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Forward guidance and fiscal rules in HANK

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Forward guidance and fiscal rules in HANK

by Ansgar Rannenberg



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Abstract

I show that in a canonical HANK model, under a balanced budget fiscal rule, the effect of a nominal interest rate peg is much larger than in a representative agent (RA) model. By contrast, under a standard fiscal rule where tax revenue responds gradually to deviations of the debt-to-GDP ratio from steady-state and depends on economic activity, the effect of forward guidance is much weaker than in the RA model, and becomes linear in the length of the peg. This result is robust to allowing for countercyclical inequality and income risk, and carries over to a quantitative model with capital.

Keywords: Forward guidance, fiscal rules, HANK.

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Non-technical summary

The development of Heterogeneous Agent New Keynesian (HANK) models has led to investigations into whether they resolve the “forward guidance puzzle” (Carlstrom et al., 2015, Giannoni et al., 2015)—the implausibly large effects of interest rate pegs that grow with the peg’s duration. Early work (McKay et al., 2016) suggested that income risk and borrowing constraints limit these effects by shortening planning horizons. However, later studies (Werning, 2015, Hagedorn et al., 2019, Bilbiie, 2020) showed this result depends on assumptions making income risk and inequality procyclical. When inequality is countercyclical, as supported by data (Heathcote et al., 2023, Bilbiie et al., 2023), HANK models amplify the forward guidance puzzle.

This paper demonstrates that the puzzle can be resolved in HANK models if fiscal policy features a small response of taxes to debt levels and a strong response of taxes to economic activity—both empirically realistic. Using the Auclert et al. (2024) one-asset sticky wage model with acyclical pre-tax income, I find that the interest rate peg’s effects vary with the fiscal rule. Under a balanced budget (BB) rule, the peg redistributes income from low-MPC asset holders to high-MPC households, amplifying forward guidance effects. Eliminating this redistribution through a “compensated balanced budget” (CBB) rule aligns the HANK response with that of a representative agent (RA) model.

Moving to a “Gradual Adjustment” (GA) rule, where taxes adjust slowly to debt changes, weakens the peg’s impact below the RA case because savings from lower interest payments reduce debt rather than being transferred to households. The GA rule also makes the peg’s effects linear in the duration of the peg rather than explosive. Adding automatic stabilizers (GAAS rule), which link tax revenue to economic activity, further dampens the response. These results hold even with long-term debt, high liquidity, and countercyclical inequality.

The GAAS rule is empirically plausible, as tax systems typically respond more to economic activity than debt levels (Leeper et al., 2017, Coenen et al., 2013, Gadatsch et al., 2016, Zubairy, 2014). The dampening mechanism under the GAAS rule parallels the effect of “Preferences Over Safe Assets” (POSA) in RA models (Rannenberg, 2024), where reduced debt raises the marginal utility of debt, softening the consumption response. A POSA model with a GAAS rule closely matches the HANK outcomes reported below.

The GA and GAAS rules also resolve the “Catch 22” identified by Bilbiie (2024), where reconciling consumption crowding-in in response to a government expenditure shock with elimination of the forward guidance puzzle previously required conflicting inequality dynamics. Under the GA and GAAS rules, government spending is debt funded and thus crowds in consumption without requiring countercyclical inequality. Countercyclical inequality, when present, raises fiscal multipliers but has only a minor effect on the impact of an interest rate peg.

I also examine the nominal debt target rule (Hagedorn et al., 2019), which attenuates forward guidance effects and anchors inflation but is less empirically convincing than the GAAS rule and still leaves the peg more powerful. The findings remain robust across more complex models featuring nominal wage and price rigidities, capital accumulation, and two-asset household portfolios (Kaplan et al., 2018).

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1 Introduction

The development of Heterogeneous Agent New Keynesian (HANK) models has been accompanied by the investigation the effect of forward guidance policies in such models, and whether HANK models offer a solution to the so called “Forward guidance puzzle” (Carlstrom et al. (2015), Del Negro et al. (2012)), i.e. the finding that an the effects of a nominal interest rate peg on output and inflation may be implausibly large and explode in the length of the peg. Early results by McKay et al. (2016) suggested that the presence of uninsurable income risk and the associated probability to hit a borrowing constraint would dampen the effects of forward guidance by effectively limiting the households planning horizon. However, as shown by Werning (2015), Hagedorn et al. (2019) and Bilbiie (2020), their result is due to specific assumptions about the distribution of firm profits and taxes which render income inequality and income risk procyclical. By contrast, with countercyclical inequality and income risk, the effects of forward guidance are larger in HANK models than in the representative agent model, as the policy raises the income share of households with a high Marginal Propensity to Consume (MPC), thus worsening the forward guidance puzzle rather than resolving it. Since in the data, income inequality is if anything countercyclical (see Heathcote et al. (2023) and Bilbiie et al. (2023)), it appears that plausibly configured HANK models do display the forward guidance puzzle.

This paper shows that the Forward guidance puzzle actually *can* be resolved in a HANK model if the fiscal policy displays a small effect of the level of government debt on taxes and an important effect of economic activity on the government budget deficit. Both features are empirically plausible.

I first consider the simple sticky wage, flexible price one-asset model of Auclert et al. (2024b) with zero profits and thus virtually acyclical pre-tax income. I find that depending on the assumed fiscal rule, the effect of an interest rate peg maybe larger than, close to or much weaker in a HANK model than in a representative agent (RA) version of the model. The reason is that in all HANK models, the real interest rate decline redistributes income from asset holders to the government. Under a balanced budget (BB) rule, the government holds lowers tax revenue in response to the decline in its interest payments. This tax cut in itself has only a marginal direct effect on the post-tax income distribution. It follows that the total effect of the decline in real interest income and the following tax cut is to redistribute income from asset holders, who have a low MPC, to households with few or no assets and thus a high MPC. This redistribution renders the effects of forward guidance on output and inflation much stronger than in the RA model and also more explosive in the length of the nominal interest rate peg. Once I eliminate this redistribution by assuming that agents instead receive an ex-post transfer compensating them exactly for the loss arising from the decline in their real interest income, a configuration I call "compensated balanced budget rule" (CBB), the effects of the policy are very close to those in a representative agent RA model.

Furthermore, moving from the CBB to a "Gradual Adjustment" (GA) rule, i.e. a rule which adjusts taxes gradually in response to deviations of government debt from a target value lowers the effects of the interest rate peg on output and inflation below those obtained in the RA model. In contrast to the CBB rule, the government does not re-inject its savings from lower interest payments into the economy via a transfer to bondholders, but instead repays debt. One can thus understand the difference in the response of household consumption between the GA and the CBB rule as the effect of removing this transfer. As the size of this transfer is proportional to the decline of the real interest rate and thus increases exponentially in the length of peg, so is the dampening impact of removing it. As a result, with the GA rule, the impact of the interest peg becomes linear in the length of the peg instead of explosive. Finally, I consider a "Gradual adjustment with Automatic Stabilizers" (GAAS) rule that adds automatic stabilizers in the form of a feedback from economic activity to tax revenue to the GA rule. This mechanism further dampens the increase in consumption. I show that these results are robust to allowing for long-term government debt, high liquidity and countercyclical inequality, a feature that has been shown to amplify the effect of forward guidance and other demand shocks.

A fiscal rule with the properties of the GAAS rule is an empirically plausible description of the response of tax revenue to the level of government debt. Firstly, the impact of economic activity on the budget deficit via changes in the tax base and (unemployment) benefit payments is common feature of tax and benefit systems. Furthermore, estimations of DSGE models with fiscal blocks routinely confirm the finding of a very small and gradual effect of the level of debt on taxes and expenditures, see Leeper et al. (2017); Coenen et al. (2013); Gadatsch et al. (2016); Leeper et al. (2010); Zubairy (2014).

The mechanism driving the attenuation of the effects of forward guidance under this fiscal rule in the HANK model partially resembles the manner in which the "Preferences Over Safe Assets" (POSA) assumption analyzed by Rannenberg (2024) attenuates the effect of forward guidance in a RA model. In particular, part of the attenuation in that environment also arises from the persistent decline in government debt observed under a gradual adjustment type fiscal rule, which dampens

the consumption increase caused by the policy by raising the marginal utility of debt relative to the marginal utility of consumption. I show that an independently calibrated POSA model with a GAAS rule approximates the results of its HANK counterpart surprisingly closely, though how closely is sensitive to the steady-state level of government debt.

Another feature of the GAAS and GA rules is that they eliminate the "Catch 22" argued by Bilbiie (2024) from the HANK model. Bilbiie (2024) shows that in response to a fully tax-funded government expenditure shock combined with a real interest rate peg, consumption crowding in requires countercyclical inequality. At the same time, in his model ruling out the forward guidance puzzle requires procyclical inequality. Consumption crowding in in response to government expenditure shocks is often considered a desirable feature of HANK models, while the forward guidance puzzle is not, hence the "Catch 22". However, if the government expenditure increase is funded partially by debt as it will be with a GA or GAAS rule, private consumption is crowded in even with acyclical inequality. (Bilbiie (2020), Auclert et al. (2024b)). Hence with the GAAS or the GA rule, the HANK model no longer displays the "Catch 22". Moreover, adding countercyclical inequality raises the fiscal multiplier further, but raises the effect of forward guidance only marginally.

I also consider the nominal debt target rule proposed by Hagedorn et al. (2019). This rule also attenuates the effects of forward guidance compared to the RA model and renders the effect linear in the length of the peg by making the price level determinate, thus anchoring inflation expectations. However, the peg remains much more powerful than under the GAAS rule. Moreover, a nominal debt target is empirically much less plausible than the GAAS rule.

Furthermore, I show that my results are robust to a number of extensions of the simple model, including long-term debt, high liquidity, and countercyclical inequality and income risk. Finally, I also repeat the analysis in a quantitative model with nominal rigidities in both wage and price setting and capital accumulation, with households holding a liquid asset and an asset that is illiquid due to portfolio adjustment costs as in Kaplan et al. (2018).

Kaplan et al. (2018) and Auclert et al. (2024a) discuss that the conduct of fiscal policy shapes the effects of ordinary monetary policy shocks. However, to my knowledge, this is the first paper that analyzes the effect of a nominal interest rate peg in a HANK model with a gradual adjustment type fiscal rule, and shows that a HANK model can resolve the forward guidance puzzle without assuming procyclical inequality. Analyses of monetary policy in HANK typically assume that government debt is held constant by fiscal policy or is absent (e.g. McKay et al. (2016), Gerke et al. (2024), Herman and Lozej (2023)). An exception are Auclert et al. (2024a) and Kaplan et al. (2018), who however do not consider an interest rate peg. In a short note, Kaplan et al. (2016) separately simulate a contemporaneous and a future anticipated innovation to the Taylor rule in different variants of their HANK model, which is quite different from simulating an interest rate peg.

The remainder of the paper is structured as follows. Section 2 develops the simple canonical HANK model. Section 3 discusses the calibration. Section 4 describes the nominal interest rate peg simulation setup I use throughout most of the paper. Section 5 discusses the results obtained in the canonical HANK model for a nominal rate peg. Section 6 analyzes the more stylized case of a real rate peg, an assumption often made in the literature on forward guidance in HANK models. Section 7 develops and analyzes the quantitative model. In Appendix E, I repeat the aforementioned simulation of Kaplan et al. (2016) in my models.

2 The model

2.1 Firms

The representative firm produces the output good from labor using a linear technology

$$Y_t = N_t \tag{1}$$

It operates under perfect competition, implying that the real wage w_t is constant at

$$w_t = 1 \tag{2}$$

and profits are zero, implying that

$$Y_t = w_t N_t \tag{3}$$

2.2 Households

2.2.1 Heterogeneous Agent model

The household side of the model follows Auclert et al. (2024b). The economy is populated by unit mass of households indexed with i facing idiosyncratic income uncertainty in the form of time varying labor productivity $e_{i,t}$. The effective labor supply of household i is given by $e_{i,t}n_{i,t}$, with n_{it} denoting household i 's labor effort, implying that aggregate hours are given by $N_t = \int e_{it}n_{it}di$.

The nominal wage per unit of effective labor W_t is sticky, implying that households take n_{it} as given. Labor hours are allocated proportionally across households via the rule

$$n_{it} = N_t \tag{4}$$

which imposes the normalization $\int e_{it}=1$. e_{it} follows a an AR(1) process with persistence ρ_e and standard deviation σ_e .

Taxes are lump sum and proportional to household i 's individual productivity. Therefore post-tax labor income z_{it} is given by $z_{it} = (w_t n_{it} - T_t) e_{it}$, where T_t denotes total lump sum tax payments. T_t should be interpreted as "net taxes", i.e. taxes net of transfer payments. Combining this expression with (3) and (4) yields

$$z_{it} = (Y_t - T_t) e_{it} \tag{5}$$

Note that this formulation implies that the pre- and post tax labor income distributions are identical, so changes in total tax revenue in itself are neutral with respect to the income distribution. Regarding the distribution of the tax burden across households, I have also considered the "retention function" setup adopted by Auclert et al. (2024b), which implies a smaller dispersion of post-tax labor income than pre-tax labor income, but the impact of the interest rate peg on output and inflation discussed below remains virtually identical. The household budget constraint is then given by

$$a_{it} + c_{it} = (1 + r_t) a_{it-1} + z_{it} \tag{6}$$

where a_{it} and r_t denote real assets and the (ex-post) real interest rate, respectively. The households is subject to the borrowing constraint

$$a_{it} \geq 0 \quad (7)$$

Households maximize

$$\sum_{i=0}^{\infty} \beta^i \left(\frac{c_{it}^{1-\sigma}}{1-\sigma} - \frac{\chi_N}{1+\eta} n_{it}^{1+\eta} \right) \quad (8)$$

subject to (6) and (7).

2.2.2 Representative Agent model

I also consider two representative agent versions of the model without idiosyncratic income shocks and borrowing constraints. The first is the standard infinite horizon model with the utility function given by (8), while in the second, households have Preferences Over Safe Assets (POSA) as in Rannenberg (2024). The utility function is given by

$$\sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \frac{\chi_N}{1+\eta} N_{t+i}^{1+\eta} + \frac{\chi_a}{1-\sigma_a} A_{t+i}^{1-\sigma_a} \right]$$

with $\chi_a, \sigma_a \geq 0$, while the budget constraint remains as before. The first order conditions with respect to assets and consumption are given by

$$\Lambda_t = \beta(1+r_{t+1})\Lambda_{t+1} + \chi_a A_t^{-\sigma_a} \quad (9)$$

$$\Lambda_t = C_t^{-\sigma} \quad (10)$$

where Λ_t denotes the marginal utility of consumption. As discussed in detail in Rannenberg (2024), with POSA ($\chi_a > 0$), effect of future interest changes on current consumption are attenuated in two different ways, which are easiest to grasp by linearizing the Euler equation. Doing so yields

$$\hat{\Lambda}_t = \theta \left[\hat{R}_t - \hat{\Pi}_{t+1} \right] + \theta \hat{\Lambda}_{t+1} - (1-\theta)\sigma_a \frac{Y}{A} \hat{A}_t \quad (11)$$

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{A}_t , which is expressed as a percentage of steady state GDP. $\theta \equiv \beta \frac{R}{\Pi}$, i.e. the product of the steady-state household discount factor and the real interest rate. θ represents the net weight the household attaches to the $t+1$ marginal utility of consumption. Assuming POSA (i.e. $\chi_a > 0$) implies that $\theta < 1$, and thus a smaller effect of future real interest rate changes on current consumption, the more so the further these changes are located in the future. This type of effect is sometimes referred to as “Discounting in the Euler equation”. Furthermore, depending on the behavior of fiscal policy, an expansionary forward guidance policy may lower real government debt via a lower real interest rate and higher tax revenues. With both POSA and declining marginal utility from safe assets ($\theta < 1$ and $\sigma_a > 0$), a decline in a household’s government bond holdings will tend to lower its consumption by raising the marginal utility of government bonds relative to the marginal utility of consumption. To put it differently, the household attempts to smooth not just consumption but also its real safe asset holdings. If fiscal policy allows \hat{A}_t to decline in response to an expansionary forward guidance policy, this “wealth

effect” also contributes to attenuating the impact of an interest rate peg on output and inflation.

2.3 Wage setting

The labor input N_t employed by firms is a CES basket of labor varieties. Hence the demand for labor variety j given by

$$N_t(j) = N_t \left(\frac{W_t(j)}{W_t} \right)^{-\epsilon_w}$$

Following Hagedorn et al. (2019), nominal wages paid for individual varieties $W_t(j)$ are set by a union which maximizes the utility of an “average” household subject to a quadratic wage adjustment costs $\frac{\xi_w^J}{2} \left(\frac{W_t^J(j)}{W_{t-1}^J(j)} - 1 \right)^2 N_t w_t$. This approach has the advantage that the resulting wage setting equation remains the same regardless of the assumptions regarding household heterogeneity. The unions objective is thus given by

$$\sum_{i=0}^{\infty} \frac{1}{\left(\frac{R_{t+i}}{\Pi_{t+1+i}} \right)^i} \left[-\chi_N \frac{\left(N_{t+i} \left(\frac{W_{t+i}(j)}{W_{t+i}} \right)^{-\epsilon_w} \right)^{1+\eta}}{(1+\eta) C_t^{-\sigma}} + \frac{(W_{t+i}(j))^{1-\epsilon_w}}{P_{t+i}^J} N_{t+i} \left(\frac{1}{W_{t+i}} \right)^{-\epsilon_w} - \frac{\xi_w^J}{2} \left(\frac{W_{t+i}(j)}{W_{t-1}(j)} - 1 \right)^2 N_{t+i} w_{t+i} \right]$$

The first order condition and the fact that all unions set the same wage imply the following non-linear wage Phillips Curve:

$$\left(\frac{\Pi_{W,t}}{\Pi} - 1 \right) \frac{\Pi_{W,t}}{\Pi} = \kappa_w \left(\frac{\epsilon_w}{\epsilon_w - 1} \frac{\chi_N (N_t)^\eta}{w_t C_t^{-\sigma}} - 1 \right) + \frac{1}{\left(\frac{R_t}{\Pi_{t+1}} \right)} \frac{N_{t+1}}{N_t} \left(\frac{\Pi_{W,t+1}}{\Pi} - 1 \right) \frac{(\Pi_{W,t+1})^2}{\Pi_{t+1} \Pi} \quad (12)$$

The linearized version of this equation is given by

$$\hat{\Pi}_{W,t} = \kappa \hat{Y}_t + \frac{1}{1+r} \hat{\Pi}_{W,t+1} \quad (13)$$

with $\kappa \equiv \kappa_w \left(\eta + \sigma \frac{Y}{C} \right)$, where I have taken into account (1), (2) and the fact that government expenditure is constant. Below I will calibrate η , σ and κ directly and set κ_w to support the chosen combination of values.

Following Hagedorn et al. (2019), I assume that wage and price adjustment costs are “as-if”, i.e. they are not actually resource costs though wage setters behave as if they are. The assumption avoids counterfactual “price-adjustment booms” that would be caused by the potentially large price changes caused by the interest rate peg I simulate.

2.4 Government

The government budget constraint in nominal terms is given

$$B_t = R_{t-1} B_{t-1} + P_t (G - T_t) \quad (14)$$

where B_t , R_t , P_t and G denote total government bonds, the short-term gross nominal interest rate, the price level and real government expenditure, respectively.

Under the first rule I consider, the total tax burden adjusts in order to fix total real debt at a target level, i.e. $\frac{B_t}{P_t} = \frac{B_{t-1}}{P_{t-1}} = b^T$. It is given by

$$T_t = G + b^T \left(\frac{R_{t-1}}{\Pi_t} - 1 \right) \quad (15)$$

I refer to this policy as “Balanced Budget” (BB) rule.

The second fiscal policy I consider is a “Compensated Balanced Budget rule” (CBB). Under this rule, the government compensates each bondholder for changes in the real interest rate ex-post. So if the real interest rate declines, households receive a transfer at the beginning of the period such that any income changes resulting from deviations of the real interest rate from steady-state are compensated as a lump sum:

$$a_{it} + c_{it} = r_t a_{it-1} + z_{it} + tr_{i,t}^a \quad (16)$$

with $tr_{i,t}^a = (r - r_t) a_{it-1}$. However, households do *not* take the dependence of $tr_{i,t+1}^a$ on a_{it} into account when making their optimal choice of a_{it} . The government budget constraints is given by

$$T = G + b^T \left(\frac{R}{\Pi} - 1 \right) \quad (17)$$

and thus total taxes are constant.

The third policy is a “Gradual Adjustment rule” (GA rule). Total taxes adjust gradually in response to deviations of the debt-to-GDP ratio from a target, a common assumption in the fiscal policy literature and especially in contributions estimating models with fiscal blocks (see Leeper et al. (2017); Coenen et al. (2013); Gadatsch et al. (2016); Leeper et al. (2010)). Total taxes are thus determined as:

$$T_t = T_t^d \quad (18)$$

$$T_t^d = T + \phi_T \left(\frac{b_{t-1} - b^T}{Y} \right) + \rho_T (T_{t-1}^d - T) \quad (19)$$

where b^T denotes the debt target. Government debt evolves as

$$b_t = \frac{R_{t-1}}{\Pi_t} b_{t-1} + G - T_t \quad (20)$$

The fourth policy rule is a modification of the GA rule where on top of the debt level, economic activity also affects tax revenues positively. This assumption proxies the impact of automatic stabilizers, i.e. countercyclical transfers and procyclical tax revenue. Hence equation (18) is replaced by

$$T_t = T_t^d + \varepsilon_{TY} \hat{Y}_t + \varepsilon_{T,t} \quad (21)$$

with $\varepsilon_{TY} > 0$. I refer to this rule as "Gradual Adjustment with Automatic Stabilizers" (GAAS)

rule. $\varepsilon_{T,t}$ denotes a tax shock that will be used below for part of the calibration of the POSA model.

The fifth policy fixes is the “Nominal Debt Targeting” (NDT) rule considered by Hagedorn et al. (2019). It fixes the *nominal* debt level at a target value B^T :

$$T_t = G + \frac{B^T}{P_t} (R_{t-1} - 1) \quad (22)$$

Note that in the RA model without POSA, all rules imply identical dynamics of all variables other than taxes and debt due to Ricardian equivalence. I will refer to this model below as RA model. By contrast, with POSA the assumed fiscal rule matters. Below I will consider results for the "POSA + BB" and "POSA + GAAS" cases.

Unless the interest rate is pegged, monetary policy is described by the following interest feedback rule:

$$\hat{R}_t = \phi_\pi \hat{\Pi}_t + \frac{\phi_y}{4} \hat{Y}_t \quad (23)$$

The net real interest rate earned by households is then determined as

$$r_t = \frac{R_{t-1}}{\Pi_t} - 1 \quad (24)$$

2.5 Equilibrium

The market for the liquid asset clears:

$$A_t = \int a_{it} di \quad (25)$$

$$b_t = A_t \quad (26)$$

The goods market clears:

$$Y_t = C_t + G \quad (27)$$

$$C_t = \int c_{it} di$$

3 Calibration

One period in the model corresponds to one quarter in the data. The calibration is reported in Table 1. I calibrate a number of parameters directly. The elasticity of intertemporal substitution $\frac{1}{\sigma}$ is set to one and the inverse Frisch elasticity of labor supply η is set to two. The calibration of the parameters of the idiosyncratic income process σ_e and ρ_e follow Auclert et al. (2024b), with the values modified to be consistent with a quarterly frequency. The share of government expenditure in output equals 20%. For the gradual adjustment rule, I assume $\rho_T = 0.95$ and set ϕ_T to a small value sufficient to guarantee debt stationarity. The literature estimating DSGE models with fiscal blocks typically finds that taxes and government expenditures respond only extremely gradually to changes in government debt, see Rannenberg (2021), Leeper et al. (2017), Gadatsch et al. (2016), Zubairy (2014) and Coenen et al. (2013). Furthermore, in the gradual adjustment

rule I set the feedback from economic activity to tax revenue $\varepsilon_{TY} = 0.5$, which equals the semi-elasticity of the budget balance with respect to the output gap as estimated by Price et al. (2015) for the US economy. Note that this parameter is a shortcut to capture the combined effect of the procyclicality of government revenues that would arise in the presence of consumption taxes and (possibly progressive) income taxes, and the counter-cyclicality of expenditures that would arise as the result of unemployment benefits and other income related transfers. The authors estimate this parameter using a bottom-up approach.

Given these choices, I calibrate a number of parameters in order to set the steady-state values of important model variables to (empirical) target values. In all models, I set the wage Phillips Curve slope κ_w such that κ equals the output coefficient of the estimated New Keynesian Phillips curve of Coibion et al. (2018),¹ the household discount factor β to match a real interest rate of 2% annually and the labor disutility weight χ_N to normalize output to one. In the heterogeneous agent model, following Auclert et al. (2024b), I set government debt target in the fiscal rules b^T and thereby the steady-state real debt level in order to set the first year Marginal Propensity to Consume (MPC) out of an income windfall to 0.51, as estimated by Fagereng et al. (2021).

¹See their “Appendix Table 1”, first column.

Table 1: Calibration

Directly calibrated parameters		
Parameter	Definition	Value
σ	Consumption curvature	1.0
η	Labor curvature	2.00
σ_e	Idiosyncratic income shock s.d.	0.46
ρ_e	Idiosyncratic income shock persistence	0.98
G	Government expenditure-to-GDP ratio	0.2
ϵ_{YT}	Budget semi-elasticity	0.5
ϕ_T	GA + GAAS rule debt response	0.03
ρ_T	GA + GAAS rule lagged tax response	0.95
ϕ_π	Taylor rule inflation	1.5
ϕ_y	Taylor rule output	0.5
μ_w	Wage markup	1.5

Parameters calibrated to match Target values		
Parameter	Definition	Value
β	Household discount factor	0.984
b^T	Debt target fiscal rule	0.76
χ_N	Labor disutility weight	0.83
κ_w	Wage markup coefficient	0.011
POSA: β	Household discount factor	0.95
POSA: χ_a	Safe asset utility weight	0.06
POSA: σ_a	Safe asset utility curvature	0.06

Target values		
Target	Definition	Value
r	Real interest rate, APR	2.0
MPC	First year MPC	0.51
Y	Output	1.0
κ	Phillips curve output coefficient	0.036
POSA: θ	Inverse discounting wedge	0.95
POSA: Debt supply on interest rate	See note below	0.05

Note: Effect of increase of the government debt-to-GDP ratio on the interest rate model counterpart: I simulate a fully anticipated one percentage point increase in the government debt-to-GDP ratio 5 years ahead, implemented as a one-off negative value of the shock $\varepsilon_{T,t}$ during quarter 17 (see equation (21)).

In the POSA model, I keep the government debt level from the heterogeneous agent model and add two additional targets to pin down the POSA related parameters, following the strategy of Rannenberg (2021) and Rannenberg (2024). In particular, I set the inverse discounting wedge θ in line with the evidence on the ratio between gross safe interest rates and individual discount rates collected by Rannenberg (2024). Furthermore, I calibrate the safe asset curvature parameter σ_a such that the effect of a one percentage point increase of the five-year-ahead government debt-to-annual-GDP ratio on the five-year-ahead ten-year-forward Treasury rate is in the empirical range of 0.03 to 0.06 percentage points found by Gale and Orszag (2004), Engen and Hubbard (2005) and Laubach (2009), which yields $\sigma_a = 0.056$ (see the note below Table 1 for details).²

I discretize the AR(1) process for e on an 11 point grid using the Rouwenhorst method. I discretize the asset space using a double-exponentially-spaced grid with 500 grid points.

4 Simulation set-up

The simulation setup follows Rannenberg (2024). The economy is initially at its steady state. In quarter one, the central bank announces that instead of following its interest feedback rule (23), it will peg \hat{R}_t at an exogenous value for a total of $D_L + D_p$ quarters. During quarters one to D_L , the central bank pegs the interest rate at its steady-state value. By contrast, for quarters $D_L + 1$ until $D_L + D_p$, it pegs the interest rate at $-\Delta$ %. Finally, the central bank promises to return to its interest feedback rule (23) in quarter $D_L + D_p + 1$. To summarize, I assume

$$\hat{R}_t = \begin{cases} 0 & \text{for } t = 1, 2, \dots, D_L \\ -\Delta & \text{for } t = D_L + 1, D_L + 2, \dots, D_L + D_p \\ \phi_\pi \hat{\pi}_t + \frac{\phi_y}{4} \hat{Y}_t & \text{for } t > D_L + D_p \end{cases} \quad (28)$$

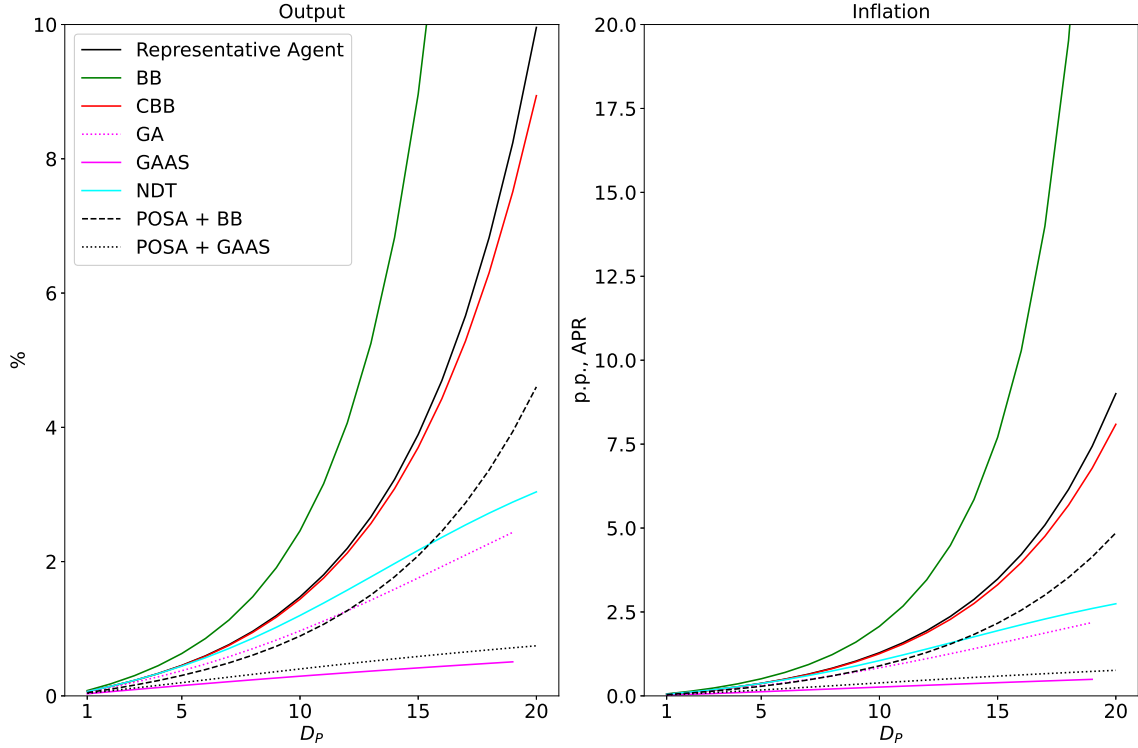
I set $D_L = 6$, following Carlstrom et al. (2015). Furthermore, prior to the forward guidance announcements of the US Federal Reserve in September 2011, January 2012 and September 2013, financial markets expected the federal funds rate to remain at the ZLB for approximately six quarters, according to the evidence reported in Del Negro et al. (2023). I set Δ to an annualized value of 0.2% (i.e. $\Delta = \frac{0.2}{4}$), which is in line with the effect of the announcement on private sector forecasts of three-month treasury bills estimated by Del Negro et al. (2023).³ Based on these assumptions, below I will investigate the macroeconomic effect of varying D_p , i.e. the length of the period during which the interest rate is pegged Δ percent below its steady-state value. In Appendix C, I also consider an alternative setup where I fix the duration of the interest rate cut at one quarter and allow instead the date of the cut to vary. More formally, I fix D_P at one and instead allow D_L to vary.

I perform nonlinear perfect foresight simulations, using the non-linear variant of the Sequence-Space Jacobian method of Auclert et al. (2021) as implemented in their Python toolbox, which allows to easily simulate the interest rate pegs just described.

²The value of σ_a obtained in this manner depends inter alia on the steady-state level of safe assets, and thus differs from Rannenberg (2024).

³See their Figures 1 and 3, respectively.

Figure 1: Forward guidance - impact effect



Note: The graph displays the results of the simulation described in Section 4. Each line refers to a specific combination of a model and a fiscal rule. Unless specifically mentioned, the model is the HANK model developed above. BB = Balanced budget rule (equations (15)). CBB = Compensated Balanced Budget rule (equation (17) and (16)), GA = Gradual Adjustment rule (equation (18)), GAAS = Gradual Adjustment Automatic Stabilizers rule (equation (21)). NDT = Nominal Debt Target (equation (22)).

5 Results in the canonical HANK model

5.1 Baseline results

Figure 1 displays the results for the RA model and the six HANK models for different peg lengths. The impact of the policy is largest in the HANK model with the BB rule (green line). Results for the model with the CBB rule (red line) are very close to the RA model (black line), while results are smallest with the GAAS rule (magenta line). Furthermore, for the RA, BB, CBB and POSA + BB model, the effect on output and inflation increase exponentially in the length of the peg.

Turning first to the RA model, the policy stimulates demand by lowering the real interest rate via lowering the nominal rate. If the peg would target the real rate instead of the nominal rate, the effect of the peg on output would be increase linearly in D_p , as can be obtained directly from equation (11), with $\frac{\partial \hat{C}_i}{\partial D_p} = \sigma \Delta = 0.2$ (with $i = 1, 2, \dots, D_L + D_P$) under the adopted calibration.⁴ The effect on inflation would accordingly be approximately linear in D_p as well (see equation 13).⁵

⁴This result can be obtained setting $\theta = 1$ iterating forward, and using (28) which yields $\hat{C}_1 = -\sigma \sum_{i=0}^{D_L+D_P} \hat{R}_{1+i} - \hat{\Pi}_{1+1+i} = \sigma \Delta D_p$.

⁵Approximately because $\frac{1}{1+r}$ is smaller than but close to one.

By contrast, with a nominal rate peg, the increase in output by $\sigma\Delta$ during each quarter of the peg represents only the *direct* demand effect of adding one quarter to the peg. The increase in output raises inflation during each quarter of the peg, which lowers the real interest rate further. With each increase in D_p , the number of preceding quarters $D_L + D_P$ during which the real interest rate declines rises, implying that the sum of future real interest rates driving the consumption increase $\sum_{i=0}^{D_L+D_P} \hat{R}_{1+i} - \hat{\Pi}_{1+1+i}$ declines more with each increase of D_p . Thus the effect of the peg increases exponentially in D_p .

The reason why the effect of the policy maybe larger or weaker in a HANK model than in the RA model, depending on the respective fiscal rule, is as follows. In all the HANK models, the real interest rate decline redistributes income from asset holders, who correspond to roughly the top 30% of the labor income distribution, to the government.⁶ Figure 3 displays the deviation of the share of the top 30% of the labor income distribution in total post-tax income, including interest income. The decline in the top 30% income share is approximately proportional to the decline in the real interest rate in the respective model. In the BB model, the government holds real debt constant and thus lowers tax revenue T_t in response to the decline in its interest payments, as can be obtained from Figure 2 (third row). This tax cut has only a marginal direct effect on the post-tax income distribution, as the individual tax burden is proportional to the idiosyncratic labor income state e_{it} (see equation 5). It follows that the combined effect of the decline in real interest income and the following tax cut is to redistribute income from the top 30% of the labor income distribution, who have a low on-impact MPC (see Table 2), to the bottom 70%, who have a high MPC. This redistribution amplifies the response of total consumption to the policy. In the context of an ordinary transitory monetary policy shock, Auclert et al. (2024a) document the feedback from a lower real interest rate to lower taxes and higher consumption implied by the BB rule.

In the HANK model with the CBB rule, this redistribution is removed by a government transfer payment to bond holders which compensates them exactly for the decline of their real interest income (see equations 16 and 17), implying acyclical post-tax income inequality (see Figure 3). In line with the literature, the effect of forward guidance then becomes close to the RA model (see Bilbiie (2020), Werning (2015)).

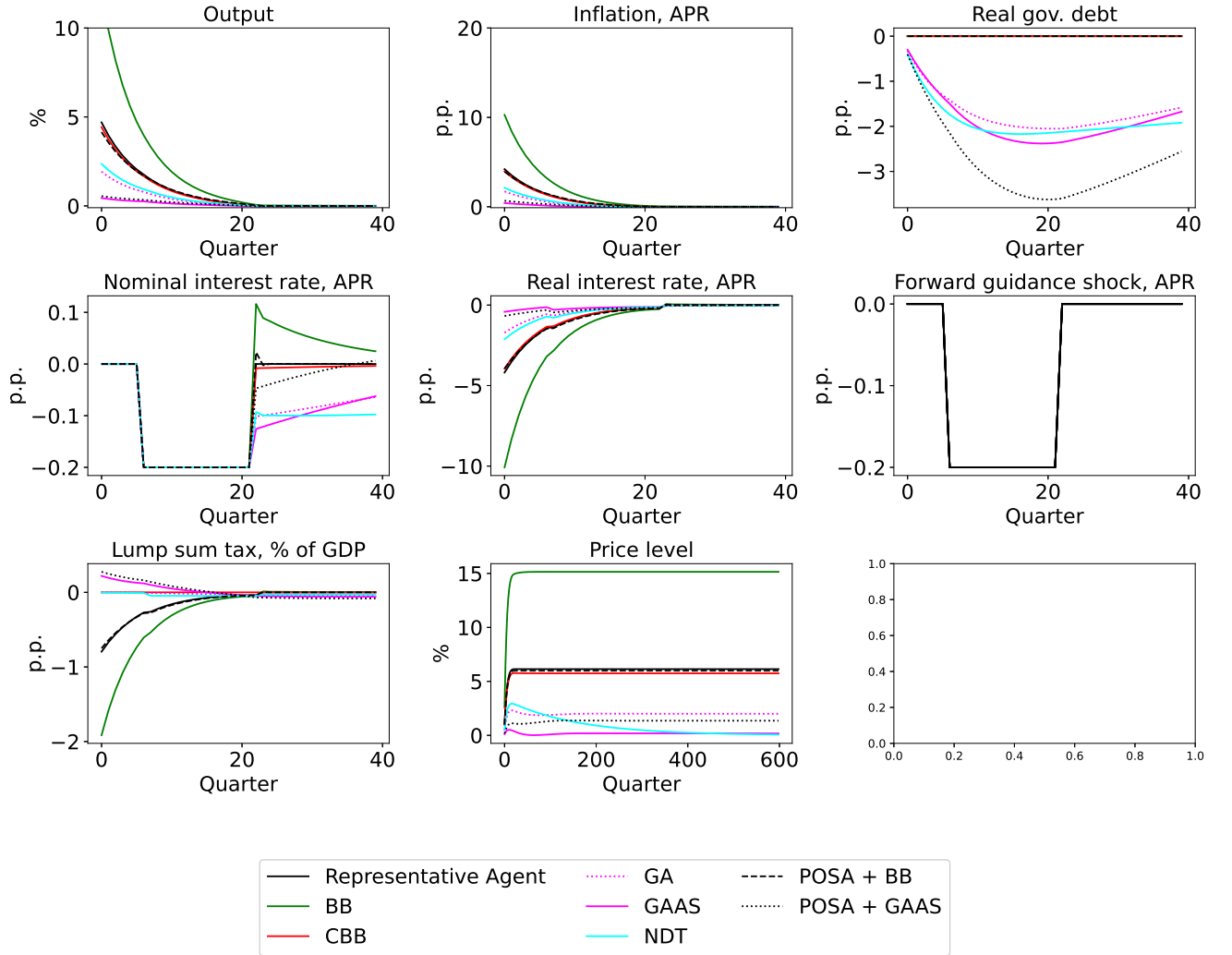
Table 2: Model MPC according to labor income deciles

Decile	MPC
1	0.98
2	0.96
3	0.92
4	0.88
5	0.75
6	0.75
7	0.23
8	0.08
9	0.05
10	0.03

By contrast, under the GA rule, the effect of the interest rate peg is lower than in the RA model or the HANK model with the CBB rule (see the magenta dotted line). For D_P equal to about 8

⁶The top three deciles of the labor income distribution own 83% of all wealth.

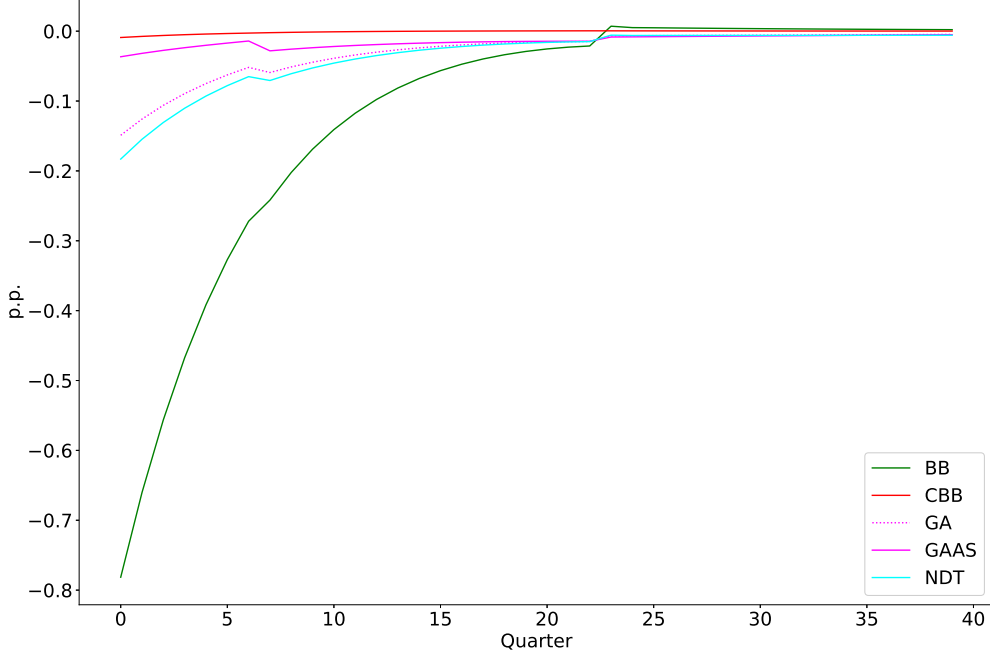
Figure 2: Forward guidance - dynamic effect



Note: The graph displays the results of the simulation described in Section 4 for $D_P = 16$. For details on the meaning of the labels see the note below Figure 1.

quarters, the effect of the policy on output and inflation are already about 30% weaker under the GA than under with the CBB rule. For $D_P = 12$, the output effect is 36% lower, and becomes approximately linear in the length of the peg. In contrast to the CBB rule, under the GA rule the government does not re-inject its savings from lower interest payments into the economy via transfer to bondholders. Instead it repays debt. Hence one can understand the difference in the response of consumption between the GA and the CBB rule as the effect of removing this transfer. As the size of this transfer is proportional to the decline of the real interest rate and thus increases exponentially in the length of peg (due to the aforementioned feedback loop between demand, inflation and the real interest rate), so is the dampening impact of removing it. In Appendix A, I confirm that this intuition is correct by showing for a numerical quasi-linear approximation of the solution of model (where the only non-linearity that remains the interest rate peg), the effect of the peg under the GA rule on the model variables X_t can be approximated by the sum of the effects of two separate simulations. The first simulation is the effect of the peg under the CBB rule. The

Figure 3: Share of the top three labor income deciles in total income with an interest rate peg of 16 quarters.



Note: Total income of an individual household equals the sum of interest and post-tax labor income: $\left(\frac{R_{t-1}}{\Pi_t} - 1\right) a_{it-1} + z_{it}$.

second simulation computes effect of a "lump sum wealth tax" in the GA model, where the tax rate $\tau_{a,t}$ equals the negative of the deviation of the ex-post real interest rate from its steady-state obtained in the first simulation, and the interest rate peg is pegged at its steady-state for $D_L + D_P$ quarters. More formally:

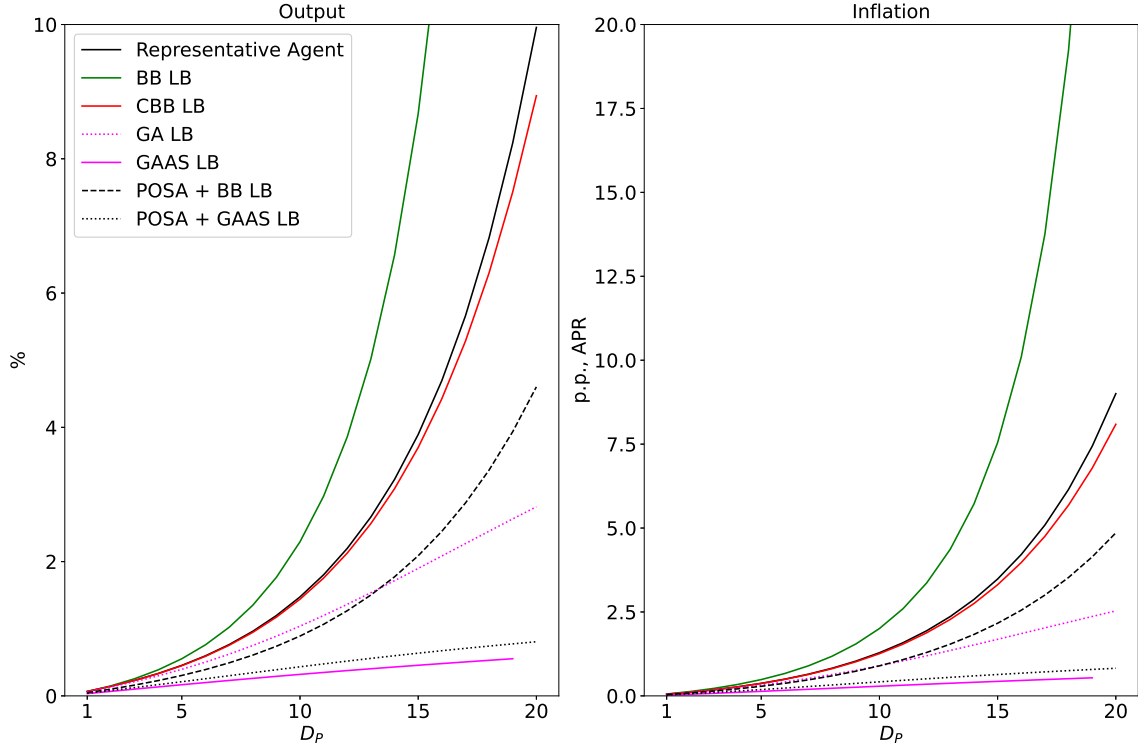
$$dX_t^{GA,D_P} \approx dX_t^{CBB,D_P} + dX_t^{GA,\tau_{a,t},D_P} \quad (29)$$

where dX_t^{GA,D_P} denotes the effect of a peg of length D_P in the model with the GA rule, dX_t^{CBB,D_P} denotes the analogous concept for the CBB rule, and $dX_t^{GA,\tau_{a,t},D_P}$ denotes the effect of the lump sum wealth tax with the interest rate pegged at its steady-state for $D_L + D_P$ periods. The tax is lump sum in the sense that households behave as if their tax burden was unrelated to their choice of their wealth level a_{it} . It is thus the reversal of the transfer that takes place under the CBB rule (see equation 16).

Moving from the GA to the GAAS rule adds the feedback from economic activity to tax revenues with $\varepsilon_{TY} > 0$ via which the forward guidance policy raises the taxes of all households, thus further dampening the increase in consumption. As can be obtained from Figure 1 (compare the magenta solid and the magenta dotted line), this additional dampening mechanism is extremely important as well. Even for a 20 quarter peg, the impact effect on output equals merely 0.6% under the GAAS rule.

Furthermore, in the RA model with POSA and the GAAS rule, the effect of forward guidance is also much weaker than in the standard RA model, in line with the findings of Rannenberg

Figure 4: Effect of forward guidance, long-term-debt - impact effect



Note: For details on the simulation setup and the meaning of the labels see the note below Figure 1.

(2024) (compare the black dotted and the black solid line), and also becomes linear in the length of the peg. Interestingly, the results for the POSA + GAAS model are close to those obtained for the HANK model with that fiscal rule (compare the black dotted to the magenta solid line). As discussed in Section 2.2.2, part of the attenuation compared to the RA model arises due to the pure “discounting” effect caused by $\theta < 1$, which implies that future real interest rates have smaller effect on current consumption the further away in the future they are located. This “discounting” is absent from the HANK model, unless one assumes income inequality is pro-cyclical (see Bilbiie (2020) and Bilbiie (2024)). The magnitude of this effect can be gauged by comparing the results for the RA model to the POSA model with the BB rule (the black solid and the black solid line). While the discounting by itself strongly attenuates the effect of forward guidance, the magnitude of the impact effect on output and inflation remains explosive in the length of the peg. Moving to the GAAS rule then activates the “wealth effect” discussed in Section 2.2.2. The wealth effect is arguably quite close in flavor to the mechanism active in the HANK model under the GAAS rule. Auclert et al. (2024b) show that a two agent model with POSA and Hand-to-mouth households (“Two Agents Bonds in the Utility” (TABU)) can proxy the government expenditure multiplier of a one-asset HANK model. I have also experimented with the TABU setup. Under the GAAS rule the effects of the peg on output and inflation were very close to the simpler representative agent POSA setup I use above, while the effect became larger under the BB rule.⁷

⁷When implementing the TABU, I followed the same calibration strategy as Auclert et al. (2024b), i.e. I set the household discount factor β to the same value as in the HANK model and calibrated the share of HtM agents and

Finally, similar to Hagedorn et al. (2019), under the nominal debt targeting rule the effects of the peg are smaller than in the RA model for peg lengths exceeding 8 quarters. As discussed in Hagedorn et al. (2019), the reason for the attenuation compared to the RA model is that the nominal debt target implies that, unlike in the other models, the price level is determinate. Hence it eventually returns to the value it had before the shock. This fact limits how far the long-term real interest rate can decline in response to the forward guidance policy. However, they are still a bit higher than under the GA rule and much higher than for the GAAS rule.

5.2 Long term bonds

I next assume that government bonds held by households are long-term instead of short-term. This assumption could potentially weaken the attenuation delivered by the GA and GAAS rules because the forward guidance policy will likely cause a jump in the bond price and thus the value of assets, thus counteracting the effect of higher inflation and tax revenues on the market value of outstanding government bonds. Following Woodford (2001), I assume that all government debt consists of perpetuities with coupons that decay exponentially. Specifically, I assume that a bond issued of one dollar in period t pays ρ^j dollars $j + 1$ periods later. I continue to assume that the bond is nominal. The real return on the bond earned by households is thus given by

$$r_t = \frac{1 + \rho P_{B,t}}{P_{B,t-1}} \frac{1}{\Pi_t} - 1 \quad (30)$$

where which replaces (24). The bond price $P_{B,t}$ is determined by a no-arbitrage condition:

$$P_{B,t} = \frac{1 + \rho P_{B,t+1}}{R_t} \quad (31)$$

This equation and the presence of the short-term nominal interest rate R_t in particular originate from the assumption that there are risk-neutral arbitrageurs trading both long and short-term bonds. Short-term bonds are in zero net supply and are also traded by the central bank. For further details see Appendix B. The government budget constraint in real terms can still be written as

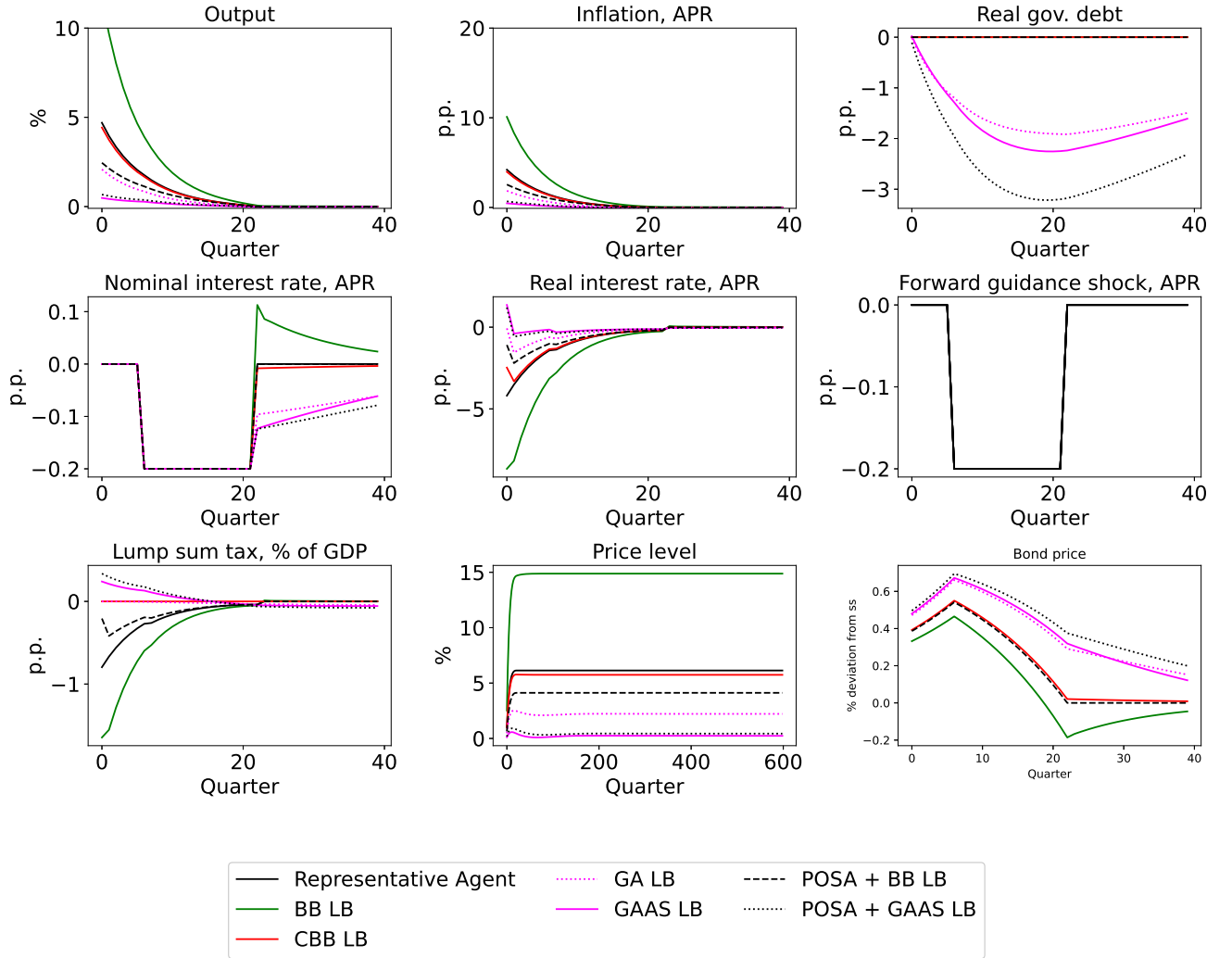
$$b_t = (1 + r_t) b_{t-1} + (G - T_t)$$

where b_t now denotes the real market value of government bonds, $\frac{B_t P_{B,t}}{P_t}$. Following Auclert et al. (2024a), I set $\rho = 0.95$.

As can be obtained from comparing Figure 4 and 1, the results are quite similar qualitatively

the wealth curvature σ_a in order to match the first and second year average intertemporal MPC obtained in the HANK model. With this approach, the effect of the peg on output and inflation under the GAAS rule would become smaller than in the HANK + GAAS model, rather than somewhat larger as it is now. In the POSA + BB model the effect of the peg would rise compared to my setup, as the implied value of θ is larger and the presence of HtM agents creates a link between lower taxes and consumption like in the BB model. However, quantitatively, the effect of the peg remains much smaller than with the HANK - BB rule configuration. These findings from those of Auclert et al. (2024b) for the fiscal multiplier, who find that the TABU model matches the multiplier of the HANK model extremely closely. This close match is likely related to the fact that they calibrate their TABU model to match the first and second year average intertemporal MPC out of a transitory income shock of their one-asset HANK model, and that as a result it also closely matches the three to six year MPC of the one-asset HANK. The intertemporal MPC is in turn the main determinant of the the fiscal multiplier, given that they assume a constant real interest rate. By contrast, when simulating an interest rate peg, the real interest rate varies and thus the interest rate sensitivity of consumption matters, which is not the same in the TABU and the one-asset HANK model (see Auclert et al. (2024b), Proposition 8 and Appendix F.4

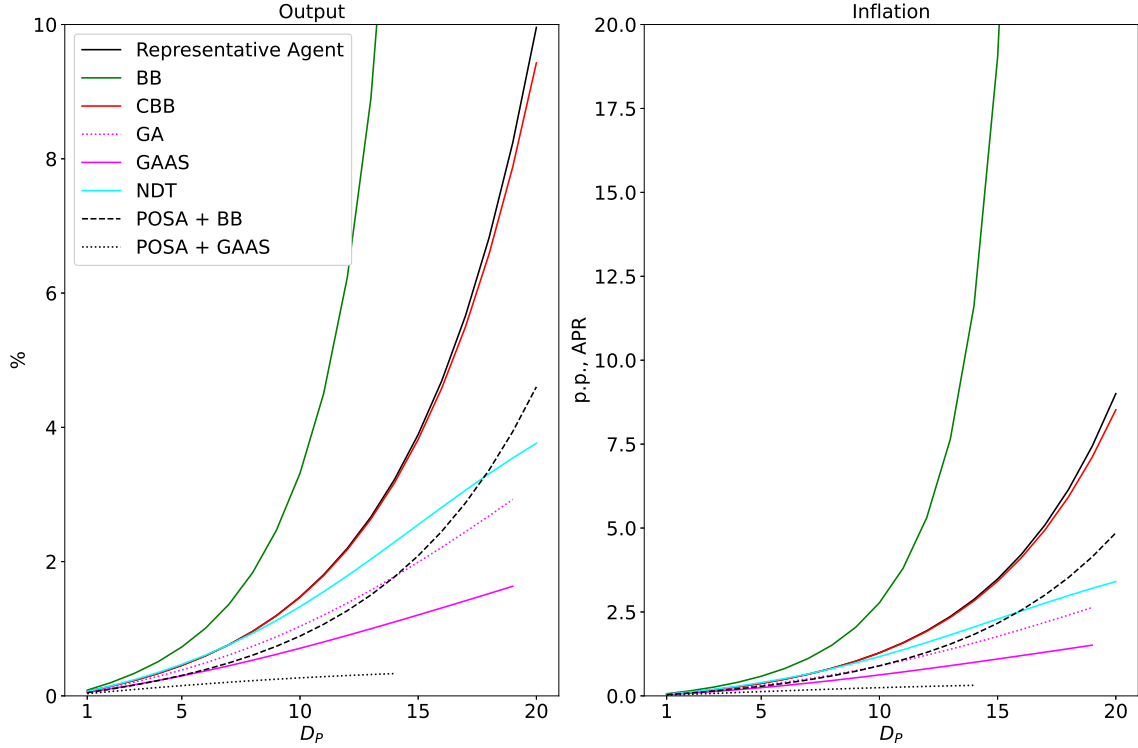
Figure 5: Effect of forward guidance with long term debt - dynamic effect



Note: For details on the simulation setup and the meaning of the labels see the note below Figure 2.

and for the most part also in quantitative terms. Effects are smaller under the BB rule because the ex-post real return on bonds declines less on impact (compare Figures 2 and 5, second row, green line), and thus the associated tax cut needed to keep real government debt constant is lower. The jump in the bond price $P_{B,t}$ in the model with long term bonds (see Figure 5, final row) offsets partly the effect of the inflation increase on the ex-post real return (see equation 30). This effect is also documented by Auclert et al. (2024a) for the case of a more standard monetary policy shock. Similarly, effects under the GAAS rule are marginally larger both in the HANK model and with POSA, because with this fiscal rule, the smaller decline in the ex-post real return on bonds implies a smaller decline in total real outstanding bonds.

Figure 6: Effect of forward guidance with higher liquidity - impact effect



Note: For details on the simulation setup and the meaning of the labels see the note below Figure 1.

5.3 High liquidity

In the baseline, following Auclert et al. (2024b), the supply of liquid assets is calibrated in order to match an empirical target for the first year MPC, implying a low steady-state government debt-to-GDP ratio. I next examine the case of a higher steady-state supply of liquid assets, i.e. I set b^T to 4, i.e. 100% of annual GDP, implying that the MPC is now considerably below the target value displayed in Table 1. As can be obtained from Figure 6, the effect of the policy is higher than in the low liquidity scenario in all the HANK model variants. However, the result under the GAAS rule remain much below those for the RA model. For instance, for $D_P = 12$, the output effect is less than half of what is observed in the RA model. By contrast, in the POSA model the effects of forward guidance under the GAAS rule are lower than in the baseline. The explanation for this stronger attenuation consists of two elements. Firstly, with a higher steady-state debt-to-GDP ratio, a given decline of the real interest rate causes a stronger decline in the debt-to-GDP ratio, which can be seen by linearizing (20). Secondly, given that my calibration strategy for the wealth curvature parameter σ_a - setting σ_a to match the effect of an expected increase in the government debt-to-GDP ratio on the forward long-term interest rate (see Section 3) keeps $(1 - \theta)\sigma_a \frac{Y}{A}$ roughly constant when the steady-state debt-to-GDP ratio $\frac{A}{Y}$ increases, this stronger decline in the debt-to-GDP ratio will lower consumption more strongly via equation (11).

5.4 Countercyclical inequality and relation to Bilbiie (2024) 's "Catch 22"

I now examine the effect of introducing countercyclical income inequality and income risk into the model. As shown by Bilbiie (2020) and Bilbiie (2024), in a simple analytically tractable zero-liquidity HANK model, this feature raises the effect of a contemporaneous interest change and adds a "compounding" effect to the aggregate Euler equation, i.e. a more than one-for-one effect of future on current consumption and thus the opposite of the "discounting" implied by say the POSA model discussed in Section 2.2.2, which in his model would require procyclical inequality. Following Auclert and Rognlie (2018), I introduce countercyclical labor income inequality and risk in a simple way by replacing (5) with

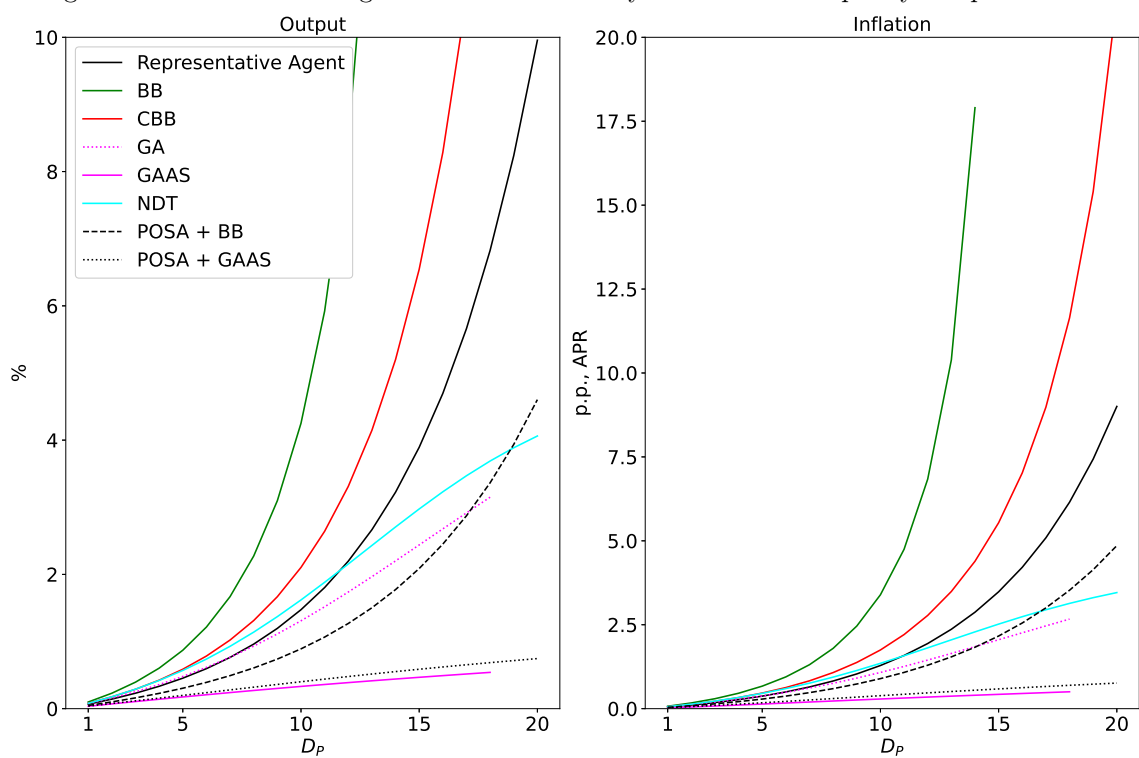
$$z_{it} = (Y_t - T_t) \frac{e_{it}^{1+\zeta \log(Y_t)}}{\int e_{it}^{1+\zeta \log(Y_t)} di} \quad (32)$$

For $\zeta < 0$, an increase of Y_t above its steady-state value of one lowers the cross sectional variance of income and thus inequality, thus channeling income to high MPC households. It also lowers the risk of a big income loss and thus precautionary saving. I set $\zeta = -0.5$. As can be obtained from Figure 7, as a result, the CBB now implies a markedly stronger effect of forward guidance than the RA model. This amplification follows directly from the two aforementioned amplification mechanisms. Figure 8 reports the effect of a 16 quarter peg on the Top 30% income share. As expected, it now declines under the CBB rule, whereas before it remained unchanged.

Under the BB rule, countercyclical inequality amplifies the effects of the policy very strongly. By contrast, under the GAAS rule, the effects of the policy on output and inflation increase only marginally. As for this fiscal rule, the output effects of the forward guidance policy are small even in the baseline model with acyclical labor income inequality, the decline in inequality triggered by this comparatively small output increase is much lower than in the other models, which in turn implies little amplification via this new channel.

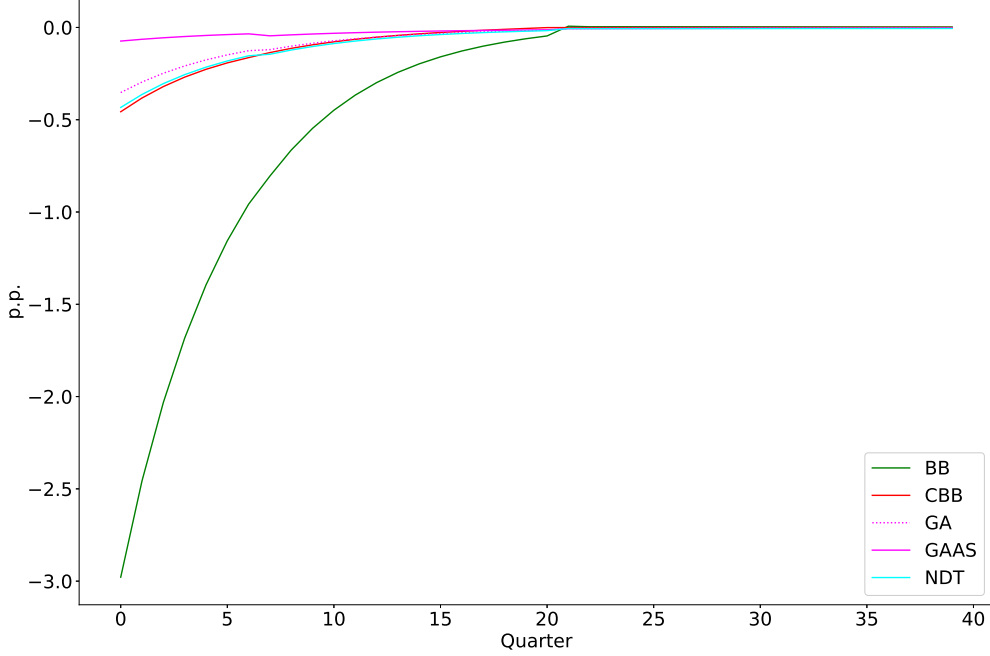
Relatedly, Bilbiie (2024) shows using his tractable model that in response to a tax-funded government expenditure shock combined with a real interest rate peg, and with taxes spread uniformly across agents, consumption crowding in requires countercyclical inequality. At the same time, ruling out the forward guidance puzzle via "discounting" in his aggregate Euler equation requires procyclical inequality. Since consumption crowding in in response to government expenditure shocks is often considered a desirable feature of HANK models, while the forward guidance puzzle is not, he labels this fact a "Catch 22". However, as has been shown elsewhere, if the government expenditure increase is funded partially by debt, private consumption is crowded in even with acyclical inequality. (Bilbiie (2020), Auclert et al. (2024b)). However as has been shown by Bilbiie (2020) and Auclert et al. (2024b), if the government expenditure increase is funded partially by debt as it will be with a GA or GAAS rule, private consumption is crowded in even with acyclical inequality, as I confirm in Appendix D. Hence with GAAS and the GA rule, the HANK model no longer displays the "Catch 22". Moreover, adding countercyclical inequality raises the fiscal multiplier further, but - as just shown- raises the effect of the interest rate peg only marginally.

Figure 7: Effect of forward guidance with countercyclical income inequality - impact effect



Note: For details on the simulation setup and the meaning of the labels see the note below Figure 1.

Figure 8: Share of the top three labor income deciles in total income with an interest rate peg of 16 quarters, countercyclical inequality



Note: Total income of an individual household equals the sum of interest and post-tax labor income: $\left(\frac{R_{t-1}}{\Pi_t} - 1\right) a_{it-1} + z_{it}$.

6 Real interest rate peg

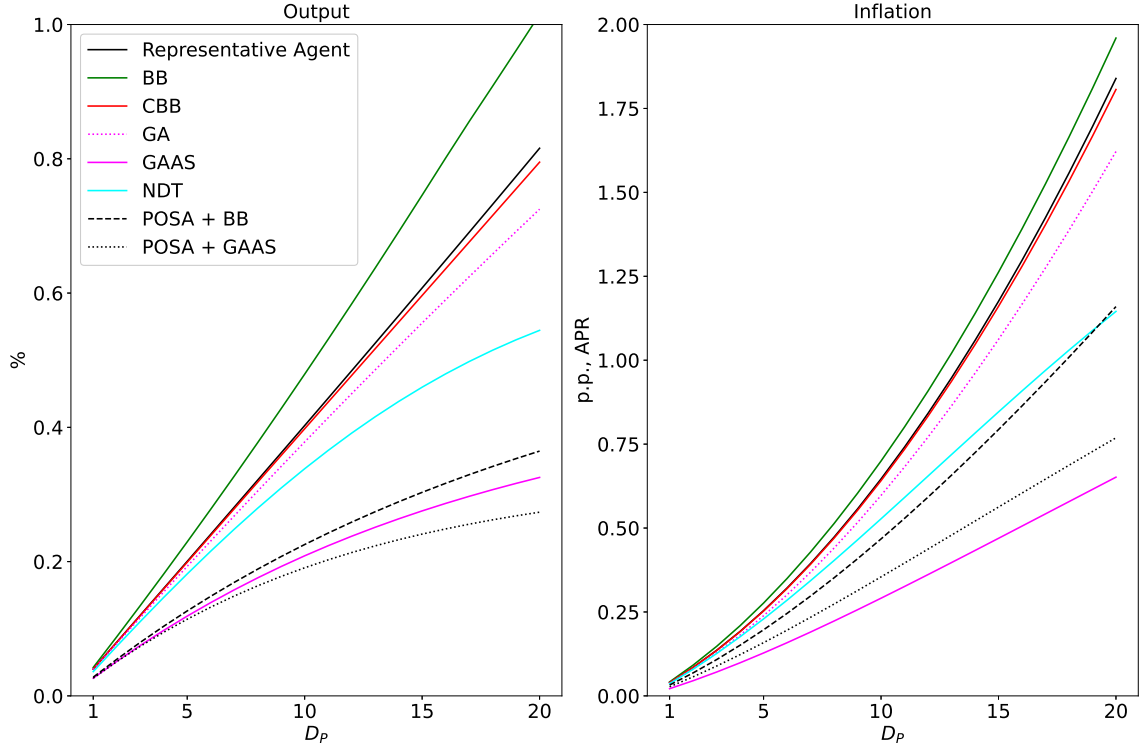
As some contributions simulate real interest rate pegs (Gerke et al. (2024), McKay et al. (2016)), in this subsection I investigate the robustness of my results to pegging the real instead of the nominal rate. The simulation setup becomes

$$\hat{R}_t = \begin{cases} 0 & \text{for } t = 1, 2, \dots, D_L \\ -\Delta + E_t \hat{\Pi}_{t+1} & \text{for } t = D_L + 1, D_L + 2, \dots, D_L + D_p \\ \phi_\pi \hat{\Pi}_t + \frac{\phi_y}{4} \hat{Y}_t & \text{for } t > D_L + D_p \end{cases} \quad (33)$$

As can be obtained from Figure 9, the effects of a real rate peg are much smaller than the effect of a nominal rate peg of the same size. Pegging the real rate implies neutralizing the effect of expected inflation on the real interest rate, implying that the decline of the real rate is much smaller than with a nominal rate peg. This neutralization also renders the effects of the peg in the RA model and for the BB rules linear in D_P . The effects become concave in D_P for the GAAS rule, the nominal debt target and the POSA models. The effects of the peg in the HANK and the POSA models under the GAAS rule are still much smaller than in the RA model and the HANK models under the two BB rules. As can be seen from the dynamic effects of a 20 quarter peg (Figure 10), except for the first quarter, results under the two balanced budget rule are now very close.⁸ Finally,

⁸The upward blip under the BB rule is due to the large transfer households receive due to drop in the real interest rate caused by the quarter one jump in inflation in combination with a $t - 1$ steady-state nominal interest rate

Figure 9: Effect of a real rate peg, impact



Note: The graph displays the results of the simulation described in Section 6. For details on the meaning of the labels see the note below Figure 1.

Figure 11 confirms that unlike a nominal rate peg, a real rate peg implies only minor differences in the income share of asset holders across fiscal rules.

7 Results in a quantitative model with capital

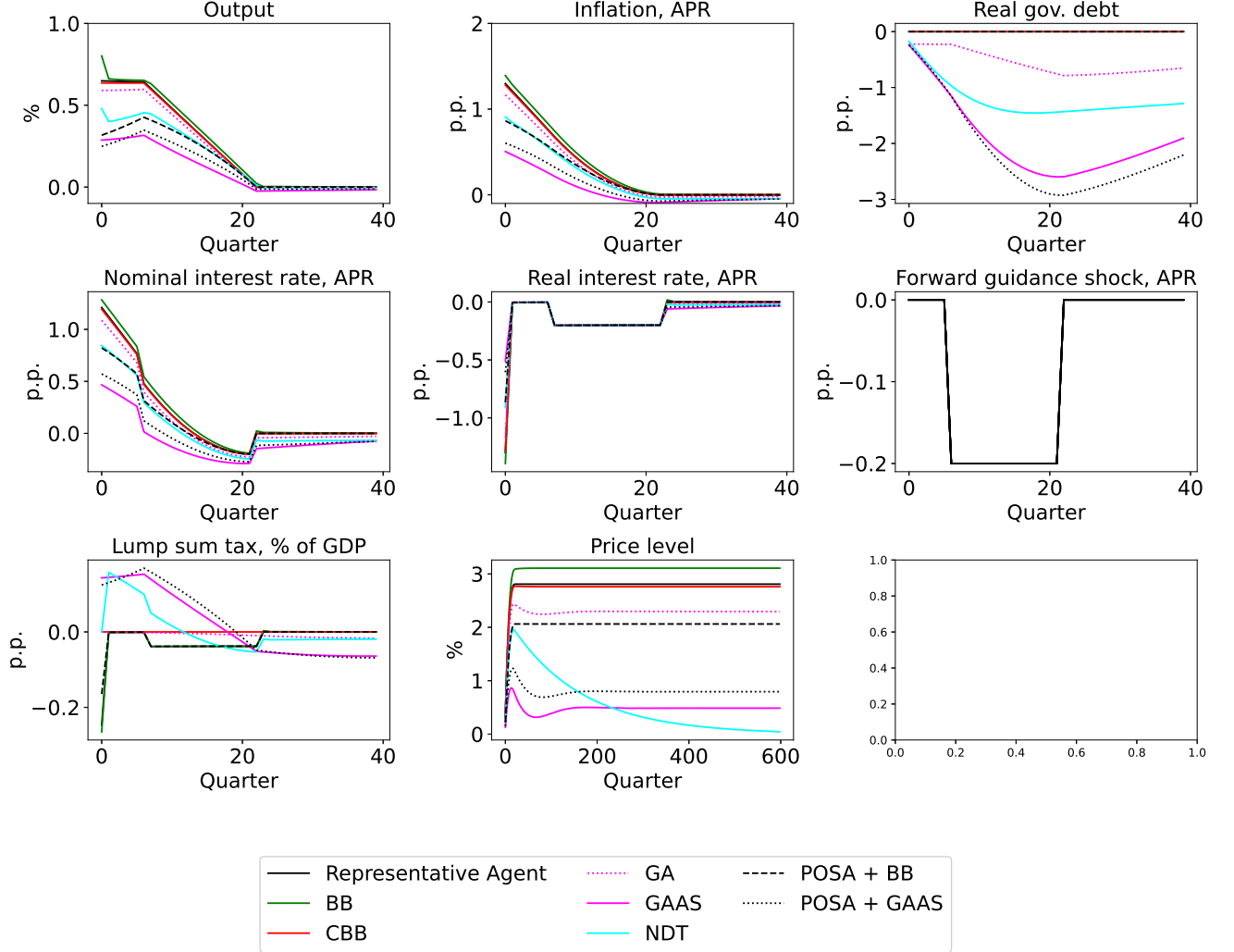
I now examine the effects of forward guidance in a quantitative model with capital, sticky prices and wages.

7.1 Households

Households have access to both a liquid account b_{it}^h and an illiquid account a_{it} as in Kaplan et al. (2018), subject to a convex portfolio adjustment cost $\Phi(a_{it}, a_{it-1})$. However, I use here the discrete time version of the household block of that model developed by Auclert et al. (2021). The Bellman equation is given by

$$V_t(z_{i,t}, b_{it-1}, a_{it-1}) = \max_{b_{it}, a_{it}} u(c_{it}) + \beta E_t V_{t+1}(z_{i,t+1}, b_{it}, a_{it})$$

Figure 10: Real rate peg 20 quarters - dynamic effect



Note: The graph displays the results of the simulation described in Section 6 for $D_P = 16$. For details on the meaning of the labels see the note below Figure 1.

subject to

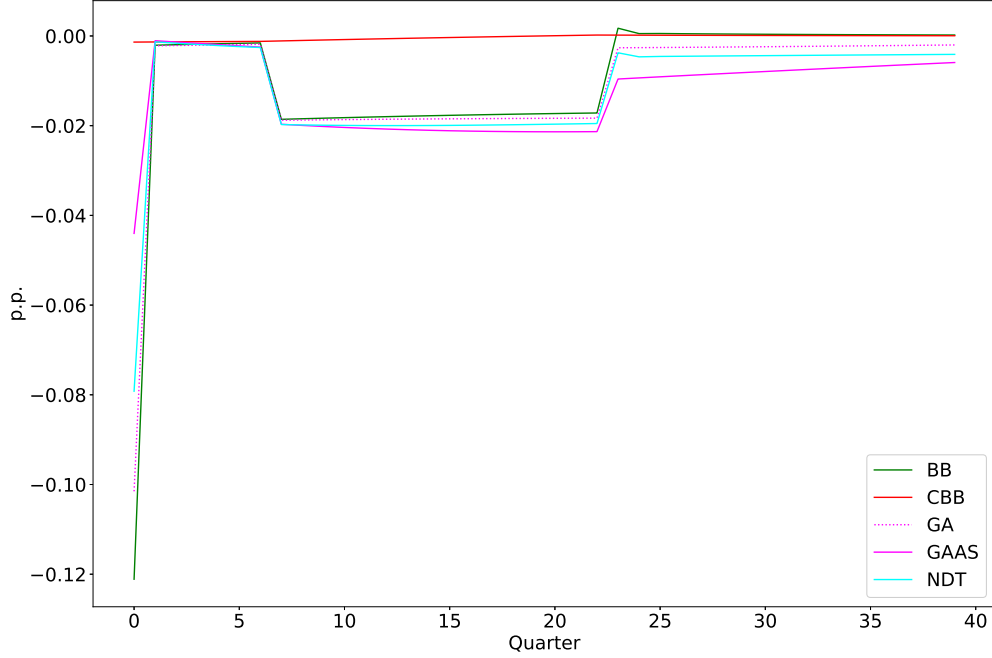
$$\begin{aligned}
 (1 + \tau_C)(c_{it} + \Phi(a_{it}, a_{it-1})) + a_{it} + b_{it}^h &= z_{it} + (1 + r_t^a) a_{it-1} + (1 + r_t^b) b_{it-1}^h \\
 a_{it} &\geq 0 \\
 b_{it} &\geq 0
 \end{aligned}$$

where r_t^a and r_t^b denote the returns on the illiquid and the liquid account, respectively, and z_{it} is the post-tax labor income of households. The adjustment cost function is given by

$$\Phi(a_{it}, a_{it-1}) = \frac{\chi_1}{2} \left(\frac{a_{it} - (1 + r_t^a) a_{it-1}}{(1 + r_t^a) a_{it-1} + \chi_0} \right)^2 [(1 + r_t^a) a_{it-1} + \chi_0]$$

with $\chi_1, \chi_0 > 0$. In order to ensure maximum comparability of saving and consumption decisions, I assume that a slightly modified version of this portfolio adjustment cost is present also in the RA

Figure 11: Real rate peg - share of the top three labor income deciles in total income with an interest rate peg of 16 quarters



version of the model, namely

$$\Phi^{RA}(a_{it}, a_{it-1}) = \frac{\chi_1}{2} \left(\frac{a_{it} - \frac{1+r_t^a}{1+r^a} a_{it-1}}{\frac{1+r_t^a}{1+r^a} a_{it-1} + \chi_0} \right)^2 \left[\frac{1+r_t^a}{1+r^a} a_{it-1} + \chi_0 \right]$$

The modification ensures that in the steady state $\Phi^{RA}(a_{it}, a_{it-1})$ and its first derivatives equal zero.

The assumptions regarding wage setting and labor demand remain unchanged, implying z_{it} is given by

$$z_{it} = ((1 - \tau_{w,t}) w_t N_t - T_t) e_{it}$$

where $\tau_{w,t}$ denotes a labor income tax, and the wage setting equation (12) remains unchanged except for the presence of that labor tax:

$$\left(\frac{\Pi_{W,t}}{\Pi} - 1 \right) \frac{\Pi_{W,t}}{\Pi} = \kappa_w \left(\frac{\epsilon_w}{\epsilon_w - 1} \frac{\chi_N (N_t)^\eta}{(1 - \tau_w) w_t C_t^{-\sigma}} - 1 \right) + E_t \left\{ \frac{1}{1 + r_t} \frac{N_{t+1}}{N_t} \left(\frac{\Pi_{W,t+1}}{\Pi} - 1 \right) \frac{(\Pi_{W,t+1})^2}{\Pi_{t+1} \Pi} \right\} \quad (34)$$

Total liquid and illiquid assets, consumption and portfolio adjustment costs are given by

$$b_t^h = \int b_{it}^h di \quad (35)$$

$$A_t = \int a_{it} di \quad (36)$$

$$C_t = \int c_{it} di \quad (37)$$

$$\Phi_t = \int \Phi(a_{it}, a_{it-1}) di \quad (38)$$

7.2 Capital markets

As in Kaplan et al. (2018), the liquid account of the household consists purely of government bonds, whose nominal return R_t is set by monetary policy. Thus it is safe in nominal terms. Hence the real period t return on the liquid account r_t^b is given by

$$r_t^b = \frac{R_{t-1}}{\Pi_t} - 1$$

The illiquid account is a mutual fund that operates under perfect competition and invests in physical capital K_t , which earns a rental rate $r_{K,t}$ and shares of the monopolistically competitive firms s_t . The mutual fund pays a fraction ω of its total assets A_t as an administration cost, and earns a return r_t^A . Any fluctuations in r_t^A are passed on to household, implying that the households return on the illiquid account equals

$$r_t^a = r_t^A - \omega \quad (39)$$

The mutual fund can substitute perfectly between shares and physical capital. Hence the share price s_t is given by

$$s_t = \frac{s_{t+1} + (1 - \tau_K) \text{div}_{t+1}}{1 + r_{t+1}^A} \quad (40)$$

where τ_K and div_t denote the tax rate on profits and dividends paid by the monopolistically competitive firms, respectively. Similarly, the $t+1$ return on capital has to satisfy

$$r_{t+1}^A = (1 - \tau_K) (r_{K,t+1} - \delta) \quad (41)$$

where τ_K and δ denote the capital tax rate and the rate of depreciation, respectively. The ex-post the return of the mutual fund is given by

$$r_t^A = \frac{s_t + (1 - \tau_K) \text{div}_t}{s_{t-1}} \frac{s_{t-1}}{s_{t-1} + K_{t-1}} + (1 + r_{K,t}) \frac{K_{t-1}}{s_{t-1} + K_{t-1}} - 1 \quad (42)$$

Capital accumulation is given by

$$K_t = (1 - \delta) K_{t-1} + I_t \quad (43)$$

Due to the earlier assumption of a portfolio adjustment cost I do not assume a capital adjustment cost, but results are robust to adding the assumption of a capital adjustment cost of the form $\frac{\epsilon_I}{2} \left(\frac{K_t}{K_{t-1}} - 1 \right)^2 K_{t-1}$.

7.3 Firms

There is a continuum of risk neutral monopolistically competitive firms producing product varieties f . The demand curve for individual varieties is given by

$$Y_t(f) = Y_t \left(\frac{P_t(f)}{P_t} \right)^{-\epsilon_p}$$

Firms face Rotemberg (1982) type price adjustment costs:

$$AC_t(f) = Y_t \frac{\xi_p}{2} \left(\frac{P_t(f)}{P_{t-1}(f)} \frac{1}{\bar{\Pi}} - 1 \right)^2$$

where $\xi_p > 0$ denotes the adjustment cost curvature and Y_t denotes total output of all firms. Output is produced by combining labor and capital in a Cobb-Douglas production function

$$Y_t(f) = Z K_t^\alpha(f) N_t^{1-\alpha}(f) - FC$$

where $FC > 0$ denotes a fixed cost of production. The first order condition with respect to prices results in the price Phillips curve:

$$\begin{aligned} & \kappa_p \left(\left(\frac{\epsilon_p}{\epsilon_p - 1} \right) mc_t - 1 \right) \\ & + \frac{1}{1 + r_{t+1}} \frac{Y_{t+1}}{Y_t} \left(\frac{\Pi_{t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{t+1}}{\bar{\Pi}} = \left(\frac{\Pi_t}{\bar{\Pi}} - 1 \right) \frac{\Pi_t}{\bar{\Pi}} \end{aligned}$$

with $\kappa_p = \frac{\epsilon_p - 1}{\xi_p}$. The FOCs with respect to employment and capital are given by

$$\begin{aligned} w_t &= (1 - \alpha) mc_t \frac{Y_t + FC}{N_t} \\ r_{K,t} &= \alpha mc_t \frac{Y_t + FC}{K_{t-1}} \end{aligned}$$

Dividends are given by

$$div_t = (1 - mc_t)(Y_t + FC) - FC \quad (44)$$

7.4 Government

The government budget constraint in real terms is now given by

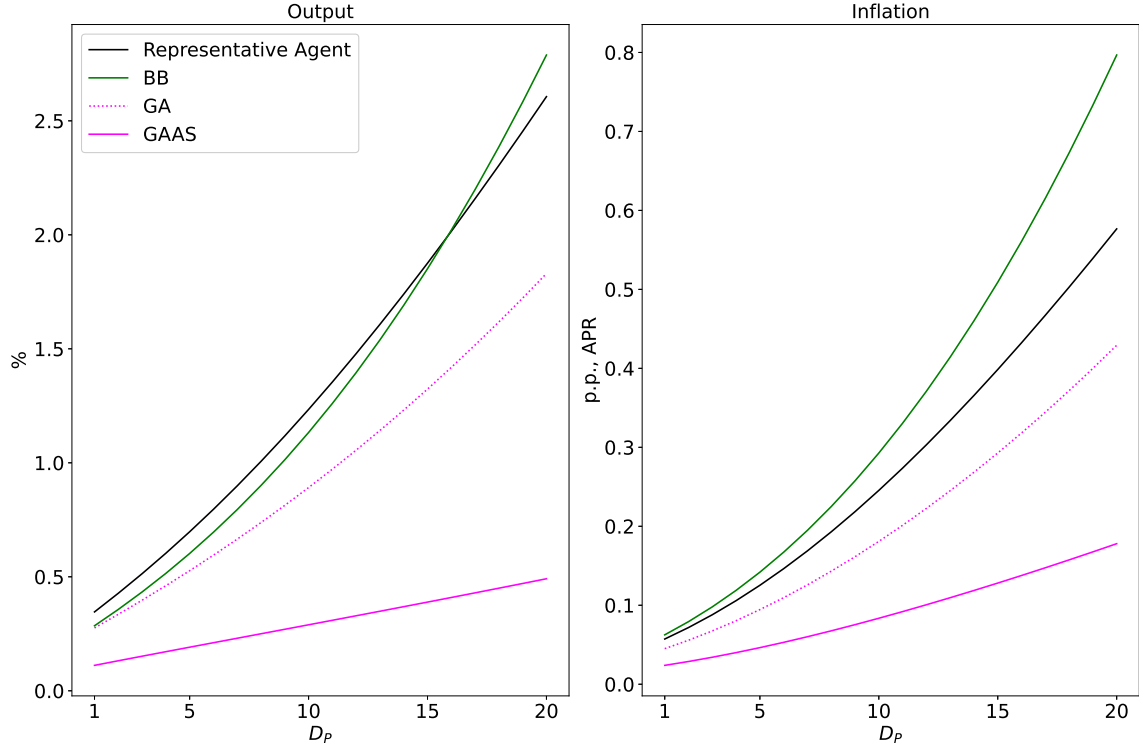
$$b_t = \frac{R_{t-1}}{\Pi_t} b_{t-1} + G - T_t - \tau_w N_t w_t - \tau_C (C_t + \Phi_t) + \tau_K (r_{K,t} - \delta) K_{t-1} \quad (45)$$

The fiscal rules are the same as those considered in the simple model.

Monetary policy is given by

$$\hat{R}_t = (1 - \rho_R) \left(\phi_\pi \hat{\Pi}_t + \frac{\phi_y}{4} \hat{Y}_t \right) + \rho_R \hat{R}_{t-1} \quad (46)$$

Figure 12: Effect of forward guidance in quantitative model, impact



7.5 Equilibrium

The market for liquid and illiquid asset clears:

$$b_t^h = b_t \quad (47)$$

$$A_t = K_t + s_t \quad (48)$$

The goods market clears:

$$Y_t = C_t + G + I_t + \Phi_t + \omega A_{t-1} \quad (49)$$

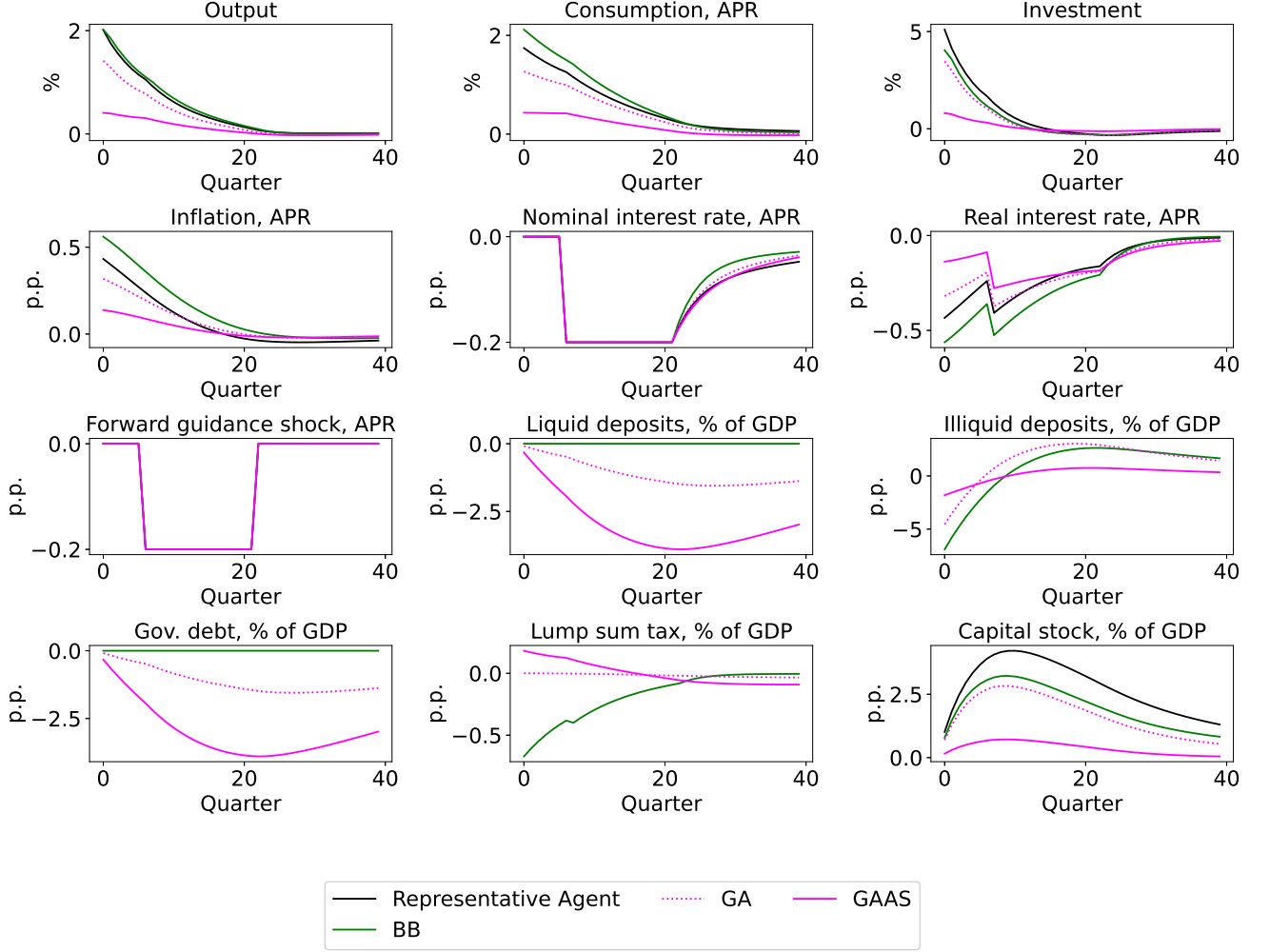
Furthermore, GDP is defined as output without portfolio adjustment and mutual fund administration costs:

$$GDP_t = C_t + G + I_t \quad (50)$$

7.6 Calibration

I calibrate a number of parameters directly. The elasticity of intertemporal substitution $\frac{1}{\sigma}$, the Frisch elasticity of labor supply $\frac{1}{\eta}$, the wage markup μ_w , the calibration of the idiosyncratic labor income process, the share of government expenditure in GDP and the fiscal rule parameters for the GAAS rule are the same as in the simple model. However, as in Auclert et al. (2021)'s analysis of the two account model, I discretize the AR(1) process for e on a three point grid. The Taylor rule

Figure 13: Effect of forward guidance in quantitative model - dynamic effect



inflation and output coefficients also remain the same, but there is now interest rate smoothing, with $\rho_i = 0.85$. The portfolio adjustment cost pivot parameter χ_0 follows Auclert et al. (2021). I construct the consumption, labor and profit tax rates from BEA NIPA data following Leeper et al. (2010) and average them over the 1987-2019 period. The lump sum tax semi-elasticity is set to the estimate of Price et al. (2015) of the output semi-elasticity of government expenditure in the US. However, for the GA rule, I set all tax rates and ε_{TY} to zero.

I set the Phillips curve slope parameters in line with recent estimates. The capital depreciation rate δ equals 0.025.

Given these choices, I calibrate nine parameters in order to set the steady-state values of important model variables to (empirical) target values, namely the household discount factor β , the illiquid asset administration cost ω , the portfolio adjustment cost scale χ_1 , the target level of government bonds b in the fiscal rule, the capital elasticity of output α , the steady-state price markup μ_p , fixed costs FC , the level of TFP and the labor disutility weight χ_N . The targets are a real return on the liquid asset of 2% annually, a spread between the return on illiquid and liquid assets $r^A - r$ of 5.1% annualized, a first year average MPC out of an income windfall of 0.44, an invest-

ment to GDP ratio of 0.18, a labor share of 0.61, a liquid-asset-to-annual GDP ratio of 0.23 and a ratio of output gross of fixed costs to output $\frac{FC+Y}{Y}$, which measures the degree of returns to scale in the production function, of 1.4. Furthermore, the steady-state levels of employment output are normalized to one. The target for liquid assets equals the value in the model of Kaplan et al. (2018), while the target for the first year average MPC corresponds to the empirical lower bound estimate of Auclert et al. (2024b) based on Italian survey data. The target for $r^A - r$ is computed by first estimating the return on capital as the average of the return on equity and Bonds, and then subtracting the three-month treasury bill yield. To compute the return on equity, I combine the estimate of the equity risk premium reported by Damodaran (2022) and the return on 10 year government bonds. For the return on bonds, I use Moody’s Seasoned Baa Corporate Bond Yield. The degree of returns to scale in production $\frac{FC+Y}{Y}$ is line with recent estimates for the US economy, e.g. Lindé et al. (2016).

Except for the MPC and the target for liquid assets, the target values are calculated as averages over the 1987 to 2019 period. I also report the implied illiquid asset to GDP ratio, which with 2.4 is somewhat lower than the value of 2.9 estimated by Kaplan et al. (2018). Furthermore, the first year MPC out of illiquid wealth of 0.032 matches closely the stock market wealth MPC estimated by Chodorow-Reich et al. (2021).⁹ As in Auclert et al. (2021)’s analysis of the two account model, I discretize the assets spaces using double-exponentially-spaced grids, with 50 and 70 grid points for liquid and illiquid assets, respectively. For the calibration of the RA model, I uses the same values for the directly calibrated parameters and impose the same values on the aforementioned variables, except for the MPC. Correspondingly, I calibrate the value for the portfolio adjustment cost scale directly, and set it to the same value as in the HANK model.

Obviously, the targeted share of liquid assets in GDP is much smaller than the government-debt-to-GDP ratio in the data. In Appendix F, I show that results are broadly robust to assuming an alternative setup for capital markets where both the liquid and the illiquid account contain government bonds. This setup allows reconciling a larger government-debt-to-GDP ratio with a large MPC out of transitory income shocks.

⁹The annual marginal propensity to consume with respect to an increase in illiquid wealth is computed as follows. $\frac{\partial C_t}{\partial r_1^a}$ denotes the partial derivative of total period t household consumption with respect to an increase in the return on illiquid assets in period 1. The period one MPC out of a period one increase in illiquid wealth is accordingly given by $\frac{\partial C_t}{\partial r_1^a} \frac{1}{A}$, and the first year average by $\frac{1}{A} \sum_{i=1}^4 \frac{\partial C_i}{\partial r_1^a}$.

Table 3: Calibration two-account model

Directly calibrated parameters		
Parameter	Definition	Value
σ	Consumption curvature	1.0
η	Labor curvature	2.0
χ_0	Portfolio adj. cost pivot	0.25
σ_e	Idiosyncratic income shock s.d.	0.46
ρ_e	Idiosyncratic income shock persistence	0.98
G	Government expenditure-to-GDP ratio	0.2
ϵ_{YT}	Expenditure semi-elasticity	0.46
τ_C	Consumption tax	0.07
τ_w	Labor tax	0.24
τ_K	Profit tax	0.21
ϕ_T	Fiscal rule debt response	0.03
ρ_T	Fiscal rule lagged tax response	0.95
ϕ_π	Taylor rule inflation	1.5
ϕ_y	Taylor rule output	0.5
ρ_i	Taylor rule lagged interest rate	0.85
μ_w	Steady-state wage markup	1.5
κ_w	Wage Phillips curve slope	0.011
κ_p	Price Phillips curve slope	0.011
ϵ_I	Capital adjustment cost curvature	0.00
δ	Depreciation rate	0.025
Parameters calibrated to match target values		
Parameter	Definition	Value
β	Household discount factor	0.989
ω	Asset administration cost	0.009
χ_1	Portfolio adj. cost scale	37
b^T	Government debt target fiscal rule	0.92
α	Capital elasticity of output	0.35
μ_p	Steady-state price markup	1.49
FC	Fixed cost	0.40
Z	TFP	0.71
χ_N	Labor disutility weight	0.59
Target values		
Parameter	Definition	Value
r	Real interest rate (safe assets, APR)	2.0
$r^A - r$	Real return (illiquid account, APR)	5.1
MPC	First-year MPC	0.44
$b/(4Y)$	Liquid asset-to-GDP ratio	0.23
$\frac{I}{Y}$	Investment-to-GDP ratio	0.18
$\frac{wN}{Y}$	Labor share	0.61
$\frac{FC+Y}{Y}$	Output gross of fixed costs-to-output ratio	1.40
Y	Output	1.0
N	Employment	1.0
$\frac{A}{4Y}$	Not targeted: Illiquid asset-to-GDP ratio	2.4
$\frac{1}{A} \sum_{i=1}^4 \frac{\partial C_i}{\partial r_1^a}$	Not targeted: First-year MPC out of illiquid assets	0.032

Note: The empirical target value for the first-year MPC is taken from Auclert et al. (2024b).

7.7 Results

The simulation setup remains as described in Section 4. In the RA version, the effects of the peg on output and inflation are much smaller than in its simple model counterpart (see Figure 12). With both price and wage stickiness, the overall degree of nominal rigidity is larger and thus a given increase in output causes a much smaller increase in inflation and correspondingly a smaller decline in the real interest rate (see Figure 13). Under the BB rule, the smaller decline of the real interest rate means a much smaller redistribution from asset holders to lower income households than in the simple model via lower lump sum taxes (see Figure 13), implying that the effects of forward guidance are now closer to the RA model. With the GAAS rule, the results of the policy continue to be much smaller than under the BB rule or in the RA model. For instance, for a 12 quarter peg, the effect of the policy on GDP equals less than one fourth of the effects in the RA model and in the HANK model with the BB rule. As can be obtained from Figure 13, liquid assets strongly decline under the GAAS rule, thus dampening the increase in consumption. The value of the illiquid account A_t drops on impact driven by a drop in the share price s_t , which declines due to a decline in dividends caused an increase in the real wage. It then recovers due to the increase in the physical capital stock. Assuming a capital adjustment cost would dampen the drop of A_t due to the on-impact increase in the value of the capital stock as a consequence of higher Tobin's Q .

8 Conclusion

The development of Heterogeneous Agent New Keynesian (HANK) models has been accompanied by the investigation the effect of forward guidance policies in such models, and whether HANK models offer a solution to the so called "Forward guidance puzzle". Early results by McKay et al. (2016) suggested that the presence of uninsurable income risk and the associated probability to hit a borrowing constraint would dampen the effects of forward guidance by effectively limiting the households planning horizon. However, as shown by Werning (2015), Hagedorn et al. (2019) and Bilbiie (2020), their result is due to specific assumptions about the distribution of firm profits and taxes which render income inequality and income risk procyclical. By contrast, with countercyclical inequality and income risk, the effects of forward guidance are larger in HANK models than in the representative agent model, as the policy raises the income share of households with a high Marginal Propensity to Consume (MPC).

This paper shows that the Forward guidance puzzle actually *can* be resolved in a HANK model if fiscal policy displays a small effect of the level of government debt on taxes and an important effect of economic activity on the government budget deficit. Both features are empirically plausible. I derive this result using first a the canonical sticky wage, flexible price one-asset model of Auclert et al. (2024b) with zero profits and thus virtually acyclical pre-tax income. I find that depending on the assumed fiscal rule, the effect of an interest rate peg maybe larger than, close to or much weaker in a HANK model than in a representative agent (RA) version of the model. The reason is that in all HANK models, the real interest rate decline redistributes income from asset holders to the government. Under a balanced budget (BB) rule, the government holds lowers tax revenue in response to the decline in its interest payments, implying that the real interest rate decline results in a redistribution of income from asset holders, who have a low MPC, to households with a high MPC. This redistribution renders the effects of forward guidance on output and inflation much

stronger than in the RA model. By contrast, once fiscal policy adjusts taxes gradually in response to deviations of government debt from a target value (GA rule), thus allowing government debt to decline in response to an expansionary interest rate peg, the effects of the peg on output and inflation become lower than in the RA model, and linear in the length of the peg. The attenuating effect becomes even stronger once I allow for automatic stabilizers (GAAS rule) generating a positive feedback from economic activity to the government budget balance. These results are robust to allowing for long-term government debt, high liquidity and countercyclical inequality, a feature that has been shown to amplify the effect of forward guidance and other demand shocks. Finally, they also carry over to a quantitative model with nominal rigidities in both wage and price setting and capital accumulation, liquid and illiquid assets as in Kaplan et al. (2018).

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A Further intuition regarding the attenuation delivered by the GA rule

In this appendix, I illustrate the attenuating mechanism that emerges with the move from the CBB rule to the GA rule. As mentioned in the main text, this shift can be understood as the effect of removing the transfer which under the CBB rule compensates asset holders exactly for the decline of their interest income resulting from higher inflation. As inflation rises exponentially in the length of the peg $D_P + D_L$, the magnitude of this transfer increases exponentially in D_P as well, and so does the attenuating effect of removing it as we move from the CBB rule to the GA rule. In this appendix, I confirm the validity of this intuition by showing that the results obtained for the GA rule can be approximated by adding the results of two distinct simulations. The first is simply the effects of the interest rate peg under the CBB rule. The second is a simulation of a "lump sum wealth tax" where the tax rate $\tau_{a,t}$ equals the negative of the deviation of the ex-post real interest rate from its steady-state obtained under the CBB rule. This tax is thus the reverse of the transfer assumed under the CBB rule (see equation 16). Furthermore, the ordinary lump sum tax T_t follows the GA rule and the nominal interest rate is pegged at its steady-state value $D_L + D_P$. More formally, I want to show that, for each variable X_t of interest,

$$dX_t^{GA,D_P} \approx dX_t^{CBB,D_P} + dX_t^{GA,\tau_{a,t},D_P} \quad (51)$$

where the superscripts GA, D_P and CBB, D_P indicate the effect of an interest peg as described in Section 4 under the respective fiscal rule. $dX_t^{GA,\tau_{a,t},D_P}$ denotes the effect of the lump sum tax under the GA rule with the nominal interest rate pegged at its steady-state for $D_L + D_P$ quarters.

With the wealth tax, the budget constraint of the household becomes

$$a_{it} + c_{it} = (1 + r_t) a_{it-1} + z_{it} - t_{it}^a$$

with

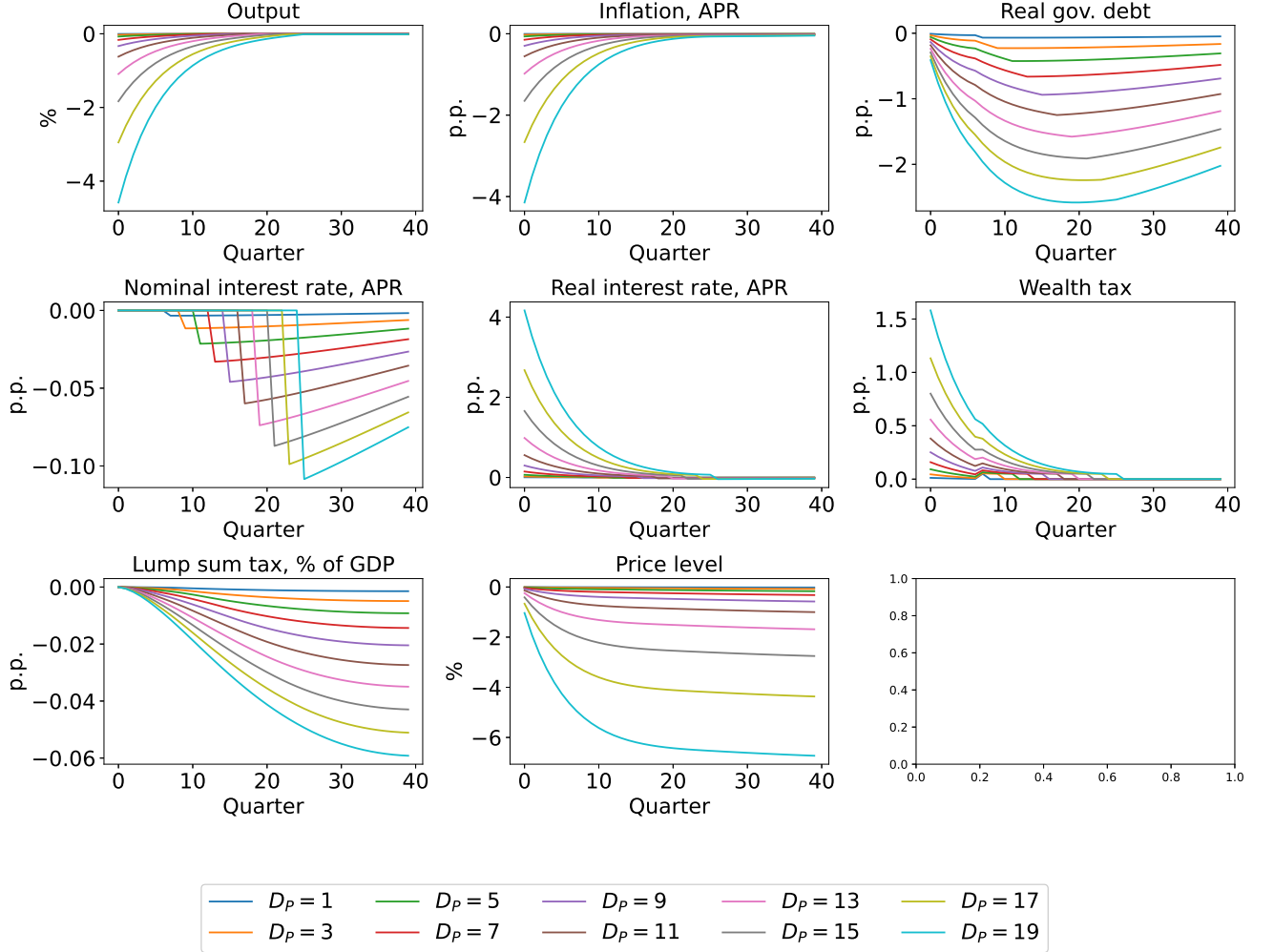
$$t_{it}^a = \tau_{a,t} a_{it-1}$$

While t_{it}^a depends on the individual wealth level of household i , the household ignores this relationship when making its optimal choices, just as for the transfer under the CBB rule. In the simulation, I set

$$\tau_{a,t}^{GA,\tau_{a,t},D_P} = \left(\frac{R}{\Pi} - \frac{R_{t-1}^{CBB,D_P}}{\Pi_t^{CBB,D_P}} \right) \quad (52)$$

, i.e. minus the percentage point deviation of the real interest rate from its steady-state obtained for the CBB rule for the respective value of D_P . As $\tau_a = 0$, note that up to first order, this would imply that $dt_{it}^a = dtr_{it}^a = \tau_{a,t} a_{it}^{ss}$, where a_{it}^{ss} denotes path of assets of household i in the steady-state

Figure 14: Effect of lump-sum wealth tax



Note: This graph displays the results of a simulation in the HANK model with the GA under the GA rule which pegs the nominal interest rate at its steady-state value for $D_P + D_L$ quarters (with $D_L = 6$), and sets the lump sum wealth tax to $\tau_{a,t}^{GA,T^a,D_P} = \left(\frac{R}{\Pi} - \frac{R_{t-1}^{CBB,D_P}}{\Pi_t^{CBB,D_P}} \right) \cdot \frac{R_{t-1}^{CBB,D_P}}{\Pi_t^{CBB,D_P}}$. $\frac{R_{t-1}^{CBB,D_P}}{\Pi_t^{CBB,D_P}}$ denotes the ex-post real interest rate trajectory obtained when simulating the peg described in 4 under the CBB rule for the respective D_P value.

(i.e. absent of aggregate shocks). The government budget constraint is given by

$$b_t = \frac{R_{t-1}}{\Pi_t} b_{t-1} + G - T_t - T_t^a$$

with

$$T_t^a \equiv \int t_{it}^a di = \tau_{a,t} \int a_{it-1} di = \tau_{a,t} b_{t-1}$$

where the final equality uses the definition of total assets and the asset market equilibrium condition (25 and 26).

In the main text, I use the non-linear solver of Auclert et al. (2021) because this approach renders implementation of the interest rate peg very easy. However, the non-linearities originating from sources other than the peg would already constitute one reason why equation (51) might not hold. Therefore I approximate a quasi-linear setup by repeating the simulation of interest rate peg for the CBB and GA rules using a "scale down - scale up" approach. Specifically, in (28), I divide the value of Δ by a scaling factor of 1000 and multiply the simulated deviations from steady-state by the same factor. I use the same approach when simulating the wealth tax.

Figure 14 displays the effects of the wealth tax peg lengths. As just discussed, the total length of the period during which the nominal interest rate is pegged at its steady-state value amounts to $D_P + D_L$, with D_L still fixed at 6 quarters. The graph displays the effect of the tax for every second (for better visibility) value of D_P I consider. The declines of output and inflation increase exponentially in D_P , which is the combined result of the longer interest rate peg *and* the fact that the trajectory of the wealth tax also increases exponentially in D_P . The reason for the latter is that $\tau_{a,t}$ is set to the negative of the deviation of the real interest rate from its steady-state under the CBB rule $\left(\frac{R}{\Pi} - \frac{R_{t-1}^{CBB}}{\Pi_t^{CBB}}\right)$ (see equation (14)), which increases exponentially in D_P .

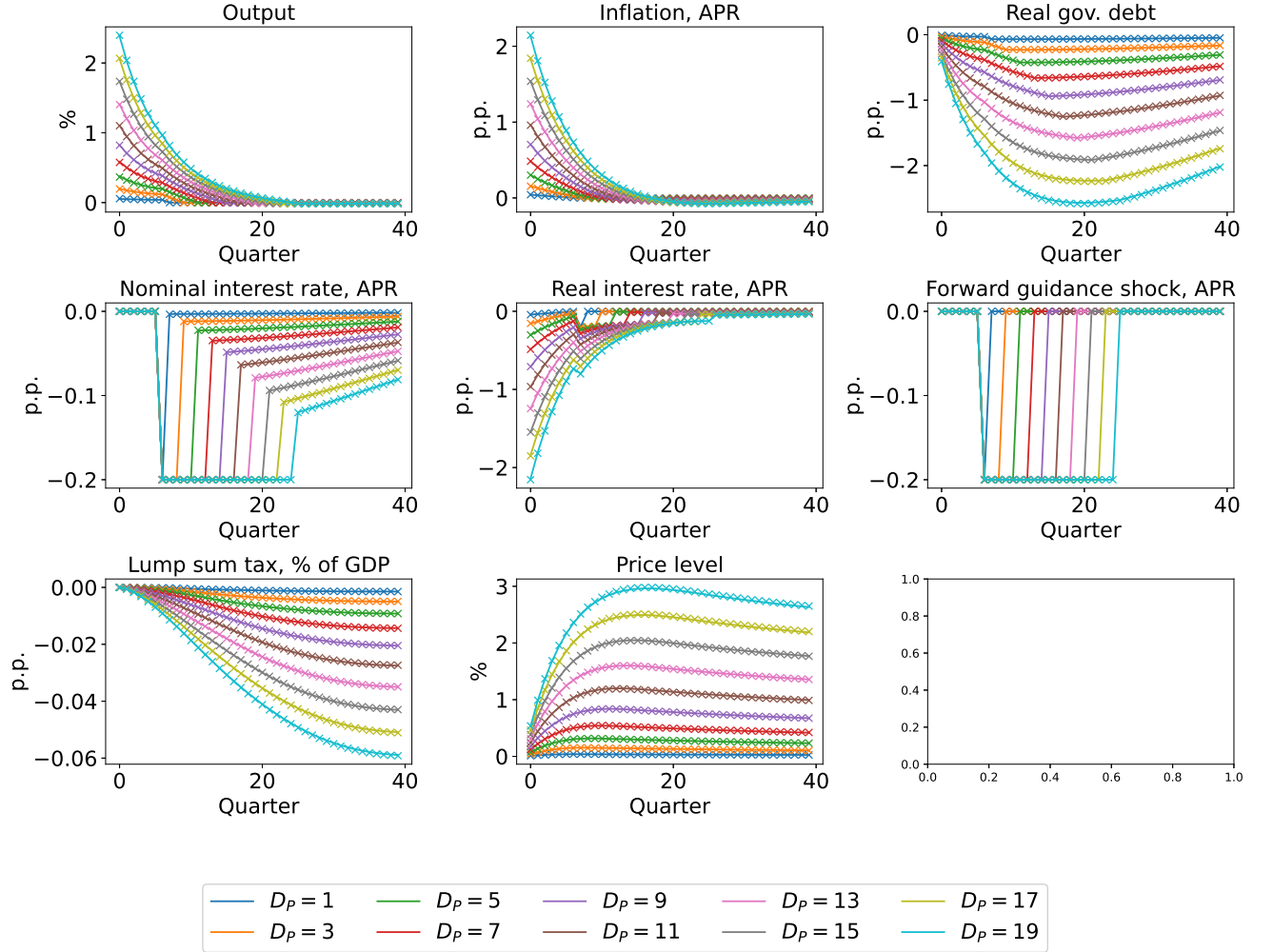
Finally, Figure 15 displays the left hand side of equation (51) as solid lines, while the right hand side is displayed as a crossed lines. Clearly, the crossed lines approximate the solid lines very closely.

B Long term bond pricing

The derivation of the bond pricing condition (31) is analogous to the derivation of the no-arbitrage condition between real and nominal short term bonds derived by Auclert et al. (2024b) (Appendix 2). As in Auclert et al. (2024b), there are short term nominal bonds $B_{S,t}$ in zero net supply that are traded by the central banks and risk neutral financial market arbitrageurs. Financial market arbitrageurs also hold long-term bonds B_t . They maximize the present value of their nominal discounted profits, defined as

$$\sum_{i=0}^{\infty} \prod_{j=1}^i \frac{1}{R_{t+j}} \left(R_{t-1+i} B_{S,t-1+i}^A + \frac{1 + \rho P_{B,t+i}}{P_{B,t-1+i}} B_{t-1+i} - B_{S,t+i}^A - B_{t+i}^A \right)$$

Figure 15: Approximation of the the effect under the GA rule as the right hand side of equation (51)



Note: This graph displays the left hand side of equation (51) for different values of D_P as a solid line. The right hand side of the equation is displayed as crosses.

where $\frac{1+\rho P_{B,t+1}}{P_{B,t-1+i}}$ represents the return on long-term bonds. Their FOC with respect to B_t^A then implies (31):

$$\begin{aligned} -1 + \frac{1}{R_t} \frac{1 + \rho P_{B,t+1}}{P_{B,t}} &= 0 \Leftrightarrow \\ P_{B,t} &= \frac{1 + \rho P_{B,t+1}}{R_t} \end{aligned} \quad (53)$$

Furthermore, their initial wealth is zero. Combined with nominal bonds in zero net supply, this assumption implies that arbitrageurs profits are zero at all times and thus can be omitted from the model.

C Alternative simulation setup

I also consider an alternative setup where I fix the duration of the interest rate cut at one quarter and allow instead the date of the cut to vary. More formally, I fix D_P at one and instead allow D_L to vary:

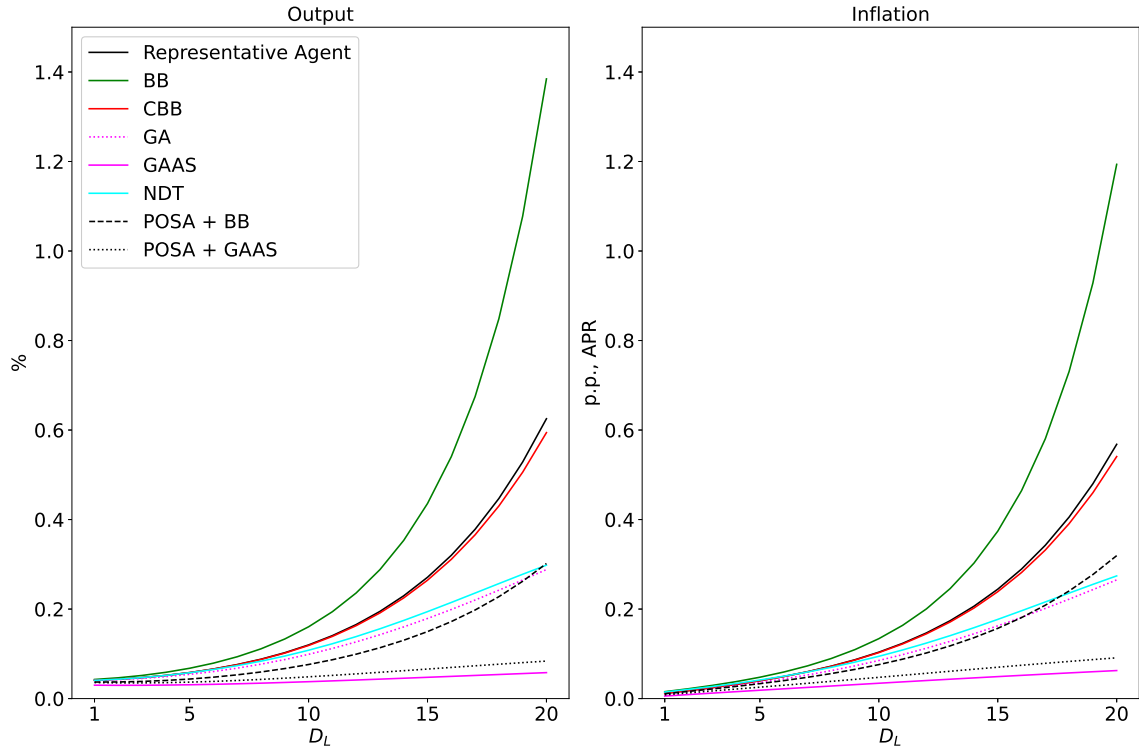
$$\hat{R}_t = \begin{cases} 0 & \text{for } t = 1, 2, \dots, D_L \\ -\Delta & \text{for } t = D_L + 1 \\ \phi_\pi \hat{\Pi}_t + \frac{\phi_y}{4} \hat{Y}_t & \text{for } t > D_L + 1 \end{cases} \quad (54)$$

This setup implies a much smaller monetary stimulus than the baseline setup and therefore the simulated effects on output and inflation are quantitatively much smaller than those reported in Section 5.1. However, qualitatively they are essentially identical. As can be obtained from Figure 16, in the HANK model with the BB rule, effects are stronger than in the RA model, while they are smaller under the NDT rule and the GA rule, and become very small under the GAAS rule. For the GA rule and $D_L = 8$, the effect of the peg on output is 13% lower than in the RA model, while for $D_L = 12$, it is 23% lower. For $D_L > 16$, the output and inflation effects of the peg become approximately linear in D_L . For the HANK model with the GAAS rule, the corresponding ratios are 61% and 85%. Results for the other model variants also considered in Section 5.1 are reported in Figures 17 to 19.

D Effect of a government expenditure shock for the BB and GAAS rule

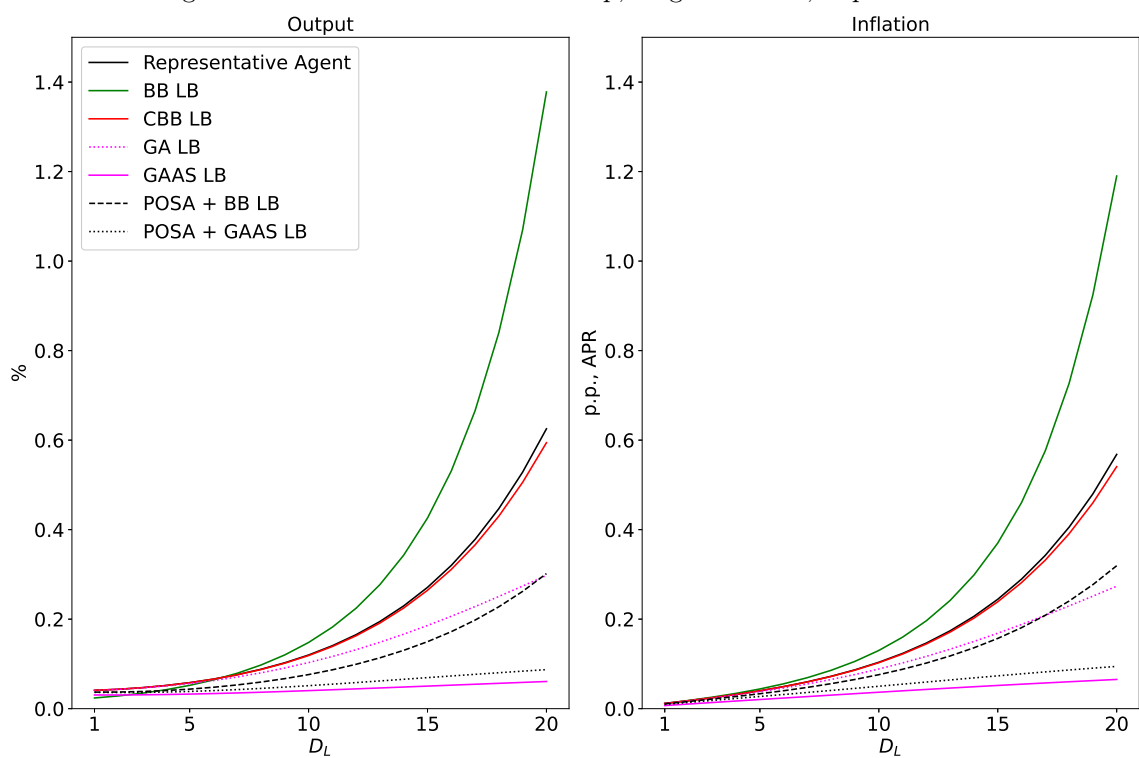
In this Section I discuss the effect of a government expenditure shock for the RA model and in the HANK models with the BB and the GAAS rule. I assume that G_t is increased for 8 quarters by 1% of GDP and then returns to its steady-state value. The central bank pegs the ex-ante real interest rate at its steady state level for 8 quarters. Furthermore I report results for the case without (solid lines) and with (dotted lines) countercyclical inequality, i.e. $\zeta = -0.5$ in equation (32). As can be obtained from Figure 20, for both the RA model and the BB model with acyclical inequality (Green and black solid line), the multiplier equals exactly one, except for the very first quarter in the BB model where the decline of the ex-post real interest rate in the first quarter means

Figure 16: Alternative simulation setup - impact effect



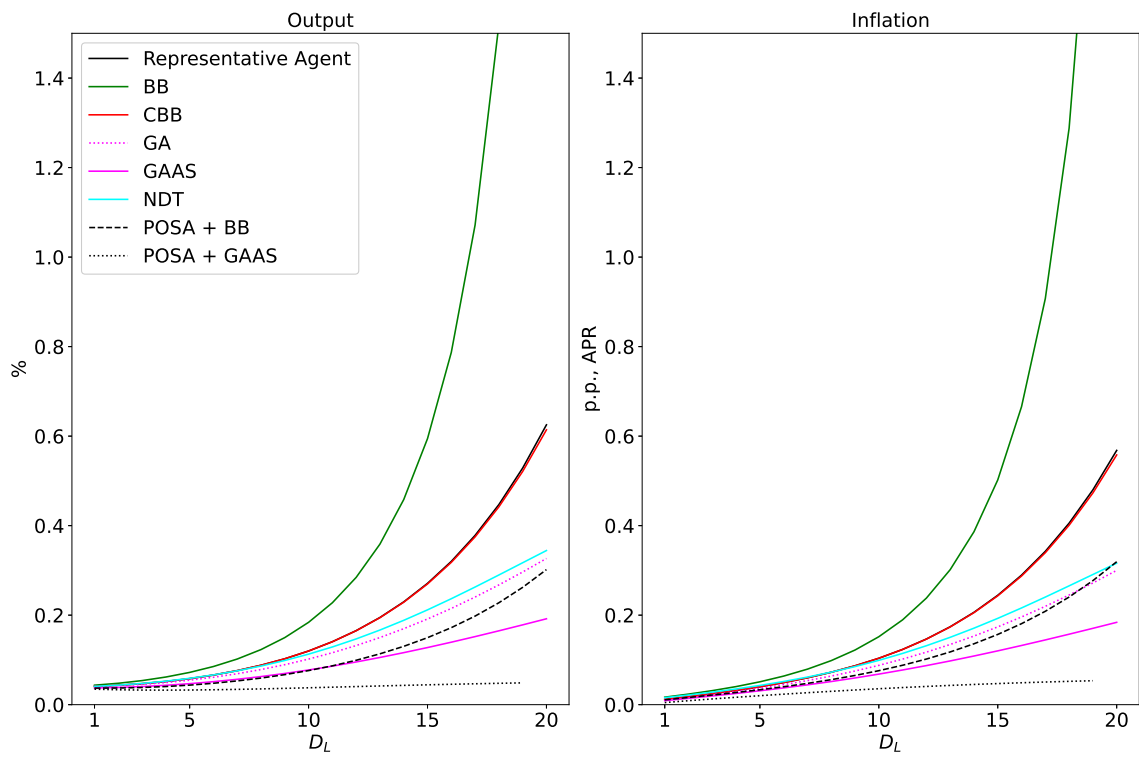
Note: The graph displays the results of the simulation described in Section 54. Each line refers to a specific combination of a model and a fiscal rule. Unless specifically mentioned, the model is the HANK model developed above. BB = Balanced budget rule (equations (15)). CBB = Compensated Balanced Budget rule (equation (17) and (16)), GA = Gradual Adjustment rule (equation (18)), GAAS = Gradual Adjustment Automatic Stabilizers rule (equation (21)). NDT = Nominal Debt Target (equation (22)).

Figure 17: Alternative simulation setup, long-term-debt, impact effect



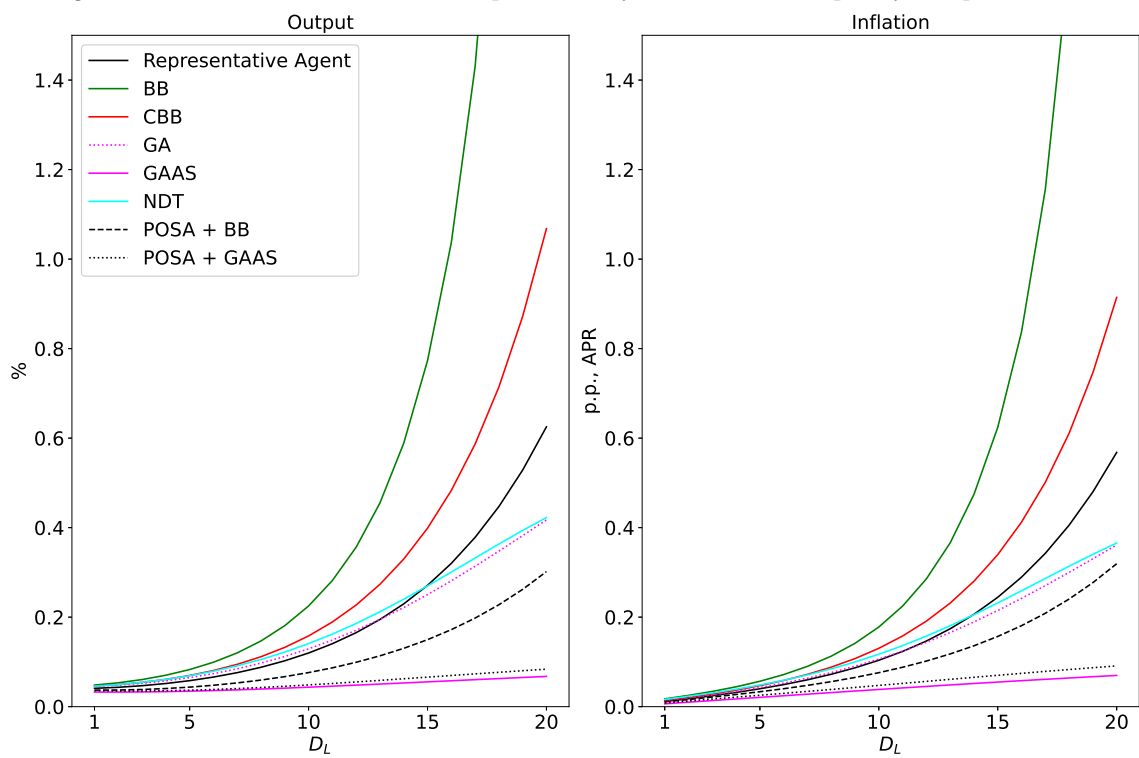
Note: For details on the simulation setup and the meaning of the labels see the note below Figure 16.

Figure 18: Alternative simulation setup, higher liquidity - impact effect



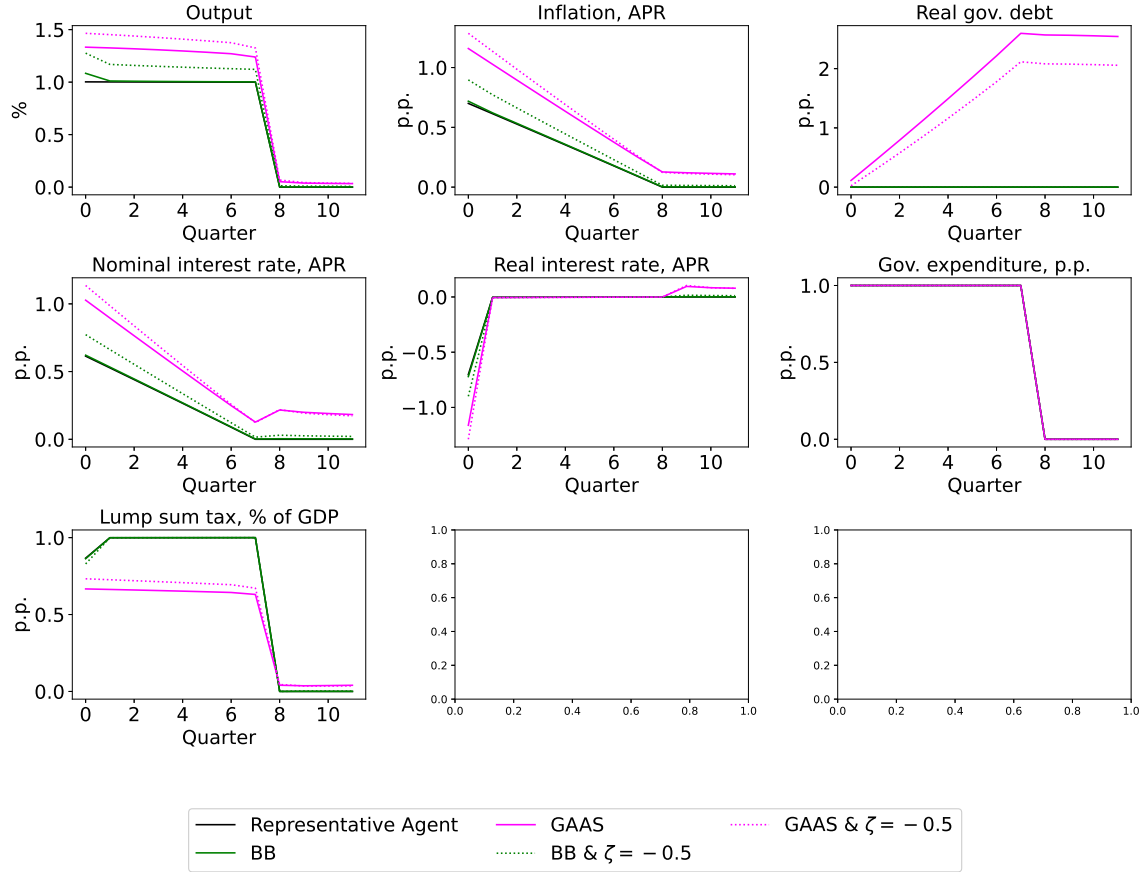
Note: For details on the simulation setup and the meaning of the labels see the note below Figure 16.

Figure 19: Alternative simulation setup, countercyclical income inequality - impact effect



Note: For details on the simulation setup and the meaning of the labels see the note below Figure 16.

Figure 20: Effect of a government expenditure shock for the BB and GAAS rules



Note: This graphs displays the effect of an increase in G_t by one % of GDP for 8 quarters. During that period, the ex-ante real interest rate is pegged at its steady-state value. Note that the graph displays the ex-post real interest rate.

that taxes increase by less than government expenditure during the first quarter. The finding of a multiplier of one for a balanced budget expansion was also reported by Auclert et al. (2024b). With countercyclical inequality, the multiplier increases above one in the BB model. By contrast, in the HANK model with the GAAS rule, the multiplier exceeds one even with acyclical inequality, and rises further with countercyclical inequality.

E Contemporaneous and anticipated monetary policy shocks

In a short note, Kaplan et al. (2016) compare the effects of of contemporaneous and anticipated monetary policy shocks (as opposed to interest rate pegs) in variants of their HANK model. I now perform the same simulation shocks in some of the models considered in the main text. For that purpose, I change the monetary policy rule (23) by adding a contemporaneous and an anticipated monetary policy shock

$$\hat{R}_t = \phi_\pi \hat{\Pi}_t + \frac{\phi_y}{4} \hat{Y}_t + \varepsilon_t^0 + \varepsilon_{t-8}^8 \quad (55)$$

with

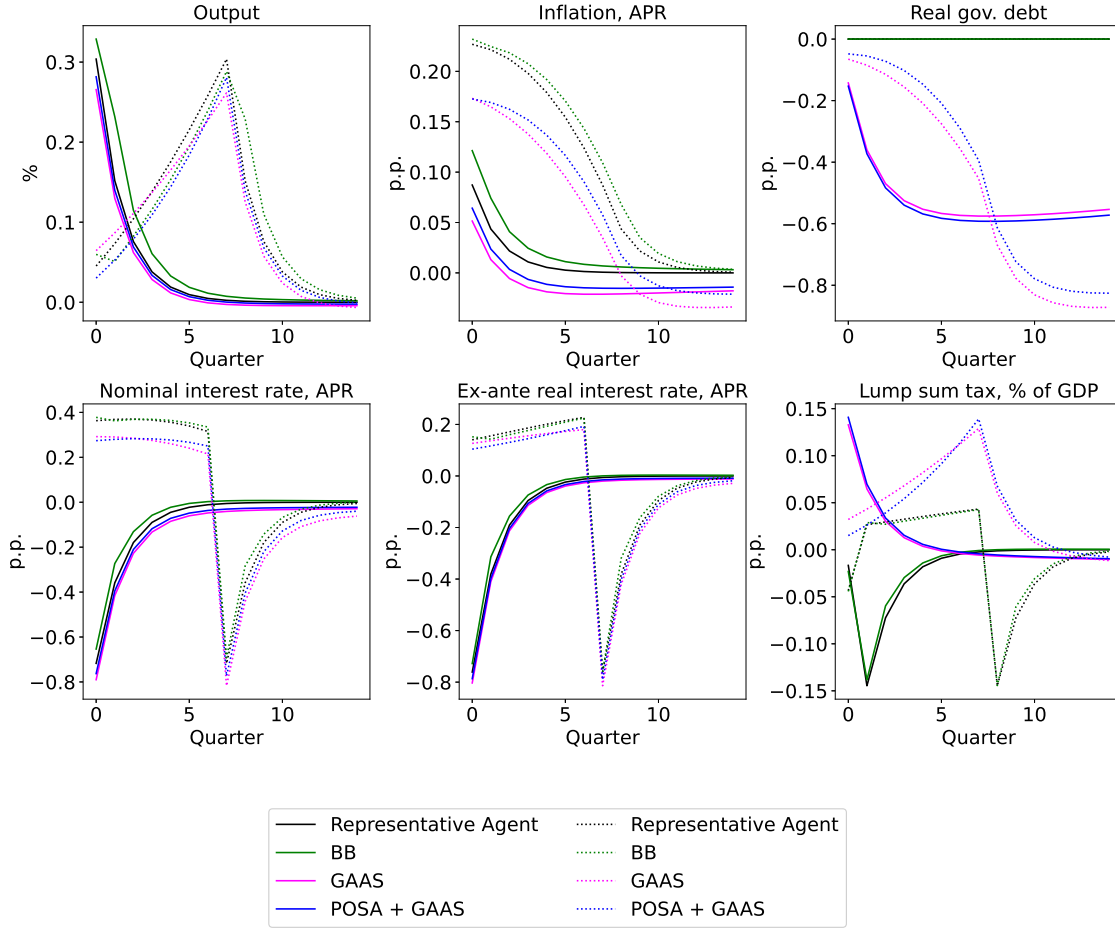
$$\begin{aligned}\varepsilon_t^0 &= \rho \varepsilon_{t-1}^0 + \eta_t^0 \\ \varepsilon_t^8 &= \rho \varepsilon_{t-1}^8 + \eta_t^8\end{aligned}$$

I set $\rho = 0.5$ and separately simulate first period increases of η_t^0 and η_t^8 by 0.0025 (1% annually). I do not display the results for the CBB rule, as they are almost identical to the RA model, both for the contemporaneous and the anticipated shock. As can be obtained from Figure 21, for the contemporaneous shock, the impact effect on output is strongest under the BB rule (green solid line), followed by the RA model. By contrast, under the GAAS rule, the effects on both output and inflation are smallest, as the policy raises tax revenue via higher output (see equation 18) and lowers government debt persistently, which has a negative effect on consumption. Furthermore, the decline in government debt is highly persistent, which is why starting in quarter 7, consumption remains slightly below steady-state for a very long period. As up to first order, via the Phillips curve inflation depends positively on current and future output, the ratio of the on impact increase of inflation under the GAAS rule to the inflation increase in the RA model is smaller than the corresponding ratio for output. As a result, the nominal and real interest rates also decline the most in this model. The finding that the output and inflation effects are larger under the BB than under the GAAS rule is consistent with Kaplan et al. (2016).

For the anticipated shock, in the RA model and all other models, the impact effect on output is much smaller than for the contemporaneous monetary policy shock, and then rises gradually until the shock arrives. Thus these output dynamics are not specific to HANK models, unlike what is suggested by Kaplan et al. (2016). In all models, inflation jumps and then declines gradually. The increase in inflation and output causes an increase in the nominal and the ex-ante real interest rate on impact via the interest feedback rule (55), with both remaining above steady-state until the shock arrives. In the RA model (black dotted line), the output profile can then be explained by the fact that via the consumption Euler equation, up to first order, consumption depends negatively on the sum of current and future real inters rates: $\hat{C}_t = -\frac{1}{\sigma} E_t \left\{ \sum_{i=0}^{\infty} \hat{R}_{t+i} - \hat{\Pi}_{t+1+i} \right\}$. As the moment of the arrival of the shock approaches, $\frac{1}{\sigma} E_t \left\{ \sum_{i=0}^{\infty} \hat{R}_{t+i} - \hat{\Pi}_{t+1+i} \right\}$ becomes more negative, thus explaining the increasing output path up until the arrival of the shock, when the real interest rate drops to its minimum value.

Unlike for the contemporaneous shock, for the anticipated shock the HANK model with the GAAS rule displays a stronger output effects than all other models during the first three quarters, while the effects on inflation are still weaker than in the other models throughout. The reason for this change in the ranking appears to be that the decline of government debt and the associated negative effect on consumption occurs in a more back-loaded fashion than for the contemporaneous shock, due to the aforementioned output profile, while the real interest rate path remains lower than under the BB rule and in the RA model due to lower inflation combined with the more than one-for-one response of the nominal interest rate to inflation via the monetary policy rule. The lower inflation trajectory than in the RA and the BB models arises because as for the contemporaneous shock, the decline in government debt with the GAAS rule eventually lowers output below steady-state. As inflation is forward looking (equation 13)), the expected sequence of low future output level lowers inflation already in quarter one. The finding of a larger on-impact output effect but a

Figure 21: Effect of contemporaneous and anticipated monetary policy shocks, impact



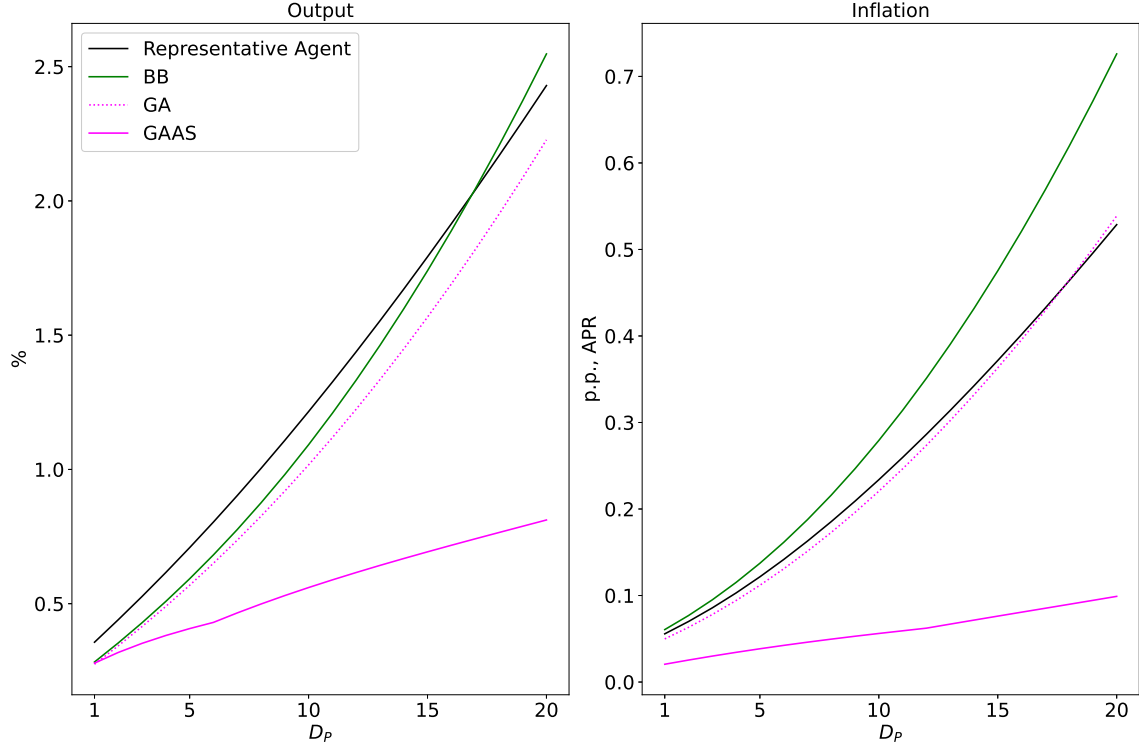
smaller peak effect than under the BB rule and the results for inflation are consistent with findings of Kaplan et al. (2016) ¹⁰

Note that under the BB rule, the output trajectory is lower than in the RA starting from the second quarter until and including the arrival of shock in quarter 8, after which it is higher than in the RA model. These dynamics are explained by the dynamics of the lump sum tax, whose trajectory under the BB rule has the same profile as the (ex-post) real interest rate in order to offset the latter's effect on the government budget. In the first quarter, the ex-post real rate drops below steady-state as inflation increases while the nominal rate is still at the steady-state. Correspondingly, the lump sum tax declines, only to rise above steady-state in quarter two when the real interest rate moves above steady-state. It drops again below steady-state when the arrival of the shock pushes the ex-post real rate below steady-state.

By contrast, in the POSA model, the on-impact output increase is smaller than in all other models. The difference with respect to the HANK model under the GAAS rule maybe due to the fact that the POSA Euler equation features not merely a wealth effect from government bonds like the HANK model, but also a smaller effect of future real interest rate deviations on current consumption, the more so the more distant these deviations are located in the future (see equation

¹⁰See their "transfers adjust" and "debt adjusts" scenarios, Figures 2 and 4.

Figure 22: Effect of forward guidance in quantitative model with gov. bonds in illiquid account, peak effect



(11)).

F Quantitative model with government bonds in both liquid and illiquid assets

In this section, I extend the model of Section 7 by assuming that a constant share ω_{il} of government bonds are located in the illiquid account. This assumption allows to jointly match the magnitude of outstanding government bonds while also matching the first year average MPC. The real world counterparts of bonds in the illiquid account could be pension and life insurance claims, term deposits or other household assets that are safe but can be liquidated only at a cost. Government bonds in the illiquid account are not subject to the administration cost ω .

Including government bonds in the illiquid account implies that the household return on the mutual fund r_t^a is now given by

$$r_t^a = \left(\frac{R_{t-1}^{A,bg}}{\Pi_t} - 1 \right) \frac{\omega_{il} b_{t-1}}{\omega_{il} b_{t-1} + K_{t-1} + s_t} + \frac{s_{t-1} + K_{t-1}}{\omega_{long} b_{t-1} + K_{t-1} + s_t} \left(r_t^{A,cap} - \omega \right) \quad (56)$$

where $R_{t-1}^{A,bg}$ and $r_t^{A,cap}$ denote the nominal return of government bonds in the illiquid account and the average ex-post real return on stocks and physical capital, respectively. $r_t^{A,cap}$ is in turn given

by

$$r_t^{A,cap} = \frac{s_t + (1 - \tau_K) div_t}{s_{t-1}} \frac{s_{t-1}}{s_{t-1} + K_{t-1}} + (1 + r_{K,t}) \frac{K_{t-1}}{s_{t-1} + K_{t-1}} - 1 \quad (57)$$

The fact that within the illiquid account, capital, shares and long-term bonds are perfect substitutes implies the following no-arbitrage conditions:

$$(1 - \tau_K)(r_{K,t+1} - \delta) = r_{t+1}^{A,cap} \quad (58)$$

$$s_t = \frac{s_{t+1} + (1 - \tau_K) div_{t+1}}{1 + r_{t+1}^{A,cap}} \quad (59)$$

$$R_t^{A,bg} = (1 + r_{t+1}^{A,cap}) \Pi_{t+1} \quad (60)$$

These equations replace equation (41) and (40). The government budget constraint is given by

$$b_t = \left((1 - \omega_{il}) \frac{R_{t-1}}{\Pi_t} + \omega_{il} \frac{R_{t-1}^{A,bg}}{\Pi_t} \right) b_{t-1} + G - T_t - \tau_w N_t w_t - \tau_C (C_t + \Phi_t) + \tau_K (r_{K,t} - \delta) K_{t-1} \quad (61)$$

where the cost of debt is now a weighted average of the return on government bonds in the liquid and the illiquid account. This equation replaces equation (45).

The market clearing conditions become

$$b_t^h = (1 - \omega_{il}) b_t \quad (62)$$

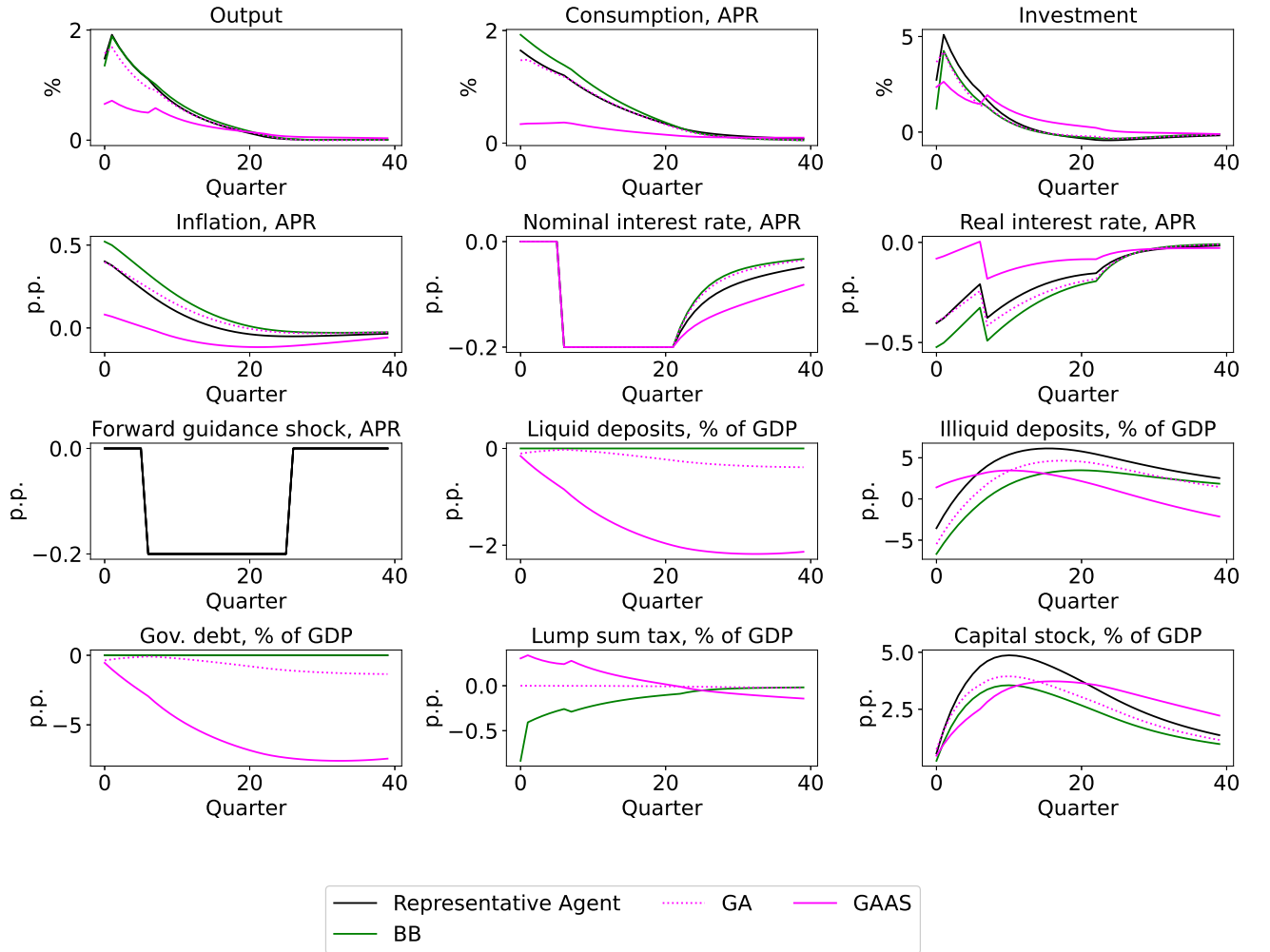
$$A_t = K_t + s_t + \omega_{il} b_t \quad (63)$$

which replace equations (47) and (48).

Regarding the calibration, I set the target for the total government debt-to-annual GDP ratio to 0.8 and keep the liquid asset-to-annual GDP ratio at 0.23, implying a calibration of the share of long-term bonds in total government debt ω_{il} of 71%. In order to continue hitting the target for the first year average MPC with this larger stock of illiquid assets, I need to raise χ_1 to 43.5. The implied spread of the household's return on government bonds in the illiquid account over the return on the liquid account $R_t^{A,bg} - R_t$ equals 1.3% annualized. This magnitude is broadly consistent with the interpretation of the government bonds in the illiquid account as longer maturity assets, as the average spread between the return on 10 year and three month government bonds amounts to 1.7%.

Figure 22 displays the peak effects of the policy on output and inflation. Effects under the GAAS rule are stronger than in the model discussed in the main text, but still much weaker than in the RA model. The stronger output increase then in the model in the main text is due to a larger increase in investment. The decline in liquid deposits is smaller than in the model in the main text (see Figures 23 and 13) since part of the increase in tax revenue is now used to repay debt in the illiquid account.

Figure 23: Effect of forward guidance in quantitative model - dynamic effect



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