State dependent Fiscal Multipliers with Preferences over Safe Assets

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Abstract

I examine the effect of fiscal policy at the zero lower bound if households have preferences over safe assets (POSA) calibrated consistent with evidence on household savings behavior and individual discount rates, and estimates of the effect of the supply of US government debt on government bond yields. POSA loosens the link between household consumption and permanent-income and imply a wealth effect from government bonds. Therefore the multiplier of a permanent expenditure change increases and approaches the multiplier of an expenditure change limited to the ZLB period. This result strengthens with credit constrained households and firms.

JEL Codes: E52; E62; E32. Keywords: Fiscal multiplier of temporary and persistent expenditure changes, zero lower bound, wealth in the utility function.

 Most of the results discussed here as well as my approach to parameterize POSA based on evidence on the wedge between individual discount rates and market interest rates were already present in an earlier version of the paper circulated as "The effect of fiscal policy and forward guidance with preferences over wealth", which was available online as of May 2017, see http://programme.exordo.com/iea2017/delegates/presentation/52/.

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1 Introduction

In the standard infinite horizon New Keynesian model, the fiscal multiplier during a period of constrained monetary policy depends, inter alia, crucially on what the change in government expenditure signals about the future government spending trajectory. More specifically, a temporary fiscal expansion implemented while monetary policy is constrained by the zero lower (ZLB) but reversed immediately afterwards increases household consumption as well as investment by increasing inflation and thus lowering the real interest rate. By contrast, a permanent fiscal expansion tends to crowd out private household consumption. The reason is that a permanent fiscal expansion entails the prospect of a lower permanent disposable income level in the new steady state the economy will ultimately converge to, which via consumption smoothing immediately lowers consumption. This consumption decline partially compensates for the increase in government expenditure rather than adding to the associated rise in aggregate demand (e.g. Woodford (2011), Christiano et al. (2011), Denes et al. (2013)).

However, this strong link between changes of the households (expected) future permanent-income and their current consumption is at odds with the micro evidence on the inter-temporal choices of high-income households, who would appear to be natural real-world counterparts of "Ricardian" households with their unconstrained consumption smoothing opportunities. Firstly, the marginal propensity to save out of an increase in their permanent-income is zero in the standard model, but appears to be in a range of 20% to 40% for the fourth and fifth income quintile of US households (Dynan et al. (2004) and Kumhof et al. (2015)). Secondly, the micro evidence on individual discount rates typically estimates them to substantially exceed market interest rates relevant for the inter temporal choice under examination by the researcher ((see Frederick et al. (2002) for a survey), even for income rich and highly educated individuals (e.g. Harrison et al. (2002) and Warner and Pleeter (2001)). This discrepancy cannot be accommodated by the standard model, where the individual discount rate applied to future nominal income streams always equals the inverse of the (gross) nominal interest rate, implying that financial market exactly compensates the household's impatience. Finally, there appears to be a positive effect of the US government debt-to-GDP ratio on US government bond yields (see Gale and Orszag (2004), Engen and Hubbard (2004) and Laubach (2009)). This finding suggests a potential role for wealth effects (see Gale and Orszag (2004)), especially since an increase in sovereign default risk would appear to be an implausible culprit in the US case. Similarly, there is evidence for a negative effect of government debt on the spread between private sector interest rates and government bond yields (see Krishnamurthy and Vissing-Jorgenson (2012)).

In this paper, I examine the effect of fiscal policy in a simple New Keynesian model without capital where households have Preferences Over Safe Assets (POSA), since preferences of this type have been shown to be able to accommodate the above micro and macro evidence (see Rannenberg (2019), Kumhof et al. (2015), Krishnamurthy and Vissing-Jorgenson (2012)), and I parameterize them accordingly. Krishnamurthy and Vissing-Jorgenson (2012) argue that safe assets may provide services if they have money-like qualities. An alternative motivation interprets the saving behavior of rich households as evidence for "Capitalist Spirit" type preferences over all forms of wealth, for instance due to the prestige, power and security associated with wealth (see for instance Carroll (2000), Dynan et al. (2004), Francis (2009) and Kumhof et al. (2015) as well as their literature review). More recently, Kaplan and Violante (2018) have suggested POSA as a simple shortcut to capture a feature of heterogenous agent models, namely the idea that in the presence of uninsurable risk, the household sector values the the existence of a safe and liquid asset due to its precautionary value.

In line with the aforementioned fiscal literature, I find in the presence of the ZLB, the multiplier of a "perfectly timed" expenditure increase, i.e. lasting exactly as long as the ZLB, exceeds one, equaling 1.4 (1.2) for an expected length of the ZLB of two years without POSA (with POSA), while the multiplier of a permanent expenditure change equals only about 0.4 without POSA (See Table 4a., second row, fifth and sixth column). My main novel result is that, with POSA, the multiplier of a permanent government expenditure change strongly increases, thus becoming closer to the multiplier of a "perfectly timed" expenditure change. The reason is that with POSA there is less consumption smoothing, because the "net weight" the household attaches to future periods' marginal utilities of consumption declines exponentially in their distance from the present, as the households individual discount rate exceeds the real interest rate. Hence the decline in consumption outside the ZLB caused by the increase in government expenditure has a smaller impact on current consumption. Furthermore, with declining marginal utility from safe assets, an increase in the household's real government bond holdings will tend to increase her consumption, as the household attempts to smooth not just consumption but also her real safe asset holdings. The combination of these two effects raises the multiplier of a permanent expenditure increase to about 1.0 with POSA (see able 4a. row four, final column).

I show that these results are robust to adopting a more realistic maturity structure of government debt (following Krause and Moyen (2016)) and assuming that the market value of the household's bond portfolio enters the utility function. This robustness check is relevant because a fiscal expansion outlasting the ZLB may reduce the market value of a unit of outstanding long-term government debt by increasing expected future short-term interest rates, which -in itself- tends to lower the market value of household wealth and -with POSA- consumption. Furthermore, my results become stronger if the government's fiscal rule uses distortionary labor taxes to ensure long-run debt stationarity, in that the multiplier of a permanent government expenditure increase remains virtually unchanged with POSA (compare rows five and eight of Table 4a., final column) but becomes even lower without POSA (compare rows three and six of Table 4a., final column). The reason is that in the new steady state, output and thus the household's disposable income are lower if labor taxes are adjusted by the fiscal rule due to the associated efficiency loss. Without POSA, this additional future burden has a strong permanent-income effect on current consumption. With POSA, the aforementioned attenuation of consumption smoothing virtually eliminates this additional permanent-income effect on consumption during the ZLB. Finally, I show that my results are robust to allowing for a lower Phillips curve slope during the period the zero lower bound is binding, a non-linearity whose importance for the analysis of fiscal policy is argued by Trabandt and Linde (2018).

Moreover, I repeat my analysis in a medium scale DSGE model with investment spending, sticky wages credit constrained firms along the lines of Bernanke et al. (1999) and credit constrained households. As shown in Freedman et al. (2010) and Carrillo and Poilly (2013), these features strongly amplify the multiplier of a temporary fiscal stimulus implemented during the ZLB only. Below I show that for permanent government expenditure changes, without POSA this amplification is virtually eliminated, because even though the credit constrained agents increase their spending in response to the fiscal expansion, in response the unconstrained households lower their spending even more than in the absence of constrained agents. By contrast, with POSA, credit constraints increase the multiplier by the same amount for perfectly timed and permanent government expenditure changes.

The result that fiscal multipliers may be much less dependent on the future expected path of government spending has important implications for fiscal policy during economic downturns. More specifically, one of the arguments in favor of "front-loaded" permanent spending cuts has been that the expectation of a lower future tax burden would induce households to spend more if the spending cut is credible, thus substantially muting the adverse effect. My results show that this optimistic assessment does not hold for POSA parameterized in line with microeconomic evidence on intertemporal choices and macro-evidence on the relationship between government debt and interest rates.

My paper contributes to the aforementioned literature exploring the relationship between the fiscal multiplier during the ZLB and the expected persistence of the government spending change beyond the length of the ZLB ((e.g. Woodford (2011), Christiano et al. (2011), Denes et al. (2013)) by showing that POSA almost eliminates this (negative) relationship by attenuating the consumption smoothing of households. An alternative approach yielding a similar effect has been explored by Lemoine and Linde (2016), who examine the effect of permanent government spending cuts in a monetary union under imperfect credibility regarding the spending cut's duration.

Furthermore, my paper adds a to a growing literature exploring the macroeconomic implications of preferences over safe assets or preferences over wealth more generally. As shown by Rannenberg (2019, 2017) and Michaillat and Saez (2018), POSA can eliminate the so called "Forward Guidance Puzzle", i.e. the finding that in DSGE models with nominal rigidities, the GDP and inflationary effects of central bank announcements regarding the future path of the short-term interest rate tend to be very large and to explode in the length of the announced interest rate peg (see Del Negro et al. (2015a) and Carlstrom et al. (2015)). Both the attenuation of the Forward Guidance Puzzle and the dilution of "Ricardian" effects of fiscal policy caused by POSA are rooted in the attenuation of consumption smoothing and the "asset smoothing" motive arising with POSA. Furthermore, preferences over wealth have been found useful in explaining the increase in US household indebtedness in the run-up to the financial crisis (Kumhof et al. 2015), and to rationalize the level of wealth held by rich households relative to their disposable income (Carroll 2000 and Francis 2009).

The remainder of this paper is organized as follows. Section 2 extends a simple New Keynesian model with POSA and Section 3 discusses the calibration. Section 4 discusses the fiscal multiplier outside and inside the ZLB and the role of the persistence of the government expenditure change. Section 5 discusses the interaction between POSA and credit constraints in a medium scale DSGE model. The robustness check allowing for a state dependent Phillips curve is discussed in Appendix D. Section 6 concludes.

2 A simple model with preferences over wealth

2.1 Households

The representative household derives utility from consumption C_t and her holdings of real government bonds $b_{G,t}$, and disutility from supplying labor N_t. Her objective is given by

$$E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \frac{\chi_N}{1+\eta} N_{t+i}^{1+\eta} + \frac{\chi_b}{1-\sigma_b} \left(b_{G,t+i} \right)^{1-\sigma_b} \right] \right\} \tag{1}$$

with $\chi_N, \sigma, \eta > 0$ and $\chi_b, \sigma_b \geq 0$. One motivation for POSA is liquidity preference. Krishnamurthy and Vissing-Jorgenson (2012) argue that liquidity preference may extend to assets with a positive yield if they have money-like qualities, and provide supporting evidence for the case of US government bonds. Fisher (2015) also adopts this argument. Another motivation pertains to rich households, who may have "Capitalist Spirit" type preferences over all forms of wealth, meaning that they derive utility from the prestige, power and security associated with wealth. Several authors have argued that such preferences are necessary to replicate the saving behavior of rich households in US data, namely the positive marginal propensity to save out of permanent-income changes (see Dynan et al. 2004) and Kumhof et al. 2015), and the level of wealth held by rich households relative to their disposable income (Carroll 2000 and Francis 2009). More recently, Kaplan and Violante (2018) have suggested POSA as a simple shortcut to capture a feature of heterogenous agent models, namely the idea that in the presence of uninsurable risk, the household sector values the the existence of a safe and liquid asset due to its precautionary value.

The household derives income from supplying labor and her ownership of government bonds. Her budget constraint is thus given by

$$b_{G,t} + (1+\tau_C)\, C_t = \varepsilon_{b,t} \frac{R_{t-1}}{\Pi_t} b_{G,t-1} + (1-\tau_w)\, w_t N_t - T_t + \Xi_t \tag{2}$$

where Π_t, R_t, w_t, Ξ_t, T_t, τ_C and τ_w denote the inflation rate, the nominal interest rate on government bonds (which is also the policy rate set by the central bank), the real wage, real profits of firms and lump-sum, consumption and labor taxes, respectively. $\varepsilon_{b,t}$ denotes a so-called "risk premium shock", i.e. a shock which renders safe assets more attractive. Throughout the paper I adopt the convention that only period t decision variables are indexed with t, implying that $b_{G,t}$ denotes the stock of government bonds at the end of period t. The first order conditions (FOCs) of the household with respect to government bonds, consumption and labor are given by

$$\Lambda_t = \beta E_t \left\{ \frac{\varepsilon_{b,t} R_t}{\Pi_{t+1}} \Lambda_{t+1} \right\} + \chi_b \left(b_{G,t}\right)^{-\sigma_b} \tag{3}$$

$$\Lambda_t \left(1+\tau_C\right) = C_t^{-\sigma} \tag{4}$$

$$\left(1-\tau_w\right) w_t \Lambda_t = \chi_N N_t^{\eta} \tag{5}$$

where Λ_t denotes the marginal utility of consumption. If $\chi_b > 0$, $\chi_b \left(b_{G,t}\right)^{-\sigma_b}$ represents an extra marginal benefit from saving over and above the utility associated with the future consumption possibility saving entails (represented by $\beta E_t \left\{ \frac{R_t}{\Pi_{t+1}} \Lambda_{t+1} \right\}$). This extra benefit has three (related) consequences. Firstly, Λ_t is now less than proportional to the marginal utility of $t+1$ consumption Λ_{t+1}, since it also depends on marginal utility of holding government bonds. Hence there will be less intertemporal consumption smoothing. Furthermore, as Λ_{t+1} is no longer proportional to Λ_{t+2} either, and so on and so forth, the attenuation of intertemporal consumption smoothing compounds the more distant in time the respective future consumption choice is located. Secondly, the extra benefit of holding government bonds implies that

$$R_t \leq \frac{1}{E_t\left\{\frac{\beta\Lambda_{t+1}}{\Lambda_t\Pi_{t+1}}\right\}} \equiv DIS_t \tag{6}$$

i.e. the nominal interest rate may be smaller than the households individual discount rate DIS_t. A third consequence of POSA arises under the assumption of declining marginal utility from government bonds ($\sigma_b > 0$), as the household in that case aims to smooth her asset holdings.

The consequences of POSA for intertemporal choice may be further illustrated by linearizing equation (3), which yields

$$\hat{C}_t = -\theta\left[\hat{R}_t - E_t\hat{\Pi}_{t+1} + \varepsilon_{b,t}\right] + \theta E_t\hat{C}_{t+1} + (1-\theta)\sigma_b\frac{Y}{b_G}\hat{b}_{G,t} \tag{7}$$

where a hat on top of a variable denotes the percentage deviation of that variable from the non-stochastic steady state, with the exception of $\hat{b}_{G,t}$, which is expressed as a percentage of steady state GDP. $\theta = \beta\frac{R}{\Pi}$, i.e. the product of the steady-state household discount factor and the real interest rate. Below I will refer to θ as the discounting wedge. θ represents the net weight the household attaches to the $t+1$ marginal utility of consumption. Assuming POSA (i.e. $\chi_b > 0$) implies that $\theta < 1$, and thus less consumption smoothing (as mentioned above). Specifically, in the absence of POSA ($\theta = 1 \Leftrightarrow \chi_b = 0$), a decline of consumption taking place in some future quarter $t+i$, has the same effect on the period t marginal utility of consumption (and thus consumption itself) as a decline in $E_t\hat{C}_{t+1}$. By contrast, with POSA ($\theta < 1 \Leftrightarrow \chi_b > 0$), the effect of a one percent decline in $E_t\hat{C}_{t+i}$ on $\hat{C}_t$ equals θ^i, thus converging to zero as i approaches infinity. Finally, with declining marginal utility from safe assets ($\theta < 1$ and $\sigma_b > 0$), an increase in the household's real government bond holdings will tend to lower her consumption, as the household attempts to smooth not just consumption but also her real safe asset holdings, implying that the path of government debt now matters for consumption and thus Ricardian equivalence breaks down.

2.2 Retailers

There is a continuum of monopolistically competitive firms owned by households, each producing a variety j from a CES basket of goods. They set prices subject to Rotemberg (1983) type quadratic price adjustment costs, which are given by

$$AC\left(j\right)_{P,t} = Y_t\left(j\right)\frac{\xi_P}{2}\left(\frac{P\left(j\right)_t}{P\left(j\right)_{t-1}}\frac{1}{\Pi} - 1\right)^2 \tag{8}$$

where $\xi_P > 0$ denotes the adjustment cost curvature. Retailers employ labor using the technology:

$$Y\left(j\right)_t = AN\left(j\right)_t \tag{9}$$

The FOC with respect to labor is given by

$$mc_t = \frac{w_t}{A} \tag{10}$$

where mc_t denote real marginal costs of production. Finally, optimal price setting implies that up to first order, inflation evolves according to the familiar New Keynesian Phillips curve

$$\hat{\Pi}_t = \kappa_\pi \hat{mc}_t + \beta E_t \hat{\Pi}_{t+1} \tag{11}$$

where $\kappa_\pi > 0$ is a constant depending inversely on the degree of adjustment cost curvature ξ_P.

2.3 Government and equilibrium

The government levies taxes and buys goods from retailers. Its budget constraint is given by

$$b_{G,t} = \frac{R_{t-1}}{\Pi_t}b_{G,t-1} + G_t - \left(T_t + \tau_{w,t}w_tN_t + \tau_C C_t\right) \tag{12}$$

For now I assume that lump-sum taxes are adjusted to ensure the long-run stationarity of government debt. The fiscal rule is thus given by

$$\hat{T}_t = \tau_b (1 - \rho_{FIN}) \hat{b}_{G,t-1} + \rho_{FIN} \hat{T}_t \tag{13}$$

where $\hat{T}_t$ and $\hat{b}_{G,t}$ denote the deviation of lump-sum taxes and government debt from their respective steady state values as a percentage of steady state GDP and $\tau_b > 0$. Monetary policy is described by a simple rule where the Central Bank responds to inflation and the deviation of output from its flexible price level $\Gamma \hat{G}_t$, with $\Gamma > 0$ as a consequence of the wealth effect on labor supply, and Γ defined in Table 1 below:

$$\hat{R}_t = max\left(\left(\phi_\pi \hat{\Pi}_t + \frac{\phi_y}{4}\left(\hat{Y}_t - \hat{Y}_t^*\right) - \varepsilon_{b,t}\right), \hat{R}_L\right) \tag{14}$$

$\hat{R}_L < 0$ denotes a lower bound on the (percentage deviation from its steady state of the) nominal interest rate $\hat{R}_t$ and $\hat{Y}_t^*$ denotes output in the absence of nominal rigidities. If the lower bound on level of the policy interest rate is zero, $\hat{R}_L = -\frac{R-1}{R}$.

Finally, output net of price adjustment costs equals the sum of household and government consumption

$$Y_t \left(1 - \frac{\xi_P}{2}\left(\frac{\Pi_t}{\Pi} - 1\right)^2\right) = C_t + G_t \tag{15}$$

2.4 Linearized equations

Linearizing and combing the above equations allows to express the model in just five equations:

$$\begin{aligned}\hat{Y}_t - \hat{G}_t = &-\frac{1}{\tilde{\sigma}}\left[\theta\left[\hat{R}_t - E_t\hat{\Pi}_{t+1} - \varepsilon_{b,t}\right] - (1-\theta)\frac{\tilde{\sigma}_b}{\tilde{\sigma}}\hat{b}_t\right] \\ &+ \theta\left(E_t\hat{Y}_{t+1} - E_t\hat{G}_{t+1}\right)\end{aligned} \tag{16}$$

Table 1: Reduced form coefficients of the stylized model

$\tilde{\sigma}$	$\tilde{\sigma}_b$	θ	Γ	κ
$\sigma\frac{C}{Y}$	$\frac{\sigma_b}{\frac{b}{y}}$	$\beta\frac{R}{\Pi}$	$\frac{\sigma}{\sigma+\eta}$	$\kappa_\pi\left(\sigma+\eta\right)$

$$\hat{\Pi}_t = \kappa(\hat{Y}_t - \Gamma\hat{G}_t) + \beta E_t\hat{\Pi}_{t+1} \tag{17}$$

$$\hat{R}_t = max\left(\left(\phi_\pi\hat{\Pi}_t + \frac{\phi_y}{4}\left(\hat{Y}_t - \hat{Y}^*_t\right) - \varepsilon_{b,t}\right), \hat{R}_L\right) \tag{18}$$

$$\hat{b}_{G,t} = \frac{R}{\Pi}\hat{b}_{G,t-1} + \frac{b_G}{Y}\frac{R}{\Pi}\left(\hat{R}_{t-1} - \Pi_t\right) - \left(\hat{T}_t + \frac{wN}{Y}\hat{\tau}_{w,t} + \tau_w\frac{wN}{Y}\left(\hat{w}_t + \hat{N}_t\right) + \tau_C\frac{C}{Y}\hat{C}_t\right) \tag{19}$$

$$\hat{T}_t \;\;=\;\; \tau_b\left(1-\rho_{FIN}\right)\hat{b}_{t-1} + \rho_{FIN}\hat{T}_{t-1}$$

The meaning of the reduced form coefficients can be obtained from Table 1.

3 Calibration

Regarding the standard parameters, namely σ, η, κ, μ_p, ϕ_π and ϕ_y, I closely follow Woodford (2011) (see Table 2). I calibrate the consumption and labor tax rates τ_C and τ_w in line with the US evidence of Jarass et al. (2017). Regarding the fiscal rule, I set ρ_b to 0.97 and τ_b to small values sufficient to guarantee debt stationarity.

Table 2: Parameters in the stylized model and empirical targets

a. Parameters in the simple model

Parameter	Parameter name	NOPOSA	POSA
β	Household discount factor	0.9955*	0.9557*
σ	Curvature consumption	1	
η	Curvature labor disutility	1.8	
σ_b	Curvature save assets	0.2*	
κ	Output coefficient Phillips curve	0.0088	
μ_p	Steady state price markup	1.25	
τ_C	Consumption tax rate	0.05	
τ_w	Labor tax rate	0.28	
τ_b	Fiscal rule, long-run response to debt	$\frac{R}{\Pi} - 1 + 0.05$	
ρ_b	Fiscal rule, inertia	0.98	
$\frac{b_G}{4Y}$	Fiscal rule, target debt-to-annual GDP ratio	0.64*	
$\frac{G}{Y}$	Steady state government expenditure share	0.2*	
ϕ_π	Taylor rule inflation	1.5	
ϕ_y	Taylor rule output gap	$\frac{0.5}{4}$	

b. Empirical targets used to calibrate the simple model

Empirical target	Model counterpart	NOPOSA	POSA	Data	Source
Real interest rate	$\left(\frac{R}{\Pi}\right)^4 - 1$	1.8%		1.8%	Federal Funds rate-CPI inflation
Gov. expenditure share	$\frac{G}{Y}$	0.2		0.2	BEA
Gov. debt-to-GDP ratio	$\frac{b_G}{4Y}$	0.64		0.64	FRED
Discounting wedge	$\theta = \beta\frac{R}{\Pi}$	1.0	0.96	0.96/0.97	See note below.
$\frac{4d\hat{R}_f}{\frac{d\hat{b}_{f,G}}{4}}$	$\tilde{\sigma}_b\frac{1-\theta}{\theta}16$	0	$0.05p.p.$	$0.03 - 0.06p.p.$	See note below.
MPS (not targeted)	See note below	0	0.32	$0.3 - 0.34$	See note below

- Parameter values labeled with * in Table a. were calibrated to match the empirical targets listed in Table b..
- All empirical targets (other than those which are estimates taken from other studies) are averages over the years 1981-2016. For more details on the data sources see Appendix A.
- Given the target for θ and the calibration of the other parameters, the bond utility weight χ_b does not matter for the linearized model dynamics and is therefore not reported.
- $\frac{4d\hat{R}_f}{\frac{d\hat{b}_{f,G}}{4}}$ is obtained from equation (7) by setting $\hat{C}_t = E_t\hat{C}_{t+1} = E_t\hat{\Pi}_{t+1} = 0$ and solving for $\hat{R}_t$.
- Model MPS: See Appendix B for details on the computation, which follows Kumhof et al. (2015).
- Empirical Effect of increase in government-debt-to-GDP ratio on interest rate: See Gale and Orszag (2004), Engen and Hubbard (2004), Laubach (2009). The authors consider regressions with the five year ahead or current real or nominal 10 year treasury rate. If the dependent variable is a nominal interest rate, a measure of long-term inflation expectations is used as a regressor.
- MPS: Marginal Propensity to save out of an exogenous increase in the household's permanent-income. This estimate is based on the Median Savings Regression results reported Kumhof et al. (2015). For more details see Appendix B.

Table 3: Empirical evidence on θ

Sample period	$DIS_t - 1$(APR)	$R_t - 1$ (APR)	Implied θ	Source of DIS_t; R_t used for comparison	Estimate of DIS_t based on...
1929-1948	33.0*	0.8*	0.82	Friedman (1962,1957); real treasury maturity$\geq$ 10 years	Tests of permanent-income hypothesis
1960	19.6*	2.0*	0.96	Heckman (1976); real 10 year treasury	Estimated life cycle earnings model
1976	24.1	2.3*	0.95	Hausman (1979); real 10 year treasury	Energy efficiency and price of air conditioners
1979	122.5	3.0*	0.82	Gately (1980), Median estimate; 10 year treasury	Energy efficiency and price of refrigerators
1979	27.4	9.5	0.96	Cylke et al. (1982); 5 year treasury	US Military reenlistment decisions
1972; 1978; 1980	54.7; 64.0; 72.1*	3.2; 2.4; 4.4*	0.9; 0.89; 0.88	Ruderman et al. (1984), Median; 10 year real treasury	Price of household appliances
1982-1989	18.3	8.6	0.98	Ausubel (1991); one month certificate of deposit	US credit card interest rates
1992-1993	18.7/53.6	6.3	0.97/0.91	Warner and Pleter (2001); 20 year treasury	US soldiers severance package choices
1996	22.5/28.1	4.2	0.96/0.95	Harrison et al. (2002); 1 year money market rate	Experiment, Danish households
2008	28.2/19.0	1.82/3.7	0.9/0.97	Wang et al. (2016); see note below.	Experiment, US econ. students.

Note:

- If information on the horizon of the choice of the agent under observation was available, $R_t - 1$ is the the safe (e.g. government) interest rate during the year the decision was made with a maturity as close as possible to this horizon. In most other cases, I use the 10 year government bond yield. Numbers marked with a * are estimates of the *real* personal discount rate. The corresponding R_t I use to compute θ is therefore a measure of the real interest rate, where expected inflation is assumed to equal the average PCE inflation rate over the current and the preceding 9 years. In case of Friedman (1962, 1957), I calculated the relevant interest rate as the difference between the average interest rate on long-term government bonds (maturity 10 yeas or more, the only long-term government bond series for this period I am aware of) over the 1929-1948 period, and the average PCE deflator inflation rate.

- Warner and Pleeter (2001): The first (second) reported value of $DIS_t - 1$ is the estimate for officers (enlisted personnel), and analogously for θ.

- Harrison et al. (2002): The first (second) reported value of $DIS_t - 1$ is the estimate for income rich households (the sample mean), and analogously for θ.

- Wang et al. (2016) allow for hyperbolical discounting and therefore allow the discount rate applied to a payment received one year ahead (the first value) to exceed the discount rate between any future period (the second value). The interest rates used to compute the corresponding two values of θ are the one year treasury bond rate, and the 9 year forward rate one year hence implied by the one and 10 year treasury bond rate.

- Ausubel's (1991) investigation of the US market for credit cards is frequently cited as evidence in favor of high personal discount rates. In his sample, more than three quarters of customers holding credit credit cards incur finance charges on substantial outstanding balances in spite of credit card interest rates ranging between 18 and 19%, and he cites industry publications saying that about 90% of an issuers outstanding balance accrue interest.

Given these choices, I calibrate some parameters in order to set the steady state values of important model variables close to their empirical counterparts, which are reported in Table 2b.. The empirical targets for the governments debt-to-GDP-ratio and the share of government expenditures on goods and services in GDP determine the debt target implicit in the fiscal rule and $\frac{G}{Y}$, respectively. Furthermore, I assume a target value for the real interest rate, which in the NOPOSA model directly pins down the household discount factor β as $\frac{1}{\beta}$.

To calibrate the two POSA-related parameters χ_b and σ_b, I follow Rannenberg (2019) in assuming an empirical target for the discounting wedge θ $(= \beta\frac{R}{\Pi})$, to be discussed below. This target pins down the steady state marginal utility of wealth via $1 - \theta = \frac{\chi_b (b_G)^{-\sigma_b}}{\Lambda}$(from equation (3)), which, given the choice of the curvature parameter σ_b (to be discussed below) pins down safe asset utility weight χ_b (which however does not appear explicitly in the linearized equations). For instance, the case without POSA corresponds to $\theta = 1 \iff \chi_b = 0$. The target value for θ pins down β as $\beta = \frac{\theta}{R/\Pi}$.

My preferred value of the discounting wedge equals $\theta = 0.96$. To obtain evidence on θ, I draw on estimates of the (time-varying) nominal individual discount rate which the household applies to future nominal income streams, $DIS_t = \frac{1}{E_t\left\{\frac{\beta\Lambda_{t+1}}{\Lambda_t\Pi_{t+1}}\right\}}$. Given estimates of DIS_t, I exploit that for sufficiently small weights on safe assets in the utility function (i.e. θ smaller than but close to one), $\theta_t = \frac{R_t}{DIS_t}$ is approximately constant across time in the model. This property is a consequence of intertemporal substitution by the household: An increase in R_t shifts consumption from t to $t+1$, thus reducing the marginal utility of future consumption and increasing DIS_t.[1] Hence $\theta \approx \frac{R_t}{DIS_t}$, which given the assumed steady state value of the real interest rate $\frac{R}{\Pi}$ then allows to pin down β. This indirect way of calibrating β avoids two problems pointed out by for instance Frederick et al. (2002) which arise if one interprets the empirical estimates of individual discount rates as measuring β itself. Firstly, calibrating θ does not require the assumption that utility is linear in money. Secondly,

[1] More formally, rearranging equation (3) as $1 - \frac{\chi_b (b_{G,t})^{-\sigma_b}}{\Lambda_t} = \beta R_t E_t \frac{\Lambda_{t+1}}{\Pi_{t+1}\Lambda_t}$, defining $\theta_t = \frac{R_t}{DIS_t} = 1 - \frac{\chi_b (b_{G,t})^{-\sigma_b}}{\Lambda_t}$ and linearizing yields $d\theta_t = \frac{\chi_b (b)^{-\sigma_b}}{\Lambda}\left(\hat{\Lambda}_t + \sigma_b \frac{Y}{b}\hat{b}_{G,t}\right) = (1-\theta)\left(\sigma_b \frac{Y}{b}\hat{b}_{G,t} - \frac{1}{\sigma}\hat{C}_t\right)$. Hence for $1-\theta$ close to zero and reasonable calibrations of σ_H and σ_b even large deviations of $\hat{C}_t$ and $\hat{b}_{G,t}$ would lead to tiny movements in θ_t, implying that $\theta \approx \frac{R_t}{DIS_t}$ is a good approximation.

it accounts for the possibility that estimates of the household discount rate based on choices between nominal amounts reflect inflation expectations (at least under the assumption that the nominal interest rate R_t reflects the same inflation expectations as DIS_t).

Regarding evidence on DIS_t, economists have attempted to estimate the personal discount rate at least since Friedman's (1957) seminal tests of the permanent-income hypotheses by studying economic agents' behavior when faced with a variety of intertemporal trade-offs (see Table 3). These range from trading off the energy efficiency and price of household appliances (eg. Hausman (1979), Gately (1979), Ruderman et al. (1984)) to the choice between different types of severance packages (Warner and Pleeter 2001), as well as field experiments where probants choose between a payment today and a larger deferred payment (Harrison et al. 2002). As can be obtained from Table 3, the elicited discount rates are quite high, though below the median value obtainable from the comprehensive literature survey of Frederick et al. (2002), which equals (approximately) 35%.[2] What is more, the discount rate estimates also typically exceed safe interest rates with a comparable maturity observed at the time the discount rates were elicited, resulting in an implied value of θ smaller than one, sometimes substantially so.

Since one may interpret the representative household with unconstrained access to financial markets as representing rich and educated households, the contributions of Harrison et al. (2002) and Warner and Pleeter (2001) are of particular relevance. Harrison et al. (2002) report estimates for (income-) rich households, while Warner and Pleeter (2002) elicit discount rate of officers and enlisted men of the United States armed forces choosing between two severance packages during the 1992-1995 military draw-down.[3] My calibration of θ is thus at the upper end of what is implied by the evidence listed in Table 3.

Given these choices, I calibrate the wealth curvature parameter σ_b such that the

[2]See his Table 1. For each study reported by Frederick et al. (2002), I calculated the mean of the reported range of the discount factor, and then the median over all midpoints, and finally converted the discount factor into a discount rate.

[3]The authors report that virtually all of the officers in their sample have a college degree, while according to the Current Population Survey the same was true for only 24.5% of all individuals in the same age group.

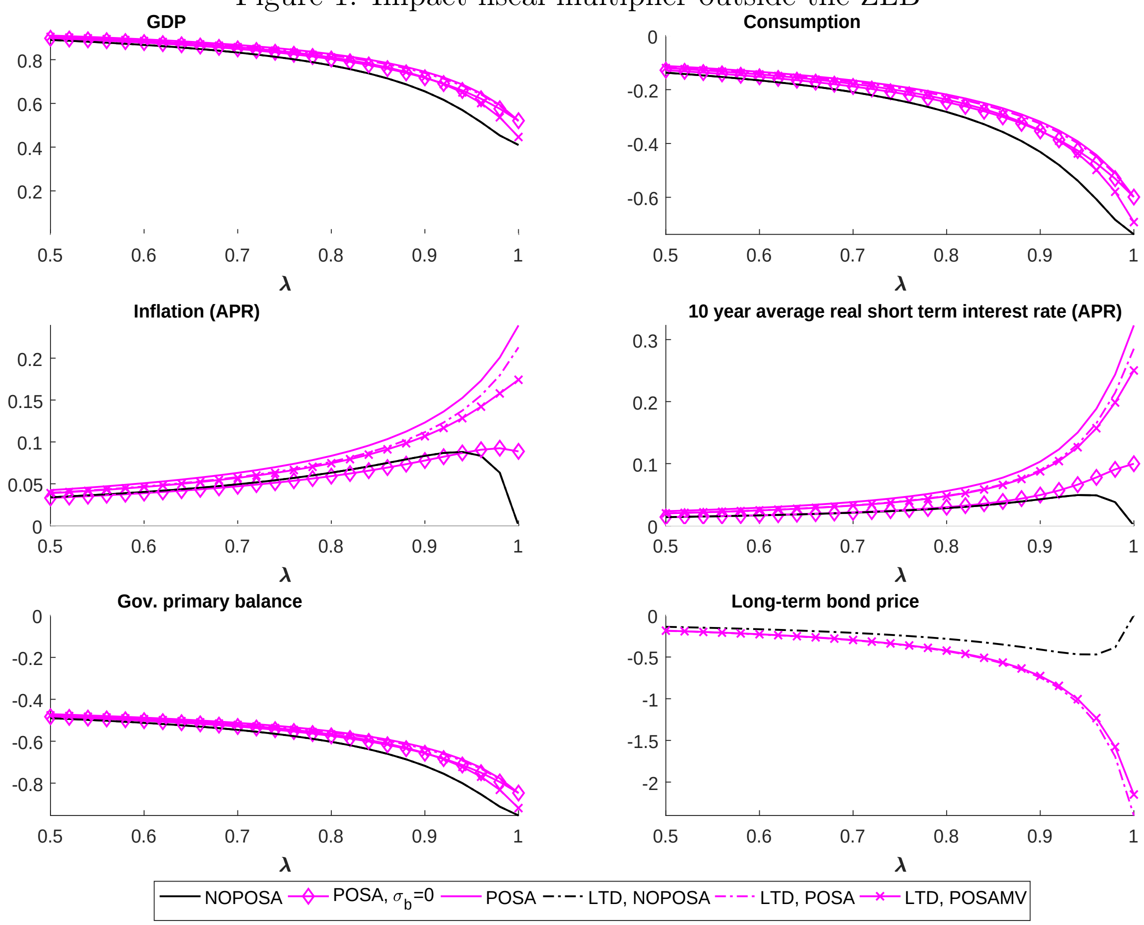
implied effect of a one percentage point permanent increase of the government debt-to-annual-GDP ratio on the real interet rate in the flexible price economy (i.e. the natural rate of interest) is consistent with the evidence of Gale and Orszag (2004), Engen and Hubbard (2004) and Laubach (2009). These authors find an effect of an increase in the debt-to-GDP ratio on the real interest rate between 0.03 and 0.06 percentage points. Furthermore, I compare the household's implied marginal propensity to save (MPS) out of an exogenous increase in their permanent-income, computed in a partial equilibrium simulation (following Kumhof et al. (2015), see Appendix B for details), to empirical estimates computed from Kumhof et al (2015) and Dynan et al. (2004). As can be obtained from Table 2, the implied MPS matches this evidence quite closely.

4 Government expenditure multiplier

4.1 Multiplier outside the ZLB

I first examine the impact effect of an increase in government spending outside the ZLB. Government spending follows an AR(1) process with persistence λ. As can be obtained from Figure 1, for all considered model variants, the more persistent the government spending increase, the stronger the crowding out of household consumption and thus the smaller the multiplier. However, with POSA, the decline in consumption is smaller and thus the increase in GDP larger. For instance, for the model with POSA developed above, a permanent increase in government expenditure increases GDP by 0.5, versus 0.4 without POSA (compare the magenta line and the the black solid line/ Table 4, line four, columns three and four, versus line two), while the real interest rate increases, even more so if there is curvature ($\sigma_b > 0$). The reasons is that for $\theta < 0.96$, households become less responsive to the rise in the monetary policy interest rate triggered by the fiscal expansion (see equation (7)), while $\sigma_b > 0$ implies a positive effect of the increase in government debt on consumption.

Figure 1: Impact fiscal multiplier outside the ZLB



Note: The graph displays the impact effect of increasing government expenditure by 1% of GDP outside the ZLB. Government expenditure follows an AR(1) process with persistence λ. The impact on GDP, consumption and the bond price are expressed as a percentage of their respective steady state value. The impact on inflation and the real interest rate are expressed in percentage points. The impact on the primary balance is expressed as a percentage of GDP. The calibration is as in Table 2, with $\sigma_b = 0.2$ unless otherwise mentioned. "POSA" refers to the model with preferences over safe assets and $\theta = 0.96$. "LTD" refers to the model with long-term government debt discussed in Section 4.4. "LTD, POSA" refers to the model with long-term government debt and preferences over the face value of government debt $b_{G,t} + b_{G,L,t}$, while "LTD, POSAMV|" refers the model with long-term debt and preferences over the market value of government debt $b_{G,t} + Q_{b,G,L,t}b_{G,L,t}$.

4.2 Multiplier during the ZLB: A "perfectly timed" expenditure change

I now examine the effect of an increase in government expenditure during the ZLB. For that purpose, I assume that an exogenous decline in the natural rate of interest hits the economy, implemented by assuming that $\varepsilon_{b,t}$ takes a positive value $\varepsilon_{b,L}$, with the superscript L denoting the "low state" of the economy, following Eggertsson (2008) and Woodford (2011). The associated decline in the natural rate is sufficiently big to reduce the policy rate to its lower bound for the complete duration of the low state. Furthermore, with probability μ_L, $\varepsilon_{b,t} = \varepsilon_{b,L}$ in the following quarter, while with probability $(1 - \mu_L)$, it will return to zero, and is expected to remain there forever. Throughout this section and the next, I will restrict the analysis to values of μ_L implying a stable and unique equilibrium. I then assume that government expenditure increases for the duration of the low state by $\hat{G}_L$. I assume the increase in government expenditure to be too small to achieve an exit of the economy from the ZLB.

Following Woodford (2011), I assume that after the exit from the low state, in each quarter there is a probability $1-\lambda$ that government expenditure returns to its steady state, and in this event is expected to remain there forever. Denoting this probability as λ is motivated by the fact that, as far as the effect on the economy in the low state is concerned, assuming that government expenditure returns to its steady state with probability λ is equivalent to assuming that post-low-state government expenditure follows an AR(1) process with persistence λ.

The effect of the assumed path for government expenditure on the economy is described by the following set of equations:

$$\begin{aligned} \hat{Y}_{L,t} - \hat{G}_L = \frac{1}{\tilde{\sigma}} \left[\theta \left[\left(\mu_L \hat{\Pi}_{L,t+1} + (1-\mu_L)\,\hat{\Pi}_{S,t+1} \right) \right] + (1-\theta) \frac{\tilde{\sigma}_b}{\tilde{\sigma}} \hat{b}_{G,L,t} \right] \\ + \theta \left(\mu_L \hat{Y}_{L,t+1} + (1-\mu_L)\,\hat{Y}_{S,t+1} \right) \\ - \theta \left((\mu_L + (1-\mu_L)\,\lambda)\,\hat{G}_L \right) \end{aligned} \tag{20}$$

$$\hat{\Pi}_{L,t} = \kappa(\hat{Y}_{L,t} - \Gamma \hat{G}_L) + \beta \left[\mu_L \hat{\Pi}_{L,t+1} + (1-\mu_L)\,\hat{\Pi}_{S,t+1} \right] \tag{21}$$

$$\hat{T}_{L,t} \;\; = \;\; \tau_b\,(1-\rho_{FIN})\,\hat{b}_{G,L,t-1} + \rho_{FIN} \hat{T}_{L,t-1}$$

$$\hat{b}_{G,L,t} = \frac{R}{\Pi}\hat{b}_{G,L,t-1} + \frac{b_G}{Y}\frac{R}{\Pi}\left(-\Pi_{L,t}\right) - \left(\hat{T}_{L,t} + \tau_w \frac{wN}{Y}\left(\hat{w}_{L,t} + \hat{N}_{L,t}\right) + \tau_C \frac{C}{Y}\hat{C}_{L,t}\right) \quad (22)$$

where the subscript L refers to the low state and the subscript $S, t+1$ refers to the value of the respective variable in the first quarter outside the low state, assuming that the economy has been in the low state in quarter t. Furthermore, a hat now refers to the effect of setting government expenditure to $\hat{G}_L$ on the deviation of the respective variable from its steady state.[4]

A useful special case is a version of the model with linear POSA ($\tilde{\sigma}_b = 0$), as under this assumption government debt does not matter for the equilibrium values of other variables and equations (20) and (21) simplify to

$$\hat{Y}_L - \hat{G}_L = \frac{\sigma\theta\left(\mu_L\hat{\Pi}_L + \lambda\left(1-\mu_L\right)\gamma_{\Pi G}\hat{G}_L\right) + \lambda\theta\left(1-\mu_L\right)\left(\gamma_{YG}-1\right)\hat{G}_L}{\left(1-\theta\mu_L\right)} \quad (23)$$

$$\hat{\Pi}_L = \frac{\kappa(\hat{Y}_L - \Gamma\hat{G}_L) + \lambda\beta\left(1-\mu_L\right)\gamma_{\Pi G}\hat{G}_L}{1-\beta\mu_L} \quad (24)$$

where $\gamma_{\Pi G}$ and γ_{YG} denote the effects of government expenditure on inflation and GDP outside the low state, as plotted in the left column of Figure 1.

I first consider the case of a stimulus expected to last exactly as long as the economy's low state, i.e. $\lambda = 0$ (which I will refer to as a "perfectly timed" expenditure change), and the special case of the model described by the aggregated demand and aggregate supply equation (23) and (24) (see Figure 2)). For $\theta = 1$, as shown by Woodford (2011), the multiplier is larger than one for $D_L > 1$ and increases exponentially in the expected duration of the low state D_L (see the black solid line), for the following reasons. With a zero probability of the low state persisting into the next quarter ($\mu_L = 0 \Longleftrightarrow D_L = 1$) increasing government expenditure leaves all $t+1$ variables unchanged. Hence the expected sum of future inflation and (since the nominal interest rate is fixed) real interest rates $\frac{\mu_L\hat{\Pi}_L}{(1-\theta\mu_L)}$ in the aggregate demand equation (23) remains at zero and thus private consumption does not increase. By contrast, if the low state and the fiscal expansion are expected to persist with some probability

[4]This reinterpretation of the hat notation allows me to drop $\hat{R}_{L,t}$ and r_L from the exposition, as they are by assumption unaffected by government expenditure.

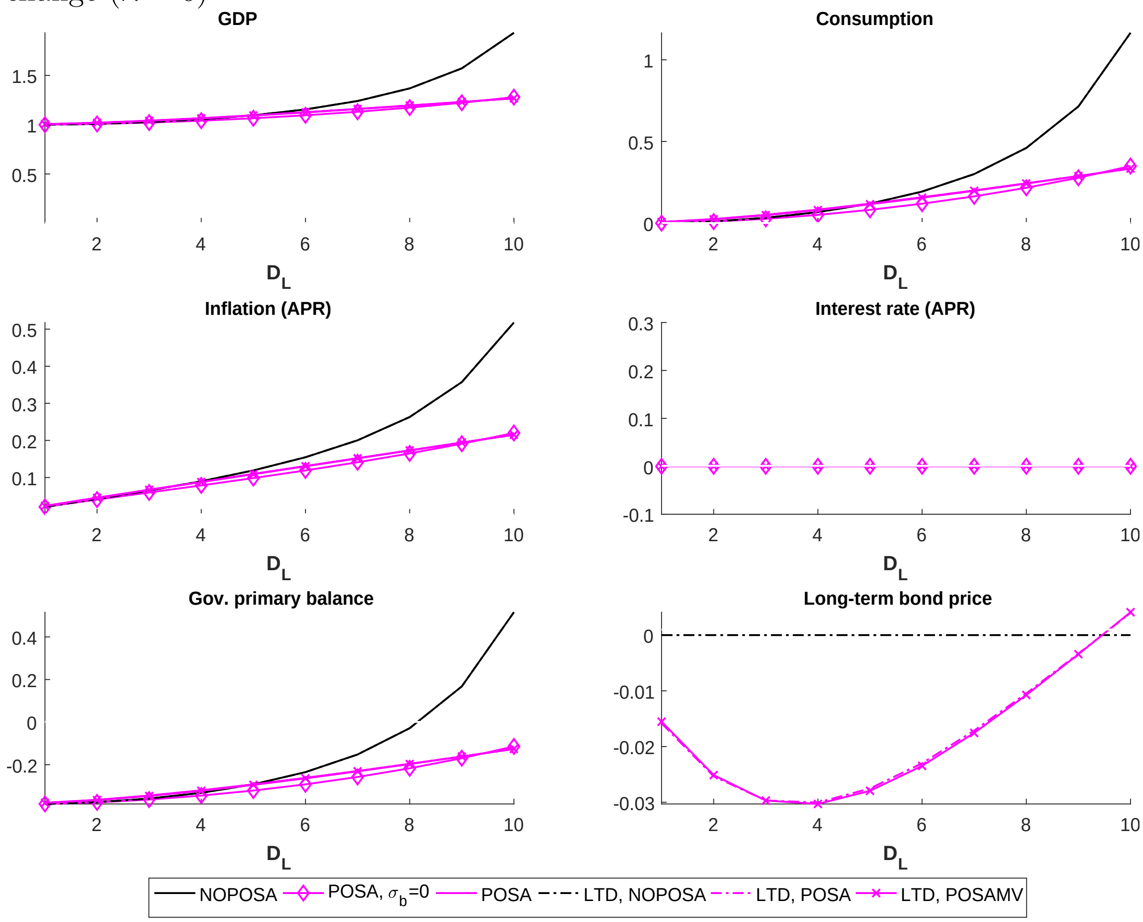
($\mu_L > 0 \Longleftrightarrow D_L > 1$), the expected sum of future real interest rates declines and unconstrained household consumption is crowded in. The associated higher GDP increases the expected sum of future output gaps $\frac{\kappa(\hat{Y}_L - \Gamma \hat{G}_L)}{1-\beta\mu_L}$ in the aggregate supply relation (24) and thus $\hat{\Pi}_L$, which feeds back into aggregated demand (24), thus accelerating the increase in $\frac{\mu_L \hat{\Pi}_L}{(1-\theta\mu_L)}$ and hence GDP. The interaction between these two infinite sums gives rise to the exponential relationship between the multiplier and D_L displayed in Figure 1 (the black solid line), which displays the impact effect of an increase of government expenditure of 1% of GDP.

However, the increase in the multiplier is smaller for $\theta < 1$ (see the magenta-diamond line). For instance, for $D_L = 10$, the multiplier equals 1.9 without preferences over wealth, but only 1.3 for $\theta = 0.96$. With $\theta < 1$, households attach an exponentially declining weight to future periods, implying that importance of future real interest rates for current consumption of forward looking households declines exponentially the further away from the current quarter they are located in time (see equation (23)). Lowering θ also lowers the effect of the future output gap on current inflation by lowering β (see equation 24), but the attenuation of this mechanism is quantitatively much less important.[5] Allowing for curvature in POSA ($\sigma_b > 0$) has only a small effect on the multiplier since the expected impact of the (temporary) fiscal expansion on real government debt is small.

As long as the economy remains in the low state, the macroeconomic effects of the fiscal expansion changes little over time (or not at all for $\theta = 1$ or $\sigma_b = 0$), as can be obtained from Appendix C for the case of $D_L = 8$. The same is true for the other variants of the simple model considered below. Therefore I limit the discussion in the main text to the impact effects and delegate the dynamic effects of the fiscal expansion to Appendix C.

[5]Results for a scenario where I fix the coefficient on expected inflation in the Phillips curve at its value for $\theta = 1$ when setting $\theta = 0.96$ are available upon request.

Figure 2: Impact fiscal multiplier during low state, perfectly timed expenditure change ($\lambda = 0$)



Note: The graph displays the impact effect of a government expenditure increase of 1% of GDP lasting exactly as long as the low state (i.e.$\lambda = 0$). The horizontal axis depicts the expected duration of the low state $D_L = \frac{1}{1-\mu_L}$. All other parameters are as in Table 2. For details on the legend and the units of the displayed variables see the note below Figure 1.

4.3 Multiplier during the ZLB: An expenditure increase outlasting the ZLB duration

I now examine the case where the increase in government expenditure is expected to persist beyond the duration of the low state (i.e. $\lambda > 0$). Outside the ZLB, an increase in government expenditure crowds out private consumption (Figure 1), the more so the more persistent it is expected to be, which via consumption smoothing tends to lower consumption during the low state. In equation (23), the expression

$\lambda\theta\,(1-\mu_L)\,(\gamma_{YG}-1)<0$ captures this mechanism. The expression is strictly negative as the fiscal multiplier outside the ZLB γ_{YG} is strictly smaller than one and declines in λ. Therefore, without POSA and assuming an expected ZLB length of 2 years ($D_L = 8$), and $\lambda = 0$, 0.8 and 1 (i.e. a permanent increase), the multiplier equals 1.4, 1.3 and 0.4, respectively (see the black solid line in Figure 3).

By contrast, with POSA, the multiplier is much less sensitive to increasing λ. For instance, with linear POSA ($\sigma_b = 0$, the magenta diamond line), values of $\lambda = 0$, 0.8 and 1 correspond to multipliers of 1.2, 1.1 and 0.8 (See also Table 4, line 3, columns five and six). The reason is that for $\theta < 1$, the household attaches a smaller weight to the low consumption/ high marginal utility of consumption state they will enter upon the exit from the low state and thus lower their consumption by less. Furthermore, there is also less consumption crowding out outside the low state if $\theta < 1$ (Figure 1). As a result of these mechanisms, the magnitude of the increase in inflation and the associated fall of the real interest rate during the low state also declines less in λ than for $\theta = 1$, which contributes to raising consumption relative to the NOPOSA case.

With declining marginal utility from safe assets (see the solid magenta line), the dependence of the multiplier on the persistence of the government expenditure increase is virtually eliminated. The increase in government debt associated with a persistent increase in government consumption increases the real wealth of unconstrained households, which has a direct positive effect on their consumption both inside (equation 20) and after the exit from the low state. As a result, for persistent expenditure increases, their consumption is higher than without curvature.

Hence with POSA, the multipliers of permanent and temporary changes in government expenditure during the ZLB become much more alike. Table 4a. summarizes this result by displaying the multipliers of both a perfectly timed and a permanent change in government consumption and an expected length of the ZLB state of 8 quarters (see row two and three, columns five and six).

Table 4: Impact fiscal multiplier of a government expenditure change

a. Simple model of Sections 2 and 4.4.

Preferences	**Fiscal rule**	**PC slope**	**Outside ZLB**	**Inside ZLB, $D_L = 8$**	
			ΔG_t permanent ($\lambda = 1$)	ΔG_t perfectly timed ($\lambda = 0$)	ΔG_t permanent ($\lambda = 1$)
NOPOSA ($\theta = 1$)	Lump-sum tax	constant	0.4	1.4	0.4
POSA, $\sigma_b = 0$	Lump-sum tax	constant	0.5	1.2	0.8
POSA, $\sigma_b = 0.2$	Lump-sum tax	constant	0.5	1.2	1.0
POSAMV, $\sigma_b = 0.2$	Lump-sum tax	constant	0.4	1.2	0.9
NOPOSA ($\theta = 1$)	Labor tax	constant	0.4	1.0	0.2
POSA, $\sigma_b = 0.2$	Labor tax	constant	0.5	1.2	1.0
POSAMV, $\sigma_b = 0.2$	Labor tax	constant	0.4	1.2	0.8
NOPOSA ($\theta = 1$)	Lump-sum tax	state-dependent	0.4	1.1	0.4
POSA, $\sigma_b = 0.2$	Lump-sum tax	state-dependent	0.5	1.1	0.9
POSAMV, $\sigma_b = 0.2$	Lump-sum tax	state-dependent	0.4	1.1	0.8

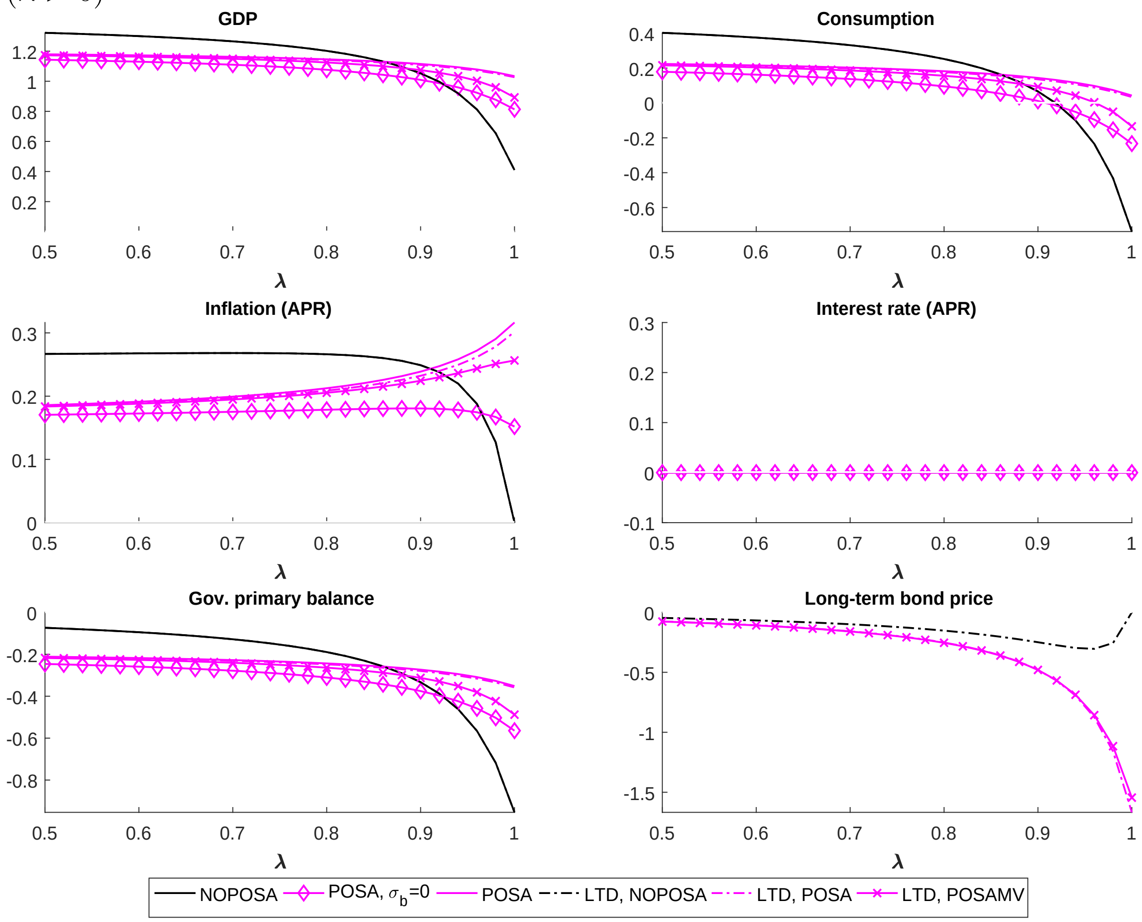
Note: Table a. displays impact fiscal multipliers under the assumption of an expected length of the low state of two years, using the simple model developed in Sections 2 and 4.4. The first column displays the type of POSA, and if applicable, the curvature parameter σ_b. "NOPOSA" indicates a model without preferences over safe assets. "POSA" indicates preferences over safe assets and $\theta = 0.96$. "POSAMV" indicates preferences over the market value of government debt in the model with long term debt (see Section 4.4). The column "Fiscal rule" displays the fiscal instrument adjusted by the fiscal rule (either the lump-sum tax (i.e. equation (13) holds) or the distortionary labor tax (equation (36)). The column "PC slope" indicates whether the Phillips curve slope κ is assumed to be constant or state dependent (see Appendix D for details). The column "Outside ZLB" ("Inside ZLB") contains government expenditure multipliers outside the ZLB (inside the ZLB, expected duration D_L of 8 quarters). The label "ΔG_t permanent" ("ΔG_t perfectly timed") refers to an expenditure change expected to be permanent (lasting exactly as long as the ZLB period).

b. Medium scale model of Section 5.

Preferences	**Credit constraints**	**Outside ZLB**	**Inside ZLB, $D_L = 8$**	
		ΔG_t permanent ($\lambda = 1$)	ΔG_t perfectly timed ($\lambda = 0$)	ΔG_t permanent ($\lambda = 1$)
NOPOSA($\theta = 1$)	NO	0.4	1.8	0.1
NOPOSA($\theta = 1$)	YES	0.4	3.8	0.5
POSAMV, $\sigma_b = 0.2$	NO	0.4	1.6	1.2
POSAMV, $\sigma_b = 0.2$	YES	0.5	3.3	2.9

Note: Table b. displays impact fiscal multipliers under the assumption of an expected length of the low state of two years, using the medium scale model developed in Section 5. The first column displays the type of POSA (see the note below Table a. for further details). The column "credit constraints" indicates the presence or absence of credit constrained households and firms.

Figure 3: Impact fiscal multiplier during low state, persistent expenditure increase ($\lambda > 0$)



Note: The graph displays the impact effect of increasing government expenditure by 1% of GDP inside the low state, with $D_L = 8$ (i.e. $\mu_L = 0.875$). The horizontal axis displays the probability λ that the increase persists after the economy's exit from the low state. All other parameters are as in Table 2. For details on the units of the displayed variables see the note below Figure 1.

4.4 Results with preferences over long-term government debt

I now examine the effect of adopting a more realistic maturity structure of government debt, and assuming that household have preferences over the market value of long-term government bonds. This case is of relevance for two reasons. Firstly, with POSA, an increase in government expenditure outside the ZLB increases the short-term interest rate, as illustrated in Figure 1. In the presence of traded long-term debt, this increase would be expected to depress the market value of government debt, which in itself would tend to lower consumption if households have preferences over the market value of government debt. Secondly, Rannenberg (2019) shows that the impact of POSA on the effect of standard shocks typically used in the DSGE literature is small if the model features long-term government debt.

Specifically, I follow Krause and Moyen (2016) and assume that public debt consists of stochastic long-term bonds. In each period such a bond pays the interest rate determined when the bond was issued, and, with a fixed probability ω_{LTD}, matures and in that event pays back the principal. Since the government issues a large number of these bonds each quarter, the probability that an individual bond matures equals the fraction of all bonds maturing each quarter in total outstanding bonds. The total real amount of outstanding stochastic bonds $b_{G,L,t}$ is thus determined by

$$b_{G,L,t} = (1 - \omega_{LTD}) \frac{b_{G,L,t-1}}{\Pi_t} + b_{G,L,n,t} \tag{25}$$

where $b_{G,L,n,t}$ denotes total newly issued stochastic bonds. The nominal average interest rate on the total amount of outstanding stochastic bonds $R_{G,L,t}$ is determined by

$$(R_{G,L,t} - 1)\, b_{G,L,t} = (1 - \omega_{LTD}) \frac{(R_{G,L,t-1} - 1)}{\Pi_t} b_{G,L,t-1} + (R_{G,L,n,t} - 1)\, b_{L,n,t} \tag{26}$$

where $R_{G,L,n,t}$ denotes the market interest rate on stochastic bonds issued in period t (see Krause and Moyen (2016) for details). Following Krishnamurthy and Vissing-Jorgenson (2012), I assume that households derive utility from the total market value of government debt $b_{G,t} + Q_{b,G,L,t} b_{G,L,t}$ (as in Rannenberg (2019)), where $Q_{b,G,L,t}$ denotes the market value of a unit of outstanding long-term debt. However, I will also report results for the case where household have preferences over the face value of government debt $b_{G,t} + b_{G,L,t}$.

The household's objective and budget constraint are therefore given by

$$E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \frac{\chi_N}{1+\eta} N_{t+i}^{1+\eta} + \frac{\chi_b}{1-\sigma_b} \left(b_{G,t+i} + Q_{b,G,L,t+i} b_{G,L,t+i} \right)^{1-\sigma_b} \right] \right\} \tag{27}$$

$$b_{G,t} + b_{G,L,n,t} + (1+\tau_C)\, C_t = \frac{R_{t-1}}{\Pi_t} b_{G,t-1} + \frac{(R_{L,t-1} - 1 + \omega_{LTD})}{\Pi_t} b_{G,L,t-1} + (1-\tau_w)\, w_t N_t - T_t + \Xi_t \tag{28}$$

Households maximize (27) subject to (28), (25) and (26), by choosing C_t, N_t, $b_{G,t}$, $b_{G,L,t}$, $b_{G,L,n,t}$ and $R_{G,L,t}$.[6] The FOCs with respect to $b_{G,t}$, $b_{G,L,t}$, $R_{G,L,t}$ and $b_{G,L,n,t}$ imply:

$$\Lambda_t = \beta E_t \left\{ \Lambda_{t+1} \frac{R_t}{\Pi_{t+1}} \right\} + \chi_b \left(b_{G,t} + Q_{b,G,L,t} b_{G,L,t} \right)^{-\sigma_b} \tag{29}$$

$$\Lambda_t = \beta E_t \left\{ \Lambda_{t+1} \frac{R_{L,n,t} - \mu_{t+1} \left(1-\omega_{LTD}\right) \left(R_{L,n,t+1} - R_{L,n,t}\right)}{\Pi_{t+1}} \right\} + Q_{b,G,L,t} \chi_b \left(b_{G,t} + Q_{b,G,L,t} b_{G,L,t} \right)^{-\sigma_b} \tag{30}$$

$$\mu_{RGL,t} = \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{1}{\Pi_{t+1}} \left[1 + \mu_{RGL,t+1} \left(1-\omega_{LTD}\right) \right] \right\} \tag{31}$$

$$\mu_{bGL,t} = \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{1}{\Pi_{t+1}} \left[\omega_{LTD} + \left(1-\omega_{LTD}\right) \mu_{bGL,t+1} \right] \right\} + \frac{Q_{b,G,L,t} \chi_b \left(b_{G,t} + Q_{b,G,L,t} b_{G,L,t} \right)^{-\sigma_b}}{\Lambda_t} \tag{32}$$

where $\mu_{RGL,t}$ and $\mu_{bGL,t}$ denote the Lagrange multipliers on the law of motions of the average interest rate (26) and total long-term government bonds (25), respectively. These equations are identical to Krause and Moyen except for the term reflecting the marginal utility of government bonds $\chi_b \left(b_{G,t} + Q_{b,G,L,t} b_{G,L,t} \right)^{-\sigma_b}$ in equations (29) and (30). The FOC with respect to short-term bonds (29) is identical to equation (3) above, except for the marginal utility of short-term bonds, which now depends on the total market value of short-term and long-term bonds $b_{G,t} + Q_{b,G,L,t} b_{G,L,t}$. Equations (29) to (31) determine private consumption and the interest rate on newly issued

[6] The reason that the average interest rate on the households bond portfolio $R_{G,L,t}$ is a choice variable is that it is affected by the households purchases of newly issued bonds $b_{L,n,t}$. By contrast, the market interest rate on newly issued bonds $R_{G,L,n,t}$ is taken as given by the household (see Krause and Moyen (2016)).

long-term bonds $R_{L,n,t}$ given the expected paths of the short-term nominal interest rate, inflation, and the supply of total real government bonds $b_{G,t} + Q_{b,G,L,t} b_{G,L,t}$. Since the Lagrange multiplier $\mu_{b,GL,t}$ represents the value of an additional unit of the portfolio of long-term bonds to the household, it follows that

$$\mu_{b,GL,t} = Q_{b,G,L,t} \tag{33}$$

Clearly, with POSA, an increase in the bond price $Q_{b,G,L,t}$ would tend to increase consumption via (29). $Q_{b,G,L,t}$ in turn depends negatively on current and expected future nominal short-term interest rates, which can be shown by linearizing and combining equations (30), (32) and (33):

$$\hat{Q}_{b,G,L,t} = -\hat{R}_t + \frac{(1 - \omega_{LTD})\, E_t \hat{Q}_{b,G,L,t+1}}{R} \tag{34}$$

Following Krause and Moyen (2016), I assume that one quarter government debt is now in zero net supply, i.e. $b_{G,t} = 0$, implying that the government budget constraint becomes

$$b_{G,L,t} = \frac{R_{G,L,t-1}}{\Pi_t} b_{G,L,t-1} + G_t - (T_t + \tau_w w_t N_t + \tau_C C_t) \tag{35}$$

which differs from its counterpart in the model with one quarter debt (12) only in that for $\omega_{LTD} < 1$, the (average) interest rate on t-1 government debt $R_{G,L,t-1}$ no longer equals the $t-1$ policy rate, but equals instead a weighted average of interest rates on bonds issued in all past periods (i.e. $R_{G,L,n,t-1}$, $R_{G,L,n,t-2}$ etc., see equation (26)).[7]

As can be obtained from Figures (1) to (3), allowing for long-term government debt does not change the results without POSA or with preferences over the face value of total government debt (compare the black solid and dashed dotted lines, and the magenta solid and dashed-dotted lines). However, with long-term debt, an increase in government expenditure outside the ZLB (see Figure 3) reduces the price of long-term government bonds (see the lower right panel, the magenta dashed dotted and crossed

[7] This equation can be obtained by combining the government budget constraint expressed in terms of newly issued debt, given by $b_{G,n,t} = \frac{(R_{L,t-1} - 1 + \alpha)}{\Pi_t} b_{G,t-1} + G_t - (T_t + \tau_w w_t N_t + \tau_C C_t)$, which corresponds to equation (13) in Krause and Moyen (2016), with equation (25).

lines). With preferences over the market value of government debt (POSAMV), this decline slightly increases the crowding out of private consumption. For an increase government expenditure during the ZLB, but outlasting it with persistence λ, a decline in the market price of government debt outside the ZLB depresses it also inside the ZLB (see Figure 1). With POSAMV, the multiplier is therefore slightly reduced. For instance, for $\lambda = 1$, it declines from 1 with POSA to 0.9 with POSAMV (compare the fourth and fifth row of Table 4a., final row, respectively). Hence even with preferences over the market value of safe assets, it remains the case that with POSA, the multipliers of permanent and temporary government expenditure changes during the ZLB become more alike.

4.5 Results with distortionary taxation in the fiscal rule

I now assume that the fiscal rule (13) adjusts distortionary labor taxes instead of lump-sum taxes, implying that equation (13) is replaced by

$$\hat{\tau}_{w,t} = \tau_b \left(1 - \rho_{FIN}\right) \hat{b}_{G,t-1} + \rho_{FIN} \hat{\tau}_{w,t} \tag{36}$$

It turns out that this modification has only marginal effects on the effect of increasing government expenditure outside the low state, the results are therefore omitted. By contrast, for the perfectly timed expenditure increase in the low state, without POSA the multiplier is much lower in the presence of distortionary taxation than without (see Figure 4, the solid black line vs. the dotted black line). The reason why putting distortionary taxation instead of lump-sum taxation into the fiscal rule reduces the multiplier may be understood as follows. With lump-sum taxes in the fiscal rule, for an expected length of the low state D_L exceeding 7 quarters, real government enters a downward trajectory lasting as long as the economy is in the low state as a consequence of increased taxes revenues and higher inflation. With NOPOSA and lump-sum tax adjustment, the expected decline of government debt and thus taxes is irrelevant for the equilibrium values of the other variables. By contrast, with distortionary taxation in the fiscal rule, such a downward trajectory of debt would tend to persistently reduce the labor tax rate $\tau_{w,t}$, the more so the longer the economy remains in the low state. However, such an expected persistent decline in the labor tax rate would lower the expected marginal cost trajectory and thus inflation, implying that the real interest would decline much less than with adjustment of lump-sum taxes, implying that consumption would also be lower. Therefore the equilibrium values of inflation and consumption are much lower with distortionary taxation in the fiscal rule than without.[8] By contrast, with POSA the effect of putting distortionary taxation into the fiscal rule is marginal.

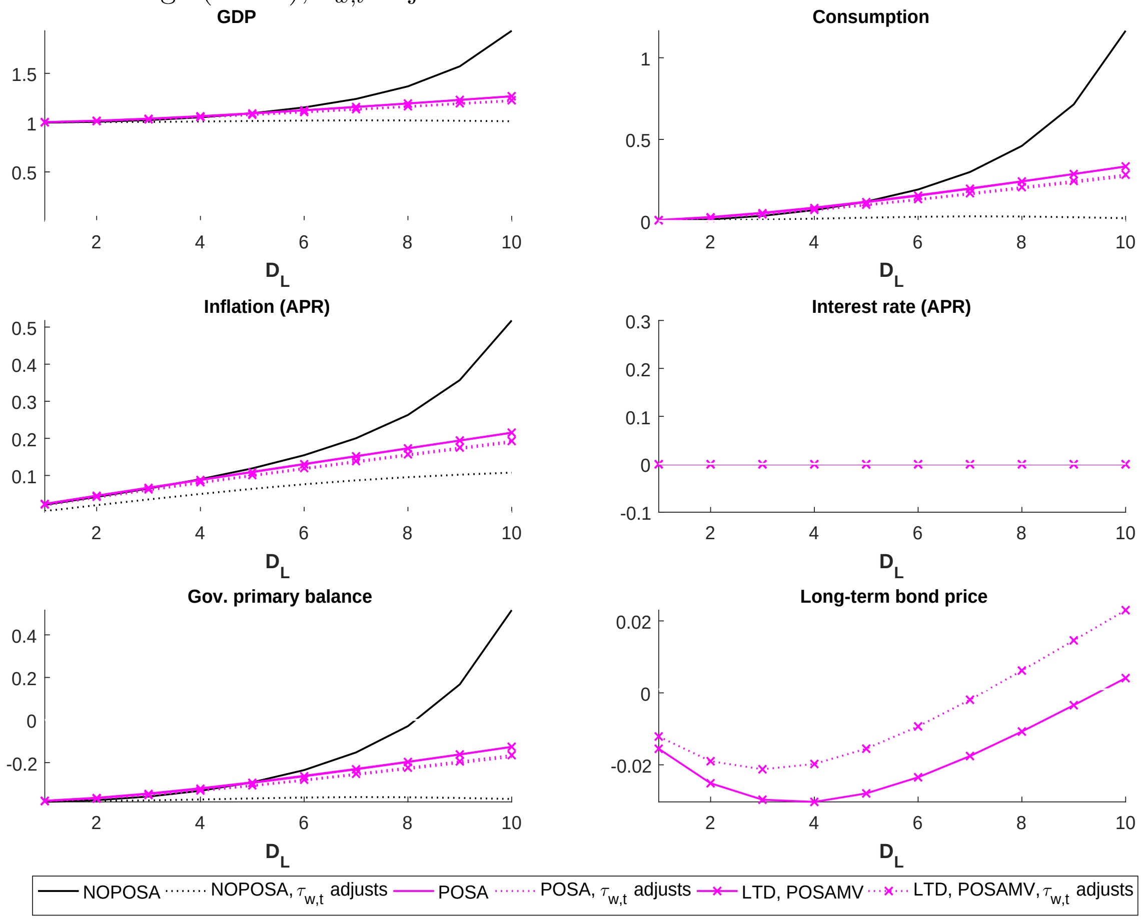
For a highly persistent increase in government expenditure (see Figure 5), with NOPOSA the multiplier is substantially smaller than with POSA due to the negative permanent-income effect discussed above. With distortionary taxation, this negative permanent-income effect is even stronger because the fiscal expansion now implies a persistently higher labor tax rate. Outside the low state, these tax dynamics imply persistently lower labor supply than with lump-sum tax adjustment and thus lower consumption. Correspondingly, due to consumption smoothing consumption declines even more during the low state than with lump-sum tax adjustment. Hence with NOPOSA, the multiplier of a permanent government expenditure increase declines from 0.4 to 0.2 (compare the second and sixth row of Table 4a., column six). By contrast, POSA virtually eliminates this additional permanent-income effect on consumption during the ZLB, for the same reasons that it attenuates the permanent-income effect of a larger future overall tax burden. Therefore the effect of assuming labor tax adjustment on the fiscal multiplier is small with POSA.

5 Medium scale model with credit constraints

In this section I show that the above results become even stronger in the presence of credit constrained households and firms. Since most of the model elements are standard, I only describe some key elements and relegate a detailed description and the calibration to Appendix E. As in Section 4.4, I assume that unconstrained households have preferences over the market value of their safe assets and that there are

[8] Correspondingly, if I assume that that outside the ZLB, the central bank implements a perfect inflation target instead of following equation (14), putting distortionary taxation into the fiscal rule does not change the result.

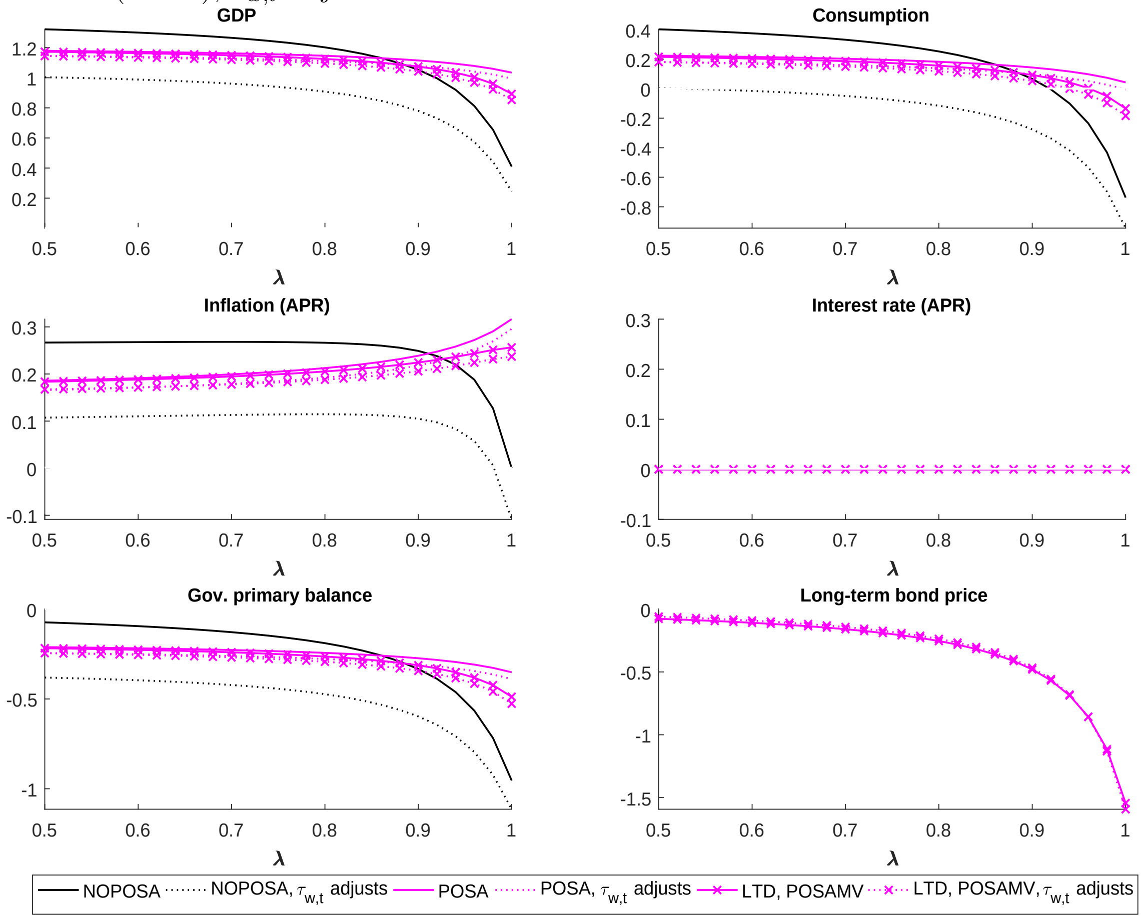
Figure 4: Impact fiscal multiplier during the low state, perfectly timed gov. expenditure change ($\lambda = 0$), $\tau_{w,t}$ adjusts



Note: The graph displays the impact effect of a government expenditure increase of 1% of GDP lasting exactly as long as the low state (i.e.$\lambda = 0$). The horizontal axis depicts the expected duration of the low state $D_L = \frac{1}{1-\mu_L}$. All other parameters are as in Table 2. "LTD" refers to the model with long-term government debt discussed in Section 4.4. "LTD, POSAMV|" refers the model with long-term debt and preferences over the market value of government debt $b_{G,t} + Q_{b,G,L,t} b_{G,L,t}$. "$\tau_{w,t}$ adjusts" refers to the case where the fiscal rule is given by equation (36), otherwise the fiscal rule is given by equation (13). For more details on the legend and the units of the displayed variables, see the note below Figure 1.

long-term government bonds. Household's one quarter safe assets b_t now include both short term government debt $b_{G,t}$ and financial intermediary deposits $b_{E,t}$ (i.e. $b_t = b_{G,t} + b_{E,t}$). Hence their objective is given by

Figure 5: Impact fiscal multiplier during the low state, persistent expenditure increase($\lambda > 0$), $\tau_{w,t}$ adjusts



Note: The graph displays the impact effect of increasing government expenditure by 1% of GDP inside the low state, with $D_L = 8$ (i.e. $\mu_L = 0.875$). The horizontal axis displays the probability λ that the stimulus persists after the economy's exit from the low state. All other parameters are as in Table 2. For details on the units of the displayed variables see the note below Figure 1.
"LTD" refers to the model with long-term government debt discussed in Section 4.4. "LTD, POSAMV|" refers the model with long-term debt and preferences over the market value of government debt $b_{G,t} + Q_{b,G,L,t}b_{G,L,t}$. "$\tau_{w,t}$ adjusts" refers to the case where the fiscal rule is given by equation (36), otherwise the fiscal rule equals (13).

$$E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{S,t+i}^{1-\sigma}}{1-\sigma} - \frac{\chi_N}{1+\eta} N_{t+i}^{1+\eta} + \frac{\chi_b}{1-\sigma_b} \left(b_{t+i} + Q_{b,G,L,t+i} b_{G,L,t+i} \right)^{1-\sigma_b} \right] \right\} \qquad (37)$$

Regarding the labor market, I assume that unconstrained households set their wage in a monopolistically competitive labor market where they face wage adjustment costs of the form $\frac{\xi_W}{2}\left(\frac{W_{S,t}}{W_{S,t-1}}\frac{1}{\Pi}-1\right)^2 N_{S,j}w_{S,t}$, where $W_{S,t}$ denotes the nominal wage. Hence their FOCs are analogous to equations (29) to (32), except that $b_{G,t}$ is replaced by b_t. Furthermore, up to first order, their wage setting is governed by the familiar New Keynesian wage Phillips Curve

$$\hat{w}_{S,t} = \frac{1}{1+\beta_S}\left(\kappa_w\left(\eta\hat{N}_{S,t}+\sigma_S\hat{C}_{S,t}-\hat{w}_{S,t}\right)+\beta_S E_t\hat{w}_{S,t+1}+\beta_S E_t\hat{\Pi}_{t+1}+\hat{w}_{S,t-1}-\hat{\Pi}_t\right) \tag{38}$$

where $\kappa_w >$ depends negatively on the degree of wage adjustment costs ξ_W.

Constrained households may only consume their disposable income. They have preferences over consumption $C_{CC,t}$ and labor $N_{CC,t}$ of the same form as unconstrained households, and face the same type of wage adjustment costs. Their wage setting is thus analogous to unconstrained households.

The economy's capital stock is owned by risk neutral entrepreneurs modeled as in Bernanke et al. (1999) and Christiano et al. (2010), who rent it to retailers producing the output good. They fund the capital stock using their own net worth and loans from a financial intermediary. Their borrowing is subject to a costly state verification (CSV) problem which implies positive relationship between the spread of the entrepreneur's expected return on capital $E_t\widehat{R}^K_{t+1}$ over the risk free rate $\widehat{R}_t$ and entrepreneurial leverage $\hat{\phi}_{E,t}$

$$E_t\widehat{R}^K_{t+1}-\widehat{R}_t = \chi_E\hat{\phi}_{E,t} \tag{39}$$

where $\chi_E > 0$ if default is costly. $E_t\widehat{R}^K_{t+1}-\widehat{R}_t$ is typically referred to as the cost of external finance. In the short run, leverage and thus $E_t\widehat{R}^K_{t+1}-\widehat{R}_t$ are mainly driven by fluctuations in the value of an additional unit of capital Q_t, since an increase in Q_t boosts entrepreneurial net worth and thus reduces leverage and the $E_t\widehat{R}^K_{t+1}-\widehat{R}_t$. A decline in $E_t\widehat{R}^K_{t+1}$ implies that the entrepreneur discounts future rental income from capital less heavily, which tends to raise Q_t further. Entrepreneurs die with a fixed probability, and in that event consume their net worth, implying that an increase in Q_t also raises their consumption $C_{E,t}$. Further details on the entrepreneurial sector can be obtained from Appendix E.3. Entrepreneurs buy new capital goods from capital goods producers (see Appendix E.4 for details).

I assume that the government adjusts the distortionary labor tax to ensure debt-stationarity (i.e. the fiscal rule is given by 36). Finally, total consumption expenditure and GDP given by

$$Y_t \left(1 - \frac{\xi_P}{2}\left(\frac{\Pi_t}{\Pi} - 1\right)^2\right) = C_{S,t} + C_{CC,t} + C_{E,t} + I_t + G_t + \frac{\xi_W}{2}\left(\frac{W_{CC,t}}{W_{CC,t-1}}\frac{1}{\Pi} - 1\right)^2 N_{CC,t}\frac{W_{CC,t}}{P_t} + \frac{\xi_W}{2}\left(\frac{W_{S,t}}{W_{S,t-1}}\frac{1}{\Pi} - 1\right)^2 N_{S,t}\frac{W_{S,t}}{P_t}$$

where I_t denotes investment.

The calibration of POSA is analogous to the simple model, in that I keep the target value of $\theta = 0.96$ (see Section 3) and continue to assume $\sigma_b = 0.2$. For details on the calibration, see Appendix E.6.

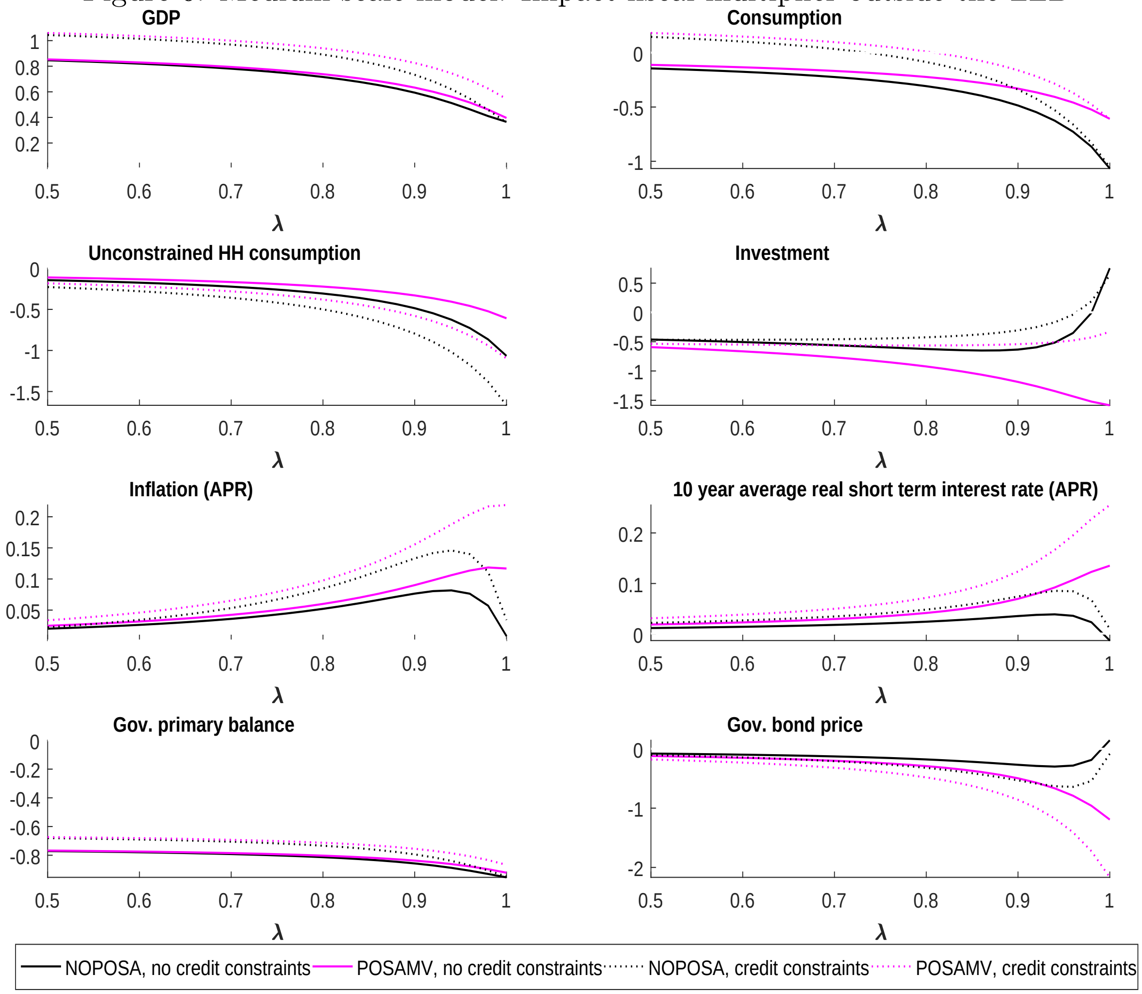
5.1 Results

I compute results for the following model variants. "credit constraints" refers to the model just described. By contrast, "no credit constraints", refers to a model without credit constraints on the firm side (in particular, $\chi_E = 0$), no credit constrained households and no entrepreneurial consumption ($C_{CC,t} = C_{E,t} = 0$), i.e. the wealth of dying entrepreneurs is transferred to saver households. Thus in the absence of POSA, the "no credit constraints" case is equivalent to a model where capital accumulation is conducted by a representative household.

Without POSA, outside the ZLB the fiscal expansion crowds out private consumption and investment (though a permanent government expenditure increase may crowd in investment). Adding POSA to the model without credit constraints has little effect on the multiplier outside the ZLB (See Figure 6, the solid magenta and black lines, and Table 4b., column three, compare rows two and four of). However, POSA implies substantially less crowding out of private consumption, compensated by a much larger crowding out of private investment due the increase in the expected safe real interest rate, which is passed on to entrepreneurs.

Furthermore, without POSA, adding credit constraints increases the multiplier

Figure 6: Medium scale model: Impact fiscal multiplier outside the ZLB

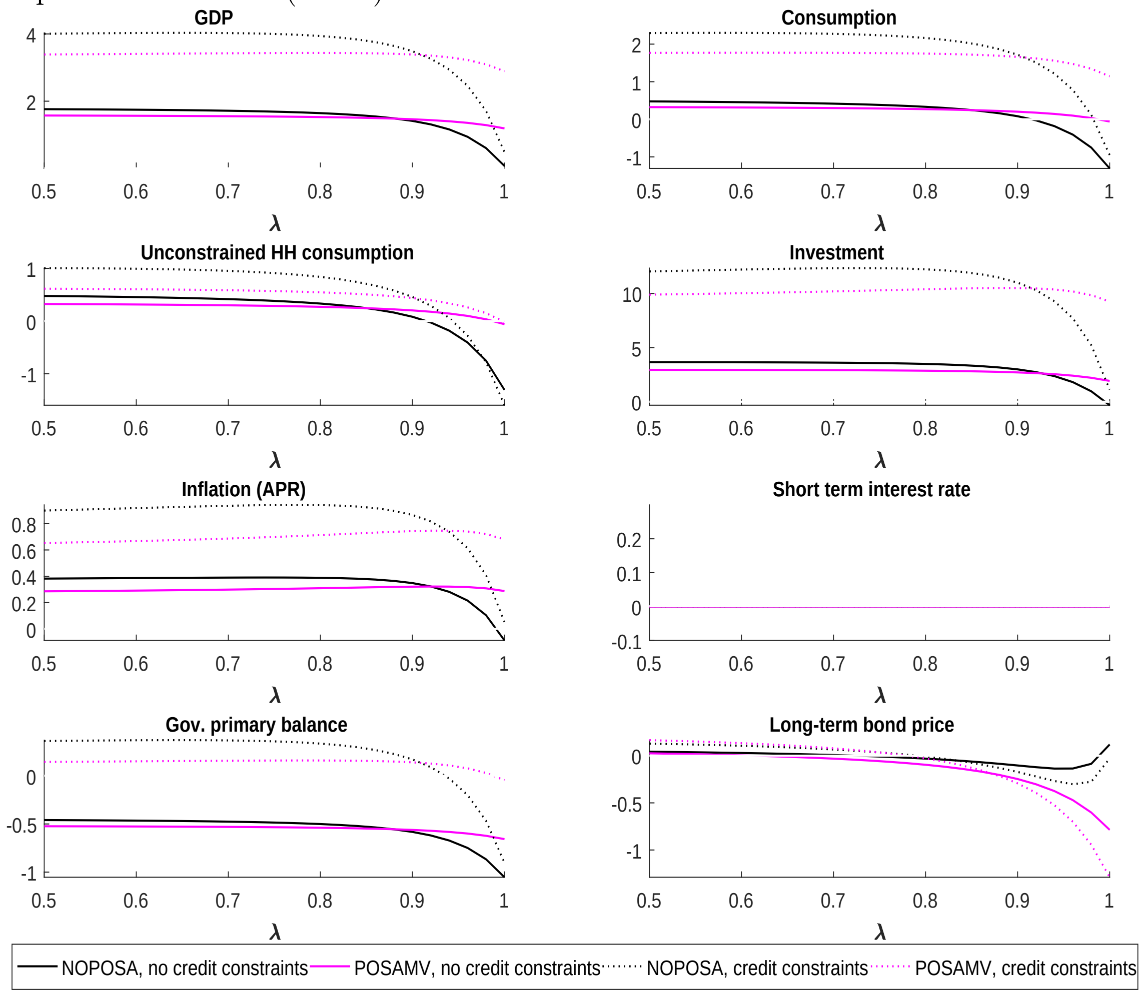


Note: The graph displays the impact effect of increasing government expenditure by 1% of GDP outside the ZLB. Government expenditure follows an AR(1) process with persistence λ. The impact on GDP, consumption, investment and the bond price are expressed as a percentage of their respective steady state value. The impact on inflation and the real interest rate are expressed in percentage points. The primary balance is expressed as a percentage of GDP. The calibration is as in Table 5. "POSAMV" refers to the case with long-term debt and preferences over the market value of safe assets $b_t + Q_{b,G,L,t} b_{G,L,t}$, as discussed in section 5. "no credit constraints" refers the case of zero bankruptcy costs and thus no financial accelerator ($\chi_E = 0$) and no credit constrained households ($\alpha_{CC} = 0$), as well as no entrepreneurial consumption. "credit constraints" indicates the presence of credit constrained households and firms.

only if the increase in government expenditure is not too persistent (compare the black solid and the black dotted line). For $\lambda = 1$, the multiplier remains virtually unchanged, due to a substantially larger crowding out of unconstrained household consumption than in the absence of credit constraints, triggered by the consumption increase of credit constrained households and entrepreneurs in response to the fiscal expansion. By contrast, with POSA, the increase in the crowding out of unconstrained household consumption associated with adding credit constraints is smaller than without POSA. Furthermore, credit constraints strongly reduce the crowding out of investment expenditure observed with POSA, as the decline in entrepreneurial leverage caused by higher revenues and a smaller capital stock reduce the pass-through of the higher real risk free rate to the expected return on capital $E_t\hat{R}_{K,t+1}$ (see equation 39), thus raising investment relative to the scenario without credit constraints (where $E_t\hat{R}_{K,t+1} = \hat{R}_t$). Without POSA, there is no such boost to investment from credit constraints because unlike with POSA, the safe real rate does not increase in the first place.

For a perfectly timed increase during the ZLB credit constraints strongly increase the fiscal multiplier, in line with Freedman et al. (2010) and Carrillo and Poilly (2013), both with and without POSA (see Table 4b., column 4, compare row two and three. For results on other variables, see Figure 14). For an expenditure increase outlasting the ZLB (see Figure 7), I continue to find that in the absence of POSA, the multiplier declines strongly for high persistence ($\lambda > 0.9$), and especially steeply in the presence of credit constraints, equaling 3.8 for a perfectly timed and 0.5 for a permanent expenditure increase (see Table 4b., row three, columns four and five). By contrast, the observed decline of the multiplier is much more moderate with POSA, implying multipliers of 3.3 and 2.9 for a perfectly timed and a permanent expenditure increase, respectively (see row five of Table 4b., columns four and five) Thus for a permanent expenditure increase, adding credit constraints raises the multiplier by 2.7 with vs. 0.4 without POSA. The reason for the differential impact of credit constraints for high λ is as follows. As discussed above, adding credit constrained households and firms increases the crowding out of unconstrained household consumption outside the ZLB, but less so with POSA. Furthermore, with POSA, a given crowding out of unconstrained household consumption outside the ZLB has a smaller effect on on consumption within the low state due to the attenuation of consumption smoothing implied by POSA. The associated higher trajectories of unconstrained household consumption and inflation also tend to raise investment, as well as constrained household consumption due to higher employment. Moreover, as discussed above, with POSA, credit constraints raise the value of physical capital Q_t outside the low state(by limiting the pass-through from the (permanently higher) safe interest rate$\hat{R}_t$ to $\hat{R}_{K,t}$), thus boosting it inside the low state as well.

Figure 7: Medium scale model: Impact fiscal multiplier during low state, persistent expenditure increase($\lambda > 0$)



Note: The graph displays the impact effect of increasing government expenditure by 1% of GDP inside the ZLB, with $D_L = 8$ (i.e. $\mu_L = 0.875$). The horizontal axis displays the probability λ that the stimulus persists after the economy's exit from the low state. For details on the units of the variables and the meaning of the legend see the note below Figure 6.

6 Conclusion

I examine the effect of fiscal policy at the ZLB if households have preferences over safe assets (POSA). I calibrate the model consistent with evidence on household saving behavior and individual discount rates and the effect of the supply of US government debt on government bond yields. POSA attenuate the effect of changes in the household's permanent income on her consumption today, and implies a consumption wealth effect from her government bond holdings. POSA therefore strongly increases the multiplier of a permanent expenditure change, moving it much closer to the multiplier of temporary expenditure changes. This result becomes even stronger with credit constrained households and firms, in the sense that with POSA, credit constraints strongly increase the multiplier regardless of whether the increase in government expenditure is permanent or temporary, while without POSA the increase is much smaller for permanent expenditure changes. Part of the reason is that, without POSA, adding credit constrained households and firms increases the crowding out of unconstrained household consumption even more, but not with POSA.

The result that fiscal multipliers may be much less dependent on the path of government expenditure has important implications for fiscal policy during economic downturns. More specifically, one of the arguments in favor of "front-loaded" permanent expenditure cuts has been that the expectation of a lower future tax burden would induce households to spend more if the expenditure cut is credible, thus substantially muting the adverse effect. My results show that this optimistic assessment does not hold with POSA parameterized in line with microeconomic evidence on intertemporal choices and macro-evidence on the relationship between government debt and interest rates.

References

[1] Ausubel, L. M. (1991), The Failure of Competition in the Credit Card Market, in: American Economic Review, Volume 81(1) pp., 50–81.

[2] Blanchard, O./ Erceg, C./ Linde J. (2016), Jump-Starting the Euro Area Recovery: Would a Rise in Core Fiscal Spending Help the Periphery?, mimeo.

[3] Calvo, G. A. (1983), Staggered prices in a utility-maximizing framework, in: Journal of Monetary Economics, 12, pp. 383-398.

[4] Carrillo, J. A./Poilly, C. (2013), How do financial frictions affect the spending multiplier during a liquidity trap? Review of Economic Dynamics, Vol. 16(2), pp. 296-311.

[5] Carlstrom, C. T./ Fuest, Timothy S./ Paustian, M. (2015), Inflation and output in New Keynesian models with a transient interest rate peg, in: Journal of Monetary Economics, Vol. 76, pp. 230-243.

[6] Christiano, L./ Eichenbaum, M./ Rebelo, (2011), When Is the Government Spending Multiplier Large?, in: Journal of Political Economy Vol. 119 (1), pp. 78-121.

[7] Cummins, J. G./ Hassett, K. A./ Olinder, S. D. (2006), Investment Behavior, Observable Expectations, and Internal Funds, in: The American Economic Review, Vol. 96(3), pp. 796-810.

[8] Cylke, S./ Goldberg, M. S./ Hogan, P./ Mairs, L. (1982), Estimation of the Personal Discount Rate: Evidence from Military Reenlistment, Center for Naval Analyses, Professional Paper 356.

[9] Del Negro, M./ Giannoni, M./ Patterson, Christina (2015), The Forward Guidance Puzzle, in: FRBNY Staff Reports No. 574.

[10] Eggertsson, Gauti (2008), Great Expectations and the End of the Depression, in: American Economic Review, Vol. 98(4), pp. 1476–1516.

[11] Eggertsson, G. B./ Krugman, P. (2012), Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach, in: The Quarterly Journal of Economics, Vol. 127(3) pp. 1469-1513.

[12] Eggertsson, G. B./ Woodford, M. (2011), The Zero Bound on Interest Rates and Optimal Monetary Policy, in: Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution, vol. 34(1), pages 139-235.

[13] Engen, E. M./ Hubbard, G. (2004), Federal Government Debt and Interest Rates, in: NBER Macroeconomics Annual Vol. 19, pp. 84-160.

[14] European Commission (2012), European Economic Forecast, Spring 2012.

[15] Denes, M./ Eggertsson, G. B./ Gilbukh, S. (2013), Deficits, Public Debt Dynamics and Tax and Spending Multipliers, in: The Economic Journal, Vol. 123(566), pp. F133-F163.

[16] Fisher, Jonas D. M. (2015), On the Structural Interpretation of the Smets–Wouters "Risk Premium" Shock, in: Journal of Money, Credit and Banking, Vol. 47(2–3).

[17] Francis, Johanna L. (2009), Wealth and the capitalist spirit, in: Journal of Macroeconomics 31 (2009), pp. 394–408.

[18] Frederick, Shane/ Loewenstein, George/ O'Donoghue, Ted (2002), Time discounting and time preference: A critical review, in: Journal of Economic Literature, Vol. XL, pp. 351-402.

[19] Freedman, C./ Kumhof, M./ Laxton, D./ Muir, D./ Mursula, S. (2010). Global effects of fiscal stimulus during the crisis, in: Journal of Monetary Economics, Vol. 57(5), pp. 506-526.

[20] Friedman, M. (1957), A Theory of the Consumption function, Princeton University Press.

[21] Friedman, M. (1962), Windfalls, the 'Horizon,' and Related Concepts in the Permanent-Income Hypothesis, in: Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld, pp. 3-28. Stanford: Stanford University Press.

[22] Gale, W. G./ Orszag, P. R. (2004), Budget Deficits, National Saving, and Interest Rates, in: Brookings Papers on Economic Activity, Vol. 2004, No. 2 (2004), pp. 101-187.

[23] Heathcote, J./ Perri, F./ Violante, G. (2010), Unequal we stand: An empirical analysis of economic inequality in the United States, 1967–2006, in: Review of Economic Dynamics, pp. 15–51.

[24] Dynan, Karen E./ Skinner, Jonathan F./ Zeldes, Stephen P. (2004), Do the Rich Save More?, in: Journal of Political Economy, Vol. 112(2).

[25] Harrison, G. W./ Lau, M. I./ Williams M. B. (2002), Estimating Individual Discount Rates in Denmark: A Field Experiment, in: American Economic Review, Vol. 92.

[26] Heckman, J. J. (1976), A Life-Cycle Model of Earnings, Learning, and Consumption, in: Journal of Political Economy, Vol. 84(4).

[27] Hens, T./ Rieger, M.-Ol./ Wang, . (2016), How Time Preferences Differ: Evidence from 53 Countries, forthcomming in Journal of Economic Psychology.

[28] Jarass, L. J./ Tokman, A./ Wright, M L. J. (2017), The Burden of Taxation in the United States and Germany, in: Chicago Fed Letter No. 382.

[29] Kaplan, G./ Violante, G. (2018), Microeconomic Heterogeneity and Macroeconomic Shocks, in: Journal of Economic Perspectives, Vol. 32(3), pp. 167–194.

[30] Kaplan, G./ Violante, G. L./ Weidner, J. (2014), The Wealthy Hand-to-Mouth, in: Brookings Papers on Economic Activity, Spring 2014, pp. 77-138.

[31] Kimball, Miles S. (1995), The quantitative analytics of the basic neomonetarist model, in: Journal of Money, Credit, and Banking, Vol. 27, pp. 1241-1277.

[32] Krause, M./ Moyen, S. (2016), Public debt and changing inflation targets, in: American Economic Journal: Macroeconomics 2016, Vol. 8(4), pp. 142–176.

[33] Kumhof, M. / Rancier, R./ Winant, P. (2015), Inequality, leverage and crises, in: American Economic Review, Vol. 105 (3), pp. 1217-1245.

[34] Laubach, T. (2009), New Evidence on the Interest Rate Effects of Budget Deficits and Debt, in: Journal of the European Economic Association June, Vol. 7(4), pp. 858–885.

[35] Lemoine, M./ Linde, J. (2016), Fiscal consolidation under imperfect credibility, in: European Economic Review, Vol. 88, pp. 108–141.

[36] Linde, J./ Trabandt, M. (2018), Should we use linearized models to calculate fiscal multipliers, in: Journal of Applied Econometrics, Vol. 33(7), pp. 937-965.

[37] Linde, J./ Trabandt, M. (2018), Resolving the Missing Deflation Puzzle, mimeo.

[38] Ruderman, H./ Levine, M. D./ McMahon, J. F. (1986), Energy-Efficiency Choice in the Purchase of Residential Appliances, in: Kempton, Willett/ Neiman, Max (eds.), Energy efficiency: Perspectives on individual behavior. Washington, DC: American Council for an Energy Efficient Economy, pp. 41–50.

[39] Rannenberg, A. (2017), The effect of fiscal policy and forward guidance with preferences over wealth, mimeo.

[40] Rannenberg, A. (2019), Forward guidance with preferences over safe assets, in: National Bank of Belgium Working Paper No. 364.

[41] Warner, J. T./ Pleeter, S. (2001), The Personal Discount Rate: Evidence From Military Downsizing Programs, in: American Economic Review, Vol. 91(1).

[42] Woodford, M. (2011), Simple Analytics of the Government Expenditure Multiplier, in: American Economic Journal: Macroeconomics, Vol. 3(1), pp. 1-35.

A For online publication only: Data sources used for the empirical targets in Tables 2 and 6

- Real Federal Funds rate: “Effective Federal Funds Rate, Percent, Monthly, Not Seasonally Adjusted”, and “Consumer Price Index for All Urban Consumers: All Items, Index 1982-1984=100, Monthly, Seasonally Adjusted”, both obtained from FRED.

- Government debt-to-GDP ratio: “Gross Federal Debt as Percent of Gross Domestic Product, Percent of GDP, Annual, Not Seasonally Adjusted”, obtained from FRED.

B For online publication only: Calibration of the curvature of household preferences over wealth

This section describes the microsimulation I use to calibrate the wealth curvature parameter for the case of the simple model of Section 2, but the procedure in the model with credit constraints is fully analogous. For the purpose of the microsimulation, I exogenize the saver households non-interest net income, as well as the real interest rate, implying that her behavior is described by

$$b_{G,t} = \frac{R}{\Pi} b_{G,t-1} + Y_{H,t} - C_t$$

$$\Lambda_t \quad = \quad C_t^{-\sigma} \tag{40}$$

$$\Lambda_t \quad = \quad \beta E_t \left\{ \Lambda_{t+1} \frac{R}{\Pi} \right\}) + \phi_b \left(b_{G,t} \right)^{-\sigma_b} \tag{41}$$

I then simulate a permanent increase in $Y_{S,t}$ occurring in $t = 1$. I compute the marginal propensity to save over a horizon of 6 years (24 quarters) as

$$MPS_{S,1-24} = \frac{b_{G,24} - b_{G,0}}{\sum_{t=1}^{24} dY_t} \tag{42}$$

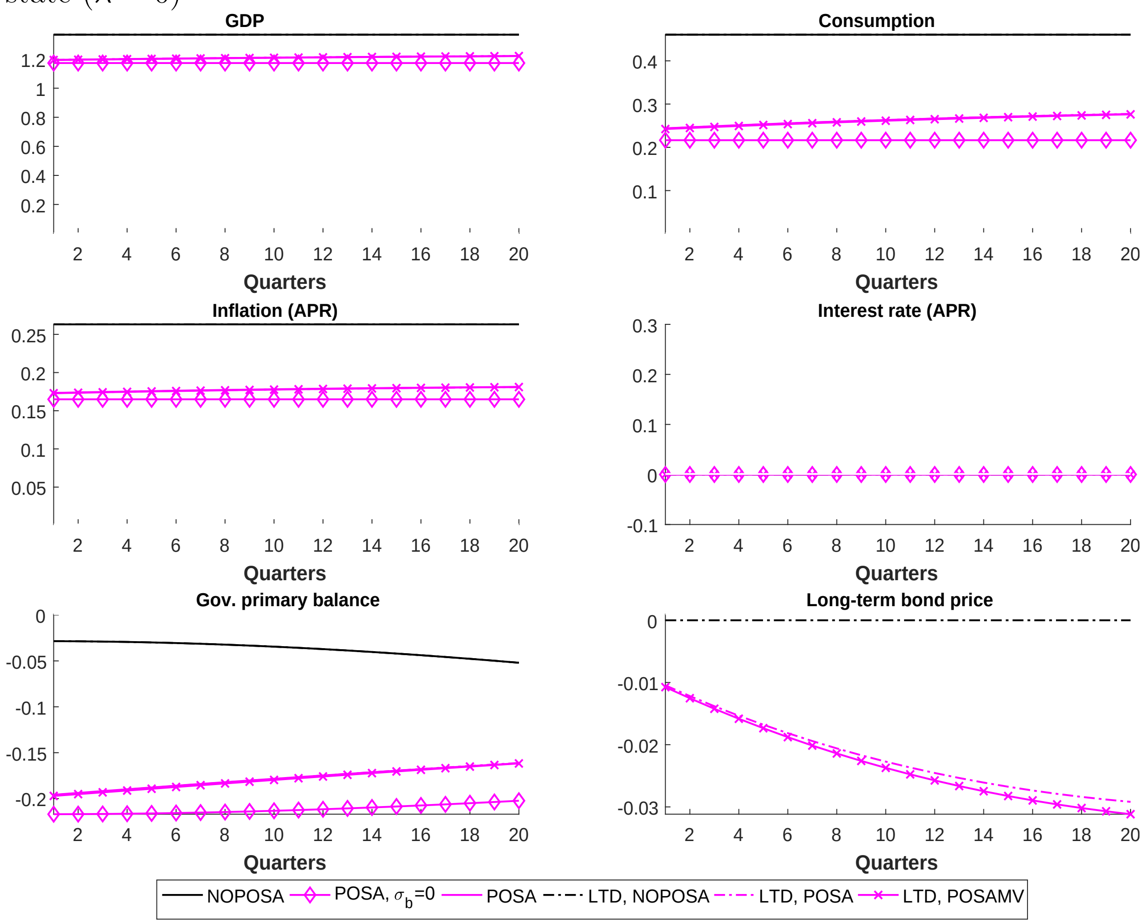
The reason for the six year horizon is that the empirical estimates of the MPS of Kumhof et al. (2015) and Dynant et al. (2004) use data on saving rates which is six years apart (see Kumhof et al. (2015) for further details on how to compute the MPS in a way consistent with the empirical estimates). Finally, given the calibration of the other parameters as described in section 3, I use σ_b to set $MPS_{S,1-24}$ to the empirical target value.

To compute the empirical counterpart of the model based value reported in Table 2b., for each quintile of the income distribution, I use the saving regression results reported by Kumhof et al. (2015) to compute the MPS, following the procedure they describe in their Appendix A.1. (equation (14)). I used the regression results they report in their Appendix C, Table 1 (second and third column), and the 1989 median income levels reported in Table 1 - 89-98 of the 2016 Survey of Consumer Finances (SCF) for different percentiles of income. The reason for using 1989 SCF data is that the saving regressions of Kumhof et al. (2015) are based on the 1989 and 1983 vintages of the SCF.

To compute the population average, I then averaged across the quintile specific MPS using the 1989 incomes share of each quintile as weights. I calculate the income share of each quintile using mean income of each quintile. This yields values of 0.34 and 0.3 (depending on the specific regression results used). Using instead the quintile specific MPS estimates reported in Dynan et al. (2004), Figure 3, yields a value of 0.3.

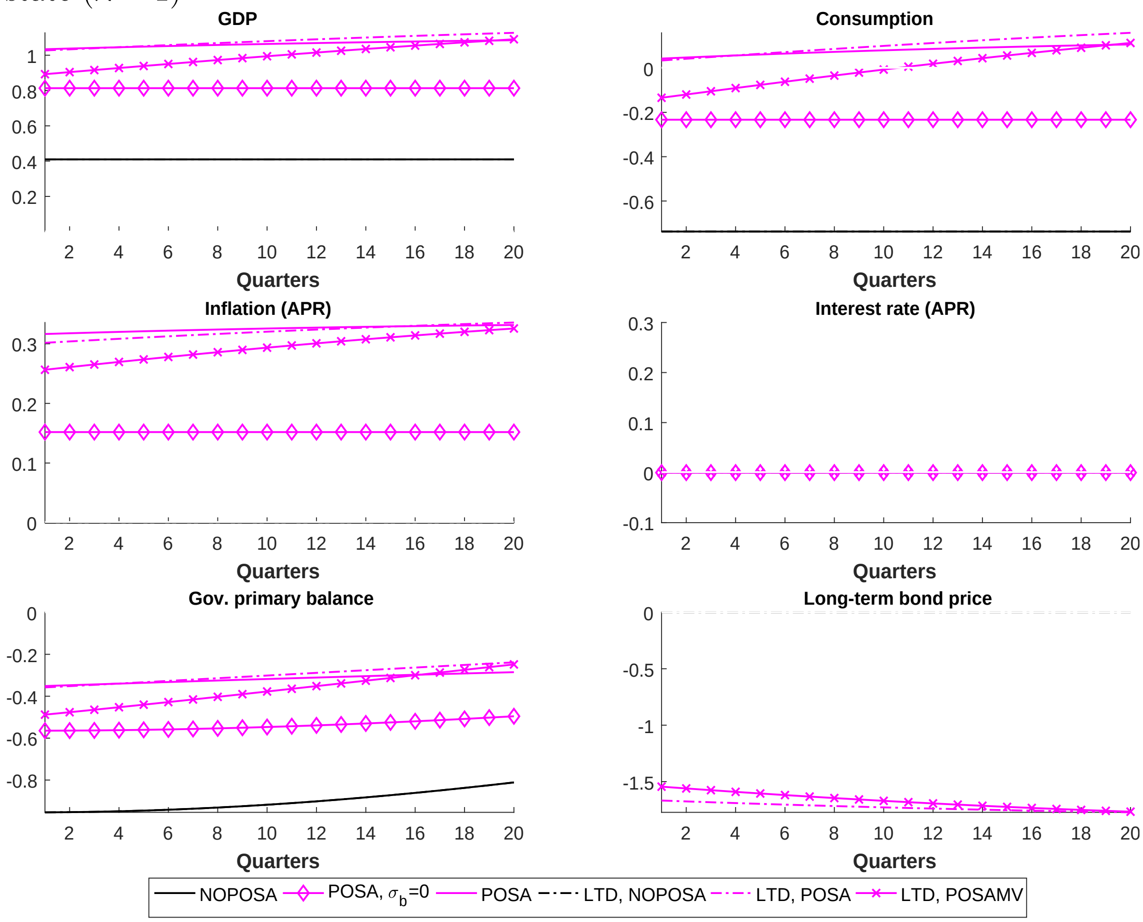
C For online publication only: Dynamic effect of a government expenditure change during the low state

Figure 8: Dynamic effect of perfectly timed gov. expenditure change during the low state ($\lambda = 0$)



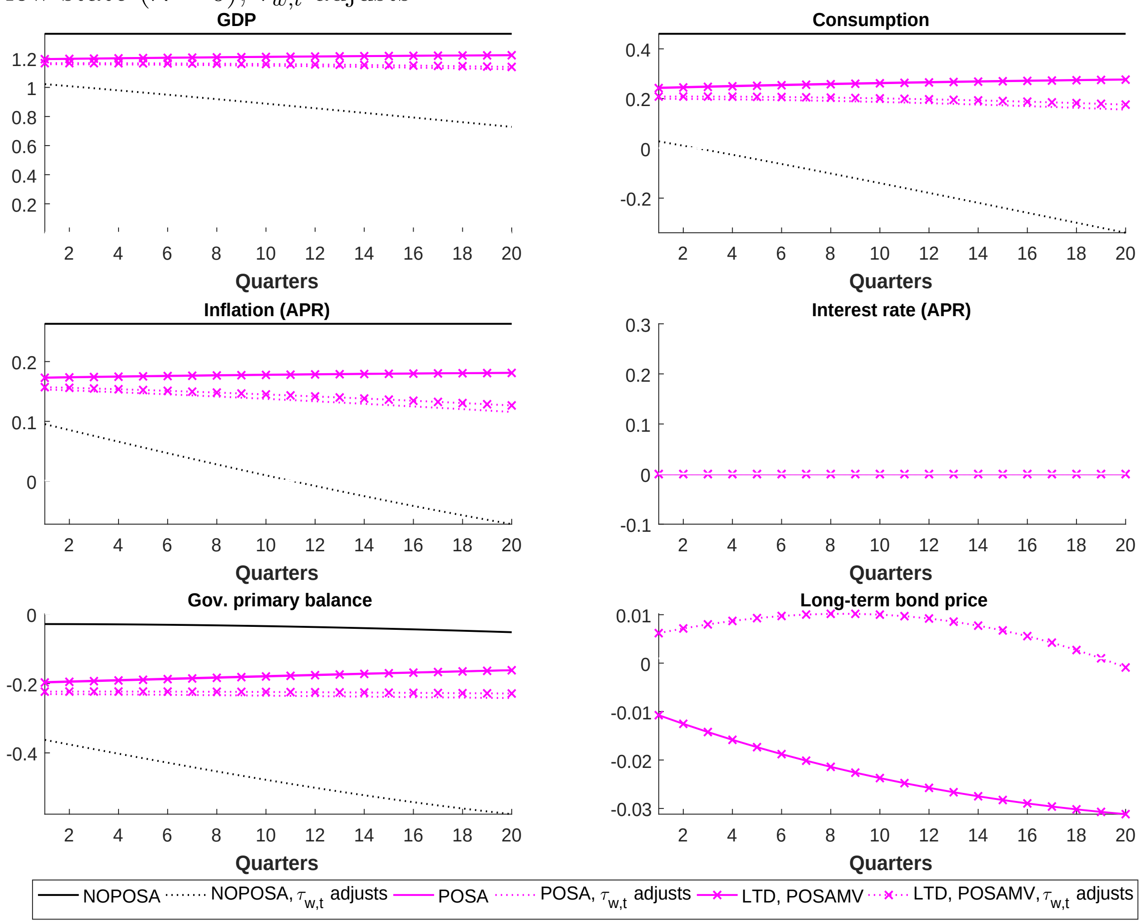
Note: The graph displays the dynamic effect of a government expenditure increase of 1% of GDP lasting exactly as long as the low state (i.e.$\lambda = 0$), conditional on the economy remaining inside the low state up until the quarter indicated on the horizontal axis. I assume a mean duration of the low state of $D_L = 8$ (i.e. $\mu_L = 0.875$). All other parameters are as in Table 2. For details on the legend and the units of the displayed variables see the note below Figure 1.

Figure 9: Dynamic effect of a permanent gov. expenditure change during the low state ($\lambda = 1$)



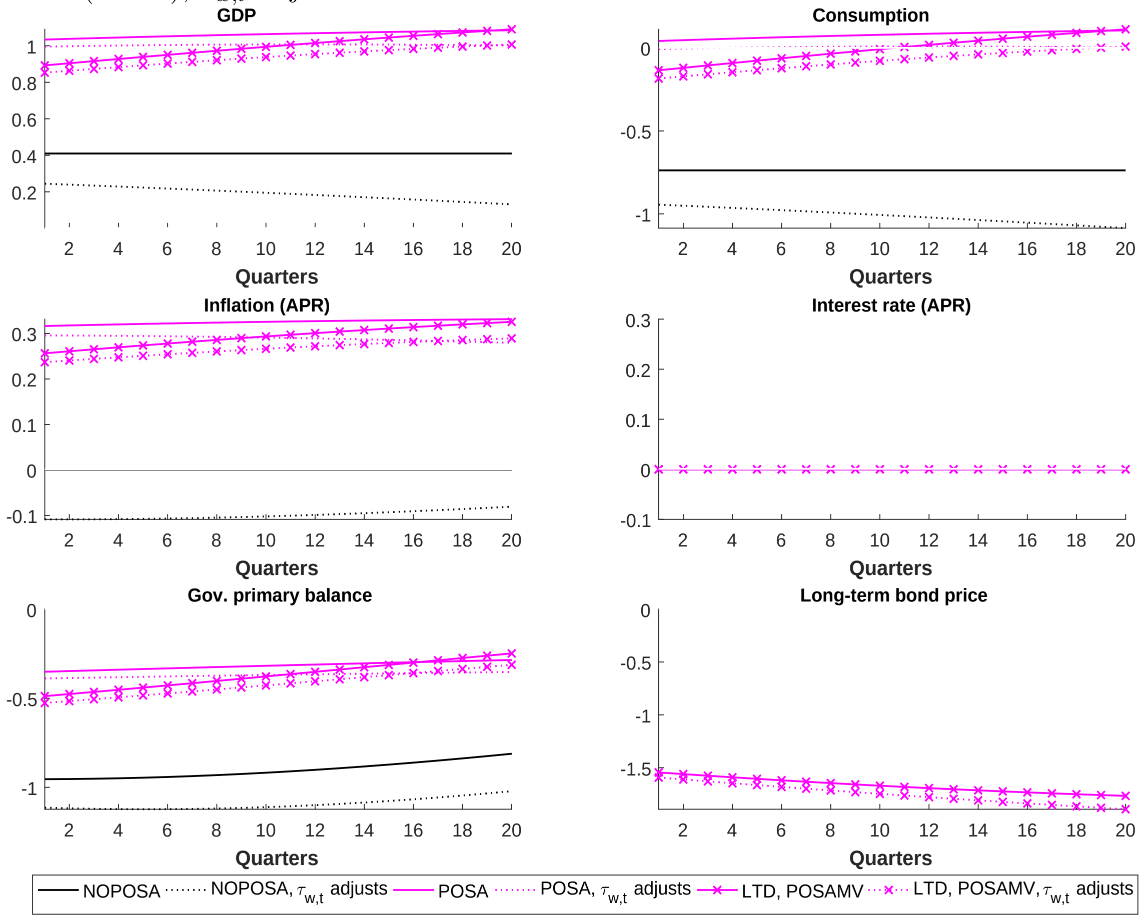
Note: The graph displays the dynamic effect of a permanent increase of government expenditure by 1% of GDP (i.e. $\lambda = 1$), conditional on the economy remaining inside the low state up until the quarter indicated on the horizontal axis. I assume a mean duration of the low state of $D_L = 8$ (i.e. $\mu_L = 0.875$). All other parameters are as in Table 2. For details on the legend and the units of the displayed variables see the note below Figure 1.

Figure 10: Dynamic effect of perfectly timed gov. expenditure change during the low state ($\lambda = 0$), $\tau_{w,t}$ adjusts



Note: The graph displays the dynamic effect of a government expenditure increase of 1% of GDP lasting exactly as long as the low state (i.e.$\lambda = 0$), conditional on the economy remaining inside the low state up until the quarter indicated on the horizontal axis. I assume a mean duration of the low state of $D_L = 8$ (i.e. $\mu_L = 0.875$). All other parameters are as in Table 2. "$\tau_{w,t}$ adjusts" refers to the case where the fiscal rule is given by equation (36), otherwise the fiscal rule is given by equation (13). For more details on the legend and the units of the displayed variables see the note below Figure 1.

Figure 11: Dynamic effect of a permanent gov. expenditure change during the low state ($\lambda = 1$), $\tau_{w,t}$ adjusts



Note: The graph displays the dynamic effect of a permanent increase of government expenditure by 1% of GDP (i.e. $\lambda = 1$), conditional on the economy remaining inside the low state up until the quarter indicated on the horizontal axis . I assume a mean duration of the low state of $D_L = 8$ (i.e. $\mu_L = 0.875$). All other parameters are as in Table 2. "$\tau_{w,t}$ adjusts" refers to the case where the fiscal rule is given by equation (36), otherwise the fiscal rule is given by equation (13). For more details on the legend and the units of the displayed variables see the note below Figure 1.

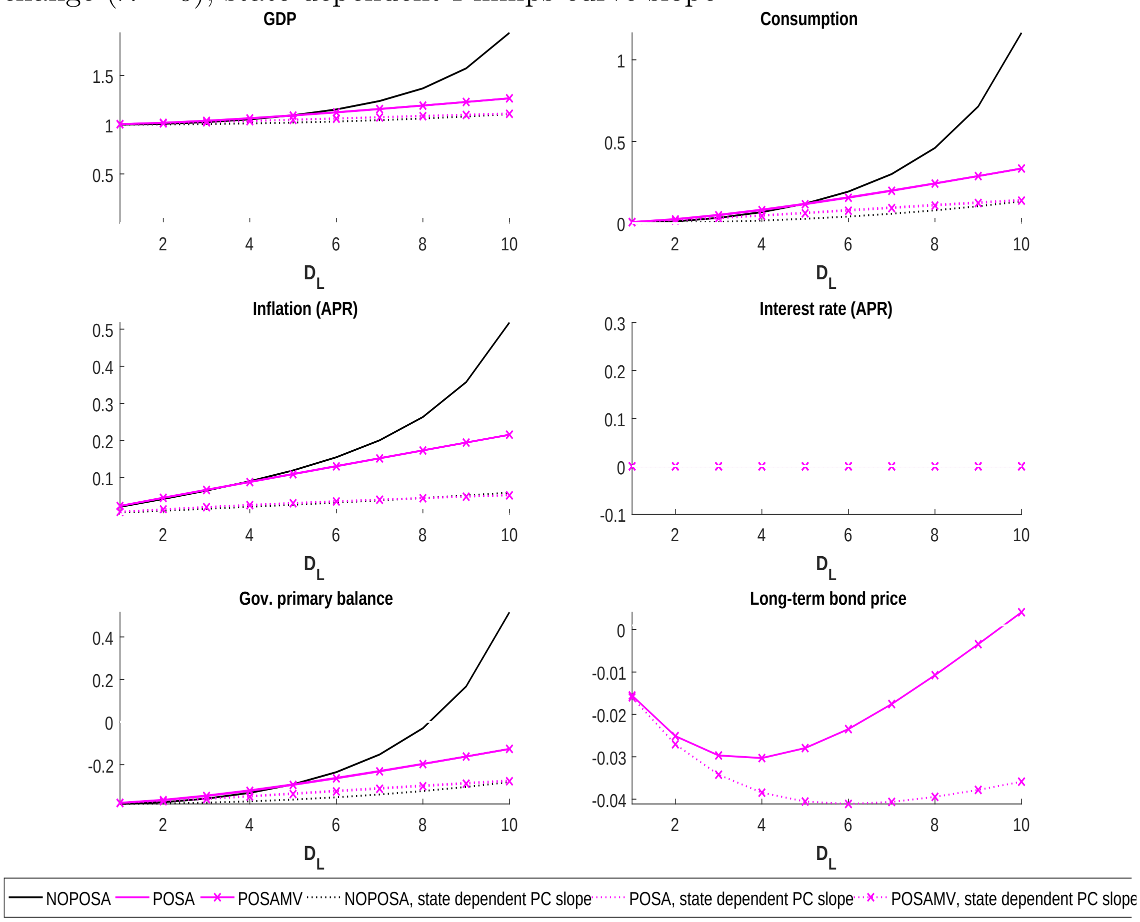
D For online publication only: State dependent Phillips Curve slope

I now check whether the above results are robust to allowing for a flatter Phillips curve during the low state. Trabandt and Linde (2018) argue that allowing for non-linearities in price and wage setting allows New Keynesian models to replicate the fact that inflation fell very little during the Great Recession against the backdrop of a large and persistent fall in GDP (sometimes referred to as “missing deflation puzzle”). In their setup the non-linearity arises from a Kimball (1995) goods basket, which combined with Calvo (1983) price setting contracts implies that the Phillips Curve becomes much flatter during periods of very negative output gaps if the model is solved non-linearly. In Trabandt and Linde (2019), they show that taking into account these non-linearities tends to reduce the fiscal multiplier by reducing the inflationary effects of a fiscal expansion, hence the associated decline in the real interest rate and thus the crowding in of private household consumption. Therefore I check whether my results are robust to allowing for a flatter Phillips curve during the low state. Specifically, instead of assuming a constant slope κ, I allow the Phillips curve slope to differ across states S and L, implying that the Phillips Curve becomes

$$\begin{aligned} \hat{\Pi}_{L,t} &= \kappa_L(\hat{Y}_{L,t} - \Gamma\hat{G}_L) + \beta\left[\mu_L\hat{\Pi}_{L,t+1} + (1-\mu_L)\,\hat{\Pi}_{S,t+1}\right] \\ \hat{\Pi}_{S,t} &= \kappa_S(\hat{Y}_{S,t} - \Gamma\hat{G}_{S,t}) + \beta\hat{\Pi}_{S,t+1} \end{aligned} \tag{43}$$

I assume $\kappa_S = \kappa$ and $\kappa_L = \frac{\kappa}{4}$. For the perfectly timed expenditure increase, I find that without POSA the multiplier is much lower due to a much smaller increase in inflation and a smaller decline in the real interest rate, in line with Linde and Trabandt (2019). For instance, for $D_L = 8$, the multiplier declines from 1.4 to 1.1 (see Table 4a., compare rows two and nine). By contrast, with POSA, the impact of allowing for a smaller PC slope has a much smaller impact since the increase in inflation is smaller to begin with, and thus the impact of the smaller low-state Phillips Curve slope on the multiplier is lower as well (compare rows 3 and 10). For instance, for $D_L = 8$, the multiplier declines by about 0.l. The same is true for an increase in government expenditure outlasting the expected length of the low (compare rows 4 and 10 of Table 4a., and see Figure 13). Hence with POSA, allowing for a much flatter Phillips curve during the low state has only a small effect on the multiplier. Furthermore, it remains the case that POSA renders the multipliers of temporary and permanent expenditure changes much more alike.

Figure 12: Impact fiscal multiplier during low state, perfectly timed expenditure change ($\lambda = 0$), state dependent Phillips curve slope



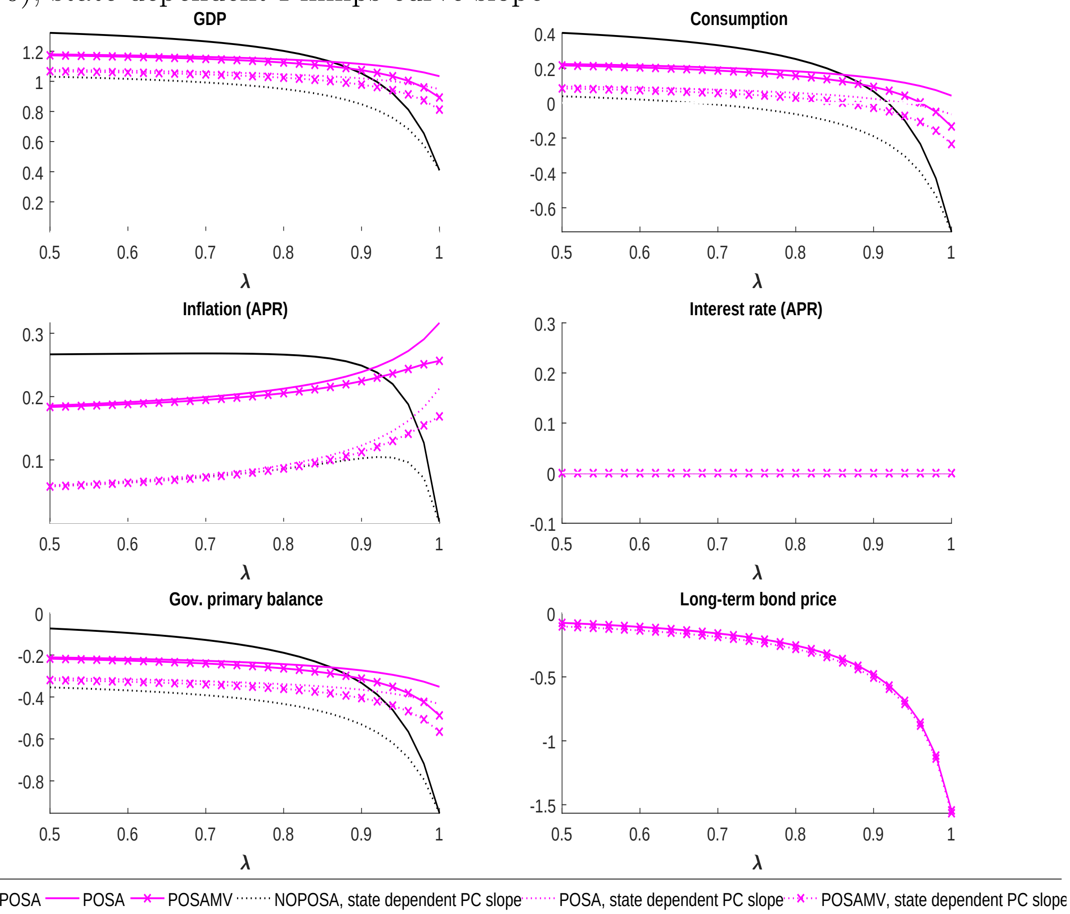
Note: The graph displays the impact effect of a government expenditure increase of 1% of GDP lasting exactly as long as the low state (i.e.$\lambda = 0$). The horizontal axis depicts the expected duration of the low state $D_L = \frac{1}{1-\mu_L}$. All other parameters are as in Table 2. "State dependent PC slope" refers the scenario where the price Phillips Curve slope differs across states (see equation (43)), with $\kappa_S = \kappa$ and $\kappa_L = \frac{\kappa}{4}$. For more details on the legend and the units of the displayed variables see the note below Figure 1.

E For online publication only: Model with credit constraints

E.1 Constrained households

Constrained households have preferences over consumption $C_{CC,t}$ and labor $N_{CC,t}$ of the same form as unconstrained households. Their intertemporal utility function is

Figure 13: Impact fiscal multiplier during low state, persistent expenditure increase ($\lambda > 0$), state dependent Phillips curve slope



Note: The graph displays the impact effect of increasing government expenditure by 1% of GDP inside the low state, with $D_L = 8$ (i.e. $\mu_L = 0.875$). The horizontal axis displays the probability λ that the increase persists after the economy's exit from the low state. All other parameters are as in Table 2. "State dependent PC slope" refers the scenario where the price Phillips Curve slope differs across states (see equation (43)), with $\kappa_S = \kappa$ and $\kappa_L = \frac{\kappa}{4}$. For more details on the units of the displayed variables see the note below Figure 1.

given by

$$E_t \left\{ \sum_{i=0}^{\infty} \beta_{CC}^i \left[\frac{C_{CC,t+i}^{1-\sigma_{CC}}}{1-\sigma_{CC}} - \frac{\chi_{N,CC}}{1+\eta} N_{CC,t+i}^{1+\eta} \right] \right\} \tag{44}$$

They can neither save nor borrow, implying that their budget constrained is given by

$$(1 + \tau_{C,t}) C_{CC,t} + T_{CC,t} = (1 - \tau_{w,t}) N_{CC,t} \frac{W_{CC,t}}{P_t} - \frac{\xi_W}{2} \left(\frac{W_{CC,t}}{W_{CC,t-1}} \frac{1}{\Pi} - 1 \right)^2 N_{CC,t} \frac{W_{CC,t}}{P_t} \tag{45}$$

Correspondingly, their real wage is determined by a Phillips Curve of the same form as equation (38).

E.2 Retailers

The production function of retailers becomes

$$Y_{j,t} = A_t N_{S,j,t}^{(1-\alpha_K-\alpha_{CC}-\alpha_E)} N_{CC,j,t}^{\alpha_{CC}} N_{E,j,t}^{\alpha_E} K_{j,t}^{\alpha_K} \tag{46}$$

where $N_{S,t}$, $N_{CC,t}$ and $N_{E,t}$ denote unconstrained, constrained and entrepreneurial household labor, respectively. As in the simple model, retailers face convex price adjustment costs (equation 8) and there are economy wide markets for all factors of production, implying that marginal costs are identical across firms. The retailer's FOCs with respect to the three labor types and physical capital are given by

$$w_{S,t} = mc_t (1 - \alpha_K - \alpha_{CC}) \frac{Y_t}{N_{S,t}} \tag{47}$$

$$w_{CC,t} = mc_t \alpha_{CC} \frac{Y_t}{N_{CC,t}} \tag{48}$$

$$w_{E,t} = mc_t \alpha_E \frac{Y_t}{N_{CC,t}} \tag{49}$$

$$r_{K,t} = mc_t \alpha_K \frac{Y_t}{K_{t-1}} \tag{50}$$

while price setting continues to be governed by equation (11).

E.3 Financial accelerator

The entrepreneurial sector follows Bernanke et al. (1999) and Christiano et al. (2010). Risk neutral entrepreneurs accumulate the physical capital stock K_t and rent it to retailers. After the collection of rental income, they liquidate their capital stock at price Q_t. Their average period t return on capital $R_{K,t}$ is thus given by

$$R_{K,t} = \Pi_t \frac{(1-\tau_K)\, r_{K,t} + \delta\tau_K + Q_t\,(1-\delta)}{Q_{t-1}} \tag{51}$$

where $r_{K,t}$ denotes the rental rate on physical capital paid by retailers. Entrepreneurs fund their capital stock using their own end of period net worth NW_t and a loan $b_{E,t}$ from a financial intermediary, with

$$b_{E,t} = Q_t K_t - NW_t \tag{52}$$

Following Christiano et al. (2010), I assume a nominal (i.e. non-inflation indexed) debt contract. The $t+1$ return on capital of the individual entrepreneur j is given by $\omega_j R_{K,t+1}$ where where j indexes the entrepreneur, and ω_j denotes a log-normally distributed idiosyncratic shock with mean 1 and variance σ_ω^2. The debt contract is state contingent such that the loan interest rate adjusts after the realization of aggregate uncertainty in period j such that the financial intermediary always earns an average return of R_t on his portfolio. The default threshold $\overline{\omega}_t$ for $\omega_{j,t}$ is given by

$$\frac{R_{t+1}^L\,(Q_t K_t - NW_t)}{R_{K,t+1} Q_t K_t} = \overline{\omega}_t \tag{53}$$

where R_{t+1}^L denotes loan rate to be adjusted depending on the aggregate state. In case of default, the financial intermediary seizes a fraction $(1-\mu)$ of the assets of the entrepreneur $R_{K,t+1}K_tQ_tP_t$, while the remainder represents a monitoring costs. As shown in Bernanke et al. (1999), in equilibrium the debt contract passes this cost on to the entrepreneur. As a result, the entrepreneur's FOCs require a positive relationship between the spread of the entrepreneur's expected return on capital $E_t\widehat{R}_{t+1}^K$ over the risk free rate $\widehat{R}_t$ and entrepreneurial leverage:

$$E_t\widehat{R}_{t+1}^K - \widehat{R}_t = \chi_E\left(\hat{Q}_t + \widehat{K}_t - N\hat{W}_t\right) \tag{54}$$

$E_t\widehat{R}_{t+1}^K - \widehat{R}_t$ is typically referred to as the cost of external finance (for details see Bernanke et al. (1999)). If μ >0, $\chi_E > 0$ as well.

Each period a fraction $1-\gamma$ of entrepreneurs dies and consumes its net worth, and is replaced with a fraction of newly born entrepreneurs. This assumption assures that entrepreneurs never become fully self-financing. Entrepreneurs supply one unit of labor to retailers at wage $w_{E,t}$, which allows newly born entrepreneurs to start their operations. Thus NW_t and entrepreneurial consumption $C_{E,t}$ are given by

$$NW_t = \gamma V_t + w_{E,t} \tag{55}$$

$$C_{E,t} = (1-\gamma) V_t \tag{56}$$

where V_t denotes beginning of period net worth, which is in turn determined as

$$V_t = Q_{t-1}K_{t-1}\frac{R_{K,t}}{\Pi_t}\left(1-\mu G\left(\overline{\omega}_t\right)\right) - \frac{R_{t-1}}{\Pi_t}\left(Q_{t-1}K_{t-1} - NW_{t-1}\right) \tag{57}$$

where $\mu G\left(\overline{\omega}_t\right)$ represents the average fraction of bankruptcy costs in total period t entrepreneurial assets $Q_{t-1}K_{t-1}$. $G\left(\overline{\omega}_t\right)$ denotes the product of expectation of ω_j conditional on $\omega_j < \bar{\omega}_t$ and the average bankruptcy rate $F\left(\bar{\omega}_t\right)$ (see Bernanke et al. (1999) for details.

E.4 For online publication only: Capital goods producers

I assume that capital goods producers produce I_t units the capital good using $I_t + \frac{\xi_I}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2 K_{t-1}$ units of the output good, with $\xi_I > 0$, taking the aggregate economy wide capital stock K_{t-1} as given. Their FOC is given by

$$1 + \xi_I\left(\frac{I_t}{K_{t-1}} - \delta\right) = Q_t \tag{58}$$

E.5 Government

The monetary policy rule now allows for interest rate smoothing:

$$\hat{R}_t = max\left((1-\rho_R)\left(\phi_\pi\hat{\Pi}_t + \frac{\phi_y}{4}\left(\hat{Y}_t - \hat{Y}_t^*\right) - \varepsilon_{b,t}\right) + \rho_R\hat{R}_{t-1}, \hat{R}_L\right) \tag{59}$$

The government budget constrained remains unchanged but for the presence of capital income tax revenue:

$$b_{G,L,t} = \frac{R_{L,t-1}}{\Pi_t} b_{G,L,t-1} + G_t - \left(T_t + \tau_{w,t}\left(w_{CC,t}N_{CC,t} + w_{S,t}N_{S,t}\right) + \tau_{C,t}C_t + \tau_{K,t}\left(\left(r_{K,t} - \delta\right)K_{t-1}\right)\right) \tag{60}$$

I assume that the government adjusts the distortionary labor tax to ensure debt-stationarity (i.e. the fiscal rule is given by 36).

E.6 Calibration

Table 5 displays the calibration. The column "credit constraints" refers to the model as developed in Sections 5 and E.1 to E.5. By contrast, "no credit constraints", refers to a model without credit constraints on the firm side (in particular, $\mu = \chi_E = 0$) and no credit constrained households ($\alpha_{CC} = 0$), as well as no entrepreneurial consumption ($C_{E,t} = 0$), i.e. the wealth of dying entrepreneurs is transferred to saver households. In the absence of POSA, the "no credit constraints" case is equivalent to a model where capital accumulation is conducted by a representative household.

If not otherwise mentioned, the calibration of both models remains as in Section 3. I set the price and wage markup coefficients κ_π and κ_w and the monetary policy rule parameters ϕ_π, ϕ_y and ϕ_i to the estimates of Linde et al. (2016).[9] I set the capital adjustment cost curvature parameter ξ_I to 7 as estimated by Cummins et al. (2006). I take the survival probability of entrepreneurs γ from Bernanke et al. (1999). Given these choices, I calibrate 11 parameters (β, μ_p, α_K, α_{CC},α_E, μ, σ_ω, the target debt-to-GDP ratio implicit in the fiscal rule, $\frac{G}{Y}$, χ_b, σ_b, marked with a *) in order to set the steady state values of important model variables close to averages of their counterparts in the data or the available empirical evidence, which are reported in Table 5. In the NOPOSA model with credit constraints, there are 9 empirical targets are the average real Federal Funds rate, the government expenditure share, the government debt-to-annual-GDP ratio, the non-residential private investment share, the non-farm business labor share, a measure of the external finance premium,

[9] See their Table 5.1, column 2. These estimates take into account the ZLB on the nominal rate, which tends to increase the degree of nominal rigidity.

a measure of the entrepreneurial bankruptcy rate, non-financial firm leverage $\frac{QK}{NW}$ and the income share of "Hand to mouth" households (as estimated by Kaplan and Violante (2014)). The calibration of the parameters related to the financial friction imply an elasticity of the expected return to capital to entrepreneurial leverage χ_E of 0.053.

Regarding POSA, I keep the target value of the "discounting wedge" θ at 0.96 and the wealth utility curvature parameter σ_b at 0.2. In the context of this more elaborate model, $\sigma_b = 0.2$ represents a conservative calibration of the wealth effect associated with government debt in the model with POSA, considering the available macro- and microevidence, for the following reasons. Firstly, the implied effect of a one percentage point increase in the government debt-to-annual-GDP ratio on the natural interest rate $\frac{4d\hat{R}_f}{\frac{d\hat{b}_{G,f}}{4}}$ now equals 0.025, less than in the simple model and at the lower end of available empirical estimates. The reason is that in the long run, the increase in the interest rate on safe assets triggered by the increase in the government debt-to-GDP ratio is passed on to entrepreneurs and thus crowds out entrepreneurial debt $b_{E,t}$, implying that the overall increase of the household safe asset holdings b_t and thus R_t is smaller than in a model where government debt is the only safe asset. Secondly, and similarly, the effect on the spread between the return on private capital and the safe interest rate in the flexible price economy $\frac{4d\left(\hat{R}_{K,f}-\hat{R}_f\right)}{\frac{d\hat{b}_{G,f}}{4}}$ is somewhat more negative than the estimate of Krishnamurthy and Vissing-Jorgenson (2012) of the effect of an increase in the debt-to-GDP ratio on the spread between BAA rated bonds and long-term treasury bonds. Thirdly, at the micro level, the adopted calibration of POSA implies that saver household have a marginal propensity to save of 0.61 out of an increase in their permanent-income in a partial equilibrium simulation (see Appendix B for details). Their income share of 71% would suggest that they correspond approximately to the top 40% of households, for which I compute an empirical MPS of 0.35-0.4 based on the evidence of Kumhof et al. (2015) and Dynan et al. (2004). Assuming a higher value for σ_b would increase $\frac{4d\hat{R}_f}{\frac{d\hat{b}_{G,f}}{4}}$ and $\frac{4d\left(\hat{R}_{K,f}-\hat{R}_f\right)}{\frac{d\hat{b}_{G,f}}{4}}$ and reduce the MPS of unconstrained households, thus moving these statistics closer towards their respective empirical range, and raise the multiplier of a permanent expenditure increase during the ZLB.

Table 5: Medium scale model: Calibration

Parameter	Parameter name	Model "credit constraints"		Model "no credit constraints"	
		NOPOSA	POSA	NOPOSA	POSA
β	Household discount factor	0.9955*	0.9557*	0.9955*	0.9557*
σ	Curvature consumption	1			
η	Curvature labor disutility	2.0			
κ_π	Markup coefficient price Phillips curve	0.0121			
κ_w	Markup coefficient wage Phillips curve	0.0121			
μ_p	Steady state price markup	1.25*			
α_K	Elasticity of output w.r.t. capital	0.24*		0.19*	
α_{CC}	Elasticity of output w.r.t. constrained HH labor	0.3*		0*	
α_E	Elasticity of output w.r.t. entrepreneurial labor	0.02*		0.0597	
ξ_I	Capital adjustment cost curvature	7			
μ	Bankruptcy costs	0.15*		0	
σ_ω	Idiosyncratic uncertainty	0.28*		0.28	
γ	Survival probability of entrepreneurs	0.978			
τ_C	Consumption tax rate	0.07			
τ_w	Labor tax rate	0.28			
τ_K	Capital tax rate	0.3			
τ_b	Fiscal rule, long-run response to debt	$\frac{R}{\Pi} - 1 + 0.05$			
ρ_b	Fiscal rule, inertia	0.98			
$\frac{b_G}{4Y}$	Fiscal rule, target debt-to-annual GDP ratio	0.64*			
$\frac{G}{Y}$	Steady state government expenditure share	0.2*			
ϕ_π	Taylor rule inflation	1.9			
ϕ_y	Taylor rule output gap	$\frac{0.4}{4}$			
ρ_R	Taylor rule interest rate smoothing	0.82			
σ_b	Curvature POSA	0.2*			

Note: Parameter values labeled with a * are calibrated such that the steady state values of the variables listed in Table 6 correspond to their empirical counterparts. Given the target for θ and the calibration of the other parameters, the bond utility weight χ_b does not matter for the linearized model dynamics and is therefore not reported. The label "no credit constraints" refers to the case of zero bankruptcy costs and thus no financial accelerator (in particular, $\mu = \chi_E = 0$) and no credit constrained households ($\alpha_{CC} = 0$), as well as no entrepreneurial consumption $\left(C_{E,t} = 0\right)$, i.e. the wealth of dying entrepreneurs is transferred to saver households.

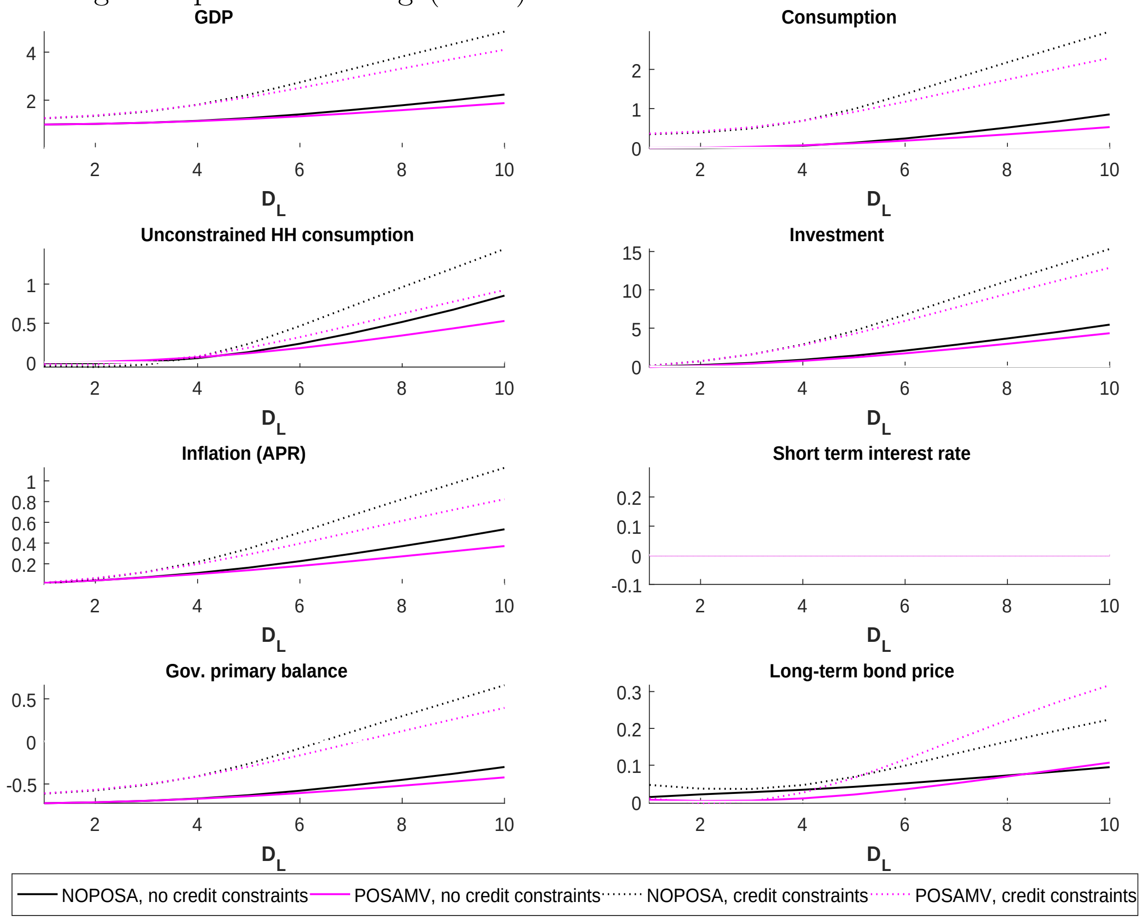
Table 6: Model with credit constraints: Empirical targets

Empirical target	Model counterpart	Model credit constraints		Model no credit constraints		Empirical value	Source
		NOPOSA	POSA	NOPOSA	POSA		
Real short-term interest rate	$\left(\frac{R}{\Pi}\right)^4 - 1$	1.8%				1.8%	Federal Funds rate-CPI inflation
Government expenditure share	$\frac{G}{Y}$	0.2				0.2	BEA
Government debt-to-GDP ratio	$\frac{b_G}{4Y}$	0.64				0.64	FRED
Non-residential private investment share	$\frac{I}{Y}$	12%				12%	BEA
Non-farm business labor share	$\frac{N_{CC}w_{CC}+N_S w_S}{Y}$	0.61				0.65	Bureau of Labor Statistics
External finance premium	$\left(\frac{R_K}{R}\right)^4 - 1$	2.5%		0		2.4	BAA bond yield minus 10 year treasury yield
Bankruptcy rate	$F(\bar{\omega})$	0.75%					Bernanke et al. (1999)
Entrepreneurial leverage	$\frac{QK}{NW}$	1.8				1.7	Flow of Funds
Constrained HH income share	$\frac{N_{CC}w_{CC}}{Y-I-\frac{R_K}{\Pi}\mu G(\bar{\omega})K}$	0.25		0		0.22	Kaplan and Violante (2014)
Discounting wedge	$\theta = \beta\frac{R}{\Pi}$	1	0.96	1	0.96	0.96	See note below
$\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$	$\frac{4d\hat{R}_f}{\frac{d\hat{b}_{f,G}}{4}}$	$0.025p.p.$	0	$0.018p.p.$	0	$0.03-0.06p.p.$	See note below
$\frac{d\text{EFP}}{d\text{ Gov. Debt ratio}}$	$\frac{4d\left(\hat{R}_{K,f}-\hat{R}_f\right)}{\frac{d\hat{b}_{G,f}}{4}}$	-0.014	0	-	-	$-0.018$to -0.041	See note below
MPS top 40% (not targeted)	See appendix B	0.61	0	0.61	0	0.35 to 0.4	See note below Table 2

Note: $\frac{4d\hat{R}_f}{\frac{d\hat{b}_{f,G}}{4}}$ is computed as the steady state effect of a permanent shock to the government's debt target (implicit in the fiscal rule (36)) on the safe interest rate in the flexible price economy. All empirical targets directly obtained from the data are 1981-2016 or the longest available subsample. For more details on the data sources see Appendix A. The range of empirical estimates of $\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$ are obtained from Gale and Orszag (2004), Engen and Hubbard (2004) and Laubach (2009), while $\frac{d\text{EFP}}{d\text{ Gov. Debt ratio}}$ is obtained from Krishnamurthy and Vissing-Jorgenson (2012).

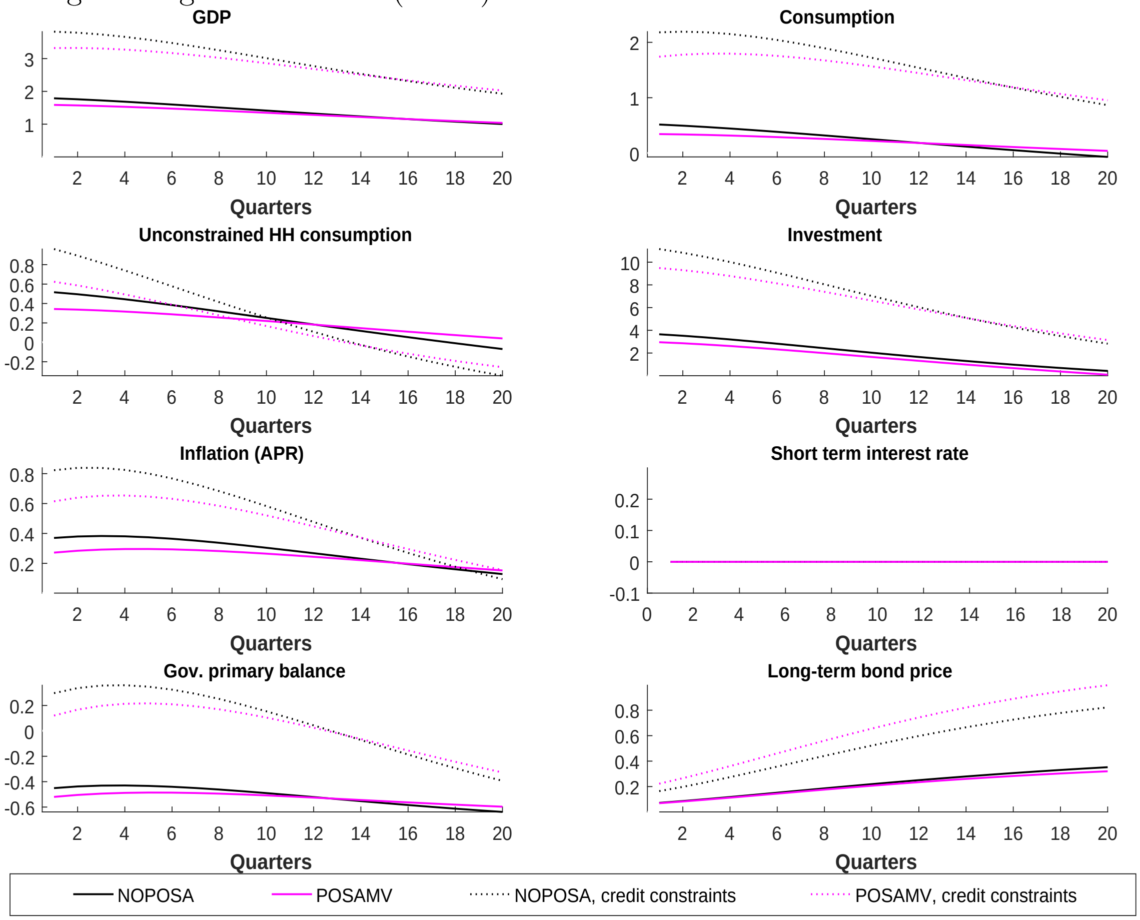
E.7 Further results medium scale model

Figure 14: Medium scale model: Impact fiscal multiplier during low state, perfectly timed gov. expenditure change($\lambda = 0$)



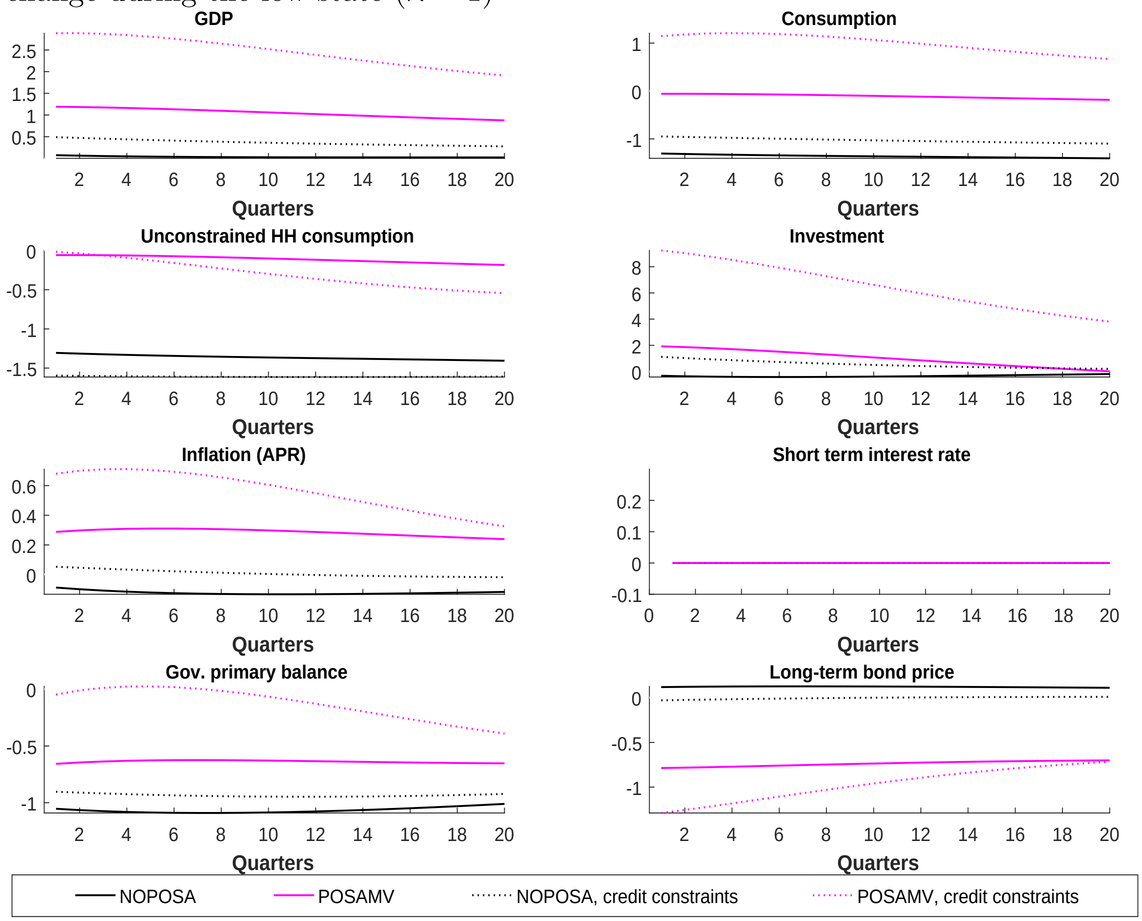
Note: The graph displays the impact effect of increasing government expenditure by 1% of GDP inside the ZLB only. The horizontal axis depicts the expected duration of the low state $D_L = \frac{1}{1-\mu_L}$. For details on the units of the variables and the meaning of the legend see the note below Figure 6.

Figure 15: Medium scale model: Dynamic effect of perfectly timed gov. expenditure change during the low state ($\lambda = 0$)



Note: The graph displays the dynamic effect of increasing government expenditure by 1% of GDP during the low state only ($\lambda = 0$), conditional on the economy remaining inside the low state up until the quarter indicated on the horizontal axis. I assume a mean duration of the low state of $D_L = 8$ (i.e. $\mu_L = 0.875$). For details on the units of the variables and the meaning of the legend see the note below Figure 6.

Figure 16: Medium scale model: Dynamic effect of a permanent gov. expenditure change during the low state ($\lambda = 1$)



Note: The graph displays the dynamic effect of a permanent increase of government expenditure by 1% of GDP, conditional on the economy remaining inside the low state up until the quarter indicated on the horizontal axis. I assume a mean duration of the low state of $D_L = 8$ (i.e. $\mu_L = 0.875$). For details on the units of the displayed variables see the note below Figure 6.