. Thus, fiscal policy and its macroeconomic effects have recently received more attention in policy circles and economic research alike. In particular, budget-neutral reforms have been on the agenda of a number of European Union countries (e.g. Auerbach and Gorodnichenko (2017), Bussière et al. (2017)). Also, the Covid-19 crisis has required swift and bold government involvement. Therefore, it is of utmost importance for policy experts to be able to undertake simulations of fiscal policy in order to evaluate the macroeconomic and fiscal consequences for the country at hand.

In this paper, we develop a fiscal DSGE model for a small open economy in a monetary union and estimate it using Latvian data. We build on the policy model of Bušs (2017) designed for the Latvian economy, which features a large number of frictions. In this respect, this paper fills a void in that, before our model, there was no fiscal DSGE model for Latvia that would be used for policy simulation and scenario analysis exercises. Therefore, we introduce a fiscal block into the otherwise already estimated and field-tested DSGE model for Latvia, with the foreign economy being represented by a SVAR model.

The fiscal sector is developed along the following lines. The key government expenditure elements comprise utility-enhancing public consumption, public investment that increases private productivity, and transfers to two types of households (optimizing and restricted hand-to-mouth households). We model unemployment benefits separately from the rest of transfers due to their cyclicity and their role in the wage bargaining process. In the case of public investment and public consumption, a part of public goods is imported from abroad. The revenue side is composed of consumption taxes, labour income taxes, SSCs by both employers and employees, capital income taxes, and lump-sum taxes (levied solely on optimizing households). We also allow for foreign holdings of domestic government debt – a feature that is not standard in the literature and that alters the model behaviour. Fiscal rules describe the reaction of fiscal authorities to the output gap, to deviations of the debt-to-GDP ratio from its targeted level, and to debt-to-GDP ratio growth.

Apart from the fiscal sector, we also describe our approach of modelling pro-cyclical wages, an attribute that has been strongly present in the Latvian data, and that has already been used several times in economic and policy simulations at Latvijas Banka.

We estimate this model using Latvian data for the period from the second quarter of 1995 to the third quarter of 2018 using 28 observables, nine of which are fiscal time series. Given the model is made for policy simulations, which may require drawing alternative paths using conditional forecasts, we make sure the model fits the data dynamics well. Our pseudo real-time forecasting exercise suggests the model's empirical fit is adequate.

Subsequently, the model is used for simulating the macroeconomic effects of shocks to the various budget expenditure and revenue items. Our study reveals the following: (i) an increase in public investment expenditure induces a persistent increase in GDP

and aggregate consumption, while maintaining the crowding-in effect for private investment in short term; (ii) the positive effect of raising public consumption on GDP is rather short-lived, with private consumption being crowded out, in line with the substitution effect between private and public consumption goods; (iii) an increase in total transfers induces a positive effect on aggregate consumption mostly because the restricted households fully consume their extra income each period.

Also, we conduct a comprehensive analysis of the effects the specific parameter choices and model elements have on the propagation of shocks. Noteworthy results include (i) having foreign-held public debt alters the model behaviour; in particular, it increases the effects of a government sector risk premium shock on the economy, as a share of government interest payments leaves the country; also, it generally breaks the Ricardian equivalence in the case of transfers being exclusively directed to optimizing households with only the lump-sum tax rule being active, as borrowing money from abroad increases the total amount of money in the economy in the short term; as a result, the optimizing households use this money to buy foreign bonds; the sign of the reaction of consumption and investment depends on the specification of the domestic risk premium; (ii) modelling productive public capital is key to induce persistent effects in response to a shock in public investment expenditure; the extent of the persistence is controlled by the calibrated share of public capital in the aggregate capital bundle; (iii) having a higher share of transfers going to the restricted households increases the correlation between transfers and GDP, and (iv) having the import content in public consumption and public investment lowers – and in some cases makes more negative – the reaction of the domestic economy in response to government expenditure shocks.

We draw upon a few papers for choosing how to specify the fiscal sector in our model. First, we follow Coenen et al. (2013)'s extended New Area-Wide Model in adding restricted non-Ricardian households, public consumption (as a CES aggregate with private consumption), public investment and capital (as a CES aggregate with private capital and subject to a time-to-build friction), asymmetric government transfers to optimizing and restricted households. Differently from Coenen et al. (2013) and this paper, Clancy et al. (2014) and Schwarzmüller and Wolters (2014) model public capital as an additional input in the intermediate goods firms' production function, and thus public capital is not bundled together with private capital and the production function exhibits increasing returns to scale.<sup>1</sup>

Second, we allow for fiscal instruments to react to (i) deviations in debt-to-GDP ratio from its target, (ii) debt-to-GDP growth, and (iii) output gap. We also allow for both unanticipated and anticipated shocks in the fiscal rules, but leave only the unanticipated shocks active in estimation. As such, our specification is similar to that of Coenen et al. (2013) and Attinasi et al. (2019), but they do not allow for the debt-to-GDP growth term, and the latter does not allow for output gap term and anticipated shocks. Fiscal rules for public consumption and investment in Ratto et al. (2009) do not feature a reaction term for the debt-to-GDP ratio deviations and anticipated shocks but instead a reaction term for the investment-to-GDP ratio and consumption-to-GDP ratio.

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<sup>1</sup> We have experimented with this approach as well but saw little difference in model behaviour for appropriate calibrations.



Third, we follow Clancy et al. (2014) by incorporating import content in public consumption and investment. In their model, public goods are composed of both tradable and non-tradable goods. Differently from them, we do not differentiate between tradable and non-tradable goods. Therefore, the import content may affect the production of public goods more strongly in our model. Relatively high import content in government investment implies that an increase in public investment expenditure leads to a considerable increase in imports and thus a net outflow of funds that only eventually would be overcompensated for by the public capital accumulation effect.

Fourth, there is a large literature on endogenous term structures in DSGE models (e.g. van Binsbergen et al. (2012), Falagiarda and Marzo (2012), Horváth et al. (2017), Rudebusch and Swanson (2012)). However, these models are mostly used for closed economies, and since Latvia is a small open economy in a monetary union whose shocks do not influence monetary policy decisions at the union level, we assume that the domestic government bond yield is not fully endogenous. The domestic government bond yield is equal to the domestic nominal interest rate in the steady state. However, we assume that it is driven by government bond-specific exogenous shocks in order to take movements in government bond yield data better into account in the estimation of the model. Moreover, it can positively react to deviations of the government debt-to-GDP ratio to make it partly endogenous and also specific to the government debt dynamics in Latvia.

Finally, our approach for modelling foreign ownership of government debt, as well as the setup of pro-cyclical wages, are of our own making. Both of these features enrich the model's behaviour considerably.

The remainder of this study is structured as follows. Section 2 develops the fiscal DSGE model for Latvia. Section 3 gives the details about the calibration and estimation of the model, as well as reports the data fitting performance of the model. Section 4 inspects the model behaviour and various channels in terms of standardized shock simulations. Finally, Section 5 concludes.

## 2. MODEL

In this paper, we take the model of Bušs (2017), which builds on Bušs (2015) and Buss (2016), as a benchmark and extend it to include a detailed fiscal block. In the following subsection, we briefly describe the benchmark model and our setup in modelling pro-cyclical wages. This is followed by a detailed description of the fiscal sector model elements in Subsection 2.2.

### 2.1 The non-fiscal part of the model

#### 2.1.1 The previous version of the model

The model of Bušs (2017) consists of three main blocks: the core block, the financial frictions block, and the labour market block. We discuss them subsequently.

First, *the core block* is similar to Christiano et al. (2005) and Adolfson et al. (2008). There are three final goods – consumption, investment, and exports – which are produced by combining the domestic homogeneous good with specialized imports for each type of final good. Specialized domestic importers purchase the homogeneous

foreign good, which they turn into a specialized input and then sell to domestic import retailers. Therefore, there are also three types of import retailers. The first one uses specialized import goods to create the homogeneous good used as an input into the production of specialized exports. The second one uses specialized import goods to create an input used in the production of investment goods. The third type uses specialized imports to produce a homogeneous input used in the production of consumption goods. Exports are defined as a Dixit and Stiglitz (1977) aggregator of export goods varieties produced by a continuum of exporters, each of which is a monopolist that produces a specialized export good. Each monopolist produces its export good using a homogeneous, domestically produced good and a homogeneous good derived from imports. The homogeneous domestic good is produced by a competitive, representative firm. A part of the domestic good is lost due to real frictions in the model economy arising from investment adjustment and capital utilization costs.

Households maximize the expected lifetime utility from a discounted stream of consumption, subject to habit formation. In the core block, households own the economy's stock of physical capital. They determine the rate at which the capital stock is accumulated and the rate at which it is utilized. Households also own the stock of net foreign assets and determine the rate of the stock accumulation. Monetary policy is conducted exogenously due to Latvia being a member of the EA with a very small share of GDP in overall EA GDP. The foreign economy is modelled as a SVAR in EA output, inflation, nominal interest rate, and unit-root technology growth, as well as foreign demand, competitors' export price, and nominal effective exchange rate. The latter three variables were added in recent years due to the necessity to use the model in regular forecasting exercises (see Appendix B.1 for the foreign block equations). The model economy has one source of exogenous growth, which is the neutral technology growth, and it is identified using the EA data in the foreign economy block. Several fixed share parameters are subject to technology diffusion as in Schmitt-Grohé and Uribe (2012), and Christiano et al. (2010).

*The financial frictions block* adds Bernanke et al. (1999) financial accelerator mechanism to the model. Financial frictions allow for borrowers and lenders being different people that have different sets of information. Thus, the model introduces "entrepreneurs" who are agents with special skills in the operation and management of capital. Their skill in operating the capital is such that it is optimal for them to operate more capital than their own resources can support by borrowing additional funds. There is a financial friction, because managing capital is risky, i.e. entrepreneurs can go bankrupt, and only entrepreneurs observe their own idiosyncratic productivity without costs. In this setup, households deposit their money in banks (which are present only implicitly). The interest rate on household deposits is nominally non-state-contingent. Banks then lend funds to entrepreneurs using a standard nominal debt contract, which is optimal given the asymmetric information.<sup>2</sup> The amount that banks are willing to lend to an entrepreneur under this debt contract is a function of the entrepreneurial net worth. This is how balance sheet constraints enter the model. When a shock reducing the value of entrepreneurs' assets occurs, it cuts their ability to borrow. As a result, entrepreneurs acquire less capital and this

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<sup>2</sup> Namely, the equilibrium debt contract maximizes the expected entrepreneurial welfare, subject to the zero profit condition on banks and the specified return on household bank liabilities.



translates into a reduction in investment and leads to a slowdown in the economy. Although individual entrepreneurs are risky, banks are not.

The financial frictions block introduces two endogenous variables into the model: the spread between the interest rate paid by entrepreneurs and the risk-free interest rate, and entrepreneurial net worth. There are also two additional shocks: the first one is idiosyncratic uncertainty of entrepreneurs, and the second one is a shock to entrepreneurial survival probability or "entrepreneurial wealth" shock, as it directly affects entrepreneurial net worth.

*The labour market block* adds the labour market search and matching framework similar to Mortensen and Pissarides (1994), Hall (2005a; 2005b), Shimer (2005; 2012), and Christiano et al. (2016). There is no exogenously imposed wage rigidity, and all changes in the total hours worked are attributed to the extensive margin of labour supply. The model allows for both vacancy posting cost and hiring fixed cost, but only the latter is assumed in our benchmark calibration. The addition of the labour market block splits the production of intermediate goods into wholesaler and retailer blocks as in Christiano et al. (2016) and Buřs (2017). The wage bargaining process takes place between wholesaler firms and workers. Wholesalers produce the intermediate good using labour, which has a fixed marginal productivity of unity. This product of wholesalers is then purchased by retailers to produce specialized inputs for the production of the homogeneous domestic good. The previous version of the model (Buřs, 2017) used the alternating-offer wage bargaining setup, while our current model deviates from that as outlined in the next section.

### 2.1.2 Modelling wage pro-cyclicality

Some amendments have been made to the model since its published version in Buřs (2017), among which one is related to the wage bargaining process. Buřs (2017) used AOB mechanism of Christiano et al. (2016). Although the model could replicate the unemployment dynamics fairly well, the wages in Latvia have been highly pro-cyclical, thus being at odds with the relatively sticky wages of AOB.

Therefore, the current wage bargaining setup in the model is Nash wage bargaining without exogenously imposed wage rigidity but with pro-cyclical worker outside option, generating pro-cyclical wages. In particular, we use a standard Nash sharing rule:

$$J_t = \frac{1-\eta}{\eta} (V_t - U_t) \quad (1)$$

where  $J_t$  is the present value of a worker to a firm,  $V_t$  is the present value of a worker being matched with a firm,  $U_t$  is the present value of a worker being unemployed, and the parameter  $\eta$  is the bargaining power of the worker. In the present value of a worker being unemployed:

$$U_t = b_t^u + \beta E_t \psi_{z^+,t+1} / \psi_{z^+,t} (f_{t+1} V_{t+1} + (1 - f_{t+1}) U_{t+1}) \quad (2)$$

where  $\beta E_t \psi_{z^+,t+1} / \psi_{z^+,t}$  is the stochastic discount factor, and  $f_t$  is the job finding rate, the search-and-matching literature typically assumes that the present value of unemployment is constant (Christiano et al. (2010)) or a constant share of wage at time  $t$  (but as wages are typically modelled relatively acyclical, so is the worker outside option; see Jacquinot et al. (2018)).

Here, we deviate from the literature by assuming that  $b_t^u$  is endogenous and pro-cyclical, in particular, linked to the labour market conditions. The practical reason of doing so is that the pro-cyclical worker outside option is a simple mechanism generating pro-cyclical worker bargaining power, thus the much needed pro-cyclical wages. Although we fully acknowledge that this mechanism is not built from micro-foundations and that the true reasons for wage pro-cyclicality may be different (thus more work on this mechanism is justified), it can be reasoned that labour market conditions affect the outside option of a worker. When the labour market is slack – as in a downturn – a worker faces less options of finding a job elsewhere, thus his/her bargaining power is lower compared to normal or boom times, hence he/she might accept a lower wage at the current employer. And, vice versa, as the labour market tightens, firms increasingly compete for workers which is reflected in a higher bargaining power of a worker via his/her higher outside option; as a result, there is a pressure on labour costs. This mechanism assumes relatively frequent and decentralized wage re-negotiation, which may suit Latvia, as labour unions in Latvia are scarce.

This mechanism is formalized via linking the worker outside option to the labour market tightness<sup>3</sup>:

$$b_t^u = (b_{t-1}^u)^{\rho_{b^u}} (b^u)^{1-\rho_{b^u}} \left( \frac{1-L}{1-L_{t-1}} \right)^{(1-\rho_{b^u})\alpha^u} \exp(\varepsilon_{b^u,t}) \quad (3)$$

where the term in the large parentheses is the measure of labour market tightness, that is, the unemployment rate relative to the NAIRU, the latter being for simplicity assumed constant and equal to the steady state of unemployment rate. The parameter  $\alpha^u$  controls for the sensitivity of the worker bargaining power to the labour market conditions, the persistence parameter  $\rho_{b^u}$  allows for persistence in the worker outside option. This expression adds a new shock  $\varepsilon_{b^u,t}$  to the model, which we interpret as a wage cost-push shock. Note that in the resulting wage setting mechanism, there is no additionally-imposed wage frictions or indexation. Also note that it is straightforward to switch back to the standard Nash bargaining setup by calibrating  $\alpha^u = 0$ .

From the above expression, it is evident that the worker bargaining power and thus the pressure on wages exhibits a non-linear pattern – the higher is the deviation of the unemployment rate from NAIRU, the increasingly larger is its effect on worker bargaining power and wages. Thus, the mechanism is well-suited for simulating the effects of various policies on labour costs at different stages of a business cycle. For example, using the aforementioned modelling mechanism in its simulations, Latvijas Banka (2017) warns about economic overheating and its negative effects on competitiveness and a subsequent deeper economic downturn. Also, it was used in Latvijas Banka's internal assessment of the effects of the government's counter-measures to the Covid-19 crisis, as the measures occurred during the times when workers had limited bargaining power.

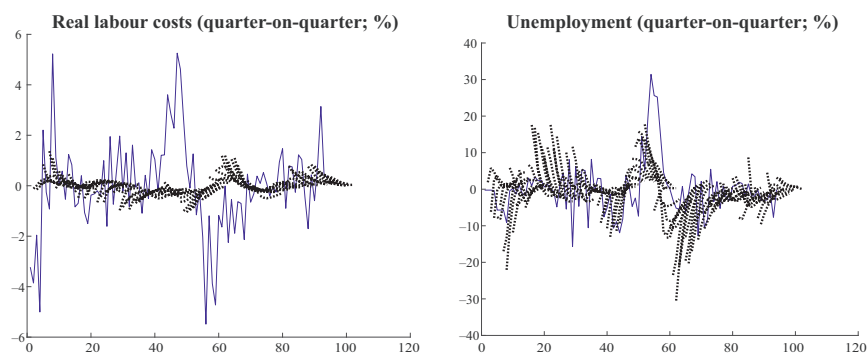
Besides, the use of this modelling approach results in a better data fit, as shown in Figure 1.

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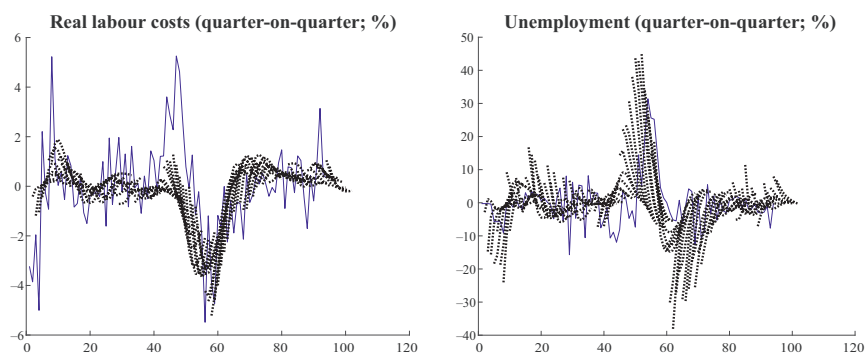
<sup>3</sup> In the codes, the expression is entered in its log form  
 $\log b_t^u = \rho_{b^u} \log b_{t-1}^u + (1 - \rho_{b^u}) \log b^u + (1 - \rho_{b^u}) \alpha^u (\log(1 - L) - \log(1 - L_{t-1})) + \varepsilon_{b^u,t}$ .

*Figure 1*  
**Data fit for constant vs. pro-cyclical worker outside option**

*Standard Nash bargaining with constant worker outside option*



*Nash bargaining with pro-cyclical worker outside option*



Notes. Data are in solid blue, iterated forecasts are in dotted black. Produced with a linearized model.

## 2.2 The fiscal block of the model

The fiscal block of the model comprises the following elements: public investment, public consumption, import content of public investment and consumption, asymmetric government transfers, with unemployment benefits being modeled separately, government debt, foreign ownership of government debt. There are six types of taxes – consumption tax, labour income tax, SSC by employer, SSC by employee, capital income tax, and a lump-sum tax. There are eight fiscal rules that determine fiscal policy. Moreover, we describe in detail the government budget constraint.

Specifically, public investment is used to build the public capital stock that is bundled together with private capital in a CES aggregate before being used in the production of intermediate goods. Building the public capital stock is subject to a time-to-build friction. However, in contrast to building private capital, we assume the absence of adjustment costs for building public capital. Hence, public investment is modelled as in Coenen et al. (2013). Additionally, we also follow the aforementioned paper in modelling public consumption. The households now obtain utility from a CES aggregate of public and private consumption. A fraction of both public investment and public consumption is imported from abroad, as in the fiscal-EAGLE model of Clancy et al. (2014). Hence, a fraction of total expenditure on public investment and public consumption is used to buy imported goods from specialized retailers. These

government retailers are different from the retailers for private investment and private consumption, with potentially different Calvo price stickiness parameters and market power. The imported goods are bundled in CES fashion with the domestic goods to form the usable public investment and public consumption goods.

Furthermore, we introduce another type of households into our model, namely, restricted (hand-to-mouth) households. These households just consume their disposable income and do not have access to any (financial or real) asset in the economy. Their income consists of private labour income, unemployment benefits, and other government transfers. The government transfers are asymmetric so that, in our baseline calibration, a larger share of them is received by the restricted households. These transfers are not taxed. Our modelling of asymmetric transfers is in spirit similar again to the modelling approach taken by Coenen et al. (2013). Unemployment benefits are modelled separately from the rest of transfers, as the former are cyclical and are part of the worker outside option.

In steady state, we fix the shares of government consumption expenditure, public investment expenditure, and government transfers to households as fractions of total government expenditure. Dynamically, these shares adjust according to the three expenditure fiscal rules we introduce in the model. These rules postulate that the government adjusts the government spending (directed to public investment, public consumption, and transfers) in response to deviations of the debt-to-GDP ratio from target, to debt-to-GDP ratio growth, and to the output gap.<sup>4</sup>

Furthermore, the government operates a fiscal deficit in the steady state that constitutes a steady-state debt level, which is used as a target value in the fiscal rules. Due to the assumed positive steady-state inflation rate and positive steady-state technology growth, a positive deficit in the steady state is congruent to a stationary debt-to-GDP ratio. The government collects labour taxes, SSCs, and consumption taxes from both households, as well as capital income taxes from entrepreneurs. With these revenues and a lump-sum tax levied on the optimizing households, the government finances the expenditures – public investment, public consumption, transfers, unemployment benefits, and debt interest payments.<sup>5</sup> To operate the fiscal debt, short-term domestic government bonds are issued. They are held by both the domestic optimizing households<sup>6</sup> and the rest of the world. As a result, a part of Latvian debt is held abroad which is taken into account by the current account equation in the model. Thus, interest payments on debt held abroad are lost to the Latvian economy.

Finally, five more fiscal rules, which are modelled in the same fashion as the aforementioned expenditure fiscal rules, are added to the model: a consumption tax rate rule, a labour income tax rate rule, SSC rules for employees and employers, and a lump-sum tax rule.

In the following subsections, the fiscal sector elements are described in detail. Firstly, we introduce public investment into the model. Secondly, public consumption is

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<sup>4</sup> See Bušs, Grüning and Tkačevs (forthcoming) "Choosing the European Fiscal Rule", for the fiscal rule specifications closer to the definitions by the European Commission.

<sup>5</sup> Additionally, there is wasteful spending, which is constant and exogenous, and has a role of a residual in the steady state.

<sup>6</sup> They need to pay quadratic adjustment costs for holdings in excess of an amount they can hold for free.

added. Thirdly, we describe the changes in the model regarding the labour block and labour taxes. Next, the government budget constraint is given alongside with the debt accumulation process and the fiscal rules that determine fiscal policy in the model. Finally, we conclude the description of the fiscal model elements by stating the aggregate resource constraint and the current account.

### 2.2.1 Government investment

To incorporate public investment and capital, the capital used in the production function of intermediate goods is given by a CES aggregate of private capital and public capital.<sup>7</sup> Building public capital is subject to a time-to-build fraction and needs to be fuelled by public investment expenditure, which is determined as an exogenous fraction of total government expenditure in the steady state and via a fiscal rule dynamically.

The production function of the  $j$ -th intermediate goods producer is:

$$Y_{j,t} = (z_t L_{j,t})^{1-\alpha} \varepsilon_t (\tilde{K}_{j,t})^\alpha - z_t^+ \phi \quad (4)$$

where  $L_{j,t}$  denotes the labour input,  $\phi$  is fixed cost of production,  $z_t, z_t^+$  are technology shocks, and the capital bundle  $\tilde{K}_t \equiv \tilde{K}_{j,t}$  is a CES aggregate of private capital  $K_t \equiv K_{j,t}$  and public capital  $K_{g,t}$ :

$$\tilde{K}_t = \left( \alpha_k^{\frac{1}{\nu_k}} (K_t)^{\frac{\nu_k-1}{\nu_k}} + (1 - \alpha_k)^{\frac{1}{\nu_k}} (K_{g,t})^{\frac{\nu_k-1}{\nu_k}} \right)^{\frac{\nu_k}{\nu_k-1}} \quad (5)$$

with elasticity of substitution denoted by  $\nu_k$  and weight on private capital denoted by  $\alpha_k$ . Private capital is subject to an endogenous utilization rate, i.e.  $K_t = u_t \bar{K}_t$  where  $\bar{K}_t$  is the total amount of capital in the economy. The amount of public capital accumulates according to the following equations where public investment  $G_{i,t}$  obeys a condition that incorporates a two-period lag in building public capital from public investment (instead of a one-period lag in building private capital):

$$K_{g,t+1} = (1 - \delta_g) K_{g,t} + A_{g,i,t-1}, \quad G_{i,t} = b_0 A_{g,i,t} + b_1 A_{g,i,t-1} \quad (6)$$

Public investment expenditure in the deterministic steady state is an exogenously specified fraction  $\tau_i^g$  of total government expenditure, and public investment expenditure is split into expenditure directed towards the domestic good and the imported public investment good (with price  $p_t^{m,g,i}$ ) as follows:

$$G_{i,ss}^{exp} = \tau_i^g G_{ss}, \quad G_{i,t}^{exp} = G_{i,t}^d + p_t^{m,g,i} G_{i,t}^m \quad (7)$$

Public investment is a CES aggregate of the domestic good  $G_{i,t}^d$  and the imported good  $G_{i,t}^m$ .

<sup>7</sup> As an alternative, we have experimented with public capital as an additional factor in the production function. Our preliminary results suggest that, with proper calibration, both specifications yield a similar model behaviour.

$$G_{i,t} = \left( (1 - \omega_{g,i})^{\frac{1}{\eta_{g,i}}} (G_{i,t}^d)^{\frac{\eta_{g,i}-1}{\eta_{g,i}}} + (\omega_{g,i})^{\frac{1}{\eta_{g,i}}} (G_{i,t}^m)^{\frac{\eta_{g,i}-1}{\eta_{g,i}}} \right)^{\frac{\eta_{g,i}}{\eta_{g,i}-1}} \quad (8)$$

where the fraction of imports is given by the constant  $\omega_{g,i}$  and the elasticity of substitution between the domestic good and the imported good is denoted by  $\eta_{g,i}$ . These imported public investment goods are produced by a specialized imports firm using a similar technology and yielding a similar demand condition as for private investment good imports:

$$G_{i,t}^m = \left[ \int_0^1 (G_{i,j,t}^m)^{\frac{1}{\lambda_{m,g,i}}} dj \right]^{\lambda_{m,g,i}}, \quad G_{i,j,t}^m = G_{i,t}^m (p_t^{m,g,i} / p_{j,t}^{m,g,i})^{\frac{\lambda_{m,g,i}}{1-\lambda_{m,g,i}}} \quad (9).$$

The total amount of this good imported is (for the trade balance):

$$S_t P_t^* R_t^{\nu,*} G_{i,t}^m (\dot{p}_t^{m,g,i})^{\frac{\lambda_{m,g,i}}{1-\lambda_{m,g,i}}} \quad (10)$$

where  $S_t$  is the nominal effective exchange rate. The non-linear pricing equations are:

$$0 = E_t \left[ \psi_{z^+,t} p_t^{m,g,i} g_{i,t}^m + (\tilde{\pi}_{t+1}^{m,g,i} / \pi_{t+1}^{m,g,i})^{\frac{1}{1-\lambda_{m,g,i}}} \beta \xi_{m,g,i} F_{m,g,i,t+1} - F_{m,g,i,t} \right] \quad (11),$$

$$0 = E_t \left[ \lambda_{m,g,i} \psi_{z^+,t} p_t^{m,g,i} m c_t^{m,g,i} g_{i,t}^m + (\tilde{\pi}_{t+1}^{m,g,i} / \pi_{t+1}^{m,g,i})^{\frac{\lambda_{m,g,i}}{1-\lambda_{m,g,i}}} \beta \xi_{m,g,i} K_{m,g,i,t+1} - K_{m,g,i,t} \right] \quad (12).$$

The first-order conditions with respect to private capital  $K_t \equiv K_{j,t}$  and labour demand  $L_t \equiv L_{j,t}$  in the cost minimization problem of the intermediate goods firm implies the following two conditions for the marginal cost function  $m c_t$  (after normalization):

$$\bar{r}_t^k = \frac{m c_t \alpha_k^{1/\nu_k} \varepsilon_t}{\tau_t^d} \left( \frac{\bar{k}_t}{\mu_{z^+,t} \mu_{\psi,t} L_t} \right)^{\alpha+1/\nu_k-1} \left( \frac{k_t}{\mu_{z^+,t} \mu_{\psi,t} L_t} \right)^{-1/\nu_k} \quad (13),$$

$$\bar{\omega}_t R_t^f = \frac{m c_t (1-\alpha) \varepsilon_t}{\tau_t^d} \left( \frac{\bar{k}_t}{\mu_{z^+,t} \mu_{\psi,t} L_t} \right)^\alpha \quad (14).$$

### 2.2.2 Government consumption

Government consumption expenditure adds to the utility of households by assuming that the utility bundle is a CES aggregate of private and government consumption.

Specifically, the optimizing household's preferences are given by the following lifetime utility function:

$$E_0 \left[ \sum_{t=0}^{\infty} \beta^t (\zeta_t^c \ln(\tilde{C}_t - b \tilde{C}_{t-1})) \right] \quad (15)$$

where the utility bundle is defined by the following CES aggregate of private consumption  $C_{o,t}$  and public consumption  $G_{c,t}$  (with elasticity of substitution  $\nu_c$  and weight on private consumption  $\alpha_c$ ):



$$\tilde{C}_t = \left( \alpha_c^{\frac{1}{v_c}} (C_{o,t})^{\frac{v_c-1}{v_c}} + (1 - \alpha_c)^{\frac{1}{v_c}} (G_{c,t})^{\frac{v_c-1}{v_c}} \right)^{\frac{v_c}{v_c-1}} \quad (16).$$

Government consumption expenditure  $G_{c,t}^{exp}$  in the deterministic steady state is calibrated to be a fraction  $\tau_c^g$  of total government expenditure. This expenditure is split into domestic goods purchase of public goods  $G_{c,t}^d$  and imported goods purchase of public goods  $p_t^{m,g,c} G_{c,t}^m$  as follows:

$$G_{c,ss}^{exp} = \tau_c^g G_{ss}, \quad G_{c,t}^{exp} = G_{c,t}^d + p_t^{m,g,c} G_{c,t}^m \quad (17).$$

Public consumption is a CES aggregate of the domestic good and the imported good:

$$G_{c,t} = \left( (1 - \omega_{g,c})^{\frac{1}{\eta_{g,c}}} (G_{c,t}^d)^{\frac{\eta_{g,c}-1}{\eta_{g,c}}} + (\omega_{g,c})^{\frac{1}{\eta_{g,c}}} (G_{c,t}^m)^{\frac{\eta_{g,c}-1}{\eta_{g,c}}} \right)^{\frac{\eta_{g,c}}{\eta_{g,c}-1}} \quad (18)$$

where  $\omega_{g,c}$  is the fraction of imports in public consumption, and the elasticity of substitution is denoted by  $\eta_{g,c}$ . Imported public consumption goods are produced by a specialized import firm using the same technology as the private consumption good import firm and yielding a similar demand condition:

$$G_{c,t}^m = \left[ \int_0^1 (G_{c,j,t}^m)^{\frac{1}{\lambda_{m,c}}} dj \right]^{\lambda_{m,c}}, \quad G_{c,j,t}^m = G_{c,t}^m (p_t^{m,g,c} / p_{j,t}^{m,g,c})^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} \quad (19).$$

The total amount of this imported good is (for the trade balance):

$$S_t P_t^* R_t^{v,*} G_{c,t}^m (\dot{p}_t^{m,g,c})^{\frac{\lambda_{m,g,c}}{1-\lambda_{m,g,c}}} \quad (20).$$

The non-linear pricing equations are:

$$0 = E_t \left[ \psi_{z^+,t} p_t^{m,g,c} g_{c,t}^m + \left( \frac{\tilde{\pi}_{t+1}^{m,g,c}}{\pi_{t+1}^{m,g,c}} \right)^{\frac{1}{1-\lambda_{m,g,c}}} \beta \xi_{m,g,c} F_{m,g,c,t+1} - F_{m,g,c,t} \right] \quad (21),$$

$$0 = E_t \left[ \lambda_{m,g,c} \psi_{z^+,t} p_t^{m,g,c} m_{c,t}^{m,g,c} g_{c,t}^m + \left( \tilde{\pi}_{t+1}^{m,g,c} / \pi_{t+1}^{m,g,c} \right)^{\frac{\lambda_{m,g,c}}{1-\lambda_{m,g,c}}} \beta \xi_{m,g,c} K_{m,g,c,t+1} - K_{m,g,c,t} \right] \quad (22).$$

The first order condition for choosing private consumption in the optimizing household's optimization problem is therefore given by:

$$\left( \frac{\zeta_t^c}{\tilde{c}_t - b\tilde{c}_{t-1} / \mu_{z^+,t}} - \beta b E_t \left[ \frac{\zeta_{t+1}^c}{\tilde{c}_{t+1} \mu_{z^+,t+1} - b\tilde{c}_t} \right] \right) \alpha_c^{\frac{1}{v_c}} C_{o,t}^{\frac{1}{v_c}} \tilde{C}_t^{\frac{1}{v_c}} - \psi_{z^+,t} p_t^c (1 + \tau_t^c) = 0 \quad (23).$$

### 2.2.3 Government transfers and restricted households

Government transfers (less unemployment benefits)  $TR_t$  to both optimizing and restricted (hand-to-mouth) households are also added to the model. These transfers are such that in the steady state they are an exogenously given percentage  $\tau_{tr}^g$  of total government expenditure:

$$TR_{SS} = \tau_{tr}^g G_{SS} \quad (24).$$

Dynamically, transfers follow a fiscal rule, specified in Subsection 2.2.5. These transfers are split into transfers to optimizing and restricted households. We assume that there is a share  $\lambda_r$  of restricted households so that the remaining share  $1 - \lambda_r$  is the mass of optimizing households. Total transfers are split according to the following distribution rule:

$$TR_t = \lambda_r TR_{r,t} + (1 - \lambda_r) TR_{o,t}, \quad \tau_r^{tr} \cdot TR_{o,t} = (1 - \tau_r^{tr}) TR_{r,t} \quad (25)$$

where  $TR_{r,t}$  denotes the transfers to restricted households and  $TR_{o,t}$  the transfers to optimizing households. The constant  $\tau_r^{tr}$  determines the fraction of transfers to restricted households. The restricted households do not optimize over their consumption and just consume their disposable income each period. Their budget constraint is therefore given by:<sup>8</sup>

$$(1 + \tau_t^c) p_t^c C_{r,t} = (1 - \tau_t^y - \tau_{w,t}^w) \bar{w}_t L_t + D_{b,t} (1 - L_t) + TR_{r,t} \quad (26).$$

The steady-state level of unemployment benefits per unemployed  $D_{b,t}$  is calibrated to be a share of steady-state gross wage,  $D_{b,t} = bshare \cdot \bar{w}_t$ . Dynamically, unemployment benefits per unemployed are endogenous and form a constant share of the worker outside option,  $D_{b,t} = bshare \cdot b_t^u / woo$ , where  $woo$  is the steady-state share of worker outside option in gross wage.

#### 2.2.4 Adjustments in the labour market block due to taxes

We distinguish between the SSCs paid by firms and the ones paid by households. Therefore, in the Nash wage bargaining problem, the present value of wages paid by a firm equals:

$$\bar{w}_t^p = (1 + \tau_{e,t}^w) \bar{w}_t + \rho \beta E_t [\psi_{z^+,t+1} / \psi_{z^+,t} \cdot \bar{w}_{t+1}^p] \quad (27)$$

where  $\tau_{e,t}^w$  denotes the employer SSC rate, which then enters the present value of a worker to a firm:

$$J_t = \vartheta_t^p - \bar{w}_t^p \quad (28)$$

where  $\vartheta_t^p$  stands for the present value of marginal revenue. And the present value of wages received by the worker is:

$$w_{p,t} = (1 - \tau_t^y - \tau_{w,t}^w) \bar{w}_t + \rho \beta E_t [\psi_{z^+,t+1} / \psi_{z^+,t} \cdot w_{p,t+1}] \quad (29)$$

where  $\tau_t^y$  denotes the labour income tax rate, and  $\tau_{w,t}^w$  stands for the employee SSC rate. It enters the present value of work to a worker:

$$V_t = w_{p,t} + A_t^w \quad (30)$$

where  $A_t^w$  is the present value of worker pay-off after separation.

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<sup>8</sup> Implicitly, we assume that the utility function of restricted households is the same as for optimizing households. In particular, public consumption enters into a CES bundle with private consumption for restricted households as well. However, the particular form of the utility function does not matter for the model's equilibrium.

The bargained gross wage  $\bar{w}_t$  is determined by maximizing the Nash product with respect to wage:

$$\max_{\bar{w}_t} (V_t - U_t)^\eta J_t^{1-\eta} \quad (31)$$

yielding the first-order condition

$$J_t = \frac{1+\tau_{e,t}^w}{1-\tau_t^y-\tau_{w,t}^w} \frac{1-\eta}{\eta} (V_t - U_t) \quad (32)$$

Thus, the presence of labour taxes affects the bargained outcome by altering the shares of surplus going to a worker and a firm.

### 2.2.5 Government budget, debt, and fiscal rules

Total government expenditure is a constant fraction  $\eta_g$  of GDP in the steady state. The total government expenditure consists of the government consumption expenditure, public investment expenditure, total transfers to households, unemployment benefits expenditure, and interest payments on debt. The residual part is wasteful government expenditure  $Z_t$ , which is given by the sum of a constant and an exogenous wasteful spending shock,  $Z_t = \bar{Z} + \varepsilon_{g,t}$ . This implies the following breakdown of total government expenditure:

$$G_t = G_{c,t}^{exp} + G_{i,t}^{exp} + TR_t + D_{b,t}(1 - L_t) + \ln(R_{g,t-1})/\pi_t \cdot D_{g,t-1} + Z_t \quad (33).$$

The debt interest rate  $R_{g,t}$  between time  $t$  and  $t + 1$  equals the foreign interest rate (i.e. Euribor) plus a government-specific risk premium:

$$R_{g,t} = \Phi_{g,t} R_t^* \quad (34),$$

$$\Phi_{g,t} = \ln(R_{ss}) - \ln(R_{ss}^*) - \tilde{\phi}_{g,a} \left( \frac{A_t}{Y_t} - \frac{A_{ss}}{Y_{ss}} \right) + \tilde{\phi}_{g,r} \left( \frac{D_{g,t}}{Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3}} - \overline{dgy} \right) + \varepsilon_{g,t}^{rp} \quad (35).$$

Above,  $A_t$  denotes the amount of foreign short-term (risk-free) bonds held by the domestic optimizing household between time  $t$  and time  $t + 1$ ,  $R_t^*$  is the foreign nominal (risk-free) interest rate,  $R_t$  is the domestic nominal (risk-free) interest rate,  $\varepsilon_{g,t}^{rp}$  is the government debt risk premium shock, and  $\tilde{\phi}_{g,a}$  and  $\tilde{\phi}_{g,r}$  are parameters controlling the sensitivity of the risk premium to the private sector's net foreign assets position and to deviations of the government debt-to-GDP ratio from target respectively. Specifically,  $\tilde{\phi}_{g,r} > 0$  allows to model a risk premium on government debt depending on the annual government debt-to-GDP ratio of the domestic economy, while  $\tilde{\phi}_{g,a} > 0$  allows for spillovers from the private sector's external debt to the public sector's risk premium.

On the revenue side, the government levies distortionary taxes on consumption  $\tau_t^c$ , capital income  $\tau_t^k$ , labour income  $\tau_t^y$ , as well as SSCs of employers  $\tau_{e,t}^w$  and employees  $\tau_{w,t}^w$ . The total tax revenue  $T_t$  from distortionary and lump-sum taxes  $T_{ls,t}$  is given by:<sup>9</sup>

<sup>9</sup> Lump-sum taxes are levied on optimizing households. If  $T_{ls,t}$  is negative, these are actually transfers.

$$T_t = \tau_t^c p_t^c (\lambda_r C_{r,t} + (1 - \lambda_r) C_{o,t}) + (\tau_t^y + \tau_{e,t}^w + \tau_{w,t}^w) L_t \bar{w}_t + \tau_t^k \bar{K}_t ((u_t \bar{r}_t^k - p_t^i a(u_t)) / (\mu_{\psi,t} \mu_{z^+,t}) - \delta p_t^i / (\pi_t \mu_{z^+,t})) + T_{ls,t}. \quad (36)$$

The government budget constraint is given by:

$$G_t = Deficit_{g,t} + T_t \quad (37)$$

where  $Deficit_{g,t}$  is the fiscal deficit at time  $t$ . Real government debt is governed by the following law of motion:

$$D_{g,t} = D_{g,t-1} / \pi_t + Deficit_{g,t} \quad (38).$$

The steady-state or target level of government debt is denoted by  $\overline{dgy}$ . Only a fraction  $\omega_h$  of government debt is held by domestic households in the steady state, the rest is held abroad. The variable  $B_{g,t-1}$  denotes domestic government debt holdings, and the variable  $B_{g,t-1}^*$  denotes foreign government debt holdings between time  $t-1$  and  $t$ . In particular, domestic households can hold an amount  $\bar{B}_g$  freely, and they need to pay quadratic adjustment costs  $\Gamma_{g,t} = 0.5\gamma_g (B_{g,t} - \bar{B}_g)^2 / \bar{B}_g$  at time  $t$  for deviating from this level. Therefore, government debt holdings evolve as follows:

$$D_{g,t} = B_{g,t} + B_{g,t}^*, \quad B_{g,ss} = \omega_h D_{g,ss} \quad (39).$$

The optimizing household's first order condition with respect to government debt holdings is equal to:

$$B_{g,t} = \left( 1 + \gamma_g^{-1} \left( E_t \left[ \frac{\beta \psi_{z^+,t+1}}{\psi_{z^+,t}} \frac{R_{g,t}}{\pi_{t+1} \mu_{z^+,t+1}} - 1 \right] \right) \right) \bar{B}_g \quad (40).$$

In steady state, total government expenditure is a constant fraction of output:

$$G_{ss} = \eta_g \cdot Y_{ss} \quad (41).$$

Dynamically, total government expenditure changes due to adjustments in the revenue or expenditure elements of the government budget. The adjustments in the revenue and expenditure elements are controlled by the following eight fiscal rules<sup>10</sup>, i.e. where  $X_t$  is an element of the set  $X = \{G_{i,t}^{exp}; G_{c,t}^{exp}; TR_t; \tau_t^c; \tau_t^y; \tau_{e,t}^w; \tau_{w,t}^w; T_{ls,t}\}$ :

$$\begin{aligned} \ln(X_t) = & (1 - \rho_x) \ln(X_{ss}) + \rho_x \ln(X_{t-1}) + (1 - \rho_x) \phi_{x,d} \left( \ln \left( \frac{D_{g,t}}{Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3}} \right) - \right. \\ & \left. \ln(\overline{dgy}) \right) + (1 - \rho_x) \phi_{x,dd} \left( \ln \left( \frac{D_{g,t}}{Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3}} \right) - \ln \left( \frac{D_{g,t-1}}{Y_{t-1} + Y_{t-2} + Y_{t-3} + Y_{t-4}} \right) \right) \\ & + (1 - \rho_x) \phi_{x,y} (\ln(Y_t) - \ln(Y_{ss})) + (1 - \psi_x) \varepsilon_{x,t} + \psi_x \varepsilon_{x,t-1} \end{aligned} \quad (42).$$

Therefore, the government adjusts the taxes or expenditures by reacting to the deviation of the debt-to-GDP ratio from the steady state (parameter  $\phi_{x,d}$ ) to the growth rate of the debt-to-GDP ratio (parameter  $\phi_{x,dd}$ ) and to the output gap (parameter  $\phi_{x,y}$ ). Moreover, the government allows for the smoothing of tax rates and

<sup>10</sup> Plus, optionally, by exogenous changes to wasteful government spending (suspended in estimation).

expenditures which is controlled by the parameter  $\rho_x$ . Finally, anticipated ( $\varepsilon_{x,t-1}$ ) or unanticipated ( $\varepsilon_{x,t}$ ) fiscal shocks may occur. The size of anticipated shocks relative to unanticipated shocks is controlled by the parameter  $\psi_x$ .

The capital income tax follows a simple AR(1) process for simulation purposes only and is not a part of estimation:

$$\ln(\tau_t^k) = (1 - \rho_{\tau,k})\ln(\tau^k) + \rho_{\tau,k}\ln(\tau_{t-1}^k) + \varepsilon_{\tau,k,t} \quad (43).$$

## 2.2.6 Aggregate resource constraint and current account

The domestic homogeneous final good is used for wasteful government expenditure, domestic part of public consumption expenditure, domestic part of private consumption, domestic part of public investment expenditure, domestic part of private investment, exports, and several frictional costs. The resource constraint is thus given by:

$$z_t^+(y_t - d_t) = Z_t + G_{c,t}^d + C_t^d + G_{i,t}^d + I_t^d + [\omega_x(p_t^{m,x})^{1-\eta_x} + (1 - \omega_x)]^{\frac{\eta_x}{1-\eta_x}}(1 - \omega_x)(\dot{p}_t^x)^{\frac{-\lambda_x}{\lambda_x-1}}(p_t^x)^{-\eta_x}Y_t^* \quad (44)$$

where

$$d_t = \frac{\mu G(\bar{\omega}_t; \sigma_{t-1})R_t^k p_{k,t-1} \bar{k}_t}{\pi_t \mu_{z^+,t}} + (n_{\kappa_v,t} \kappa_v Q_t^{-1} + n_{\kappa_h,t} \kappa_h) \chi_t L_{t-1} + \frac{\gamma_g (b_{g,t} - \bar{b}_g)^2}{2\bar{b}_g} \quad (45)$$

is a sum of entrepreneur monitoring costs, vacancy posting and recruitment costs, and bond adjustment costs. In the current account, we need to take into consideration that a part of government debt is held abroad and thus some funds, especially the interest payments on foreign-held debt, are flowing out of the country and are therefore lost to the domestic economy. At the same time, we require that net exports are zero in the steady state. In order to retain this property with the aforementioned new outflow of funds, we have to introduce a new transfer  $\bar{tr}_f$  from abroad<sup>11</sup>. This transfer is constant, received by the optimizing household, and just used to balance exports with imports in the steady state. The current account is balanced dynamically by adjustments in the optimizing household's holdings of foreign short-term risk-free bonds  $a_t$  and by adjustments in the net exports balance  $nx_t$ :

$$nx_t = exports_t - imports_t \quad (46)$$

$$\begin{aligned} &= q_t p_t^c p_t^x x_t - q_t p_t^c R_t^{v,*} \left( c_t^m (\dot{p}_t^{m,c})^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} + g_{c,t}^m (\dot{p}_t^{m,g,c})^{\frac{\lambda_{m,g,c}}{1-\lambda_{m,g,c}}} + i_t^m (\dot{p}_t^{m,i})^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} \right. \\ &\quad \left. + g_{i,t}^m (\dot{p}_t^{m,g,i})^{\frac{\lambda_{m,g,i}}{1-\lambda_{m,g,i}}} + x_t^m (\dot{p}_t^{m,x})^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}} \right) \end{aligned} \quad (47)$$

where  $q_t = S_t P_t / P_{c,t}$  is the real exchange rate. The definition of the current account is therefore:

<sup>11</sup> This transfer can vaguely proxy for the foreign transfers to Latvia, such as foreign direct investment, EU funds or remittances.

$$a_t + \frac{b_{g,t-1}^* R_{g,t-1}}{\pi_t \mu_{z^+,t}} = n x_t + \frac{a_{t-1} R_{t-1}^* \Phi_{t-1} s_t}{\pi_t \mu_{z^+,t}} + b_{g,t}^* + \overline{tr}_f \quad (48)$$

where  $s_t = S_t/S_{t-1}$  is nominal exchange rate growth.

### 3. CALIBRATION, ESTIMATION, AND DATA FIT

This section lays out our choices for the parameter calibration (see Subsection 3.1), our estimation approach and its results (see Subsection 3.2), and the data fit of our estimated model (see Subsection 3.3).

#### 3.1 Model calibration

One period in the model corresponds to a quarter. A subset of the model's parameters are calibrated and the rest are estimated using data for Latvia (domestic part) and the foreign economy.

We calibrate a subset of the parameters to ensure matching key ratios in the model and estimate the remaining parameters, as it is standard practice in estimating DSGE models. We relegate the information about the calibration of the non-fiscal part of the model to Appendix C, as the calibration of that part largely follows Bušs (2017). A few parameters from there are worth mentioning though. First, the share of restricted households is set to 50% in line with other DSGE models (e.g. Attinasi et al. (2019)), evidence from Latvian micro-level data, as well as from our exercises of fitting the model to the data.<sup>12</sup> Second, the unemployment benefit share of gross wage is set to 0.1 in order to match the unemployment benefit expenditure share in total government expenditures, which is roughly 1% in the recent years (before the Covid-19 recession). As a result, we differentiate between the steady-state level of unemployment benefit share and the worker outside option in the wage bargaining mechanism, as we estimate the steady state of the latter (with the posterior mode typically fluctuating around 0.5).

Moving to the fiscal block, its calibrated parameters are reported in Table 1. Consistent with Latvian data, the steady-state government spending share in GDP is 38%; therefore, we set  $\eta_g = 0.38$ . The steady-state target for the public debt to annual GDP ratio is set to 30%, a value consistent with the long-run average in the data. Also, this calibration implies that the steady-state deficit-to-GDP ratio is equal to about 0.9%, which aligns well with the recent historical data and with the medium-term objective for Latvia (structural balance to GDP share of up to -1%) set by the European Commission. A minor part of this debt is held domestically, i.e. within the Latvian economy, in the data, as most of Latvian government debt was bought by the European Commission and the International Monetary Fund during the great financial crisis. After the crisis, a slow upward trend in domestically-owned public debt share can be observed. Therefore, we assume that only 10% are held by an optimizing household in the model, i.e. we set  $\omega_h = 0.1$ .

<sup>12</sup> Our data fitting exercises suggest a 50%–60% share of restricted households.



*Table 1*  
**Calibrated parameters, fiscal block**

Parameter	Value	Description
<i>Fiscal block</i>		
$\eta_g$	0.3800	Steady-state government spending share per GDP
$\overline{dgy}$	0.3000	Target of government debt per annual GDP
$\omega_h$	0.1000	Share of government debt held domestically
$\tau^k$	0.1000	Steady-state capital income tax rate
$\tau_e^w$	0.1550	Steady-state employer SSC rate
$\tau_w^w$	0.0610	Steady-state employee SSC rate,
$\tau^c$	0.2100	Steady-state consumption tax rate
$\tau^y$	0.1640	Steady-state labour income tax rate
$\lambda_{m,g,c}$	1.0500	Price mark-up for imported public consumption good
$\lambda_{m,g,i}$	1.0500	Price mark-up for imported public investment good
$\omega_{g,c}$	0.1300	Import share in public consumption goods
$\omega_{g,i}$	0.4500	Import share in public investment goods
$\tau_r^{tr}$	0.7000	Transfer share going to hand-to-mouth households
$\tau_c^g$	0.4630	Steady-state share of government consumption expenditure in government spending
$\tau_i^g$	0.1170	Steady-state share of public investment expenditure in government spending
$\tau_{tr}^g$	0.3000	Steady-state share of transfers in government spending
$\alpha_k$	0.8500	Share of private capital in aggregate capital bundle
$b_0$	1.0000	Parameter in time-to-build technology of public capital
$b_1$	0.0000	Parameter in time-to-build technology of public capital
$10\tilde{\phi}_{g,r}$	0.0500	Sensitivity of public sector risk premium to deviations of public debt to GDP ratio
$\tilde{\phi}_{g,a}$	0.0000	Sensitivity of public sector risk premium to deviations of net foreign assets position
$\psi_{g,c}$	0.0000	Fiscal rule, total government consumption expenditure, anticipated shock fraction
$\psi_{g,i}$	0.0000	Fiscal rule, public investment expenditure, anticipated shock fraction
$\psi_{tr}$	0.0000	Fiscal rule, total transfers expenditure, anticipated shock fraction
$\psi_{\tau,c}$	0.0000	Fiscal rule, consumption tax rate, anticipated shock fraction
$\psi_{\tau,y}$	0.0000	Fiscal rule, labour income tax rate, anticipated shock fraction
$\psi_{\tau,w,e}$	0.0000	Fiscal rule, employer SSC rate, anticipated shock fraction
$\psi_{\tau,w,w}$	0.0000	Fiscal rule, employee SSC rate, anticipated shock fraction
$\psi_{ls}$	0.0000	Fiscal rule, lump-sum tax, anticipated shock fraction

The tax rates are calibrated using the data on the effective tax rates, that is, tax revenues divided to the corresponding tax base. As such, the effective tax rates are typically smaller than the nominal standard tax rates due to both imperfect tax compliance and the existence of alternative tax regimes. The effective tax rates are 15.5% (employer SSC rate), 6.1% (employee SSC rate), 21% (consumption: value added tax effective rate 13.5% plus excise tax), and 16.4% (labour income tax rate). We do not have data on the effective capital tax rate, and we calibrate it to 10% (formal tax rate on income from renting a property is 10%, while the rate on capital gains and dividends is 20%). We set price markups for imported public consumption and investment in line with their counterparts in the core block, that is, to 1.05. The calibrated import shares for public consumption and public investment are  $\omega_{g,c} = 0.13$  and  $\omega_{g,i} = 0.45$  respectively. For those, we use input-output tables and adjust the numbers upwards in line with the calibrated imports shares for the private

sector which are also calibrated higher than what input-output tables would suggest. We assume that 70% of government transfers are directed to hand-to-mouth households, i.e.  $\tau_r^{tr} = 0.7$ . We motivate this calibration by the fact that the largest part of public transfers is pensions, and most pensioners in Latvia would likely fall into the restricted households type.

The total government spending in the steady state is composed of public consumption expenditure of 46.3% ( $\tau_c^g = 0.463$ ), public investment expenditure of 11.7% ( $\tau_i^g = 0.117$ ), and transfers expenditure of 30% ( $\tau_{tr}^g = 0.300$ ) of the total budget. The remaining smaller expenditure items comprise debt service payments, expenses related to unemployment benefits (modelled separately from other transfers, as they are cyclical), and wasteful government expenditure as a residual. The quasi-share of private capital in the aggregate capital bundle is set to  $\alpha_k = 0.85$ , close to Latvijas Banka's internal estimates of a private capital share in total capital in Latvia. As in Coenen et al. (2013), we postulate that building public capital is subject to an additional one-period lag. Therefore, building public capital lasts two quarters instead of the usual one quarter. This implies that we set  $b_0 = 1$  and  $b_1 = 0$  in the model. Finally, the sensitivity of the risk premium process for the public debt interest rate with respect to deviations of public debt-to-GDP ratio from its target is set to a small positive number, i.e.  $\tilde{\phi}_{g,r} = 0.005$ , while that to the deviations of total net foreign assets position is suspended, i.e.  $\tilde{\phi}_{g,a} = 0$ . We suspend the anticipated fiscal shocks in our benchmark version for ease of interpretation.

### 3.2 Model estimation

The model is estimated with Bayesian techniques in the Matlab and Dynare environment (Adjemian et al. (2011)) using 28 observables, nine of which are fiscal variables. The real variables are in terms of demeaned per capita quarterly growth rates. The data cover the period from the second quarter of 1995 to the third quarter of 2018. The model's estimation strategy is similar to the one of Bušs (2017). The foreign block is estimated separately in line with the assumption used in forecasting rounds that shocks in Latvia do not affect the foreign economy.

#### Observables

The fiscal observables are: government consumption expenditure, government investment expenditure, government debt-to-GDP ratio, government transfers, effective consumption tax rate, effective labour income tax rate, effective employee SSC rate, effective employer SSC rate, and nominal government bond yield.

The non-fiscal observables are: nominal short-term deposit rate, real private consumption, real total investment, real imports, real exports, real GDP, real labour costs, unemployment rate, CPI inflation, total investment deflator inflation, GDP deflator inflation, the spread between the bank short-term lending rate to non-financial corporations and short-term deposit rate, as well as real house price.

The following variables enter the estimation of the foreign (SVAR) block: EA nominal short-term interest rate, EA CPI inflation, EA GDP, Latvia's foreign demand, Latvia's competitors price on the export side, and the nominal effective exchange rate. The latter is modelled as an AR(1) process.

**Table 2**  
**Estimated parameters and shocks, fiscal block**

Parameter	Description	Prior			Posterior	
		Distr.	Mean	St.d.	Mode	St.d.
<i>Fiscal block</i>						
$\xi_{m,g,c}$	Calvo parameter, imports for public consumption	$\beta$	<b>0.75</b>	0.075	<b>0.702</b>	0.023
$\xi_{m,g,i}$	Calvo parameter, imports for public investment	$\beta$	<b>0.75</b>	0.075	<b>0.638</b>	0.030
$\kappa_{m,g,c}$	Inflation indexation, imports for public consumption	$\beta$	<b>0.50</b>	0.15	<b>0.480</b>	0.046
$\kappa_{m,g,i}$	Inflation indexation, imports for public investment	$\beta$	<b>0.50</b>	0.15	<b>0.172</b>	0.037
$\eta_{g,c}$	Elasticity of substitution, domestic good and imports for public consumption	$\Gamma$	<b>1.50</b>	0.40	<b>1.394</b>	0.107
$\eta_{g,i}$	Elasticity of substitution, domestic good and imports for public investment	$\Gamma$	<b>1.50</b>	0.40	<b>1.010</b>	0.128
$\alpha_c$	Share of private consumption in aggregate consumption bundle	$\beta$	<b>0.85</b>	0.075	<b>0.894</b>	0.027
$\nu_c$	Elasticity of substitution between private and public consumption	$\beta$	<b>0.90</b>	0.075	<b>0.827</b>	0.024
$\nu_k$	Elasticity of substitution between private and public capital	$\Gamma$	<b>1.50</b>	0.40	<b>1.320</b>	0.096
<i>Fiscal rules</i>						
$\rho_{g,c}$	Fiscal rule, total government consumption expenditure, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.740</b>	0.030
$\rho_{g,i}$	Fiscal rule, public investment expenditure, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.806</b>	0.022
$\rho_{tr}$	Fiscal rule, total transfers expenditure, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.870</b>	0.021
$\rho_{\tau,c}$	Fiscal rule, consumption tax rate, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.956</b>	0.014
$\rho_{\tau,y}$	Fiscal rule, labour income tax rate, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.884</b>	0.017
$\rho_{\tau,w,e}$	Fiscal rule, employer SSC rate, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.987</b>	0.010
$\rho_{\tau,w,w}$	Fiscal rule, employee SSC rate, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.929</b>	0.012
$\rho_{ls}$	Fiscal rule, lump-sum tax, persistence	$\beta$	<b>0.85</b>	0.075	<b>0.655</b>	0.031
$\theta_{g,c,d}$	Fiscal rule, total government consumption expenditure, reaction to public debt level	$N$	<b>-0.15</b>	0.05	<b>-0.126</b>	0.015
$\theta_{g,i,d}$	Fiscal rule, public investment expenditure, reaction to public debt level	$N$	<b>-0.10</b>	0.05	<b>-0.032</b>	0.026
$\theta_{tr,d}$	Fiscal rule, total transfers expenditure, reaction to public debt level	$N$	<b>-0.05</b>	0.05	<b>-0.035</b>	0.024
$\theta_{\tau,c,d}$	Fiscal rule, consumption tax rate, reaction to public debt level	$N$	<b>0.10</b>	0.05	<b>0.145</b>	0.023
$\theta_{\tau,y,d}$	Fiscal rule, labour income tax rate, reaction to public debt level	$N$	<b>0.10</b>	0.05	<b>0.107</b>	0.013
$\theta_{\tau,w,e,d}$	Fiscal rule, employer SSC rate, reaction to public debt level	$N$	<b>0.05</b>	0.05	<b>0.012</b>	0.013
$\theta_{\tau,w,w,d}$	Fiscal rule, employee SSC rate, reaction to public debt level	$N$	<b>0.10</b>	0.05	<b>0.157</b>	0.011
$\theta_{ls,d}$	Fiscal rule, lump-sum tax, reaction to public debt level	$N$	<b>0.10</b>	0.075	<b>0.163</b>	0.025
$\theta_{g,c,dd}$	Fiscal rule, total government consumption expenditure, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>-0.269</b>	0.058
$\theta_{g,i,dd}$	Fiscal rule, public investment expenditure, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>-0.032</b>	0.026
$\theta_{tr,dd}$	Fiscal rule, total transfers expenditure, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>0.022</b>	0.053
$\theta_{\tau,c,dd}$	Fiscal rule, consumption tax rate, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>0.145</b>	0.029
$\theta_{\tau,y,dd}$	Fiscal rule, labour income tax rate, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>0.146</b>	0.037
$\theta_{\tau,w,e,dd}$	Fiscal rule, employer SSC rate, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>0.055</b>	0.051
$\theta_{\tau,w,w,dd}$	Fiscal rule, employee SSC rate, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>-0.036</b>	0.061
$\theta_{ls,dd}$	Fiscal rule, lump-sum tax, reaction to public debt growth	$N$	<b>0.00</b>	0.15	<b>0.010</b>	0.039
$\theta_{g,c,y}$	Fiscal rule, total government consumption expenditure, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>0.071</b>	0.020
$\theta_{g,i,y}$	Fiscal rule, public investment expenditure, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>0.072</b>	0.030
$\theta_{tr,y}$	Fiscal rule, total transfers expenditure, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>-0.018</b>	0.027
$\theta_{\tau,c,y}$	Fiscal rule, consumption tax rate, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>-0.043</b>	0.021
$\theta_{\tau,y,y}$	Fiscal rule, labour income tax rate, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>0.013</b>	0.028
$\theta_{\tau,w,e,y}$	Fiscal rule, employer SSC rate, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>0.067</b>	0.015
$\theta_{\tau,w,w,y}$	Fiscal rule, employee SSC rate, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>-0.044</b>	0.023
$\theta_{ls,y}$	Fiscal rule, lump-sum tax, reaction to output gap	$N$	<b>0.00</b>	0.075	<b>0.029</b>	0.015
$\rho_{\bar{\phi}}$	Persistence, government risk premium	$\beta$	<b>0.85</b>	0.075	<b>0.975</b>	0.011
<i>Shock standard deviations</i>						
$\sigma_{\tau^m,g,c}$	Mark-up, imports for public consumption	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.239</b>	0.325
$\sigma_{\tau^m,g,i}$	Mark-up, imports for public investment	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.307</b>	0.066
$10\sigma_{g,c}$	Government consumption	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.241</b>	0.020
$10\sigma_{g,i}$	Government investment	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.230</b>	0.156
$10\sigma_{tr}$	Government transfers	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.624</b>	0.051
$10\sigma_{ls}$	Lump-sum tax	$\Gamma^{-1}$	<b>0.10</b>	inf	<b>0.136</b>	0.012
$100\sigma_{\tau,y}$	Labour income tax	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.317</b>	0.035
$100\sigma_{\tau,c}$	Consumption tax	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.198</b>	0.036
$100\sigma_{\tau,w,e}$	Employer SSCs	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.616</b>	0.074
$100\sigma_{\tau,w,w}$	Employee SSCs	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.970</b>	0.090
$100\sigma_{\bar{\phi}}$	Government risk premium	$\Gamma^{-1}$	<b>0.40</b>	inf	<b>0.342</b>	0.024

### Estimated shock processes

In total, there are 30 estimated exogenous stochastic variables in our model. In the core block, there are three technology shocks: the stationary neutral technology shock  $\varepsilon_t$ , the stationary marginal efficiency of investment shock  $Y_t$ , and the unit-root neutral technology shock  $\mu_{z,t}$ . Furthermore, there is a shock to consumption preferences  $\zeta_t^c$ , a domestic risk premium shock affecting the relative riskiness of foreign assets compared to domestic assets  $\Phi_t$ , a stationary exports technology shock  $\varepsilon^x$ , and a shock to nominal effective exchange rate growth  $s_t$ .

Moreover, there are five mark-up shocks in the core block of the model, one for each type of intermediate good: domestic,  $\tau_t^d$ , exports,  $\tau_t^x$ , imports for consumption,  $\tau_t^{m,c}$ , imports for investment,  $\tau_t^{m,i}$ , and imports for exports,  $\tau_t^{m,x}$ . The financial frictions block allows for one more shock: a shock to entrepreneurial survival probability  $\gamma_t$ , which serves as a wealth shock. The labour market block adds another shock: a shock to the worker outside option  $D_{b,t}$ . There are also shocks to each of the five foreign observed variables: EA GDP  $Y_t^{ea}$ , EA inflation  $\pi_t^{ea}$ , EA nominal interest rate  $R_t^{ea}$ , foreign demand  $dem_t^*$ , competitors price on exports side  $\pi_t^{comp^x}$ .

The fiscal block adds 11 estimated shocks: two mark-up shocks, for imports of government consumption and government investment; a shock to government consumption expenditure  $G_{c,t}^{exp}$ , government investment expenditure  $G_{i,t}^{exp}$ , government transfers  $TR_t$ , consumption tax rate  $\tau_t^c$ , labour income tax rate  $\tau_t^y$ , employer SSC rate  $\tau_{e,t}^w$ , employee SSC rate  $\tau_{w,t}^w$ , lump-sum tax  $T_{ls,t}$  (to close the government budget balance), and public sector risk premium  $\tilde{\phi}_{g,t}$ .

In addition to the above stochastic processes, there are measurement errors except for the domestic deposit rate and the foreign variables. The variance of the measurement errors is calibrated to correspond to 10% of the variance of each data series. Measurement errors are also applied to the fiscal observables, except the debt-to-GDP ratio, for which we assume there are no measurement errors, and the two SSC series, for which the size of measurement errors is halved.

Due to the estimation of the non-fiscal part of the model being already described in previous papers (Bušs (2015; 2017) and Buss (2016)), we do not repeat the description of the similar results here and refer the interested reader to those papers or to Appendix C for the prior-posterior tables.

### Estimated fiscal parameters

Here we briefly discuss the estimated parameters of the fiscal block reported in Table 2. First, with the prior mean for the elasticity of substitution between private and public consumption,  $\nu_c$ , set to 0.9 and the posterior being 0.83, the data provide evidence for moderate complementarity between private and public consumption. Second, when the prior mean for the elasticity of substitution between private and public capital is set to below unity, the posterior goes to close to unity; so in our benchmark version the prior mean is set above unity (1.5), with the posterior mode being 1.3. Thus, the estimation results show evidence of moderate substitution between private and public capital. In comparison, the estimation results of Coenen et al. (2013) suggest strong complementarity between private and public consumption and moderate complementarity between private and public capital in the EA as a whole. Third, the posterior of the quasi-share of private consumption in the aggregate consumption bundle,  $\alpha_c$ , is 0.89, that is, slightly above its prior of 0.85, the latter

roughly corresponding to the share of private consumption in total consumption of the data.

Fourth, and turning to the discussion of the fiscal rules, the priors for the parameters relating fiscal instruments to public debt are set so that the model is dynamically stable, that is, fiscal instruments should at least weakly react to public debt deviations from target in a manner to reduce debt deviations. The estimated posterior modes, in several cases, are not far from their priors, suggesting some of these parameters are weakly identified. Fifth, with priors for the fiscal instrument reaction to debt *growth* centred around zero, the posterior modes suggest (weak) stabilization of public debt growth, namely, government consumption and investment decreasing and most tax rates increasing when faced with debt growth. The fiscal rule parameters relating to debt and debt growth are likely to be influenced mostly by the 2009-recession episode, though.

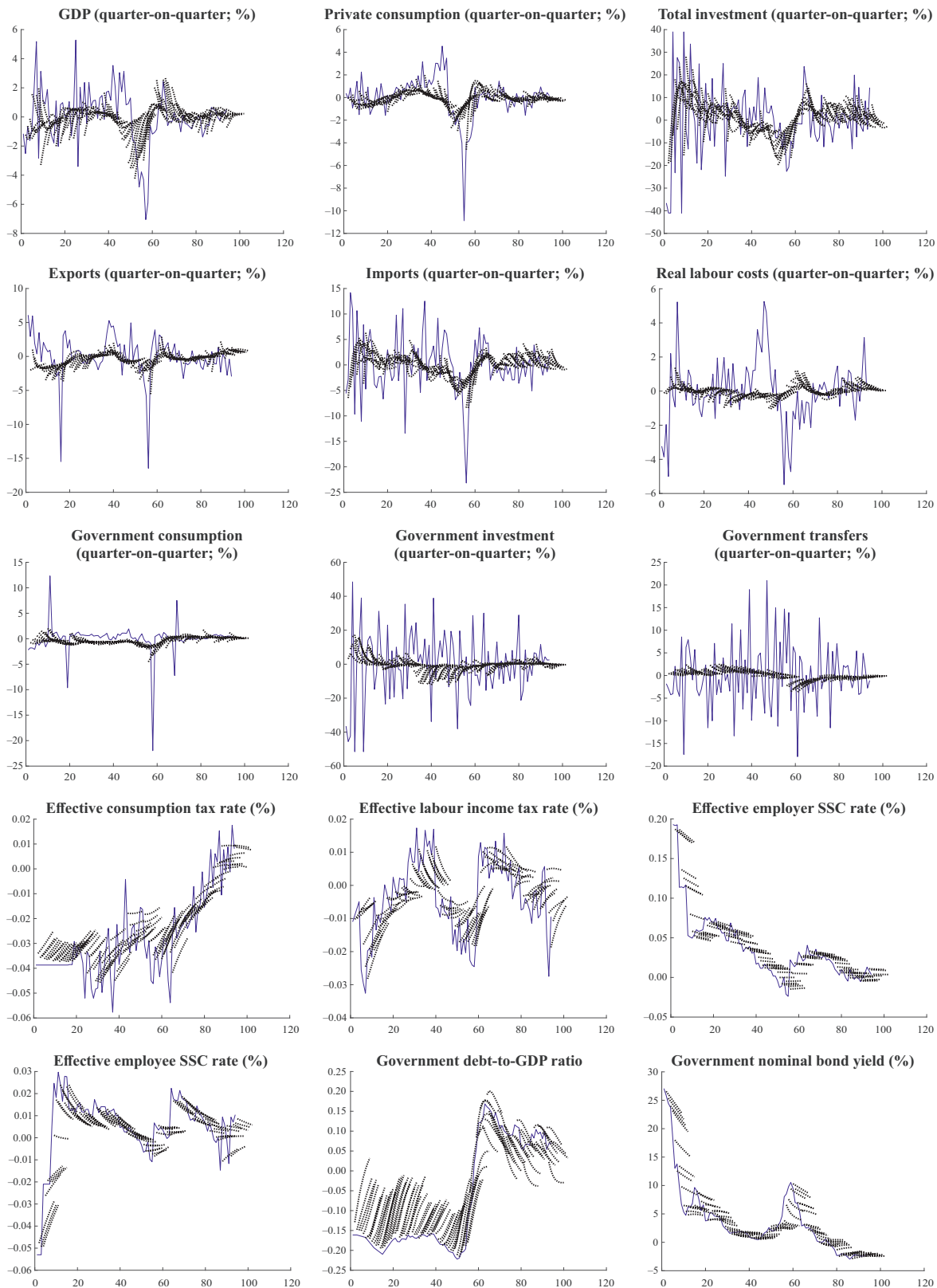
Lastly, the estimated parameters relating fiscal instruments to output gap suggest that fiscal instruments have been weakly pro-cyclical, that is, setting prior means to zero, posterior modes show that both public consumption and public investment have positively reacted to the output gap. Also, a couple of the respective parameters for effective tax rates (including consumption tax) are negative, also suggesting a pro-cyclical fiscal nature; yet, for the revenue side, one cannot exclude that the pro-cyclical nature of effective tax rates is driven by a pro-cyclical tax base, a countercyclical shadow economy or endogenous private sector expenditure switching (Bems and di Giovanni (2016)).

### 3.3 Data fit

As this model is created for the purposes of scenario analysis, which may involve building alternative scenarios around the baseline using conditional forecasts, we pay particular attention to our model's data fit and its dynamic behaviour in terms of projections.

2 contains the results from our pseudo real-time forecasting exercise that allows us to evaluate the data fit of the model. The figure shows the data in solid lines and the iterated forecasts in dotted lines for the whole estimation sample. The forecasts are produced with the Kalman filter using our final estimated parameters and shock standard deviations. Despite the fact that there is a considerable short-term volatility, trends, and level shifts in the data, overall, the model fits the data decently. Particularly, there is no substantial bias in forecasts for any observable, as well as the amplitude and the timing of the cyclical fluctuations are captured relatively accurately. Although the model fit still could be improved for some series, we are broadly satisfied with our model's data fit, which enhances our trust in the model's simulation results. The model's simulation properties are reported in the following section.

**Figure 2**  
**Data fit and forecasting**



Notes. Data are in solid blue, iterated forecasts are in dotted black. All variables are in net of their steady-state values. Expenditure components are in real terms.



## 4. INSPECTION OF MODEL BEHAVIOUR

In this section, we present results from deterministic simulations of our model. First, in Subsection 4.1 we will inspect the macroeconomic effects of fiscal shocks. The shocks are normalized to imply a change of 0.5%<sup>13</sup> of steady-state GDP on either the revenue or the expenditure side. In Subsection 4.2, we investigate how specific model elements and assumptions affect the propagation of shocks by changing some features of the model relative to the benchmark calibration.

### 4.1 Fiscal shocks

In this subsection, we shock the following items of the government balance sheet: (i) government investment expenditure, (ii) government consumption expenditure, (iii) government transfers, (iv) consumption tax rate, (v) labour income tax rate, (vi) employer SSC rate, (vii) employee SSC rate, and (viii) capital income tax rate. Moreover, all fiscal rules are deactivated for the first eight quarters; after that, only the lump-sum tax rule becomes active. The shock persistence parameters are set to 0.85 for all instruments.

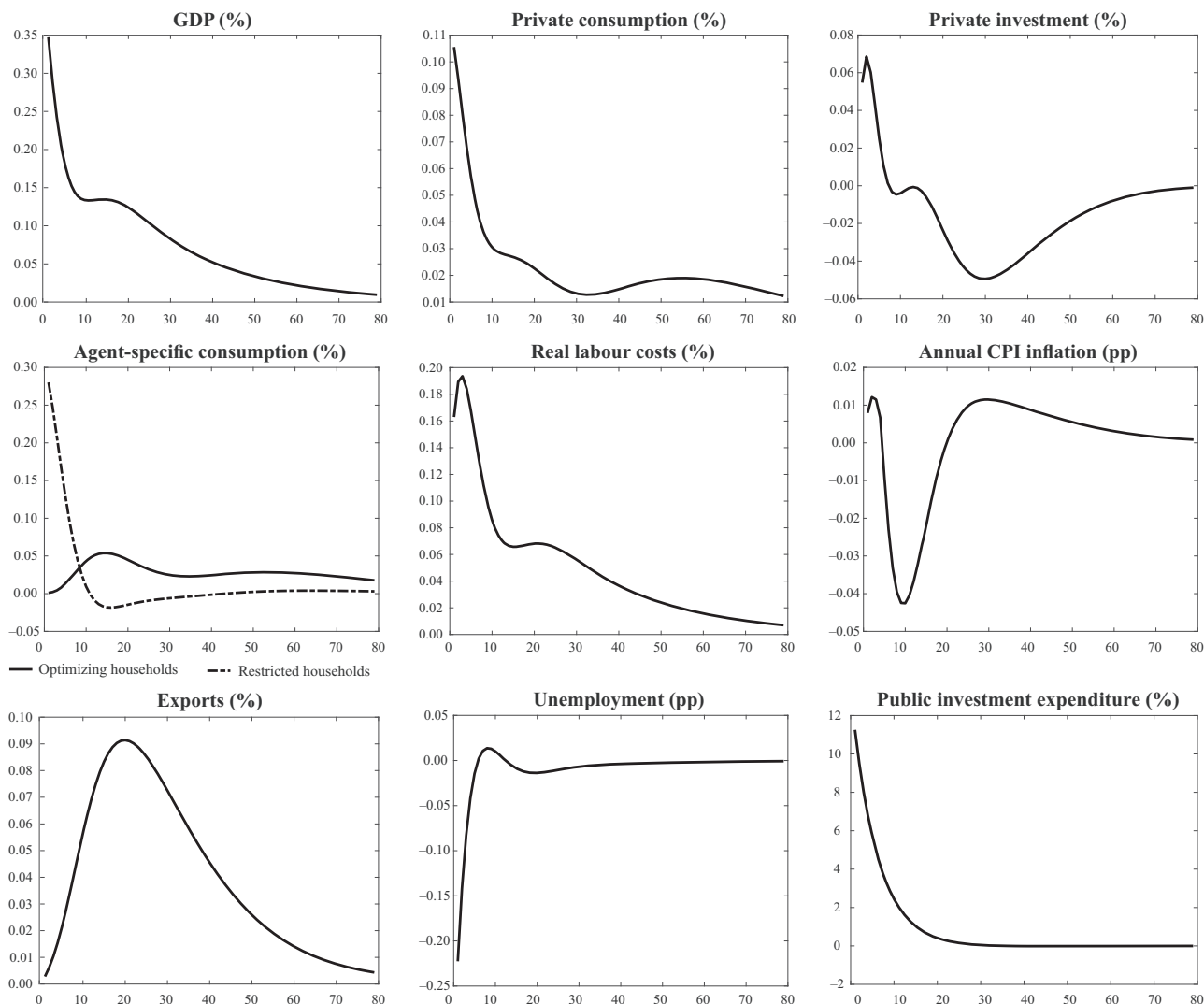
#### 4.1.1 Shock to government investment expenditure

In Figure 3, we depict the impulse responses of key macroeconomic quantities to a positive shock to public investment expenditure. An increase in government investment not only raises GDP directly, but also crowds in private investment in the first few years and boosts employment. Demand for workers causes upward pressures on wages. As both employment and wages go up, so does consumption. The favourable developments in terms of trade caused by the productivity increase are not outweighed by labour costs therefore exports increase. The overall effect on the economy is lasting for an extensive period of time, which is controlled by the calibrated share of public capital in the aggregate capital bundle as shown in the next subsection.

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<sup>13</sup> The effects caused by 1% of GDP shocks to fiscal instruments seemed too large in some cases.

**Figure 3**  
**Shock to government investment expenditure**

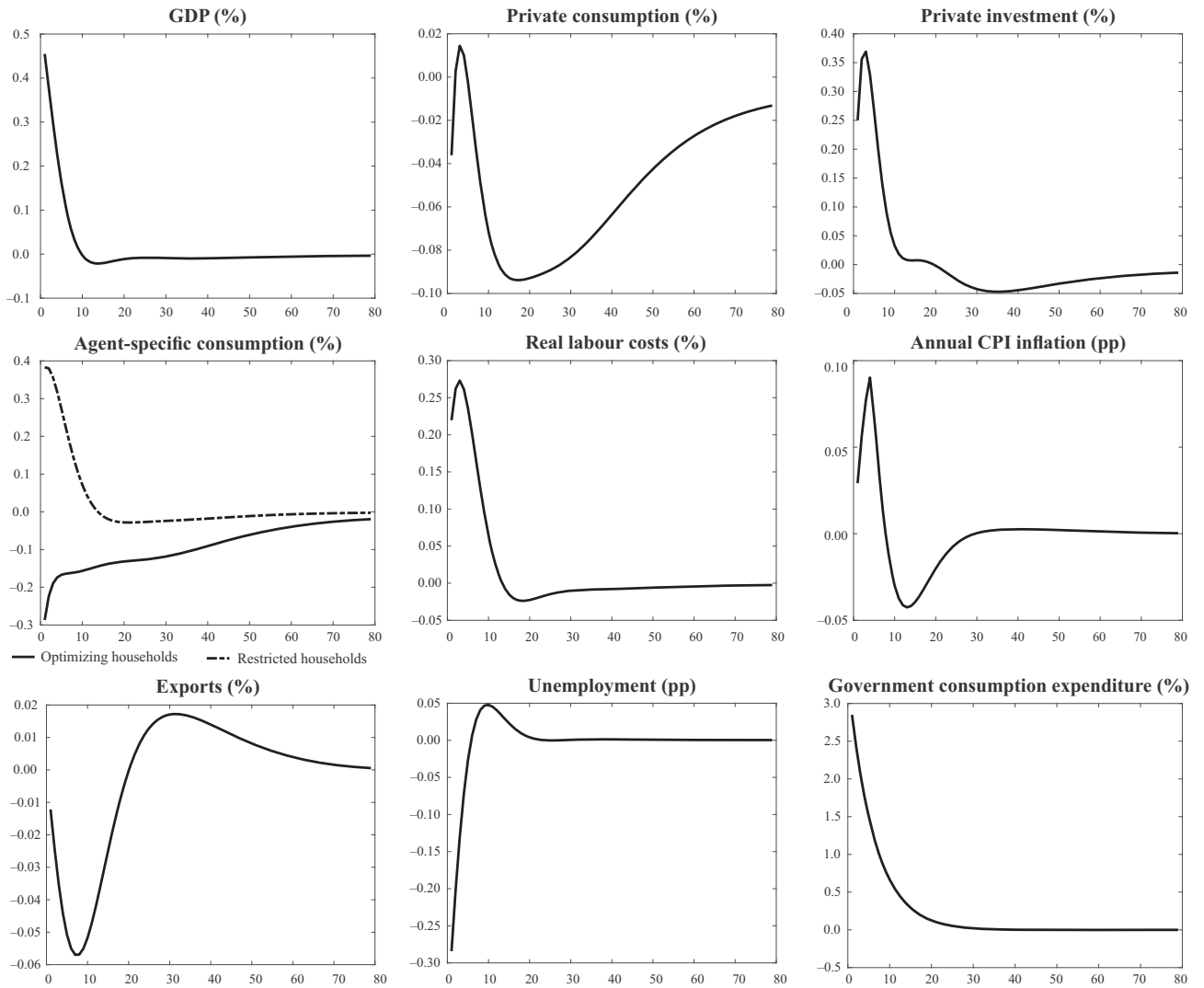


**4.1.2 Shock to government consumption expenditure**

Figure 4 shows the impulse response functions for an increase in government consumption expenditure. As the optimizing households obtain more utility with higher public consumption, they substitute away from consumption in favour of other budget items, such as investment. A rise in private investment and employment increases the consumption of the restricted households. Therefore, an increase in government consumption is a policy that reduces consumption inequality. On net, total consumption decreases for most of the time. Also, exports go down.

Comparing these effects with those of raising government investment, it can be seen that an increase in government consumption yields much less persistence in the effects on GDP. This theme is expanded in Latvijas Banka (2019), which, using this model, considers balancing the government budget via reducing government consumption or investment. It clearly shows that cutting government consumption would be more favourable for the economy, especially in the medium term.

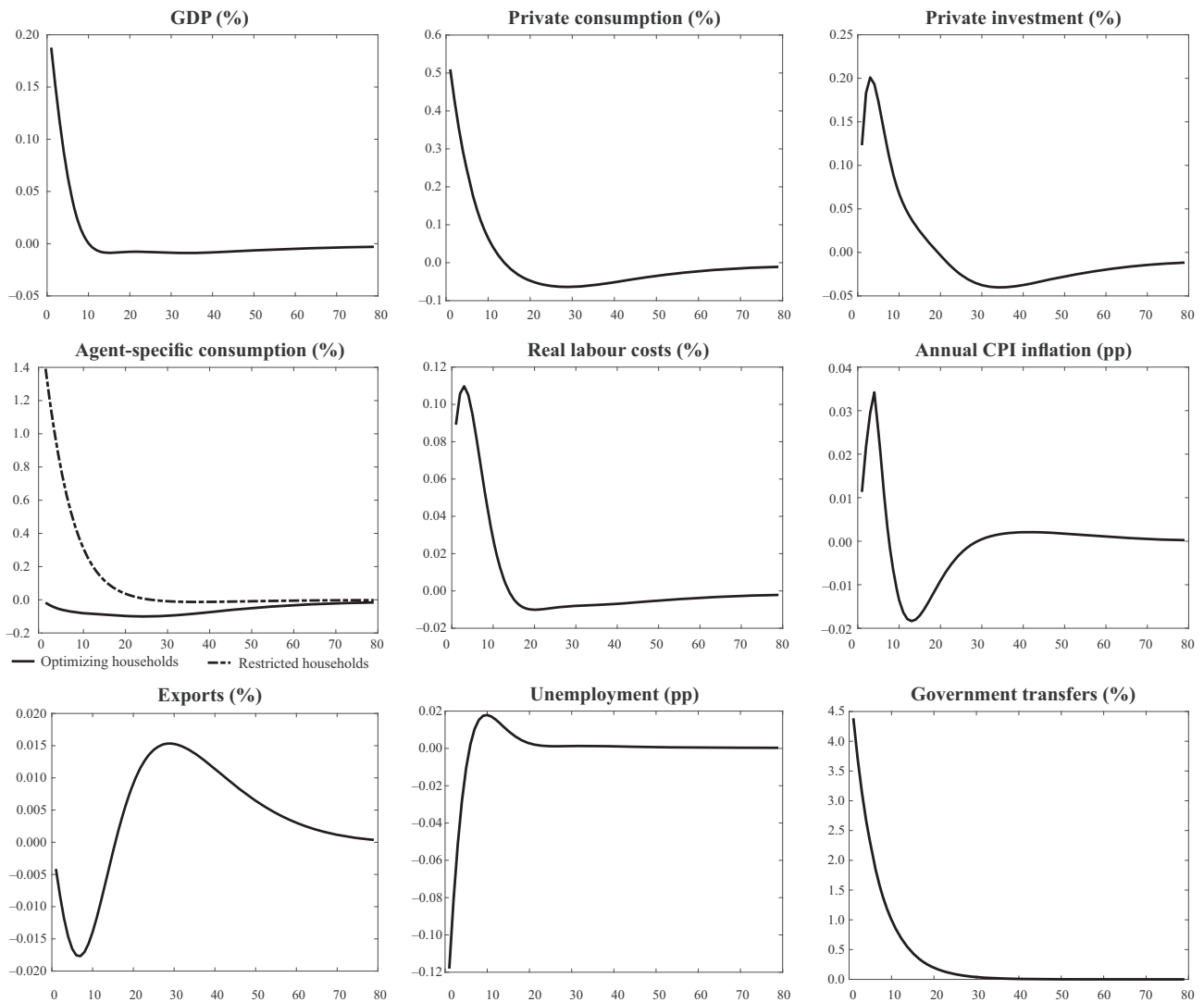
**Figure 4**  
**Shock to government consumption expenditure**



### 4.1.3 Shock to government transfers

Figure 5 depicts the impulse responses to a shock to government transfers (less unemployment benefits).

*Figure 5*  
**Shock to government transfers (less unemployment benefits)**

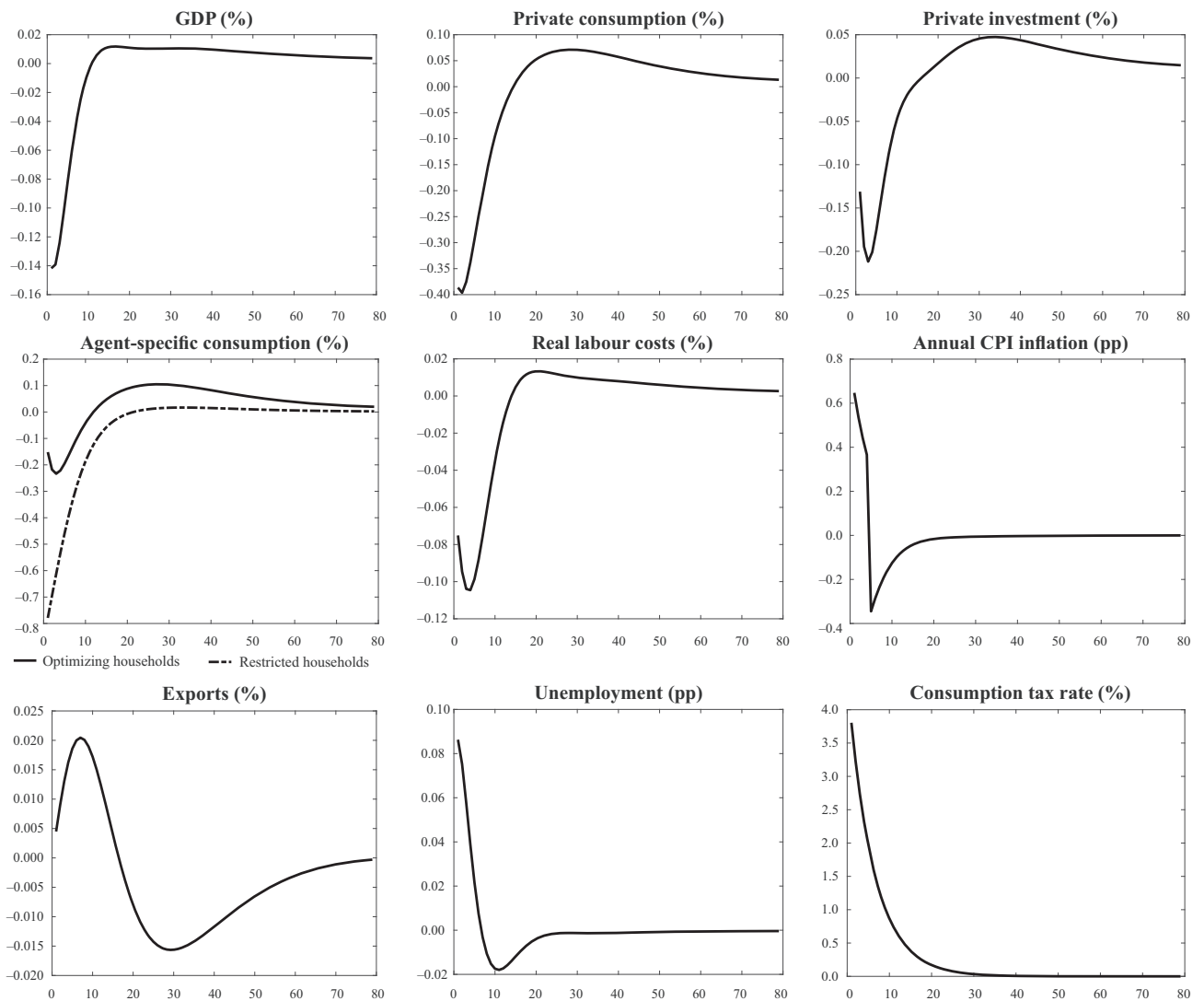


An increase in transfers, of which 70% are directed to the restricted households, pushes up the consumption of the restricted households. In contrast, the optimizing households decrease their consumption slightly, as they raise investment in face of a higher demand. Higher investment pulls higher employment and wages. Overall, there is a short-lived expansion in GDP, and macroeconomic effects similar to those we saw previously along with an increase in government consumption, except mainly for the behaviour in private consumption, which edges up in this case.

### 4.1.4 Shock to consumption tax rate

In the remaining subsections, we analyse shocks to the various revenue components of the government budget. First, we look at an increase in the consumption tax rate (see Figure 6) that makes consumption more expensive, reflected in a visible spike in CPI inflation. As a result, consumption decreases. A drop in demand causes a decline in investment, employment and wages, especially hurting the restricted households which cannot smooth out consumption. A contraction in imports caused by a lower demand (and a marginal increase in exports benefiting from lower intermediate goods prices) improves the foreign trade balance.

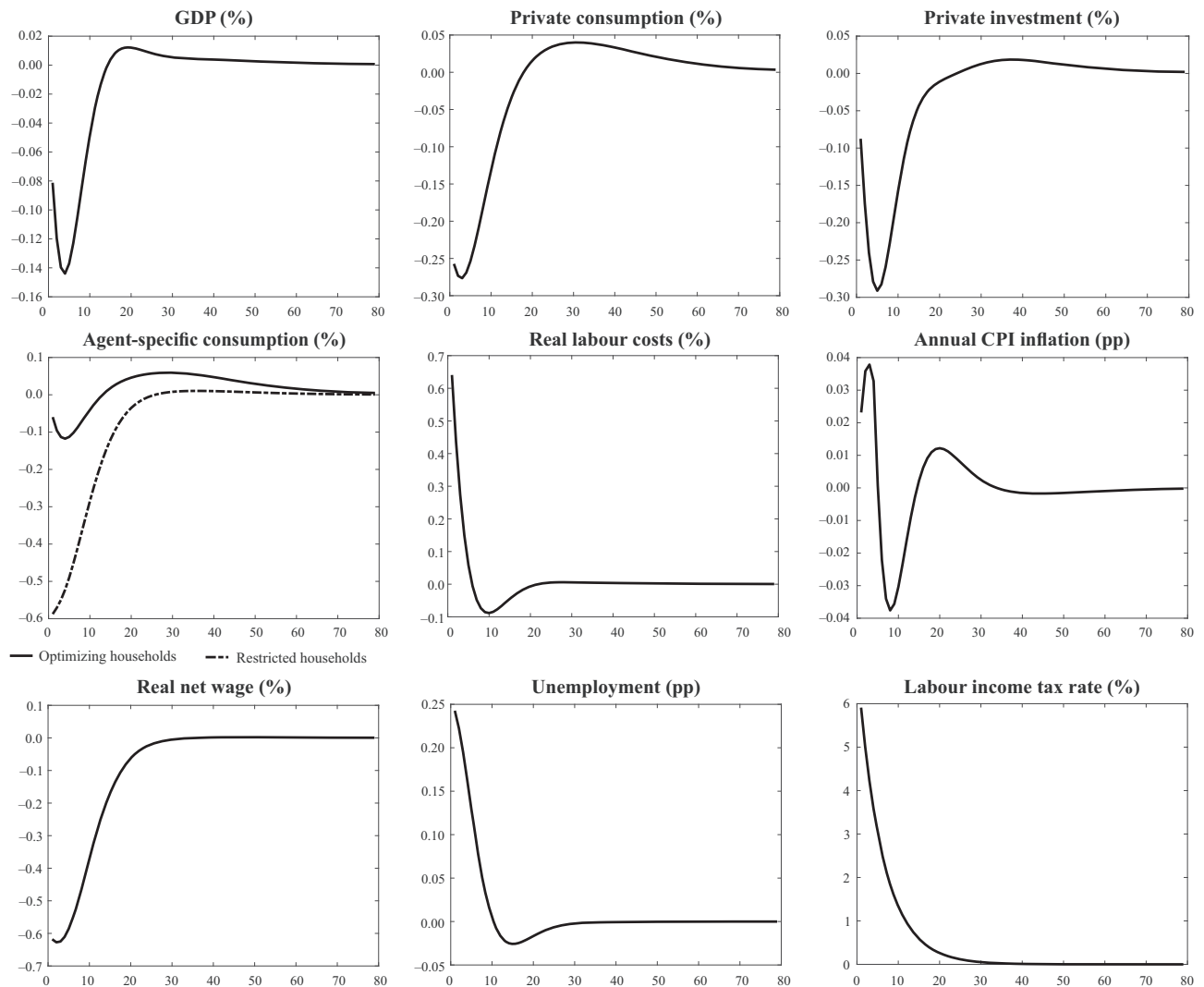
Figure 6  
Shock to consumption tax rate



### 4.1.5 Shock to labour income tax rate

Impulse response functions to a shock to a labour income tax rate are shown in Figure 7. An increase in the labour income tax rate causes lower incomes for workers. A part of the tax burden is shared with employers via the wage bargaining process. The extent of sharing the labour tax burden can be partly controlled by a proper recalibration of the elasticity of the worker outside option to labour market conditions, which we will illustrate in shocking SSCs below, while in the current case we stick to the benchmark calibration. In the benchmark calibration, there is a relatively tight link between the worker outside option and labour market conditions. As a result, there are both demand pressures from lower labour incomes and supply pressures from higher labour costs. Consequently, there is a drop across consumption, investment, employment, and foreign trade.

Figure 7  
Shock to labour income tax rate

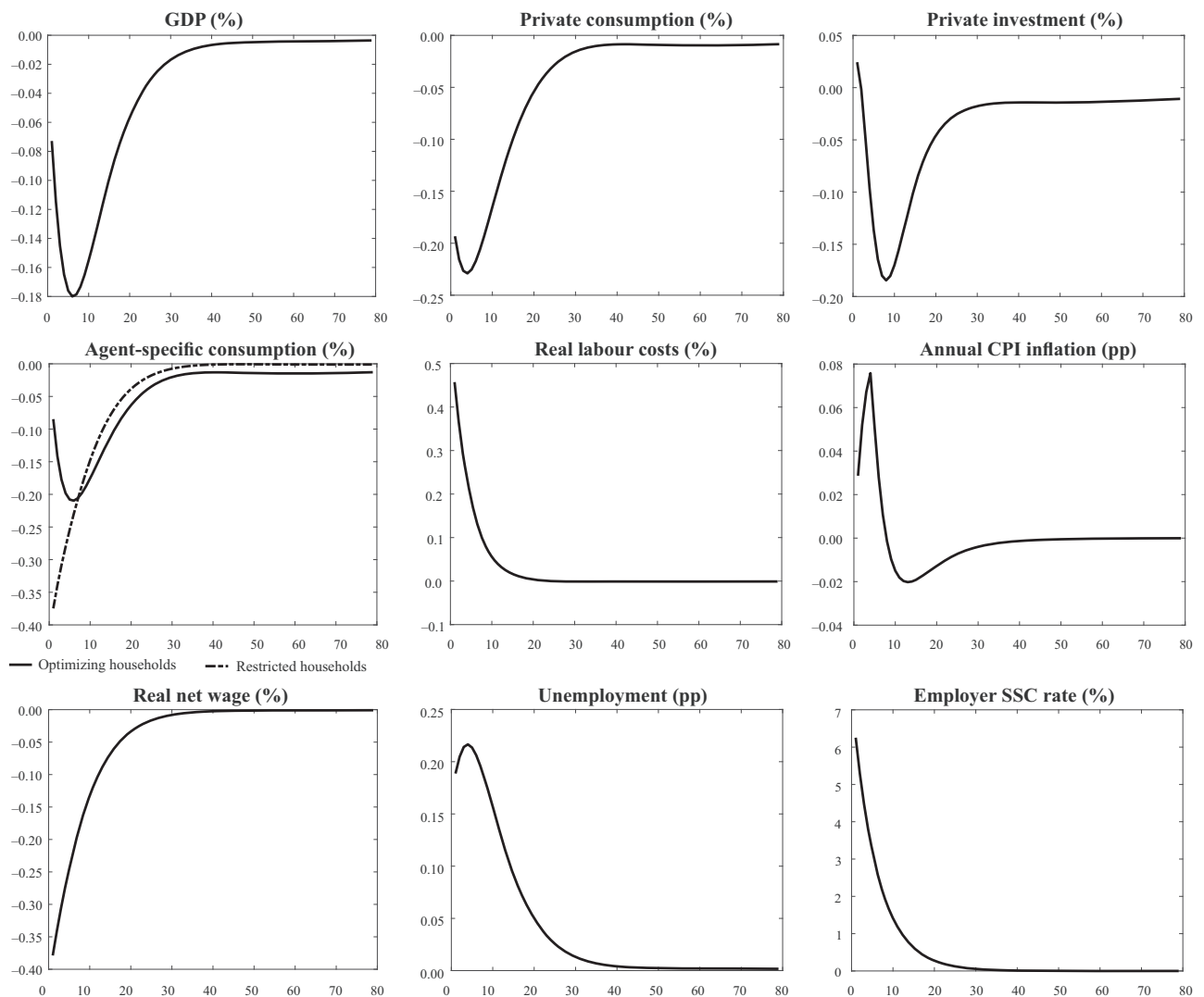




### 4.1.6 Shock to employer SSC rate

Impulse response functions to a shock to the employer SSC rate are shown in Figure 8. As economists tend to think that changing the employer SSC rate would affect mostly the employer in the medium term, here we utilize our specification of the worker outside option and calibrate its elasticity to labour market conditions to zero, such that gross wages would not decrease much. Essentially, this is the case of a standard Nash wage bargaining. As a result, most of the tax burden is borne by the employer, and only a small portion spills over to an employee by decreasing the gross wage. As wages are relatively rigid in this case, there is a protracted period of heightened unemployment in reaction to an increase in labour cost. Consequently, there is a prolonged decrease in consumption.

*Figure 8*  
Shock to employer SSC rate

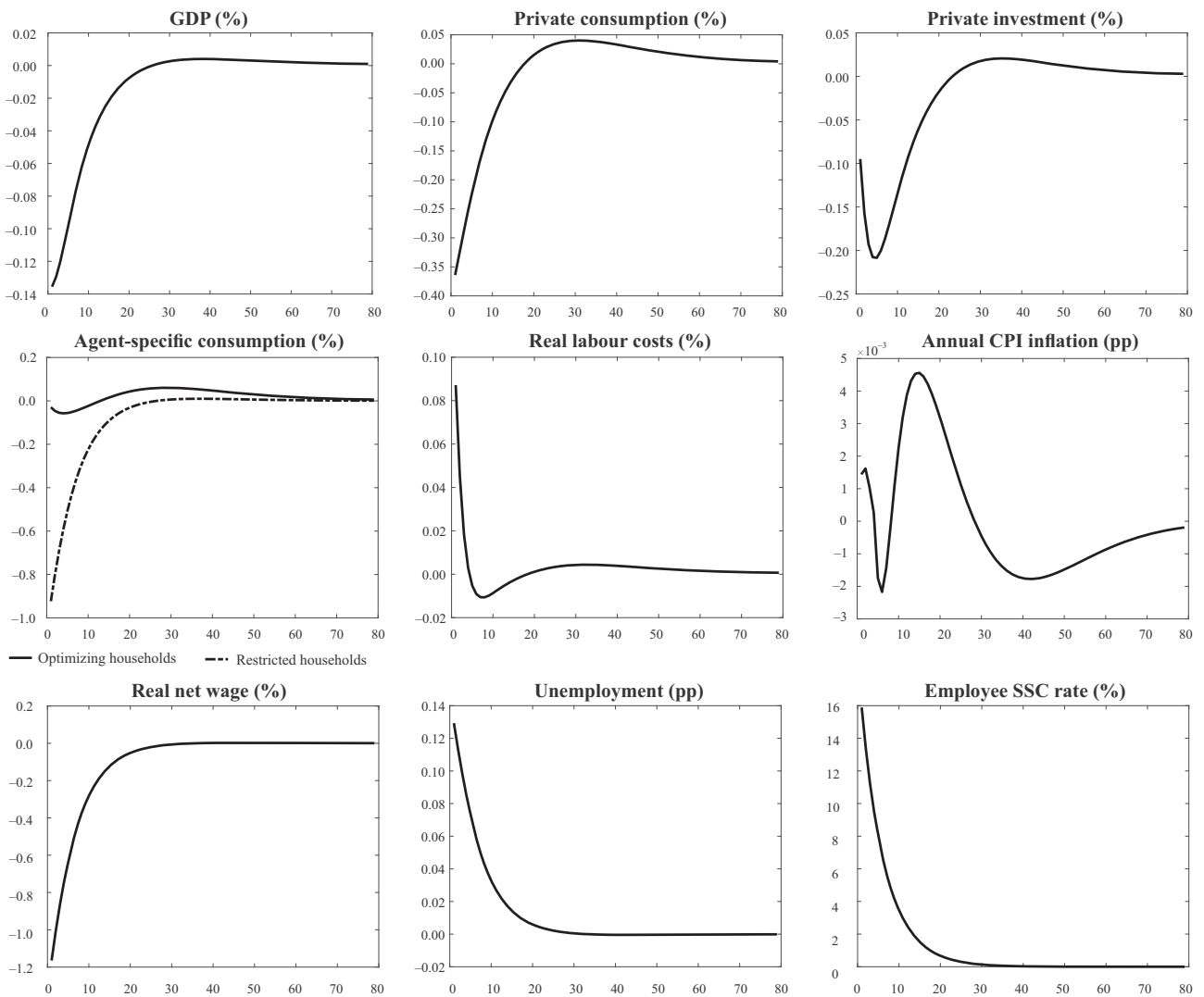


There is a slight and short-lived increase in investment due to the shift from labour to the relatively cheaper capital before investment is dragged down. The foreign trade balance deteriorates with an increase in the domestic prices. Overall, we see a protracted economic downturn.

### 4.1.7 Shock to employee SSC rate

Figure 9 depicts the impulse responses to a shock to the employee SSC rate. In order to differentiate the effects from the employer SSC rate and in accord with economists' perception that a change in the employer SSC rate would mostly affect an employee, we set a unit elasticity of the worker outside option to the contemporary labour market conditions. As a result, the largest part of the tax burden is borne by an employee, with only a minor share borne by an employer. Consumption drops due to lower net income per worker (less so due to unemployment), sequentially dragging down investment. The effect on output is smaller in both magnitude and duration, compared to that in the case of raising the employer SSC rate.

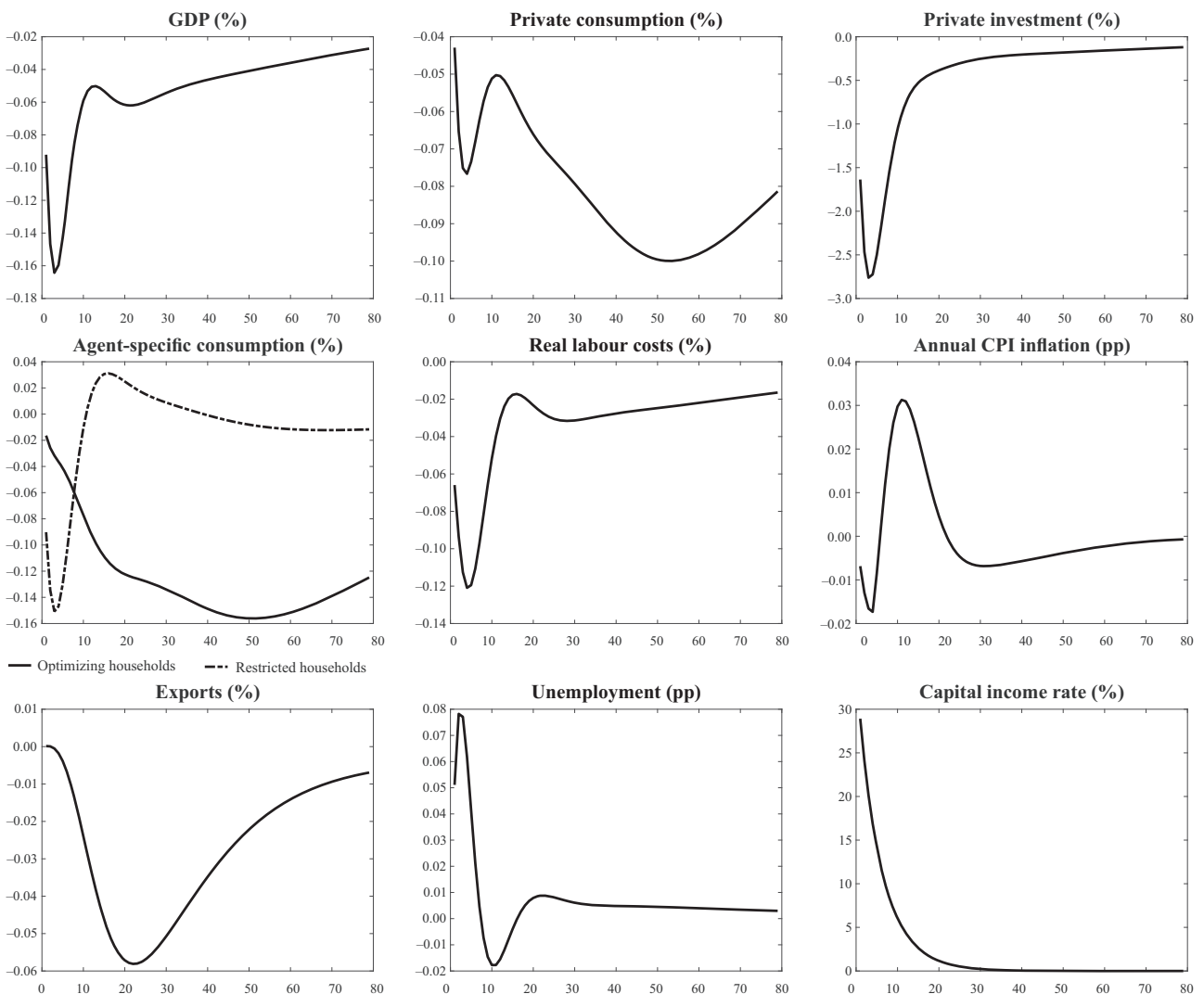
*Figure 9*  
Shock to employee SSC rate



### 4.1.8 Shock to capital income tax

A shock to the (physical) capital income tax rate (see Figure 10) reduces the rate of return on physical capital. As a result, private investment goes down, dragging down employment, consumption, and GDP. A double-dip consumption pattern results from the divergent paths of consumption of the restricted and optimizing households. Consumption of the restricted households experiences a sharp decline but recovers with the recovery of labour market due to the adjustment of labour costs. Meanwhile, consumption of the optimizing households declines slowly but persistently. Overall, an increase in capital income tax rate results in a protracted downturn. A long downturn in investment is partly due to substitution away from physical capital to other assets, such as foreign bonds, which are not subject to a tax increase in this case. Taxing income from all assets, including bonds, might reduce the negative effects of capital tax on investment in physical capital.

Figure 10  
Shock to (physical) capital income tax rate



## 4.2 Sensitivity analysis of channels in the fiscal block

This subsection is devoted to the sensitivity analysis of the fiscal block by changing specific model features, one at a time. We then compare the model behaviour with and without a particular feature.<sup>14</sup> The benchmark model is the model that employs the parameters reported in Tables 1 and 2, and with all fiscal rules active, unless stated otherwise.<sup>15</sup>

### 4.2.1 Household utility-enhancing government consumption channel

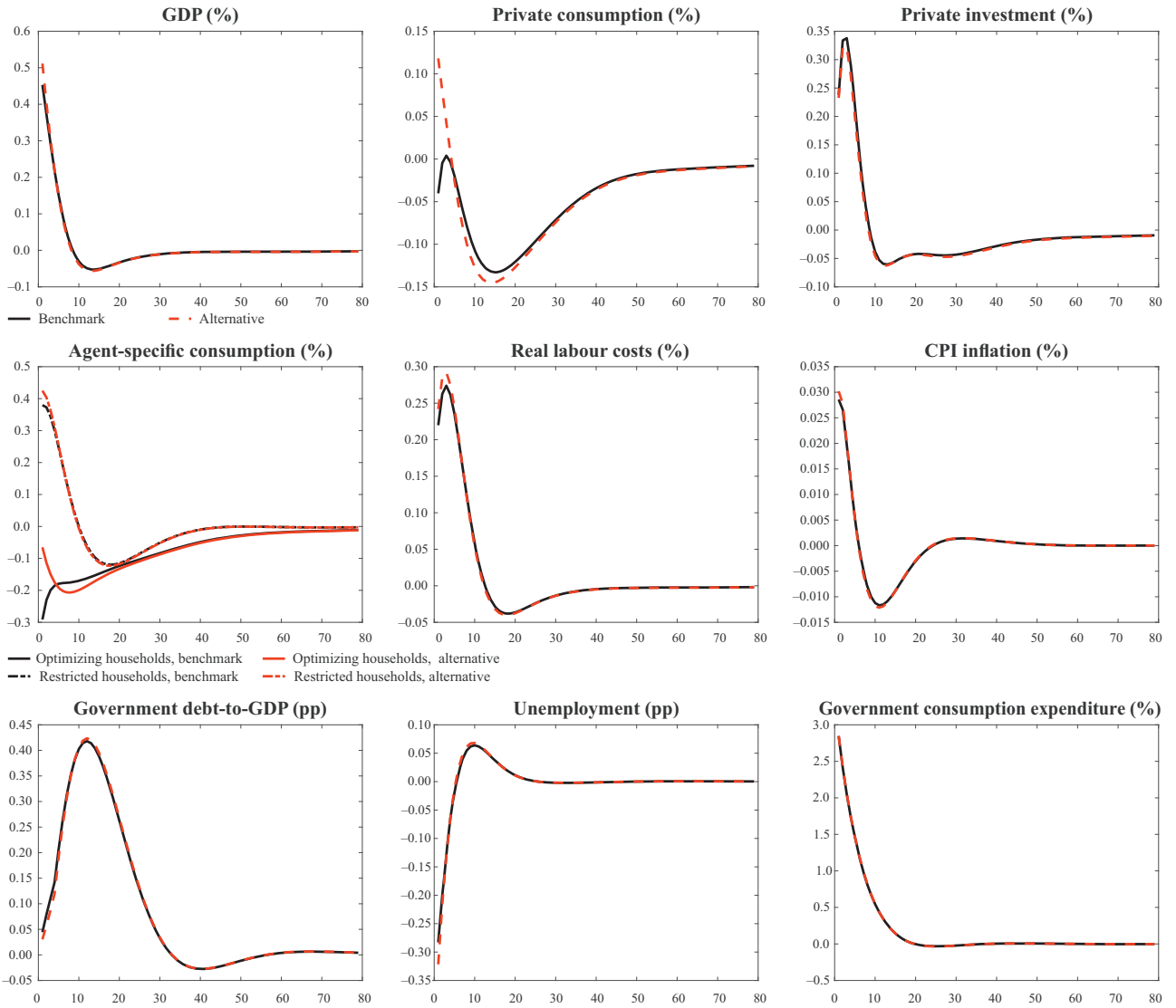
Public consumption is bundled together with private consumption to enhance the utility of households in the benchmark model. In order to better understand the role of utility-enhancing public consumption in the model, we simulate an alternative model where public consumption is not entering the utility bundle. In other words, public consumption becomes wasteful. For this purpose, we set  $\alpha_c = 1$  in the alternative model. This implies an increase of  $\alpha_c$  by (only) 0.11. The impulse responses of both models to a shock to government consumption expenditure (corresponding to additional government spending of 0.5% of GDP) are shown in Figure 11. It can be seen that the only stark difference the household utility-enhancing government consumption produces is the negative short-term response of private consumption, as households substitute their consumption for government consumption. Having public consumption as part of total household consumption bundle decreases initial co-movement between the government and private consumption.

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<sup>14</sup> Note that most of the modified models we analyse in this section have (slightly) different steady states than the benchmark model which may affect some of the magnitudes in the reported impulse responses.

<sup>15</sup> We equalize the persistence of fiscal rules to 0.85.

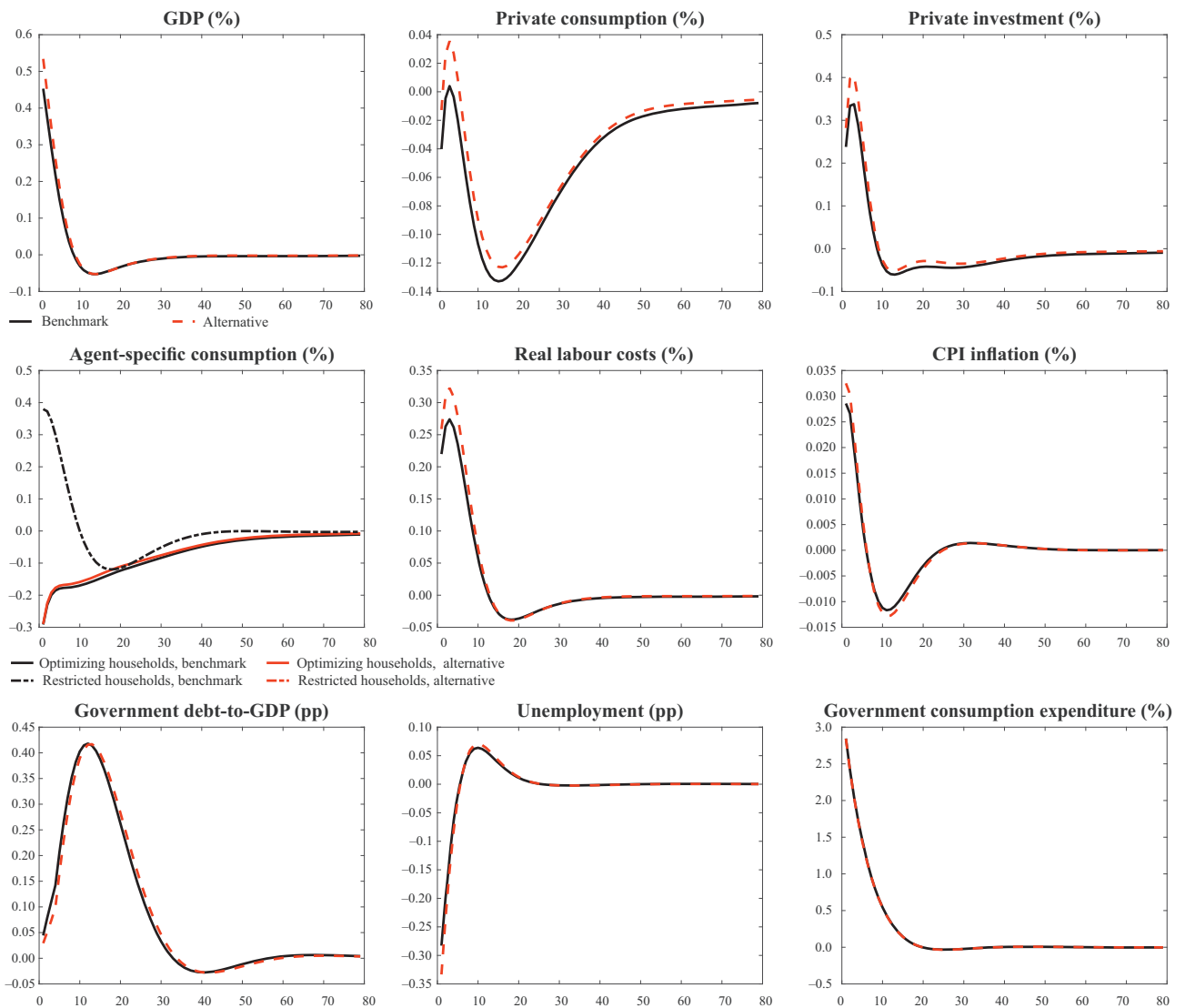
**Figure 11**  
**Shock to government consumption expenditure – useful vs. wasteful public consumption**



### 4.2.2 Import content in the public consumption channel

In our benchmark model, a fraction of public consumption is imported from abroad. Alternatively, we assume that all public consumption is sourced domestically. Figure 12 compares the model behaviour to a shock to the government consumption expenditure. The results show that having a share of public consumption that is imported makes the reaction of private consumption more negative, and, overall, dampens the reaction of investment, employment, GDP, and inflation, while slightly increases the reaction of the government debt-to-GDP ratio in the short run.

*Figure 12*  
**Shock to government consumption expenditure – with vs. without import content in public consumption**

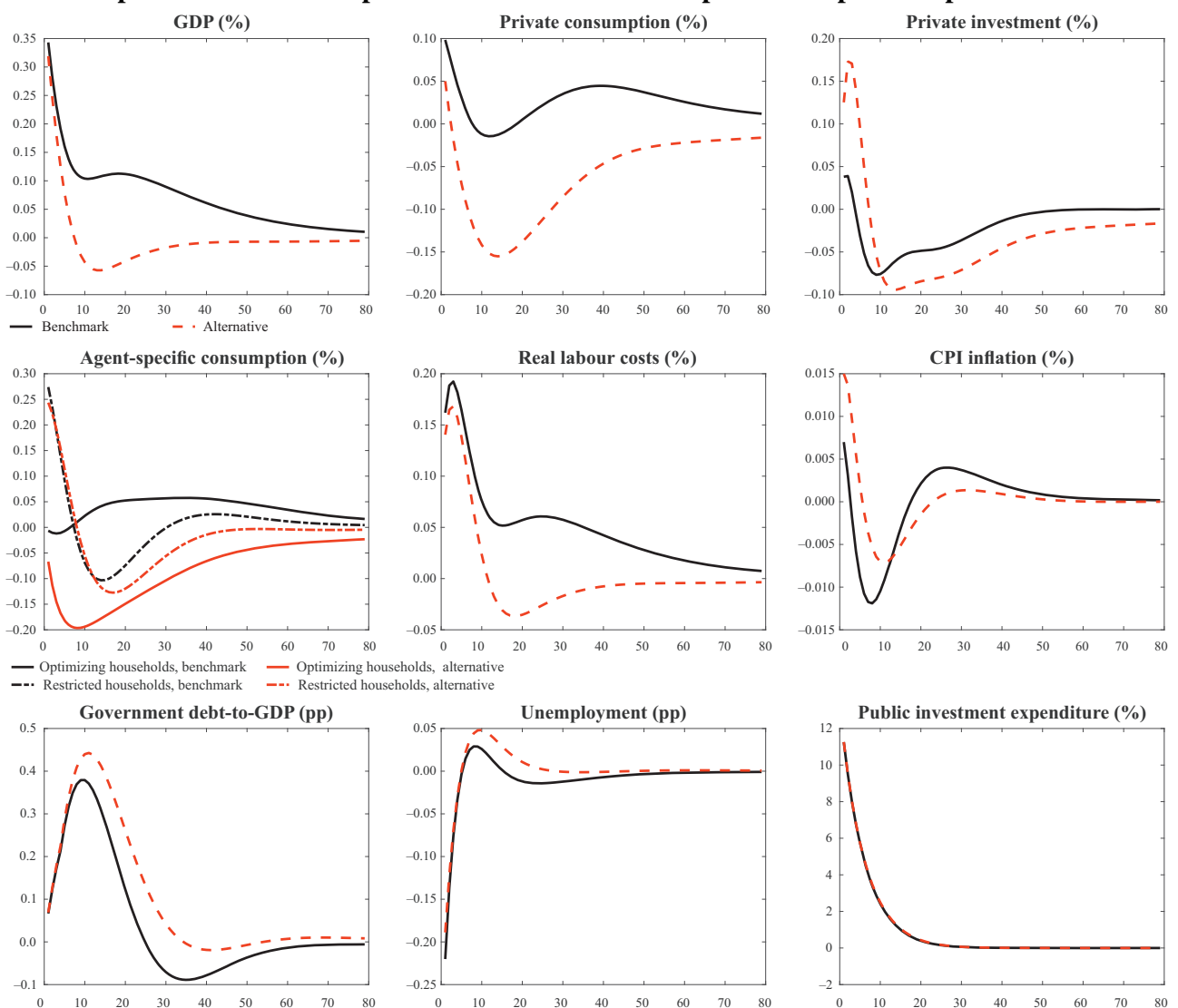




### 4.2.3 Productivity-enhancing government investment channel

In the benchmark model, government investment enhances private productivity. Alternatively, we make public investment wasteful, that is we assume a zero share of public capital in the total capital bundle ( $\alpha_k = 1$ ). The model behaviour is compared in Figure 13 for shock to public investment expenditure. An inspection of the impulse responses reveals that, having productive public capital, the private sector does not have to increase investment after this demand shock that much, as the government investment makes the private sector more productive. Therefore, the optimizing households can direct a part of these saved resources to consumption. Therefore, having productive public capital yields considerably more positive reaction of private consumption to public investment, as otherwise there would be a decrease in consumption for a prolonged period of time. As a result, the productive public investment channel produces a positive reaction of consumption and GDP to public investment substantially longer, while without this feature the GDP reaction is short lived.

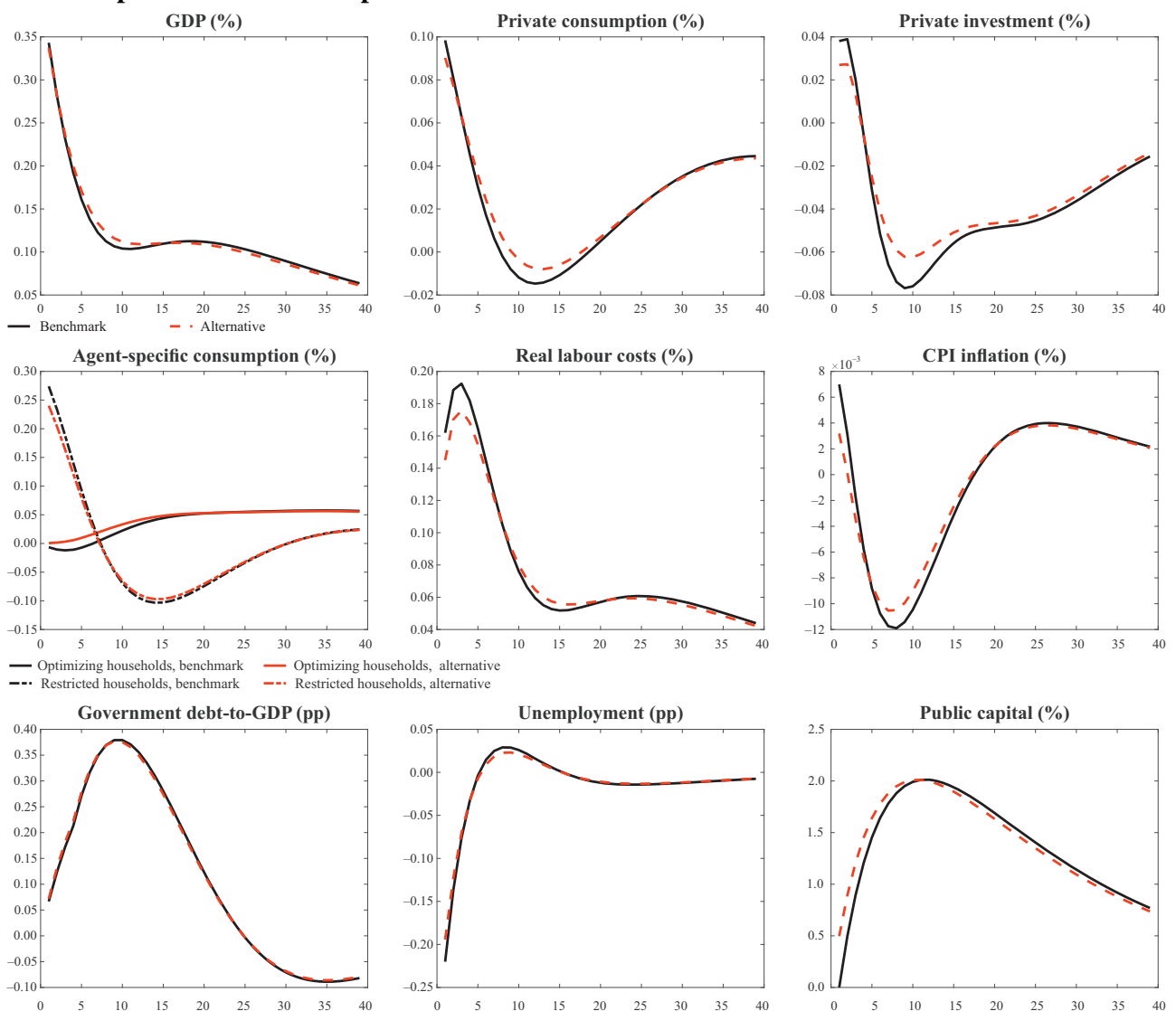
**Figure 13**  
**Shock to public investment expenditure – with vs. without productive public capital**



### 4.2.4 Time-to-build friction in building public capital channel

In the benchmark model, building public capital is subject to a time-to-build friction, i.e. it takes one more quarter for public investment compared to private sector investment to result in public capital. Alternatively, we assume the absence of this friction (i.e. we set  $b_0 = 0$  and  $b_1 = 1$ ). Figure 14 compares the model behaviour for a shock to public investment expenditure. The figure shows that the time-to-build friction induces a one-quarter lag in the public capital dynamics and slightly higher volatility in several macro variables. The intuition is as follows. Given there is a positive shock to public investment, GDP rises. The private sector faces higher demand, thus there is motivation to create jobs and invest. Given that, initially, public investment does not become productivity-enhancing capital, private firms invest their own resources more than in the situation where there were no time-to-build frictions. As productivity-enhancing public capital appears, the private sector divests. Thus, the time-to-build friction raises the volatility of private investment, along with other macroeconomic aggregates.

**Figure 14**  
**Shock to public investment expenditure – with vs. without time-to-build friction**

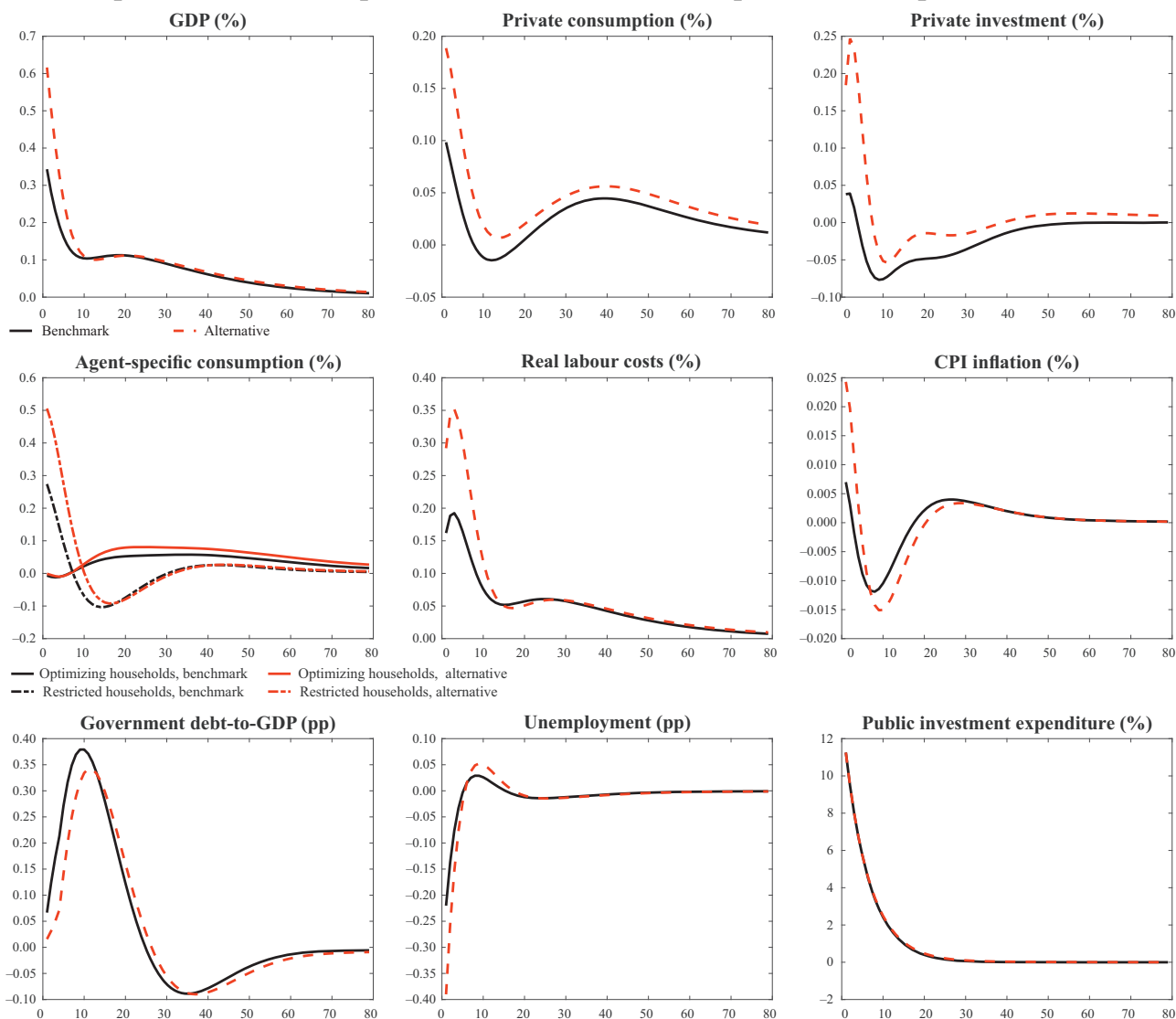


### 4.2.5 Import content in the government investment channel

In the benchmark model, a fraction of public investment is imported from abroad. Alternatively, we assume that all public investment is sourced domestically. Figure 15 compares the model behaviour for a shock to public investment expenditure. Similarly to the results for the import content in public consumption covered in Subsection 4.2.2, we see that having import content in government investment dampens the reaction (in the case of private investment and consumption makes it more negative) of macroeconomic variables. The differences are more sizeable in the government investment case compared to the government consumption case due to our assumed larger import content in government investment than in government consumption.

Figure 15

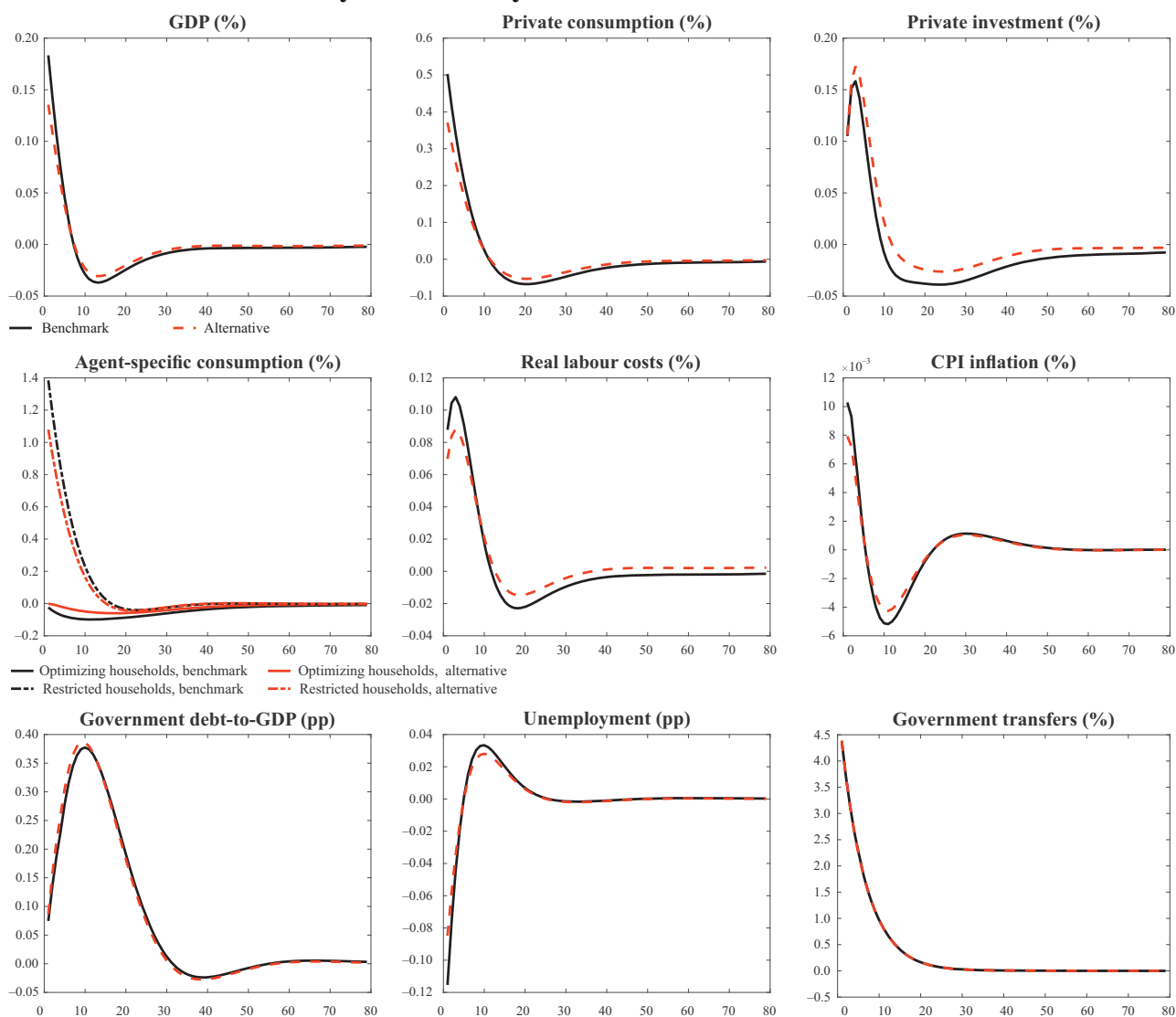
#### Shock to public investment expenditure – with vs. without import content in public investment



### 4.2.6 Asymmetric transfers channel

In the benchmark model, we assume that government transfers are asymmetrically distributed between the optimizing and restricted households. Alternatively, we assume transfers are symmetrically distributed. Figure 16 compares the model behaviour for a positive shock to government transfers. Having a larger share of transfers going to the restricted households amplifies the reaction of private consumption, dominated by an asymmetrically higher consumption of the restricted households. Consequently, the reaction of GDP is amplified.

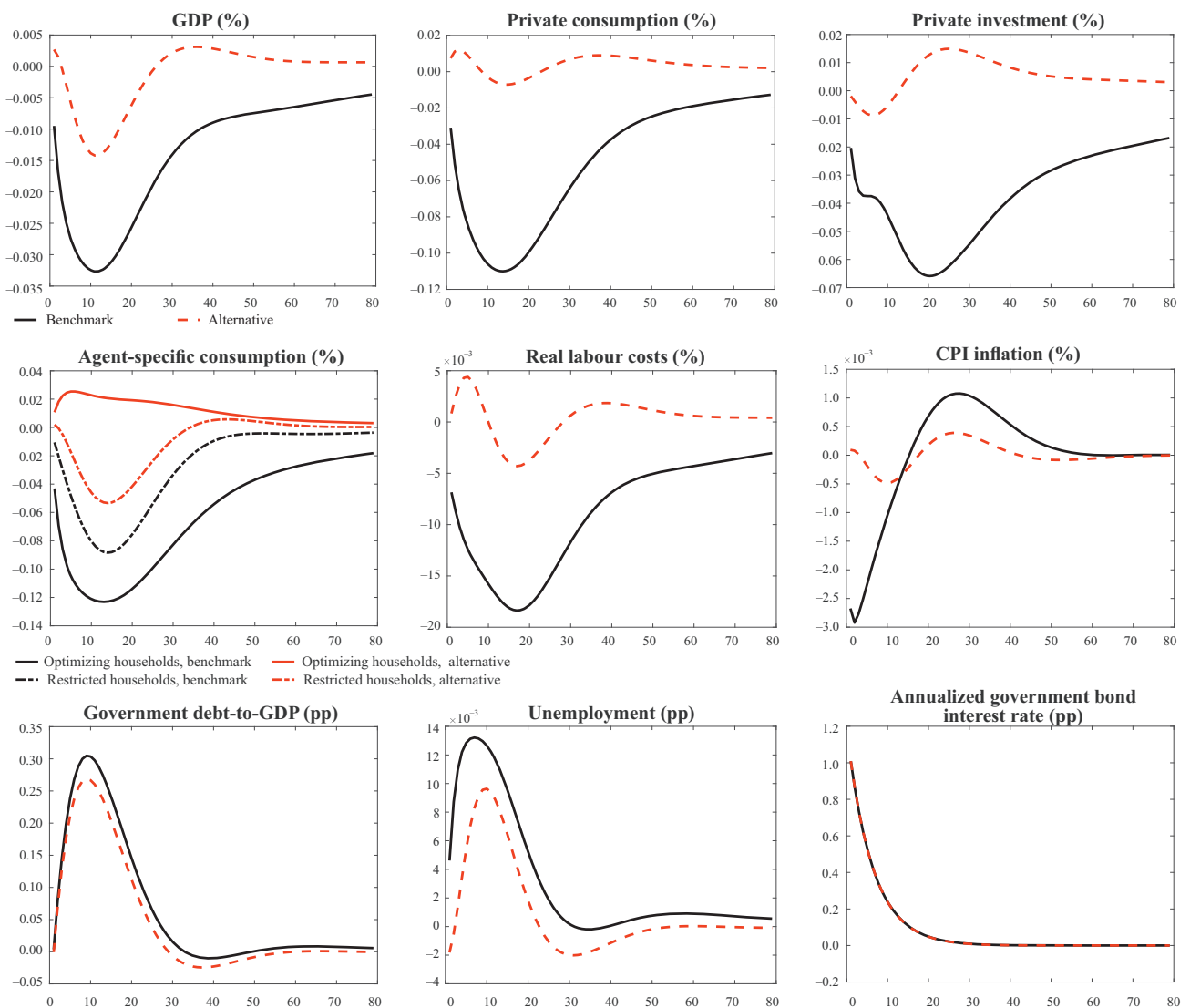
Figure 16  
Shock to total transfers – asymmetric vs. symmetric transfers



### 4.2.7 Foreign ownership of the government debt channel

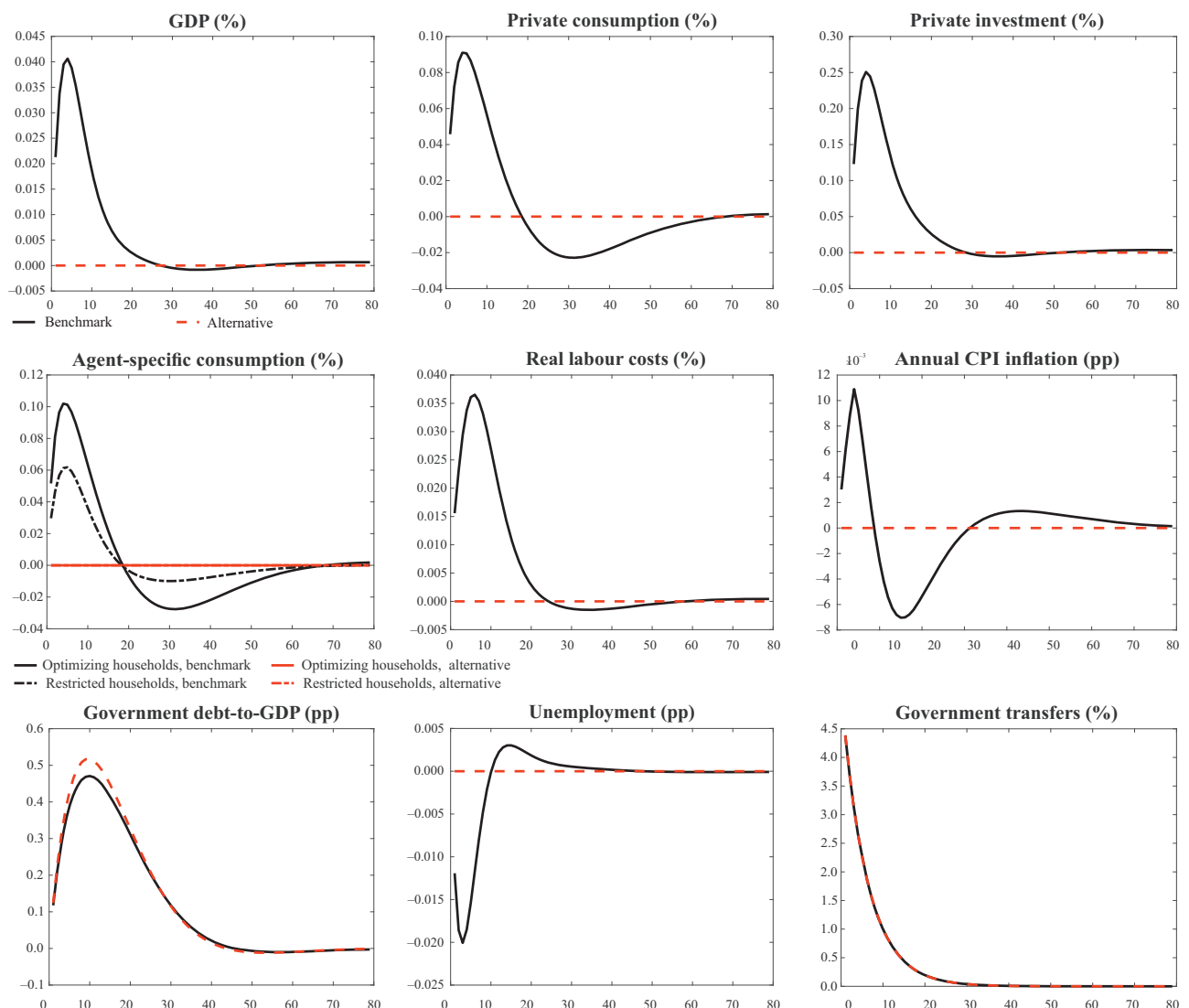
In the benchmark model, we assume that a large part of government debt is held abroad. Alternatively, we assume that all the government debt is held domestically by the optimizing households (i.e. we assume  $\omega_h = 1$ ). The model behaviour for a shock to the government risk premium (by one percentage point) is compared in Figure 17. When all the government debt is held domestically, the increased debt service payments by the government flow into the pockets of the optimizing households; therefore, overall, there is only a small impact on the economy, with the optimizing households consuming slightly more. With a substantial share of the government debt held abroad, a higher government risk premium means that more money leaves the economy therefore the optimizing households cut their consumption. The consequences for the economy are now negative and considerably larger in magnitude.

Figure 17  
Shock to the government risk premium – with vs. without foreign-held debt



A different angle of what the foreign-held government debt channel produces is shown in Figure 18. In this case, we direct all government transfers to the optimizing households, increase those transfers to an amount of 0.5% of GDP and activate only the lump-sum tax rule. Then we compare two cases – with vs. without foreign-held government debt. It can be seen that if all government debt is held domestically, the well-known Ricardian equivalence holds, as the total amount of money in the economy stays unchanged – the government borrows from the optimizing households and gives back to the optimizing households the same amount. However, with a positive share of the government debt held abroad, the total amount of money in the economy temporarily increases, as part of it flows from abroad. Therefore, temporarily, the optimizing households have more money, which they utilize buying foreign bonds. This channel generally breaks the Ricardian equivalence effects. As this channel is not typical in the literature and appears to be not discussed, we consider it in more detail.

**Figure 18**  
**Shock to transfers to optimizing households – with vs. without foreign-held debt**



The effect on the domestic economy depends on the specification of the domestic risk premia. In the benchmark model, we separate the government sector's risk premium



from the private sector's risk premium. The former defines the dynamics of the government bond yield, while the latter forms the dynamics of the deposit rate. Historically, the two series have behaved differently; therefore, in order to fit the data, we distinguish between the two underlying processes. The government risk premium depends on the government debt-to-GDP ratio (plus a government-specific exogenous shock), while the private sector's risk premium is subject to the net private foreign assets-to-GDP position (plus a private-sector specific exogenous shock). Note that the total net foreign assets position is stabilized, as the government's foreign debt is stabilized via active fiscal rules.

Given our risk premia specifications, a transfer to the optimizing households financed, at least partly, with foreign-held debt prompts the optimizing households to invest the received money in foreign bonds. As a result, the private sector's risk premium decreases, thus consumption and investment move up despite an increase in the government's risk premium due to its mounting debt.

In order to restore the Ricardian equivalence in face of foreign-held government debt, a specific – not necessarily realistic – constellation of calibrated parameters is needed. One way is to define the private sector's risk premium as a function of the *total* net foreign assets position,

$$R_t = \Phi_t R_t^* \quad (49),$$

$$\Phi_t = \ln(R_{SS}) - \ln(R_{SS}^*) - \tilde{\phi}_a \left( \frac{A_t - B_{g,t}^*}{Y_t} - \frac{A - B_g^*}{Y} \right) + \varepsilon_t^{rp} \quad (50)$$

and, importantly, to remove the government sector's risk premium process by assuming a constant government bond yield for all times (and being equal to the steady-state deposit rate). Then, as the government's foreign debt would offset the private sector's holdings of foreign bonds one-to-one, the deposit rate, and also consumption and investment, would not move.

However, the above assumption that the private sector's risk premium takes the government sector's foreign debt fully into account, while the government sector does not face any risk premium neither from its own debt nor via spillovers from the private sector's debt, is a strong one. If it is relaxed, the Ricardian equivalence, in general, does not hold. With the total net foreign assets position in the private sector's risk premium and a positive government risk premium to its debt level, one can generate a negative reaction of private consumption and investment to an increase in transfers to the optimizing households. To complicate the matters further, one could introduce a partial spillover to the private sector's risk premium from the government's foreign debt via a spillover parameter  $0 \leq \alpha^r \leq 1$ ,

$$\Phi_t = \ln(R_{SS}) - \ln(R_{SS}^*) - \tilde{\phi}_a \left( \frac{A_t - \alpha^r B_{g,t}^*}{Y_t} - \frac{A - \alpha^r B_g^*}{Y} \right) + \varepsilon_t^{rp} \quad (51).$$

But then the question would arise about the reciprocal feedback from the private sector's risk premium to the government sector. When building the model, we considered a non-zero risk premium on the government sector due to the private net foreign assets position via parameter  $\tilde{\phi}_{g,a}$  in equation (35), but gave it up by setting it to zero due to the complication it produced in interpreting simulation results. For the same reason, in the benchmark model, we do not allow for the government's foreign debt in the private sector's risk premium formula.

## 5. CONCLUSION

In this paper, we develop a fiscal DSGE model for Latvia, a small open economy within a monetary union. The key fiscal sector elements comprise government investment, government consumption, import content in government investment and consumption, asymmetric directed transfers to optimizing and restricted households, cyclical unemployment benefits, foreign-held public debt, six types of taxes, and fiscal rules. The model features search-and-matching labour market frictions with procyclical wages, a financial accelerator, import content in consumption, investment and exports, and the foreign sector represented as an SVAR.

The model is estimated using Latvian data for the period from the second quarter of 1995 to the third quarter of 2018. We make sure the model fits the data well. Our analysis of the key fiscal shocks reveals that having productive public capital is key to generate a persistent increase in GDP in response to a shock to public investment. Having public consumption in the household utility function weakens the initial positive co-movement between private and public consumption in response to an increase in public consumption, as households substitute their consumption for government consumption. A positive share of import content in public consumption and investment dampens (and in some cases makes more negative) the effect from fiscal shocks to the domestic economy. The higher the share of transfers directed to the restricted households, the larger the economic response to a shock of total transfers.

Foreign-held domestic government debt amplifies the economic response to a shock to the government risk premium, as a part of tax-payers' money is leaving the economy to service the government debt. The channel of foreign-held public debt also generally breaks the Ricardian equivalence in the case of directing lump-sum transfers to the optimizing households via the endogenous part of the domestic risk premium. Temporarily, as there is a change in the total money in the economy, the optimizing households alter their holding of the foreign bonds, affecting the domestic risk premium and thus their consumption and investment in response to changes in transfers. The foreign-held government debt channel has not yet received much attention in the literature.

Overall, the rich structure of the model should be able to contribute meaningfully to various fiscal policy studies and scenario analyses in a small open economy within a monetary union, such as Latvia; it has already been extensively field-tested before and during the Covid-19 crisis in studying various fiscal policy alternatives, and, we hope, will be used to shape policy discussions also in the future.

## APPENDIX A. FIRST-ORDER (MARGINAL COST) CONDITIONS

### A.1 Model without public capital

Intermediate goods firms minimize total costs subject to the production function. Therefore, the optimization problem we solve here is:

$$\min_{\{L_t, K_t\}} \{TC_t = \tau_t^d \omega_t R_t^f L_t + \tau_t^d r_t^k K_t + z_t^+ \phi\} \quad (52)$$

subject to

$$Y_t = (z_t L_t)^{1-\alpha} \varepsilon_t K_t^\alpha - z_t^+ \phi \quad (53).$$

The Lagrange multiplier is denoted by  $mc_t$ , as it equals the real marginal costs function in equilibrium. The first order conditions are:

$$K_t: \tau_t^d r_t^k = mc_t (z_t L_t)^{1-\alpha} \varepsilon_t \alpha K_t^{\alpha-1} \quad (54),$$

$$L_t: \tau_t^d R_t^f \omega_t = mc_t (1-\alpha) z_t^{1-\alpha} L_t^{-\alpha} \varepsilon_t K_t^\alpha \quad (55).$$

Re-normalized, these conditions become:

$$\tau_t^d \bar{r}_t^k = mc_t \alpha \varepsilon_t L_t^{1-\alpha} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha-1} \quad (56),$$

$$\tau_t^d R_t^f \bar{\omega}_t = mc_t (1-\alpha) \varepsilon_t L_t^{-\alpha} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^\alpha \quad (57).$$

These normalized conditions can also be written as follows:

$$mc_t = \frac{\tau_t^d \bar{r}_t^k}{\alpha \varepsilon_t \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha-1}} \quad (58),$$

$$mc_t = \frac{\tau_t^d R_t^f \bar{\omega}_t}{(1-\alpha) \varepsilon_t \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^\alpha} \quad (59).$$

Equating equations (58) and (59) and substituting the following resulting equation, i.e.

$$\frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} = \frac{R_t^f \bar{\omega}_t L_t}{\bar{r}_t^k} \frac{\alpha}{1-\alpha} \quad (60),$$

into equation (58) leads to the following expression after some simple algebra:

$$mc_t = \frac{\tau_t^d}{\varepsilon_t} \left( \frac{1}{\alpha} \right)^\alpha \left( \frac{1}{1-\alpha} \right)^{1-\alpha} (\bar{r}_t^k)^\alpha (R_t^f \bar{\omega}_t)^{1-\alpha} \quad (61).$$

### A.2 Model with public capital in CES bundle

Intermediate goods firms minimize total costs subject to the production function. Therefore, the optimization problem we solve here is:

$$\min_{\{L_t, K_t\}} \{TC_t = \tau_t^d \omega_t R_t^f L_t + \tau_t^d r_t^k K_t + z_t^+ \phi\} \quad (62),$$

subject to

$$Y_t = (z_t L_t)^{1-\alpha} \varepsilon_t \tilde{K}_t^\alpha - z_t^+ \phi \quad (63)$$

where:

$$\tilde{K}_t = \left( \alpha_k^{1/v_k} (K_t)^{v_k-1} + (1-\alpha_k)^{1/v_k} (K_{g,t})^{v_k-1} \right)^{v_k} \quad (64).$$

The Lagrange multiplier is denoted by  $mc_t$  as it equals the real marginal costs function in equilibrium. The first order conditions are:

$$K_t: \tau_t^d r_t^k = mc_t (z_t L_t)^{1-\alpha} \varepsilon_t \alpha_k^{1/v_k} \tilde{K}_t^{\alpha+1/v_k-1} K_t^{-1/v_k} \quad (65),$$

$$L_t: \tau_t^d R_t^f \omega_t = mc_t (1-\alpha) z_t^{1-\alpha} L_t^{-\alpha} \varepsilon_t \tilde{K}_t^\alpha \quad (66).$$

Re-normalized, these conditions become:

$$\tau_t^d \bar{r}_t^k = mc_t \alpha_k^{1/v_k} \varepsilon_t L_t^{1-\alpha} \left( \frac{\bar{k}_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha+1/v_k-1} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^{-1/v_k} \quad (67),$$

$$\tau_t^d R_t^f \bar{\omega}_t = mc_t (1-\alpha) \varepsilon_t L_t^{-\alpha} \left( \frac{\bar{k}_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^\alpha \quad (68).$$

These normalized conditions can also be written as follows:

$$mc_t = \frac{\tau_t^d \bar{r}_t^k}{\alpha_k^{1/v_k} \varepsilon_t \left( \frac{\bar{k}_t}{\mu_{z+,t} \mu_{\psi,t} L_t} \right)^{\alpha+1/v_k-1} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t} L_t} \right)^{-1/v_k}} \quad (69),$$

$$mc_t = \frac{\tau_t^d R_t^f \bar{\omega}_t}{(1-\alpha) \varepsilon_t \left( \frac{\bar{k}_t}{\mu_{z+,t} \mu_{\psi,t} L_t} \right)^\alpha} \quad (70).$$

Equating equations (69) and (70) and substituting the following resulting equation, i.e.

$$\frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} = \left( \frac{\bar{r}_t^k}{R_t^f \bar{\omega}_t L_t} \right)^{-v_k} \left( \frac{1-\alpha}{\alpha} \right)^{-v_k} \alpha_k \left( \frac{\bar{k}_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^{1-v_k} \quad (71),$$

into equation (69) leads to the following expression after some simple algebra:

$$mc_t = \frac{\tau_t^d \left( \frac{\bar{k}_t}{\mu_{z+,t} \mu_{\psi,t} L_t} \right)^{-\alpha} R_t^f \bar{\omega}_t}{\varepsilon_t (1-\alpha)} \quad (72).$$

Alternatively, equating equations (69) and (70) and substituting the following resulting equation, i.e.

$$\frac{\bar{k}_t}{\mu_{z+,t} \mu_{\psi,t}} = \left( \frac{\bar{r}_t^k}{R_t^f \bar{\omega}_t L_t} \right)^{v_k/(1-v_k)} \left( \frac{1-\alpha}{\alpha} \right)^{v_k/(1-v_k)} \alpha_k^{v_k-1} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^{1/(1-v_k)} \quad (73),$$

into equation (72) lead to the following expression after some not so simple algebra:

$$mc_t = \frac{\tau_t^d}{\varepsilon_t} (R_t^f \bar{\omega}_t)^{\frac{\alpha v_k}{1-v_k} + 1} (\bar{r}_t^k)^{\frac{\alpha v_k}{v_k-1}} (\alpha)^{\frac{\alpha v_k}{1-v_k}} (\alpha_k)^{\frac{\alpha}{1-v_k}} (1-\alpha)^{\frac{\alpha v_k}{v_k-1} - 1} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t} L_t} \right)^{\frac{\alpha}{v_k-1}} \quad (74).$$

### A.3 Model with public capital as an additional production factor

Intermediate goods firms minimize total costs subject to the production function. Therefore, the optimization problem we solve here is:

$$\min_{\{L_t, K_t\}} \{TC_t = \tau_t^d \omega_t R_t^f L_t + \tau_t^d r_t^k K_t + z_t^+ \phi\} \quad (75)$$

subject to

$$Y_t = z_t^{1-\alpha-\alpha_k} L_t^{1-\alpha} \varepsilon_t K_t^\alpha K_{G,t}^{\alpha_k} - z_t^+ \phi \quad (76).$$

The Lagrange multiplier is denoted by  $mc_t$ , as it equals the real marginal costs function in equilibrium. The first order conditions are:

$$K_t: \tau_t^d r_t^k = mc_t z_t^{1-\alpha-\alpha_k} L_t^{1-\alpha} \varepsilon_t \alpha K_t^{\alpha-1} (K_{G,t})^{\alpha_k} \quad (77),$$

$$L_t: \tau_t^d R_t^f \omega_t = mc_t (1-\alpha) z_t^{1-\alpha-\alpha_k} L_t^{-\alpha} \varepsilon_t K_t^\alpha (K_{G,t})^{\alpha_k} \quad (78).$$

Re-normalized, these conditions become:

$$\tau_t^d \bar{r}_t^k = mc_t \alpha \varepsilon_t L_t^{1-\alpha} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha-1} \left( \frac{k_{G,t}}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha_k} \quad (79),$$

$$\tau_t^d R_t^f \bar{\omega}_t = mc_t (1-\alpha) \varepsilon_t L_t^{-\alpha} \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} \right)^\alpha \left( \frac{k_{G,t}}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha_k} \quad (80).$$

Note that the definition of  $z_t^+$  changes into the following one:

$$z_t^+ = \Psi_t^{\frac{\alpha+\alpha_k}{1-\alpha-\alpha_k}} z_t \quad (81).$$

These normalized conditions can also be written as follows:

$$mc_t = \frac{\tau_t^d \bar{r}_t^k}{\alpha \varepsilon_t \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t} L_t} \right)^{\alpha-1} \left( \frac{k_{G,t}}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha_k}} \quad (82),$$

$$mc_t = \frac{\tau_t^d R_t^f \bar{\omega}_t}{(1-\alpha) \varepsilon_t \left( \frac{k_t}{\mu_{z+,t} \mu_{\psi,t} L_t} \right)^\alpha \left( \frac{k_{G,t}}{\mu_{z+,t} \mu_{\psi,t}} \right)^{\alpha_k}} \quad (83).$$

Equating equations (82) and (83) and substituting the following resulting equation, i.e.

$$\frac{k_t}{\mu_{z+,t} \mu_{\psi,t}} = \frac{R_t^f \bar{\omega}_t L_t}{\bar{r}_t^k} \frac{\alpha}{1-\alpha} \quad (84),$$

into equation (82) leads to the following expression after some simple algebra:

$$mc_t = \frac{\tau_t^d}{\varepsilon_t} \left( \frac{1}{\alpha} \right)^\alpha \left( \frac{1}{1-\alpha} \right)^{1-\alpha} (\bar{r}_t^k)^\alpha (R_t^f \bar{\omega}_t)^{1-\alpha} \left( \frac{k_{G,t}}{\mu_{z+,t} \mu_{\psi,t}} \right)^{-\alpha_k} \quad (85).$$

## APPENDIX B. FOREIGN BLOCK AND MEASUREMENT EQUATIONS

### B.1 Foreign block

The adaptation of the DSGE model for forecasting purposes over the last years has altered the specification of the foreign block to include observables, such as the foreign demand (measured as the weighted average imports of the trading partners), the competitors' prices, as well as the nominal effective exchange rate.

The first five rows below are taken from the previous version of the model and represent the EA output, EA inflation, EA interest rate, the neutral unit-root technological process, and the (suspended in the benchmark model) investment-specific unit-root technological process. The sixth and seventh rows reflect the competitors' prices and foreign demand, while the last row is the log-difference of the nominal effective exchange rate, modelled as an AR(1) process.

$$\begin{pmatrix} \log\left(\frac{y_t^*}{y^*}\right) \\ \pi_t^* - \pi^* \\ R_t^* - R^* \\ \log\left(\frac{\mu_{z,t}}{\mu_z}\right) \\ \log\left(\frac{\mu_{\psi,t}}{\mu_{\psi}}\right) \\ \pi_t^f - \pi^f \\ \log\left(\frac{y_t^f}{y^f}\right) \\ \log(s_t) \end{pmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & a_{23} & a_{24} & \frac{a_{24}\alpha}{1-\alpha} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & a_{34} & \frac{a_{34}\alpha}{1-\alpha} & 0 & 0 & 0 \\ 0 & 0 & 0 & \rho_{\mu_z} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \rho_{\mu_{\psi}} & 0 & 0 & 0 \\ a_{61} & a_{62} & 0 & 0 & 0 & a_{66} & a_{67} & 0 \\ a_{71} & 0 & 0 & 0 & 0 & a_{76} & a_{77} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_s \end{bmatrix} \begin{pmatrix} \log\left(\frac{y_{t-1}^*}{y^*}\right) \\ \pi_{t-1}^* - \pi^* \\ R_{t-1}^* - R^* \\ \log\left(\frac{\mu_{z,t-1}}{\mu_z}\right) \\ \log\left(\frac{\mu_{\psi,t-1}}{\mu_{\psi}}\right) \\ \pi_{t-1}^f - \pi^f \\ \log\left(\frac{y_{t-1}^f}{y^f}\right) \\ \log(s_{t-1}) \end{pmatrix} \\
 + \begin{bmatrix} \sigma_{y^*} & 0 & 0 & 0 & 0 & 0 & c_{17} & 0 \\ c_{21} & \sigma_{\pi^*} & 0 & c_{24} & \frac{c_{24}\alpha}{1-\alpha} & 0 & 0 & 0 \\ c_{31} & c_{32} & \sigma_{R^*} & c_{34} & \frac{c_{34}\alpha}{1-\alpha} & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_{\mu_z} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma_{\mu_{\psi}} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma_{\pi^f} & c_{67} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma_{y^f} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \sigma_s \end{bmatrix} \begin{pmatrix} \varepsilon_{y^*,t} \\ \varepsilon_{\pi^*,t} \\ \varepsilon_{R^*,t} \\ \varepsilon_{\mu_z,t} \\ \varepsilon_{\mu_{\psi},t} \\ \varepsilon_{\pi^f,t} \\ \varepsilon_{y^f,t} \\ \varepsilon_{s,t} \end{pmatrix} \quad (86).$$

The variables  $\varepsilon_t$ 's are mean zero, unit variance, and Gaussian i.i.d. processes uncorrelated with each other.

### B.2 Measurement equations

The measurement equations linking the model variables to the data are shown below where  $\varepsilon_{i,t}^{me}$  denotes a measurement error for variable  $i$ .

Nominal deposit interest rate:

$$R_{D,t}^{data} = 400(R_t - 1) \quad (87).$$



Nominal government bond yield:

$$R_{L,t}^{data} = 400(R_{g,t} - 1) \quad (88).$$

Foreign (EA) nominal interest rate:

$$R_t^{*,data} = 400(R_t^* - 1) \quad (89).$$

GDP deflator inflation:

$$\pi_t^{d,data} = 400 \log \pi_t - 400 \log \pi + \varepsilon_{\pi,t}^{me} \quad (90).$$

CPI inflation (after consumption tax):

$$\pi_t^{c,data} = 400 \log \pi_t^{c,\tau_c} - 400 \log \pi^c + \varepsilon_{\pi^c,t}^{me} \quad (91)$$

where

$$\pi_t^{c,\tau_c} = \pi_t^c \frac{1+\tau_t^c}{1+\tau_{t-1}^c} \quad (92).$$

Investment deflator inflation:

$$\pi_t^{i,data} = 400 \log \pi_t^i - 400 \log \pi^i + \varepsilon_{\pi^i,t}^{me} \quad (93).$$

Foreign (EA) CPI inflation:

$$\pi_t^{*,data} = 400 \log \pi_t^* \quad (94).$$

Competitors' export price inflation:

$$\pi_t^{f,data} = 400 \log \pi_t^f \quad (95).$$

GDP quarter-on-quarter growth:

$$\Delta \log y_t^{data} = 100(\log \mu_{z^+,t} + \Delta \log y_t^{gdp} - \log \mu_{z^+}) + \varepsilon_{y,t}^{me} \quad (96)$$

where

$$y_t^{gdp} = y_t - p_t^i a(u_t) \frac{\bar{k}_t}{\mu_{\psi,t} \mu_{z^+,t}} - \frac{\mu_G(\bar{\omega}_t; \sigma_{t-1}) R_t^k p_{k,t-1} \bar{k}_t}{\pi_t \mu_{z^+,t}} - (n_{\kappa_v,t} \kappa_v Q_t^{-1} + n_{\kappa_h,t} \kappa_h) \chi_t L_{t-1} - \Gamma_{g,t} / Z_t^+ \quad (97)$$

is the measured GDP without capital utilization costs, entrepreneur monitoring costs, vacancy posting and recruiting costs, and bond adjustment costs.

Foreign (EA) GDP quarter-on-quarter growth:

$$\Delta \log y_t^{*,data} = 100(\log \mu_{z^+,t} + \Delta \log y_t^* - \log \mu_{z^+}) \quad (98).$$

Foreign demand (trading partners' imports) quarter-on-quarter growth:

$$\Delta \log y_t^{f,data} = 100(\log \mu_{z^+,t} + \Delta \log y_t^f - \log \mu_{z^+}) \quad (99).$$

Nominal effective exchange rate quarter-on-quarter growth:

$$\log s_t^{data} = 100 \log s_t + \varepsilon_{s,t}^{me} \quad (100).$$

Private consumption quarter-on-quarter growth:

$$\Delta \log c_t^{data} = 100(\log \mu_{z^+,t} + \Delta \log c_t - \log \mu_{z^+}) + \varepsilon_{c,t}^{me} \quad (101).$$

(Total) investment quarter-on-quarter growth:

$$\Delta \log i_t^{data} = 100[\log \mu_{z^+,t} + \log \mu_{\psi,t} + \Delta \log i_t^{tot}] - 100(\log \mu_{z^+} + \log \mu_{\psi}) + \varepsilon_{i,t}^{me} \quad (102)$$

where

$$i_t^{tot} = i_t + g_{i,t} \quad (103)$$

is total real investment. Exports quarter-on-quarter growth:

$$\Delta \log x_t^{data} = 100(\log \mu_{z^+,t} + \Delta \log x_t - \log \mu_{z^+}) + \varepsilon_{x,t}^{me} \quad (104).$$

Imports quarter-on-quarter growth:

$$\Delta \log imp_t^{data} = 100(\log \mu_{z^+,t} + \Delta \log imp_t - \log \mu_{z^+}) + \varepsilon_{imp,t}^{me} \quad (105)$$

where

$$imp_t = \begin{pmatrix} c_t^m (\dot{p}_t^{m,c})^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} \\ + i_t^m (\dot{p}_t^{m,i})^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} \\ + x_t^m (\dot{p}_t^{m,x})^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}} \\ + g_{c,t}^m (\dot{p}_t^{m,g,c})^{\frac{\lambda_{m,g,c}}{1-\lambda_{m,g,c}}} \\ + g_{i,t}^m (\dot{p}_t^{m,g,i})^{\frac{\lambda_{m,g,i}}{1-\lambda_{m,g,i}}} \end{pmatrix} \quad (106)$$

is total imports, and where the last two rows represent imports for government consumption and government investment.

Real labour cost quarter-on-quarter growth deflated by after-tax CPI<sup>16</sup>:

$$\Delta \log w_t^{lc,data} = 100(\log \mu_{z^+,t} + \Delta \log w_t^{lc} - \log \mu_{z^+} + \log \pi_t - \log \pi_t^{c,\tau_c}) + \varepsilon_{lc,t}^{me} \quad (107)$$

where

$$w_t^{lc} = (1 + \tau_{e,t}^w) \bar{w}_t \quad (108).$$

Unemployment rate quarter-on-quarter growth:

$$\Delta \log Unemp_t^{data} = 100 \Delta \log(1 - L_t) + \varepsilon_{Unemp,t}^{me} \quad (109).$$

Net worth as measured by real house price index, quarter-on-quarter growth:

<sup>16</sup> The default model variable is deflated by GDP deflator, but its data counterpart is considerably noisier than that deflated by after-tax CPI; thus, here we transform the model variable in the measurement equation such that the deflator is after-tax CPI, consistent with the data.

$$\Delta \log n_t^{data} = 100(\log \mu_{z^+,t} + \Delta \log n_t - \log \mu_{z^+}) + \varepsilon_{n,t}^{me} \quad (110).$$

Nominal interest rate spread between lending and risk-free rate:

$$Spread_t^{data} = 400(spread_t - spread) + \varepsilon_{Spread,t}^{me} \quad (111)$$

where

$$spread_t = Z_{t+1} - R_t = \frac{\bar{\omega}_{t+1} R_{t+1}^k}{1 - \frac{n_{t+1}}{p_{k,t} k_{t+1}}} - R_t \quad (112).$$

Government consumption quarter-on-quarter growth:

$$\Delta \log g_{c,t}^{data} = 100(\log \mu_{z^+,t} + \Delta \log g_{c,t} - \log \mu_{z^+}) + \varepsilon_{g,c,t}^{me} \quad (113).$$

Government investment quarter-on-quarter growth:

$$\Delta \log g_{i,t}^{data} = 100[\log \mu_{z^+,t} + \log \mu_{\psi,t} + \Delta \log g_{i,t}] - 100(\log \mu_{z^+} + \log \mu_{\psi}) + \varepsilon_{g,i,t}^{me} \quad (114).$$

Government debt-to-GDP ratio:

$$debt2GDP_t^{data} = \frac{D_{g,t}}{Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3}} \quad (115).$$

Government transfers quarter-on-quarter growth:

$$\Delta \log tr_t^{data} = 100(\log \mu_{z^+,t} + \Delta \log tr_t - \log \mu_{z^+}) + \varepsilon_{tr,t}^{me} \quad (116).$$

Effective consumption tax rate:

$$\tau_t^{c,data} = \tau_t^c + \varepsilon_{\tau^c,t}^{me} \quad (117).$$

Effective labour income tax rate:

$$\tau_t^{y,data} = \tau_t^y + \varepsilon_{\tau^y,t}^{me} \quad (118).$$

Effective employer SSC rate:

$$\tau_{e,t}^{w,data} = \tau_{e,t}^w + \varepsilon_{\tau_e^w,t}^{me} \quad (119).$$

Effective employee SSC rate:

$$\tau_{w,t}^{w,data} = \tau_{w,t}^w + \varepsilon_{\tau_w^w,t}^{me} \quad (120).$$

## APPENDIX C. CALIBRATION AND ESTIMATION OF THE NON-FISCAL PART OF THE MODEL

Table 3  
Calibrated parameters, non-fiscal part

Parameter	Value	Description
<i>Core block</i>		
$\alpha$	0.4000	Capital share in production of intermediate goods
$\beta$	0.9995	Time discount factor, optimizing households
$\omega_c$	0.4500	Import share in consumption goods
$\omega_i$	0.6500	Import share in investment goods
$\omega_x$	0.3300	Import share in export goods
$\tilde{\phi}_a$	0.0100	Elasticity of domestic risk premium to net foreign assets position
$\mu_z$	1.0031	Steady-state quarterly growth rate of neutral technology
$\mu_\psi$	1.0000	Steady-state growth rate of investment technology
$\bar{\pi}$	1.0043	Steady-state gross inflation target
$\lambda_d$	1.3000	Price mark-up for domestic good
$\lambda_{m,c}$	1.0500	Price mark-up for imported consumption good
$\lambda_{m,i}$	1.0500	Price mark-up for imported investment good
$\lambda_{m,x}$	1.0500	Price mark-up for imported exports good
$\lambda_x$	1.0500	Price mark-up for exported good
$v^f$	0.5483	Working capital fraction, intermediate good
$v^*$	0.5483	Working capital fraction, imports
$v^x$	0.5483	Working capital fraction, exports
$\lambda_r$	0.5000	Share of restricted households
$\theta^d$	0.5000	Technology diffusion parameter (common)
<i>Financial frictions block</i>		
$100W_e/y$	0.1000	Transfers to entrepreneurs
<i>Labour market block</i>		
$L$	0.8744	Steady-state fraction of employment (1 – unemployment rate)
$bshare$	0.1000	Unemployment benefit share of gross wage
$vshare$ (%)	0.0000	Vacancy posting cost as share of GDP
$\rho$	0.7000	Exogenous survival rate of a match
$\sigma$	0.7392	Unemployment share in matching technology

Note. This table contains the key calibrated parameters and steady states of the core model.

*Table 4*  
**Targeted steady states and selected implied parameters**

Parameter	Description	Value
<i>Targeted steady states</i>		
$p_x x \tilde{\varphi} / y$	Exports to gross output	0.6100
$p_i i / y$	Investment to gross output	0.2200
$n / (p_k k)$	Firm net worth to capital	0.7000
<i>Implied parameters</i>		
$\delta$	Capital quarterly depreciation rate	0.0412
$\tilde{\varphi}$	Real exchange rate	0.8867
$\gamma$	Entrepreneurial survival rate	0.9542
$\sigma_m$	Level parameter in matching function	0.6823
$f$	Job finding rate	0.6762
$v$	Vacancy rate	0.4286
$p_c c / y$	Private consumption to gross output	0.6477

Note. This table contains the key targeted steady states in the model and selected implied parameters.

*Table 5*  
**Estimated parameters and shocks, non-fiscal part**

Parameter	Description	Prior			Posterior	
		Distr.	Mean	St.d.	Mode	St.d.
$\xi_d$	Calvo parameter, domestic good	$\beta$	<b>0.75</b>	0.075	<b>0.781</b>	0.017
$\xi_x$	Calvo parameter, exports	$\beta$	<b>0.75</b>	0.075	<b>0.836</b>	0.022
$\xi_{m,c}$	Calvo parameter, imports for consumption	$\beta$	<b>0.75</b>	0.075	<b>0.944</b>	0.010
$\xi_{m,i}$	Calvo parameter, imports for investment	$\beta$	<b>0.75</b>	0.075	<b>0.650</b>	0.032
$\xi_{m,x}$	Calvo parameter, imports for exports	$\beta$	<b>0.66</b>	0.10	<b>0.809</b>	0.024
$\kappa_d$	Inflation indexation, domestic good	$\beta$	<b>0.50</b>	0.15	<b>0.152</b>	0.043
$\kappa_x$	Inflation indexation, exports	$\beta$	<b>0.05</b>	0.02	<b>0.069</b>	0.009
$\kappa_{m,c}$	Inflation indexation, imports for consumption	$\beta$	<b>0.50</b>	0.15	<b>0.448</b>	0.077
$\kappa_{m,i}$	Inflation indexation, imports for investment	$\beta$	<b>0.50</b>	0.15	<b>0.247</b>	0.040
$\kappa_{m,x}$	Inflation indexation, imports for exports	$\beta$	<b>0.05</b>	0.02	<b>0.048</b>	0.006
$v^j$	Working capital share	$\beta$	<b>0.50</b>	0.1	<b>0.548</b>	0.017
$b$	Habit in consumption	$\beta$	<b>0.65</b>	0.15	<b>0.660</b>	0.056
$0.1S''$	Investment adjustment costs	$\Gamma$	<b>0.40</b>	0.15	<b>0.069</b>	0.013
$\sigma_a$	Variable capital utilization	$\Gamma$	<b>0.30</b>	0.1	<b>0.291</b>	0.027
$\eta_x$	Elasticity of substitution, domestic good and imports for exports	$\underline{\Gamma}$	<b>1.50</b>	0.25	<b>1.349</b>	0.050
$\eta_c$	Elasticity of substitution, domestic good and imports for consumption	$\underline{\Gamma}$	<b>1.50</b>	0.25	<b>1.668</b>	0.081
$\eta_i$	Elasticity of substitution, domestic good and imports for investment	$\underline{\Gamma}$	<b>1.50</b>	0.25	<b>1.125</b>	0.044
$\eta_f$	Elasticity of substitution, exports and foreign good	$\underline{\Gamma}$	<b>1.50</b>	0.25	<b>1.010</b>	0.034
$\mu$	Monitoring cost	$\beta$	<b>0.35</b>	0.075	<b>0.474</b>	0.014
$F(\bar{w})$	Steady-state bankruptcy rate	$\beta$	<b>0.015</b>	0.002	<b>0.020</b>	0.001
$hshare$	(%) Hiring fixed costs	$\Gamma$	<b>0.20</b>	0.075	<b>0.180</b>	0.042
$woo$	Worker outside option parameter	$\beta$	<b>0.40</b>	0.075	<b>0.541</b>	0.014
$\alpha^u$	Power parameter in outside option equation	$\beta$	<b>0.90</b>	0.075	<b>0.891</b>	0.019
$\rho_\varepsilon$	Persistence, stationary technology	$\beta$	<b>0.85</b>	0.075	<b>0.911</b>	0.022
$\rho_\gamma$	Persistence, marginal efficiency of private investment	$\beta$	<b>0.85</b>	0.075	<b>0.579</b>	0.018
$\rho_{\zeta^c}$	Persistence, consumption preference shock	$\beta$	<b>0.85</b>	0.075	<b>0.739</b>	0.028
$\rho_{\bar{\phi}}$	Persistence, domestic risk premium	$\beta$	<b>0.85</b>	0.075	<b>0.959</b>	0.014
$\rho_g$	Persistence, government spending	$\beta$	<b>0.85</b>	0.075	<b>0.841</b>	0.020
$\rho_\gamma$	Persistence, entrepreneurial wealth	$\beta$	<b>0.85</b>	0.075	<b>0.675</b>	0.023
$\rho_{\varepsilon^x}$	Persistence, exports stationary technology	$\beta$	<b>0.85</b>	0.075	<b>0.869</b>	0.031
$\rho_{bu}$	Persistence, outside option	$\beta$	<b>0.80</b>	0.075	<b>0.911</b>	0.012
<i>Shock standard deviations</i>						
$10\sigma_\varepsilon$	Stationary technology	$\Gamma^{-1}$	<b>0.10</b>	inf	<b>0.100</b>	0.010
$\sigma_\gamma$	Marginal efficiency of private investment	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.101</b>	0.015
$\sigma_{\zeta^c}$	Consumption preference shock	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.075</b>	0.018
$100\sigma_{\bar{\phi}}$	Domestic risk premium	$\Gamma^{-1}$	<b>0.40</b>	inf	<b>0.097</b>	0.009
$\sigma_{\tau^d}$	Mark-up, domestic good	$\Gamma^{-1}$	<b>0.10</b>	inf	<b>0.232</b>	0.070
$\sigma_{\tau^x}$	Mark-up, exports	$\Gamma^{-1}$	<b>0.40</b>	inf	<b>0.104</b>	0.032
$\sigma_{\tau^{m,c}}$	Mark-up, imports for consumption	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.617</b>	0.264
$\sigma_{\tau^{m,i}}$	Mark-up, imports for investment	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.926</b>	0.283
$\sigma_{\tau^{m,x}}$	Mark-up, imports for exports	$\Gamma^{-1}$	<b>0.50</b>	inf	<b>0.305</b>	0.099
$10\sigma_\gamma$	Entrepreneurial wealth	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.280</b>	0.026
$10\sigma_{\varepsilon^x}$	Exports stationary technology	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.169</b>	0.033
$10\sigma_{bu}$	Outside option	$\Gamma^{-1}$	<b>0.10</b>	inf	<b>0.189</b>	0.022
<i>Model fit statistic</i>						
$\mathcal{L}$	Log marginal likelihood (Laplace approximation)					-4491.7

Notes. This table contains the estimated parameters for the core model. Note that truncated priors, denoted by  $\underline{\Gamma}$ , with no mass below 1.01, have been used for the elasticity parameters  $\eta_j$ ,  $j = \{x, c, i, f\}$ .

*Table 6*  
**Estimated foreign SVAR parameters**

Parameter	Description	Prior			Posterior	
		Distr.	Mean	St.d.	Mode	St.d.
$\rho_{\mu_z}$	Persistence, unit-root technology	$\beta$	<b>0.60</b>	0.075	<b>0.707</b>	0.057
$a_{11}$	Persistence, EA output	$\beta$	<b>0.90</b>	0.075	<b>0.994</b>	0.014
$a_{22}$	Persistence, EA inflation	$\beta$	<b>0.30</b>	0.075	<b>0.310</b>	0.063
$a_{33}$	Persistence, EA interest rate	$\beta$	<b>0.70</b>	0.075	<b>0.668</b>	0.060
$a_{66}$	Persistence, competitors price inflation	$\beta$	<b>0.30</b>	0.075	<b>0.304</b>	0.059
$a_{77}$	Persistence, foreign demand	$\beta$	<b>0.85</b>	0.075	<b>0.941</b>	0.023
$\rho_s$	Persistence, nominal effective exchange rate	$\beta$	<b>0.20</b>	0.075	<b>0.132</b>	0.024
$a_{12}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.10	<b>0.012</b>	0.082
$a_{13}$	Foreign SVAR parameter	$N$	<b>-0.10</b>	0.05	<b>-0.059</b>	0.037
$a_{21}$	Foreign SVAR parameter	$N$	<b>0.10</b>	0.10	<b>0.071</b>	0.032
$a_{23}$	Foreign SVAR parameter	$N$	<b>-0.10</b>	0.05	<b>-0.097</b>	0.049
$a_{24}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.10	<b>0.024</b>	0.064
$a_{26}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>0.010</b>	0.014
$a_{31}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>0.106</b>	0.019
$a_{32}$	Foreign SVAR parameter	$N$	<b>0.10</b>	0.005	<b>0.099</b>	0.005
$a_{34}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.005	<b>0.002</b>	0.005
$a_{61}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>-0.009</b>	0.047
$a_{62}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>0.007</b>	0.052
$a_{67}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>-0.023</b>	0.022
$a_{71}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>0.001</b>	0.048
$a_{76}$	Foreign SVAR parameter	$N$	<b>0.20</b>	0.05	<b>0.246</b>	0.047
$c_{17}$	Foreign SVAR parameter	$N$	<b>0.10</b>	0.10	<b>0.096</b>	0.017
$c_{21}$	Foreign SVAR parameter	$N$	<b>0.05</b>	0.05	<b>0.018</b>	0.049
$c_{31}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>0.111</b>	0.033
$c_{32}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.05	<b>0.063</b>	0.022
$c_{24}$	Foreign SVAR parameter	$N$	<b>-0.05</b>	0.05	<b>-0.067</b>	0.045
$c_{34}$	Foreign SVAR parameter	$N$	<b>0.00</b>	0.005	<b>0.001</b>	0.005
$c_{67}$	Foreign SVAR parameter	$N$	<b>0.20</b>	0.05	<b>-0.023</b>	0.022
<i>Shock standard deviations</i>						
$100\sigma_{\mu_z}$	Unit root technology	$\Gamma^{-1}$	<b>0.25</b>	inf	<b>0.223</b>	0.038
$100\sigma_{y^{ea}}$	EA GDP	$\Gamma^{-1}$	<b>0.20</b>	inf	<b>0.256</b>	0.031
$1000\sigma_{\pi^{ea}}$	EA inflation	$\Gamma^{-1}$	<b>0.25</b>	inf	<b>0.256</b>	0.019
$100\sigma_{R^{ea}}$	EA interest rate	$\Gamma^{-1}$	<b>0.05</b>	inf	<b>0.048</b>	0.005
$10\sigma_{dem^*}$	Foreign demand	$\Gamma^{-1}$	<b>0.20</b>	inf	<b>0.239</b>	0.017
$10\sigma_{\pi^{compx}}$	Competitors price on exports side	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.160</b>	0.013
$10\sigma_s$	Nominal effective exchange rate	$\Gamma^{-1}$	<b>0.15</b>	inf	<b>0.157</b>	0.015

Notes. This table contains the estimated parameters for the foreign economy. Informative priors are used to generate plausible impulse response functions. The structure of the SVAR model used to describe the behaviour of the foreign economy is described in Appendix B.

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