EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

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Counter-cyclical fiscal rules and the zero lower bound

No 2715 / August 2022

Abstract

We analyse the effectiveness of optimal simple and implementable monetary and fiscal policy rules in stabilising economic activity, inflation and government debt in face of an occasionally binding lower bound on the nominal interest rate in a New Keynesian model. We show that, within the traditional assignment of active monetary policy and passive fiscal policy, the optimal fiscal policy rule features a strong counter-cyclical response to the deviation of inflation from the central bank's target - providing significant macroeconomic stabilisation especially at the lower bound - while also featuring a strong response to government debt. Our quantitative results show that the optimal counter-cyclical fiscal feedback to inflation significantly improves welfare and reduces the lower-bound frequency. In addition, the optimal simple monetary and fiscal rules almost completely resolve the deflationary bias associated with the lower bound.

Keywords: Fiscal Rules, Zero Lower Bound, Inflation Targeting, Deflationary Bias

JEL Classification: E31, E52, E61, E62

Non-technical summary

The zero lower bound (ZLB) on the nominal interest rate reduces the scope for monetary policy to stabilise inflation and real activity in response to dis-inflationary shocks. Episodes with a binding ZLB and below-target inflation might become more frequent in light of the persistent decline of the equilibrium real interest rate. The economic distortions associated with the ZLB have triggered an ongoing debate on the effectiveness of alternative policy tools to stabilise economic activity. In particular, the question whether and to what extent fiscal policy can support monetary policy in stabilising economic activity and inflation has received significant attention.

This paper contributes to a recent literature that analyses the effectiveness of monetary and fiscal rules to stabilise the economy in face of the ZLB. The analysis remains rooted in a *conventional* regime of monetary-fiscal interaction in which monetary policy controls inflation while fiscal policy adjusts the primary surplus to stabilise government debt. Unlike in the previous literature, however, we allow fiscal policy to directly respond to deviations of inflation from the central bank's target value, in addition to reacting to government debt and the output gap.

We show that besides ensuring debt stability, the optimal simple fiscal rule is characterised by a strong counter-cyclical response of government spending to inflation, whereas the optimal fiscal response to the output gap is zero. Paired with a strong monetary policy response to inflation, the rule-based interaction of monetary and fiscal policy generates a low frequency of ZLB episodes and almost completely resolves the deflationary bias that is associated with the risk of encountering the ZLB in the future.

Hence, a strong counter-cyclical fiscal response to inflation supports monetary policy in its goal to stabilise inflation around its target value *and*, by reducing the ZLB frequency, gives monetary policy more "room-to-manoeuvre". An important political-economy corollary of our results is that the appropriate design of counter-cyclical fiscal policy rules allows monetary policy and fiscal policy to continue operating in the traditional active monetary policy - passive fiscal policy configuration. This latter configuration has been shown to be particularly successful in ensuring price stability in face of inflationary shocks. Our results suggests that this configuration can also be successful in countering the dis-inflationary bias induced by the ZLB provided that fiscal policy provides adequate support.

1. Introduction

The zero lower bound (ZLB) on the nominal interest rate reduces the scope for monetary policy to stabilise inflation and real activity in response to dis-inflationary shocks. Episodes with a binding ZLB and below-target inflation might become more frequent in light of the persistent decline of the equilibrium real interest rate (e.g. Kiley and Roberts, 2017).[1] The economic distortions associated with the ZLB have triggered an ongoing debate on the effectiveness of alternative policy tools to stabilise economic activity. In particular, the question whether and to what extent fiscal policy can support monetary policy in stabilising economic activity and inflation has received significant attention.

A recent literature analyses the effectiveness of monetary and fiscal rules to stabilise the economy in face of the ZLB. Coenen et al. (2020) emphasise the effectiveness of an *asymmetric* fiscal rule that makes the fiscal stimulus depending on whether the ZLB is binding or not. Bianchi and Melosi (2019) show that the ZLB can be avoided if monetary and fiscal policy commit to inflate away crisis-related build-ups of government debt. Further, Billi and Walsh (2022) show that one possibility to address the ZLB distortions is for monetary and fiscal policy to permanently switch to a regime in which fiscal policy stabilises inflation and monetary policy ensures debt sustainability.

Our analysis, in contrast, remains rooted in a *conventional* regime of monetary-fiscal interaction, characterised by active monetary policy and passive fiscal policy in the terminology of Leeper (1991).[2] In the tradition of Schmitt-Grohé and Uribe (2007), we examine the effectiveness of optimal simple and symmetric policy rules in mitigating economic fluctuations and stabilising inflation. Unlike in the previous literature, we allow fiscal policy to directly respond to deviations of inflation from the central bank's target value, in addition to reacting to government debt and the output gap.

We show that the conventional monetary-fiscal interaction is effective in stabilising the economy and in addressing the distortions associated with the ZLB. Importantly, both monetary and fiscal policy are strongly counter-cyclical with respect to deviations of inflation from its target value. In turn, the fiscal feedback to output is an imperfect substitute for the fiscal inflation feedback and is zero under the optimal simple rule. At the same time, the strong counter-cyclical fiscal feedback to inflation is accompanied by a strong fiscal feedback to government debt.

We analyse the interaction of simple monetary and fiscal policy rules within a New Keynesian framework in which government debt is a relevant state variable. Government debt affects real allocations and inflation because the fiscal authority finances its expen-

[1] For empirical evidence on the persistent decline in the equilibrium real interest rate, see Del Negro et al. (2019) and Holston et al. (2017).

[2] In the terminology of Leeper (1991), monetary policy is "active" if it controls inflation while "passive" fiscal policy adjusts the primary surplus to stabilise government debt.

ditures with distortionary labour taxes and one-period risk-free government debt.[3] To create a link between inflation and real activity, monopolistically competitive firms face price adjustment costs à la Rotemberg (1982). We assume that monetary policy sets the nominal interest rate according to a Taylor (1993)-type rule and may be *occasionally* constrained by the ZLB. Fiscal policy is characterised by a simple rule that sets government spending as a function of government debt, the output gap, and inflation. We solve the fully non-linear specification of the model with global methods to avoid potentially large approximation errors that results from a version of the model where all equilibrium conditions are linearised except for the ZLB constraint (e.g. Braun and Körber, 2011).

Under the optimal simple rules, the government spending rule includes a strongly counter-cyclical response to deviations of inflation from the central bank's target value. The counter-cyclical fiscal feedback to inflation strongly contributes to the stabilisation of aggregate demand and inflation – especially when the ZLB is a binding constraint. The improved effectiveness of an increase in government spending during ZLB episodes stems from the stimulation of inflation expectations that decreases the real interest rate and thereby stimulates private consumption. The stimulation of private consumption, in turn, stimulates inflation and thereby inflation expectations, and so forth. Due to the improved stabilisation of demand and inflation, counter-cyclical fiscal policy is desirable from a welfare perspective.

Importantly, we show that the optimal fiscal rule includes a counter-cyclical feedback to inflation only but not to the output gap. Intuitively, in response to a large contractionary demand shock where inflation falls below its target value, the increase in government spending is initially so strong that aggregate demand *increases* on impact. The increase in aggregate demand, in turn, stabilises inflation and thereby reduces the resource loss caused by price adjustment costs. A counter-cyclical fiscal output feedback, however, would prevent output to increase on impact. Hence, the strong fiscal activism in response to large contractionary shocks is more effective if the fiscal rule includes a counter-cyclical feedback to inflation.[4]

At the same time, however, the strong counter-cyclicality embedded in the fiscal rule is accompanied by a comparatively strong fiscal debt feedback. In line with Schmitt-Grohé and Uribe (2007), if fiscal policy only responds to government debt and therefore does not include any counter-cyclical elements, the (thus constrained) optimal fiscal rule is characterised by a muted debt feedback. However, if the fiscal rule embeds (and optimally) strong counter-cyclical feedback to inflation, the optimal debt feedback coefficient in the

[3] To be more precise, fiscal policy has access to lump-sum taxes which, however, are only used to finance a wage subsidy that renders the deterministic steady state efficient.

[4] Arguably, the absence of the output gap from the optimal simple fiscal rule enhances implementability as it is well-known that output gap estimates suffer from severe measurement uncertainty especially in real time (see Orphanides and Norden, 2002; Taylor and Williams, 2010).

fiscal rule becomes more pronounced. The reason for the increased debt feedback stems from the increased volatility of private consumption and government spending which results from the counter-cyclical fiscal feedback to inflation. Since a strong counter-cyclical fiscal response during ZLB episodes is effective in stabilising demand and inflation, the stronger debt feedback smooths the government spending and consumption path the period after the initial downturn.

Further, we show that a counter-cyclical fiscal response to inflation endogenously reduces the ZLB frequency. Hence, fiscal policy gives monetary policy more “room-to-manoeuvre” in response to contractionary demand shocks. Moreover, since private sector expectations are forward-looking, they internalise that fiscal policy stabilises aggregate demand and inflation during ZLB episodes. The expected fiscal stimulus attenuates the downward shift in inflation expectations and thereby the deflationary bias that is associated with the risk of encountering the ZLB in future periods (e.g. Adam and Billi, 2007; Nakov, 2008). As a consequence, fiscal policy supports monetary policy in its attempt to stabilise inflation around its target value and thereby reduces the welfare costs associated with nominal rigidities.

The welfare impact of a counter-cyclical fiscal feedback on inflation depends on the monetary policy response to inflation. In the jointly optimal policy setting, monetary policy itself responds aggressively to deviations of inflation from the target, which ensures that the central bank reacts forcefully at the onset of a lower-bound episode. This is complemented by a strong fiscal policy response to inflation. If instead the monetary policy response to inflation is assumed to be less aggressive than optimal (while still satisfying the Taylor principle), the optimal simple fiscal rule that features a counter-cyclical inflation feedback is relatively more effective in stabilising the economy both during and outside of ZLB episodes. Intuitively, the counter-cyclical fiscal inflation feedback serves as a partial substitute for monetary policy in stabilising inflation around its target value. However, if monetary policy is optimally aggressive towards inflation fluctuations, fiscal policy’s effectiveness in stabilising inflation and output is mostly confined to ZLB episodes.

Further, the welfare costs associated with the ZLB decrease if the fiscal feedback to inflation is set to its optimal value. Relative to the optimal simple rules where fiscal policy only responds to government debt, the welfare costs of the ZLB are substantially reduced under the optimal simple rules that include an optimally set fiscal inflation feedback.

Our paper is related to several strands of the literature. Schmitt-Grohé and Uribe (2007) show that the optimal simple rules are characterised by active monetary policy and passive fiscal policy. Kirsanova and Wren-Lewis (2012) find the optimal fiscal feedback on debt to be small when monetary policy is determined optimally. Both papers, however, abstract from an occasionally binding ZLB constraint on the nominal interest rate and focus on fiscal rules that only include a feedback to government debt. We show that the optimal simple fiscal rule features a counter-cyclical feedback to inflation which and that the strength of the feedback depends on the presence of the ZLB.

A recent literature analyses simple monetary and fiscal rules in face of the ZLB. If the ZLB is occasionally binding, Billi and Walsh (2022) show that a permanent switch to a passive monetary - active fiscal policy regime improves welfare relative to an active monetary - passive fiscal policy regime.[5] Coenen et al. (2020) analyse the stabilising role of an asymmetric fiscal stimulus that increases government purchases only ZLB is binding. Croitorov et al. (2021) show that an asymmetric fiscal feedback to the output gap improves the fiscal effectiveness in stabilising the economy.[6] Instead, we show that an active monetary - passive fiscal regime that includes a strong counter-cyclical fiscal inflation feedback is very effective in stabilising output and inflation and in addressing the distortions associated with the ZLB. This finding is important not least from a political-economy perspective. Billi and Walsh (2022), for example, acknowledge that the alternative passive monetary - active fiscal policy regime may face credibility problems outside the ZLB when inflation is above the central bank's target and it would be the role of the government - and not of an independent central bank - to take action to control inflation. In our setting instead the central bank remains in charge of maintaining inflation at target, complemented by fiscal policy to the extent needed to address the ZLB.

We further relate to the literature that points to the benefits of expansionary fiscal policy in face of the ZLB. Christiano et al. (2011) and Woodford (2011) show that the fiscal multiplier can exceed one if the zero lower bound is binding. In contrast to this literature, government spending in our model does not follow an exogenous path but is set endogenously by a fiscal rule. Further, in our model the ZLB is an occasionally binding constraint and is not assumed to be binding for a predetermined period. Hence, fiscal policy *endogenously* affects the ZLB frequency and thereby the frequency and severity of recessions.

The remainder of this paper is structured as follows. Section 2 presents the New Keynesian model with an occasionally binding zero lower bound on the nominal interest rate. In section 3 we define the first best allocation, define the welfare measure, show the parametrisation of the model and give an overview of the solution method. Section 4 analyses the welfare effects of different monetary and fiscal policies and their impact on the distortions associated with the ZLB. Section 5 concludes.

[5]Under a debt-financed fiscal stimulus that is unbacked by future fiscal adjustments, passive monetary policy generates an increase in inflation expectations which is particularly beneficial at the ZLB. Burgert and Schmidt (2014) and Eggertsson (2006) show that if the policymaker does not have access to a commitment technology, government debt serves as a commitment device. In particular, government debt renders the optimal time-consistent policy history-dependent which is helpful to stimulate inflation expectations at the ZLB.

[6]Bianchi et al. (2021) show that an asymmetric monetary policy rule that responds more strongly to an undershooting of inflation below its target than to an overshooting resolves the deflationary bias. Their paper, however, abstracts from the role of fiscal policy.

2. Model

We analyse the interaction of fiscal and monetary policy rules in a standard New Keynesian framework (e.g. Galí, 2015, Ch.3). To create a link between inflation and real activity, monopolistically competitive firms face price adjustment costs à la Rotemberg (1982). We assume that monetary policy sets the nominal interest rate according to Taylor (1993)-type rules and may be *occasionally* constrained by the zero-lower bound on nominal interest rates (ZLB, henceforth). The economy is shifted towards the ZLB by sufficiently large demand shocks that shift output and inflation downwards such that monetary policy cannot sustain a positive nominal interest rate.

2.1. Households

There is a representative infinitely lived household who has preferences defined over private consumption, c_t, government spending, g_t, and labour effort, h_t. Preferences are described by the utility function

$$\mathbb{E}_t \sum_{k=t}^{\infty} \beta^{k-t} \left(\prod_{j=t}^{k} \delta_{j-1} \right) u(c_k, g_k, h_k) \ , \tag{1}$$

where $\mathbb{E}_t$ denotes the mathematical expectations operator conditional on information available at time t. Further, $\beta \in (0,1)$ denotes the subjective discount factor and $u(\cdot)$ denotes the felicity function that is separable in all its arguments. Moreover, $u(\cdot)$ is strictly increasing in its first two arguments, strictly decreasing in its third argument, and strictly concave. Moreover, δ_t is a preference shock that (asymptotically) follows the process:

$$\delta_j = (1-\rho_d)\bar{\delta} + \rho_d \delta_{j-1} + \epsilon_t \ , \qquad \epsilon_t \sim N\left(0, \sigma_\epsilon^2\right) \ . \tag{2}$$

where $\rho_d \in (0,1)$ denotes the persistence of the process, $\bar{\delta}$ denotes the steady state value of the process which we normalise to 1, and ϵ denotes and i.i.d. innovation that is normally distributed with mean zero and constant variance σ_ϵ^2. We normalise the initial condition to be $\delta_{t-1} = \bar{\delta} = 1$. The *nominal* period-by-period budget constraint is given by:

$$P_t c_t + q_t B_t^d = B_{t-1}^d + (1-\tau) P_t w_t h_t + \mathcal{D}_t - P_t T_t$$

where P_t denotes the price of the consumption good, w_t the real wage earned on each unit of labour effort, τ denotes a time-invariant labour tax, $\mathcal{D}_t$ denotes the total amount of nominal lump-sum profits from the ownership of firms, and T_t denotes a lump-sum tax.[7] Moreover, B_t^d denotes nominal one-period non-state-contingent government bonds that the household purchases at price $q_t \equiv R_t^{-1}$, where R_t is the gross one-period, riskless, nominal interest rate. The household maximises (1) subject to the budget constraint and the no-Ponzi game condition:

$$\lim_{k\to\infty} \mathbb{E}_t \left(Q_{t,t+1+k} B_{t+k}^d \right) = 0 \tag{3}$$

where $Q_{t,t+k} \equiv \prod_{s=1}^{k} q_{t+s-1}$ with $Q_{t,t} = 1$. The first order necessary conditions for household optimality are given by:

$$\lambda_t = \frac{u_{c,t}}{P_t} \tag{4}$$

$$1 = \beta\delta_t R_t \mathbb{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \tag{5}$$

$$w_t = -\frac{1}{1-\tau}\frac{u_{h,t}}{u_{c,t}} \tag{6}$$

where $u_{c,t}$ denotes the marginal utility of consumption and $u_{h,t}$ denotes the marginal disutility of labour. Further, λ_t denotes the Lagrange multiplier on household's nominal budget constraint at time t.

2.2. Firms

There are two types of firms. Final good firms use intermediate inputs to provide an aggregate consumption good. Intermediate good firms are owned by households and operate on a monopolistically competitive market.

2.2.1. Final Good Firm

The aggregate consumption good in the economy, y_t, is produced by a perfectly competitive firm which is aggregating intermediate goods $i \in [0, 1]$ produced by intermediate firms according to the technology:

$$y_t = \left[\int_0^1 y_{i,t}^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}} , \tag{7}$$

where $\theta > 0$ is the *intra*temporal elasticity of substitution among the intermediate goods, $y_{i,t}$. The final good firm chooses the quantities of intermediate goods to maximise its

[7] Below will assume that lump-sum taxes are only financing a wage-subsidy that corrects for distortions stemming from distortionary taxation of labour income and monopolistic competition in the deterministic steady state. Importantly, this assumption ensures that the mix between debt and lump-sum taxes is *not* indeterminate and irrelevant.

profits. The demand for intermediate good i is given by:

$$y_{i,t} = \left(\frac{P_{i,t}}{P_t}\right)^{-\theta} y_t \ , \tag{8}$$

where $P_{i,t}$ denotes the price at which the intermediate good firm i sells the input to final good producers.

2.2.2. Intermediate Good Firms

The representative household owns an equal share in each intermediate good firm $i \in [0, 1]$ that produces a differentiated good on a monopolistically competitive market. Production of good follows the technology:

$$y_{i,t} = l_{i,t} \ , \tag{9}$$

where $l_{i,t}$ denotes labour demand of firm i which is a function of the wage w_t. Intermediate firm i sells its good at price $P_{i,t}$ but, when changing its price, pays quadratic nominal price adjustment costs à la Rotemberg (1982). Hence, the firm faces an inter-temporal problem that stems from the effect of $P_{i,t}$ on future price adjustment costs. The costs of changing prices are proportional to the nominal value of aggregate production:

$$\frac{\psi}{2}\left(\frac{P_{i,t}}{\Pi P_{i,t-1}} - 1\right)^2 P_t y_t,$$

where ψ measures the degree of nominal rigidity and Π denotes steady state of gross inflation.[8] The adjustment cost increase in the scale of price changes and in the size of economic activity. Current *nominal* period profits, $\mathcal{D}_{i,t}$, of firm i are given by:

$$\mathcal{D}_{i,t} = P_{i,t} y_{i,t} - P_t(1-\chi) w_t l_{i,t} - \frac{\psi}{2}\left(\frac{P_{i,t}}{\Pi P_{i,t-1}} - 1\right)^2 P_t y_t \ ,$$

where χ denotes a constant employment subsidy that corrects for distortions arising from distortionary taxation of households and from monopolistic competition. The firm discounts future nominal profits by the gross nominal interest rate between today and future dates, r_t. Taking aggregate prices as given, firm i chooses $P_{i,t}$ to solve the problem:

$$\max_{P_{i,t}} \mathbb{E}_t \sum_{j=0}^{\infty} Q_{t,t+j} \ \mathcal{D}_{i,t+j} \tag{10}$$

[8] Note that we assume that the firm perfectly indexes its price to the steady state inflation which corresponds to monetary policy's inflation target.

subject to the demand schedule of final good firms (8) and the production technology (9). From this definition and the optimality condition of the household (5), firms discount factor coincides with household's (nominal) stochastic discount factor:

$$Q_{t,t+1} = \beta\delta_t \frac{\lambda_{t+1}}{\lambda_t} \ .$$

Let the optimal price that solves the maximisation problem of intermediate good firm i be given by $P^{\star}_{i,t}$. Since all firms face the same optimisation problem, we focus on a symmetric price equilibrium where $P^{\star}_{i,t} = P_t$ for all i and t. From the first order necessary condition of the problem in (10) we get the New Keynesian Phillips Curve (NKPC):

$$\left(\frac{\Pi_t}{\Pi} - 1\right)\frac{\Pi_t}{\Pi} = \beta\delta_t \mathbb{E}_t\left[\frac{u_{c,t+1}}{u_{c,t}}\frac{y_{t+1}}{y_t}\left(\frac{\Pi_{t+1}}{\Pi} - 1\right)\frac{\Pi_{t+1}}{\Pi}\right] + \frac{\theta}{\psi}\left(\mathrm{mc}_t - \mu\right) \ , \tag{11}$$

where $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ denotes the gross inflation rate, $\mu \equiv \frac{\theta-1}{\theta}$ and mc_t denotes firms' *real* marginal costs

$$\mathrm{mc}_t \equiv (1-\chi)w_t \ ,$$

resulting from their cost minimisation problem.

2.3. Government

2.3.1. Monetary Policy

The nominal interest rate on bonds is determined by a monetary policy authority that sets it according to a feedback rule:

$$R_t = \max\left\{R\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\Pi}, 1\right\} \tag{12}$$

where R and Π denote the steady state interest rate and the inflation target, respectively. The parameter ϕ_Π denotes the feedback coefficient that determines the sensitivity of the nominal interest rate to deviations of inflation from its target value.

2.3.2. Fiscal Policy

We assume that government debt is risk-free. The government finances its consumption expenditures, g_t, using lump-sum taxes, T_t, and by issuing one-period nominal government bonds, B_t, at price q_t. The government budget constraint is then given by:

$$g_t + \chi w_t h_t = T_t + \tau w_t h_t + q_t b_t - b_{t-1}\Pi_t^{-1} \ , \tag{13}$$

where $b_t \equiv B_t/P_t$ denotes real one-period government debt supply. We make the following assumption on lump-sum taxes:

Assumption 1 (**Lump-sum Taxes**)**.** Lump-sum taxes are used to finance the wage subsidy *only*, i.e.

$$T_t = \chi w_t h_t \ ,$$

with $\chi \equiv 1 - \mu(1-\tau)$.

Assumption 1 states that the government uses lump-sum taxes *only* to finance the employment subsidy that corrects for the steady state distortions arising from distortionary taxation of labour income and monopolistic competition. In addition, this restriction on lump-sum taxes ensures that the government budget constraint becomes an equilibrium condition and that variations in government spending are financed by distortionary taxation and/or government debt. The government budget constraint then simplifies to

$$b_t = R_t \left(b_{t-1} \Pi_t^{-1} + g_t - \tau w_t h_t \right) \ , \tag{14}$$

Fiscal Policy Rule. We assume that real government spending follows the rule:

$$g_t = g + \varphi_b \left(b_{t-1} - b \right) + \varphi_y \left(y_t - y \right) + \varphi_\Pi \left(\Pi_t - \Pi \right) \ , \tag{15}$$

where g, b, and y denote the deterministic steady state of government spending, government debt and output, respectively. According to the rule in (15), fiscal policy responds to deviations of government debt from its deterministic steady state, b. In addition, we allow government spending to react to deviations of output from its steady state value and of inflation from the central bank's target value, Π.

2.4. Market Clearing and Equilibrium

Labour Market. Labour market clearing requires that the wage equates aggregate working hours supplied by the household, h_t, with the working hours demanded by the firms, $l_t \equiv \int_0^1 l_{i,t} di$:

$$h_t = l_t \ . \tag{16}$$

Note that $l_t = \int_0^1 y_{i,t} di \equiv y_t \Delta_t^p$ where $\Delta_t^p \equiv \int_0^1 \left(\frac{P_{i,t}}{P_t} \right)^\theta di$ is an index of relative price distortions. Since we focus on a symmetric price equilibrium, $\Delta_t^p = 1$.

Bond market. Market clearing for government bonds requires the bond price $q_t \equiv R_t^{-1}$ to equate government's supply of bonds, b_t, with household's demand b_t^d

$$b_t = b_t^d \; . \tag{17}$$

Goods Market. Clearing of the goods market requires that the total number of goods produced, y_t, equals the sum of private and public goods demand, taking into account the dead-weight loss due to repricing cost:

$$(1 - \varrho_t) y_t = c_t + g_t \; . \tag{18}$$

where $\varrho_t \equiv \frac{\psi}{2}\left(\frac{\Pi_t}{\Pi} - 1\right)^2$ denotes the efficiency wedge arising from the Rotemberg adjustment cost which is zero in the deterministic steady state. Due do Walras' law, the market for goods clears whenever labour and bond markets clear.

Definition 1 (**Equilibrium**)**.** Given an initial level of government debt, b_{-1}^s, and goods price P_{-1}, a *rational expectations equilibrium* consists of paths for prices $\{P_t, w_t, R_t\}_{t=0}^{\infty}$, private sector quantities $\{c_t, h_t, b_t^d, y_t, l_t\}_{t=0}^{\infty}$, government policies $\{g_t, b_t\}_{t=0}^{\infty}$, exogenous states $\{\delta_t\}_{t=0}^{\infty}$, and shocks $\{\epsilon_t\}_{t=0}^{\infty}$, such that

1. $\{c_t, h_t, b_t^d\}_{t=0}^{\infty}$ solves the household optimisation problem given prices and policies,
2. $\{P_t\}_{t=0}^{\infty}$ solves firms' optimisation problem (10),
3. the government budget constraint is satisfied and fiscal policies are set according to the rule (15),
4. monetary policy sets the nominal interest rate on government bonds according to the rule (12),
5. the markets for goods, labour, and government bonds clear, and
6. the law of motion for δ_t is given by (2).

3. Calibration, Welfare Measure and Solution Method

3.1. Calibration and Functional Forms

We follow Adam (2011) and assume that the felicity function $u(c_t, g_t, h_t)$ takes the following form which is consistent with balanced growth:

$$u(c_t, g_t, h_t) = \ln(c_t) + \omega_g \ln(g_t) - \omega_h \frac{h_t^{1+\eta}}{1+\eta} \; , \tag{19}$$

where η denotes the inverse Frisch labour supply elasticity and $\omega_g > 0$, $\omega_h \geq 0$. The fact that the felicity function is additively separable in its arguments and logarithmic in private consumption ensures an analytical expression of the welfare costs (shown below).

We calibrate the model to the U.S. economy where one period in the model corresponds to one quarter. All values chosen are standard within the literature and are summarised in Table 1. The households' discount factor β is calibrated to get a steady state real annualised return on risk-free bonds of 2.00%. This value lies within the range of estimates provided by the literature (e.g. Del Negro et al., 2019). Furthermore, in line with Bianchi et al. (2021) and Nakata (2017), we set the elasticity of substitution among intermediate goods to $\theta = 11.0$ which implies a steady state mark-up of 10%. The Rotemberg adjustment cost parameter is chosen to match a fraction of roughly 83% non-adjusters in a linearised version of the model with Calvo price setting which implies an average price duration of six quarters.[9] The tax rate on labour income is set such that the steady state government spending share, g/y, is 20% and the steady state government debt share to annualised output, $b/4y$, is 60%:

TABLE 1: Parameter Choices – Baseline Calibration

Parameter	**Description**	**Value**
β	Discount factor	0.995
ω_g	Utility weight (government spending)	0.25
ω_h	Utility weight (labour effort)	11.48
η	Elasticity marginal utility of labour	1.00
θ	Elasticity of substitution	11.0
ψ	Rotemberg parameter	300.0
Π	Inflation Target	1.005
γ_g	Steady state government spending as share of GDP	0.2
γ_b	Steady state government debt as share of GDP	2.4
τ	Labour tax rate	0.175
ϕ_π	MP inflation parameter	1.50
φ_b	FP debt parameter	−0.03
ρ_d	Persistence demand shock	0.80
σ_ϵ	Std. deviation demand shock innovation ϵ (in %)	0.345

$$\tau = \frac{1}{1 + \frac{1}{\gamma_g - \gamma_b(\beta - 1)/\Pi}}$$

where $\gamma_g \equiv g/y$ and $\gamma_b \equiv b/y$. Further, we consider a baseline (non-optimised) calibration of the simple rules where fiscal policy only responds to government debt. Under the baseline calibration, we set the the Taylor coefficient on inflation to 1.5 which is the

[9] The resulting slope of the New Keynesian Phillips Curve in the linearised version of the model amounts to 0.033 which is in line with value in Burgert and Schmidt (2014).

standard value chosen in the literature. The fiscal debt feedback coefficient is set to -0.03 which is in line with estimates of Bohn (1998) and Galí and Perotti (2003). The persistence of the demand shock, ρ_d, is set to 0.8 which is the value commonly used in the literature that includes the ZLB on the nominal interest rate (e.g. Fernández-Villaverde et al., 2015). The standard deviation of the innovation to the demand shock, σ_ϵ, is chosen to obtain a ZLB frequency of roughly 10% which is in line with the ZLB frequency observed in the U.S. post-war period (see Dordal i Carreras et al., 2016). The parameters $\omega_g > 0$ and $\omega_h \geq 0$ ensure that in the first best allocation (described below), the government spending share γ_g and the labour supply is equal to 0.2 and 0.33, respectively.

3.2. Welfare Measure

We follow Schmitt-Grohé and Uribe (2007) and search for the combinations of policy parameters included in the vector $\xi_p \equiv (\phi_\pi, \varphi_b, \varphi_y, \varphi_\pi)$ that maximise *unconditional* lifetime utility, defined as

$$V_0 \equiv \sum_{t=0}^{\infty} \beta^t \mathbb{E}\left(u(c_t, g_t, h_t)\right) \ ,$$

where $\mathbb{E}$ denotes the unconditional expectations operator.[10] To rank alternative parametrisations of the policy rules, we compute the welfare costs under a specific parametrisation relative to the social planner solution.

Social Planner Solution. The social planner only takes into account household preferences and the production technology constraints. Formally, the social planner solution is given by:

$$u_{c,t} = u_{g,t} = -u_{h,t} \ . \tag{20}$$

Hence, the social planner equates the marginal utility of private and public consumption to the marginal disutility of labour. Note, that in our economy the preference shock δ_t does not affect the marginal rate of substitution between consumption and leisure nor does it affect the marginal product of labour. Consequently, private and public consumption as well as labour (i.e., production) are constant under the social planner solution. Note that the wage subsidy χ is set such that the deterministic steady state in the decentralised economy corresponds to the social planner solution.

Welfare Ranking. To rank alternative parametrisations of the policy rules, we compute the welfare costs under a specific parametrisation relative to the first best solution. Let

[10]Note that we used the fact that the unconditional mean of the discount factor shock is equal to one.

the social planner solution be denoted by s and the policy regime under a particular parametrisation of the policy rules by a. The unconditional lifetime utility under the time-invariant social planner solution is given by:

$$V_0^s \equiv \sum_{t=0}^{\infty} \beta^t \mathbb{E}\left(u(c_t^s, g_t^s, h_t^s)\right) = \frac{1}{1-\beta} u(c^s, g^s, h^s) \; .$$

In turn, the unconditional lifetime utility under the policy regime a is defined by:

$$V_0^a \equiv \sum_{t=0}^{\infty} \beta^t \mathbb{E}\left(u(c_t^a, g_t^a, h_t^a)\right) \; .$$

Let λ_u be the unconditional welfare cost obtained under policy regime a relative to the social planner solution s. Formally,

$$V_0^a = \frac{1}{1-\beta} u(c^s(1-\lambda_u), g^s, h^s) \; .$$

Due to the specific functional form of the felicity function (19), we can derive λ_u analytically:

$$\lambda_u = 1 - \exp\Big\{(1-\beta)V_0^a - u(c^s, g^s, h^s)\Big\} \; .$$

Intuitively, λ_u measures fraction of consumption that the household has to forego in economy s to be indifferent between staying in economy s and joining economy a.

3.3. Solution Method

We solve the model by finding a fixed-point in the space of policy functions. To find the fixed-point, we start from a guess of the values that the policy functions take on a finite number of grid points of the state variables. The values that the policy functions take at intermediate values are linearly interpolated. Given that guess for the policy functions, we compute expectations and solve the model to obtain an update of the policy functions. We proceed in this manner until convergence.

3.4. Description of the Policy Experiment

We search for the combination of policy parameters that minimises the unconditional welfare loss, λ_u. To do so, we set up a grid for each parameter in the vector ξ_p. Note that for the monetary policy parameter , ϕ_Π, we restrict attention to a grid on the interval $[1.01, 3.0]$. Since we focus on active monetary policy, the lower bound is set to a value that satisfies the Taylor principle, i.e. $\phi_\Pi > 1$. The upper bound of the interval is set to the one chosen by Schmitt-Grohé and Uribe (2007). They argue that values for ϕ_Π above 3.0 are difficult to communicate to both policymakers and the public. Further, this comparatively strong monetary feedback to inflation is consistent with estimates based on a simple regression analysis using instrumental variables (see Erceg and Lindé, 2014). A parameter value of 3.0, furthermore, is increasingly used within the literature that conducts a quantitative analysis within a non-linear version of the New Keynesian model with an occasionally zero lower bound (e.g. Hills et al., 2019; Nakata, 2017). Note, however, that our results are robust if we increase the upper bound of the interval.

Importantly, we define a policy combination to be *feasible* if the parametrisation of ξ_p ensures convergence of the solution algorithm as described in the previous subsection and a covariance-stationary process of the endogenous variables.

4. Evaluation of Simple Policy Rules

In this section, we evaluate the welfare implications of different parametrisations of the policy rules based on the unconditional welfare cost, λ_u. Moreover, we show how different policies affect the frequency of ZLB episodes and the costs associated with these episodes. We proceed as follows. We first determine the "standard" optimal simple rules (OSR), where we optimise the monetary policy parameter and the debt feedback coefficient while fixing the fiscal feedback to inflation and output to zero. In the next step, we fix the monetary policy parameter to its baseline value in Table 1 and determine the optimal simple fiscal rule whereby we optimise over all fiscal policy parameters. Finally, we determine the fully OSR where we optimise over all policy parameters included in the vector ξ_p.

4.1. Standard Optimal Simple Rules

We start our analysis by focusing on the rule-based monetary-fiscal interaction where government spending *only* responds to deviations of government debt from its deterministic steady state while the fiscal feedback to both output and inflation is fixed at zero. We label the interaction based on this parametrisation of the fiscal rule as the "standard" monetary-fiscal interaction, because it is the parametrisation that is commonly used within the literature (e.g. Leeper and Leith, 2016; Schmitt-Grohé and Uribe, 2007). The result of this experiment is shown in the second row of Table 2. Besides the policy vector, we display the welfare costs λ_u (in %), the unconditional probability of reaching the ZLB $\mathbb{P}(R_t = 1)$, and the ergodic mean of the annualised net inflation rate $\mathbb{E}(\pi_t^{\text{ann}})$. We refer to the latter variable as "long-run inflation". We compare the results obtained under the optimised simple rule to the one from the baseline calibration ("baseline policy rules") which is displayed in the first row of Table 2. The standard optimal simple rule ("stan-

Table 2: Evaluation of Simple Policy Rules

	Policy Parameter				**Policy Evaluation**		
Policy Rules	ϕ_Π	φ_b	φ_y	φ_Π	λ_u	$\mathbb{P}(R_t = 1)$	$\mathbb{E}(\pi_t^{\text{ann}})$
Baseline SR	1.5	−0.03	0.0	0.0	0.439	10.0	1.66
Standard OSR	3.0	−0.01	0.0	0.0	0.102	8.58	1.93
Baseline MP & Optimal SFR	1.5	−0.05	0.0	−1.9	0.230	0.72	1.95
OSR	3.0	−0.15	0.0	−1.7	0.077	2.60	1.99

Notes. For each parameterisation of the policy rules, we simulated the model economy for $T = 300,000$ periods. Both the unconditional welfare costs, λ_u, and the unconditional ZLB probability, $\mathbb{P}(R_t = 1)$ are presented in percentage terms. $\mathbb{E}(\pi_t^{\text{ann}})$ denotes the ergodic mean of the annualised net inflation rate.

dard OSR") features an aggressive monetary policy response to inflation while the fiscal debt feedback is muted. In line with Schmitt-Grohé and Uribe (2007), monetary policy aggressively adjusts the nominal interest rate to stabilise inflation in order to minimise the resource loss ϱ_t generated by the Rotemberg price adjustment costs. Note that, under the standard OSR, the monetary policy parameter ϕ_Π corresponds to the upper bound of the pre-specified set of parameter values over which we conduct our search routine. As we increase the upper bound to 100, the monetary policy parameter under the standard OSR still corresponds to the upper bound.[11] Hence, from a welfare perspective, monetary policy should aggressively contain deviations of inflation from its target value.

The reason for the optimal debt coefficient being small is twofold. First, since households' felicity function is concave in government spending, they prefer a smooth government spending path. As shown in the left panel of Figure 1, the volatility of government spending decreases as the debt feedback becomes less pronounced because government spending gets less responsive to deviations of government debt from its steady state value. Note, however, that for a sufficiently weak debt feedback, government spending volatility slightly *increases* as the debt feedback turns even weaker. Intuitively, deviations of government debt from its steady state value become more persistent with a lower debt feedback coefficient. For a sufficiently weak debt feedback, the reduction in government spending volatility caused by a marginal reduction in the debt feedback is dominated by the increase in government debt volatility. Hence, the optimal debt feedback coefficient should be too weak from a welfare perspective.[12]

Second, a weaker debt feedback slightly reduces the resource loss ϱ_t, as shown in the right panel of Figure 1. The reduction in the price adjustment costs stems from the lower pro-cyclicality of fiscal policy as the debt feedback gets smaller – with pro-cyclicality being particularly harmful at the ZLB. To see this, consider Figure 2 where we plot

[11] A similar finding can be found in Schmitt-Grohé and Uribe (2007) in their footnote 8.
[12] The weakest possible debt feedback that yields a feasible solution is −0.006.

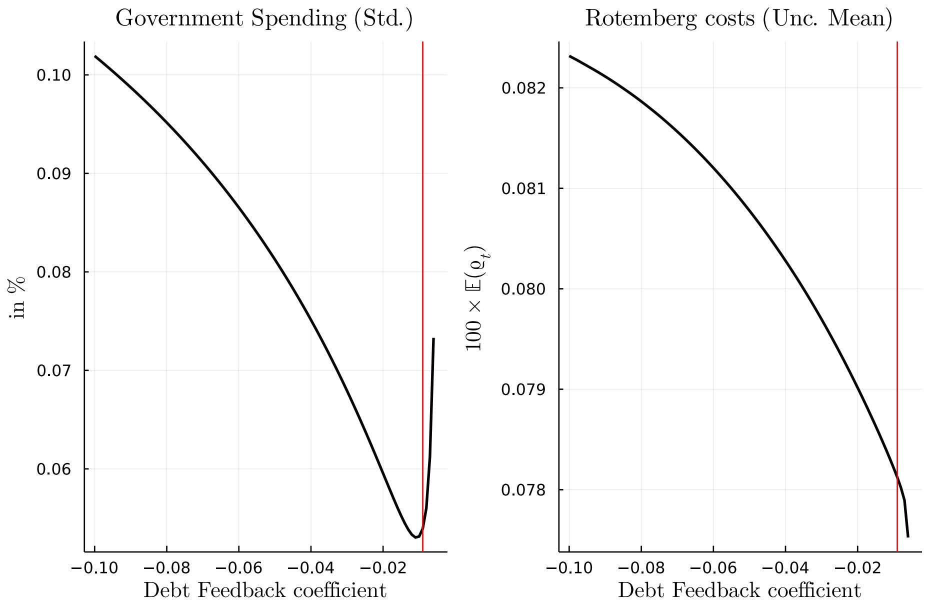

FIGURE 1: Standard Optimal Simple Rule: Optimal debt feedback

Notes. Left: Unconditional standard deviation of government spending (in %). Right: Unconditional mean of Rotemberg costs (multiplied by factor 100). Red vertical line: Optimal debt feedback coefficient under Standard OSR. For each value of φ_b, we simulate the model for $T = 300,000$.

impulse responses of macroeconomic variables after a three standard deviation shock to the discount factor. The black solid line denotes the response under the standard OSR while the red solid line denotes the response when the monetary policy parameter is set to its optimal value while the debt feedback coefficient is set to -0.15. In response to the deflationary demand shock that renders the ZLB a binding constraint, government debt increases because the reduction in inflation increases the real debt burden and the reduction in output reduces the tax base. As a result, the government *cuts* government spending the period after the shock occurs in order to stabilise government debt. The reduction in public demand further depresses aggregate demand, inflation and inflation expectations. A decrease in the latter variable increases the real interest rate which further depresses private consumption. Hence, it is desirable to lower the debt feedback coefficient in order to mitigate the drop in inflation.

The welfare cost under the standard OSR amount to roughly 0.10%. Compared to the baseline policy with a less aggressive monetary policy and a strong debt feedback, the welfare costs reduce by a factor of four. Moreover, the reduction in the debt feedback coefficient relative to the one under the baseline policy reduces the ZLB frequency, $\mathbb{P}(R_t = 1)$. The reduction in $\mathbb{P}(R_t = 1)$ also stems from the lower pro-cyclicality of fiscal policy because it mitigates the reduction in inflation during deflationary recessions where the risk of encountering the ZLB is high. Further, a lower debt feedback reduces the so-called *deflationary bias* which typically arises if the ZLB is an occasionally binding constraint on

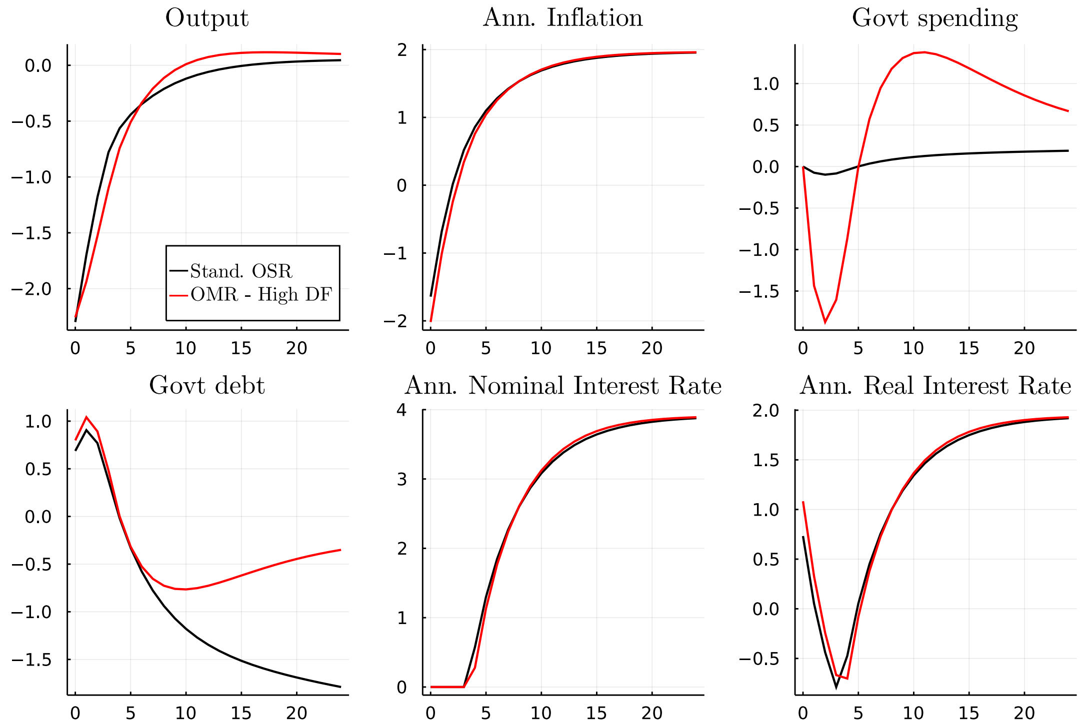

FIGURE 2: IRF Demand Shock: The Role of Debt Feedback

Notes. Impulse Response Functions (IRFs) after three standard deviation shock to discount factor. Black solid: IRFs under Standard OSR; Red solid: IRFs under optimal monetary rule (OMR) and high debt feedback coefficient ($\varphi_b = -0.15$). Output, government spending, and government debt are presented as percentage deviation from respective steady state. Inflation, nominal interest rate, and real interest rate are presented in annualised terms in percent.

the nominal interest rate (e.g., Adam and Billi, 2007; Nakov, 2008). Intuitively, forward-looking firms anticipate that in response to a sufficiently large deflationary demand shock, the ZLB constraint might be binding in future periods. Since the ZLB constraint is binding, the resulting decrease in inflation is larger than the increase in inflation caused by an inflationary demand shock of the same absolute magnitude. As a result, firms lower their inflation expectations which already decreases current inflation – even if the ZLB is currently not binding. Consequently, the unconditional mean of inflation falls below its target value (see Nakata, 2017). If fiscal policy is pro-cyclical, the anticipation of a cut in public demand puts further downward pressure on firms' inflation expectations and hence current inflation. Consequently, the deflationary bias decreases with a weaker fiscal debt feedback.

Note, that the decrease in the welfare costs that can be attributed to the implementation of the optimal debt feedback parameter is quantitatively small. Figure 3 shows the welfare cost as a function of the debt feedback coefficient for the baseline monetary policy parameter (black solid line) and the parameter value under the Standard OSR (black dashed line). It can be seen that the the welfare cost is a relatively flat function of the

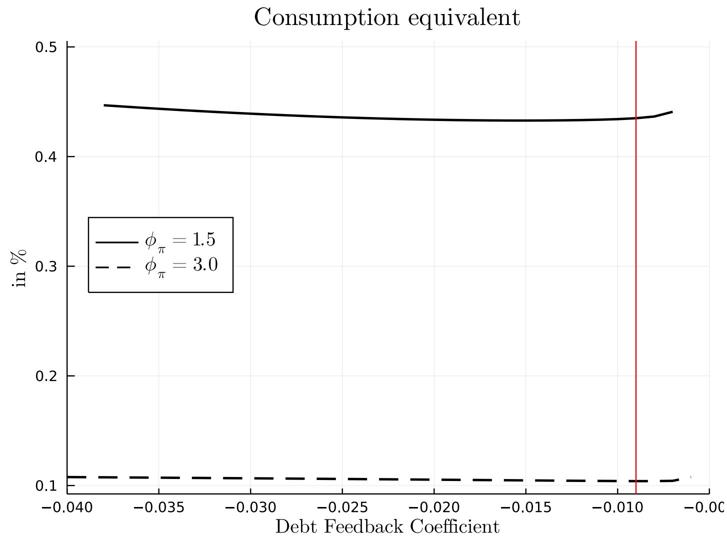

FIGURE 3: Welfare Cost Reduction and Fiscal Debt Feedback

Notes. Consumption equivalent (CE) as a function of the debt feedback coefficient, φ_b. Black solid: CE for the baseline monetary policy parameter. Black dashed: CE for the monetary policy parameter under the Standard OSR. Red vertical line: Optimal debt feedback coefficient under Standard OSR. For each value of φ_b, we simulate the model for $T = 300,000$.

debt feedback coefficient.[13] Hence, the bulk of the reduction in the welfare costs relative to the baseline policy is generated by implementing the optimal (i.e., aggressive) response of monetary policy to inflation.

4.2. Baseline Monetary Policy and Optimal Fiscal Rule

The previous subsection has shown that the welfare gain generated by the implementation of the optimal debt feedback coefficient is quantitatively small. In the next step, we analyse whether fiscal policy can be more effective in stabilising the economy if government spending is free to respond to movements in output and inflation. In this subsection, we determine the optimal simple fiscal rule when the monetary policy parameter is fixed at its baseline value. The result of this policy interaction is shown in the third row of Table 2. There are three crucial results. First, the optimal simple fiscal rule (SFR) features a strong counter-cyclical response to inflation but no response to the output gap. Second, the strong counter-cyclical inflation feedback is accompanied by a debt feedback coefficient that is roughly five times larger than under the Standard OSR. Third, the optimal counter-cyclical fiscal policy rule is effective in reducing the welfare costs, the ZLB frequency and the deflationary bias irrespective of the monetary response to inflation, with the fiscal rule's contribution being particularly strong if monetary policy is less aggressive than optimal. We will discuss all three results consecutively.

[13]The same holds true for the deflationary bias as well as the ZLB frequency.

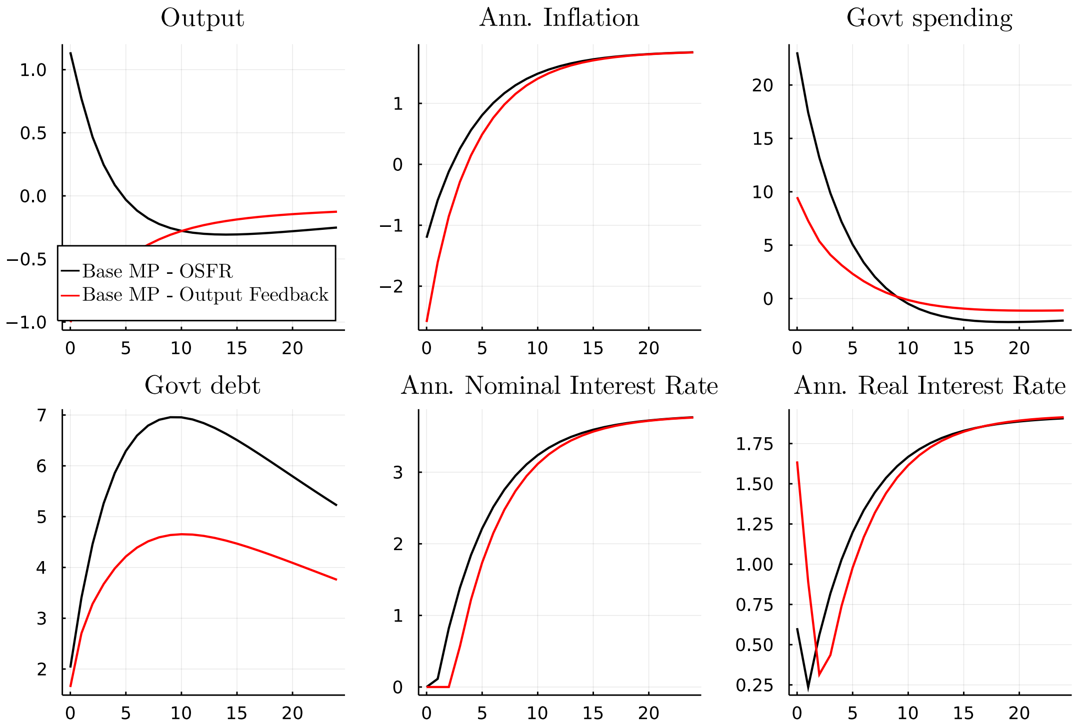

FIGURE 4: IRF Demand Shock: Fiscal Feedback to Inflation vs. Output

Notes. Impulse Response Functions (IRFs) after three standard deviation shock to discount factor. Black solid: IRFs under Baseline MP - OSFR; Red solid: IRFs under baseline MP, high fiscal output feedback ($\varphi_y = -1.9$) and zero fiscal inflation feedback. Output, government spending, and government debt are presented as percentage deviation from respective steady state. Inflation, nominal interest rate, and real interest rate are presented in annualised terms in percent.

4.2.1. Counter-Cyclical Fiscal Policy

The fact that the simple optimal fiscal rule includes a counter-cyclical response of government spending results from the stabilising effect on output and inflation – especially when the ZLB is binding. Importantly, the optimal simple fiscal rule only responds to deviations of inflation from monetary policy's target value while the fiscal output feedback is zero. This is because the fiscal feedback to output is an imperfect substitute for the one on inflation. To see why, consider Figure 4 where we show IRFs for a three standard deviation shock to the discount factor that renders the ZLB binding. The black solid line denotes the IRFs under the optimal simple fiscal rule while the red solid line denotes the IRFs when the fiscal inflation feedback is set to zero while the output feedback is set to -1.9. The crucial difference between the two responses to the deflationary demand shock rest on the response of output. Under the optimal SFR, output *overshoots*, on impact, which results from a very large increase in government spending in the period when the shock hits the economy. The overshooting of output puts upward pressure on inflation which is particularly beneficial at the ZLB because it lowers the real interest rate thereby

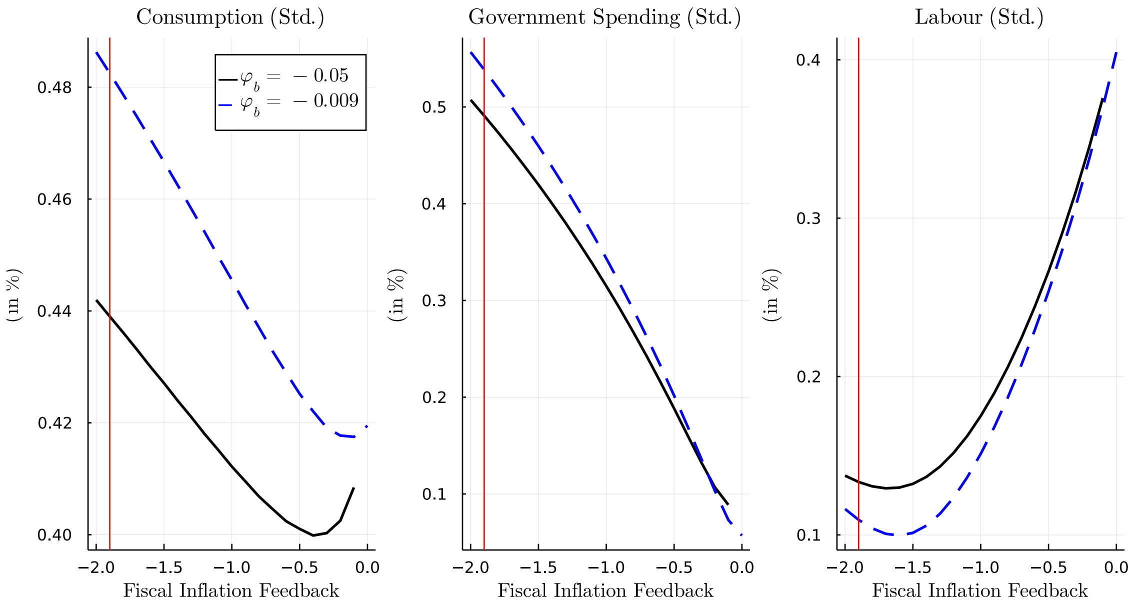

FIGURE 5: Optimal debt feedback under Baseline Monetary Policy Rule

Notes. For each value of φ_Π, we simulate the model for $T = 300,000$ and compute the unconditional standard deviation. Each standard deviation is normalised by the value obtained under the baseline policy. Red horizontal line: debt feedback coefficient that minimises consumption equivalent.

mitigating the downturn in private consumption (not shown). Crucially, the overshooting of output is not counteracted with a counter-cyclical reduction in government spending because the fiscal feedback to output is zero. Due to the aggressive fiscal response to inflation, the lift-off of the nominal interest rate from the ZLB occurs earlier. Hence, even after a large deflationary demand shock, the ZLB only binds on impact which explains the low ZLB frequency under the optimal SFR. If instead fiscal policy counter-cyclically responded to output only, output would drop on impact. Consequently, the drop in inflation is more pronounced under the fiscal rule that only responds to output. Hence, the fiscal feedback to inflation is more effective in stabilising inflation and hence in reducing the resource loss generated by the price adjustment costs (ϱ_t) than a fiscal feedback to output could deliver.

4.2.2. Debt Feedback under Counter-Cyclical Fiscal Policy

Counter-cyclical fiscal policy reduces the volatility in both output and inflation. However, the strong counter-cyclical fiscal feedback increases the the volatility of government spending. Since households' preferences are concave in government spending, a higher volatility in government spending is undesirable from a welfare perspective. To understand the higher fiscal debt feedback under the optimal SFR and the baseline monetary policy, Figure 4 shows the standard deviation of the welfare relevant macroeconomic variables (in %): private consumption, government spending, and labour (i.e. output). The

Figure shows the standard deviation of the respective variable as a function of the fiscal inflation feedback, φ_Π under the optimal simple fiscal rule (black solid line) and under a fiscal rule with the optimised value for φ_Π but a low debt feedback coefficient.[14]

There are several noteworthy observations. First, government spending volatility strictly increases in the fiscal feedback to inflation. This is quite intuitive: as already seen in Figure 4, a strong counter-cyclical fiscal feedback increases the responsiveness of government spending to demand shocks. Further, the effect of counter-cyclical fiscal policy on the volatility of consumption is ambiguous. On the one hand, a counter-cyclical fiscal policy reduces the volatility in inflation and thereby fluctuations in the real interest rate. The lower real interest rate volatility reduces the volatility of consumption. On the other hand, the higher volatility of government spending increases the volatility of private consumption via the resource constraint. It can be seen that for a sufficiently weak fiscal inflation feedback, consumption volatility decreases. However, if the fiscal feedback to inflation gets sufficiently pronounced, the effect of the increased volatility of government spending via the resource constraint dominates the real interest rate effect so that consumption volatility increases.

Second, the volatility of labour is a U-shaped function of φ_Π. For $-1.6 \leq \varphi_\Pi$, labour volatility decreases which is desirable because households' dis-utility of labour is convex. However, if the fiscal inflation feedback gets sufficiently strong, the labour volatility increases. As shown in the previous section, output overshoots in response to a disinflationary demand shock in order to stimulate inflation expectations. As government spending becomes sufficiently counter-cyclical, the overshooting is so pronounced that labour volatility starts to increase. The increase in labour volatility explains the interior solution for the fiscal inflation feedback. While the overshooting in output unambiguously stimulates inflation expectations, the cost of letting output deviate from its efficient target exceed the benefits of higher inflation expectations for sufficiently large (negative) values for φ_Π.

Third, while a higher debt feedback coefficient increases labour volatility, it unambiguously *reduces* the volatility of consumption and, for a sufficiently strong fiscal inflation feedback, also reduces the volatility of government spending. It is this trade-off that makes a higher debt feedback coefficient desirable from a welfare perspective. As shown in Section 4.1, if fiscal policy is unresponsive to inflation and output, the standard deviation of government spending *decreases* as the debt feedback weakens. However, the counter-cyclical fiscal feedback that stabilises short-term fluctuations on labour and inflation increases the volatility in government spending and consumption. Intuitively, in response to demand shocks, the counter-cyclical fiscal feedback mitigates the fluctuation in demand and, in particular, inflation. To counteract the adverse effect of an increased

[14]The value low debt feedback coefficient corresponds to the value obtained under the standard OSR.

government spending and consumption volatility, fiscal policy increases the speed of adjustment of government spending (and hence government debt) towards its steady state. The resulting reduction in the volatility of consumption and government spending makes a higher debt feedback coefficient desirable from a welfare perspective. Hence, the optimal simple fiscal rule is characterised by a strong counter-cyclicality *and* a stronger adjustment of government spending in response to deviations of government debt from its target value.[15]

4.2.3. Stabilisation Role of Fiscal Policy

If the monetary policy parameter is fixed at its (non-optimal) baseline value, the implementation of the optimal simple fiscal rule almost halves the welfare cost relative to the baseline simple rule. At the same time, the strong counter-cyclical fiscal response almost completely resolves the deflationary bias and substantially reduces the ZLB frequency. Fiscal policy is especially effective in reducing the ZLB frequency because its instrument is not constrained by the ZLB. An increase of the monetary policy parameter on inflation, ϕ_Π, has two opposing effects on the ZLB frequency. First, for a negative demand shock that does not lead the economy to the ZLB, a higher value of ϕ_Π reduces the downward shift in inflation, ceteris paribus. A mitigation of the drop in inflation, in turn, reduces the likelihood that in future periods inflation will fall below the value for which the ZLB is binding. Second, for a given inflation rate below the target value, a deflationary shock is more likely to render the ZLB binding because the reduction in the nominal interest rate is more pronounced as ϕ_Π increases. Since the ZLB frequency decreases under the standard OSR, the first effect dominates the second effect: the improved stabilisation of inflation fluctuations is sufficiently strong so that the unconditional probability of a binding ZLB decreases. The two-sided effect is absent for fiscal stabilisation because the fiscal response is not constrained by the ZLB. Hence, counter-cyclical fiscal policy unambiguously reduces the ZLB frequency. As a consequence of the lower ZLB frequency, also the deflationary bias is smaller under the optimised fiscal rule. From the perspective of addressing the ZLB frequency and the deflationary bias, counter-cyclical fiscal policy can act as substitute for a more aggressive feedback of monetary policy to inflation deviations.

However, as shown in the last subsection, counter-cyclical fiscal stabilisation comes at the cost of a higher volatility of government spending and more pronounced movements in government debt. While a more aggressive monetary policy response to inflation unambiguously reduces the overall macroeconomic volatility, the same does not necessarily hold true for a strong counter-cyclical fiscal feedback to inflation. It is the increased

[15] Note that the strong increase in government spending volatility receives a comparatively low weight in households' period-utility function, i.e. ω_g is relatively small. Hence, the reduction in labour volatility receives relatively more weight from a welfare perspective which contributes to the result of the strong counter-cyclicality.

volatility of private and public consumption that renders a counter-cyclical response of government spending an imperfect substitute for monetary policy in terms of welfare. This can be seen by the fact that the unconditional welfare costs under the standard optimal monetary-fiscal interaction amounts to roughly 0.10%. Consequently, the household prefers the optimal standard monetary-fiscal interaction to the economy under the baseline monetary policy response and the optimal simple fiscal rule.

4.3. Optimal Simple Rules

We now determine the fully optimised simple monetary and fiscal policy rules. The result is shown in the last row of Table 2. Again, the optimal simple monetary policy rule features an aggressive response to deviations of inflation from its target value in order to minimise the resource loss resulting from price adjustment costs. The optimal simple fiscal rule also features a strong counter-cyclical response to deviations of inflation from its target value while the optimal feedback to output is zero. Note that relative to the optimal fiscal rule under the baseline monetary policy, the fiscal feedback to inflation slightly decreases. Hence, the more aggressive monetary policy response to inflation partly substitutes for the fiscal inflation feedback. As discussed above, an increase in the monetary policy parameter does not increase the volatility of government spending. As soon as monetary policy is more aggressive in stabilising inflation, fiscal policy slightly decreases the counter-cyclical fiscal feedback to inflation. At the same time, however, the optimal fiscal debt feedback strongly increases relative to the corresponding value under the standard OSR and even further increases relative to the optimal simple fiscal rule under the baseline monetary policy.

Relative to the standard OSR, the welfare costs under the fully optimised simple rules decrease by another 25%. Again, the bulk of the reduction in the welfare costs relative to the baseline policy (first row) is driven by implementing the optimal response of monetary policy to inflation. However, fiscal policy contributes to the overall stabilisation of the economy, in particular when monetary policy is constrained by the ZLB. Counter-cyclical fiscal policy is particularly effective in reducing the ZLB frequency and thereby alleviates the distortions associated with the ZLB, such as the deflationary bias. In fact, under the jointly optimal simple monetary and fiscal policy rules, the deflationary bias is almost completely resolved.

4.4. The Role of the ZLB

In this subsection, we analyse how the optimal simple monetary and fiscal rules are affected by the presence of the ZLB. In particular, we are interested whether and to what degree the ZLB affects the strength of the counter-cyclical fiscal policy. Moreover, we analyse how the welfare costs associated with the ZLB are affected if the fiscal feedback coefficients on output and inflation are optimised. We compute the welfare costs associated with the ZLB as follows: For a given parametrisation of the policy rules p, we compute the welfare costs in the model version with the ZLB and in the model version without the ZLB and take the difference between those two values as the welfare costs caused by the ZLB. Let the unconditional welfare costs caused by the ZLB be given by $\Delta^{\text{ZLB}}\lambda_u$. We focus on two versions of the fiscal policy rule: (a) the baseline fiscal rule where fiscal policy only adjusts government spending in response to movements in government debt; (b) the counter-cyclical fiscal rule where all policy parameters are optimised. For both specifications monetary policy follows the optimised rule. The results are summarised in Table 3.

Table 3: Optimal Simple Policy Rules and the Role of the ZLB

	Policy Parameters				Variable		
Policy	ϕ_π	φ_b	φ_y	φ_π	λ_u	$\Delta^{\text{ZLB}}\lambda_u$	$\mathbb{E}(\pi_t^{\text{ann}})$
Standard OSR	3.0	-0.01	0.0	0.0	0.080	0.022	2.00
OSR	3.0	-0.01	0.0	-0.80	0.073	0.004	2.00

Notes. For each parameterisation of the policy rules, we simulated the model economy for $T = 300,000$ periods. The unconditional welfare costs, λ_u is presented in percentage terms. $\Delta^{\text{ZLB}}\lambda_u$ denotes the change in the welfare costs associated with the ZLB. $\mathbb{E}(\pi_t^{\text{ann}})$ denotes the ergodic mean of the annualised net inflation rate.

Under standard OSR (first row of Table 3), the inflation coefficient of the monetary policy rule and the debt coefficient of the fiscal policy rule take on the same values as in the model with ZLB. The welfare costs under this specification of the monetary-fiscal interaction amounts to 0.08%. Moreover, absent the ZLB, the deflationary bias is completely resolved – even without counter-cyclical fiscal policy.

The optimal simple rule (second row of Table 3) again includes a strong counter-cyclical fiscal feedback to inflation. Thus the optimality of a counter-cyclical fiscal response does not hinge on the presence of the ZLB. Note, however, that the optimal fiscal feedback to inflation roughly halves relative to the corresponding value in the model version with ZLB. Hence, if the nominal interest rate is not constrained from below by the ZLB, there is a lower stabilisation role for fiscal policy. Intuitively, counter-cyclical fiscal policy is particularly effective in stabilising output and inflation when the ZLB is a binding constraint. Hence, during ZLB episodes, a strong increase in government spending (i.e. a strong counter-cyclical fiscal feedback to inflation) is beneficial. If the ZLB constraint on the nominal interest rate is removed, however, episodes in which counter-cyclical fiscal policy is particularly effective are removed. While a counter-cyclical fiscal inflation feedback is still optimal even if the ZLB is removed, the marginal benefit through an improved stabilisation of output and demand decreases. As a consequence, the fiscal feedback to inflation becomes less counter-cyclical. The optimal fiscal feedback to inflation therefor crucially depends on the presence of the ZLB. An evaluation of simple fiscal rules that neglects the ZLB understates the optimal counter-cyclical fiscal feedback to inflation. Further, the optimal fiscal debt feedback coefficient is substantially smaller relative to the OSR in the model version with the ZLB. In particular, if the ZLB is not a binding constraint, fiscal policy is substantially less counter-cyclical so that it is no longer required to counteract the increased volatility of government spending and consumption with a higher debt feedback coefficient.

The size of the welfare cost caused by the ZLB, $\Delta^{\text{ZLB}}\lambda_u$, decreases if fiscal policy is free to adjust government spending in response to deviations of inflation from its target value. While $\Delta^{\text{ZLB}}\lambda_u$ increases by roughly 0.02 percentage points under the standard monetary-fiscal interaction, the corresponding increase in the welfare costs is reduced by a factor of five if the optimal fiscal inflation feedback is implemented. Hence, counter-cyclical fiscal policy substantially mitigates the welfare cost associated with the ZLB.

5. Conclusion

In this paper we analyse the effectiveness of simple monetary and fiscal rules in stabilising the economy in face of an occasionally binding ZLB constraint on the nominal interest rate. Besides ensuring debt stability, the optimal simple fiscal rule is characterised by a strong counter-cyclical response of government spending to inflation, whereas the optimal fiscal response to the output gap is zero. Paired with a strong monetary policy response to inflation, the rule-based interaction of monetary and fiscal policy generates a low frequency of ZLB episodes and almost completely resolves the deflationary bias that is associated with the risk of encountering the ZLB in the future.

Hence, a strong counter-cyclical fiscal response to inflation supports monetary policy in its goal to stabilise inflation around its target value *and*, by reducing the ZLB frequency, gives monetary policy more “room-to-manoeuvre”. An important political-economy corollary of our results is that the appropriate design of counter-cyclical fiscal policy rules allows monetary policy and fiscal policy to continue operating in the traditional active monetary policy - passive fiscal policy configuration. This latter configuration has been shown to be particularly successful in ensuring price stability in face of inflationary shocks. Our results suggest that this configuration can also be successful in countering the dis-inflationary bias induced by the ZLB provided that fiscal policy provides adequate support.

Worthwhile extensions of our paper would include analysing the effectiveness of simple monetary and fiscal rules within a currency union setup in which countries may be hit by asymmetric economic shocks. The natural question arises whether the simple and symmetric fiscal rules analysed in this paper are also effective in contributing to the stabilisation of aggregate economic activity in a monetary union where cross-country spillover effects may be important. Another worthwhile extension would be to analyse the optimal monetary-fiscal policy configuration in face of adverse supply shocks.

References

Adam, Klaus (2011). Government debt and optimal monetary and fiscal policy. *European Economic Review* **55**(1), pp. 57–74.

Adam, Klaus and Roberto M. Billi (2007). Discretionary monetary policy and the zero lower bound on nominal interest rates. *Journal of Monetary Economics* **54**(3), pp. 728–752.

Bianchi, Francesco and Leonardo Melosi (2019). The dire effects of the lack of monetary and fiscal coordination. *Journal of Monetary Economics* **104**, pp. 1–22.

Bianchi, Francesco, Leonardo Melosi, and Matthias Rottner (2021). Hitting the elusive inflation target. *Journal of Monetary Economics* **124**, pp. 107–122.

Billi, Roberto M. and Carl E. Walsh (2022). Seemingly Irresponsible but Welfare Improving Fiscal Policy at the Lower Bound. *Working Paper.*

Bohn, Henning (1998). The behavior of US public debt and deficits. *Quarterly Journal of Economics* **113**(3), pp. 949–963.

Braun, R. Anton and Lena Mareen Körber (2011). New Keynesian dynamics in a low interest rate environment. *Journal of Economic Dynamics and Control* **35**(12), pp. 2213–2227.

Burgert, Matthias and Sebastian Schmidt (2014). Dealing with a liquidity trap when government debt matters: Optimal time-consistent monetary and fiscal policy. *Journal of Economic Dynamics and Control* **47**, pp. 282–299.

Christiano, Lawrence, Martin Eichenbaum, and Sergio Rebelo (2011). When is the government spending multiplier large? *Journal of Political Economy* **119**(1), pp. 78–121.

Coenen, Günter, Carlos Montes-Galdón, and Frank Smets (2020). Effects of state-dependent forward guidance, large-scale asset purchases and fiscal stimulus in a low-interest-rate environment. *ECB Working Paper Series 2352.* European Central Bank.

Croitorov, Olga, Massimo Giovannini, Philipp Pfeiffer, Marco Ratto, and Lukas Vogel (2021). Fiscal stabilisation in a low-interest and high-debt environment. *Working Paper.*

Del Negro, Marco, Domenico Giannone, Marc P. Giannoni, and Andrea Tambalotti (2019). Global trends in interest rates. *Journal of International Economics* **118**, pp. 248–262.

Dordal i Carreras, Marc, Olivier Coibion, Yuriy Gorodnichenko, and Johannes Wieland (2016). Infrequent but long-lived zero lower bound episodes and the optimal rate of inflation. *Annual Review of Economics* **8**, pp. 497–520.

Eggertsson, Gauti B. (2006). The deflation bias and committing to being irresponsible. *Journal of Money, Credit, and Banking* **38**(2), pp. 283–321.

Erceg, Christopher and Jesper Lindé (2014). Is there a fiscal free lunch in a liquidity trap? *Journal of the European Economic Association* **12**(1), pp. 73–107.

Fernández-Villaverde, Jesús, Grey Gordon, Pablo Guerrón-Quintana, and Juan F Rubio-Ramirez (2015). Nonlinear adventures at the zero lower bound. *Journal of Economic Dynamics and Control* **57**, pp. 182–204.

Galí, Jordi (2015). Monetary policy, inflation, and the business cycle: An introduction to the new Keynesian framework and its applications: Second edition. 2nd ed. Princeton: Princeton University Press.

Galí, Jordi and Roberto Perotti (2003). Fiscal policy and monetary integration in Europe. *Economic policy* **18**(37), pp. 533–572.

Hills, Timothy S., Taisuke Nakata, and Sebastian Schmidt (2019). Effective lower bound risk. *European Economic Review* **120**, p. 103321.

Holston, Kathryn, Thomas Laubach, and John C. Williams (2017). Measuring the natural rate of interest: International trends and determinants. *Journal of International Economics* **108**, S59–S75.

Kiley, Michael T. and John M. Roberts (2017). Monetary Policy in a Low Interest Rate World. *Brookings Papers on Economic Activity* **48**(1 (Spring), pp. 317–396.

Kirsanova, Tatiana and Simon Wren-Lewis (2012). Optimal Fiscal Feedback on Debt in an Economy with Nominal Rigidities. *Economic Journal* **122**(559), pp. 238–264.

Leeper, E. M. and C. Leith (2016). Understanding Inflation as a Joint Monetary–Fiscal Phenomenon. In: *Handbook of Macroeconomics*.

Leeper, Eric M. (1991). Equilibria under 'active' and 'passive' monetary and fiscal policies. *Journal of Monetary Economics* **27**(1), pp. 129–147.

Nakata, Taisuke (2017). Uncertainty at the zero lower bound. *American Economic Journal: Macroeconomics* **9**(3), pp. 186–221.

Nakov, Anton A. (2008). Optimal and Simple Monetary Policy Rules with Zero Floor on the Nominal Interest Rate. *International Journal of Central Banking* **4**, pp. 73–127.

Orphanides, Athanasios and Simon van Norden (2002). The unreliability of output-gap estimates in real time. *Review of Economics and Statistics* **84**(4), pp. 569–583.

Rotemberg, Julio J (1982). Sticky Prices in the United States. *Journal of Political Economy* **90**(6), pp. 1187–1211.

Schmitt-Grohé, Stephanie and Martin Uribe (2007). Optimal simple and implementable monetary and fiscal rules. *Journal of Monetary Economics* **54**(6), pp. 1702–1725.

Taylor, John B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Confer. Series on Public Policy* **39**, pp. 195–214.

Taylor, John B. and John C. Williams (2010). Simple and robust rules for monetary policy. In: *Handbook of Monetary Economics*. Vol. 3. Elsevier, pp. 829–859.

Woodford, Michael (2011). Simple analytics of the government expenditure multiplier. *American Economic Journal: Macroeconomics* **3**(1), pp. 1–35.

Acknowledgements

We thank Bartosz Mackowiak, Benjamin Moll, Johannes Pfeifer, Ricardo Reis, Andreas Schabert and Sebastian Schmidt for their advice and suggestions.

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PDF ISBN 978-92-899-5300-9 ISSN 1725-2806 doi:10.2866/887345 QB-AR-22-080-EN-N