# Fiscal stabilisation in a low-interest and high-debt environment[*]

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**Preliminary and incomplete version**

## Abstract

This paper makes a case for asymmetric government spending rules in an estimated state-of-the-art DSGE model for the euro area. We analyse rules that prescribe (additional) fiscal expansion only when the economy operates at the (endogenous) effective lower bound (ELB). Stabilisation gains are large in the case of long-lasting ELB episodes, and smaller if ELB episodes are infrequent and shorter. Fiscal costs are, at the same time, modest and decreasing with ELB duration. Symmetric counter-cyclical rules, by contrast, have less favourable fiscal implications without comparable extra benefits. Tax cuts with deflationary impact are rather destabilising at the ELB.

*JEL classification*: E17, E62, E63, E70
*Keywords*: Estimated DSGE model, Euro Area, Monetary-fiscal interactions, Fiscal policy, Zero lower bound

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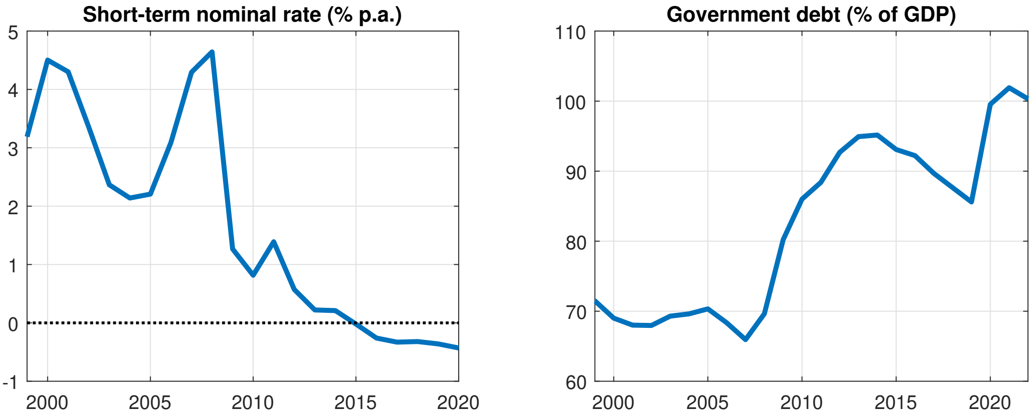
# 1 Introduction

The euro area (EA) economy has operated at the effective lower bound (ELB, often also "zero lower bound") in recent years. Nominal short-term interest rates have fallen during the last 15 years, and they have been close to or slightly below zero for almost a decade now (Figure 1). The ELB environment limits the effectiveness of monetary policy, which is left only with unconventional measures. It also revalues the role of fiscal policy, however. Fiscal stabilisation policy tends to become more important and more powerful. In particular, fiscal multipliers tend to be higher in the absence of a compensating monetary policy response. The room for fiscal expansion is limited at the same time. EA government debt has risen during the Global financial crisis, the EA debt crises and the COVID pandemic to around 100 per cent of GDP (Figure 1). Debt sustainability may not be an immediate concern, but there is a sustainability risk associated with rising interest rates in the future. Wanted in this context are fiscal strategies that reconcile output stabilisation, when needed, with limited government debt build-up.



Source: AMECO. Note: ECFIN Spring 2021 forecast for 2021 and 2022.

Figure 1: EA interest rates and government debt

This paper explores such strategies. In particular, we consider ('asymmetric') fiscal rules that respond to the business cycle only when monetary policy hits the ELB and compare them to ('symmetric') countercyclical instrument rules that are active over the entire business cycle, analogously to automatic stabilisers in the tax and benefit system.

The ‘asymmetric’ and ‘symmetric’ rules are assessed with respect to their potential of stabilising output (notably, reducing and shortening the occurrence of ELB episodes) and their implications for government finances (deficit and debt levels). We also provide a welfare-based assessment of the different rules [to be completed]. Furthermore, we discuss the implications for business cycle stabilisation and debt dynamics of deactivating budget stabilisation rules when the economy reaches the ELB [to be completed].

The analysis uses an estimated DSGE model of the EA with endogenous ELB to provide quantitatively plausible answers. Model estimation, in particular, provides information about shocks sizes, the frequency of ELB episodes, and the effectiveness of fiscal policy (fiscal multipliers). We focus our discussion on government consumption and the labour income tax as two prototypical fiscal instruments, one on the expenditure, and one on the revenue side. Robustness checks extend the set of fiscal instruments to state-dependent consumption taxes and government transfers [to be completed]. We also test the robustness of our conclusions with respect to plausible deviations from the assumption of fully rational expectations.

Our results can be summarised as follows. First, rule-based fiscal stabilisation through additional government spending (only) at the ELB reduces the variance (and skewness) of the inflation and output gap distributions around their respective (policy) target values. It also significantly lowers the probability of entering a liquidity trap and the risk of deep and entrenched recessions. Second, the additional government spending implied by the asymmetric rule deteriorates the primary government balance only slightly, reflecting the high spending multiplier at the ELB. Third, (’symmetric’) fiscal rules that are active over the entire business cycle have less favourable implications for public finances. Fourth, expenditure-based fiscal expansion outperforms countercyclical labour tax cuts at the ELB in our stochastic simulations, owing to the deflationary impact of labour tax reduction (positive supply shift) at the ELB. Finally, we show that our results are robust to deviations from fully rational expectations, i.e. they do not depend on fiscal equivalents of the forward-guidance puzzle. This robustness check is important because higher multipliers at the ZLB partially hinge upon on an inflation expectations channel.

The paper connects to various strands of the literature. First, the comparison of fiscal stabilisation at and away from the ELB connects to the large (empirical and model-based) literature on fiscal multipliers in 'normal' and 'bad' times (e.g. Auerbach and Gorodnichenko (2012); Coenen et al. (2012); Erceg and Lindé (2014); Leeper et al. (2017); Ramey (2016); Ramey and Zubairy (2018)). The finding of a smaller tax multiplier at the ELB, second, mirrors the emphasis by Eggertsson (2011) and Eggertsson et al. (2014) on unfavourable effects of (deflationary) supply-side policies and tax cuts at the ELB ('paradox of toil'), which here carries over to a medium-scale model. Third, the idea of additional stimulus in large recessions ('semi-automatic stabilisers') has been put forward by Blanchard and Summers (2020), Eichenbaum (2019), and Furman and Summers (2020). Unconventional fiscal policies at the ELB and in EMU are, fourth, explored in Beetsma and Jensen (2004) and Correia et al. (2013). Investigating the debt implications of alternative policy rules relates, fifth, to the discussion about the relevance of high government debt when interest rates are low (but may rise again), such as Blanchard (2019) and Eichenbaum (2021). Sixth, welfare evaluations of fiscal expansions have been proposed previously by, e.g., Blanchard et al. (2017). Deviations from rational expectations, finally, build on myopia along the lines of Gabaix (2020) and Erceg et al. (2021).

## 2 Model economy

This section sets up a quantitative model with an endogenous ELB constraint and a rich fiscal framework, including fiscal rules and endogenous tax revenues. A share of liquidity-constrained households introduces non-Ricardian features, while nominal rigidities link inflation and real activity. Standard real rigidities enhance the empirical plausibility of the model as commonly assumed in estimated DSGE models (Smets and Wouters, 2007).[1] We consider a closed economy consisting of households, intermediate goods producers, a final goods firm, a fiscal authority and a central bank. Wages are sticky and set by trade unions. We estimate the model for the EA, including ELB episodes. Time is discrete and indexed by $t$.

## 2.1 Households

Two representative households consume and provide labour to intermediate good producers.

**Savers.** A share $\omega^s$ of households are savers ($s$) who own domestic firms and participate in financial markets. Savers maximise their life-time utility

$$E_0 \sum_{t=0}^{\infty} \beta_t \left\{ \frac{(C^s_{j,t} - hC^s_{t-1})^{1-\theta}}{1-\theta} - \omega^N_t \frac{\left(N^s_{j,t}\right)^{1+\theta^N}}{1+\theta^N} - \overline{\lambda^s_t} \frac{\mathcal{U}^B_{t-1}}{P^{c,vat}_t} \right\}, \tag{1}$$

subject to

$$\begin{aligned} P^{C,vat}_t C^s_{j,t} + B^{rf}_{j,t+1} + B^g_{j,t+1} + B^s_{j,t+1} &= \left(1 - \tau^N_t\right) W_t N^s_{j,t} \\ + \left(1 + i^{rf}_{t-1}\right) B^{rf}_{j,t+1} + \left(\omega^g + i^g_{t-1}\right) B^g_{j,t} + \left(1 + i^s_t\right) B^s_{j,t} &+ T^s_{j,t} + tax_t + \left(1 - N^s_{j,t}\right) W_t b \end{aligned} \tag{2}$$

where, in eq. (1), $0 < \theta, \theta^N$. $h$ governs the importance of external consumption habits. $\beta_t$ and $\omega^N_t$ are the stochastic discount factor and a stochastic labour disutility term, respectively.[2] $P^{C,vat}_t = (1 + \tau^C)P_t$, i.e. prices accounting for the value-added tax $\tau^C$. $\tau^N_t$, $T^s_{j,t}$, $tax_t$ and $b$ denote the labour tax rate, transfers, lump-sum taxes, and replacement

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[1] The model is a simplified version of the European Commission's GM model (Albonico et al. (2019))

[2] Formally, $\beta_t = \beta \frac{\Theta_{t+1}}{\Theta_t}$, where $\frac{\Theta_{t+1}}{\Theta_t} \equiv \exp\left(\varepsilon^C_t\right)$ introduces an exogenous shock saving shock. To ensure a balanced growth path, labour disutility features a multiplicative term $C^{1-\theta}_t$, such that $\omega^N_t = \omega^N \exp(\varepsilon^U_t) C^{1-\theta}_t$ where $\varepsilon^U_t$ is exogenous. Following a similar strategy, an exogenous marginal utility scales asset-specific utility. Finally, note that, unless stated otherwise, all exogenous random variables follow autoregressive processes of order 1.

rate, respectively.

The savers' financial portfolio consists of long-term government bonds ($B_t^g$) and corporate shares ($B_t^s$). Risk-free bonds ($B_t^{rf}$), are in zero net supply in equilibrium. The term $\mathcal{U}_{t-1}^B$ explicitly introduces stochastic preferences for (real) asset holdings ('risk shocks') into the utility function.[3] We define the disutility as

$$\mathcal{U}_{t-1}^B = \sum_{\mathcal{Q}=s,g} \left(\alpha^{\mathcal{Q}} - \varepsilon_{t-1}^{\mathcal{Q}}\right) B_t^{\mathcal{Q}}, \tag{3}$$

with asset-specific risk premium shocks $\varepsilon_{t-1}^{\mathcal{Q}}$. Asset-specific intercepts, $\alpha^{\mathcal{Q}}$, capture steady-state risk premia except for risk-free assets. Fisher (2015) interprets an increase in $\varepsilon_t^{\mathcal{Q}}$ as a wedge between the returns on corporate assets and government bonds, on the one hand, and risk-free assets on the other. These financial shocks also capture the precautionary saving behaviour of households in the absence of high-order risk. As in other estimated models (e.g. Christiano et al., 2015; Gust et al., 2017; Del Negro et al., 2017), risk premium shocks will be important drivers of demand fluctuations in our framework.

Following Krause and Moyen (2016), we approximate the maturity structure for government debt. In this formulation, the total stock of debt $B_t^g$ evolves as

$$B_t^g = (1 - \omega^g) B_{t-1}^g + B_t^{g,n}, \tag{4}$$

where $B_t^{g,n}$ and $\omega^g$ denote newly issued bonds and the probability of maturing, respectively.[4]

**Liquidity-constrained households.** The remaining households $(1 - \omega^s)$ are liquidity-constrained ($c$) and consume their net disposable income (wages and transfers minus

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[3] We follow Krishnamurthy and Vissing-Jorgensen (2012), which incorporate bonds in the utility function.

[4] With many bonds maturing each period, the fraction of bonds maturing is identical to the call probability. Moreover the average interest rate can be conveniently expressed as $i_t^g B_t^g = (1-\omega^g) i_{t-1}^g B_{t-1}^g + \omega^g i_t^{g,n} B_t^{g,n}$, where $i_t^{g,n}$ denotes the interest rate of newly issues bonds.

taxes) in each period. The budget constraint of liquidity-constrained households is hence

$$P_t^{c,vat} C_{j,t}^c = \left(1 - \tau_t^N\right) W_t N_{j,t}^c + T_{j,t}^c + tax_t + \left(1 - N_{j,t}^c\right) W_t b. \tag{5}$$

## 2.2 Wage setting

We consider a sticky wage model. A monopolistic EA trade union "differentiates' homogeneous EA labour hours provided by the two domestic household types into imperfectly substitutable labour services. The union then offers those services to local intermediate good firms. The labour input $N_{i,t}$ in those firms' production functions is a CES aggregate of the differentiated labour services. The union sets wage rates at a markup over the marginal rate of substitution between leisure and consumption. The wage markup is inversely related to the substitutability between labour varieties in intermediate good production. We introduce nominal wage rigidity in the form of quadratic wage adjustment costs, captured by parameter $\gamma^w$. In addition, parameter $\gamma^{wr}$ governs real wage rigidity as in Blanchard and Galí (2007) and Coenen and Straub (2005). A share $(1 - sfw)$ of unions sets wages indexed to past inflation. The real wage follows

$$\left(mrs_t - \mu_t^w\right)^{1-\gamma^{wr}} \left(\frac{(1-\tau^N)W_{t-1}}{P_{t-1}^{C,vat}}\right)^{\gamma^{wr}} = \frac{W_t}{P_t^{C,vat}}(1-\tau^N), \tag{6}$$

where $mrs_t$ is the share-weighted marginal rate of substitution between consumption and leisure of both households. $\mu_t^w$ denotes the gross wage markup, which fluctuates due to backward-looking wage setting and nominal frictions. Since this labour market model is standard, we relegate details to Appendix B.

## 2.3 Production

Monopolistically competitive firms produce value added $Y_t$ aggregates EA intermediate goods

$$Y_t = \left[ \int_0^1 Y_{i,t}^{\frac{\sigma^y - 1}{\sigma^y}} di \right]^{\frac{\sigma^y}{\sigma^y - 1}}, \tag{7}$$

where $Y_{i,t}$ denotes intermediate good $i \in [0, 1]$. $\sigma^y > 0$ is the elasticity of substitution between varieties $Y_{i,t}$. The production function for good $i$ is

$$Y_{i,t} = \left( A_t^Y N_{i,t} \right)^{\alpha} \left( cu_{i,t} K_{i,t}^{tot} \right)^{1-\alpha} - A_t^Y \Phi, \tag{8}$$

where $A_t^Y$ is an exogenous stochastic technology level, subject to trend and level shocks. $N_{i,t}$, $K_{i,t}$, and $cu_{i,t}$ are firm $i$'s labour input, capital stock, and endogenous capacity utilisation, respectively. $\Phi$ are fixed costs. Total capital $K_{i,t}^{tot}$ is a sum of private installed capital, $K_{i,t}$, and public capital, $K_t^G$. Gross private investment $I_{i,t}$ drives the law of motion for private capital $K_{i,t+1} = K_{i,t}(1 - \delta) + I_{i,t}$, with $0 < \delta < 1$.[5]

Period $t$ dividends are:

$$D_{i,t} = P_{i,t} Y_{i,t} - W_t N_{i,t} - P_t I_{i,t} - \Gamma_{i,t}. \tag{9}$$

$P_t$ and $W_t$ are the price level and the nominal wage rate, respectively. $\Gamma_{i,t}$ collects quadratic price and factor adjustment costs. Each firm $i$ sets its price $P_{i,t}$ in a monopolistically competitive market subject to price adjustment costs as in Rotemberg (1982) and the demand function $Y_{i,t} = \left( \frac{P_{i,t}}{P_t} \right)^{-\sigma^y} Y_t$. A share $(1 - sfp)$ of firms sets prices indexed to past inflation. The return on firm shares is $(1 + i_t^S) = (P_t^S + D_t)/P_{t-1}^S$, where $P_t^S$ denotes the share price. Appendix B presents the corresponding equilibrium conditions for the firm sector.

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[5] Public capital follows an analogous law of motion.

## 2.4 Monetary policy

Outside the ELB, monetary policy follows a Taylor-rule (1993) subject to an occasionally binding ELB constraint. The target interest rate $i_t^{not}$ responds sluggishly to deviations of inflation and the output gap ($Y_t^{gap}$) from their respective target levels:

$$i_t^{not} - \bar{i} = \rho^i (i_{t-1} - \bar{i}) + (1 - \rho^i) \left[ \frac{\eta^{i\pi}}{4} \left( \pi_t^{C,QA} - \bar{\pi}^{C,QA} \right) + \frac{\eta^{iy}}{4} Y_t^{gap} \right], \tag{10}$$

where $\bar{i} = 0.02$. $\pi_t^{C,QA}$ denotes quarterly annualised inflation and $\bar{\pi}^{C,QA}$ its steady state value.[6] Variable $i_t$ is the actual or effective short-term interest rate. $\rho^i$, $\eta^{i\pi}$, $\eta^{iy}$ govern interest rate inertia and the response to annualised inflation and output gap, respectively. The latter equals the (log) difference between actual and potential output, i.e. $Y_t^{gap} = \log\left(\frac{Y_t}{Y_t^{pot}}\right)$. Potential output at date $t$ is the output level that would prevail if labour input equalled hours worked in the absence of nominal wage rigidity as in Galí (2011) (we denote this $\bar{N}_t$), the capital stock was utilised at full capacity, and TFP equalled its trend component $A_t$. Thus,

$$Y_t^{pot} = \left( A_t \bar{N}_t \right)^a \left( K_t^{tot} \right)^{1-a}. \tag{11}$$

**The zero lower bound.** The target rate equals the effective policy rate $i_t$ only if the former is above the ELB, which we set to zero. The effective policy rate satisfies

$$i_t = \max\{ i_t^{not}, 0 \} + \varepsilon_t^i, \tag{12}$$

where $\varepsilon_t^i$ is a white noise monetary policy shock.

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[6] Quarterly annualised inflation is defined as $\pi_t^{C,QA} = \log\left(\sum_{r=0}^{3} P_{t-r}^{C,vat}\right) - \log\left(\sum_{r=4}^{7} P_{t-r}^{C,vat}\right)$.

## 2.5 Fiscal policy

The fiscal authority raises constant linear taxes on consumption ($\tau^C$) and corporate profits ($\tau^K$), lump-sum taxes ($tax_t$) and variable wage income tax ($\tau_t^N$). It finances consumptive purchases ($G_t$), investments ($IG_t$) and transfers ($T_t$). Nominal debt evolves as

$$B_t^{g,n} = (\omega^g + i_t^g)B_{t-1}^g - R_t^g + P_tG_t + P_tIG_t + P_tT_t + (1 - N_t)W_tb, \tag{13}$$

where $R_t^g$ are the nominal government revenues:

$$R_t^g = \tau^C C_t P_t + \tau^K \Big(P_tY_t - W_tN_t - \delta P_tK_{t-1}\Big) + \tau_t^N N_tW_t + tax_t. \tag{14}$$

**Baseline expenditure rules.** Fiscal strategies are the key element in our analysis. For the *baseline* model, used for the parameter estimation, we assume that the items' output shares move in line with potential growth.[7] Our policy experiments, which we discuss next, will also consider other feedback rules. Formally, the baseline rule for all items follows:

$$\frac{E_t^g}{Y_t^n} = \frac{E_{t-1}^g}{Y_t^n} + \Big(\frac{Y_t^{pot,n}}{Y_{t-1}^{pot,n}} - 1\Big)\frac{E_{t-1}^g}{Y_t^n}, \tag{15}$$

where $E^g \in \{G_t^n, IG_t^n, T_t^n\}$ are the nominal government expenditure components and $Y_t^n$ and $Y_t^{pot,n}$ denote nominal GDP and nominal potential GDP.

**Asymmetric and symmetric countercyclical policy.** Our policy experiments modify the baseline government expenditure and tax rules.[8] We consider two extended fiscal reaction functions, in which government expenditure responds to deviations of the output

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[7] Here, we build on the discretionary fiscal effort indicator as defined by the European Commission (2013).

[8] We have also experimented with alternative specifications, in which we modified the transfer rule along the same lines. These results are available upon request.

gap. This assumption implies that the government expands its consumption in a (deep) recession with negative output gaps. Under the *asymmetric* rule ($\eta^{Ga} > 0, \eta^{Gs} = 0$), this feedback is active only when the economy is at the ELB, as captured by the indicator function $\mathbb{1}_{\{i_t=0\}}$. Upon exit of the ELB, government expenditure follows the baseline rule again. The *symmetric* version of the rule ($\eta^{Ga} = 0, \eta^{Gs} > 0$), by contrast, assumes that the feedback to the output gap applies independently of the monetary policy regime. Formally, we extend the feedback rule (15) for government expenditure as follows:

$$\frac{G_t^n}{Y_t^n} = \underbrace{\frac{G_{t-1}^n}{Y_t^n} + \left(\frac{Y_t^{pot,n}}{Y_{t-1}^{pot,n}} - 1\right)\frac{G_{t-1}^n}{Y_t^n}}_{\text{baseline component}} - \underbrace{\mathbb{1}_{\{i_t=0\}}\eta^{Ga}Y_t^{gap}}_{\text{asymmetric component}} - \underbrace{\eta^{Gs}Y_t^{gap}}_{\text{symmetric component}} . \tag{16}$$

In the baseline model, the labour tax ($\tau_t^N$) responds deviation of the debt or deficit from their respective targets $\overline{DEF}$ and $\overline{B^g}$. Here, too, we will experiment with state-dependent policies:

$$\tau_t^N - \tau^N = \underbrace{\rho^{\tau^N}(\tau_{t-1}^N - \tau^N) + \eta^{DEF}\left(\frac{\Delta B_{t-1}^g}{P_{t-1}Y_{t-1}} - \overline{DEF}\right) + \eta^B\left(\frac{B_{t-1}^g}{P_{t-1}Y_{t-1}} - \overline{B^g}\right)}_{\text{baseline component}} + \underbrace{\mathbb{1}_{\{i_t=0\}}\eta^{\tau n}Y_t^{gap}}_{\text{asymmetric tax component}} , \tag{17}$$

where $\eta^{\tau n} > 0$ implies reductions in the labour tax in response to output gaps (at the ELB).

### 2.6 Aggregation

Total consumption and hours supplied by households are $C_t = (1 - \omega^s) C_t^c + \omega^s C_t^s$ and $N_t = (1 - \omega^s) N_t^c + \omega^s N_t^s$, respectively. The resource constraint is given by

$$Y_t = C_t + I_t + IG_t + G_t. \tag{18}$$

## 3 Model estimation

This section briefly summarises our data set, the estimation procedure, and key estimates. Appendix A provides additional details.

### 3.1 Data

The model estimation uses fourteen EA time series (listed in Table A.5 of Appendix A). In addition to standard macroeconomic aggregates, we also include information from fiscal data and observe government expenditure items (government consumption, public investment, transfers) as well as interest payments on government debt and the debt-to-GDP ratio. The quarterly data ranges from the introduction of the euro 1999:Q1 until 2019:Q4.

### 3.2 Econometric procedure

We follow a two-step procedure to capture salient features of the data. First, we calibrate a subset of parameters to match long-run data targets, such as the steady-state government expenditure share. The remaining parameters mostly pertain to our behavioural assumptions and dynamic adjustment processes. In a second step, we estimate these parameters using Bayesian methods as explained in Giovannini et al. (2021). Importantly, our model solution *and* estimation technique account for the nonlinear ELB constraint by using a piecewise-linear model approximation.

### 3.3 Key estimates

We conduct our estimation in the baseline model where we set the fiscal feedback rules to $\eta^{Ga} = \eta^{Gs} = \eta^{\tau n} = 0$. On the household side, relatively high consumption habits suggest a smooth consumption response to changes in the income for savers. Estimated risk aversion and the inverse labour supply elasticity are 1.55 and 3.79, respectively. These estimates are similar to the literature (e.g., Kollmann et al. (2016)). Our posterior estimates suggest sticky prices and wages and a substantial share of forward-looking price and wage-setting behaviour. In addition, we also find pronounced real wage rigidities. The estimated investment adjustment costs imply a sluggish investment response to changes in profitability. Outside the ELB, the estimated Taylor rule suggests a sluggish interest rate response to inflation and the output gap. The estimated debt stabilisation responds to the deficit and, to a lesser extent, to deviations from the debt target.

## 4 Fiscal policy at the ELB

We characterise macroeconomic implications of the asymmetric government spending rule (16) in stylised recession scenarios to illustrate key properties of the model dynamics. In particular, calibrated saving shocks generate a drop of GDP by around 2% (moderate recession, blue lines in Figure 2) or 5% in the trough (severe recession, red lines) for the benchmark regime ($\eta^{Ga} = \eta^{Gs} = 0$). The initial condition implies that the nominal interest rate hits the ELB in response to the positive saving shock within one year. As shown by the response of the nominal (policy) interest rate, the economy remains at the ELB for four years in the moderate recession case and for around six years in the severe recession one. Consumer price inflation falls via the Phillips curve relationship, leading to an increase in real interest rates at the ELB. Government debt to GDP increases as the recession lowers tax revenue for given tax rates and increases unemployment benefit payments for a given replacement rate.

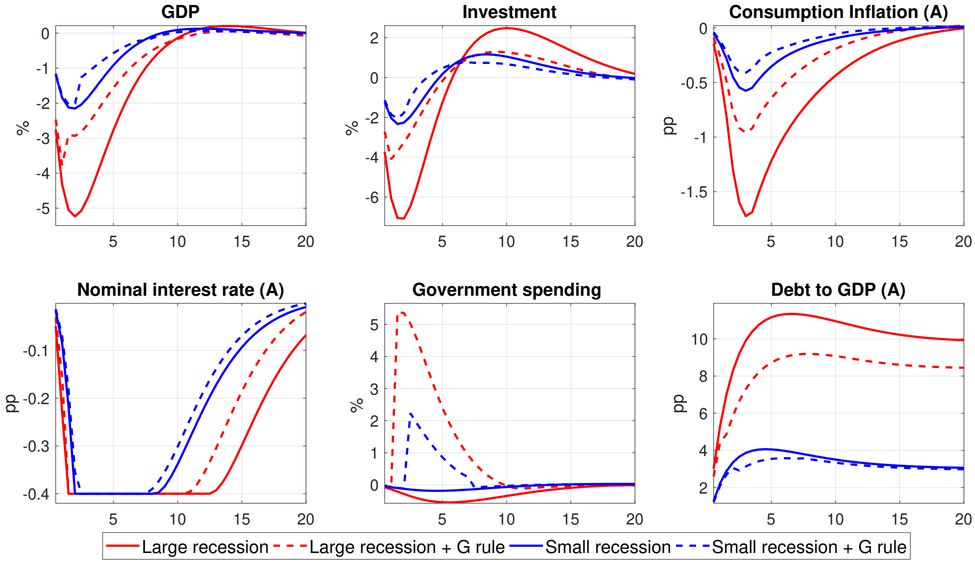

Figure 2: Stylised recession scenarios and fiscal policy

*Notes:* This figure displays impulse responses to a calibrated saving shock under the baseline and asymmetric rule.

The dashed lines indicate the response of the economy to the same shocks under the asymmetric government spending rule (16) with $\eta^{Ga} = 1$ and $\eta^{Gs} = 0$. The asymmetric government spending rule cushions the recession. This result is particularly obvious in the severe recession, with a trough of less -4% rather than -5% and medium-term stabilisation gains as indicated by the surface between the dashed and solid red lines. The spending rule implies an earlier (by 3 quarters) exit from the ELB in the severe recession case, and a less negative inflation response. Most interestingly, the countercyclical government spending does not aggravate government-sector debt problems in the recession. To the contrary, government debt to GDP increases less with the additional fiscal impulse (dashed lines), and the difference is particularly pronounced in the severe recession. The reason is threefold: Large fiscal multipliers at the ELB imply a favourable response of employment and tax revenues. Large multipliers also weaken the unfavourable denominator effect, i.e. less contraction of (real and nominal) GDP. Finally, fiscal expansion limits the increase in the real interest rate at the ELB, which affects debt service costs of the government.

Finally, note that the symmetric version of the spending rule (16) with $\eta^{Ga} = 0$ and $\eta^{Gs} = 1$ has similar effects at the ELB. Both rules imply the same response at the ELB, but the symmetric policy rule also responds on the way to and away from the ELB, where the spending multiplier is smaller.

# 5 Fiscal policy over the business cycle

This section investigates the performance of alternative fiscal rules (symmetric versus symmetric, expenditure versus taxation) and the (possible) trade-off between business cycle and debt stabilisation more generally and systematically. We perform stochastic simulations that provide us with the effects on macroeconomic outcomes (particularly, GDP growth, inflation, government debt) unconditionally and conditionally on reaching the ELB. The following sub-section describes the scenarios that we compare and our approach to the simulations. The second sub-section discusses the main results.

## 5.1 Simulation setup

We look at four experiments to assess the performance of rules with asymmetric versus symmetric and spending versus tax responses to the business cycle:[9]

1. Baseline scenario: All government expenditure items respond only to changes in potential output and tax rates are constant, except for the medium-term adjustment of labour taxes for gradual deficit and debt stabilisation embodied in eq. (17).

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[9] We plan to further extend the discussion to consumption tax adjustment and targeted transfers. Temporary VAT reductions have been implemented occasionally to stimulate the demand for durable consumption goods, including during the COVID-19 recession, and they closely mimic the impact of real interest rate reduction on the consumer side (Correia et al. (2013)). Targeted transfers can be effective in the presence of financial frictions, and they do not suffer from the welfare ”penalty” associated with non-inclusion of government consumption in the household utility function (1).

2. Asymmetric government spending: More aggressive rule-based fiscal stabilisation through additional government consumption (only) at the ELB.

3. Symmetric spending: More aggressive rule-based fiscal stabilisation via government consumption over the entire business cycle (fiscal contraction in booms and expansion in recessions), in the spirit of the functioning of automatic stabilisers.

4. Asymmetric tax cuts: Rule-based reduction of the labour tax rate when the economy operates at the ELB.

Table 1 summarises the parametrisation of the four experiments. In the government spending experiments, we set $\eta^{Ga} = 1; \eta^{Gs} = 0$ in the asymmetric rule and $\eta^{Ga} = 0; \eta^{Gs} = 1$ in the symmetric one, i.e. government consumption shares respond to the output gap with a (semi-)elasticity of 1 when the corresponding rules are active. To imply an ex-ante budgetary effect that is similar to the corresponding expenditure rule, we set $\eta^{\tau n} = 1.7$ in the scenario with asymmetric labour tax rule. In all four scenarios, monetary policy follows the Taylor rule for short-term interest rates (10) subject to the endogenous ELB constraint (12). Our model does not feature non-conventional monetary measures that could substitute for short-term rate reduction at the ELB.[10]

| Scenario | $\eta^{Ga}$ | $\eta^{Gs}$ | $\eta^{\tau n}$ |
|---|---|---|---|
| Baseline | 0 | 0 | 0 |
| Asymmetric spending | 1 | 0 | 0 |
| Symmetric spending | 0 | 1 | 0 |
| Asymmetric tax cuts | 0 | 0 | 1.7 |

Table 1: Scenario overview

We evaluate the parametrised rules in a stochastic setting to capture realistic economic fluctuations. In particular, we first run a long simulation of 80000 periods, using stochastic i.i.d. innovations (shocks). We then randomly select periods from this ergodic distribution

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[10] To the extent that non-standard monetary policies have been important in shaping the path of the observables during ELB episodes, they are reflected in the estimated saving and investment risk shocks.

as starting points for 100 additional shock samples of 100 periods, which we will use in the following experiments. The 100 samples bootstrap shocks from the estimated baseline model, similar to the approach by Bernanke (2019). Compared to simulating i.i.d. shocks, this provides a more plausible ELB duration (around 20%) by featuring more negative than positive innovations.[11] This high ELB probability is crucial for our analysis. Finally, we feed these shocks into 100 simulations to analyse the role of different policy settings.[12]

## 5.2 Simulation results

Figure 3 provides histograms of the simulations under the baseline (government consumption grows with potential output) versus the asymmetric fiscal policy regime (additional stimulus when monetary policy reaches the ELB) for a selection of variables (monetary policy rate, inflation, government primary surplus, and the output gap). Sub-plot (a) provides results for the entire set of simulations (100 simulations of 100 periods each). Sub-panel (b) only includes simulations that include at least one ELB episode of six years or longer. The vertical axis shows the relative density of the respective observation, which adds up to one in each panel. The vertical blue line shows the median value for each variable in the baseline setting, and the dashed red line shows the median in the scenario with asymmetric government spending rule.

The baseline simulations (blue bars) with the simulated draws from the estimated shocks reproduce stylised facts from the historical data (2000-2019). The ELB binds around 20% of the time. The ELB constraint and the estimated shocks induce noticeable skewness in our simulated data. In particular, annualised median inflation is 1.7%, below the 2%-target, and the median output gap is slightly negative. There are also rare deflationary episodes.

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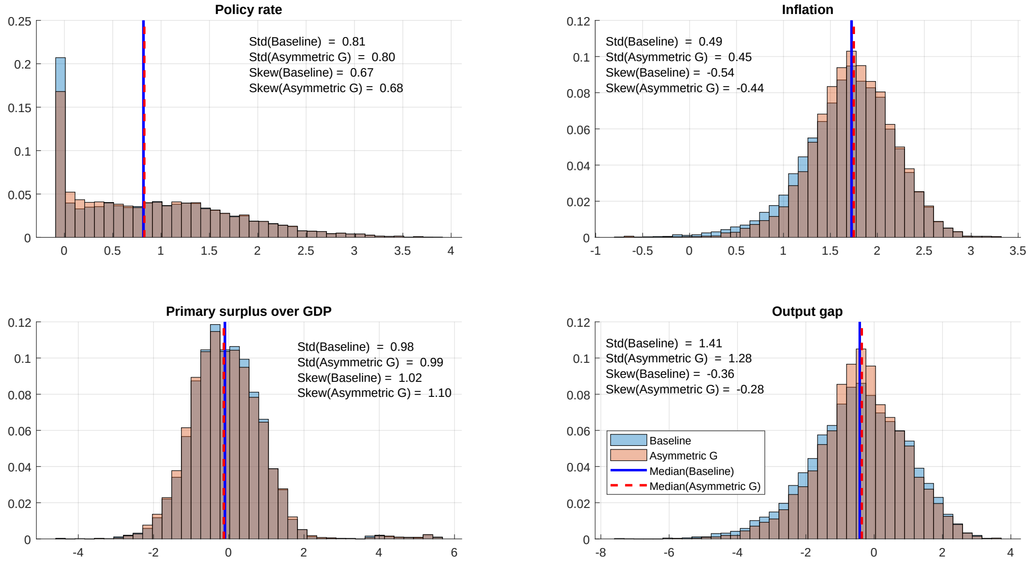
[11] By comparison, Erceg et al. (2021) use Gaussian shocks and find only 4-5% probability of hitting the ELB.

[12] We eliminate all smoothed fiscal shocks from these simulations.

(a) Asymmetric spending: Unconditional



(b) Asymmetric spending: Conditional on long expected liquidity traps

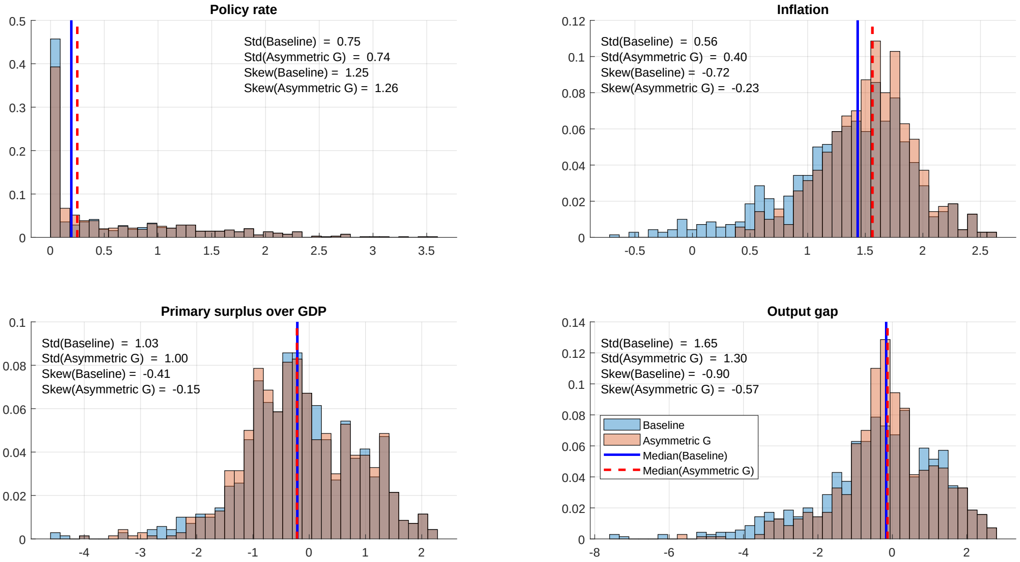


Figure 3: Histogram of simulations under baseline and asymmetric fiscal policy regimes

*Notes:* The upper (lower) panels display results based on all simulations (samples, which feature at least one ELB event with expected duration of six years or longer). The vertical axis shows the relative density of respective observations (adding up to 1). The horizontal axis shows outcomes in absolute terms (i.e. not in deviations from the steady state). Policy rate and inflation are annualised.

The asymmetric spending rule (orange bars) lowers the probability of hitting the ELB by about one fourth to around 15%, which increases the space for (standard) monetary policy. It also moves the economy closer to achieving the central bank's 2% inflation target on average and a smaller output gap, i.e. actual being close to potential output. The standard deviations of inflation and the output gap fall from 0.49 to 0.45 and from 1.41 to 1.28, respectively. The asymmetric rule also reduces the skewness on the negative side in both variables by reducing the frequency of (far) below-target inflation and negative output gap episodes. Interestingly, the additional government spending reduces the primary surplus only slightly, reflecting the high spending multiplier at the ELB that strengthens tax revenue and reduces spending on unemployment benefits in the model. The overall median macroeconomic outcomes under the asymmetric rule remain close to the baseline scenario, however, reflecting the fact that the asymmetric expenditure rule operates only during ELB episodes and that the reaction coefficient in this scenario is set to the rather moderate value of $\eta^{Ga} = 1$.

The differences between the two policy regimes become more pronounced when we condition the simulation samples on long expected liquidity traps (subplot b). When conditioning on samples with long liquidity traps, notably at least one ELB event of six years or longer in the baseline regime, the asymmetric government spending rule reduces the standard deviations of inflation and the output gap more strongly. The longer and more frequent ELB events trigger the asymmetric spending rule to respond more often relative to the overall sample size. Together with higher spending multipliers at long (expected) ELB episodes, the asymmetric rule becomes more powerful in stabilising economic fluctuations without deteriorating public finances. Importantly, the asymmetric policy also reduces the risk of very negative output gaps, as shown by smaller fat (left) tails of the output gap distribution.

Results look different for the symmetric government spending rule ($\eta^{Gs} = 1$). Figure 4 shows that the symmetric spending component increases the probability of hitting the

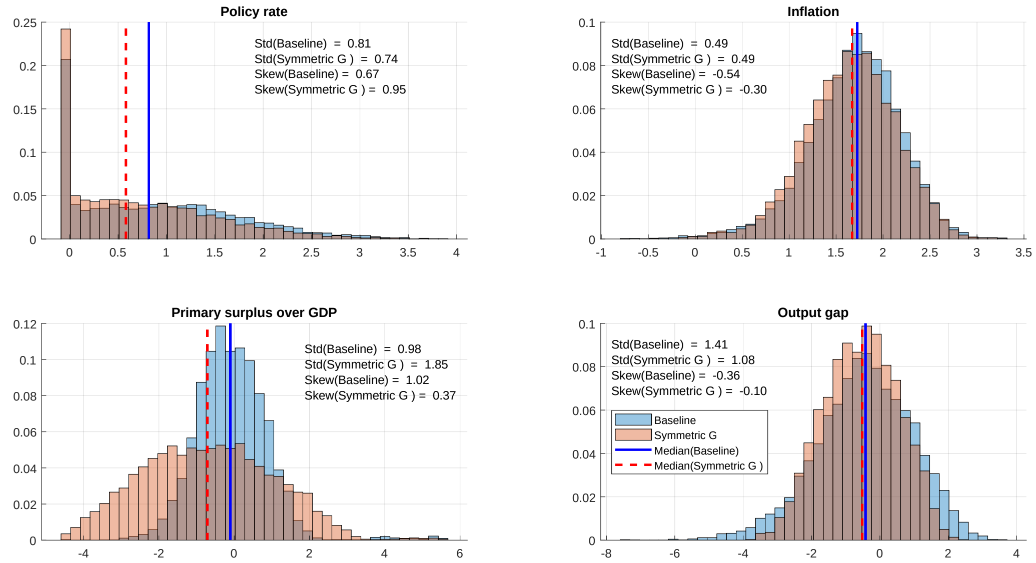


Figure 4: Histogram of simulations under baseline and symmetric fiscal policy regimes

*Notes:* Results based on all samples. The vertical axis shows the relative density. The horizontal axis shows outcomes (policy rate and inflation are annualised).

ELB. Since fiscal policy is 'leaning against the wind' over the entire cycle, it also substantially reduces the variability of inflation and the output gap. In contrast to the asymmetric rule, the symmetric one deteriorates public finances. Lower multipliers outside the ELB reduce the median primary surplus compared to the baseline fiscal policy setting. With more frequent negative output gaps, primary deficits become more frequent.

Table 2 summarises the stochastic simulations with the asymmetric and symmetric government consumption rules by focusing on key variable means under the different policy regimes, over the entire sample and during periods with longer ELB. The asymmetric government consumption rule lowers the frequency of ELB occurrence in the overall simulation sample by around one fourth, from 20% to 15%, whereas it increases by almost one fifth to 24% under the symmetric rule. The average debt-to-GDP ratio is stable under the asymmetric rule (and even declines in long-ELB periods) but increases for the symmetric one. During longer expected ELB episodes, annual real GDP growth is higher by 0.1 pp and inflation by 0.3-0.5 pp. Both rules constitute an improvement over the baseline setting in this case, which is not surprising given that both rules are equivalent at the ELB. The symmetric rule implies additional expansion with a lower multiplier in shallower recession periods, however, which implies a higher average fiscal cost.

| | Baseline | Gov asymmetric | Gov symmetric |
|---|---|---|---|
| Total | | | |
| ZLB occurence | 20.20 | 15.33 | 23.67 |
| Debt to GDP | 70.09 | 69.90 | 74.22 |
| GDP growth | 0.38 | 0.38 | 0.38 |
| Inflation (A) | 1.66 | 1.71 | 1.63 |
| ZLB expected more than 3 years | | | |
| Debt to GDP (A) | 70.63 | 68.47 | 75.18 |
| GDP growth | 0.07 | 0.16 | 0.19 |
| Inflation (A) | 1.01 | 1.49 | 1.26 |
| Excess G/Y during ZLB | - | 0.19 | 0.24 |

Table 2: Stochastic simulations: selected variable means

We conclude this section by considering the state-dependent labour income tax policy of equation (17) with $\eta^{\tau n} = 1.7$. Figure 5 shows that labour tax cuts at the ELB increase the time spent in the liquidity trap, by around one fourth. The reason is that labour tax cuts are deflationary by lowering labour and production costs. This prolongs the time during which the target ('shadow') rate is below the ELB, and it gives rise to an increase in real interest rates at the ELB in line with the 'paradox of toil' (Eggertsson (2011); Eggertsson et al. (2014)). The consequences are higher output gap and inflation volatility. At the same time, the tax cut, together with the smaller labour tax multiplier at the ELB, reduces tax revenues so that the government primary balance deteriorates on average.

Taken together, the experiments suggest that fiscal policy can be a powerful complement to monetary policy at the ELB, not least because of the larger government spending multiplier that increases with the (expected) ELB duration. However, stronger countercyclical spending *per se*, as under the symmetric rule that acts over the entire business

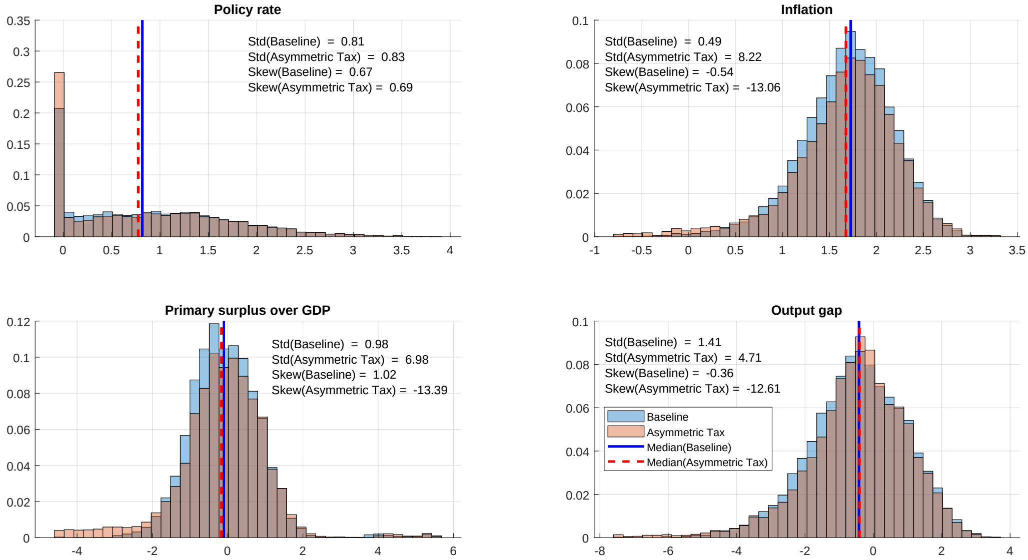


Figure 5: Histogram of simulations under baseline and asymmetric tax policy regimes

*Notes:* Results based on all samples. The vertical axis shows the relative density. The horizontal axis shows outcomes (policy rate and inflation are annualised).

cycle, does not lead to a similar combination of effective stabilisation and beneficial budgetary effects. Asymmetric labour tax cuts are also less attractive, given their deflationary effects at the ELB (rise in the real interest rate) and the smaller multiplier.

## 5.3 Alternative fiscal instruments

[TBD: We plan to include simulation results for consumption tax (VAT) rules and targeted transfers to households. In theory, temporary consumption tax reductions at the ELB closely replicate the intertemporal substitution effect of interest rate cuts with respect to consumption demand, and they directly raise the real disposable income of financially constrained consumers. Transfers to households may avoid the problem of ”wasteful” government spending, but their multiplier may be small in extreme situations (e.g. the increase in household savings during the COVID pandemic).]

## 5.4 Welfare

We complement the previous discussion of results along key macroeconomic variables with a comparison of welfare effects. The welfare assessment ranks the different scenarios along a single common metric. It also estimates the costs of business cycle fluctuations and the gains from stabilisation policy from the household perspective. Table 3 provides the results, based on equation (1) of the model. Positive deviations from the baseline signify welfare gains and negative ones welfare losses compared to the baseline. Note that the numbers account (only) for gains or losses associated with consumption and hours worked in (1), excluding the asset holding term introduced to motivate premia on risky assets.

| | Baseline | Gov asymmetric | Gov symmetric |
|---|---|---|---|
| Total | | | |
| Liquidity constrained (%) | 0 | 0.0020 | -0.4534 |
| Savers (%) | 0 | -0.0008 | -0.4321 |
| Total (%) | 0 | 0.0001 | -0.4391 |
| ZLB expected more than 3 years | | | |
| Liquidity constrained (%) | 0 | 0.0342 | -0.5892 |
| Savers (%) | 0 | -0.0160 | -0.5563 |
| Total (%) | 0 | -0.0005 | -0.5671 |
| ZLB expected less than 3 years | | | |
| Liquidity constrained (%) | 0 | 0.0011 | -0.5344 |
| Savers (%) | 0 | -0.0006 | -0.4757 |
| Total (%) | 0 | -0.0001 | -0.4951 |

Table 3: Welfare effects under alternative spending policies

Table 3 suggests that liquidity-constrained households tend to gain from the asymmetric government consumption rule, particularly during prolonged ELB episodes. Ricardian saver households' welfare declines, to the contrary, neutralising average welfare effects in the aggregate. Interestingly, welfare effects for the symmetric government consumption rule are negative for both household types and overall as well as during prolonged ELB episodes. A dominance of episodes of fiscal expansion implies an average increase in the level of government spending, which is perceived as a resource cost by our utility function that does not include government purchases. Quantitatively, stabilisation gains under the asymmetric rule are modest even with long expected ELB episodes.

# 6 Behavioural extension

This section analyses how bounded rationality in the form of partial myopia towards events in the future affects our results. The issue is particularly important in light of our focus on the ELB. Del Negro et al. (2012), e.g., show that the commitment to keep interest rates low for long ('forward guidance') can have (implausibly) large expansionary effects in the standard New Keynesian model. Large government spending multipliers at the ELB hinge upon a similar mechanism, where effects on low expected future real interest rates (via higher inflation) boost consumption and investment today.

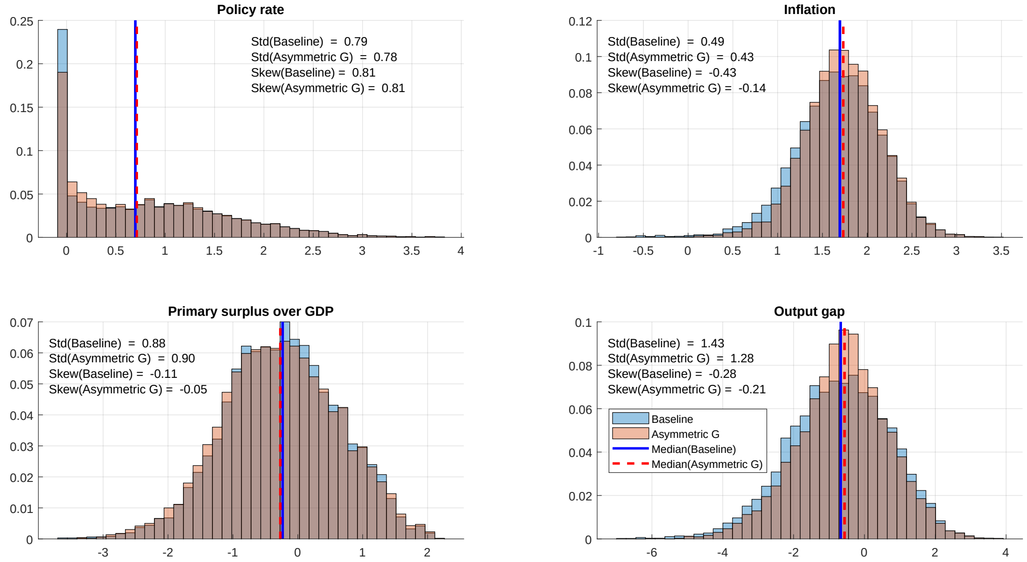
In light of the importance of private-sector expectations for the effectiveness of monetary and fiscal policies at the ELB, we consider a variant of the model that allows for different degrees of forward-lookingness. In particular, we follow Gabaix (2020) and consider agents that are not fully rational in the sense of not perfectly anticipating (atypical) future events. The effects of the behavioural discounting at the ELB are a priori ambivalent. On the one hand, myopia reduces the expansionary effect associated with a path of low future (real) interest rates. On the other hand, the depth of the recession associated with a set of persistent contractionary shocks may be smaller, and fiscal policy could be more powerful if myopia limited Ricardian effects of government budget deficits.

As in Gabaix (2020), introducing myopia implies that $t+1$ variables in the households budget constraint (2) are pre-multiplied by a discounting parameter $M^h < 1$ (which in our setting is also internalised by trade unions as wage setters), while firms discount the future expected dividend streams using $M^f < 1$. We follow Gabaix (2020) and linearise the model around the steady state of the fully rational model, i.e. $M^h = M^f = 1$. The behavioral feature does, therefore, not alter the long-run steady state, but it matters for the dynamic adjustment to shocks. The dynamic response to persistent shocks also changes because the initial response of agents to shock persistence is less strong in this framework. To ensure comparability across experiments, we, therefore, re-estimate a new series of smoothed shocks using the historical data as discussed above. We then bootstrap from these estimated shocks obtained with the behavioural model. The resulting baseline distributions are close to those obtained with the fully-rational model version. In a last step, we re-run the policy experiment with government spending rules described in the preceding section.

Figure 6 shows that our key results carry over to the behavioural model, where we set $M^h = M^f = 0.98$ based on estimated model versions with the extension. For brevity, we focus our discussion on the asymmetric spending rule. In line with the baseline model (baseline fiscal policy setting), we find that the asymmetric government spending rule shortens the time spent at the ELB. Additionally, the fiscal expansion at the ELB reduces the variance and skewness of inflation and the output gap. Due to the higher multiplier for shorter ELB duration compared to the case of fully-rational expectations (limited Ricardian effects), the behavioural model even strengthens the finding of the effectiveness of the asymmetric policy rule and its relatively favourable budgetary effects. As before, the stabilisation gains become more apparent in samples featuring longer (more) ELB episodes (panel b), where we see a reduction of particularly negative tail events in the inflation and output gap distribution. Finally, the behavioural model maintains the relative strength of the asymmetric compared to the symmetric government spending rule (not shown here).

Table 4 collects sample means of key variables from the stochastic simulations with the alternative government consumption rules. As in the RE-benchmark, the asymmetric spending rule lowers the frequency of ELB episodes and raises inflation average inflation in the direction of the 2% target. In periods with prolonged (expected) ELB, the symmetric

(a) Asymmetric spending: Unconditional



(b) Asymmetric spending: Conditional on long expected liquidity traps

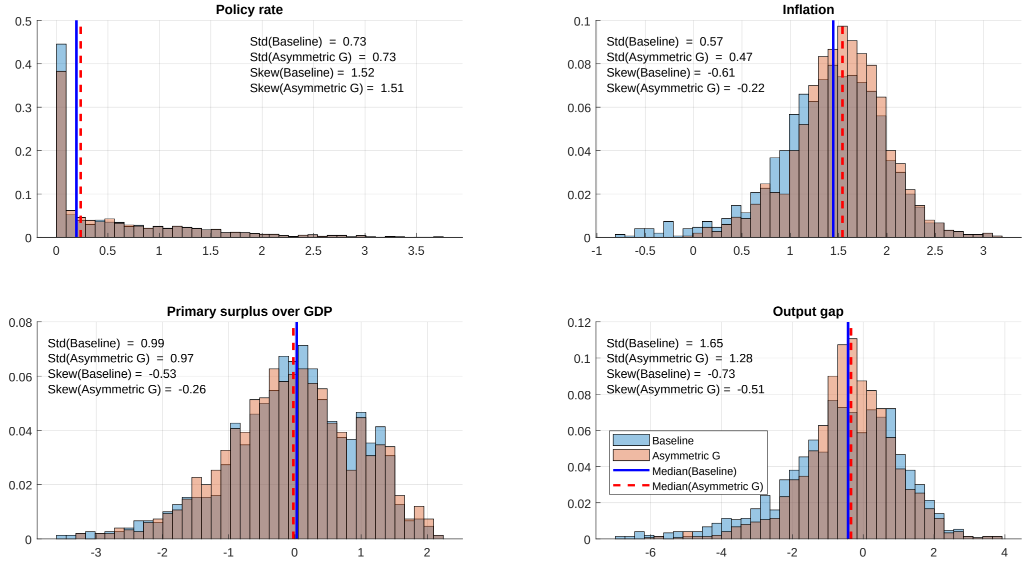


Figure 6: Histogram of simulations under different fiscal policy regimes: Behavioural model

*Notes:* The upper (lower) panel displays results based on all simulations (samples which feature at least one ELB event which is expected to lasts six years or longer.) The vertical axis shows the relative density. The horizontal axis shows outcomes (policy rate and inflation are annualised).

rule achieves growth and inflation stabilisation similar to the asymmetric rule, but at a higher fiscal cost in terms of increasing government debt to GDP.

| | Baseline | Gov asymmetric | Gov symmetric |
|---|---|---|---|
| | Total | | |
| ZLB occurence | 23.48 | 18.57 | 22.94 |
| Debt to GDP | 72.75 | 72.53 | 78.94 |
| GDP growth | 0.27 | 0.27 | 0.27 |
| Inflation (A) | 1.55 | 1.61 | 1.55 |
| | ZLB expected more than 3 years | | |
| Debt to GDP (A) | 76.06 | 74.05 | 82.08 |
| GDP growth | 0.15 | 0.22 | 0.25 |
| Inflation (A) | 0.80 | 1.22 | 1.16 |
| Excess G/Y during ZLB | - | 0.24 | 0.21 |

Table 4: Stochastic simulations: selected variable means in the behavioural model

## 7 Conclusion

This paper has analysed the fiscal policy implications of persistent and frequent effective lower bound (ELB) episodes. Estimating a medium-scale DSGE provides us with information about shocks sizes, the frequency of ELB episodes, and the effectiveness of fiscal policy (fiscal multipliers). Using the estimated model with an endogenous ELB for the euro area (EA), we have considered various fiscal rules that respond to the business cycle. In particular, we quantify the gains from using expansionary fiscal policy when monetary policy is constrained. Rule-based fiscal stabilisation through additional government spending (only) at the ELB is shown to be particularly successful. It lowers the probability of hitting the ELB and reduce the variance (and skewness) of the inflation and output gap distributions around their respective (policy) target values. The asymmetric spending rule particularly reduces the risk of very negative output gaps, i.e. deep and entrenched recessions. The additional government spending implied by the asymmetric rule, at the same time, deteriorates the government primary balance only slightly, reflecting the high spending multiplier at the ELB that strengthens tax revenue and reduces spending on unemployment benefits in the model.

Countercyclical fiscal rules that are active over the entire business cycle, i.e. independently of the monetary policy space, by contrast, have less favourable implications for public finances. Lower government spending multipliers in booms and contractions away from the ELB as well as the dominance of downside events in our sample of estimated shocks deteriorate the government's primary balance more strongly.

The asymmetric government spending rule also outperforms the labour tax rule that we test in stochastic simulations. Labour tax cuts are deflationary at the ELB. The lower labour and production costs (positive supply shock) without triggering an accommodating monetary expansion. Instead, labour tax cuts at the ELB lead to a rise in real interest rates that prolongs the ELB episode and causes a higher output gap and inflation volatility ('paradox of toil').

Our results carry over to a behavioural model version in the spirit of Gabaix (2020), which mitigates forward-guidance effects of the policy rules, notably their impact on the expected ELB duration.

There is sufficient scope for future robustness checks and extensions to our work. Re-calibrating our policy experiments with more aggressive fiscal stabilisation (larger response coefficients) will amplify differences across fiscal instruments and rules. Focusing on area-wide spending policies in a closed economy, our paper has abstracted from country heterogeneity and the open-economy dimension of fiscal policy. Multipliers can be lower in open economies, while multi-country analysis can highlight important spillover effects. This is an important aspect for quantitative exploration in multi-country models with individual EA countries in future work.

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| **Euro Area** | |
|---|---|
| $i$ | Nominal short term interest rate |
| $\log(actr_k)$ | Log of active rate population |
| $\log \frac{B^g}{Y}$ | Log of nominal gov. bonds share |
| $\log \frac{C^g}{Y}$ | Log of nominal gov. consumption share |
| $\log \frac{C}{Y}$ | Log of nominal consumption share |
| $\log \frac{i^g}{Y}$ | Log of nominal gov. interest payments share |
| $\log \frac{I^g}{Y}$ | Log of nominal gov. investment share |
| $\log \frac{I}{Y}$ | Log of nominal investment share |
| $\log(N)$ | Log of hours |
| $\log(Pop)$ | Log of population |
| $\log(P)$ | Log of observed GDP price |
| $\log(t\bar{f}p)$ | Log of TFP trend |
| $\log \frac{T}{Y}$ | Log of nominal gov transfers share |
| $\log \frac{W}{Y}$ | Nominal wage share |
| $\log(Y)$ | Log of observed GDP |

Table A.5: List of observables.

# A Details on data and econometric approach

## A.1 Data

The analysis uses quarterly and annual data for the period 1999q1 to 2019q4 based on the data set of the European Commission's Global Multi-country Model (Albonico et al., 2019). This appendix repeats the description contained therein for convenience. Data for EMU countries and the Euro Area aggregate (EA19) are taken from Eurostat (in particular, from the European System of National Account ESA95). Table A.5 lists the observed time series. The trend component of total factor productivity is computed using the DMM package developed by Fiorentini et al. (2012). The obtained series at quarterly frequency is then used to estimate potential output.

We make a few transformations to the raw investment series. In particular, we compute the deflator of public investments based on annual data and then obtain its quarterly frequency counterpart through interpolation. This series together with nominal public investments is then used to compute real quarterly public investments. In order to assure consistency between nominal GDP and the sum of the nominal components of aggregate demand, we impute change in inventories to the series of investments.

## A.2 Calibrated shares and long-run targets

All real variables grow at the average growth rate of EA GDP (1.3%). Price level trend growth corresponds to the targeted inflation rate of 2% per year. The steady-state ratios of main economic aggregates to GDP match historical averages. The discount factor of 0.998 (quarterly) implies an annual interest rate of 1%. The share of savers is 0.67. The Cobb-Douglas labour share, $\alpha$, equals 0.65.

## A.3 Posterior estimates

Table A.7 reports estimates for a number of key parameters. The Appendix **??** presents the estimates for the remaining parameters.

| | | |
|---|---|---|
| Monetary Policy | | |
| Nominal interest rate in SS | $\bar{i}_{EA}$ | 0.004 |
| CPI inflation in SS (A) | $\bar{\phi}_{EA}^{c,vat}$ | 0.02 |
| Interest rate persistence | $\rho_{EA}^{i}$ | 0.85 |
| Response to inflation | $\eta_{EA}^{i,\phi}$ | 2.28 |
| Response to output gap | $\eta_{EA}^{i,y}$ | 0.11 |
| Households | | |
| Preference for government bonds | $\alpha^B$ | -0.001 |
| Preference for stocks | $\alpha^S$ | 0.005 |
| Intertemporal discount factor | $\beta$ | 0.998 |
| Savers share | $\omega^S$ | 0.67 |
| Weight of disutility of labor | $\omega^N$ | 2.66 |
| Steady state markup | $\mu^W$ | 1.20 |
| Persistence of secular stagnation shock | $\rho^\beta$ | 0.975 |
| Production | | |
| Cobb-Douglas labor share | $\alpha$ | 0.65 |
| Depreciation of private capital stock | $\delta$ | 0.014 |
| Linear capacity utilization adj. costs | $\gamma^{u,1}$ | 0.028 |
| Value-added demand elasticity | $\sigma^y$ | 6.570 |
| Fiscal policy | | |
| Consumption tax | $\tau^C$ | 0.20 |
| Corporate profit tax | $\tau^k$ | 0.30 |
| Deficit target | $def^T$ | 0.025 |
| Debt target | $\bar{B}G$ | 3.03 |
| Probability of maturing | $1-\omega^g$ | 0.039 |
| Replacement rate | $b$ | 0.385 |
| Steady state ratios | | |
| Private consumption share in SS | $C/Y$ | 0.56 |
| Private investment share in SS | $I/Y$ | 0.18 |
| Govt consumption share in SS | $C^G/Y$ | 0.20 |
| Govt investment share in SS | $I^G/Y$ | 0.03 |
| Transfers share in SS | $T/Y$ | 0.16 |

Table A.6: Calibrated key parameters

| | | Distr. | Mean | Std. | Mean | 10% | 90% |
|---|---|---|---|---|---|---|---|
| Preferences | | | | | | | |
| Consumption habit persistence | $h$ | Beta | 0.5 | 0.1 | 0.87 | 0.79 | 0.92 |
| Risk aversion | $\theta$ | Gamma | 1.5 | 0.2 | 1.55 | 1.29 | 2.12 |
| Inverse Frisch elasticity of labor supply | $\theta^N$ | Gamma | 2.5 | 0.5 | 3.79 | 2.60 | 4.73 |
| Nominal and real frictions | | | | | | | |
| Price adjustment cost | $\gamma^P$ | Gamma | 60 | 40 | 34 | 31 | 51 |
| Nominal wage adjustment cost | $\gamma^w$ | Gamma | 15 | 3 | 14 | 9 | 19 |
| Real wage rigidity | $\gamma^{wr}$ | Beta | 0.95 | 0.02 | 0.93 | 0.90 | 0.96 |
| Employment adjustment cost | $\gamma^N$ | Gamma | 60 | 40 | 2.19 | 1.50 | 15.73 |
| Share of forward looking price setters | $sfp$ | Beta | 1 | 0.2 | 1.00 | 0.83 | 1.00 |
| Share of forward looking wage setters | $sfw$ | Beta | 0.5 | 0.2 | 0.94 | 0.81 | 0.98 |
| SS Share of liquidity constrained firms | $s\bar{l}i$ | Beta | 0.20 | 0.08 | 0.16 | 0.11 | 0.30 |
| Investment adjustment cost | $\gamma^I$ | Gamma | 60 | 40 | 82 | 19 | 130 |
| Fiscal policy | | | | | | | |
| Labour tax persistence | $\rho^{\tau^N}$ | Beta | 0.85 | 0.06 | 0.79 | 0.68 | 0.90 |
| Labour tax response to deficit | $\eta^{DEF}$ | Beta | 0.03 | 0.008 | 0.020 | 0.013 | 0.033 |
| Demand shock processes | | | | | | | |
| Subjective discount factor - AR(1) coeff. | $\rho^P$ | Beta | 0.5 | 0.2 | 0.66 | 0.61 | 0.80 |
| Subjective discount factor - std. | $\varepsilon^P$ | Gamma | 0.01 | 0.004 | 0.014 | 0.006 | 0.014 |
| Investment risk prem. - AR(1) coeff. | $\rho^S$ | Beta | 0.5 | 0.2 | 0.91 | 0.84 | 0.94 |
| Investment risk prem. - std. | $\varepsilon^S$ | Gamma | 0.008 | 0.004 | 0.004 | 0.003 | 0.009 |

Table A.7: Prior and posterior distribution of key estimated model parameters.

# B Model details

This appendix provides additional model details omitted in the main text. The model shares many standard elements with Albonico et al. (2019) and we refer also to the model description contained therein.

## B.1 Households

There are two representative households indexed $r$. Savers maximize lifetime utility

$$\max_{C_{j,t},B^{\mathcal{Q}}_{j,t}} E_0 \sum_{t=0}^{\infty} (\beta_t)^t \left\{ \frac{(C^s_{j,t} - hC^s_{t-1})^{1-\theta}}{1-\theta} - \omega^N_t \frac{(N^s_{j,t})^{1+\theta^N}}{1+\theta^N} + \sum_{\mathcal{Q}} B^{\mathcal{Q}}_{j,t}(\varepsilon^{\mathcal{Q}}_t - \alpha^{\mathcal{Q}}) \right\}, \tag{B.1}$$

subject to a sequence of budget constraints

$$P^C_t C^s_{j,t} + B_{j,t+1} = W_t N^s_{j,t} + D_t + R^r_t B_{j,t} + T^s_{j,t}, \tag{B.2}$$

The portfolio $B_{j,t}$ consists of risk-free domestic bonds $(rf)$, and domestic firm shares $(S)$. We also include government bonds $(G)$ in the portfolio. We have omitted this asset in the main text due to its negligible estimated effects. Each asset has gross nominal return $R^{\mathcal{Q}}_t$. Thus, $R^r_t B_{j,t} = \sum_{\mathcal{Q}} R^{\mathcal{Q}}_t B^{\mathcal{Q}}_{j,t}$. The net of transfers and taxes is

$$T^s_{j,t} = TR^s_{j,t} - tax^s_{j,t} - \tau^N W_t N^s_{j,t} - \tau^C P^C_t C^s_{j,t}, \tag{B.3}$$

where $TR^s_{j,t}, tax^s_{j,t}$, $\tau^C$ and $\tau^N$ denote transfers, lump-sum taxes, the consumption (sales) tax and the labor tax rate, respectively.

Saver households are identical and make identical choices. The first order necessary conditions in a symmetric equilibrium are for $\mathcal{Q} \in \{rf, S, G\}$:

$$1 = E_t \left[ \Lambda^s_{t,t+1} \frac{R^{\mathcal{Q}}_t + \varepsilon^{\mathcal{Q}}_t - \alpha^{\mathcal{Q}}}{1 + \pi^{C,vat}_{t+1}} \right], \tag{B.4}$$

where $\alpha^{rf} = 0$, $\lambda^s_t = (C^s_t - h^s C^s_{t-1})^{-\theta}$, and $\Lambda^s_{t,t+1} = \beta_t \frac{\lambda^s_{t+1}}{\lambda^s_t}$.

The remaining households with population share $1 - \omega^s$ are liquidity-constrained $(c)$. In each period, they consume their wage incomes and net transfers/taxes. Thus,

$$P^C_t C^c_{j,t} = W_t N^c_{j,t} + T^c_{j,t}. \tag{B.5}$$

Total consumption by EA households is

$$C_t = (1 - \omega^s)\, C^c_t + \omega^s C^s_t \tag{B.6}$$

and total EA labor supply

$$N_t = (1 - \omega^s)\, N^c_t + \omega^s N^s_t. \tag{B.7}$$

## B.2 Wage setting

The labor market structure follows Albonico et al. (2019): Households are providing differentiated labor services $N_{j,t}$ in a monopolistically competitive market. A labor union bundles labor hours provided by both types of domestic households into a homogeneous labor service and resells it to intermediate good producing firms. We assume that Ricardian and liquidity-constrained households' hours are distributed proportionally to their respective population shares. Since both households face the same labor demand schedule, each household works the same number of hours as the average of the economy. It follows that the individual union's choice variable is a common nominal wage rate for both types of households. The union maximizes the discounted future stream of the weighted average of lifetime utility of its members with respect to the wage and subject to the weighted sum of their budget constraints, $C_{j,t}$.

$$\max_{W_{j,t}} U_{j,t} = \sum_{t=0}^{\infty} (\beta_t)^t U(C_{j,t}, N_{j,t}, \cdot) \tag{B.8}$$

subject to:

$$P_t^C C_{j,t}^s + \omega^s B_{j,t+1} + \Gamma_{jt}^W = W_{j,t} N_{j,t} + \omega^s (R_t^r B_{j,t} + D_t) + T_{j,t} \tag{B.9}$$

$$N_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{-\sigma^n} N_t, \tag{B.10}$$

where $\Gamma_{j,t}^W = \frac{\gamma^w(\sigma^n - 1)}{2} W_t N_t \left(\pi_t^w - \pi^w - (1 - sfw)(\pi_{t-1}^{C,vat} - \bar{\pi})\right)^2$ is a quadratic wage adjustment cost that is born by the households and 1-$sfw$ is the share of wage setters that index the growth rate of wages to the previous period inflation. $\sigma^n$ is the inverse of the steady state gross wage markup. Additionally, we allow for a slow adjustment of real wages as in Blanchard and Galí (2007). The resulting wage equation is:

$$\left(\frac{U_{N,t}}{\lambda_t}\right)^{1-\gamma^{wr}} \left[\frac{(1 - \tau^N) W_{t-1}}{P_{t-1}^{C,vat}}\right]^{\gamma^{wr}} = \frac{W_t}{P_t^{C,vat}} (1 - \tau^N) \mu_t^w, \tag{B.11}$$

where $\mu_t^w$ is the fluctuating gross wage markup:

$$\mu_t^w = \mu^w + \frac{\mu^w \gamma^w}{1 - \tau^N} \left[\frac{\partial \Gamma_t^w}{\partial W_t} - \beta_t E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}^{C,vat} + 1} \frac{\partial \Gamma_{t+1}^w}{\partial W_t} + \frac{1}{\gamma^w} \varepsilon_t^U\right].$$

$\mu^w = (\frac{\sigma^n}{1-\sigma^n})^{\gamma^{wr}-1}$ is the steady state markup, $\gamma^{wr}$ and $\gamma^w$ govern real and nominal rigidity, respectively. $\varepsilon_t^U$ is a labor supply shock. $U_{N,t}$ is the derivative of the utility function with respect to labor. $P_t^{C,vat}$ is price of consumption goods adjusted for the sales tax ($P_t^{C,vat} = (1 + \tau^C) P_t^C$).

## B.3 Intermediate goods

Each firm $i \in [0, 1]$ produces a variety of the domestic good which is an imperfect substitute for varieties produced by other firms. Firms are monopolistically competitive and face a downward-sloping demand function for goods.

Differentiated goods are produced using total capital, $K_{i,t-1}^{tot}$, and labor, $N_{i,t}$, which are combined in a Cobb-Douglas production function:

$$Y_{i,t} = \left(A_t^Y N_{i,t}\right)^{\alpha} \left(cu_{i,t} K_{i,t-1}^{tot}\right)^{1-\alpha} - A_t^Y \Phi_i, \tag{B.12}$$

where $\alpha$ is the steady-state labor share, $A_t^Y$ represents the labor-augmenting productivity common to all firms in the differentiated goods sector, $cu_{i,t}$ denotes firm-specific capital utilization. $\Phi_i$ captures fixed costs in production. Total capital is a sum of private installed capital, $K_{i,t}$, and public capital, $K_{i,t}^G$:

$$K_{i,t}^{tot} = K_{i,t} + K_{i,t}^G. \tag{B.13}$$

Since total factor productivity (TFP) is not a stationary process, we allow for two types of technology shocks, $\varepsilon_t^{GA}$ and $\varepsilon_t^{A}$. They are related to a non-stationary process and its autoregressive component $\rho^A$:

$$\log(A_t^Y) - \log(A_{t-1}^Y) = g_t^A + \varepsilon_t^A, \tag{B.14}$$

$$g_t^A = \rho^A g_{t-1}^A + (1-\rho^A) g^A + \varepsilon_t^{GA}, \tag{B.15}$$

where $g_t^A$ and $g^A$ are the time-varying growth and the long-run growth of technology, respectively.

Monopolistically competitive firms maximize the real value of the firm $\frac{P_t^S}{P_t} S_t^{tot}$, that is the discounted stream of expected future profits, subject to the output demand $Y_{i,t} = \left(\frac{P_{i,t}}{P_t}\right)^{-\sigma^y} Y_t$, the technology constraint (B.12) and a capital accumulation equation $K_{i,t} = I_{i,t} + (1-\delta)K_{i,t-1}$.[13] Their problem can be written as:

$$\max_{P_{i,t}, N_{i,t}, I_{i,t}, cu_{i,t}, K_{i,t}} \sum_{s=t}^{\infty} D^S \Pi_{i,t}^f, \tag{B.16}$$

where the stochastic discount factor, $D^S$, is:

$$D^S = \frac{1 + r_t^S}{\Pi_{r=t}^S (1 + r_r^S)} \tag{B.17}$$

with $1 + r_t^S = \frac{1 + i_{t+1}^S}{1 + \pi_{t+1}}$ being the real stock return.

$P_{i,t}$ is the price of intermediate inputs and the corresponding price index is:

$$P_t = \left( \int_0^1 (P_{i,t})^{1-\sigma^y} di \right)^{\frac{1}{1-\sigma^y}}. \tag{B.18}$$

The period $t$ profit of an intermediate goods firm $i$ is given by:

$$\Pi_{i,t}^f = (1-\tau^K)\Big(\frac{P_{i,t}}{P_t} Y_{i,t} - \frac{W_t}{P_t}(N_{i,t})\Big) + \tau^K \delta \frac{P_t^I}{P_t} K_{i,t-1} - \frac{P_t^I}{P_t} I_{i,t} - \Gamma_{i,t}, \tag{B.19}$$

where $I_{i,t}$ is the physical investment at price $P_{i,t}^I$, $\tau^K$ is the corporate tax and $\delta$ the capital depreciation rate.

Firms face quadratic factor adjustment costs, $\Gamma_{i,t}$, measured in terms of production input factors:

$$\Gamma_{i,t} = \Gamma_{i,t}^P + \Gamma_{i,t}^N + \Gamma_{i,t}^I + \Gamma_{i,t}^{cu} \tag{B.20}$$

Specifically, the adjustment costs are associated with the output price $P_{i,t}$, labor input $N_{i,t}$, investment $I_{i,t}$, as well as capacity utilization variation $cu_{i,t}$:

$$\Gamma_{i,t}^P = \sigma^y \frac{\gamma^P}{2} Y_t \left[ \frac{P_{i,t}}{P_{i,t-1}} - \exp(\bar{\pi}) \right]^2, \tag{B.21}$$

$$\Gamma_{i,t}^N = \frac{\gamma^N}{2} Y_t \left[ \frac{N_{i,t}}{N_{i,t-1} + \varepsilon_{t-1}^{tN}} - \exp(g^{pop}) \right]^2, \tag{B.22}$$

$$\Gamma_{i,t}^I = \frac{P_t^I}{P_t} \left[ \frac{\gamma^{I,1}}{2} K_{t-1} \Big( \frac{I_{i,t}}{K_{t-1}} - \delta_t^K \Big)^2 + \frac{\gamma^{I,2}}{2} \frac{(I_{i,t} - I_{i,t-1}\exp(g^Y + g^{P^I}))^2}{K_{t-1}} \right], \tag{B.23}$$

$$\Gamma_{i,t}^{cu} = \frac{P_t^I}{P_t} K_{i,t-1}^{tot} \left[ \gamma^{cu,1}(cu_{i,t} - 1) + \frac{\gamma^{cu,2}}{2}(cu_{i,t} - 1)^2 \right], \tag{B.24}$$

where $\gamma$-parameters capture the degree of adjustment costs. $\bar{\pi}$ denotes steady state inflation. $g^{pop}$, $g^Y$,

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[13] We assume that the total number of shares $S_t^{tot} = 1$.

and $g^{PI}$ are trend factors of population, GDP and prices for investment goods, respectively. $\delta_t^K \neq \delta$ is a function of the depreciation rate adjusted for the capital trend in order to have zero adjustment costs on the trend-path.[14]

Given the Lagrange multiplier associated with the technology constraint, $\mu^y$, the FOCs with respect to labor, capital, investments and capital utilization are given by:

$$(1-\tau^K)\frac{W_t}{P_t} = \alpha\left(\mu_t^y - \varepsilon_t^{ND}\right)\frac{Y_t}{N_t} - \frac{\partial\Gamma_t^N}{\partial N_t} + E_t\Big[\frac{1+\pi_{t+1}}{1+i_{t+1}^s}\frac{\partial\Gamma_{t+1}^N}{\partial N_t}\Big], \tag{B.25}$$

$$Q_t = E_t\left[\frac{1+\pi_{t+1}}{1+i_{t+1}^s}\frac{P_{t+1}^I}{P_{t+1}}\frac{P_t}{P_t^I}\left(\tau^K\delta^K - \frac{\partial\Gamma_t^{cu}}{\partial K_{t-1}} + Q_{t+1}(1-\delta) + (1-\alpha)\mu_{t+1}^Y\frac{P_{t+1}}{P_{t+1}^I}\frac{Y_{kt+1}}{K_t^{tot}}\right)\right], \tag{B.26}$$

$$\begin{aligned}\frac{I_t}{K_{t-1}} - \delta_t^K = sli_t\Big(\zeta_1\left(\frac{GOS_{i,t}}{K_{i,t-1}}\frac{P_t}{P_t^I}\right) - \zeta_0 - \delta^K\Big) + \frac{1-sli_t}{\gamma^{I,1}}Q_t - 1 - \gamma^{I,2}\frac{(I_t - I_{t-1}\text{exp}(g^Y + g^{P^I}))}{K_{t-1}}\\ +E_t\Big[\frac{1+\pi_{t+1}}{1+i_{t+1}^s}\frac{P_{t+1}^I}{P_{t+1}}\frac{P_t}{P_t^I}\text{exp}(g^Y + g^{P^I})\gamma^{I,2}\frac{(I_{t+1} - I_t\text{exp}(g^Y + g^{P^I}))}{K_t}\Big],\end{aligned} \tag{B.27}$$

$$\mu_t^y(1-\alpha)\frac{Y_t}{cu_t}\frac{P_t}{P_t^I} = K_{t-1}^{tot}\Big[\gamma^{u,1} + \gamma^{u,2}(cu_t - 1)\Big], \tag{B.28}$$

where $Q_t = \mu_t^y / \frac{P_t^I}{P_t}$.

In a symmetric equilibrium ($P_{i,t} = P_t$), the FOC with respect to $P_{i,t}$ yields the New Keynesian Phillips curve:

$$\begin{aligned}\mu_t^y\sigma^y = (1-\tau^K)(\sigma^y - 1) + \sigma^y\gamma^P\frac{P_t}{P_{t-1}}\Big(\pi_t - \bar{\pi}\Big)\\ - \sigma^y\gamma^P\left[\frac{1+\pi_{t+1}}{1+i_{t+1}^s}\frac{P_{t+1}}{P_t}\frac{Y_{t+1}}{Y_t}\Big(\pi_{t+1} - \bar{\pi}\Big)\right] + \sigma^y\varepsilon_t^\mu,\end{aligned} \tag{B.29}$$

where here $\varepsilon_t^\mu$ is a white noise markup shock. The final New Keynesian Phillips curve takes then the following form:

$$\begin{aligned}\mu_t^y\sigma^y &= (1-\tau^K)(\sigma^y - 1) + \sigma^y\gamma^P\frac{P_t}{P_{t-1}}\Big(\pi_t - \bar{\pi}\Big)\\ &- \sigma^y\gamma^P\frac{1+\pi_{t+1}}{1+i_{t+1}^s}\frac{P_{t+1}}{P_t}\frac{Y_{t+1}}{Y_t}\left[sfp\Big(\pi_{t+1} - \bar{\pi}\Big) + (1-sfp)(\pi_{t-1} - \bar{\pi})\right]\\ &+ \sigma^y\varepsilon_t^\mu,\end{aligned} \tag{B.30}$$

where $sfp$ is the share of forward looking price setters.

## B.4 Fiscal policy

The accumulation equation for government capital is:

$$K_t^G = (1-\delta)K_{t-1}^G + I_t^G, \tag{B.31}$$

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[14] We specify $\delta_t^K = exp(g^Y + g^{PI}) - (1-\delta)$ so that $\frac{I}{K} - \delta^k \neq 0$ along the trend path.

where $\delta$ is the depreciation rate.

The model uses a measure of discretionary fiscal effort (DFE) as defined by the European Commission (2013):

$$DFE_t = \frac{R_t^G}{Y_t^N} - \frac{\Delta E_t^G - (\frac{y_t^{pot}}{y_{t-1}^{pot}} - 1)E_{t-1}^G}{Y_t}, \tag{B.32}$$

where $R_t^G$ stands for government revenues in nominal terms, $E_t^G$ is the adjusted nominal expenditure aggregate, $y_t^{pot}$ is the medium-term nominal potential output, and $Y_t^N$ is nominal GDP.[15] Following the definition of DFE, we define the aggregate nominal expenditure as:

$$E_t^G = P_t^G G_t + P_t^{IG} I_t^G + P_t T_t. \tag{B.33}$$

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[15] The adjusted nominal expenditure removes interest payments and non-discretionary unemployment expenditures from total nominal expenditure.

# C Additional results

## C.1 Behavioural model

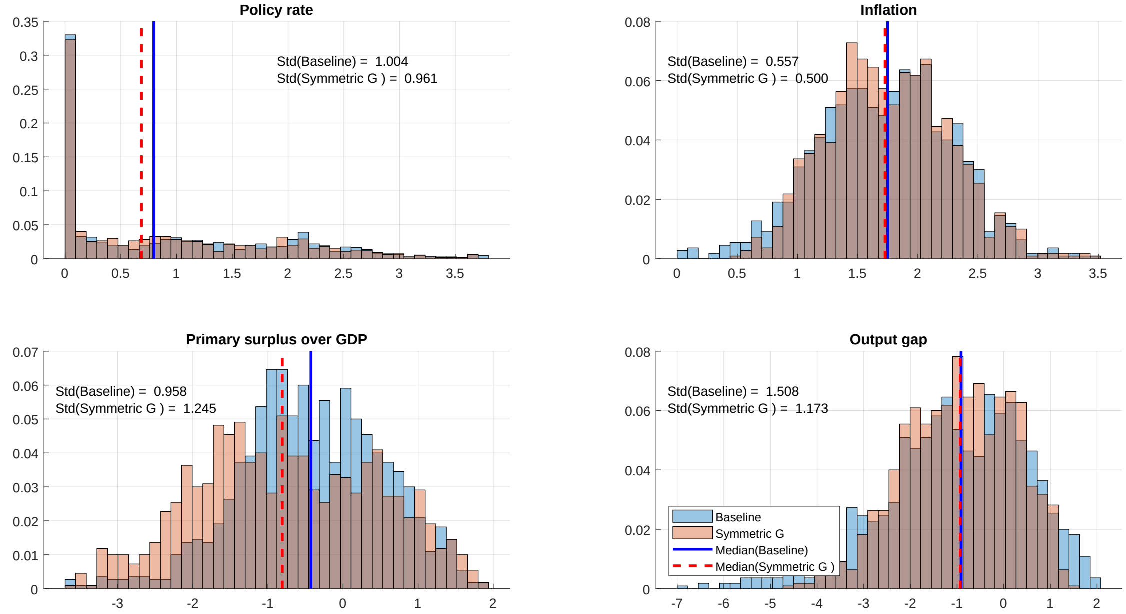

Figure C.1: Histogram of simulations under different fiscal policy regimes: Behavioural model

*Notes:* This figure displays results based on all simulation under symmetric spending rule and behavioural expectation formation. The vertical axis shows the relative density. The horizontal axis shows outcomes (policy rate and inflation are annualised).