# Simple Fiscal Policy Rules: Two Cheers for a Debt Brake?

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February 26, 2009

**Abstract**

In a New Keynesian DSGE model with non-Ricardian consumers, we show that automatic stabilization according to a counter-cyclical spending rule following the idea of the debt brake results to perform quite well to steer the economy and in terms of welfare. Especially, the so-called adjustment account installed to memorize public deficits and surpluses serves well to keep the level of government debt stable. However, it is essential to design its feedback to government spending correctly, where discretionary lapses should be corrected faster than lapses due to estimation errors.

*Keywords:* fiscal policy, debt brake, welfare, dsge.

*JEL code:* E 32, G 61, E 62.

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‡We would like to thank Peter Bofinger, Johannes Clemens, Jürgen Hamker, Heinz Herrmann, Jana Kremer, Thomas Laubach, Dan Stegarescu and Karsten Wendorff for their helpful comments. The opinions expressed in this paper do not necessarily reflect the opinions of the Deutsche Bundesbank or of its staff. Any errors are ours alone.

# 1 Introduction

In the political debate, the stabilizing and potentially welfare enhancing effects of counter-cyclical fiscal policy are attracting more and more attention. Even the International Monetary Fund (IMF) has just recently identified a possibly positive role for rule based fiscal policy in economic cycles in its *World Economic Outlook* (see IMF, 2008; chapter 5). Allsopp and Vines (2005) and Solow (2005) have noticed that, after quite a time in which the stabilizing role of fiscal policy has been widely neglected because of the basically disappointing experiences in the 1970s, there seems to arise somewhat of a consensus that fiscal policy could be an appropriate instrument to steer the economy. In Europe, a potential role for (automatic) fiscal stabilization has more or less seriously been discussed since the start of this decade (see e.g. European Commission, 2001), which is also visible in the Stability and Growth Pact that allows member countries for some (sustainable) stabilization by demanding budgets to be 'close to balance or in surplus' without actually calling for corrective means if the corresponding member state does not systematically violate the 3% deficit ceiling.

In the political debate, a rule based automatic stabilizer called "debt brake" is on the agenda since rather recently. It is somehow interpretable as a further step in the quest to find a "Taylor rule" for fiscal policy.[1] The basic idea is that real government expenditures in a certain period, including interest on outstanding debt, should be equal to real trend revenues raised by the government and not fluctuate with cyclical revenue deviations. In principle, this means that, in "good times", i.e. in times of output above trend, expenditures should fall short of revenues and, thus, the government should save. In "bad times", i.e. when output is below trend, the government is allowed to deficit-finance some of its expenditures. Actual (discretionary) lapses in this pre-determined spending and potential deficits/surpluses resulting from cyclical revenue fluctuations are memorized on what is called "adjustment account". A positive balance of the adjustment account then forces governments to cut future spending. Hence, this spending rule is supposed to be welfare enhancing due to its counter-cyclical behavior and sustainable as it diminishes the deficit bias because of the memorization of discretionary lapses. For symmetric shocks, this rule should have a determined (fixed) level of debt in the long run (see Danninger, 2002; Müller, 2006; German Council of Economic Experts, 2007; Kastrop and Snelting, 2008; and Kremer and Stegarescu, 2008; for a discussion). Rules in this vein have already been implemented in Switzerland in 2001 and it is currently discussed to implement such rules in Germany.

The present paper, to the best of our knowledge being the first, analyzes business cycle dynamics and welfare effects of the debt brake (in the following DB) in a DSGE model and

[1] Much of the earlier work on fiscal policy has tended to focus on cyclical impact rather than debt feedback (see e.g. Favero and Monacelli, 2005; Taylor, 2000; or Auerbach, 2002), while only lately, the discussion about simple stabilizing fiscal rules related to debt, their optimal design and, partly, their strategic interaction with monetary policy has been taken up (see e.g. Kirsanova and Wren-Lewis, 2007; Kirsanova et al. 2005, 2007; and Fragetta and Kirsanova, 2007). The focus of the debt brake is on keeping debt at its optimal level in the long-run, while equally allowing for stabilizing fluctuations in debt. In this respect, the present analysis adds to current literature on stabilizing and sustainable fiscal policy.

compares them to a balanced budget rule (in the following BB) as well as active rule based stabilization (in the following AS). From a theoretical perspective, the DB is somewhere in the middle between a BB (which only allows to spend as much as the government really has) and the AS (which allows government spending to actively react counter-cyclically to output deviations). While BB indeed exist, e.g. for most US states[2], the AS reflects – to a certain extent – how automatic stabilizers have conventionally been modelled in the literature (see e.g. Taylor, 2000).[3] In this analysis, we will see which are important setscrews of the DB and how recent proposals may be improved in their design from the presented model's perspective. The model is in the manner of Gali et al. (2007), Leith and Wren-Lewis (2007) and Linnemann and Schabert (2003, 2006) with Ricardian and non-Ricardian households, a firm sector with staggered price setting as in Calvo (1983), a monetary authority, for which we assume that it follows a simple Taylor rule, and a fiscal authority that implements a DB, a BB or AS, respectively.

We find that none of these rules can be considered as the "new Taylor rule" of fiscal policy as all of them perform significantly worse than optimal discretion. In monetary policy, the Taylor rule is advisable because the "Taylor principle" fits to all shocks. Unfortunately, none of the fiscal rules analyzed here embeds such a principle. Our general finding hence is that a rule which steers fiscal expenditures along the trend path and abstains from activism is preferable as it at least prevents disasters.

The BB potentially destabilizes the economy and gives rise to sunspot equilibria. Due to erratic spending schemes, the BB regime triggers boom-bust cycles in consumption among non-Ricardian households. As monetary authorities do not have leverage on these hand-to-mouth consumers, such a fiscal policy stance may give rise to sunspot equilibria, even if the central bank adopts the Taylor principle (see also Gali, 2004). Accordingly, the overall welfare loss would increase by 7.2% if fiscal authorities would switch from a DB to a BB. Even though the DB ties real government spending to real government trend revenue, it also acts mildly pro-cyclical, which can be attributed to the interest payments on outstanding debt and to the commitment to keep overall debt constant over time. For a shock positively influencing actual real government revenue, this implies that these additional funds are gradually spend over time. The AS explicitly necessitates stabilization in output. This, indeed, generates, in principle, a counter-cyclical response to any economic shock. Note, however, as the government equally has to redeem interest on debt and is committed towards a constant level of real debt in the long run, the overall fiscal stance does not necessarily move counter-cyclical to GDP, but depends on the size of the different effects. A distinct difference to the two previous rules stems from the need to design a feedback from tax rates to changes in government debt in order to attain a stable equilibrium. Without this feedback,

[2]In principle, US states follow a BB rule. However, some of them have installed a so-called "rainy day fund" which may, under certain circumstances, allow for counter-cyclical fiscal policy (see Rodriguez-Tejedo, 2006; for an overview).

[3]Note, however, that the AS and the DB are both automatic stabilizers only influencing that government spending reacts to output fluctuations to a different extent.

the adaption of government spending due to the adjustment account to real government expenditures would not suffice to stabilize debt in the AS regime. In terms of welfare, calculated as an average consumer loss function, a DB and AS are very comparable as the welfare difference is only 4%. Nevertheless, the AS wins the DSGE horse race because it keeps expenditures itself closer to real trend than the DB itself. Therefore, it attenuates the adverse effects of government spending on wages, in particular, in the case of cost-push shock, as it does not crowd in private consumption as much as the DB does.

With regard to the adjustment account, we find that the feedback of the to real government spending should ideally differ with the shock. Discretionary government spending shocks should be corrected as soon as possible, while all the other shocks (generating expectation errors) should fade out slowly over time in order to keep fluctuations actively introduced into the system low. We should further stress that trend revenue is assumed to be known in our basic model. Estimating trend, however, is a difficult task. Taking into account estimation errors in simulating our model, we find that the adjustment account is well suited to prevent debt from dramatically increasing, while equally stabilizing inflation and output whenever the feedback is set optimally. If the feedback is set too low, the economy is subject to more pronounced cycles in GDP and inflation and, thus, welfare losses. In practice, the estimation problem is usually tackled as follows. Government spending is tied to expected revenues (instead of trend revenues) augmented by a counter-cyclical component increasing/decreasing spending according to the expected cyclical situation, which is similar to the setup we have labeled AS. The difference is, however, that within this setup, estimation errors regarding future revenues also have to be booked on the adjustment account. With this construction, one has to be very careful to adapt the reaction of government spending to the elasticities of revenues and output correctly, as the latter tends to be lower than the first. If this adaption is not done correctly (and elasticities are assumed to be equal, as seems to be done in practice), one easily generates a strong pro-cyclical feedback of the DB, which is, in terms of welfare, not quite as bad as the balanced budget rule, but far from the performance of the basic idea of a debt brake.

**Related literature:** As already mentioned earlier, the focus of economic stabilization has, for quite a while, been devoted to monetary policy alone (see e.g. Clarida et al., 1999; and Woodford, 2003; for an overview). One reason may have been that, in the classical theory, Ricardian equivalence dominated the scientific arena. Ricardian equivalence means that, as households know that higher (potentially deficit-financed) government spending today means higher taxes tomorrow, the fiscal multiplier is zero (under the assumption of tax distortions, it may even become negative, see Sutherland, 1997; and Hemming et al., 2002). The fact that, empirically, there was and is large evidence suggesting that, indeed, fiscal multipliers with respect to GDP are significantly different from zero (see e.g. Baxter and King, 1993; Fatas and Mihov, 2001; Blanchard and Perotti, 2002; Perotti, 2005; Heppke-Falk et al., 2006), has led to the development of models incorporating such features. The first wave of DSGE-papers studied fiscal policy alongside monetary policy and focussed on how the stability properties of monetary policy rules are influenced by fiscal policy, basically building on Leeper's (1991) active and passive monetary policy (see e.g. Lubik, 2003; Kremer, 2004; Railavo, 2004; Schmitt-Grohé and Uribe, 2006, 2007; Leith and von Thadden, 2008; and Stehn and Vines, 2008). In contrast to the contribution by Woodford and Benigno (2003) or Schmitt-Grohé and Uribe (2007) we explicitly assume that there are no commitment technologies such as commitment under a timeless perspective or optimal Ramsey plans available. Additionally fiscal authorities are pledged towards a constant debt to GDP to debt ratio in steady state. Thus we exclude by assumption that debt follows a random walk as it is optimal under commitment. Gali et al. (2007) show that the reactions of macroeconomic variables to a fiscal policy shock found empirically can be reconciled in DSGE models with rule-of-thumb consumers as well as sticky prices and deficit financing. Going a step further, Straub and Tchakarov (2007), Leith and Wren-Lewis (2007) and Gali and Monacelli (2008) find that, indeed, counter-cyclical fiscal policy may be welfare enhancing in such setups. The main reason is that such fiscal actions help to at least partly internalize the externalities caused by the implemented rigidities and market imperfection and keep fluctuations in inflation and disutility of labor smaller than without stabilization. Mayer and Grimm (2008) approve that counter-cyclical tax rules can also improve welfare for supply-side shocks. They show that this even holds for balanced budget rules if the tax rule is contingent on the observed welfare gap or on the shock. The question thus is which fiscal rule should be followed. This paper will contribute to the discussion by comparing the DB, a AS regime and a BB both in terms of their effect on macroeconomic variables and in terms of welfare, and, further, point out which are important setscrews to be taken into account.

We will proceed as follows. Section 2 introduces the model used and derives the log-linearized version. In section 3, we analyze the impulse responses of our model, while section 4 contains some welfare considerations. In section 5, we have a look at some important policy issues. Section 6 concludes. A detailed mathematical appendix is added.

## 2 The model

In this section, we present a New Keynesian DSGE model with firms, households as well as monetary and fiscal authorities. As standard, firms are categorized into the final good sector and a continuum of intermediate good producers. Intermediate good producers have some monopoly power over prices that are set in a staggered way following Calvo (1983). Households obtain utility from consumption, public goods and leisure, and further invest in state contingent securities. The household sector is partitioned into so called Ricardian and non-Ricardian Households. The Ricardian households, with share $(1-\lambda)$, own the firms and are able to save, i.e. invest in bonds and state contingent securities, whereas non-Ricardian households, with share $\lambda$, are hand-to-mouth consumers in the sense that they spend each period their total labor income. Monetary policy is assumed to be given by a standard Taylor rule. Government expenditures are financed by distortionary taxes levied on wages and consumption. Fiscal policy is implemented by a spending rule incorporating the DB, the AS regime or the BB rule. The model is built on the framework of Gali, Lopez-Salido and Valles (2007), Leith and Wren-Lewis (2007), and Mayer and Grimm (2008).

In what follows, any aggregated variable $X_t$ is defined by a weighted average of the corresponding variables for each consumer type, i.e., in general, $X_t = \lambda X_t^r + (1-\lambda) X_t^o$, where the superscripts $o$ and $r$ stand for optimizing and rule-of-thumb consumers, respectively. Further, variables with a "bar" (as in $\bar{X}$) indicate the deterministic steady-state value of the variable $X$, while variables with a "hat" (as in $\hat{X}$) denote percentage deviations from the steady-state given by $\hat{X}_t = log\left(X_t/\bar{X}\right) \approx (X_t - \bar{X})/\bar{X}$. As the model is quite standard (except for the fiscal regime), most calculations are relegated to the appendix, whereas the main text only states the equations of origin and the resulting outcomes.

## 2.1 Firms and Price Setting

### 2.1.1 Final good producers

The final good is bundled by a representative firm which operates under perfect competition. The technology available to the firm is

$$Y_t = \left[\int_0^1 Q_t(j)^{\frac{\epsilon_t - 1}{\epsilon_t}} dj\right]^{\frac{\epsilon_t}{\epsilon_t - 1}}, \tag{1}$$

where $Y_t$ is the final good, $Q_t(j)$ are the quantities of intermediate goods, indexed by $j \in (0,1)$, and $\epsilon_t > 1$ is the time-varying elasticity of substitution in period $t$. Profit maximization implies the following demand schedule for all $j \in (0,1)$

$$Q_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_t} Y_t. \tag{2}$$

The zero-profit theorem implies $P_t = \left[\int_0^1 P_t(j)^{(1-\epsilon_t)} dj\right]^{\frac{1}{(1-\epsilon_t)}}$, where $P_t(j)$ is the price of the intermediate good $j \in (0,1)$. In a similar way to Smets and Wouters (2003), we assume that $\epsilon_t$ is a stochastic parameter. This implies that $\Phi_t = \frac{\epsilon_t}{(\epsilon_t - 1)}$ reflects the time-varying markup in the goods market. We get $\Phi_t = \Phi + \hat{\Phi}_t$, where we assume that $\hat{\Phi}_t$ is i.i.d. normal distributed. Then, $\Phi = \frac{\epsilon}{(\epsilon - 1)}$ is the deterministic markup in steady state.

### 2.1.2 Intermediate good producers and prices

The intermediate good sector behaves in the usual manner. Profit by firm $j$ at time $t$ is given by

$$\Pi_t(j) = P_t(j) Q_t(j) - W_t(1 + \tau_t^w)(1 - \tau_n^s) N_t(j), \tag{3}$$

where $W_t$ denotes the nominal wage rate, $N_t$ are labor services rented and $\tau_t^w$ are social security contributions of firms. The production technology available to firms is given by

$$Q_t(j) = A_t \cdot N_t(j), \tag{4}$$

in which labor is the sole input. For analytical simplicity, it is linear in the shock, where $\bar{A} = 1$. We assume staggered price setting which implies that only a fraction $(1-\theta_P)$ of firms is able to adapt prices, where $\theta_P$ is the Calvo parameter (see Calvo, 1983). Additionally, we assume that firms receive constant employment subsidies $\tau_n^s$ on gross labor costs $(1+\tau_t^w)W_tN_t(j)$ which undoes the distortions associated with monopolistic competition and the tax wedge in the steady state such that we are able later on to take a second order approximation around the efficient steady state without altering the dynamics of the model (for more details, see also Gali and Monacellli; 2008 and Leith and Wren-Lewis, 2007, among others). The subsidies are financed by assuming that there are lump-sum taxes available which are levied on optimizing households.

## 2.2 The Household Sector

We assume a continuum of households indexed by $j \in (0,1)$ of which $(1-\lambda)$ households are assumed to own the assets such as contingent claims, i.e. they are Ricardian consumers, whereas the rest $\lambda$ has a consumption ratio of one, i.e. they are non-Ricardian consumers, in the following rule-of-thumb consumers. Let us assume that any household $j$ is characterized by the following lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t^i \left(C_t^i(j), L_t^i(j)\right), \tag{5}$$

where $i = o, r$ indicates optimizing and rule-of-thumb households, respectively. The per-period utility function for all households is given by

$$U_t^i(j) = \zeta_t \left[(1-\chi) log\left(C_t^i(j)\right) + \chi log\left(G_t\right) + \upsilon log\left(L_t^i(j)\right)\right], \tag{6}$$

where $\zeta_t$ is a common preference shock, with $E\{\zeta_t\} = \bar{\zeta} = 1$. $L_t^i(j)$ is household $j$'s leisure, where $N_t^i(j) = 1 - L_t^i(j)$ gives the corresponding labor supply of household $j$. $\upsilon > 0$ measures how leisure is valued compared to consumption $C_j^i(j)$. $\chi \in (0,1)$ measures the relative weight of public goods consumption $G_t$.

### 2.2.1 Optimizing Households

The flow budget constraint of optimizing households in real terms is given by

$$(1+\tau_t^C)C_t^o(j) + \frac{B_{t+1}^o(j)}{P_tR_t} - T_t^{s,n} \leq (1-\tau_t^d)\frac{W_t}{P_t}N_t^o(j) + \frac{\Pi_t^o(j)}{P_t} + \frac{B_t^o(j)}{P_t}, \tag{7}$$

where $B_t$ is a bond issued by the government. The bond pays a gross interest equal to the risk free nominal rate $R_t$, which is assumed to be the monetary authority's policy instrument. $W_t$ is the nominal wage rate. As we assume that the productivity of Ricardian and non-Ricardian consumers is identical and that their labor services offered to firms are perfect substitutes we can drop the superscript $o$ and $r$ in the following regarding wages. $\Pi_t^o(j)$ are nominal profits from the intermediate good sector. $\tau_t^d$ is a distortionary tax rate levied on nominal labor income, while $\tau_t^C$ is a consumption (quasi value added) tax. $T_t^{s,n}$ denotes the lump-sum tax levied on optimizing households to finance the employment subsidy $\tau_n^s$.

Each optimizing household maximizes his utility, equation (5) – given equation (6) – with respect to consumption, leisure and bond holdings subject to the intertemporal version of the budget constraint, equation (7). We find that (see Appendix B)

$$\frac{\zeta_t}{C_t^o(j)} = \beta R_t E_t \left\{ \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \cdot \frac{\zeta_{t+1}}{C_{t+1}^o(j)} \cdot \frac{P_t}{P_{t+1}} \right\} \tag{8}$$

is the consumption Euler equation for optimizing households and derive

$$\frac{C_t^o(j)}{L_t^o(j)} = \frac{(1-\chi)}{\upsilon} \cdot \frac{(1-\tau_t^d)}{(1+\tau_t^C)} \cdot w_t \tag{9}$$

as the labor supply schedule of optimizing households expressed in terms of leisure, where $w_t = \frac{W_t}{P_t}$ and $L_t^o(j) = [1 - N_t^o(j)]$.

### 2.2.2 Rule-of-Thumb Consumers

The lifetime utility of rule-of-thumb consumers is also given by equations (5) and (6). However, as they do not have access to the capital market, their budget constraint becomes static and is given by

$$(1+\tau_t^C)C_t^r(j) = (1-\tau_t^d)\frac{W_t}{P_t}N_t^r(j), \tag{10}$$

which implies that they spend all their per-period income. Hence, rule-of-thumb consumers maximize equation (5) – given equation (6) – with respect to $C_t^r(j)$ and $L_t^r(j)$ subject to the intertemporal version of the static budget constraint, equation (10). We get (see Appendix B)

$$\frac{C_t^r(j)}{L_t^r(j)} = \frac{(1-\tau_t^d)}{(1+\tau_t^C)}\frac{(1-\chi)}{\upsilon}w_t, \tag{11}$$

which, substituted in equation (10) and remembering that $N_t^r = 1 - L_t^r$ yields

$$N_t^r(j) = \frac{(1-\chi)}{(1-\chi)+\upsilon} \;\Leftrightarrow\; L_t^r(j) = \frac{\upsilon}{(1-\chi)+\upsilon}. \tag{12}$$

Hence, labor supply by rule-of-thumb consumers is exogenously fixed by the parameter $\upsilon$, which values leisure compared to consumption, and by $(1-\chi)$, which gives the relative weight of private consumption. Using equation (12) and equation (11), we find that

$$C_t^r(j) = \frac{(1-\chi)}{(1-\chi)+\upsilon} \cdot w_t \cdot \frac{(1-\tau_t^d)}{(1+\tau_t^C)}. \tag{13}$$

## 2.3 Fiscal Authorities

The government issues bonds $B_{t+1}$ each period (which have to be repaid with interest in the following period), and collects consumption taxes $\tau_t^C P_t C_t$ and labor income taxes $\tau_t^L W_t N_t$, where $\tau_t^L = \tau_t^w + \tau_t^d$. The receipts are used to finance government expenditure $P_t G_t$ and interest on outstanding debt $R_{t-1}B_t$ of the previous period, where $R_{t-1}$ is the gross interest rate. Furthermore, the government has to pay subsidies on labor costs for which it also collects the corresponding lump-sum taxes. Hence, the government's flow budget constraint reads

$$B_{t+1} + (\tau_t^L - \tau_n^s)W_t N_t + \tau_t^C P_t C_t = R_{t-1}B_t + P_t G_t + T_t^{s,n}. \tag{14}$$

At each point in time, it holds that $\tau_n^s W_t N_t = T_t^{s,n}$ such that it cancels out of equation (14), see also Leith and Wren-Lewis (2007). Simplifying accordingly, expressing equation (14) in real terms and normalizing by $\bar{Y}$, where $\bar{Y}$ is the steady-state output, yields

$$\frac{B_{t+1}}{P_t\bar{Y}} + \frac{\tau_t^L w_t N_t}{\bar{Y}} + \frac{\tau_t^C C_t}{\bar{Y}} = \frac{R_{t-1}B_t}{P_{t-1}\bar{Y}}\frac{P_{t-1}}{P_t} + \frac{G_t}{\bar{Y}}. \tag{15}$$

Defining $\tilde{b}_t = \frac{B_t}{P_{t-1}\bar{Y}}$ as the cyclically adjusted debt, and government tax revenues as $\Psi_t = \tau_t^L W_t N_t + \tau_t^C P_t C_t$, where

$$\frac{\Psi_t}{P_t\bar{Y}} = \frac{\tau_t^L w_t N_t}{\bar{Y}} + \frac{\tau_t^C C_t}{\bar{Y}}, \tag{16}$$

equation (15) rewrites to

$$\tilde{b}_{t+1} + \frac{\Psi_t}{P_t\bar{Y}} = R_{t-1}\tilde{b}_t\frac{P_{t-1}}{P_t} + \frac{G_t}{\bar{Y}}. \tag{17}$$

For later use, we will further define

$$b_t = \tilde{b}_t - \bar{b} = \frac{B_t}{P_{t-1}\bar{Y}} - \frac{\bar{B}}{\bar{P}\bar{Y}} \tag{18}$$

as the deviation of the percentage of the cyclically adjusted debt from its steady-state ratio. In what follows, we will describe the different fiscal spending rules in more detail.

### 2.3.1 The Balanced Budget Rule (BB)

As a benchmark for a sustainable spending rule, we introduce a BB, which implies that – as government spending is usually planned at least one period in advance – the government is not allowed to spend more than the projected funds raised. Any expectation errors, i.e. differences between projected and actual funds raised and (active) discretionary spending shocks $\nu_t$ are booked on an adjustment account $AC_t$ to memorize lapses in the spending behavior. Thus, (ex-ante) spending according to the balance budget rule is determined by projected revenues minus previous balances booked on the adjustment account, i.e. $E_{t-1}\{\Psi_t\} - \rho \cdot AC_{t-1}$, where $\rho$ is a parameter indicating how much effect earlier lapses in the spending behavior have on current spending. It can be interpreted as the speed of adjustment. This implies, actual (ex-post) spending is given by $(R_{t-1}-1)B_t + P_tG_t = E_{t-1}\{\Psi_t\} - \rho AC_{t-1} + \nu_t$. The adjustment account for the balanced budget rule reads $AC_t = (1-\rho)AC_{t-1} + \nu_t + E_{t-1}\{\Psi_t\} - \Psi_t$. In normalized real terms, for the budget constraint, this reads

$$(R_{t-1}-1)\tilde{b}_t + \frac{G_t}{\bar{Y}} = \underbrace{E_{t-1}\left\{\frac{\Psi_t}{P_t\bar{Y}}\right\} - \rho \cdot \frac{P_{t-1}}{P_t} \cdot ac_{t-1}}_{=\text{Rule based spending}} + \frac{\nu_t}{P_t\bar{Y}} \tag{19}$$

and, for the adjustment account,

$$ac_t = (1-\rho)\frac{P_{t-1}}{P_t} \cdot ac_{t-1} + \frac{\nu_t}{P_t\bar{Y}} + \underbrace{E_{t-1}\left\{\frac{\Psi_t}{P_t\bar{Y}}\right\} - \frac{\Psi_t}{P_t\bar{Y}}}_{\text{Expectation error}}, \tag{20}$$

where $ac_t = \frac{AC_t}{P_t\bar{Y}}$.

#### 2.3.2 The Debt Brake (DB) and Active Rule Based Stabilization (AS)

As described in the introduction, the main idea of the DB is that real spending, including interest on outstanding real debt, should be equal to real trend revenues, i.e. $\frac{\bar{\Psi}}{P}$, which yields a counter-cyclical fiscal stance as deficits diminish in "good times" and accumulate in "bad times". Within the AS, government spending (relatively) increases with negative output fluctuations (and vice versa), which is how automatic stabilization has conventionally been modelled earlier (see e.g. Taylor, 2000; Artis and Buti, 2000; or Buti et al., 2001). In order to make this rule comparable to the DB, we assume that, in the steady-state, both rules are tied to steady-state revenues (which implies that $\frac{\bar{\Psi}}{P}$ is regarded as a fixed constant in the AS regime). However, the more active counter-cyclical component of the AS augments the rule based spending by $E_{t-1}\left\{\left(\bar{Y}/Y_t\right)^{\alpha}\right\}$, where $\alpha > 0$ captures the magnitude of the activism. This implies relatively more spending in expected "bad times", $Y_t < \bar{Y}$, and vice versa. This discussion can formally be summarized (in normalized real terms) by

$$(R_{t-1}-1)\tilde{b}_t + \frac{G_t}{\bar{Y}} = \underbrace{\frac{\bar{\Psi}}{\bar{P}\bar{Y}} \cdot E_{t-1}\left\{\left(\frac{\bar{Y}}{Y_t}\right)^{\alpha}\right\} - \rho \cdot \frac{P_{t-1}}{P_t} ac_{t-1}}_{=\text{Rule based spending}} + \frac{\nu_t}{P_t\bar{Y}}, \tag{21}$$

where $\nu_t$ is a (discretionary) government spending shock and $ac_t$ and $\rho$ are interpreted as for the BB. Further it applies that $\alpha = 0$ for the DB and $\alpha > 0$ for the AS. Note, from a theoretical perspective, fiscal authorities should, of course, try to replicate the allocation under flexible prices, such that $(Y_t^{flex}/Y_t)$ is a relevant measure to stabilize. However, in the political debate fiscal authorities act as if they try to stabilize output around a smoothed trend, which we identify as the steady state of $Y$ in our model. Within this paper, we do not attempt to measure the welfare loss which can be attached to such a behavior.

Regarding the adjustment account, we know that a discretionary spending shock $\nu_t$ must reduce future spending as in the BB. As the DB ties spending to trend revenues, any deficit resulting from deviations of true revenues from trend revenues have to be repatriated in future periods and the adjustment account books $\frac{\bar{\Psi}}{\bar{P}\bar{Y}} - \frac{\Psi_t}{P_t Y_t}$. For the AS, the deviations of output from trend output determine spending behavior. Hence, only deviations of expected outcome to actual outcome, i.e. $E_{t-1}\left\{\left(\bar{Y}/Y_t\right)^{\alpha}\right\} - \left(\bar{Y}/Y_t\right)^{\alpha}$, are booked on the adjustment account. It thus formally holds that

$$ac_t = (1-\rho) \cdot \frac{P_{t-1}}{P_t} \cdot ac_{t-1} + \frac{\nu_t}{P_t \bar{Y}} + \frac{\bar{\Psi}}{\bar{P}\bar{Y}} \cdot \underbrace{\left[E_{t-1}\left\{\left(\frac{\bar{Y}}{Y_t}\right)^{\alpha}\right\} - \left(\frac{\bar{Y}}{Y_t}\right)^{\alpha}\right]}_{\textit{Expectation error AS};\ \alpha>0,\ \varrho=0} + \underbrace{\varrho\left[\frac{\bar{\Psi}}{\bar{P}\bar{Y}} - \frac{\Psi_t}{P_t \bar{Y}}\right]}_{\textit{Expectation error DB};\ \alpha=0,\ \varrho=1}, \quad (22)$$

where $\varrho = 1$ for the DB and $\varrho = 0$ for the AS (note that $\alpha$ applies according to the spending rule).[4]

## 2.4 Market Clearance

In clearing of factor and goods markets, the following conditions are satisfied

$$Y_t = C_t + G_t, \quad (23)$$

where $C_t = \lambda C_t^r + (1-\lambda) C_t^o$ is aggregated consumption.[5] Further,

$$Y_t(j) = Q_t(j) \quad (24)$$

and (in per-capita units)

$$N_t = \frac{1}{\lambda}\int_0^{\lambda} N_t^r(j)dj + \frac{1}{(1-\lambda)}\int_{\lambda}^{1} N_t^o(j)dj. \quad (25)$$

[4]Note that, as the government is committed towards keeping real debt constant in the long run, debt services and the adjustment account can almost chancel out the AS component such that the fiscal stance might only move mildly counter-cyclical to GDP.

[5]Note that, within each group $i = o, r$ each household consumes the same due to constant labor supply for rule-of-thumb consumers and state-contingent claims for optimizing consumers (see also Woodford, 2003; and Appendix B for details).

## 2.5 Linearized Equilibrium Conditions

In this section, we summarize the model by taking a log-linear approximation of the key equations around a symmetric equilibrium steady state.

**Firms (*for mathematical derivations, see Appendix A*):** From the firm sector, we find that the log-linearized marginal cost function is given by

$$\hat{mc}_t(i) = -\hat{A}_t + \hat{w}_t + \iota^w \hat{\tau}_t^w, \tag{26}$$

where $\iota^w = \frac{\bar{\tau}^w}{(1+\bar{\tau}^w)}$. From the production technology, equation (4), we know that

$$\hat{N}_t = \hat{Y}_t - \hat{A}_t. \tag{27}$$

Solving the firm's optimality condition for the optimal reset price and following Gali et al. (2001), we can derive the Phillips curve

$$\hat{\pi}_t = \beta \cdot E_t \{\hat{\pi}_{t+1}\} + \kappa \cdot \hat{mc}_t + \hat{\epsilon}_t, \tag{28}$$

where

$$\kappa = \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p}.$$

Note that we defined $\hat{\pi}_t = \hat{P}_t - \hat{P}_{t-1}$.

**Households (*for mathematical derivations, see Appendix B*):** The log-linearized version of the aggregated consumption Euler equation expressed in deep parameters reads

$$\hat{C}_t = E_t\hat{C}_{t+1} - \Theta_n E_t \Delta \hat{N}_{t+1} + \iota^C E_t \Delta \hat{\tau}_{t+1}^C - E_t[\hat{R}_t - \hat{\pi}_{t+1}] + E_t[\hat{\zeta}_t - \hat{\zeta}_{t+1}], \tag{29}$$

where $\Theta_n = \frac{\lambda\gamma_r\varphi}{(1-\gamma_r\lambda)}$, $\iota^C \equiv \frac{\bar{\tau}^C}{(1+\bar{\tau}^C)}$, $\varphi = \frac{\bar{N}}{1-\bar{N}}$, $\gamma_r = \frac{\upsilon}{1-\chi+\upsilon}\frac{1}{1-\bar{N}}$, and we have used the fact that, in the steady-state, $\bar{R} = \beta^{-1}$. Note that $\Delta\hat{N}_{t+1} = \hat{N}_{t+1} - \hat{N}_t$ and so on. The wage evolution (labor supply schedule) is given by

$$\hat{w}_t = \hat{C}_t + \varphi\hat{N}_t + \iota^d\hat{\tau}_t^d + \iota^C\hat{\tau}_t^C, \tag{30}$$

where $\iota^d \equiv \frac{\bar{\tau}^d}{(1-\bar{\tau}^d)}$.

**Fiscal authorities (*for mathematical derivations, see Appendix C*):** Log-linearizing the normalized budget constraint, equation (17) around its steady-state yields

$$b_{t+1} - \beta^{-1}b_t = \gamma_G \underbrace{\left[\hat{G}_t - (\hat{\Psi}_t - \hat{P}_t)\right]}_{=Primary\ Deficit} + \bar{\bar{b}} \underbrace{\left(1-\beta^{-1}\right)}_{<0} \left[\hat{\Psi}_t - \hat{P}_t\right] + \bar{\bar{b}}\beta^{-1}\left[\hat{R}_{t-1} - \hat{\pi}_t\right]. \tag{31}$$

Equation (31) determines the evolution of the level of debt after a deviation of other the parameters. Real government revenues evolve according to

$$\hat{\Psi}_t - \hat{P}_t = \underbrace{\frac{\bar{\tau}^L \bar{W} \bar{N}}{\bar{\Psi}}}_{=Rev^L} \left( \hat{\tau}_t^L + \hat{w}_t + \hat{N}_t \right) + \underbrace{\frac{\bar{\tau}^C \bar{P} \bar{C}}{\bar{\Psi}}}_{=Rev^{VAT}} \left( \hat{\tau}_t^C + \hat{C}_t \right), \tag{32}$$

where $Rev^L = \frac{\bar{\tau}^L(\epsilon-1)}{\epsilon(1+\bar{\tau}^w)(1-\tau_n^s)[\gamma_G-(1-\beta^{-1})\bar{\tilde{b}}]}$ and $Rev^{VAT} = \frac{\bar{\tau}^C}{\gamma_C[\gamma_G-(1-\beta^{-1})\bar{\tilde{b}}]}$ are the percentages of labor tax revenue and of value added tax revenue calculated in deep parameters, respectively. Note that $Rev^L + Rev^{VAT} = 1$ (see Appendix D for more details). Equation (32) thus determines the deviation of government revenue from its steady-state value.

Log-linearized government spending is given by

$$\begin{aligned} \hat{G}_t = \quad & \frac{(1-\beta^{-1})}{\gamma_G} b_t - \frac{\rho}{\gamma_G} \cdot ac_{t-1} + \frac{1}{\gamma_G \bar{P}\bar{Y}} \cdot \nu_t + \frac{\bar{\tilde{b}}(1-\beta^{-1})}{\gamma_G} \hat{\pi}_t - \beta^{-1} \frac{\bar{\tilde{b}}}{\gamma_G} \hat{R}_{t-1} \\ & + \frac{\gamma_G - (1-\beta^{-1})\bar{\tilde{b}}}{\gamma_G} \underbrace{\left[ \varnothing_1 \cdot \underbrace{E_{t-1}\left\{ \hat{\Psi}_t - \hat{P}_t \right\}}_{BB} - \alpha \cdot \underbrace{E_{t-1}\left\{ \hat{Y}_t \right\}}_{AS} \right]}_{=0\ for DB}, \end{aligned} \tag{33}$$

while the log-linearized adjustment account is given by

$$\begin{aligned} ac_t \quad = \quad & (1-\rho) ac_{t-1} + \frac{\nu_t}{\bar{P}\bar{Y}} + \left( \gamma_G - (1-\beta^{-1})\bar{\tilde{b}} \right) \left[ \left( \varnothing_1 \cdot E_{t-1}\left\{ \hat{\Psi}_t \right\} - \varrho \hat{\Psi}_t \right) \right. \\ & \left. - \left( \varnothing_1 \cdot E_{t-1}\left\{ \hat{P}_t \right\} - \varrho \hat{P}_t \right) - \alpha \left( E_{t-1}\left\{ \hat{Y}_t \right\} - \hat{Y}_t \right) \right], \end{aligned} \tag{34}$$

where $\varnothing_1 = \alpha = 0$ and $\varrho = 1$ for the DB, $\varnothing_1 = \varrho = 0$ and $\alpha > 0$ for the AS and $\varnothing_1 = \varrho = 1$ and $\alpha = 0$ for the BB.

**Proposition 1** *Define a stationary combination of variables as indicated by equation (34). Assume for the sake of exposition that the economy is driven by a set of orthogonal white noise error terms. Then* $ac_t = (1-\rho)ac_{t-1} + \eta_t$ *will be non-stationary if* $\rho = 0$ *across all regimes.*

**Proof.** By backward induction, it holds that

$$\begin{aligned} ac_t \quad = \quad & (1-\rho)^{\infty} ac_{t-\infty}^{\infty} + \sum_{k=0}^{\infty} (1-\rho)^k \frac{\nu_{t-k}}{\bar{P}\bar{Y}} + \varnothing_2 \left( \gamma_G - (1-\beta^{-1})\bar{\tilde{b}} \sum_{k=0}^{\infty} (1-\rho)^k \epsilon_{DB,t-k} \right) \\ & + \varnothing_3 \alpha \left( \gamma_G - (1-\beta^{-1})\bar{\tilde{b}} \sum_{k=0}^{\infty} (1-\rho)^k \epsilon_{AS,t-k} \right) \\ & + \varnothing_4 \left( \gamma_G - (1-\beta^{-1})\bar{\tilde{b}} \sum_{k=0}^{\infty} (1-\rho)^k \epsilon_{BB,t-k} \right), \end{aligned}$$

where $\epsilon_{DB,t} = \hat{\Psi}_t - \hat{P}_t$, $\epsilon_{AS,t} = E_{t-1}\left\{\hat{Y}_t\right\} - \hat{P}_t$ and $\epsilon_{BB,t} = E_{t-1}\left\{\hat{\Psi}_t - \hat{P}_t\right\} - \left\{\hat{\Psi}_t - \hat{P}_t\right\}$ are white noise processes with $\o_2 = 1$, $\o_3 = \o_4 = 0$ for the DB, $\o_3 = 1$, $\o_2 = \o_4 = 0$ for the AS and $\o_4 = 1$, $\o_2 = \o_3 = 0$ for the BB. It holds that $ac_t$ will be stationary if $0 < |\rho| < 1$, as all sums are bounded. ■

Proposition 1 states that even if shocks are symmetrically distributed, they will not chancel out each other over the business cycle such that $ac_t$ will be a non-stationary variable. Thus, the pure existence of exceptional errors is sufficient to justify a partial feedback from the adjustment account to government spending as business cycle dynamics will not render $ac_t$ stationary by itself. This result is important because, in the political debate, there seems to be the conjecture that a sustainable fiscal policy is a necessary and sufficient condition for stationarity – which it is not.

**Monetary authorities:** We assume that monetary authority acts as given by the following simple Taylor rule,

$$\hat{R}_t = (1-\mu)\left[\phi_\pi \hat{\pi}_t + \phi_Y \hat{Y}_t\right] + \mu \hat{R}_{t-1} + z_t, \tag{35}$$

where $\phi_\pi$ and $\phi_Y$ denote the reaction coefficients towards inflation and output deviations, respectively. $\mu$ denotes the degree of interest rate smoothing. $z_t$ defines the monetary shock.

**Market clearing:** Market clearing implies that

$$\hat{Y}_t = \gamma_C \hat{C}_t + \gamma_G \hat{G}_t, \tag{36}$$

where $\gamma_C$ and $\gamma_G$ are the shares of output devoted to private and public consumption, respectively. They can be expressed in terms of deep parameters (see Appendix D).

**Additional feedback and shocks:** We further assume that there may exist an additional feedback of debt to tax rates in order to generate existence of an unique equilibrium. This implies that we assume $\hat{\tau}_t^C = \chi_C b_t$, $\hat{\tau}_t^w = \chi_w b_t$ and $\hat{\tau}_t^d = \chi_d b_t$. Note that, except for the automatic stabilizer, we are able to set $\chi_k = 0$, where $k = C, w, d$ (see section 3 for a more detailed discussion). For the shocks we assume autocorrelation implying $\zeta_t = \rho_\zeta \cdot \zeta_{t-1} + \tilde{\zeta}_t$, $A_t = \rho_A \cdot A_{t-1} + \tilde{A}_t$, $\epsilon_t = \rho_\epsilon \cdot \epsilon_{t-1} + \tilde{\epsilon}_t$, $\upsilon_t = \rho_\upsilon \cdot \upsilon_{t-1} + \tilde{\upsilon}_t$, $z_t = \rho_z \cdot z_{t-1} + \tilde{z}_t$, $\nu_t = \rho_\nu \cdot \nu_{t-1} + \tilde{\nu}_t$ and $\xi_t = \rho_\xi \cdot \xi_{t-1} + \tilde{\xi}_t$, where $\tilde{\zeta}_t, \tilde{A}_t, \tilde{\epsilon}_t, \tilde{\upsilon}_t, \tilde{z}_t, \tilde{\nu}_t$ and $\tilde{\xi}_t$ are random i.i.d. shocks. Hence, equations (26) to (36), as well as the feedback and shock rules describe the economy.

**Proposition 2** *All endogenous macro-variables and, thus, welfare can be expressed by deep parameters and fixed levels of tax rates $\bar{\tau}^w$, $\bar{\tau}^d$ and $\bar{\tau}^C$ in the steady-state and are identical across all fiscal regimes considered.*

**Proof.** See Appendix D. ■

Proposition 2 states that the steady-state levels of all variables are identical across fiscal regimes. This is of utmost importance for our welfare exercise as it allows us to focus on the business cycle implications of fiscal policy, whereas we do not need to adjust our conclusions for differences in the steady-states.

# 3 Calibration and Impulse Response Analysis

In this section we provide details on the business cycle dynamics if fiscal authorities implement the fiscal rules discussed above.

## 3.1 Calibration Strategy

While conducting the calibration exercise of the deep parameters we rely on parameter values typically recommended to describe the euro area.

For fiscal authorities, we set in particular tax rates such that the level of public to private consumption is roughly speaking one to three as in the euro area. The labor tax rate is set to $\bar{\tau}^d = 0.10$, which includes labor income tax. The consumption tax rate is calibrated to be $\bar{\tau}^C = 0.18$. This endogenously determines the private consumption to output ratio and the government consumption to output ratio which are equal to $\gamma_C = 0.74$ and $\gamma_G = 0.26$.[6]

For the fraction of liquidity constraint consumers we choose $\lambda = 0.33$, which engineers a more moderate crowding out of private consumption to a highly autocorrelated exogenous expenditure shock on impact. For moderately autocorrelated spending shocks, it is able to replicate a crowding-in of private consumption, which is in line with evidence reported from a VAR by Gali et al. (2007). For lower values of $\lambda$ as, for instance, proposed by Coenen et al. (2008), our model would still predict a substantial crowding out in private consumption which might be considered as counterfactual.

Since we do not have a distinctive imagination for appropriate numerical values for $\rho$, which governs the partial feedback from the adjustment account to expenditures and for $\chi_j$, where $j = C, d, w$, which governs the feedback from changes in public debt to tax rates, we choose the parameters such that our welfare metric, which is discussed in section 4, is minimized. We find in particular that for all shocks except government expenditure shocks the algorithm preferred rather small parameters for $\rho$ and $\chi_j$. Accordingly, we set $\rho = 0.05$ (see Appendix F), which generates a unique and determined rational expectations equilibrium. We are able to set $\chi_j = 0$. This is advisable as it allows us to eliminate movements in distortional taxes on labor and value added at the business cycle frequency. Note however, as we will discuss below, we need some moderate feedback of taxes to changes in debt for an automatic stabilizer to output to prevent the equilibrium to be non-unique.

[6]Coenen et al. (2008) propose instead to set tax rates equal to marginal rates. Although appealing at first sight this would inflate the endogenously determined government to output ratio beyond 0.4 in our model.

For the supply side of the model to imply a substantial degree of nominal rigidities we set $\theta_p = 0.75$, which implies that prices are fixed on average for four quarters. This is calibrated somehow in the middle of the range typically reported in literature. Coenen et al. (2008) and Smets and Wouters (2004) estimate an average price duration for optimal price setting of ten quarters using full information Baysian estimation techniques, while Del Negro et al. (2005) only report an average price duration of three quarters. Micro-data for the euro-area on price setting report low price durations with a median of around 3.5 quarters (see Alvaraez et al., 2006 for a summary of recent micro-evidence). The steady-state mark-up of intermediate good producers over marginal cost is set at 10 per cent, implying that $\epsilon = 11$.

Following Gali et al. (2007), who specify the household sector in a similar setting as we do (i.e. a log-utility function), we calibrate the inverse of the Frisch elasticity of labor supply equal to $\varphi = 1$. The discount factor is fixed to $\beta = 0.99$, implying a 4% steady-state real interest rate.

The Taylor-rule coefficients display values in line with Schmitt-Grohé and Uribe (2007). The inflation coefficient on the inflation rate is set to $\phi_\pi = 3.0$, while for the output gap coefficient we opt for $\phi_Y = 0.25$ (see Del Negro et al., 2005; Coenen et al., 2008; and Smets and Wouters, 2003). Following Gali et al. (2004), we set the inflation coefficient to a somewhat higher value than originally proposed by Taylor (1993) as, in the light of rule-of-thumb consumers, the central bank is forced to follow a more anti-inflationary policy. Additionally, Schmitt-Grohé and Uribe (2007) report evidence that values well above 1.5 are welfare-enhancing in economies with nominal frictions and hence, set $\phi_\pi = 3.0$. The interest rate smoothing coefficient is set to $\mu = 0.85$.

The exogenous driving forces $\zeta_t, A_t, z_t$ and $\epsilon_t$ are assumed to follow a univariate autoregressive process where the first order coefficients are set as follows: $\rho_\zeta = 0.882$, $\rho_\epsilon = 0.890$, $\rho_z = 0.150$ and $\rho_A = 0.822$. These values reflect coefficients found in Coenen et al. (2006) and Smets and Wouters (2003, 2007). For the case of the exogenous fiscal spending shock, the recent literature has not yet found a clear cut consensus. While some authors report evidence for highly auto-correlated fiscal expenditure shocks such as Smets and Wouters (2004) with $\rho_\upsilon = 0.956$. Chari et al. (2007) attribute only little role to fiscal expenditure shocks at all. Still, others estimate DSGE models and remain tacit whether there is any role for fiscal expenditure shocks by not specifying them (Coenen at al., 2008). An overview is found in Table 1, while Table 2 provides an overview of the standard deviation of shocks.

| Parameter | Symbol | Value |
|---|---|---|
| Discount factor | $\beta$ | 0.990 |
| Elasticity of demand in intermediate good sector | $\epsilon$ | 11.000 |
| Taylor rule coefficient: inflation | $\phi_\pi$ | 3.000 |
| Taylor rule coefficient: output | $\phi_Y$ | 0.250 |
| Taylor rule coefficient: interest rate smoothing | $\mu$ | 0.850 |
| Feed back of adjustment account to spending | $\rho$ | 0.050 |
| Fraction of firms that leave their price unchanged | $\theta_p$ | 0.750 |
| Fraction of firms that do price indexation | $\omega_p$ | 0.000 |
| Share of liquidity constraint consumers | $\lambda$ | 0.330 |
| Steady state rate of employee wage taxes | $\bar{\tau}^d$ | 0.100 |
| Steady state rate of employer social security contribution | $\bar{\tau}^w$ | 0.000 |
| Steady state rate of consumption taxes | $\bar{\tau}^C$ | 0.180 |
| Feedback of debt to taxes | $\chi_d, \chi_w, \chi_C$ | 0.000 |
| Autoregressive parameter for consumer preference shock | $\rho_\zeta$ | 0.822 |
| Autoregressive parameter for technology shock | $\rho_A$ | 0.828 |
| Autoregressive parameter for supply shock | $\rho_\epsilon$ | 0.890 |
| Autoregressive parameter for monetary policy shock | $\rho_z$ | 0.150 |
| Autoregressive parameter for government spending shock | $\rho_\nu$ | 0.956 |
| Relative weight of leisure to consumption | $\upsilon$ | 1.000 |

Table 1: Baseline Calibrationn

| Shock type | Standard deviations |
|---|---|
| Consumer preferences | 0.324 |
| Technology | 0.628 |
| Price mark-up | 0.140 |
| Monetary policy | 0.240 |
| Government expenditure | 0.331 |
| Government revenue | 0.329 |

Table 2: Standard Deviations of Shocks

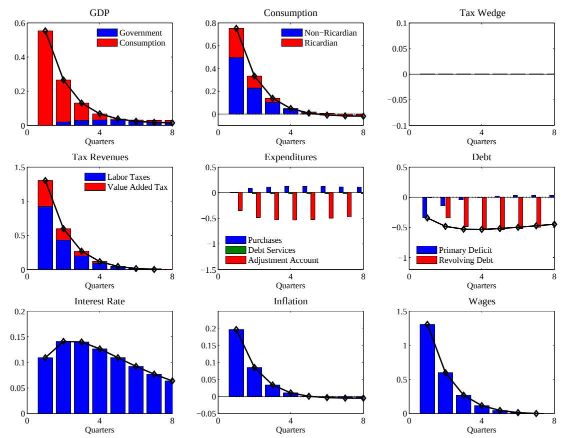


Figure 1: DB and CPS

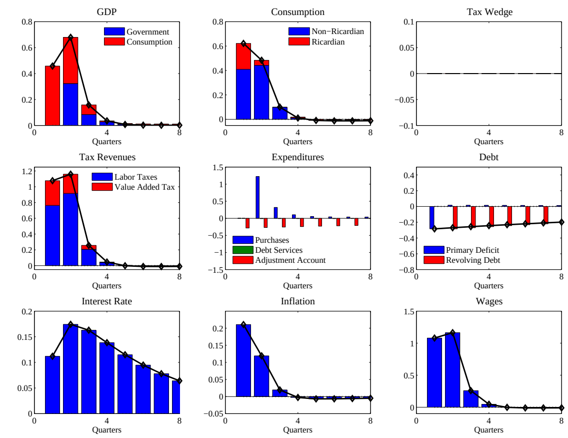


Figure 2: BB and CPS

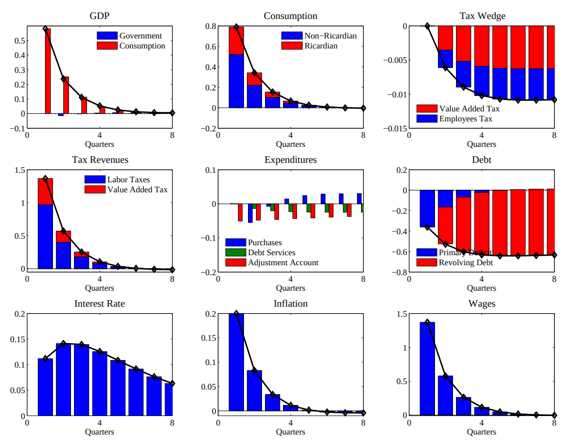


Figure 3: AS and CPS

## 3.2 Impulse Response Analysis

Given the above calibration, we kick off to analyze the different sets of fiscal policy rules. In this section the emphasis is on the identification of distinct differences across fiscal regimes following a shock to consumer preferences, to a price mark-up , and to technology. In section 4, we will draw welfare conclusions.

### Shock to consumer preferences (CPS)

Figure 1 portrays the dynamic response of selected variables to a shock to consumer preferences if fiscal policy follows a DB.

Due to the additional demand posted to firms, firms that are allowed to reset prices increase those to cushion the increasing marginal cost pressure stemming from higher wages to incite households to work more in order to satisfy the additional demand. The increase in real wages, in turn, encourages Non-Ricardian consumers to increase their consumption expenditures. Although they only account for one third of the household sector they drive, on impact, almost 50% in the consumption dynamics and start to dominate the picture onward. As monetary authorities are determined to dampen inflation variability they increase real interest rates and slowdown consumption expenditures such that inflation falls quickly. The somewhat tough stance on inflation and the implied high interest rate along the adjustment path almost completely wipes out the positive impact of the consumer preference shock for Ricardian households from quarter three onwards. The impulse responses portray that fiscal authorities keep expenditures largely stable over the cycle. In particular, the additional funds raised due to an increase in labor and consumption taxes are not spent but pathed through to debt. Thus the DB embodies automatic stabilization on the revenue side as government expenditures are decoupled from cyclical movements in revenues and kept at trend. The mildly pro-cyclical movement in government expenditures can be attributed to interest rate payments on outstanding debt and the commitment of fiscal authorities to keep overall debt constant in the long run, which means that the additional funds are spent gradually over time. This is engineered by a low feedback from the adjustment account to government expenditures.

Figure 2 depicts the business cycle dynamics if fiscal authorities are determined to balance the budget in each period. Due to the planning horizon of one period, the budget will not balanced in the first period as the unexpected tax revenues are not accounted for in the predetermined government expenditure plans. The regime shift leads to a number of remarkable changes in the business cycle. First, government expenditures become the driving component of GDP quantitatively, whereas for the DB, private consumption expenditures dominated the picture over the first five quarters. From period two onward, the government spends the additional tax revenues which has two effects on the economy. On the one hand, firms have to pay significantly higher wages to optimizing households to extent their hours worked, while, on the other hand, the significantly higher wages lead to a boom in consumption among liquidity constraint consumers. Accordingly, compared to a DB, we observe a somewhat higher inflation rate and higher interest rates, which almost completely crowd out the consumption expenditures of Ricardian households. The low feedback running from the partial adjustment account to expenditures gradually reduces the debt accumulated in the first period due to the expectations error.

Figure 3 illustrates the response to a consumer- preference shock if the government tries to implement the AS rule. In the upper right panel, we plot the tax wedge. It serves as a measure for the cumulative distortions imposed on the economy due to movements in tax rates at the business cycle frequency. Following Coenen et. al (2007), it is measured as follows: Define the real effective wage income of households as $\frac{(1-\tau_t^d)}{(1+\tau_t^C)}\frac{W_t}{P_t}$ and the effective labor cost of firms as $(1+\tau_t^w)\frac{W_t}{P_t}$. In an undistorted equilibrium, the ratio of the two would be one. Accordingly,

$$\tau_t^{wedge} = 1 - \frac{(1-\tau_t^d)}{(1+\tau_t^C)(1+\tau_t^w)}$$

serves as a summary statistic to measure the evolution of the tax wedge over the cycle. A distinct difference of the AS regime to the two previous regimes stems from the need to design a feedback from tax rates to changes in government debt. Without this feedback, the moderate cut in government spending due to the feedback from the adjustment account to real government expenditures would not be sufficient to stabilize the net present value of outstanding real government liabilities and, thus, generate explosive equilibria. As for the case of a DB, the additional revenues are not spent but passed through to debt. Because the government needs to rely on pro-cyclical taxation, the surpluses in revenues quickly vanish and debt starts to return gradually to its initial steady state. Generally, the effects are very similar to those of the DB. However, note that, for the AS, government spending acts very mildly counter-cyclical (or, basically, stays constant), while it is mildly pro-cyclical for the DB.

**Shock to price mark-up (PMS)**

Figure 4 illustrates the course of business cycle dynamics if the economy is hit by a persistent shock to the price mark-up. Those firms who can reset prices adjust them upward as market power has risen. Monetary authorities increase real interest rates to set incentives to Ricardian households to reallocate planned consumption expenditures into the future. This depresses contemporaneous aggregate demand such that firms have to engineer cuts in production by offering lower real wages. As consumption expenditures of Non-Ricardian households are driven by real wages, the downturn of the economy is accelerated.

If fiscal authority's implement a DB, the basic operating principles are identical to those observed for the case of a demand shock. The cyclical shortfall in revenues does not trigger cuts in government expenditures but is absorbed by debt. This builds in an automatic stabilization mechanism for the evolution of GDP as government expenditures move mildly but persistently pro-cyclical. This pro-cyclical behavior stems from debt services and more moderate fiscal expenditure from quarter two onward as the government is committed towards keeping the steady state debt to GDP ratio constant over time.

Figure 5 depicts the course of the economy if fiscal authorities are committed towards a BB. It prevails that the basic operating principles are comparable to the case of a shock to consumer preferences. The deterioration of the tax base during the economic downturn forces cuts in expenditures from quarter two onward. This amplifies the economic downturn, in particular, as Non-Ricardian households sharply cut their expenditures because real wages decline more pronounced than under a debt brake regime. The fiscal contraction helps somewhat to relieve the economy from inflationary pressure such that the increase in real interest rates is more moderate as it would be if fiscal authorities kept the expenditure stream

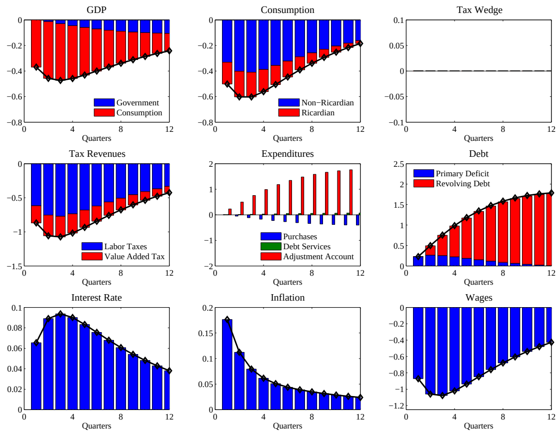


Figure 4: DB and PMS

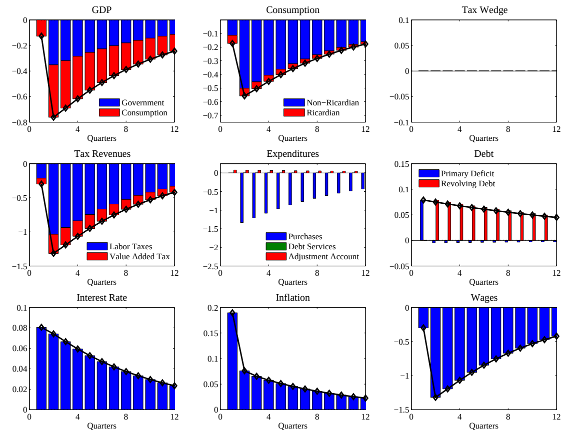


Figure 5: BB and PMS

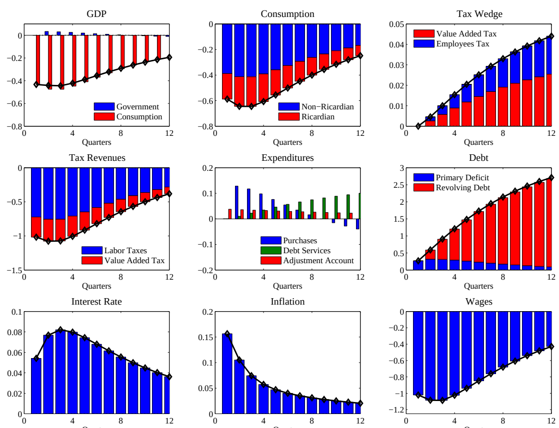


Figure 6: AS and PMS

at trend.

Figure 6 portrays the dynamics of the business cycle if fiscal authorities implement AS. For the case of a price mark-up shock, this regimes turns out to be the most passive one in terms of fiscal expenditures because the counter-cyclical stance due to rule based stabilization in output and the need to bring back real debt in the medium term chancel out. Hence, government expenditures are effectively kept constant. Consequently, fiscal authorities are less ambitious to reverse debt dynamic which prevail more persistence. As beforehand a sufficiently strong pro-cyclical movement in tax rates is a necessary condition to revert debt dynamics and anchor the outstanding real government liabilities. As tax rates are increased, tax revenues are at their trend level after four quarters. The dynamics of the inflation rate and wage dynamics are similar as those observed under a DB.

### Shock to technology (TS)

Figure 7 portrays the course of the business cycle dynamics if the economy is hit by a technology shock under a DB regime. The technology shock augments productivity and, thus, cuts marginal costs of firms. For a given level of output, this allows firms to cut employment or augment production for a given level of employment. This impulse responses portray that in the first quarter fiscal balances deteriorate as labor tax revenues decrease, while in later periods additional value added tax receipts tend to improve the fiscal balance. In order to cut employment, firms reduce wages, which decreases labor supply and consumption of Ricardian households. As marginal costs and wage costs decrease, those firms which can will reset their prices to a lower level, which decreases inflation. The fall in inflation makes the central bank cut interest rates, which, in turn, augments consumption of Ricardian households. In total, consumption rises. Higher demand for goods implies that additional production is needed and, therefore, firms raise wages from period three onward, which then increases consumption of Non-Ricardian households. The rise in consumption and output drive inflation back to its original level. Following the DB, the government basically keeps expenditures fixed to trend revenues and passes the fall in revenues to debt, which, as in the other cases, yields a very mild counter-cyclical spending behavior due to the interest payments.

In figure 8, we see how the business cycle dynamics change when the government follows a BB. In the first two periods, revenues decrease as labor and consumption tax receipts decline, which is not anticipated by the government and passed through to debt. However, in the third period, we see, in contrast to the DB regime, a sharp decrease in government expenditure due to the BB requirement. As inflation rates are below the central banks inflation target, interest rate cuts encourage Ricardian households to increase consumption expenditures, which reverses the drop in GDP and leads to a sustained boom in output, such that labor tax revenues and value added taxes are above trend. Following a BB, the additional funds are spent, so fiscal authorities fuel the boom in output.

Figure 9 illustrates the business cycle dynamics under a AS regime. However, the counter-cyclical component in government expenditures builds in a negative correlation between GDP and government expenditures. From period three onward, the higher demand for goods and output makes firms rise wages to generate higher labor supply, which augment government revenue. These extra revenues are, basically, fully passed into debt which falls stronger than in the case of the debt brake. Still, government spending stays low as the counter-cyclical component is not compensated by the reduced debt services (more precisely, the additional income resulting from negative levels of debt).

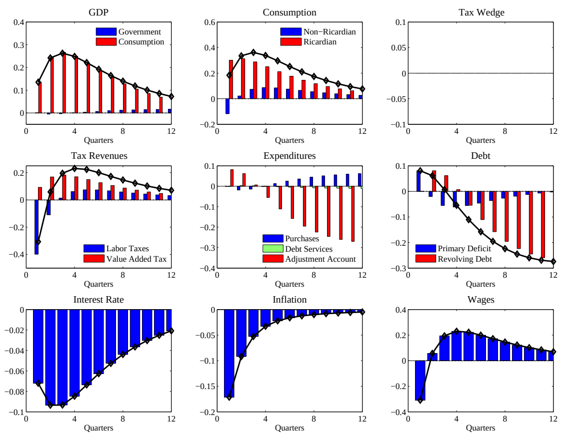


Figure 7: DB and TS

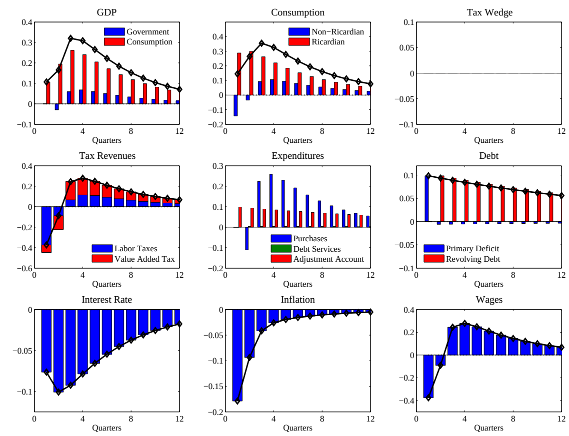


Figure 8: BB and TS

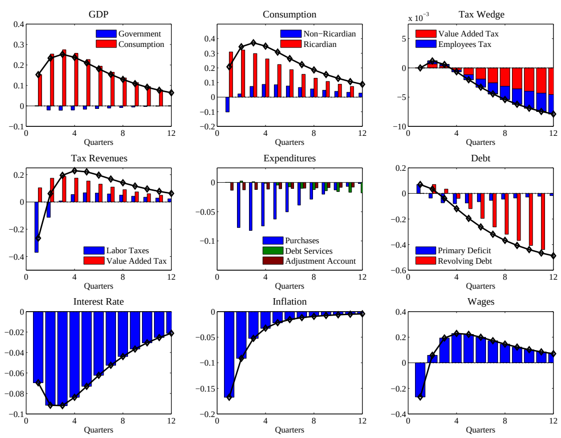


Figure 9: AS and TS

# 4 Welfare

As shown in Appendix E, the welfare criterion is derived by a second-order approximation of the average utility of a household around the deterministic long-run steady state (see also Erceg, Henderson, and Levine, 2000; Gali and Monacelli, 2008; and Woodford, 2003). The welfare function can be written as follows

$$\mathbb{W}_0 = E_0 \sum_{t=0}^{\infty} U_t = \sum_{t=0}^{\infty} \frac{(1-\upsilon\varphi)}{2} \left[ (1+\hat{Y}_t)^2 - (\hat{Y}_t - \hat{\zeta}_t)^2 \right] - \upsilon\varphi \cdot \frac{\epsilon}{\kappa} \sum_{t=0}^{\infty} \beta^t \hat{\pi}_t^2. \tag{37}$$

Next, we characterize the welfare implications of the different fiscal policy regimes by means of numerical analysis for four types of shocks, namely shocks to consumer preferences, shocks to the price mark-up, transitory technology shocks and fiscal spending shocks. For the baseline calibration, more than 90% of the welfare losses are driven by these shocks. Therefore, we only discuss these three shocks in turn before presenting the overall welfare statistics.

Figures 10 to 13 portray the adjustment path of the annualized inflation rate in the upper panel (which dominates the welfare metric) for the different fiscal policy regimes under consideration. In the lower panel, the response of fiscal authorities under the different regimes is shown. As a reference point we additionally report how a discretionary optimizing fiscal authority that responds to the predetermined state variables $\hat{\zeta}_t$, $\hat{\epsilon}_t$, $\hat{A}_t$, $\nu_t$ and $b_{t+1}$ behaves by implementing the following rules

$$\hat{G}_t = -15.56_{(2.10)} \cdot \hat{\zeta}_{t-1} - 0.38_{(0.10)} \cdot b_t, \tag{38}$$

$$\hat{G}_t = -48.41_{(10.53)} \cdot \hat{\epsilon}_{t-1} - 0.36_{(0.11)} \cdot b_t \tag{39}$$

$$\hat{G}_t = +7.50_{(0.57)} \cdot \hat{A}_{t-1} - 0.33_{(0.05)} \cdot b_t \tag{40}$$

and

$$\hat{G}_t = -7.22_{(9.40)} \cdot \nu_{t-1} - 0.95_{(0.66)} \cdot b_t, \tag{41}$$

where the coefficients are chosen such that the welfare loss function, equation (37), is minimized. In order to give a fair comparison, we assume informational symmetry. This means that the optimizing fiscal policymaker can only observe the predetermined state variables with one period delay such that public expenditures are predetermined in the first quarter across all considered regimes. The following remarks summarize the main findings.

**Remark 1** *All proposed simple fiscal policy regimes perform remarkably worse than an optimal discretionary fiscal policymaker that implements rules (38) to (41).*

The impulse responses illustrate that an optimal discretionary fiscal policymaker designs a negative correlation between the inflation rate and government expenditures. Such a contractionary policy stance is welfare enhancing as fiscal authorities succeed to influence wage dynamics and marginal costs favorably by manipulating production plans. Accordingly, any policy measure which contributes to inflation stabilization increases welfare (see also the description of the business cycle dynamics in section 3.2).

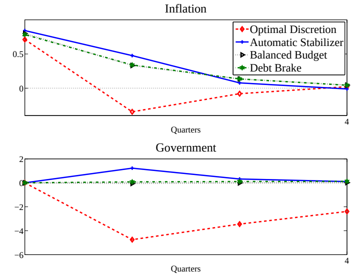


Figure 10: Preference shock and welfare

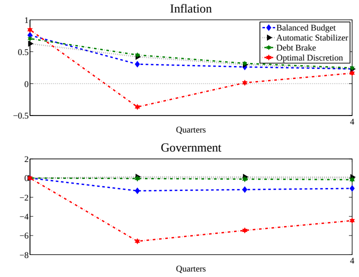


Figure 11: Cost push shock and welfare

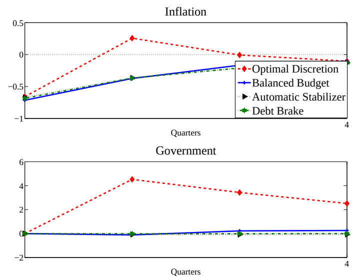


Figure 12: Technology shock and welfare

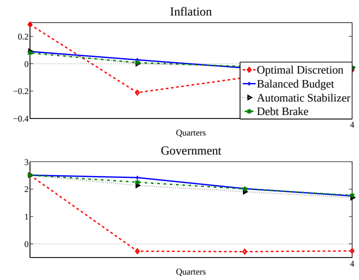


Figure 13: Fiscal shock and welfare

**Remark 2** *In particular, a BB moves government expenditures pro-cyclical to inflation which aggravates the adverse welfare affects of price dispersion as it promotes a boom in overall consumption and (relatively) boosts inflation.*

In presence of the BB, government spending, in principle, moves pro-cyclically with inflation, whereas the optimal response would be to move exactly in the opposite direction. An exception is the presence of a cost-push shock. In this case, as described in detail in Figure 5, tax revenues fall, which implies a fall in government spending when adapting the BB (while the other rules imply a rather fixed spending path, see Figure 11). Note, however, that this is the only type of shock in which the BB moves government spending in the right direction.

**Remark 3** *The DB and the AS generally keep government spending stable and, thus, avoid to be a source of economic disturbance. They do a lot better than the BB, namely* 11.4% *for the AS and* 7.2% *for the DB.*

As becomes clear by the description in section 3.2, government spending is more or less kept constant according to the DB and the AS. Hence, the inflation dynamics are quite similar. Inspection of Figure 10 shows that, for a consumer preference shock, inflation dynamics are, on impact, a little lower for the DB than for the AS, while the opposite holds for the cost-push shock.

Comparing the results for a cost push shock, we observe that the AS does better than the DB. This can be explained as follows: We observe in quarter one that consumption over both consumer types drops faster for the case of the AS. Accordingly, we observe a more pronounced cut in real wages, which moderates the increase of the inflation rate and is thus welfare enhancing. Therefore inflation on impact is 10 percent lower than under a DB regime.

The economic mechanism which drives the result for the DB is explained by the mild but highly persistent movement in government expenditures. As we have shown before, for the case of highly correlated shocks, movements in public expenditures lead to significant crowding out effects. Therefore the anticipation of a highly persistent cut in government expenditures crowds in consumption as the drop of consumption among Non-Ricardian households is only moderate. The crowding in effect is driven by expectations of higher interest rates along the adjustment path on the behalf of monetary authorities. These crowding in effects retard the drops in GDP and accordingly of wages on impact. Only from period three onward, when the cuts in government expenditures actually materialize, the impulse responses among the two regimes start to converge.

In sum, the anticipation effect of highly correlated government expenditures, which only materialize in later periods, drive the differences in welfare results for a DB and an AS regime. As the anticipation of highly correlated government expenditures promotes a more moderate drop in wages this supports higher inflation rates and is in turn welfare reducing.

Is this evidence gained from Figures 10 to 13 robust? To discuss this issue we conduct a simple robustness exercise. Precisely speaking, we compute the expected value of the loss function, equation (37), for the DB and for a BB and AS regime, respectively, and, then, take the ratio of the two. If the ratio takes a value one, then the loss under a DB and the two alternative fiscal policy regimes would be identical. If the value of the ratio is above (below) one, then the loss under a DB is smaller (larger) than the loss under the alternative fiscal policy regimes. The lines in Figure 14 indicate how the ratio changes for each of the three shocks when the deep parameters displayed is altered, while the other parameters remain fixed at their baseline values.

The following results stand out. While the relative performance of the DB in comparison to the AS remains somewhat constant over a wide range of parameters, the relative performance of a BB quite critically hinges on the concrete parameter constellation. It prevails, in particular, that for an increasing share of Non-Ricardian households, the BB regime does poorly and ultimately fails to generate a determinate equilibrium. With an increasing share of Non-Ricardian households monetary authorities loose their leverage on the intertemporal consumption decision of the average household, as documented by Gali et al. (2004). As a balanced budget regime generates larger amplitude in real wages this promotes a boom in consumption for rule-of-thumb consumers. If their share increases this will offset the drop in consumption of Ricardian households and ultimately destabilize the economy.

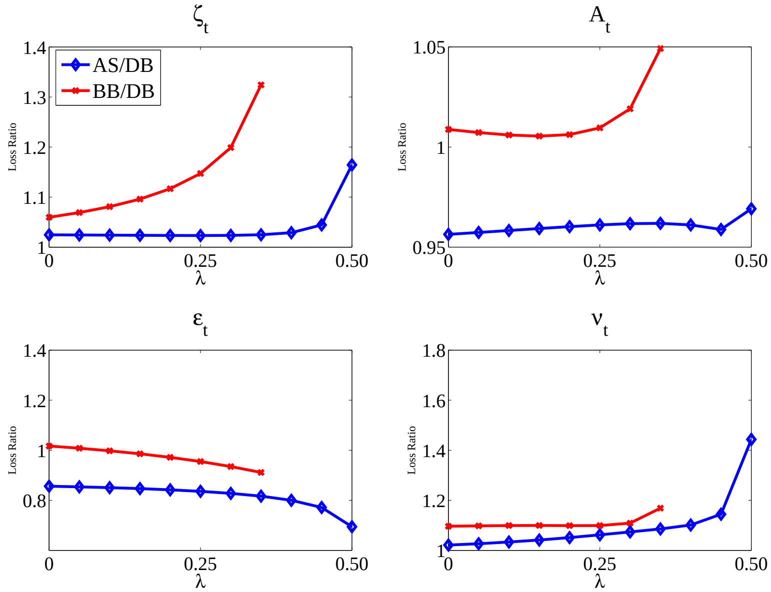


Figure 14: Robustness $\lambda$

# 5 Discussion and further Research Questions

This section is meant to address some relevant policy issues from the perspective of our model, caveats of the model and point out which are important further research questions regarding fiscal policy rules in vein of a DB. The arguments made here verbally can, on a more analytical basis, be retraced in Appendix F.

The first question coming to mind is how strongly the balance of the adjustment account should feedback to government spending. In order to analyze this question within our model, it seems natural to minimize the welfare metric presented in equation (37) with respect to the feedback parameter $\rho$ dependent on each shock. We find that the feedback should be rather small, around $\rho \approx 0.05$ as in our baseline-calibration, in order for fiscal policy not to create much fluctuation within the economy. Only for discretionary fiscal policy shocks, the feedback should be high and, thus, there should be a sharp correction of the earlier lapses because a positive government spending shocks and a negative correction through the adjustment account cancel out relatively easily. Similar evidence is reported by Kremer and Stegarescu (2008), who report the optimal speed of adaption for German data.

As a device to compare the proposed debt brake regime to the Swiss debt brake, we simulate the model over 500.000 quarters, where we draw the shocks from a multivariate normal distribution with standard deviations as reported in Table 2. As in Switzerland, we introduced a critical threshold of $-6\%$ of the adjustment account normalized by steady state fiscal expenditures and compute relevant statistics.

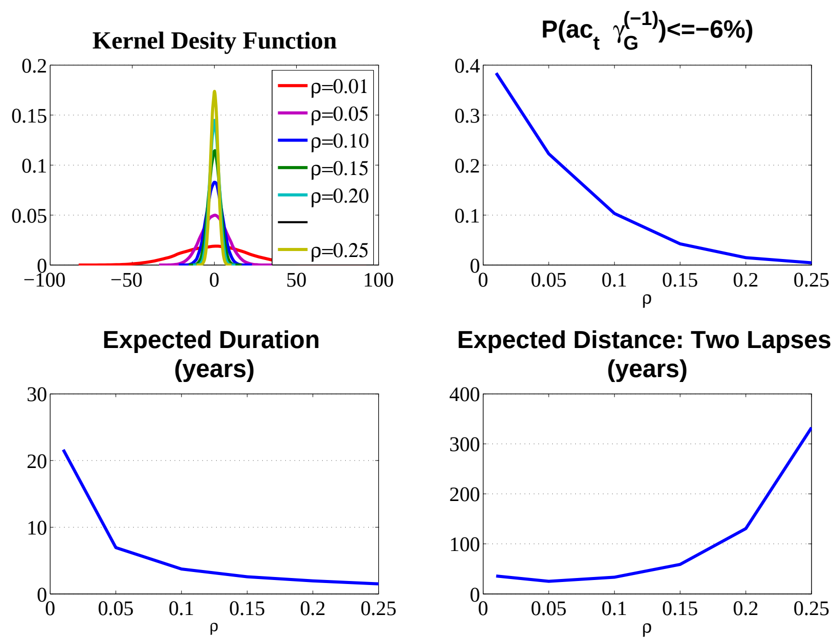


Figure 15: Adjustment account dynamics and feedback parameter

In the upper panel the figure illustrates that the shape of the kernel density function of the adjustment account is driven by the choice of the adjustment parameter. Given Proposition 1, this does not come as a surprise as the distribution flattens with decreasing values of $\rho$ and exhibits a near random walk behavior for $\rho = 0.01$.

The analysis of the simulation leads to the following findings. First, the unconditional probability that the adjustment account is below $-6\%$ decreases along a convex line with an increasing feedback parameter $\rho$ and drops below $1\%$ for $\rho = 0.25$. Second, if the adjustment account passes the threshold values of $-6\%$, the unconditionally expected duration of consecutive violations of the threshold value is decreasing along a convex line with increasing values of $\rho$. For the baseline, the expected duration is well above six years. Third, violations of the threshold value are highly persistent if they occur but are rare events. The expected duration between two lapses is increasing along a convex path for increasing values of $\rho$. For the baseline calibration, the expected distance between two lapses is 25 years. We conclude that, by choosing $\rho$ appropriately, the unconditional probability, the expected duration, as well as the distance between two violations is endogenous to the government.

Another issue inflicting immediately is the fact that, in our model, trend output is known to all the agents within the model. This, of course, does not hold in reality and there is quite some evidence for estimation errors being an issue (see Brunez, 2003; Kremer and Stegarescu, 2008). Heinemann (2006) even suggests that politicians may have an incentive to mis-estimation. As a first and highly stylized approach to tackle this issue, we ran the following experiment in our model. Assume that the government falls prey to estimation errors for 16 quarters in a row and that trend output is estimated one percentage point higher than it actually is. It is then evident that government spending tends to be too high, which cannot be neutralized by the feedback from the adjustment account. Further assume that, from quarter 16 to 17, the government finally realizes that trend was wrongly estimated and adjusts its expenditures accordingly. We then find three important points. First, the higher the feedback to the adjustment account, the lower the increase in debt. Second, from quarter 16 to 17, the economy goes into a deeper recession if fiscal expenditures are corrected sharply as, in particular, non-Ricaridan households reduce consumption expenditures. Third, the inflation response for the optimal baseline feedback evolves smoother than the others. We conclude that the installation of an adjustment account is able to balance the desire to keep the debt bounded, while equally not irritating the economy at large, if fiscal authorities fall prey to measurement errors (see Appendix F.2). However, the simple example shows that this is certainly an issue of further research.

We already know that the aim of DBs currently in action or proposed (see Colombier, 2004, 2006; Danninger, 2002, German Council of Economic Experts, 2007) is to tie government spending to trend revenue. Due to estimation problems, however, they proceed as follows. They tie spending to estimated future revenue and correct this by a cyclical component. In terms of our model, they follow the AS approach except that they do not multiply the cyclical component $E_{t-1}\left\{(\bar{Y}/Y_t)^{\alpha}\right\}$ with trend revenue but with expected revenue and, thus, additionally book estimation errors regarding revenue mis-estimations on the adjustment account as well. This implies, however, that government spending reacts pro-cyclical to exogenous shocks. The reason for this is that the elasticity of real government revenues to any shock is larger than the elasticity of output to the same shock. This implies that, given any positive shock, government real revenues increase by more than the counter-cyclical component to dampen spending. In total, spending rises with any positive shock. Girouard and André (2005) have shown empirically that the elasticity relation in our model appears to hold. To solve this problem in such a setting, it seems natural in our model to set $\alpha > 1$ according to the relevant elasticity such that government spending remains to be tied to trend revenues. However, this may be quite a challenging task as it can be shown that the optimal $\alpha$ differs according to the shock.

# 6 Conclusion

In this paper, we analyze the effects of simple government spending rules which aim at stabilizing the economy in a sustainable way. We use a conventional New Keynesian DSGE model to implement the idea of a BB, a DB and AS. The DB, which is currently in action in Switzerland and proposed to be implemented in Germany, is a rule tying government spending to real trend revenues. Cyclical surpluses and deficits and those resulting from discretionary fiscal actions are booked on an adjustment account. The (positive) balance of the account cuts future government spending in order to keep debt at a constant level in the long run. The AS implies active stabilization policy by making government spending react counter-cyclically with output deviations, while also implementing the adjustment account just described.

We find that, not surprisingly, the BB gives pro-cyclical impulses to the economy as it directly moves with (projected) government revenues. The DB and the AS have very similar business cycle effects. However, the debt brake still acts mildly pro-cyclical which can be attributed to the interest payments on outstanding debt and to the commitment to keep overall debt stable in the long run, while the AS indeed acts mildly counter-cyclical. In terms of welfare, calculated as an average consumer loss function, the DB and the AS are very similar. Nevertheless, on an aggregated level, the AS seems to generate slightly smaller a welfare loss of 4% for our baseline calibration. This can be explained by the anticipation effect of highly correlated government expenditures, which only materialize in later periods and drive the differences in welfare results for the DB and the AS regime.

In summary, we find that none of the rules can adequately be called the "New Taylor rule" for fiscal policy. Our general finding hence is that a rule which steers fiscal expenditures along the trend path and abstains from activism is preferable as it at least prevents to actively introduce fluctuations into the economy as does the BB, for example. Given political incentives, we think that a DB or AS as described here are indeed preferable to a theoretical "optimal" fiscal spending reaction as the latter is not implementable and the rules at least help to prevent disasters. Hence, the paper points out that the debt brake may receive only one cheer as there is still room for improvement. Nevertheless, with implementable rules at hand, it seems to be the most advantageous one.

Regarding the design of a simple fiscal rule, we can keep hold of the fact that, generally, attention should be devoted to the feedback of the adjustment account to real government spending, which shapes the distribution of the adjustment account. Only for discretionary spending shocks, this feedback should be relatively strong, while adjustment of debt due to other economic shocks should die out slowly. Additionally, it is important to take into account potential estimation errors, especially, regarding trend output. Overestimating trend generates too high government spending. We conclude that the installation of an adjustment account is able to balance the desire to keep debt bounded, while not irritation the economy at large, if fiscal authorities fall prey to measurement errors.

# Appendix

# A Optimal Firms' Price Setting and the Phillips Curve

Real marginal costs per firm can be represented by

$$mc_t(i) = \frac{W_t(1+\tau_t^w)(1-\tau_n^s)N_t(j)}{P_tQ_t(j)} = \underbrace{A_t^{-1}}_{=N_t/Q_t}[(1+\tau^w)(1-\tau_n^s)w_t]. \tag{42}$$

Using equation (3), we can state real profits to be

$$\frac{\Pi_t(j)}{P_t} = \left[\frac{P_t(j)}{P_t} - mc_t(j)\right]Y_t(j). \tag{43}$$

Hence, a firm resetting its price in period $t$ will seek to maximize

$$E_t\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}\left[\frac{P_t(j)}{P_{t+k}} - mc_{t+k}(j)\right]Q_{t+k}(j), \tag{44}$$

with respect to $P_t(j)$ and $Q_{t+k}(j)$, where $\theta_p$ is the exogenous Calvo probability that prices remain unchanged (see Calvo, 1983). The product demand constraint $Q_{t+k}(j)$ is given by equation (2), which is the isoelastic demand function. $\Lambda_{t,t+k}$ denotes the stochastic discount factor of shareholders, to whom profits are redeemed. It is defined as $\Lambda_{t,t+k} = (U_C(C_{t+k})/U_C(C_t))$. $\beta$ denotes a discount factor with $\beta \in (0,1)$. The corresponding Lagrangian is thus given by

$$E_t\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}\left\{\left[\frac{\tilde{P}_t(j)}{P_{t+k}} - mc_{t+k}(j)\right]Q_{t+k}(j) - \vartheta_{t+k}^j\left[Q_{t+k}(j) - \left(\frac{\tilde{P}_t(i)}{P_t}\right)^{-\epsilon}Y_{t+k}\right]\right\},$$

where $\tilde{P}_t(i)$ is the optimal reset price and $\vartheta_t^j$ denotes the Lagrangian multiplier. The relevant first-order conditions of the firm's maximization problem are given by

$$\frac{\partial(.)}{\partial Q_t(j)} = \theta_p\beta\Lambda_t\left[\frac{\tilde{P}_t(j)}{P_{t+k}} - mc_{t+k}(j) - \vartheta_t^j\right] \equiv 0 \tag{45}$$

and

$$\frac{\partial(.)}{\partial\tilde{P}_t(j)} = E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}\left[\frac{Q_{t+k}(j)}{P_{t+k}} - \vartheta_{t+k}\cdot\epsilon\left(\frac{\tilde{P}_t(i)}{P_{t+k}}\right)^{-\epsilon}\frac{P_{t+k}}{\tilde{P}_{t+k}(j)}\frac{1}{P_{t+k}}Y_{t+k}\right]\right\} \equiv 0. \tag{46}$$

Using equations (2) and (45) to substitute into equation (46), we get

$$E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}\left(\frac{\tilde{P}_t(i)}{P_{t+k}}\right)^{-\epsilon}Y_{t+k}\left[\frac{1}{P_{t+k}}-\epsilon\left(\frac{1}{P_{t+k}}-\frac{mc_{t+k}(j)}{\tilde{P}_{t+k}(j)}\right)\right]\right\}=0.$$

$$\Rightarrow\quad(\epsilon-1)E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}\left(\frac{\tilde{P}_t(i)}{P_{t+k}}\right)^{-\epsilon}\frac{Y_{t+k}}{P_{t+k}}\right\}$$

$$=\epsilon E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}\left(\frac{\tilde{P}_t(i)}{P_{t+k}}\right)^{-\epsilon}Y_{t+k}\frac{mc_{t+k}(j)}{\tilde{P}_{t+k}(j)}\right\}$$

$$\Rightarrow\quad\tilde{P}_t^{-\epsilon}(j)(\epsilon-1)E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}P_{t+k}^{\epsilon-1}Y_{t+k}\right\}$$

$$=\tilde{P}_t^{-\epsilon-1}(j)\epsilon E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}P_{t+k}^{\epsilon}Y_{t+k}mc_{t+k}(j)\right\}.$$

Solving for $\tilde{P}_t(j)$ yields

$$\tilde{P}_t(j)=\frac{\epsilon}{\epsilon-1}\cdot\frac{E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}P_{t+k}^{\epsilon}Y_{t+k}mc_{t+k}(j)\right\}}{E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}P_{t+k}^{\epsilon-1}Y_{t+k}\right\}}\tag{47}$$

as the optimal reset price for firm $j$ that is able to reset prices. Note that if all firms were allowed to reset prices (i.e. $\theta_p=0$), we would get

$$\tilde{P}_t(j)=\frac{\epsilon}{\epsilon-1}\cdot E_t\{mc_t^{flex}\cdot P_t^{flex}\}=P_t^{flex}.\tag{48}$$

Equation (48) implies that, in the flexible price equilibrium, in steady-state, $\bar{mc}=\Phi=\frac{\epsilon}{\epsilon-1}$ (see also section 2.1.1), which will become handy to remember for later use.

$\tilde{P}_t(j)E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}P_{t+k}^{\epsilon-1}Y_{t+k}\right\}=\frac{\epsilon}{\epsilon-1}E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\Lambda_{t,t+k}P_{t+k}^{\epsilon}Y_{t+k}mc_{t+k}(j)\right\}$ is the rearranged equation (47), which, log-linearized, gives

$$\bar{\Lambda}\bar{P}^{\epsilon-1}\bar{Y}\bar{\tilde{P}}(j)E_t\left\{\frac{1}{1-\beta\theta_p}\hat{\tilde{P}}_t(j)+\sum_{k=0}^{\infty}(\beta\theta_p)^k\left(\hat{\Lambda}_{t+k}+\hat{Y}_{t+k}+(\epsilon-1)\hat{P}_{t+k}\right)\right\}$$

$$=\frac{\epsilon}{\epsilon-1}\bar{\Lambda}\bar{P}^{\epsilon}\bar{Y}\bar{mc}E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\left(\hat{\Lambda}_{t+k}+\hat{Y}_{t+k}+\epsilon\hat{P}_{t+k}+\hat{mc}_{t+k}\right)\right\},$$

where we have used $\sum_{k=0}^{\infty}(\beta\theta_p)^k=\frac{1}{1-\beta\theta_p}$. Further, we know from equation (47) that $\bar{\tilde{P}}=\frac{\epsilon}{\epsilon-1}\bar{mc}\bar{P}$ which allows us to simplify the previous equations as

$$\hat{\tilde{P}}_t(j)=(1-\beta\theta_p)E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_p)^k\left(\hat{P}_{t+k}+\hat{mc}_{t+k}\right)\right\},$$

which can also be written as

$$\hat{\tilde{P}}_t(j) = (1-\beta\theta_p)\left\{\left(\hat{P}_t + \hat{mc}_t\right) + \beta\theta_p \hat{\tilde{P}}_{t+1}(j)\right\}. \tag{49}$$

The aggregated price index $P_t$ evolves as $P_t^{(1-\epsilon)} = (1-\theta_p)(P_t^*)^{(1-\epsilon)} + \theta_p P_{t-1}^{(1-\epsilon)}$ (see Gali et al., 2001), which, in log-linearized form, yields $\hat{P}_t = (1-\theta_p)\hat{P}_t^* + \theta_p \hat{P}_{t-1}$. We further assume that the group of price setters is subdivided into optimizers, with share $(1-\omega_p)$, and those who index their prices, with share $\omega_p$. Hence, $\hat{P}_t^* = (1-\omega_p)\hat{\tilde{P}}_t(j) + \omega_p \hat{P}_t^b$, where the indexation rule is conducted according to $\hat{P}_t^b = \hat{P}_{t-1}^* + \hat{\pi}_{t-1}$. Making use of this set of equations, it holds that

$$\hat{\tilde{P}}_t(j) = \frac{1}{1-\omega_p}\hat{P}_t^* - \frac{\omega_p}{1-\omega_p}[\hat{P}_{t-1}^* + \hat{\pi}_{t-1}]$$

and we further know that

$$\hat{P}_t^* = \frac{1}{1-\theta_p}\hat{P}_t - \frac{\theta_p}{1-\theta_p}\hat{P}_{t-1},$$

which yields (combining these two equations and rearranging)

$$\hat{\tilde{P}}_t(j) = \frac{\hat{P}_t + [\theta_p\omega_p - 2\omega_p - \theta_p]\hat{P}_{t-1} + \omega_p\hat{P}_{t-2}}{(1-\omega_p)(1-\theta_p)}.$$

Substituting the previous expression into equation (49) yields

$$\begin{aligned}\frac{\hat{P}_t + [\theta_p\omega_p - 2\omega_p - \theta_p]\hat{P}_{t-1} + \omega_p\hat{P}_{t-2}}{(1-\omega_p)(1-\theta_p)} &= (1-\beta\theta_p)\left(\hat{P}_t + \hat{mc}_t\right) \\ &\quad + \beta\theta_p\frac{\hat{P}_{t+1} + [\theta_p\omega_p - 2\omega_p - \theta_p]\hat{P}_t + \omega_p\hat{P}_{t-1}}{(1-\omega_p)(1-\theta_p)},\end{aligned}$$

which we can rearrange to

$$\begin{aligned}&[1-(1-\omega_p)(1-\theta_p)(1-\beta\theta_p) - \beta\theta_p(\theta_p\omega_p - 2\omega_P - \theta_p)]\hat{P}_t \\ =\; &\beta\theta_p\hat{P}_{t+1} + [-(\theta_p\omega_p - 2\omega_P - \theta_p) + \beta\theta_p\omega_p]\hat{P}_{t-1} - \omega_p\hat{P}_{t-2} \\ &+(1-\omega_p)(1-\theta_p)(1-\beta\theta_p)\hat{mc}_t.\end{aligned}$$

Using that $\hat{\pi}_t = \hat{P}_t - \hat{P}_{t-1}$, this can be written as

$$[\theta_p + \omega_p(1-\theta_p(1-\beta))]\hat{\pi}_t = \beta\theta_p\hat{\pi}_{t+1} + \omega_p\hat{\pi}_{t-1} + (1-\omega_p)(1-\theta_p)(1-\beta\theta_p)\hat{mc}_t,$$

which yields

$$\begin{aligned}\hat{\pi}_t &= \frac{\beta\theta_p}{[\theta_p + \omega_p(1-\theta_p(1-\beta))]}\hat{\pi}_{t+1} + \frac{\omega_p}{[\theta_p + \omega_p(1-\theta_p(1-\beta))]}\hat{\pi}_{t-1} \\ &\quad + \frac{(1-\omega_p)(1-\theta_p)(1-\beta\theta_p)}{[\theta_p + \omega_p(1-\theta_p(1-\beta))]}\hat{mc}_t,\end{aligned}$$

which is equation (28). Note that in the main text, we will set $\omega_p = 0$.

# B Aggregation of Household Sector

**Households' FOCs:** The first-order conditions for optimizing households are

$$\frac{\partial(.)}{\partial C_t^o(j)} = \frac{(1-\chi)\zeta_t}{C_t^o(j)} - \lambda_t^o(1+\tau_t^C) = 0, \tag{50}$$

$$\frac{\partial(.)}{\partial L_t^o(j)} = \frac{\upsilon\zeta_t}{L_t^o(j)} - \lambda_t^o(1-\tau_t^d)w_t = 0, \tag{51}$$

and

$$\frac{\partial(.)}{\partial B_{t+1}^o(j)} = -\frac{1}{R_t P_t}\lambda_t^o + \beta E_t\left\{\lambda_{t+1}^o \frac{1}{P_{t+1}}\right\} = 0, \tag{52}$$

where $\lambda_t^o$ is the Lagrangian multiplier associated with the budget constraint, equation (7). From equation (52), we know that

$$R_t^{-1} = \beta E_t\left\{\frac{\lambda_{1,t+1}^o}{\lambda_{1,t}^o}\frac{P_t}{P_{t+1}}\right\}, \tag{53}$$

which is the stochastic discount factor. Using equation (50) yields equations (8) and (9).

The first-order conditions for rule-of-thumb consumers are given by

$$\frac{\partial(.)}{\partial C_t^r(j)} = \frac{(1-\chi)\zeta_t}{C_t^r(j)} - \lambda_t^r(1+\tau_t^C) = 0 \tag{54}$$

and

$$\frac{\partial(.)}{\partial L_t^r(j)} = \frac{\upsilon\zeta_t}{L_t^r(j)} - \lambda_t^r(1-\tau_t^d)w_t = 0, \tag{55}$$

where $\lambda_t^r$ is the Lagrangian multiplier associated with the corresponding budget constraint. From equations (54) and (55), we derive equation (11).

**Aggregated Consumption Euler equation:** The aim of the rest of this section is to derive an aggregated consumption Euler equation (in log-linearized terms) expressed only in aggregated variables and deep parameters. To achieve this, we revert to the households' consumption decisions derived in subsections 2.2.1 and 2.2.2. This means that we have to back-step every now and then to simplify the resulting equations. We know with the help of equation (12) that

$$N_t = \lambda N_t^r + (1-\lambda)N_t^o = \frac{\lambda\cdot(1-\chi)}{(1-\chi)+\upsilon_t} + (1-\lambda)N_t^o \tag{56}$$

and that

$$\begin{aligned} C_t &= \lambda C_t^r + (1-\lambda) C_t^o \\ &= \lambda \left[ \frac{(1-\chi)}{\upsilon} w_t \frac{(1-\tau_t^d)}{(1+\tau_t^C)} L_t^r \right] + (1-\lambda) \left[ \frac{(1-\chi)}{\upsilon} w_t \frac{(1-\tau_t^d)}{(1+\tau_t^C)} L_t^o \right] \\ &= \left[ \frac{(1-\chi)}{\upsilon} w_t \frac{(1-\tau_t^d)}{(1+\tau_t^C)} \right] \underbrace{[\lambda L_t^r + (1-\lambda) L_t^o]}_{\equiv L_t}, \end{aligned} \tag{57}$$

where the index $j$ has been dropped for notational convenience[7], while $C_t^r$ is given by equation (11) and $C_t^o$ by equation (9). Log-linearization of equation (57) yields

$$\hat{C}_t - \hat{L}_t = \hat{w}_t - \iota^d \hat{\tau}_t^d - \iota^C \hat{\tau}_t^C,$$

where $\iota^d \equiv \frac{\bar{\tau}^d}{(1-\bar{\tau}^d)}$ and $\iota^C \equiv \frac{\bar{\tau}^C}{(1+\bar{\tau}^C)}$. We know that $\hat{L}_t = -\frac{\bar{N}}{1-\bar{N}} \hat{N}_t = -\varphi \hat{N}_t$ from log-linearizing $L_t = 1 - N_t$, where $\varphi = \frac{\bar{N}}{1-\bar{N}}$ is the inverse of the Frisch labor supply elasticity. Substituting $\hat{L}_t$ and rearranging thus gives

$$\hat{w}_t = \hat{C}_t + \varphi \hat{N}_t + \iota^d \hat{\tau}_t^d + \iota^C \hat{\tau}_t^C, \tag{58}$$

which is equation (30) of the main text.

We now come to some side-steps to derive be able to derive the aggregated Consumption-Euler equation. From equation (13) we know that, in steady-state, $\bar{C}^r = \frac{(1-\bar{\tau}^d)(1-\chi)}{((1-\chi)+\upsilon)(1+\bar{\tau}^C)} \bar{w}$, while, from equation (57) and $\bar{L} = 1 - \bar{N}$, it is clear that $\bar{C} = (1-\bar{N}) \frac{(1-\bar{\tau}^d)(1-\chi)}{\upsilon(1+\bar{\tau}^C)} \bar{w}$, which yields

$$\frac{\bar{C}^r}{\bar{C}} = \frac{\upsilon}{1-\chi+\upsilon} \cdot \frac{1}{1-\bar{N}} \equiv \gamma_r, \tag{59}$$

where $\gamma_r$ is, thus, the per-head consumption share of rule-of-thumb households relative to total per-head consumption. As we further know from equation (57) that $\bar{C} = \lambda \bar{C}^r + (1 - \lambda) \bar{C}^o$, we find that $1 = \lambda \frac{\bar{C}^r}{\bar{C}} + (1-\lambda) \frac{\bar{C}^o}{\bar{C}}$, which, using equation (59) can be reformulated as

$$\frac{\bar{C}^o}{\bar{C}} = \frac{1}{1-\lambda} - \frac{\lambda}{1-\lambda} \underbrace{\frac{\upsilon}{1-\chi+\upsilon} \frac{1}{1-\bar{N}}}_{=\gamma_r} = \frac{1-\gamma_r \lambda}{1-\lambda} \equiv \gamma_o, \tag{60}$$

which, equivalently, gives the per-head consumption share of optimizing households relative to total per-head consumption. (Note that, whenever optimizing households consume more than rule-of-thumb households, $\gamma_o > 1$ may well be possible and vice versa). Using $\bar{L} =$

[7]Note that, due to state-contingent claims available for optimizing households, which is generally assumed in this type of model, and the fact that rule-of-thumb consumers consume all of their income, each individual household's consumption in $i = o, r$ is equal anyway (see Woodford, 2003, chapter 2).

$\lambda \bar{L}^r + (1-\lambda)\bar{L}^o = \lambda(1-\bar{N}^r) + (1-\lambda)\bar{L}^o$, where $\bar{N}^r$ is given by equation (12), we know that $\bar{L} = \lambda\left(1 - \frac{(1-\chi)}{1-\chi+\upsilon}\right) + (1-\lambda)\bar{L}^o$, which, dividing both sides by $\bar{L} = (1-\bar{N})$ yields $1 = \gamma_r\lambda + (1-\lambda)\frac{\bar{L}^o}{\bar{L}}$, where $\gamma_r$ is given by equation (59). Thus,

$$\frac{\bar{L}^o}{\bar{L}} = \frac{1-\gamma_r\lambda}{1-\lambda} = \gamma_o \tag{61}$$

is also the per-head leisure of optimizing households relative to total per-head leisure.

From equation (8), we know that, for the optimizing households, it holds that

$$\frac{\zeta_t}{C_t^o \cdot (1+\tau_t^C)} = \beta R_t E_t\left\{\frac{\zeta_{t+1}}{C_{t+1}^o \cdot (1+\tau_{t+1}^C)} \cdot \frac{P_t}{P_{t+1}}\right\}. \tag{62}$$

A Taylor expansion and use of $E_t r_t = E_t\left\{R_t \cdot \frac{P_t}{P_{t+1}}\right\}$ yields

$$\frac{\bar{\zeta}}{\bar{C}^o \cdot (1+\bar{\tau}^C)}\left[-\frac{(C_t^o - \bar{C}^o)}{\bar{C}}\frac{\bar{C}}{\bar{C}^o} + \frac{(\zeta_t - \bar{\zeta})}{\bar{\zeta}} - \frac{\bar{\tau}^C}{1+\bar{\tau}^C}\frac{(\tau_t^C - \bar{\tau}^C)}{\bar{\tau}^w}\right]$$
$$= \beta\bar{r}\frac{\bar{\zeta}}{\bar{C}^o \cdot (1+\bar{\tau}^C)}E_t\left[-\frac{(C_{t+1}^o - \bar{C}^o)}{\bar{C}}\frac{\bar{C}}{\bar{C}^o} + \frac{(\zeta_{t+1} - \bar{\zeta})}{\bar{\zeta}} - \frac{\bar{\tau}^C}{1+\bar{\tau}^C}\frac{(\tau_{t+1}^C - \bar{\tau}^C)}{\bar{\tau}^w} + \frac{1}{\bar{r}}(r_t - \bar{r})\right].$$

We now define $\hat{C}_t^o \equiv \frac{(C_t^o - \bar{C}^o)}{\bar{C}}$ and $\hat{L}_t^o \equiv \frac{(L_t^o - \bar{L}^o)}{\bar{L}}$ and note that $\frac{\bar{C}}{\bar{C}^o} = \frac{\bar{L}}{\bar{L}^o} = \frac{1}{\gamma_o}$ (see equations (60) and (61))[8] as well as $\bar{r} = \beta^{-1}$. Substitution and rearranging yields

$$\left[-\hat{C}_t^o\frac{1}{\gamma_o} + \hat{\zeta}_t - \iota^C\hat{\tau}_t^C\right] = E_t\left[-\hat{C}_{t+1}^o\frac{1}{\gamma_o} + \hat{\zeta}_{t+1} - \iota^C\hat{\tau}_{t+1}^C + \hat{r}_t\right],$$

where $\iota^C = \frac{\bar{\tau}^C}{1+\bar{\tau}^C}$. Rearranging gives

$$\hat{C}_t^o = E_t\hat{C}_{t+1}^o + \gamma_o\left\{\iota^C E_t[\hat{\tau}_{t+1}^C - \hat{\tau}_t^C] + E_t[\hat{\zeta}_t - \hat{\zeta}_{t+1}] - \hat{r}_t\right\}. \tag{63}$$

We define $\Delta\hat{L}_{t+1}^o = [\hat{L}_{t+1}^o - \hat{L}_t^o]$ and $\Delta\hat{\tau}_{t+1}^C = [\hat{\tau}_{t+1}^C - \hat{\tau}_t^C]$ for later use.

From equation (56), we know that $\frac{N_t}{\bar{N}} = \frac{\lambda\cdot(1-\chi)}{\bar{N}((1-\chi)+\upsilon)} + (1-\lambda)\frac{N_t^o}{\bar{N}}$. A first-order Taylor expansion implies that

$$\hat{N}_t^o = \frac{\hat{N}_t}{1-\lambda} \;\;\Rightarrow\;\; \hat{L}_t^o = -\frac{\varphi}{1-\lambda}\hat{N}_t \tag{64}$$

because $\hat{L}_t = -\frac{\bar{N}}{1-\bar{N}}\hat{N}_t = -\varphi\hat{N}_t$, where we have defined $\hat{N}_t^o = \frac{N_t^o - \bar{N}^o}{\bar{N}}$. From equation (13) and (57), it must hold that $\frac{C_t^r}{\bar{C}} = \frac{C_t}{\bar{C}}\frac{\upsilon}{(1-\chi)+\upsilon}\frac{1}{1-N_t}$, where a first-order Taylor expansion yields

$$\hat{C}_t^r = \gamma_r\hat{C}_t + \varphi\gamma_r\hat{N}_t, \tag{65}$$

[8]Note that this is, then, the deviation of $C_t^o$ or $L_t^o$ from its steady-state value evaluated at the steady-state value of total consumption/leisure. This is corrected for by dividing this term by $\gamma_o$ in the following equation. The slightly different definition from the standard definition will be useful for further calculations.

where we have used the definition for $\gamma_r$ (see equation (59)), $\varphi = \bar{N}/(1-\bar{N})$ and defined $\hat{C}_t^r = \frac{C_t^r - \bar{C}^r}{\bar{C}}$. Log-linearizing aggregated consumption $C_t = \lambda C_t^r + (1-\lambda)C_t^o$ yields $\hat{C}_t = \lambda\hat{C}_t^r + (1-\lambda)\hat{C}_t^o$. Solving this for $\hat{C}_t^o$ and using equation (65) yields

$$\hat{C}_t^o = \underbrace{\frac{1-\gamma_r\lambda}{1-\lambda}}_{=\gamma_o}\hat{C}_t - \frac{\lambda\gamma_r\varphi}{1-\lambda}\hat{N}_t. \tag{66}$$

From equation (64), we know that $\Delta\hat{L}_{t+1}^o = -\frac{\varphi}{(1-\lambda)}\Delta\hat{N}_{t+1}$ must hold. Substituting this and equation (66) into equation (63) we get

$$\begin{aligned}\gamma_o\hat{C}_t \quad - \quad & \frac{\lambda\gamma_r\varphi}{(1-\lambda)}\hat{N}_t - \gamma_o\hat{\zeta}_t = \gamma_o E_t\hat{C}_{t+1} - \frac{\lambda\gamma_r\varphi}{(1-\lambda)}E_t\hat{N}_{t+1} \\ & +\gamma_o\left\{\iota^C E_t\Delta\hat{\tau}_{t+1}^C - E_t[\hat{\zeta}_{t+1}] - E_t[\hat{R}_t - \hat{\pi}_{t+1}]\right\},\end{aligned}$$

where we have used that $\hat{r}_t = [\hat{R}_t - \hat{\pi}_{t+1}]$, with $\hat{\pi}_{t+1} \approx \hat{P}_{t+1} - \hat{P}_t$. Dividing by $\gamma_o$, i.e. multiplying by $\frac{(1-\lambda)}{1-\gamma_r\lambda}$, we get equation (29). Equation (29) is the standard aggregated consumption Euler equation expressed in aggregated variables and deep parameters only. Individual steady-state relations have been substituted out but, of course, still drive equation (29) through the "correct" substitution.

# C The Fiscal Spending Rule

Before deriving the spending rule in log-linearized terms, it seems appropriate to have some steady-state considerations regarding the spending rule, equations (19) and (21), and the adjustment account, equations (20) and (22). From these equations, we see that, in steady-state,

$$(\bar{R}-1)\bar{\bar{b}} + \frac{\bar{G}}{\bar{Y}} = \frac{\bar{\Psi}}{\bar{P}\bar{Y}} - \rho\cdot\bar{ac} \tag{67}$$

and

$$\bar{ac} = (1-\rho)\bar{ac} + \frac{\bar{\Psi}}{\bar{P}\bar{Y}} - \frac{\bar{\Psi}}{\bar{P}\bar{Y}} \;\Rightarrow\; \rho\cdot\bar{ac} = 0. \tag{68}$$

As we know that $\rho > 0$ if the adjustment account feeds back on government spending, $\bar{ac} = 0$ has to hold in steady-state. Then, from equation (67), we know that $\frac{\bar{\Psi}}{\bar{P}\bar{Y}} = \gamma_G - (1-\beta^{-1})\bar{\bar{b}}$, where we have used the definition $\gamma_G = \frac{\bar{G}}{\bar{Y}}$ and the fact that $\bar{R} = \beta^{-1}$ in steady-state. Note that these conditions correspond to the evolution of debt in steady-state, given by equation (17) in steady-state, which also gives $\frac{\bar{\Psi}}{\bar{P}\bar{Y}} = \gamma_G - (1-\beta^{-1})\bar{\bar{b}}$, but where the adjustment account has not yet been taken into account. Hence, the fact that $\bar{ac} = 0$ in steady-state is consistent with the model.

A first-order Taylor expansion of equation (17) yields

$$\underbrace{\left[\bar{\bar{b}} + \frac{\bar{\Psi}}{\bar{P}\bar{Y}}\right]}_{=\gamma_G+\beta^{-1}\bar{\bar{b}}} + \underbrace{\left(\tilde{b}_{t+1} - \bar{b}\right)}_{=b_{t+1}} + \frac{1}{\bar{P}\bar{Y}}\left(\Psi_t - \bar{\Psi}\right) - \frac{\bar{\Psi}}{\bar{P}^2\bar{Y}}\left(P_t - \bar{P}\right)$$

$$= \underbrace{\left[\bar{R}\bar{\bar{b}} + \frac{\bar{G}}{\bar{Y}}\right]}_{=\gamma_G+\beta^{-1}\bar{\bar{b}}} + \bar{\bar{b}}\left(R_{t-1} - \bar{R}\right) + \bar{R}\underbrace{\left(\tilde{b}_t - \bar{b}\right)}_{=b_t} + \frac{\bar{R}\bar{\bar{b}}}{\bar{P}}\left(P_{t-1} - \bar{P}\right)$$

$$-\frac{\bar{R}\bar{\bar{b}}\bar{P}}{\bar{P}^2}\left(P_t - \bar{P}\right) + \frac{1}{\bar{Y}}\left(G_t - \bar{G}\right),$$

where use has been made of equations (18) and (67) to derive the terms in the under-braces. Using the definition for any variable's deviation around its steady-state as well as equation (67) and $\bar{R} = \beta^{-1}$, we can rearrange the above equation to $b_{t+1} + \left[\gamma_G - \bar{\bar{b}}(1-\beta^{-1})\right]\left(\hat{\Psi}_t - \hat{P}_t\right) = \beta^{-1}b_t + \beta^{-1}\bar{\bar{b}}\left(\hat{R}_{t-1} + \hat{P}_{t-1} - \hat{P}_t\right) + \gamma_G\hat{G}_t$.[9] Using the definition $\hat{\pi}_t \approx \hat{P}_t - \hat{P}_{t-1}$, rearranging yields equation (31).

A first-order Taylor expansion of the spending rule, equation (21), yields

$$\underbrace{\left[(\bar{R}-1)\bar{b} + \frac{\bar{G}}{\bar{Y}}\right]}_{=\gamma_G-(1-\beta^{-1})\bar{\bar{b}}} + (\bar{R}-1)\underbrace{\left(\tilde{b}_t - \bar{b}\right)}_{=b_t} + \bar{\bar{b}}\left(R_{t-1} - \bar{R}\right) + \frac{(\bar{R}-1)\bar{\bar{b}}}{\bar{P}}\left(P_{t-1} - \bar{P}\right)$$

$$-\frac{(\bar{R}-1)\bar{\bar{b}}\bar{P}}{\bar{P}^2}\left(P_t - \bar{P}\right) + \frac{1}{\bar{Y}}\left(G_t - \bar{G}\right)$$

$$= \underbrace{\left[\frac{\bar{\Psi}}{\bar{P}\bar{Y}}\right]}_{=\gamma_G-(1-\beta^{-1})\bar{\bar{b}}} - \underbrace{\left[\frac{\bar{\Psi}}{\bar{P}\bar{Y}}\right]}_{=\gamma_G-(1-\beta^{-1})\bar{\bar{b}}} \cdot\alpha \cdot E_{t-1}\left\{\hat{Y}_t\right\} + \frac{\nu_t}{\bar{P}\bar{Y}} - \rho \cdot ac_{t-1},$$

whereas a first-order Taylor expansion of equation (19) yields

$$\underbrace{\left[(\bar{R}-1)\bar{b} + \frac{\bar{G}}{\bar{Y}}\right]}_{=\gamma_G-(1-\beta^{-1})\bar{\bar{b}}} + (\bar{R}-1)\underbrace{\left(\tilde{b}_t - \bar{b}\right)}_{=b_t} + \bar{\bar{b}}\left(R_{t-1} - \bar{R}\right) + \frac{(\bar{R}-1)\bar{\bar{b}}}{\bar{P}}\left(P_{t-1} - \bar{P}\right)$$

$$-\frac{(\bar{R}-1)\bar{\bar{b}}\bar{P}}{\bar{P}^2}\left(P_t - \bar{P}\right) + \frac{1}{\bar{Y}}\left(G_t - \bar{G}\right)$$

$$= \underbrace{\left[\frac{\bar{\Psi}}{\bar{P}\bar{Y}}\right]}_{=\gamma_G-(1-\beta^{-1})\bar{\bar{b}}} + \underbrace{\left[\frac{\bar{\Psi}}{\bar{P}\bar{Y}}\right]}_{=\gamma_G-(1-\beta^{-1})\bar{\bar{b}}} \cdot E_{t-1}\left\{\hat{\Psi}_t - \hat{P}_t\right\} + \frac{\nu_t}{\bar{P}\bar{Y}} - \rho \cdot ac_{t-1}.$$

[9] Remember that $\bar{\Psi}/(\bar{P}\bar{Y}) = \gamma_G - \bar{\bar{b}}(1-\beta^{-1})$.

where we have already used the fact that $\bar{ac} = \bar{\nu} = 0$ and we used the definition of equation (18) and and the steady-state condition (67). Solving for $\hat{G}_t$, and combining the two previous equations yields equation (33).

A first-order Taylor expansion of equation (22) yields

$$\begin{aligned}(ac_t - \bar{ac}) &= (1-\rho)(ac_{t-1} - \bar{ac}) + \underbrace{\frac{\bar{ac}}{\bar{P}}(P_{t-1} - \bar{P}) - \frac{\bar{ac}}{\bar{P}^2}(P_t - \bar{P})}_{=0} + \frac{\nu_t}{\bar{P}\bar{Y}} \\ &- \underbrace{\frac{\bar{\Psi}}{\bar{P}\bar{Y}}}_{=\gamma_G - (1-\beta^{-1})\bar{\bar{b}}} \cdot \left[\alpha\left(E_{t-1}\left\{\hat{Y}_t\right\} - \hat{Y}_t\right) + \varrho\left(\hat{\Psi}_t - \hat{P}_t\right)\right],\end{aligned}$$

while a fist-order Taylor expansion of equation (20) is given by

$$\begin{aligned}(ac_t - \bar{ac}) &= (1-\rho)(ac_{t-1} - \bar{ac}) + \underbrace{\frac{\bar{ac}}{\bar{P}}(P_{t-1} - \bar{P}) - \frac{\bar{ac}}{\bar{P}^2}(P_t - \bar{P})}_{=0} + \frac{\nu_t}{\bar{P}\bar{Y}} \\ &+ \underbrace{\frac{\bar{\Psi}}{\bar{P}\bar{Y}}}_{=\gamma_G - (1-\beta^{-1})\bar{\bar{b}}} \cdot \left[\left(E_{t-1}\left\{\hat{\Psi}_t\right\} - \hat{\Psi}_t\right) - \left(E_{t-1}\left\{\hat{P}_t\right\} - \hat{P}_t\right)\right],\end{aligned}$$

which can be combined to equation (34).

# D Steady-state considerations and social planner's solution

We know that, in the long-run, equilibrium prices will be equal to the flex-price equilibrium. Then, we know that it holds that (see also equation (48))

$$\bar{mc} = \frac{\epsilon - 1}{\epsilon}, \tag{69}$$

where we have used that $\tilde{P}_t(i) = P_t^{flex}$ holds in the long-run steady-state. Additionally, we know from the cost minimization problem of a representative firm that (see equation (42))

$$\bar{w} = \cdot \bar{mc}\frac{\bar{Y}}{\bar{N}}\frac{1}{(1+\bar{\tau}^w)(1-\tau_n^s)}. \tag{70}$$

From equation (57), we know that $\bar{w} = \frac{\upsilon}{(1-\chi)}\frac{\bar{C}}{1-\bar{N}}\frac{(1+\bar{\tau}^C)}{(1-\bar{\tau}^d)}$, which, in combination with equation (70) yields

$$\frac{(\epsilon-1)}{\epsilon}\frac{(1-\bar{\tau}^d)}{(1+\bar{\tau}^C)(1+\bar{\tau}^w)} = (1-\tau_n^s)\frac{\upsilon}{(1-\chi)}\frac{\bar{C}}{(1-\bar{N})}\frac{\bar{N}}{\bar{Y}}.$$

As we know that, in an undistorted steady-state without price mark-up, it must hold that $1 = \frac{\upsilon}{(1-\chi)} \frac{\bar{C}}{(1-\bar{N})} \frac{\bar{N}}{\bar{Y}}$, the following condition for the subsidy $\tau_n^s$ needs to hold in order to reach the undistorted steady-state in our model setup

$$\tau_n^s = 1 - \frac{(\epsilon - 1)}{\epsilon} \frac{(1 - \bar{\tau}^d)}{(1 + \bar{\tau}^C)(1 + \bar{\tau}^w)}. \tag{71}$$

With this subsidy at hand, it holds that

$$\frac{\bar{N}}{1 - \bar{N}} = \frac{1}{\gamma_C} \frac{(1 - \chi)}{\upsilon}, \tag{72}$$

where we have defined $\gamma_C = \frac{\bar{C}}{\bar{Y}}$. The solution for the steady-state labor supply is thus given by $\bar{N} = \frac{(1-\chi)}{\chi\gamma_C + (1-\chi)}$. This implies that $\bar{N}$ can be expressed in exogenous parameters if we are able to find a solution for $\gamma_C$ which we will derive now.

Note that, from steady-state condition resulting from equation (67), we know that $\frac{\bar{\Psi}}{\bar{P}\bar{Y}} = \gamma_G - (1 - \beta^{-1})\bar{\bar{b}}$ holds, where $\bar{\bar{b}} = 0$ in the zero steady-state debt case. Further, it holds that (see equation (16))

$$\frac{\bar{\Psi}}{\bar{P}\bar{Y}} = \bar{\tau}^L \bar{w} \frac{\bar{N}}{\bar{Y}} + \bar{\tau}^C \frac{\bar{C}}{\bar{Y}},$$

where $\bar{\tau}^L = \bar{\tau}^w + \bar{\tau}^d$. Using equations (69) and (70), the definition $\gamma_C = \frac{\bar{C}}{\bar{Y}}$ and combining the last two equations yields

$$\gamma_G - (1 - \beta^{-1})\bar{\bar{b}} = \bar{\tau}^L \frac{\epsilon - 1}{\epsilon} \frac{1}{(1 + \bar{\tau}^w)(1 - \tau_n^s)} + \bar{\tau}^C \gamma_C. \tag{73}$$

From the resource constraint, $\bar{Y} = \bar{C} + \bar{G}$, we know that $1 = \frac{\bar{C}}{\bar{Y}} + \frac{\bar{G}}{\bar{Y}} = \gamma_C + \gamma_G$. Using this and equation (73), we then find that

$$\frac{\bar{G}}{\bar{Y}} = \gamma_G = \frac{1}{(1 + \bar{\tau}^C)} \left\{ (1 - \beta^{-1})\bar{\bar{b}} + \frac{\epsilon - 1}{\epsilon} \bar{\tau}^L \frac{1}{(1 + \bar{\tau}^w)(1 - \tau_n^s)} + \bar{\tau}^C \right\} \tag{74}$$

is determined by exogenous parameters. Hence, from the resource constraint, we know that, then

$$\frac{\bar{C}}{\bar{Y}} \equiv \gamma_C = 1 - \gamma_G. \tag{75}$$

From the first-order condition of the cost minimizing problem of the firm, we know that $\bar{mc} = \frac{\bar{N}}{\bar{Y}} \left[ (1 + \bar{\tau}^w)(1 - \tau_n^s)\bar{w} \right]$ (see equation (42)), where $\frac{\bar{N}}{\bar{Y}} = \frac{1}{\bar{A}} = 1$ as $\bar{A} = 1$ (see equation (4)), which, using equation (69) and rearranging yields

$$\bar{w} = \frac{1}{(1 + \bar{\tau}^w)(1 - \tau_n^s)} \frac{\epsilon - 1}{\epsilon} = \frac{(1 + \bar{\tau}^C)}{(1 - \bar{\tau}^d)}, \tag{76}$$

where use has been made of equation (71). From equation (57) we can then calculate

$$\bar{C} = \frac{(1-\chi)}{\upsilon} \cdot \frac{1-\bar{\tau}^d}{1+\bar{\tau}^C}(1-\bar{N})\bar{w} = \frac{(1-\chi)}{\upsilon} \cdot (1-\bar{N}), \tag{77}$$

where $\bar{w}$ is given by equation (76) and $\bar{N}$ by equation (72). Using equation (77) and $\gamma_C = \frac{\bar{C}}{\bar{Y}}$, where $\gamma_C$ is given by equation (75), we can calculate

$$\bar{Y} = \frac{\bar{C}}{\gamma_C}. \tag{78}$$

An analogous proceeding allows us – using equations (74) and (78) – to derive

$$\bar{G} = \gamma_G \bar{Y} = \bar{C}\frac{\gamma_G}{\gamma_C}. \tag{79}$$

Further, we know, using equation (73), that

$$1 = \underbrace{\frac{\bar{\tau}^L(\epsilon-1)}{\epsilon(1+\bar{\tau}^w)(1-\tau_n^s)[\gamma_G - (1-\beta^{-1})\bar{\tilde{b}}]}}_{=Rev^L} + \underbrace{\frac{\bar{\tau}^C}{\gamma_C[\gamma_G - (1-\beta^{-1})\bar{\tilde{b}}]}}_{=Rev^{Vat}}, \tag{80}$$

where all parameters are know following the calculation above. This implies that we are able to express all aggregated variables in terms of exogenous parameters. Note that these aggregated variables in steady-state are independent of the implemented government spending policy regime, i.e. they are independent of whether automatic stabilizers, the debt brake or no restriction on government spending apply. Note further that $\chi = \gamma_G$ following from an "optimal social planner's solution" (see also Gali and Monacelli, 2008; who apply exactly the same calculation procedure that is necessary here).

**Social planner's solution:** In the following, we will show that the competitive steady-state we equilibrium we just derived is identical to the solution of the social planner, if $\gamma_G = \chi$ (which we assume the social planner can choose). Therefore, we can, in the following, claim to approximate around an efficient steady-state. The optimal allocation of the model can be described by a social planner maximizing

$$\begin{aligned} SP_{Problem} &= \max\{\zeta_t\{\lambda[(1-\chi)log(C_t^r) + \chi log(G_t) + \upsilon log(L_t^r)]\} \\ &\quad +(1-\lambda)[(1-\chi)log(C_t^o) + \chi log(G_t) + \upsilon log(L_t^o)]\}\} \end{aligned} \tag{81}$$

with respect to $C_t^r$, $C_t^o$, $L_t^r$, $L_t^o$ and $G_t$ subject to the constraints $Y_t = C_t + G_t$ (market clearing), $Y_t = A_t N_t$ (technology constraint), $1 = N_t + L_t$ (labor constraint), where $L_t = \lambda L_t^r + (1-\lambda)L_t^o$ and $C_t = \lambda C_t^r + (1-\lambda)C_t^o$, which can be summarized in

$$A_t[1-(\lambda L_t^r + (1-\lambda)L_t^o)] = \lambda C_t^r + (1-\lambda)C_t^o + G_t. \tag{82}$$

The corresponding first-order conditions are given by

$$\frac{\partial(.)}{\partial C_t^r} = \zeta_t \lambda (1-\chi)\frac{1}{C_t^r} - \lambda \cdot o = 0,$$

$$\frac{\partial(.)}{\partial C_t^o} = \zeta_t (1-\lambda)(1-\chi)\frac{1}{C_t^o} - (1-\lambda) \cdot o = 0,$$

$$\frac{\partial(.)}{\partial L_t^r} = \zeta_t \lambda (1-\chi)\frac{1}{L_t^r} - \lambda \cdot o = 0,$$

$$\frac{\partial(.)}{\partial L_t^o} = \zeta_t (1-\lambda)(1-\chi)\frac{1}{L_t^o} - (1-\lambda) \cdot o = 0$$

and

$$\frac{\partial(.)}{\partial G_t} = \zeta_t \frac{\chi}{C_t^r} - \cdot o = 0,$$

where $o$ is the corresponding Lagrangian parameter. Substituting it out, we find that

$$\frac{(1-\chi)}{C_t^r} = \frac{(1-\chi)}{C_t^o} = \frac{\upsilon}{A_t L_t^r} = \frac{\upsilon}{A_t L_t^o} = \frac{\chi}{G_t}, \tag{83}$$

which states that an efficient steady-state allocation implies that marginal utility of consumption across types of households and across alternative uses (public versus private good) needs to be equal to the marginal utility of an additional unit of leisure across types. Using $L_t = (1 - N_t)$, we thus find that, for optimal the steady-state level of employment from a social planner's perspective it holds that

$$\frac{\bar{Y}}{\bar{N}}\frac{(1-\chi)}{\bar{C}} = \frac{\upsilon}{(1-\bar{N})} \Rightarrow \frac{\bar{N}}{(1-\bar{N})} = \frac{1}{\gamma_C}\frac{(1-\chi)}{\upsilon},$$

which corresponds to equation (72) and, hence, is exactly identical to the steady-state outcome in the competitive equilibrium with the labor subsidy at hand.

For the optimal distribution between public and private consumption goods, we make use of the fact that $\gamma_G = 1 - \gamma_C$ resulting from $\bar{Y} = \bar{C} + \bar{G}$, the market clearing condition. Using equation (83), this can be transformed to $\gamma_G = 1 - \frac{1}{\bar{Y}}\left[\lambda \bar{C}^r + (1-\lambda)\bar{C}^o\right]$, while we know from the first-order conditions of the social planner's problem that it must hold that $\bar{C}^r = \bar{C}^o = \frac{(1-\chi)}{\chi}\bar{G}$. Substituting in the previous equation, this implies $\gamma_G = 1 - \frac{\bar{G}}{\bar{Y}}\frac{(1-\chi)}{\chi} = 1 - \gamma_G\frac{(1-\chi)}{\chi}$, which yields $\chi = \gamma_G$. Using this, the optimal labor supply just calculated and the optimal consumption level from the first-order conditions, we find that

$$\bar{N} = \frac{1}{1+\upsilon}$$

and

$$\bar{C} = \frac{(1+\upsilon)}{(1-\gamma_G)}.$$

As shown above, this is equal to the solution obtained under the competitive equilibrium for $\chi = \gamma_G$ (see equations (72) and (77)), which implies that the competitive equilibrium is thus an efficient steady-state.

# E Welfare Approximation

We know that per-period utility of household $j$ of type $i$ is given by

$$\left\{ \underbrace{\zeta_t \left[(1-\chi)log\left(C_t^i(j)\right) + \chi log(G_t)\right]}_{=u^i} + \underbrace{\zeta_t \upsilon_t log\left(L_t^i(j)\right)}_{=V^i} \right\}, \tag{84}$$

where $i = o, r$ (see also equation (6)). In what follows, we will derive the second-order Taylor approximation of the consumption part of this equation (indicated by $u^i$) and the leisure part (indicated by $V^i$) separately for convenience. For consumption, we then get

$$\begin{aligned} u_t^i &\approx \bar{u}^i + \bar{u}_{C^i}^i\left(C_t^i - \bar{C}^i\right) + \frac{1}{2}\bar{u}_{C^iC^i}^i\left(C_t^i - \bar{C}^i\right)^2 + \bar{u}_G^i\left(G_t - \bar{G}\right) + \frac{1}{2}\bar{u}_{GG}^i\left(G_t - \bar{G}\right)^2 \\ &\quad + \bar{u}_{C^i\zeta}^i\left(C_t^i - \bar{C}^i\right)\left(\zeta_t - \bar{\zeta}\right) + \bar{u}_{G\zeta}^i\left(G_t - \bar{G}\right)\left(\zeta_t - \bar{\zeta}\right) \\ &= \bar{u}^i + (1-\chi)\frac{\left(C_t^i - \bar{C}^i\right)}{\bar{C}^i} - (1-\chi)\frac{1}{2}\frac{\left(C_t^i - \bar{C}^i\right)^2}{(\bar{C}^i)^2} + \chi\frac{\left(G_t - \bar{G}\right)}{\bar{G}} - \chi\frac{1}{2}\frac{\left(G_t - \bar{G}\right)^2}{\bar{G}^2} \\ &\quad + \frac{\left(\zeta_t - \bar{\zeta}\right)}{\bar{\zeta}}\left[(1+\chi)\frac{\left(C_t^i - \bar{C}^i\right)}{\bar{C}^i} + \chi\frac{\left(G_t - \bar{G}\right)}{\bar{G}}\right] \\ &= \bar{u}^i + (1+\hat{\zeta}_t)\left\{(1-\chi)\left[\frac{\hat{C}_t^i}{\gamma_i} - \frac{1}{2}\frac{(\hat{C}_t^i)^2}{\gamma_i^2} + \frac{1}{2}\frac{(\hat{C}_t^i)^2}{\gamma_i^2}\right] + \chi\left[\hat{G}_t - \frac{1}{2}(\hat{G}_t)^2 + \frac{1}{2}(\hat{G}_t)^2\right]\right\} \\ &= \bar{u}^i + (1+\hat{\zeta}_t)\left\{(1-\chi)\frac{\hat{C}_t^i}{\gamma_i} + \chi\hat{G}_t\right\}, \end{aligned} \tag{85}$$

where we have used the fact that we defined $\hat{C}_t^i = \frac{(C_t^i - \bar{C}^i)}{\bar{C}}$ earlier, used the definitions for $\gamma_r$ and $\gamma_o$ (see equations (59) and (60), respectively) and made use of the commonly known fact that, for any variable $X$, it holds that $(X_t - \bar{X}) \approx \bar{X}[\hat{X}_t + \frac{1}{2}\hat{X}_t^2]$ and $(X_t - \bar{X})^2 \approx \frac{1}{2}\hat{X}_t^2$ when approximating second order. Further, we have neglected the individual household parameter $j$ for notational convenience and remembered that $\bar{\zeta} = 1$. In an analogous proceeding as before, we get for the disutility of labor (utility of leisure, respectively)

$$\begin{aligned} V_t^i &\approx \bar{V}^i + \bar{V}_{L^i}^i \left(L_t^i - \bar{L}^i\right) + \frac{1}{2}\bar{V}_{L^iL^i}^i \left(L_t^i - \bar{L}^i\right)^2 + \bar{V}_{L^i\zeta}^i \left(L_t^i - \bar{L}^i\right)\left(\zeta_t - \bar{\zeta}\right) \\ &= \bar{V}^i + \upsilon \frac{\left(L_t^i - \bar{L}^i\right)}{\bar{L}^i} - \upsilon \frac{1}{2}\frac{\left(L_t^i - \bar{L}^i\right)^2}{(\bar{L}^i)^2} + \upsilon \frac{\left(L_t^i - \bar{L}^i\right)(\zeta_t - 1)}{\bar{L}^i} \\ &= \bar{V}^i + \upsilon \left\{ \left[ \frac{\hat{L}_t^i}{\gamma_i} - \frac{1}{2}\frac{(\hat{L}_t^i)^2}{\gamma_i^2} + \frac{1}{2}\frac{(\hat{L}_t^i)^2}{\gamma_i} \right] \right\} + \frac{\hat{L}_t^i}{\gamma_i}\left(\upsilon \hat{\zeta}_t\right) \\ &= \bar{V}^i + (1+\hat{\zeta}_t)\upsilon \frac{\hat{L}_t^i}{\gamma_i} = \bar{V}^i + (1+\hat{\zeta}_t)\upsilon \frac{\hat{L}_t^i}{\gamma_i}. \end{aligned} \tag{86}$$

Combining the utility of consumption and disutility of labor, we get for household $j$ of type $i = o, r$ that

$$U_t^i(j) = \underbrace{\bar{u}^i(j) + \bar{V}^i(j)}_{\bar{U}^i} + (1+\hat{\zeta}_t)\left\{ (1-\chi)\frac{\hat{C}_t^i(j)}{\gamma_i} + \chi \hat{G}_t \right\} + (1+\hat{\zeta}_t)\upsilon \frac{\hat{L}_t^i(j)}{\gamma_i}. \tag{87}$$

Noting that individuals of type $r$ have a constant consumption pattern due to constant labor supply (see equations (12) and (13)), we know that $\hat{C}_t^r(j) = \hat{C}_t^r$, where the latter is given by equation (65). Due to the assumption of complete markets and state-contingent claims that can be purchased by households of type $o$, we know that $\hat{C}_t^o(j) = \hat{C}_t^o$ (see Woodford, 2003, chapter 2 for more details), where the latter is given by equation (66). Unfortunately, this does not hold for the labor supply (i.e. leisure) except for households of type $r$. We will come back to this in a second. As we further know that a share $\lambda$ of households is of type $r$, while the remaining ones, i.e. $(1-\lambda)$, are of type $o$, aggregated per-period utility can be expressed through the second-order Taylor approximation

$$\begin{aligned} U_t &= \underbrace{\lambda \bar{U}^r + (1-\lambda)\bar{U}^o}_{=\bar{U}} + (1+\hat{\zeta}_t)\left\{ (1-\chi)\left[ \lambda \frac{\hat{C}_t^r}{\gamma_r} + (1-\lambda)\frac{\hat{C}_t^o}{\gamma_o} \right] + \chi \hat{G}_t \right\} \\ &\quad + (1+\hat{\zeta}_t)\upsilon \left[ \lambda \frac{\frac{1}{\lambda}\int_0^\lambda \hat{L}_t^r(j)dj}{\gamma_r} + (1-\lambda)\frac{\frac{1}{(1-\lambda)}\int_\lambda^1 \hat{L}_t^o(j)dj}{\gamma_o} \right] \end{aligned} \tag{88}$$

We can use the definition of the consumption aggregate and the labor aggregate, where it holds that

$$\hat{L}_t = \lambda \frac{1}{\gamma_r}\hat{L}_t^r + (1-\lambda)\frac{1}{\gamma_o}\hat{L}_t^o \;\; and \;\; \hat{C}_t = \lambda \frac{1}{\gamma_r}\hat{C}_t^r + (1-\lambda)\frac{1}{\gamma_o}\hat{C}_t^o,$$

where $\hat{L}_t^i$ and $\hat{C}_t^i$ denote the per capita log-deviations in the respective household segment. By definition, we know that $C_t^r = \frac{1}{\lambda}\int_0^\lambda C_t^r(j)dj$ and, henceforth, $\frac{1}{\gamma_r}\hat{C}_t^r = \frac{1}{\gamma_r}\frac{1}{\lambda}\int_0^\lambda \hat{C}_t^r(j)dj$.

In complete analogy, we get $\frac{1}{\gamma_r}\hat{L}_t^r = \frac{1}{\gamma_r}\frac{1}{\lambda}\int_0^\lambda \hat{L}_t^r(j)dj$, $\frac{1}{\gamma_o}\hat{C}_t^o = \frac{1}{\gamma_o}\frac{1}{(1-\lambda)}\int_\lambda^1 \hat{C}_t^o(j)dj$ and $\frac{1}{\gamma_o}\hat{L}_t^o = \frac{1}{\gamma_o}\frac{1}{(1-\lambda)}\int_\lambda^1 \hat{L}_t^o(j)dj$. Substitution into equation (88) and rearranging gives

$$U_t = \bar{U} + (1+\hat{\zeta}_t)\left[(1-\chi)\hat{C}_t + \chi\hat{G}_t\right] - (1+\hat{\zeta}_t)\upsilon\varphi\hat{N}_t,$$

where we have substituted leisure for labor through $\hat{L}_t = -\frac{\bar{N}}{\bar{L}}\hat{N}_t = -\frac{\bar{N}}{1-\bar{N}}\hat{N}_t = -\varphi\hat{N}_t$. Further, we can use

$$N_t = \int_0^1 N_t(j)dj = \int_o^1 \frac{Y_t(j)}{A_t}dj = \frac{Y_t}{A_t}\int_0^1 \frac{Y_t(j)}{Y_t}dj = \frac{Y_t}{A_t}\int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} dj$$

and log-linearize, which yields $\hat{N}_t = \hat{Y}_t - \hat{A}_t + \hat{q}_t$, where $\hat{q}_t = log\left(\int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} dj\right)$. Using standard results as in Woodford (2003), we know that $q_t = (\epsilon/2)\,\sigma_t^2$, where $\sigma_t^2 = \int_0^1 \left[p_t(j) - p_t\right]^2 dj$, in which the lower case letters $p$ denote second-order log-deviations. Substituting into the latest equation for the second-order Taylor approximation, we get

$$U_t = \bar{U} + (1+\hat{\zeta}_t)\left[(1-\chi)\hat{C}_t + \chi\hat{G}_t\right] - (1+\hat{\zeta}_t)\upsilon\varphi\left[\hat{Y}_t - \hat{A}_t + \frac{\epsilon}{2}\sigma_t^2\right],$$

which can be simplified to

$$U_t = \bar{U} + (1+\hat{\zeta}_t)\left[(1-\chi)\hat{C}_t + \chi\hat{G}_t\right] - (1+\hat{\zeta}_t)\upsilon\varphi\hat{Y}_t - \upsilon\varphi\frac{\epsilon}{2}\sigma_t^2 + o\left(||a^3||\right) + t.i.p., \quad (89)$$

where terms of order three (such as $\sigma_t^2\zeta_t^2$) are collected in $o\left(||a^3||\right)$, while terms independent of policy (such as $(1+\hat{\zeta}_t)\upsilon\varphi\hat{A}_t$) have been put into $t.i.p.$. Using the income identity $\hat{Y}_t = \gamma_C\hat{C}_t + \gamma_G\hat{G}_t$ and the fact that $\chi = \gamma_G = (1-\gamma_C)$ in the efficient steady-state, we get

$$U_t = \bar{U} + \left[1-\upsilon\varphi\right](1+\hat{\zeta}_t)\hat{Y}_t - \upsilon\varphi\frac{\epsilon}{2}\sigma_t^2 + o\left(||a^3||\right) + t.i.p., \quad (90)$$

Noting that $\hat{\zeta}_t\hat{Y}_t = \frac{1}{2}\left[\hat{\zeta}_t^2 + \hat{Y}_t^2 - (\hat{Y}_t - \hat{\zeta}_t)^2\right]$, we are able to rearrange this to

$$U_t = \frac{(1-\upsilon\varphi)}{2}\left[(1+\hat{Y}_t)^2 - (\hat{Y}_t - \hat{\zeta}_t)^2\right] - \upsilon\varphi\frac{\epsilon}{2}\sigma_t^2 + o\left(||a^3||\right) + \overline{t.i.p.}, \quad (91)$$

where

$$\overline{t.i.p.} = t.i.p. + \hat{\zeta}_t^2\frac{(1-\upsilon\varphi)}{2} - \frac{(1-\upsilon\varphi)}{2}$$

is the full set of variables independent of policy. Noting that $\frac{1}{2}\sum_{t=0}^\infty \beta^t\sigma_t^2 = \frac{\epsilon}{\kappa}\sum_{t=0}^\infty \beta^t\hat{\pi}_t^2$ (see Woodford, 2003) and taking conditional expectations at date zero and neglecting al terms higher than second order, the discounted sum of utility streams can be written as equation (37).

# F Design and stress testing

In this section, we will refer to some important issues that may arise when designing a debt brake. We do not claim completeness, however, think that the issues addressed below are of great importance.

## F.1 How to set the feedback of the adjustment account

Thorough the last sections we have set $\rho = 0.05$, claiming that such a value is roughly welfare optimal. In this section we will verify this claim and make a proposition to install a two tired adjustment account framework as the fiscal shock calls for a rather high value of $\rho$, while for all other shocks it is advisable to set $\rho$ to a small number, which still supports a determinate rational expectations equilibrium and anchors the real value of outstanding government liabilities.

Figure 16 illustrates which value of $\rho$ would be optimal from a welfare perspective if it would be possible to fine tune $\rho$ towards a specific shock. Precisely speaking we compute the ratio of the expected loss if we allow $\rho$ varying from zero to one, while all other parameters remain fixed at their baseline calibration and take the ratio to the baseline where we have set $\rho$ to 0.05.

Recall, if $\rho$ is close to one fiscal authorities are forced to balance the adjustment account almost completely in the quarter following the laps, while $\rho$ close to zero indicates a near random walk behavior of the adjustment account and only calls for gradually reductions in government expenditures over time.

Figure 16 portrays that for the case of a shock to consumer preferences, to technology, to price mark- up and to the interest rate the optimal feedback value of $\rho$ should be small. Thus, if the source of movements in the adjustment account can be traced back towards cyclical movements in government revenues that are related to fundamental shocks fiscal authorities are well advised not to correct fiscal expenditures to sharply in the previous period as this would work against the automatic stabilizer build in the debt brake.

For the case a fiscal shock itself, the recommendation is completely reversed. If a fiscal policy shock is the source of movement in the adjustment account the welfare analysis reports clear evidence that a sharp correction in the following period is advisable.

As we assume that the government has no technology at hand to fine tune the partial adjustment parameter towards the specific fundamental shock, we compute $\rho$ in a somewhat crude way as follows. Assuming that fundamental shocks are orthogonal, we are able to compute the value of the loss function for each shock for $\rho$ on the discrete interval $[0.00, 0.05, 0.10, 0.15, 0.20]$, and then compute for each $\rho$ the overall value of the "aggregated" loss function

$$\mathbb{W}_0(\rho) = \mathbb{W}_0^{TS}(\rho) + \mathbb{W}_0^{CPS}(\rho) + \mathbb{W}_0^{PMS}(\rho) + \mathbb{W}_0^{MS}(\rho) + \mathbb{W}_0^{FS}(\rho),$$

where the superscripts indicate a technology shock (TS), a consumer preference shock (CPS), a price mark-up shock (PMS), a monetary shock (MS) and a fiscal shock (FS). Summing up

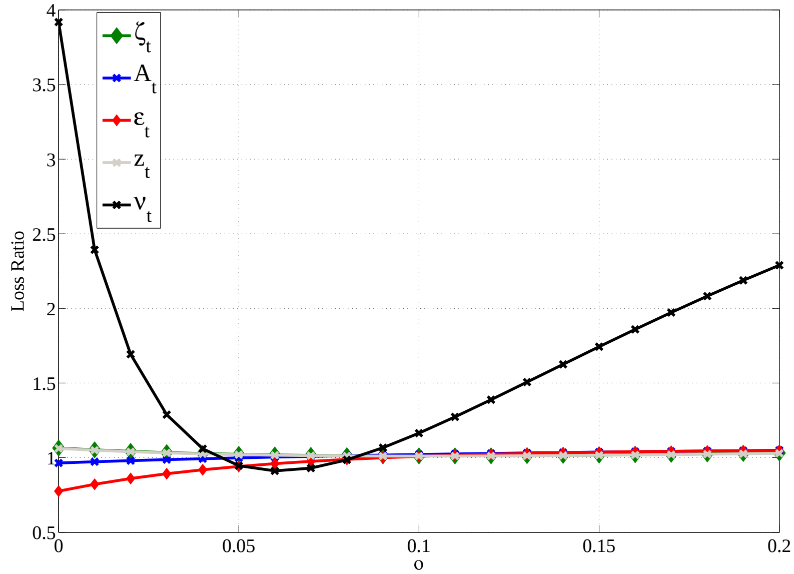


Figure 16: Optimal feedback coefficient for each shock

over the individual shocks, we find that the overall welfare metric is minimized for $\rho = 0.05$. A more sophisticated way to find the optimal value for $\rho$ will not change our results presented in this paper qualitatively.

## F.2 Trend estimation errors

In this section, we extent the setting derived in the previous parts of the paper to allow for measurement error on trend output on behalf of fiscal authorities. In practice, it prevails that governments are often subject to persistent measurement errors in trend output. Additionally, estimations vary according to who estimates the trend; further, there is quite a high frequency of trend revisions as time moves on.[10] For analytical simplicity and without loss of generality, we assume that $\bar{\tilde{b}} = 0$, i.e. we consider a zero debt economy. Reverting to equations (21) and (22), we can express the debt brake in presence of trend mis-estimations as

$$(R_{t-1} - 1)\tilde{b}_t + \frac{G_t}{\bar{Y}} = \underbrace{\frac{\bar{\Psi}}{\bar{P}\bar{Y}} \cdot E_{t-1}\left\{a_t\right\} - \rho \cdot \frac{P_{t-1}}{P_t} ac_{t-1}}_{=\textit{Rule based spending}} + \frac{\nu_t}{P_t\bar{Y}},$$

[10]As Fritsche and Döpke (2006) put it, "*it [may] not always [be] advisable to listen to the majority of forecasters*". The issue of trend mis-estimation and its implications are briefly addressed within this section, but not in a very sophisticated manner as it is not the primary focus of this analysis. However, it is certainly an important topic for further research.

where $E_{t-1}\{a_t\}$ denotes an estimation error in trend output. Whenever it is greater one, trend is overestimated and vice versa. The adjustment account is then given by

$$ac_t = (1-\rho)\cdot\frac{P_{t-1}}{P_t}\cdot ac_{t-1} + \frac{\nu_t}{P_t\bar{Y}} + \left[\frac{\bar{\Psi}}{\bar{P}\bar{Y}}E_{t-1}\{a_t\} - \frac{\Psi_t}{P_t\bar{Y}}\right].$$

In log-linearized terms, this is translates into

$$\hat{G}_t = \frac{(1-\beta^{-1})}{\gamma_G}b_t + \frac{\nu_t}{\bar{P}\bar{Y}} + E_{t-1}\{\hat{a}_t\} - \rho ac_{t-1} \tag{92}$$

where we assume that $E_{t-1}\{\hat{a}_t\}$ in the following experiment and

$$ac_t = (1-\rho)ac_{t-1} + \frac{\nu_t}{\bar{P}\bar{Y}} + \gamma_G\left[E_{t-1}\{\hat{a}_t\} - \left(\hat{\Psi}_t - \hat{P}_t\right)\right]. \tag{93}$$

We see from equation (92) that overestimating trend revenues, i.e. $E_{t-1}\{\hat{a}_t\} > 0$, unambiguously increases government spending. Although this is booked on the adjustment account and partly repaid in future periods, it is straightforward to see that government spending will remain high for quite some periods, even when the estimation error is corrected immediately in the next period as the adjustment account does only partially feed back on government spending. Because trend mis-estimations are usually correlated over time due to the available time series-estimation methods, and it take quite a while to realize that $E_{t-1}\{\hat{a}_t\} > 0$ was wrong, things may even get worse. As Brunez (2003) has shown, a bias in trend estimations cannot be neglected. Kremer and Stegarescu (2008) show with German data that trend tends to be over-estimated in booms and under-estimated in downturns, while, on average, there seems to be an over-estimation. Furthermore, there may also be a positive political economic bias as suggested by Heinemann (2006).

In Figure 17, we report evidence from the following case study. We assume that the government falls prey to estimation errors for 16 quarters in a row as trend output is estimated one percentage point higher than it actually is. Each period, the government is surprised to learn that output is lower than initially expected. Nevertheless, it attributes this to some other source but trend mis-estimation.

From quarter 16 to 17, the government then realizes that trend was wrongly estimated and adjusts its expenditures accordingly. The green (high feedback, $\rho = 0.99$), black (low feedback, $\rho = 0.01$) and red (optimal baseline feedback, $\rho = 0.05$) lines report how the economy evolves under the different feedbacks. The following differences prevail.

First, the higher the feedback to the adjustment account, the lower the increase in debt. Second, from quarter 16 to 17, the economy goes into a deeper recession if fiscal expenditures are corrected sharply as, in particular, Non-Ricaridan households reduce consumption expenditures. Third, the inflation response for the optimal baseline feedback evolves smoother than the others.

We conclude that the installation of an adjustment account is able to balance the desire to keep the debt bounded, while equally not irritating the economy at large, if fiscal authorities fall prey to measurement errors.

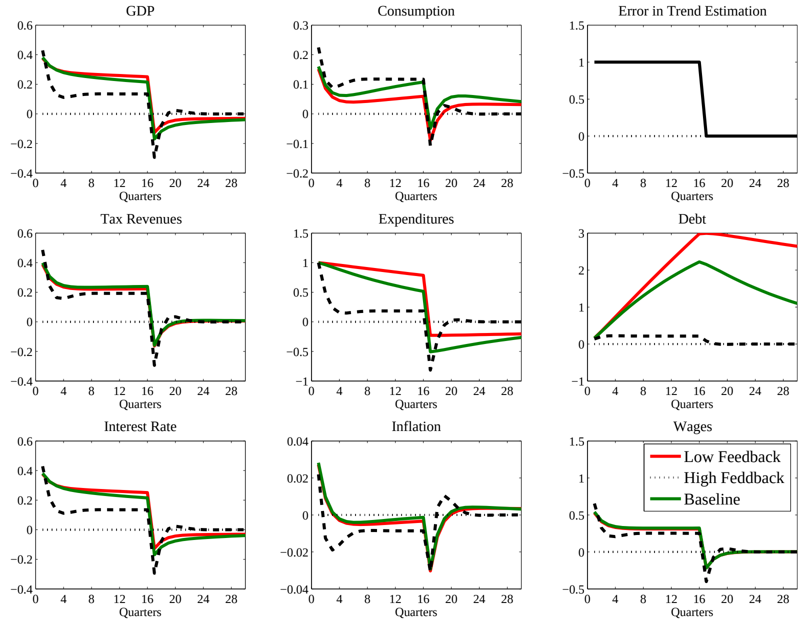


Figure 17: Trend estimation errors

## F.3 Elasticities

Under current time-series estimation methods, debt brakes in action in Switzerland or proposed for Germany tie government spending to real trend revenue by estimating future revenue and correct this by a cyclical component similar to the automatic stabilizer derived in section 2.3.2 in order to boost spending in "bad times" and diminish spending in "good times" (see Colombier, 2004, 2006; Danninger, 2002; German Council of Economic Experts, 2007; Kastrop and Snelting, 2008; and Kremer and Stegarescu, 2008 for a description about the precise design of the debt brake in Switzerland and the proposals for Germany). This approach may, however, result in a pro-cyclical tool which is, in terms of our model, more (but not yet fully) a balanced budget rule than an automatic stabilizer even when abstracting from estimation errors.

To make the argument clearer, let us step back to describe existing or proposed rules in terms of our model (referring also to section 2.3). Government spending, including interest on outstanding debt, according to the debt brake design just described, should be tied to projected funds raised by the government, i.e. $E_{t-1}\left\{\Psi_t\right\}$. This is augmented by projected counter-cyclical component $E_{t-1}\left\{\bar{Y}/Y_t\right\}$. Hence, ex-post government spending is given by

$$(R_{t-1}-1)B_t + P_t G_t = \underbrace{E_{t-1}\left\{\Psi_t \cdot \left(\frac{\bar{Y}}{Y_t}\right)^{\alpha}\right\} - \rho AC_{t-1}}_{=\textit{Rule based spending}} + \nu_t,$$

where, as in section 2.3.2, $\alpha > 0$ is the magnitude how much revenues react in expected deviations from (estimated) trend output and the adjustment account evolves according to

$$AC_t = (1-\rho)AC_{t-1} + \nu_t + \underbrace{E_{t-1}\left\{\Psi_t \cdot \left(\frac{\bar{Y}}{Y_t}\right)^{\alpha}\right\} - \left(\Psi_t \cdot \left(\frac{\bar{Y}}{Y_t}\right)^{\alpha}\right)}_{Expectation\ error}.$$

Expressing these equations in real terms (i.e. dividing by $P_t$), normalizing (i.e. dividing by $\bar{Y}$), assuming a zero debt economy for analytical convenience (i.e. $\bar{\bar{b}} = 0$ without loss of generality) and log-linearization (i.e. following the same procedure as presented in Appendix C), we find that

$$\hat{G}_t = \frac{(1-\beta^{-1})}{\gamma_G} b_t + \frac{\nu_t}{\bar{P}\bar{Y}} + \underbrace{E_{t-1}\left\{\hat{\Psi}_t - \hat{P}_t\right\} - \alpha \cdot E_{t-1}\left\{\hat{Y}_t\right\}}_{=Rule\ based\ spending} - \rho ac_{t-1} \tag{94}$$

and

$$ac_t = (1-\rho)ac_{t-1} + \frac{\nu_t}{\bar{P}\bar{Y}} + \underbrace{\left[E_{t-1}\left\{\hat{\Psi}_t - \hat{P}_t\right\} - \left(\hat{\Psi}_t - \hat{P}_t\right)\right] - \alpha\left[E_{t-1}\left\{\hat{Y}_t\right\} - \hat{Y}_t\right]}_{Expectation\ error}. \tag{95}$$

Taking the descriptions of the rules literally, the rules seem to imply $\alpha = 1$. However, in this case, it is a straightforward to show that, referring to equation (94), *Rule based spending* $>$ 0, which means that government spending reacts pro-cyclically to exogenous shocks. The reason for this is that the elasticity of real government revenues to any shock is larger than the elasticity of output to the same shock. This implies that, given any positive shock, government real revenues increase by more than the counter-cyclical component to dampen spending. In total, spending rises with any positive shock, while the idea of the debt brake says that it should not react (see section 2.3.2). Girouard and André (2005) have shown empirically that the elasticity relation in our model appears to hold. To solve this problem, it seems natural to set $\alpha > 1$ such that *Rule based spending* $= 0$, which corresponds with the basic idea of the rule. However, this may be quite a challenging task as it can be shown that the optimal $\alpha$ differs according to the shock.

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