Long-Term Government Debt and Monetary Transmission in HANK Models

Sean Lavender

25 April 2024

(Preliminary Draft)

This paper considers the effect of long-term government debt on the transmission of monetary policy in heterogeneous-agent New Keynesian (HANK) models. The interactions between the maturity composition of government debt and the design of fiscal policy are important determinants of the aggregate and distributional effects of monetary policy. When the maturity of government debt is longer, the fiscal effects of monetary policy can serve to dampen the fall in consumption following a monetary policy contraction. This dampening is most significant when the fiscal rule is more responsive to the level of government debt, and when the tax system is less progressive.

1 Introduction

Government debt issuance has risen markedly over the past two decades, a trend exacerbated by the COVID-19 pandemic. As the supply of debt has increased, many developed countries have also seen a lengthening of government debt maturities. Figure 1 shows the average maturity of outstanding government debt for the G7, using data from De Graeve and Mazzolini (2023). The data show that government debt maturities increased for six of the G7 countries between 1995 and 2022. The lengthening was most stark for the United Kingdom, where over 85% of government debt takes the form of longer-term bonds, with the average maturity rising from 10 years to over 14 years over the period.

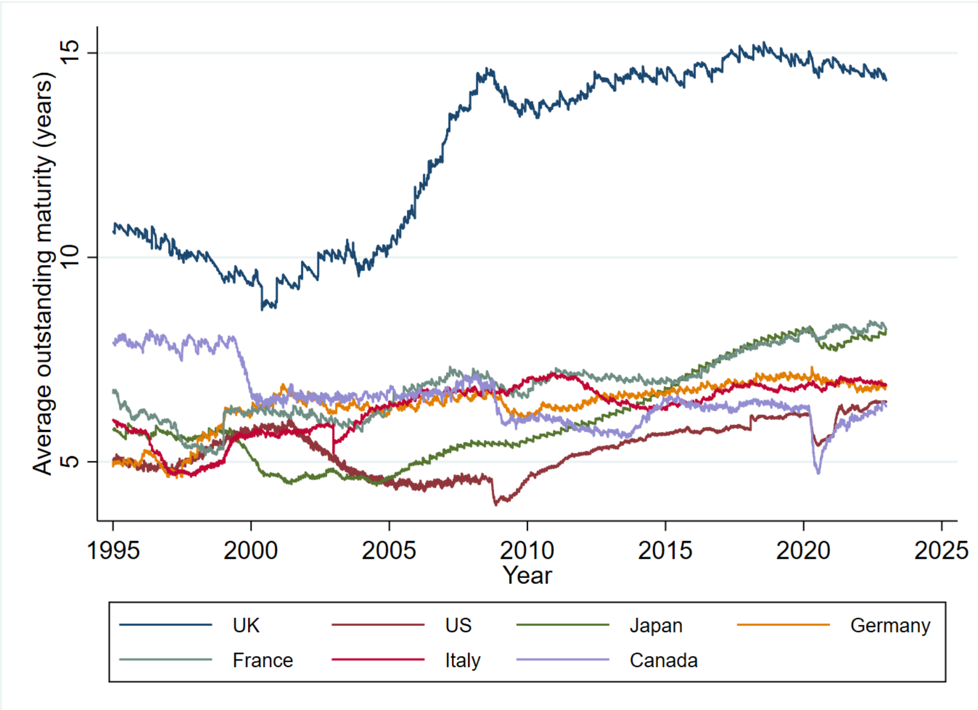

Figure 1: Weighted average maturity of outstanding government debt for G7 members between 1995 and 2022. Data sourced from De Graeve and Mazzolini (2023).

While much of the theoretical literature abstracts from debt maturity, this paper seeks to understand the effect of long-term government debt on the transmission of monetary policy in heterogeneous-agent New Keynesian (HANK) models. The results show that the aggregate and distributional effects of monetary policy depend critically upon the interactions between the maturity composition of government debt and the design of fiscal policy. In particular, the share and duration of long-term government debt, the progressivity of the tax system, and the fiscal rule chosen by the government significantly affect the fiscal effects of monetary contractions, and therefore the magnitude the consumption response.

To illustrate the main transmission mechanisms, I first extend the tractable HANK (THANK) model developed by Bilbiie (2018; 2020) to allow households to save in either liquid short-term government bonds or illiquid long-term government bonds. When a monetary contraction causes real interest rates to rise, the value of outstanding long-term government bonds falls. This revaluation of the government's long-term liabilities mitigates the tightening of the budget constraint caused by the rise in short-term real rates. Relative to the case with only short-term government debt, this creates fiscal space and enables the government to respond by setting a lower path of taxes. This reduction in taxes can dampen the aggregate and distributional effects of the monetary contraction.

As the composition of government debt matters for the fiscal effects of monetary policy, the introduction of long-term debt therefore gives rise to important fiscal-monetary interactions. When the government issues a larger share of long-term government debt, or when the duration of long-term government bonds rises, a monetary contraction leads to a larger downward revaluation of the government's liabilities. This revaluation leads to a lower path of taxes when the fiscal rule is more responsive to the value of outstanding government debt. The impact of this lower path of taxes on consumption and inequality is greatest when households with a higher marginal propensity to consume receive a larger share of the tax cuts. That is, when the tax system is less progressive such that high-MPC households pay a larger share of taxes and receive a larger share of tax cuts. Calculating the impulse responses to a monetary policy shock in the THANK model confirms that a longer government debt maturity dampens the effect of a monetary contraction on consumption and inequality. Moreover, this dampening is indeed more pronounced when the fiscal rule is more responsive, and when the tax system is less progressive.

I then extend the THANK model and show that the fiscal-monetary interactions introduced by long-term debt are present in a richer quantitative model. I calculate the impulse responses to a monetary contraction in a variant of the two-account HANK model developed by Kaplan et al. (2018) in which the liquid asset is short-term government debt and the illiquid asset is long-term government debt. The results show that a longer government debt maturity again dampens the effect of monetary policy on consumption. This dampening is greater when the share of long-term government debt is higher, when the fiscal rule is more responsive to the value of government debt, and when the tax system is less progressive as defined by Heathcote et al. (2017).

In studying the fiscal effects of monetary policy with long-term government debt, this paper relates to a large and growing literature which shows that the interactions between fiscal and monetary policy play an important role in monetary transmission in many different classes of HANK models. In the THANK model developed by Bilbiie (2018; 2020), fiscal policy is critical in determining the extent to which the addition of hand-to-mouth households amplifies or dampens the aggregate response to monetary policy. Bilbiie shows that the degree of profit redistribution induced by the tax system is a key driver of the cyclicality of income inequality, which serves as a sufficient statistic for aggregate demand amplification within the model. Bilbiie et al. (2020) also study the interactions between fiscal and monetary policy in the THANK model. The authors show that redistributive fiscal policy causes output the deviate from its perfect-insurance level, and creates a tradeoff between redistribution and stabilisation for the monetary authority.

The quantitative HANK literature has also emphasised the strong interconnections between fiscal and monetary policy in models without Ricardian equivalence. Kaplan et al. (2018) show that the government budget and the fiscal rule are important determinants of the output response to monetary policy. When a monetary policy contraction increases interest rates in a model with short-term government debt, the tightening of the government's budget constraint necessitates an increase in taxes. Due to the presence of hand-to-mouth households, the size of this fiscal response determines the aggregate effects of monetary policy. Alves et al. (2020) show that the design of the fiscal reaction function is the the primary determinant of monetary amplification in HANK models, exerting a greater influence than both capital adjustment costs and the unequal incidence of income and dividends. In a HANK model with short-term government debt, the consumption response to a monetary expansion was shown to be twice as large when the fiscal authority follows a balance budget rule compared to the case with more gradual tax adjustment. The paper presented here builds upon this literature in showing that the introduction of long-term government debt gives rise to additional interactions between fiscal and monetary policy which are not present in models which abstract from the maturity structure of government debt. With long-term government debt, monetary policy reduces the value of the government's liabilities. It is the design of the fiscal rule and the progressivity of the tax system which determines the extent to which this additional fiscal space dampens the consumption effects of monetary policy.

Secondly, this paper relates to work considering the effects of asset maturities on monetary policy transmission. Auclert (2019) introduces the 'interest rate exposure channel', showing that rise in interest rates causes redistribution towards households with long-term liabilities and short-term assets. Contractionary monetary policy reduces the value of these long-term liabilities, increasing the financial income of debtors at the expense of creditors. As households with short-term assets and longer-term liabilities are shown to have higher MPCs, this channel dampens monetary policy. In this paper, I examine the role of the revaluation of *government debt* in monetary transmission. As households do not take negative positions in government debt, high-MPC households do not see a direct increase in their financial wealth due to the revaluation of government debt. Instead, the revaluation of government debt represents redistribution from bondholders to the government. It is therefore the tax system which determines whether income is redistributed from high-wealth to low-wealth households when government debt is revalued. If the fiscal rule is highly responsive to changes in government debt, the fiscal authority returns the gains from the fall in the value of its liabilities to households through a reduction in taxes. If high-MPC households receive a larger share of this tax cut, then fiscal policy will be more effective in offsetting the contractionary impact of monetary policy on aggregate consumption.

Caramp and Feilich (2022) and Caramp and Silva (2023) develop representative-agent and two-agent New Keynesian models in which the downward revaluation of long-term government bonds can amplify monetary policy by reducing the financial wealth of households. The magnitude of this wealth effect is shown to be determined by the fiscal response to monetary policy. In this paper, long-term government debt is illiquid and cannot be used for self-insurance against idiosyncratic risk. It is therefore the impact of the long-term bond revaluation on the government budget constraint (and not its direct effect on household balance sheets), and the subsequent impact on redistributive fiscal policy, which drives the aggregate effects of monetary policy.

Two recent papers by Cantore and Meichtry (2023) and Cantore and Leonardi (2024) also develop two-agent New Keynesian models in which the liquidity of assets plays an important role in monetary and fiscal policy transmission. Cantore and Meichtry (2023) consider a TANK model with short- and long-term government debt in which imperfect substitutability between bonds of different maturities and a zero lower bound on nominal interest rates generate a state-dependent role for quantitative easing. The focus of the paper presented here is instead on the impact of illiquid long-term government debt on conventional monetary policy through the government budget constraint. Cantore and Leonardi (2024) extend the Bilbiie (2018) THANK model to a three-agent setting in which households can save in liquid one-period bonds or illiquid capital. The design of fiscal and monetary policy impacts the liquidity premium, which depends on differences between consumption across household types. The THANK model in this paper will also yield a similar liquidity premium, with the difference in return between short-term and long-term government debt reflecting the degree of idiosyncratic risk faced by saver households.

Lastly, the paper relates to the literature on the optimal maturity of government debt (Missale and Blanchard 1994; Greenwood et al. 2015; Faraglia et al. 2019). Greenwood et al. (2015) emphasise that the government's debt maturity choice involves a tradeoff between liquidity provision and the mitigation of fiscal risk. In this paper, the introduction of long-term government reduces the government's exposure to short-term real interest rate increases, providing the fiscal authority with the headroom to reduce taxes and dampen the aggregate and distributional effects of monetary tightening.

The paper proceeds as follows. Section 2 introduces the THANK model with illiquid long-term government debt. Section 3 shows the impulse responses to a monetary shock in the THANK model and illustrates the key fiscal-monetary interactions. Section 4 extends the analysis to the quantitative two-account HANK model. Section 5 concludes.

2 A Tractable HANK Model with Illiquid Long-Term Government Debt

To study the effects of the maturity composition of government debt on monetary policy transmission, I extend the THANK model with positive steady state liquidity developed by Bilbiie (2018) to include long-term government bonds as an additional illiquid savings instrument. Due to the absence of Ricardian equivalence, the fiscal effects of monetary policy, which are determined by the interactions between the debt composition and the design of taxes, have significant effects on the aggregate impact of a monetary contraction.

2.1 Households

As in Bilbiie (2018), there are two types of household in the model. Savers (denoted by S) earn income from labour and dividends paid by firms, and have access to bond markets. Hand-to-mouth households earn only labour income, and do not save. As a a result, hand-to-mouth households have a unit marginal propensity to consume out of their own income. Households face idiosyncratic risk in the form of movement between income states, which follows an exogenous Markov transition matrix:

$$\begin{pmatrix} h & 1-h \\ 1-s & s \end{pmatrix}.$$

A hand-to-mouth household remains hand-to-mouth with probability h, and a saver remains a saver with probability s. This Markov process gives rise to a stationary distribution, where the stationary mass of hand-to-mouth households is equal to:

$$\lambda = \frac{1-s}{2-s-h}.$$

To insure against this idiosyncratic risk, households can save using short-term (one-period) government bonds, which pay a return equal to the short-term real interest rate:

$$1 + r_t = \frac{1+i_{t-1}}{1+\pi_t}$$

where i_t denotes the nominal interest rate set in period t, and π_t is the inflation rate. The short-term government bonds are liquid in that a saver who becomes hand-to-mouth in period $t+1$ still earns the return from their period t savings.

I extend the model to also allow households to save using long-term government bonds. These bonds, are modelled as perpetuities with an exponentially declining coupon following Woodford (2001). A long-term government bond purchased for a price Q_t in period t pays a stream of real payments equal to $1, \rho, \rho^2, ...$ in subsequent periods. The real return on the long-term bond is given by:

$$1 + r_t^{LT} = \frac{1+\rho Q_t}{Q_{t-1}}.$$

The Macaulay duration of the bond, which measures the sensitivity of the bond price to interest rate movements, is equal to:

$$Duration = \frac{1}{1-\beta\rho}$$

where β is the common household discount factor. The parameter ρ determines the duration of the bond. When $\rho = 0$, all government bonds are one-period bonds. In the opposite limit with $\rho = 1$, bonds are consols. Long-term government bonds are illiquid. They are not available to hand-to-mouth households and cannot be used to self-insure against idiosyncratic income risk. That is, a long-term bond purchased by a saver in period t cannot be transferred to the hand-to-mouth income state in the next period.[1]

[1]The use of illiquid government debt reflects the fact that longer-term government bonds are generally held only indirectly by households in investment or pension accounts. As a result, hand-to-mouth consumers do not have exposure to long-term bond revaluation and the marginal propensity to consume out of these revaluations is low. If households can instead self-insure using liquid long-term government debt, the balance sheet effects of bond revaluation may amplify monetary contractions. See Appendix B for a discussion of this case, and of the empirical evidence on household exposure to government debt.

Following Bilbiie (2018; 2020), resources are pooled within household types. Therefore, there is perfect risk-sharing *within* types, but only imperfect insurance *across* types. The consumption-saving decisions of each household type are made by a 'family head' to maximise utility subject to the household budget constraints and the laws of motion for the short-term and long-term government bonds across income states.

The budget constraints of the saver and the hand-to-mouth are given by:

$$\begin{aligned} C_t^S + Z_{t+1}^{S,ST} + Z_{t+1}^{S,LT} &= W_t N_t^S + D_t^S + TR^S - T_t^S + (1+r_t)B_t^{S,ST} + (1+r_t^{LT})B_t^{S,LT} \\ C_t^H + Z_{t+1}^{H,ST} &= W_t N_t^H + D_t^H + TR^H - T_t^H + (1+r_t)B_t^{H,ST}. \end{aligned}$$

The variables C_t^j and $W_t N_t^j$ denote the consumption and labour income of the two household types. Lump-sum taxes levied on each of the household types are denoted by T_t^j. Households also receive steady-state transfers denoted by TR^j. Firms are owned by savers, and the dividends paid by the firms are redistributed by a profit tax (with rate τ^D) such that households' dividend incomes are equal to:

$$\begin{aligned} D_t^S &= \frac{1-\tau^D}{1-\lambda} D_t \\ D_t^H &= \frac{\tau^D}{\lambda} D_t. \end{aligned}$$

The variables $B_t^{j,ST}$ and $B_t^{j,LT}$ represent short-term and long-term bonds held by households of type j at the beginning of period t. The short-term and long-term bond savings chosen at the end of period t are denoted by $Z_{t+1}^{j,ST}$ and $Z_{t+1}^{j,LT}$. We will focus on equilibria in which the hand-to-mouth households do not save. This, taken with the fact that hand-to-mouth households do not have access to long-term government debt, mean that the quantities of the bonds held by the two household types are equal to:

$$\begin{aligned} B_t^{S,ST} &= \frac{s}{1-\lambda} B_t^{ST}, \ B_t^{H,ST} = \frac{1-s}{\lambda} B_t^{ST} \\ B_t^{S,LT} &= \frac{1}{1-\lambda} B_t^{LT} \end{aligned}$$

where B_t^{ST} and B_t^{LT} give the total supply of short-term and long-term government debt. The budget constraints can therefore be rewritten as:

$$\begin{aligned} C_t^S + \frac{1}{1-\lambda}(B_{t+1}^{ST} + B_{t+1}^{LT}) &= W_t N_t^S + \frac{1-\tau^D}{1-\lambda} D_t + TR^S - T_t^S + \frac{1}{1-\lambda}\left[(1+r_t)sB_t^{ST} + (1+r_t^{LT})B_t^{LT}\right] \\ C_t^H &= W_t N_t^H + \frac{\tau^D}{\lambda} D_t + TR^H - T_t^H + (1+r_t)\frac{1-s}{\lambda} B_t^{ST}. \end{aligned}$$

As only savers choose to save in government bonds, the bonds are priced according to the Euler equations of the saver. The saver optimisation problem yields the same self-insurance Euler equation for short-term bonds as in Bilbiie (2018):

$$(C_t^S)^{-\frac{1}{\sigma}} = \beta E_t \left\{ (1 + r_{t+1}) \left[s(C_{t+1}^S)^{-\frac{1}{\sigma}} + (1-s)(C_{t+1}^H)^{-\frac{1}{\sigma}} \right] \right\}$$

where σ is the intertemporal elasticity of substitution. The saver chooses government bonds in order to equalise the marginal cost of saving today (the marginal utility of foregone consumption) with the expected marginal return to saving. With probability s, the saver remains a saver next period. With probability $1 - s$, the saver becomes hand-to-mouth.

The long-term government bonds are priced according to a second Euler equation:

$$(C_t^S)^{-\frac{1}{\sigma}} = \beta E_t \left\{ (1 + r_{t+1}^{LT})(C_{t+1}^S)^{-\frac{1}{\sigma}} \right\}$$

which reflects the fact that the long-term government bonds cannot be used for self-insurance. Combining the two Euler equations yields an arbitrage relationship between the returns on the short-term and long-term government bonds:

$$E_t \left\{ (1 + r_{t+1}^{LT})(C_{t+1}^S)^{-\frac{1}{\sigma}} \right\} = E_t \left\{ (1 + r_{t+1}) \left[s(C_{t+1}^S)^{-\frac{1}{\sigma}} + (1-s)(C_{t+1}^H)^{-\frac{1}{\sigma}} \right] \right\}.$$

When the short-term real interest rate rises, the return on long-term debt must also rise. This requires that the long-term bond price falls. It is this downward revaluation of long-term government bonds that drives the key fiscal effects of monetary policy in this model.

Loglinearising the model around a zero-inflation steady state with equal consumption gives an expression for the term/liquidity premium in the model:

$$r_{t+1}^{LT} - r_{t+1} = \frac{1-s}{\sigma} E_t \left(c_{t+1}^S - c_{t+1}^H \right)$$

where c_t^j is expressed in terms of log deviations from steady-state consumption. The liquidity premium is increasing in the level of idiosyncratic risk, which is given by the probability $(1 - s)$ of a saver becoming hand-to-mouth next period, and in the difference in consumption across states. That is, the liquidity property of the short-term bonds is valued more highly by savers when they face a higher probability of entering the hand-to-mouth state, and when the transition to the hand-to-mouth state is expected to entail a larger fall in consumption.[2]

[2]This equation closely resembles the equation for the liquidity premium which drives the main mech-

Household intratemporal optimality gives the following labour supply equations:

$$\frac{\left(N_t^S\right)^{\varphi}}{W_t} = \left(C_t^S\right)^{-\frac{1}{\sigma}}$$
$$\frac{\left(N_t^H\right)^{\varphi}}{W_t} = \left(C_t^H\right)^{-\frac{1}{\sigma}}$$

where φ is the inverse Frisch elasticity of labour supply to the wage rate.

2.2 Government Debt and Fiscal Policy

The total real-terms value of debt issued by the government is equal to the sum of short- and long-term debt issuance:

$$B_{t+1} = B_{t+1}^{ST} + B_{t+1}^{LT}.$$

As in Harrison (2012), government debt management stipulates that the real-terms stock of long-term debt is fixed, such that the value of long-term government debt is given by:

$$B_{t+1}^{LT} = Q_t \bar{B}^{LT}.$$

The debt management rule allows the value of long-term government debt to fluctuate around its steady-state value with changes in the bond price. This is consistent with the empirical evidence, which documents that the share of government debt which takes the form of long-term bonds is highly persistent within countries (De Graeve and Mazzolini 2023). The steady-state level of government debt is equal to a proportion ν^{LT} of the total steady-state government debt. The weighted average duration of government debt is therefore given by:

$$Average\ Duration = \frac{1 - \beta\rho(1 - \nu^{LT})}{1 - \beta\rho}.$$

The government uses short- and long-term debt issuance and taxation to service its outstanding debt. Abstracting from government spending, this yields the following flow government budget constraint:

$$B_{t+1} + T_t = \left(1 + r_t\right) B_t^{ST} + \left(1 + r_t^{LT}\right) B_t^{LT}.$$

anism in the analysis of Cantore and Leonardi (2024).

Total lump-sum taxes, T_t, are set according to a fiscal rule. Following Woodford (2001), the government implements a liability targeting tax consolidation rule. The fiscal authority increases taxes above their steady-state level when the value of its liabilities rises above its steady-state level:

$$T_t = T + \phi^B \left(L_t^G - L^G\right)$$
$$where\ L_t^G = (1 + r_t)\, B_t^{ST} + \left(1 + r_t^{LT}\right) B_t^{LT}.$$

The parameter ϕ^B gives the responsiveness of taxation to changes in the value of the government's liabilities, and therefore plays a central role in the impact of long-term government debt on the transmission of monetary policy.[3] When a monetary contraction causes the short-term real interest rate to rise, the price of long-term bonds falls. This reduces the value of the government's liabilities, mitigating the tightening of the government's budget constraint caused by the rise in short-term debt servicing costs. The longer is the average duration of government debt, the larger is the fall in the value of the government's liabilities. Due to the fiscal rule, the government can respond to the long-term debt revaluation by setting a lower path of taxes. Due to the presence of hand-to-mouth households (which breaks Ricardian equivalence), this fall in taxation will dampen the contractionary effects of monetary policy on consumption. The larger is the value of ϕ^B, the larger is the fall in taxes, and the stronger is the dampening introduced by a longer debt maturity.

With heterogeneous households, the progressivity of taxation is also an important factor in determining the effect of long-term government debt on monetary policy transmission. To incorporate a progressive tax system, I follow Bilbiie et al. (2020) in assuming that hand-to-mouth households pay a share α of total taxes. Total taxes are therefore given by:

$$T_t = \lambda T_t^H + (1 - \lambda) T_t^S$$
$$where\ \lambda T_t^H = \alpha T_t.$$

When $\alpha < \lambda$, the tax system is progressive as the percentage of taxes paid by hand-to-mouth households is less than their share of the population. When the tax system is less progressive (or more regressive), a reduction in total taxation has a smaller effect on aggregate consumption. This is because the hand-to-mouth households with unit MPC pay a larger share of taxes, and receive a larger share of tax cuts. The fiscal

[3] We will focus on equilibria in which $\phi^B > 1 - \beta$ such that debt dynamics are stable and fiscal policy is locally Ricardian as defined by Woodford (2001).

effects of monetary policy due to the revaluation of long-term government debt will have a greater dampening effect on aggregate consumption when taxation is less progressive. The interactions between the maturity composition of government debt, the fiscal rule and the progressivity of the tax system are therefore important in determining the aggregate and distributional effects of monetary policy.[4]

2.3 Monetary Policy

The central bank sets the nominal interest rate according to a standard Taylor rule:

$$\frac{1+i_t}{1+\bar{\imath}} = \left(\frac{1+\pi_t}{1+\pi}\right)^{\phi^\pi} \varepsilon_t^i$$

where ϕ^π is set such that the Taylor principle is satisfied and monetary policy is 'active' as defined by Leeper (1991). The monetary policy shock ε_t^i follows an AR(1) process in logarithms.

2.4 Firms and Supply

As in Bilbiie (2018), a continuum of monopolistically competitive intermediate firms produce using a linear production technology, $Y_t(k) = N_t(k)$. The firms set their price to maximise profit subject to quadratic Rotemberg (1982) price adjustment costs. The maximisation problem of firm k is:

$$\max_{P_t(k)} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{P_0 C_0^S}{P_t C_t^S}\right)^{\frac{1}{\sigma}} \left[\left(1+\tau^S\right) P_t(k) Y_t(k) - \tilde{W}_t N_t(k) - \frac{\psi}{2}\left(\frac{P_t(k)}{P_{t-1}(k)} - 1\right)^2 P_t Y_t\right],$$

$$\textit{subject to } Y_t(k) = \left(\frac{P_t(k)}{P_t}\right)^{-\epsilon} Y_t.$$

The term τ^S is the production subsidy, which is financed through a lump-sum tax on firms, ϵ is the elasticity of substitution between varieties, and $\tilde{W}_t$ denotes the nominal wage rate. Under the optimal production subsidy, the first-order condition of the problem

[4] Central bank asset purchases could represent a further source of fiscal-monetary interactions stemming from the revaluation of long-term debt. If the central bank is exposed to significant interest rate risk due to large holdings of long-term government debt, a monetary contraction could tighten the consolidated budget constraint. This could serve to both adversely impact the government's fiscal space, and to compromise the independence of the central bank. This consideration is left to future work.

yields the nonlinear dynamic Philips curve:

$$\pi_t(1+\pi_t) = \beta \mathbb{E}_t \left[\left(\frac{C_t^S}{C_{t+1}^S} \right)^{\frac{1}{\sigma}} \frac{Y_{t+1}}{Y_t} \pi_{t+1}(1+\pi_{t+1}) \right] + \frac{\epsilon}{\psi}(W_t - 1)$$

which follows the NKPC derived by Bilbiie (2018).

2.5 Market Clearing

Aggregate consumption and labour supply are equal to the sum of the consumption and labour supply of the of the savers and the hand-to-mouth:

$$C_t = \lambda C_t^H + (1-\lambda) C_t^S$$
$$N_t = \lambda N_t^H + (1-\lambda) N_t^S.$$

Production and goods market clearing require that:

$$Y_t = N_t$$
$$Y_t \left(1 - \frac{\psi}{2}\pi_t^2\right) = C_t.$$

Aggregate profits are given by $D_t = Y_t - W_t N_t$.

3 Monetary Policy and Long-Term Government Debt in THANK

To illustrate the effects of the maturity of government debt on monetary policy transmission, I loglinearise the nonlinear equilibrium conditions above around a zero-inflation steady state in which consumption is equalised across income states.[5] I then calculate the impulse responses to a 25 basis-point monetary contraction, and compare the results for parameterisations with only short-term debt to a parameterisation with a longer maturity structure.

[5]See Appendix A for a full description of the steady state and the list of linear equilibrium conditions.

3.1 Baseline Parameterisation

Using data from De Graeve and Mazzolini (2023), figure 2 shows the share of outstanding government debt with maturity longer than one year. In steady state, this share corresponds to the parameter ν^{LT} in the THANK model. Since 1995, the share of longer-term government debt has been significantly above 50% for all of the G7 members. The United States, likely due to its unique role as the issuer of the world's primary reserve currency, has the smallest share of longer-term debt, averaging around 65% over the period. The debt stocks of France, Germany, Italy and Japan had longer-term shares in excess of 80% for much of the period. The United Kingdom has the largest share, averaging over 90%.

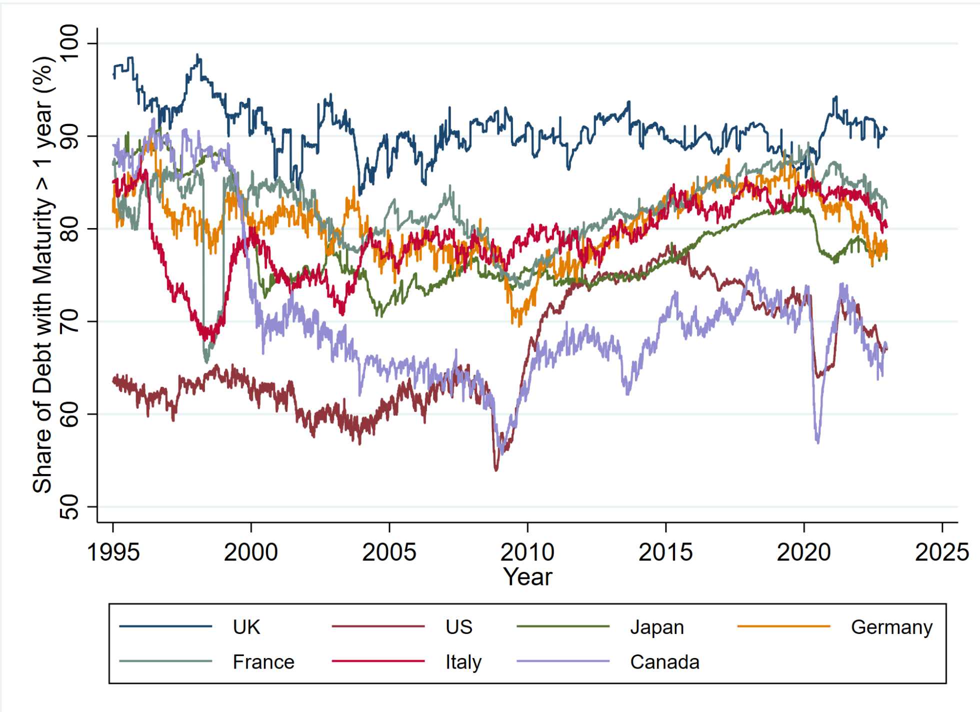

Figure 2: Share of outstanding government debt with maturity longer than one year (by market value) for G7 members. Calculated using data from De Graeve and Mazzolini (2023).

To illustrate the effect of a longer maturity profile on monetary transmission, I contrast the impulse responses for the standard short-term debt case ($\nu^{LT} = 0$) to a parameterisation with $\nu^{LT} = 0.85$. The UK also issued long-term government debt with longest average maturity, with the maturity of longer-term debt averaging over 16 years during the last 10 years of the sample. I therefore set $\rho = 0.977$ to replicate the maturity profile of the UK.[6]

[6] The parameter ρ determines the Macaulay duration of government debt in the model. With zero-

The remaining parameters used in the baseline THANK are shown in table 1. The intertemporal elasticity of substitution, the inverse Frisch elasticity and the slope of the loglinearised Phillips curve are set equal to the parameter values used in Bilbiie et al. (2022). As in Bilbiie (2018), the cyclicality of income inequality is given by:

$$\chi \equiv 1 + \phi \left(1 - \frac{\tau^D}{\lambda}\right).$$

When $\chi > 1$, income inequality is countercyclical, with the income of the hand-to-mouth rising by more than aggregate income during an expansion and falling by more than aggregate income during a contraction. I set the profit tax rate in order to achieve countercyclical income inequality ($\chi = 1.5$). I set the share of hand-to-mouth households and the degree of idiosyncratic risk in order to achieve consistency with both the quantitative HANK model in section 4, and with empirical evidence on the asset distribution and income process in the US used in the HANK literature.[7]

For the specification of fiscal policy, I initially consider the case of uniform taxation ($\alpha = \lambda$), and then study the impact of making the tax system less progressive. The baseline value for the fiscal rule responsiveness parameter is 0.6. Compared to a a balanced budget rule, this allows for a slower adjustment of taxes and the debt stock. I then consider the impact of making the fiscal rule more responsive to the value of the government's liabilities ($\phi^B = 0.8$). A relatively high ϕ^B may be most applicable to a fiscal authority such as the UK government in the run-up to the 2024 general election, where the government has sought to use the entirety of its fiscal headroom to fund cuts in personal taxation.

3.2 Long-Term Government Debt and Monetary Tightening

Figure 3 shows the impulse responses to a 25 basis-point increase in the nominal interest rate. Compared to the case in which the government issues only short-term government debt, the parameterisation with $\nu^{LT} = 0.85$ sees a significant dampening of the effect of monetary policy on aggregate consumption. The impulse responses show that this dampening is driven by the fiscal effects of monetary policy, which operate through the government budget constraint.

coupon debt, the maturity and the duration of the debt stock are equal. Otherwise, the duration is an upper-bound for the maturity. For simplicity, I calibrate the duration to match the maturity of the debt stock. The central transmission mechanisms are unchanged by instead calibrating the model to match the duration observed in the data.

[7] See Appendix A for a detailed discussion on how the THANK and HANK models are calibrated to achieve consistency across the models.

	Description	Value (annual)
β	Discount factor.	0.99
σ	Intertemporal elasticity of substitution.	1
φ	Frisch elasticity.	1
τ^D	Profit tax rate.	0.2
λ	Share of hand-to-mouth households.	0.4
s	Probability of remaining S.	0.96
ϕ^B	Fiscal rule debt coefficient.	0.6
α	Hand-to-mouth tax share.	0.4
ν^{LT}	Share of long-term debt.	0/0.85
ρ	Long-term duration parameter.	0/0.977
ϕ^π	Taylor rule coefficient.	1.5
ρ^M	Persistence of monetary shock.	0.7
κ	Phillips curve slope.	0.05

Table 1: Baseline parameter values for the loglinearised THANK model with short-term and long-term government debt.

When the central bank increases the nominal interest rate, the short-term real-interest rate rises. Arbitrage between short-term and long-term government debt then causes the price of long-term government bonds to fall. This downward revaluation of long-term government bonds reduces the value of the government's liabilities, loosening the government budget constraint. In contrast, when the government issues only short-term debt, the rise in short-term real interest rates increases the government's liabilities on impact. The additional fiscal space generated by the introduction of long-term debt allows the government to set a lower path of taxes. Due to the presence of non-Ricardian hand-to-mouth households, this fall in taxes dampens the effect of monetary policy on aggregate consumption. As Ricardian savers have a low marginal propensity to consume out of the reduction in taxes, the monetary contraction also leads to a much smaller rise in consumption inequality when the government issues a larger share of long-term government debt. This smaller rise in consumption inequality across income states is reflected in the liquidity premium, which rises by a smaller amount relative to the case with only short-term debt.

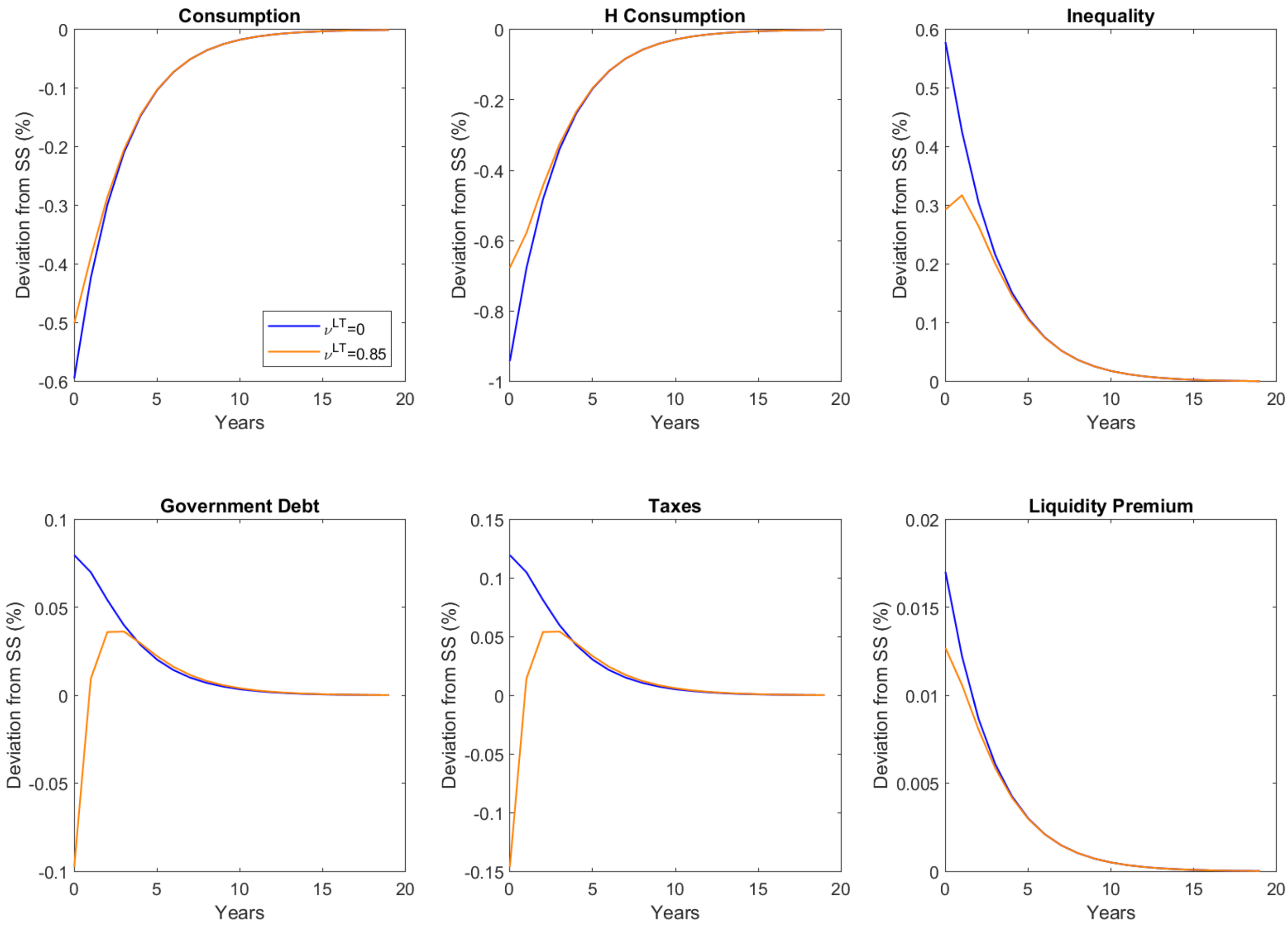

Figure 3: Impulse responses to a 25 bps monetary contraction for the THANK model with short-and long-term debt. $\rho = 0.977$, $\alpha = 0.4$ and $\phi^B = 0.6$.

3.3 Debt Maturity, Tax Progressivity and the Fiscal Rule

Figure 4 shows the impulse responses to a monetary policy contraction under a more regressive tax system in which the hand-to-mouth households (40% of the population) pay 60% of total taxes. The IRFs show that the dampening introduced by a longer debt maturity profile is more pronounced under this less progressive tax system.

When the government issues only short-term debt, the government increases taxes upon impact of a monetary contraction due to the rise in debt servicing costs. When the tax system is more regressive, a larger share of this tax increase falls upon the hand-to-mouth households. As the hand-to-mouth households have unit MPC, the tax increase amplifies the effect of monetary policy on aggregate consumption, inequality and the liquidity premium. Conversely, the downward revaluation of long-term government debt following a monetary policy contraction generates additional fiscal space and allows the government to reduce taxes. When the tax system is more regressive, a larger share of the tax cut accrues to the hand-to-mouth households. This creates a stronger dampening effect, reducing the impact of monetary tightening on aggregate consumption, consumption inequality and the liquidity premium. With uniform taxes, increasing the share of long-term debt from 0 to 85% dampened the impact effect of monetary policy on aggregate consumption by 15%. In figure 4, the fall in aggregate consumption is dampened by over 32%.

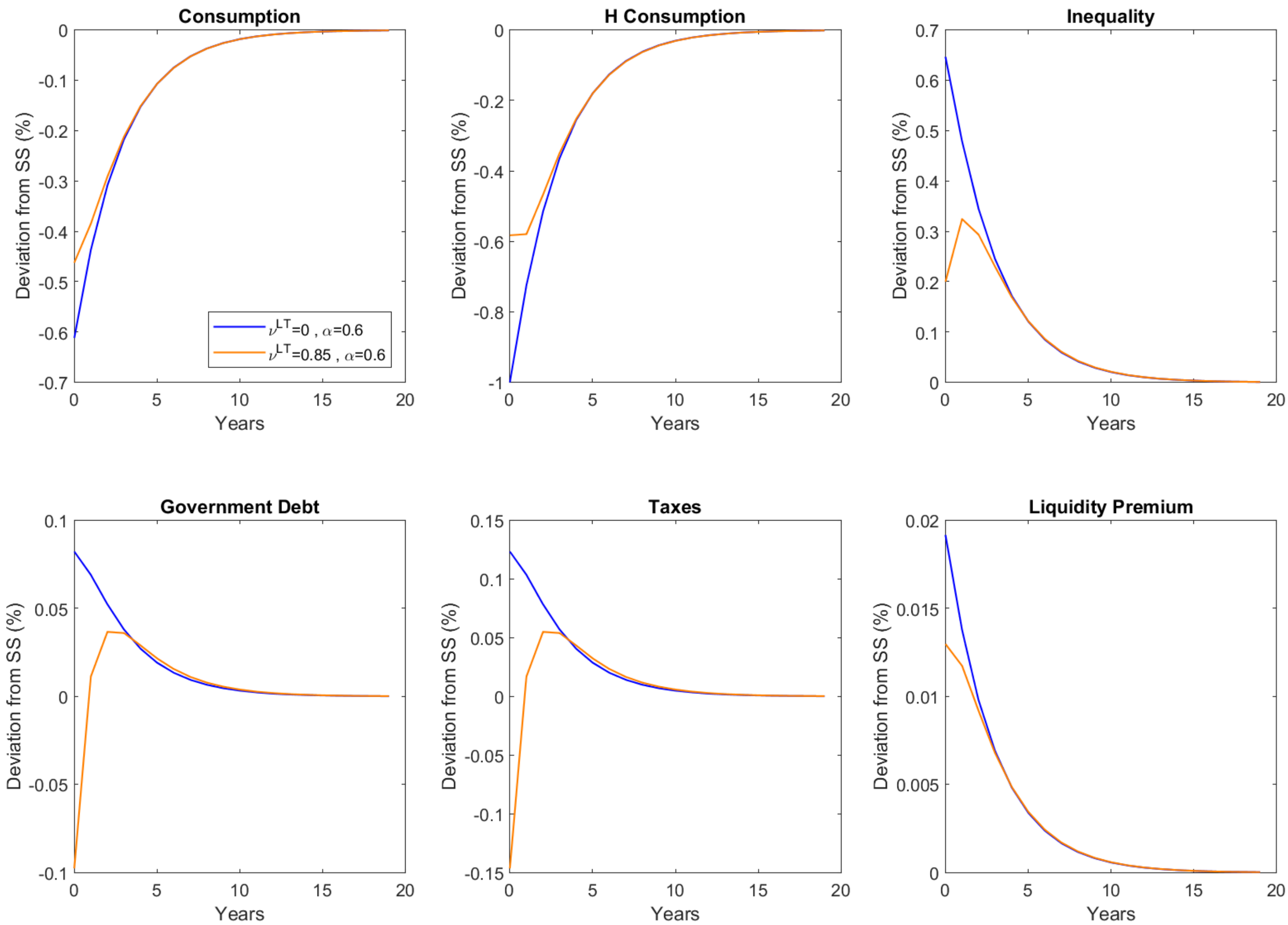

Figure 4: Impulse responses to a 25 bps monetary contraction for the THANK model with short-and long-term debt. $\rho = 0.977$, $\alpha = 0.6$ and $\phi^B = 0.6$.

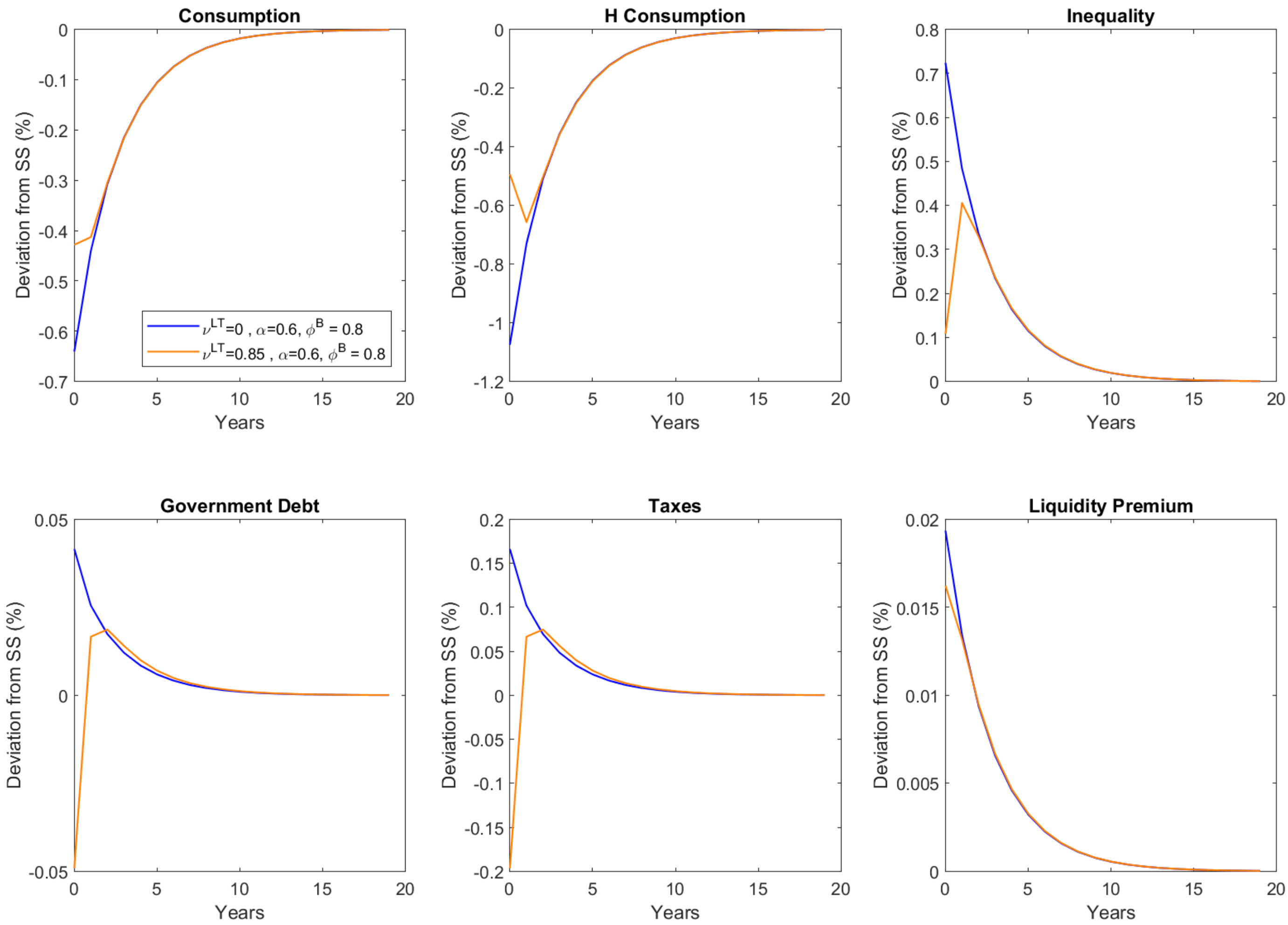

Figure 5: Impulse responses to a 25 bps monetary contraction for the THANK model with short-and long-term debt. $\rho = 0.977$, $\alpha = 0.6$ and $\phi^B = 0.8$.

The fiscal rule also plays an important role in determining the degree of dampening introduced by long-term government debt. Figure 5 shows the IRFs for the case with a more regressive tax system ($\alpha = 0.6$) and a more responsive fiscal rule ($\phi^B = 0.8$). The dampening effect of a longer debt maturity profile is more significant when the fiscal rule is more responsive. When the rise in short-term real interest rates revalues long-term government debt, a government with a more responsive fiscal rule uses more of this fiscal headroom to reduce taxes. As a result, the impact effect of the monetary contraction on aggregate consumption and consumption inequality is dampened further. The more responsive fiscal rule does, however, create a tradeoff. While the revaluation of long-term debt does provide the government with the fiscal space to reduce taxes and mitigate the rise in inequality, a larger impact reduction in taxes does lead to a higher path of future taxes. Therefore, the monetary tightening does have a more persistently contractionary effect on aggregate consumption under the more responsive fiscal rule.

4 A Two-Asset HANK Model with Long-Term Government Debt

In this section, I extend the THANK analysis to a quantitative HANK model. As in the THANK model, the interactions between the maturity composition of government debt, the progressivity of the tax system and the fiscal rule are important in determining the aggregate effects of monetary policy. When the maturity of long-term debt is increased, the consumption effects of monetary policy are dampened. This dampening is more significant when taxes are less progressive, when the fiscal rule is more responsive, and when the share of long-term government is higher.

4.1 Households

The model is based on the exposition of the Kaplan et al. (2018) two-asset HANK by Auclert et al. (2021). Households face idiosyncratic risk in the form of an income shock, denoted by $e_{i,t}$, and can insure against this risk by saving in liquid short-term government debt, $b^{ST}_{i,t+1}$. Households can also save in illiquid long-term government bonds, $b^{LT}_{i,t+1}$. These long-term bonds are illiquid as they are subject to portfolio adjustment costs. The real return on the long-term government bond is given by:

$$1 + r^{LT}_t = \frac{1 + \rho Q_t}{Q_{t-1}}$$

while the short-term government bonds earn the short-term real interest rate, and trade at a liquidity premium of ω.

The Bellman equation for the household problem is given by:

$$\begin{aligned} V_t(e_{i,t}, b^{ST}_{i,t}, b^{LT}_{i,t}) &= \max_{c_{i,t}, b^{ST}_{i,t+1}, b^{LT}_{i,t+1}} \left\{ u(c_{i,t}) + \beta \mathbb{E}_t V_{t+1}(e_{i,t+1}, b^{ST}_{i,t+1}, b^{LT}_{i,t+1}) \right\} \\ &\textit{subject to} \\ c_{i,t} + b^{ST}_{t,t+1} + b^{LT}_{t,t+1} &= y(e_{i,t}) - t(e_{i,t}) + (1 + r_t) b^{ST}_{i,t} + (1 + r^{LT}_t) b^{LT}_{i,t} - \xi(b^{LT}_{i,t}, b^{LT}_{i,t+1}) \end{aligned}$$

where the term $y(e_{i,t}) - t(e_{i,t})$ denotes the household's disposable labour income.[8] The function $\xi(b_{i,t}^{LT}, b_{i,t+1}^{LT})$ gives the adjustment costs incurred when changing long-term government debt holdings. Following Auclert et al. (2021), the cost function takes the form:

$$\xi(b_{i,t}^{LT}, b_{i,t+1}^{LT}) = \left[\frac{b_{i,t+1}^{LT} - (1 + r_t^{LT})b_{i,t}^{LT}}{(1 + r_t^{LT})b_{i,t}^{LT} + \psi_0}\right]^2 \left[(1 + r_t^{LT})b_{i,t}^{LT} + \psi_0\right].$$

The adjustment costs mean that long-term government debt is less liquid than short-term government debt, and that households have a lower marginal propensity to consume out of changes in the value of their long-term debt holdings.

4.2 Government Debt, Fiscal Policy and Monetary Policy

Taxes are set according to the same Woodford (2001) tax-consolidation liability-targeting rule as in the THANK model:

$$T_t = T + \phi^B \left(L_t^G - L^G\right)$$
$$\textit{where } L_t^G = (1 + r_t)\, B_t^{ST} + \left(1 + r_t^{LT}\right) B_t^{LT}.$$

The government issues both short- and long-term government debt, with the steady-state share of long-term government debt again equal to ν^{LT}.

To incorporate tax progressivity, I follow Auclert et al. (2018) in using the Heathcote et al. (2017) tax function. The taxes and disposable income (denoted by $z(e_{i,t})$) of a household with income shock e_{it} are equal to:

$$t(e_{i,t}) = y(e_{i,t}) - \theta\left[y(e_{i,t})\right]^{1-\tau}$$
$$z(e_{i,t}) = \theta\left[y(e_{i,t})\right]^{1-\tau}.$$

Individual income is equal to $e_{i,t}Y_t$, where $Y_t = \int y(e_{i,t})di$ denotes aggregate income. We can therefore integrate to obtain individual disposable income as a function of the idiosyncratic income shock, aggregate output and aggregate taxation:

$$z(e_{i,t}) = \frac{Y_t - T_t}{\int e_{i,t}^{1-\tau}} e_{i,t}^{1-\tau}.$$

The parameter τ determines the degree of tax progressivity. When $\tau > 0$, taxes are

[8]For simplicity, labour supply and production follow Auclert et al. (2018). Households exogenous supply the same quantity of labour, and firms produce using linear technology subject to sticky prices and flexible wages.

progressive as the ratio of marginal taxes to average taxes is greater than one for all incomes. When $\tau < 0$, taxes are regressive.

As in Auclert et al. (2018), the central bank directly sets the short-term real interest rate according to the simple rule:

$$r_t = r + \varepsilon_t^r$$

where ε_t^r follows an AR(1) process in logarithms.

4.3 Market Clearing

Aggregate output (net of adjustment costs) is equal to the sum of aggregate consumption and government spending:[9]

$$Y_t - \int \xi(b_{i,t}^{LT}, b_{i,t+1}^{LT})di = \int c_{i,t}di + G.$$

Asset market clearing requires that total government debt is equal to total household savings:

$$B_{t+1}^{ST} = \int b_{i,t+1}^{ST}di$$
$$B_{t+1}^{LT} = \int b_{i,t+1}^{LT}di.$$

4.4 Parameters and Calibration

4.4.1 Parameterisation

Table 2 gives the baseline parameters used for the HANK model. For the maturity composition of government debt, I consider long-term debt shares of 65% and 85%. A long-term debt share of 65% is consistent with the US and Canada, which exhibit the smallest long-term shares in the G7. A long-term share of 85% better-approximates the maturity structure of the debt stock in the UK, Japan, France, Italy or Germany. The long-term debt duration parameter ρ is set to either 0.925 or 0.975. The former gives a long-term bond duration of 9 years, while the latter gives a long-term duration of 16

[9]Government spending is assumed to be constant, and is set equal to 20% of steady-state output.

years. The average maturity of longer-term government bonds (with maturity longer than one year) is over 16 years in the UK, and between 7.5 and 10 years for the remainder of the G7.

In the baseline impulse responses, I set the tax progressivity parameter τ equal to 0 to achieve uniform taxation. To study the impact of tax progressivity, I then increase the value of τ to 0.084 and 0.081. These values correspond to the optimal and observed degrees of tax progressivity in the US as calculated by Heathcote et al. (2017). As in the case of the THANK model, I also consider the effect of fiscal rule responsiveness by calculating impulse responses with ϕ^B set equal to 0.4, 0.6 and 0.8.

The intertemporal elasticity of substitution, the portfolio cost adjustment parameter and the asset grids follow the two-asset HANK model in Auclert et al. (2021). The persistence and standard deviation of the income process follow Auclert et al. (2018).

	Description	**Value (annual)**
σ	Intertemporal elasticity of substitution	0.5
ψ_0	Portfolio adjustment costs	0.25
ρ_e	Persistence of income	0.91
σ_e	Standard deviation of income	0.92
n_e	Number of income states	3
n_{LT}	Number of long-term debt gridpoints	100
n_{ST}	Number of short-term debt gridpoints	50
ϕ^B	Fiscal rule debt coefficient	0.6
τ	Tax progressivity	0
ν^{LT}	Share of long-term debt	0.65/ 0.85
ρ	Long-term duration parameter	0.925/0.975
ρ^M	Persistence of monetary shock	0.7

Table 2: Baseline parameterisation for the HANK with short-term and long-term government debt.

4.4.2 Calibrated Parameters

The total level of government debt is calibrated to achieve an average annual marginal propensity to consume of 0.41. This is chosen to match the average MPC in the baseline two-asset HANK model developed by Alves et al. (2020). For the US-style parameterisation with $\nu^{LT} = 0.65$, the calibrated ratio of government debt to output is 0.82. The (untargeted) share of 'hand-to-mouth' households with zero liquid asset holdings under this calibration is 40%. The share of 'poor hand-to-mouth' households with zero total assets is 16%, with 24% of households being 'wealthy hand-to-mouth'. These values are consistent with the 2019 Survey of Consumer Finances data targeted by Alves et al.

(2020). The data show that 41% of US households are hand-to-mouth, with the shares of poor and wealthy hand-to-mouth households being 14% and 27% respectively.

The liquidity premium ω was calibrated to match the desired steady-state share of long-term government debt, while the discount factor β was calibrated to achieve asset market clearing. For the US-style parameterisation, the values of ω and β were 3.7 p.p and 0.79 respectively.

Calibrated Parameters ($\nu^{LT} = 0.65$)			
	Description	**Value**	**Target**
β	Household discount factor	0.79	Asset market clearing
ω	Term/liquidity premium	3.69 p.p	Steady-state long-term debt
B_Y	Steady-state debt ratio	0.82	Average MPC=0.41

Hand-to-mouth Shares ($\nu^{LT} = 0.65$)		
	Model	**Data**
Total hand-to-mouth share	0.40	0.41
Poor hand-to-mouth share	0.16	0.14
Wealthy hand-to-mouth share	0.24	0.27

Table 3: Calibrated parameters and untargeted hand-to-mouth shares for the two-asset HANK model with $\nu^{LT} = 0.65$. The 'data' column is sourced from Alves et al. (2020).

4.5 Long-Term Government Debt and Monetary Tightening

The impulse responses to a monetary policy contraction in the HANK model are consistent with those from the THANK model, showing that the introduction of longer-term government debt can dampen the aggregate effects of monetary policy.[10] Figure 6 shows the impulse responses to a 25 basis-point hike when 85% of government debt takes the form of illiquid long-term bonds. The IRFs show that increasing the duration of long-term bonds from around 9 years to 16 years dampens the effect of monetary policy on consumption. This operates through the same mechanism as in the THANK model. When the rise in the short-term real interest rate reduces the value of outstanding long-term government debt, the fiscal authority can respond by reducing taxes. This reduction in taxes dampens the fall in consumption. When the duration of long-term government debt is longer, the rise in the real interest rate causes a larger fall in the value of the

[10]The impulse responses are calculated using the SSJ toolbox developed by Auclert et al. (2021).

government's liabilities, generating more fiscal space for a reduction in taxes. The larger fall in taxes leads to more significant dampening of monetary policy.

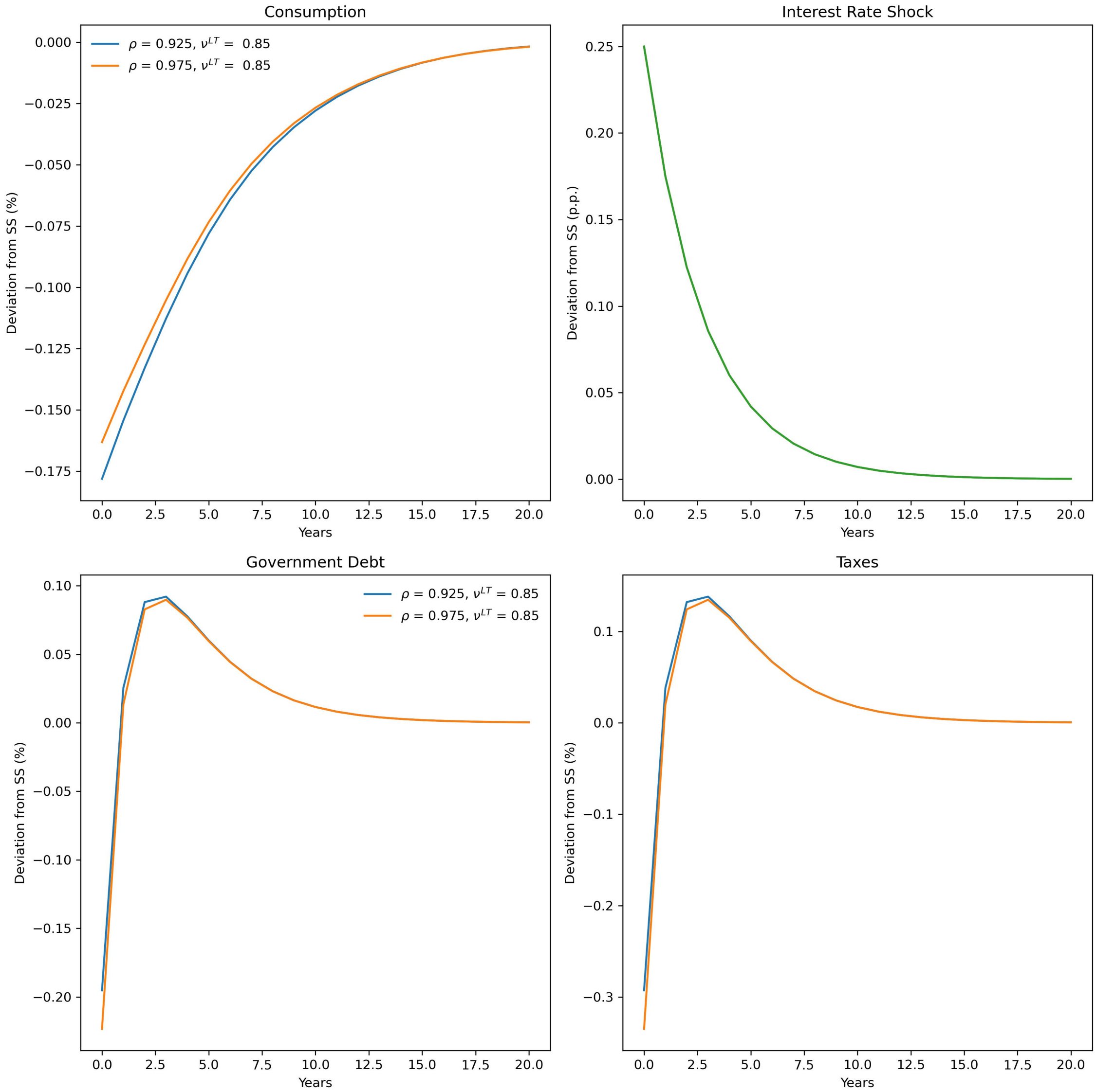

Figure 6: Impulse responses to a 25bps real interest rate increase in the two-asset HANK model with long-term government debt ($\nu^{LT} = 0.85$).

Figure 7 compares the impulse responses to a monetary contraction across different values of the long-term debt share and the long-term debt duration. The graph shows that the impact response of consumption is greatest for the US-style parameterisation in which only 65% of government debt is long term and the maturity of long-term debt is around 9 years. The impact response of consumption is the smallest for the UK-style parameterisation with a a larger share of long-term debt and a longer debt duration. The IRFs also show that increasing the duration of longer-term debt has a greater dampening effect when the share of long-term debt is higher. This is because the impact of long-term bond revaluation on the government budget constraint and taxation is heightened when a larger share of government borrowing takes the form of liquid long-term bonds. Hence, the fiscal effects of monetary policy generate greater dampening on impact when ν^{LT} is larger.

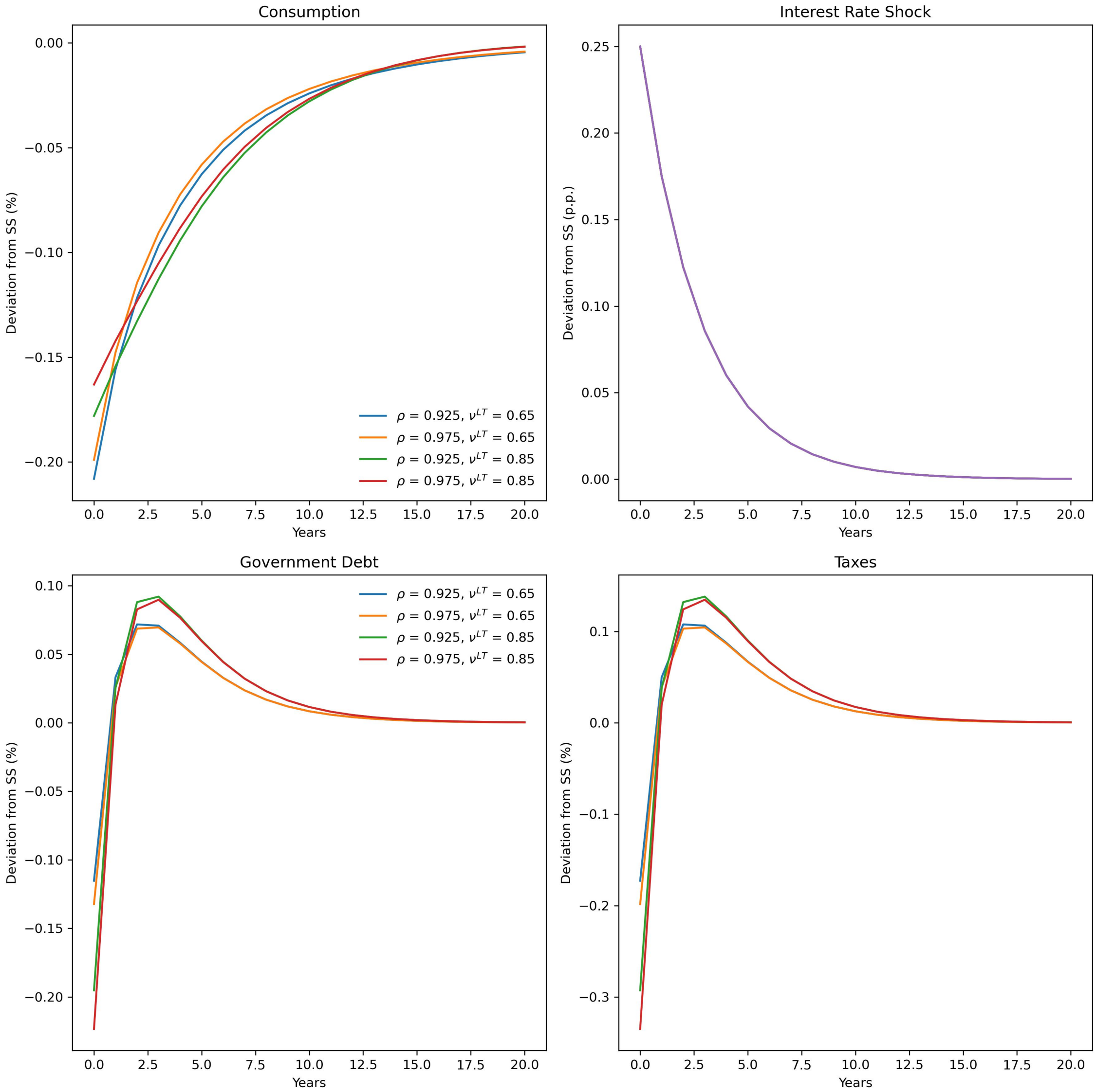

Figure 7: Impulse responses to a 25bps real interest rate increase in the two-asset HANK model with long-term government debt.

While the impact effect of monetary policy on consumption is much smaller when the share of long-term government debt is higher, figure 7 also shows that the fall in consumption is more persistent. The peak level of taxation is higher under the parameterisation with a larger long-term debt share, meaning that consumption remains below its steady-state level for a longer period.

4.6 Interactions Between Debt Maturity and Fiscal Policy

As in the THANK model, it is the design of the tax system which determines the degree of dampening introduced by the fiscal effects of monetary policy. Figure 8 shows the effect of tax progressivity on the dampening introduced by a longer government debt duration. The dampening is greatest when the duration of government debt is longer and taxes are uniform ($\rho = 0.975, \tau = 0$). The effect of monetary policy on consumption is largest when the duration of government debt is shorter and the tax system is more progressive ($\rho = 0.925, \tau = 0.181$). This is because the share of taxation paid by low-income households is lower when the tax system is more progressive. As a result, the fiscal effects of monetary policy generated by long-term government debt have a smaller dampening effect on aggregate consumption under a more progressive tax system.

The fiscal rule also plays an important role in the fiscal effects of monetary policy with long-term government debt. Figure 9 shows the effect of changing the fiscal rule on the dampening introduced by a longer government debt duration. Increasing the duration of government debt generates greater dampening when the fiscal rule is more responsive ($\phi^B = 0.8$), and less dampening when the fiscal rule is less responsive ($\phi^B = 0.4$). When a monetary contraction revalues the government's outstanding liabilities, it is the fiscal rule which determines the extent to which the government responds by reducing taxes. When the fiscal rule is more responsive, the government uses more of its fiscal space to cut taxes. This dampens the effect of the monetary policy on aggregate consumption. The impulse responses in figure 9 also show that the fall in aggregate consumption is more persistent when the fiscal rule is more responsive. When ϕ^B is higher, the government responds to changes in the value of government debt with larger changes in taxation. Therefore, when long-term term bond revaluation reduces the value of government debt, the fiscal authority cuts taxes further and the impact effect of monetary policy is dampened. However, when the rise in debt servicing costs causes the value of government debt to rise after the first period, the peak level of taxation is higher. This means that consumption remains further below its steady state value under the more responsive fiscal rule.

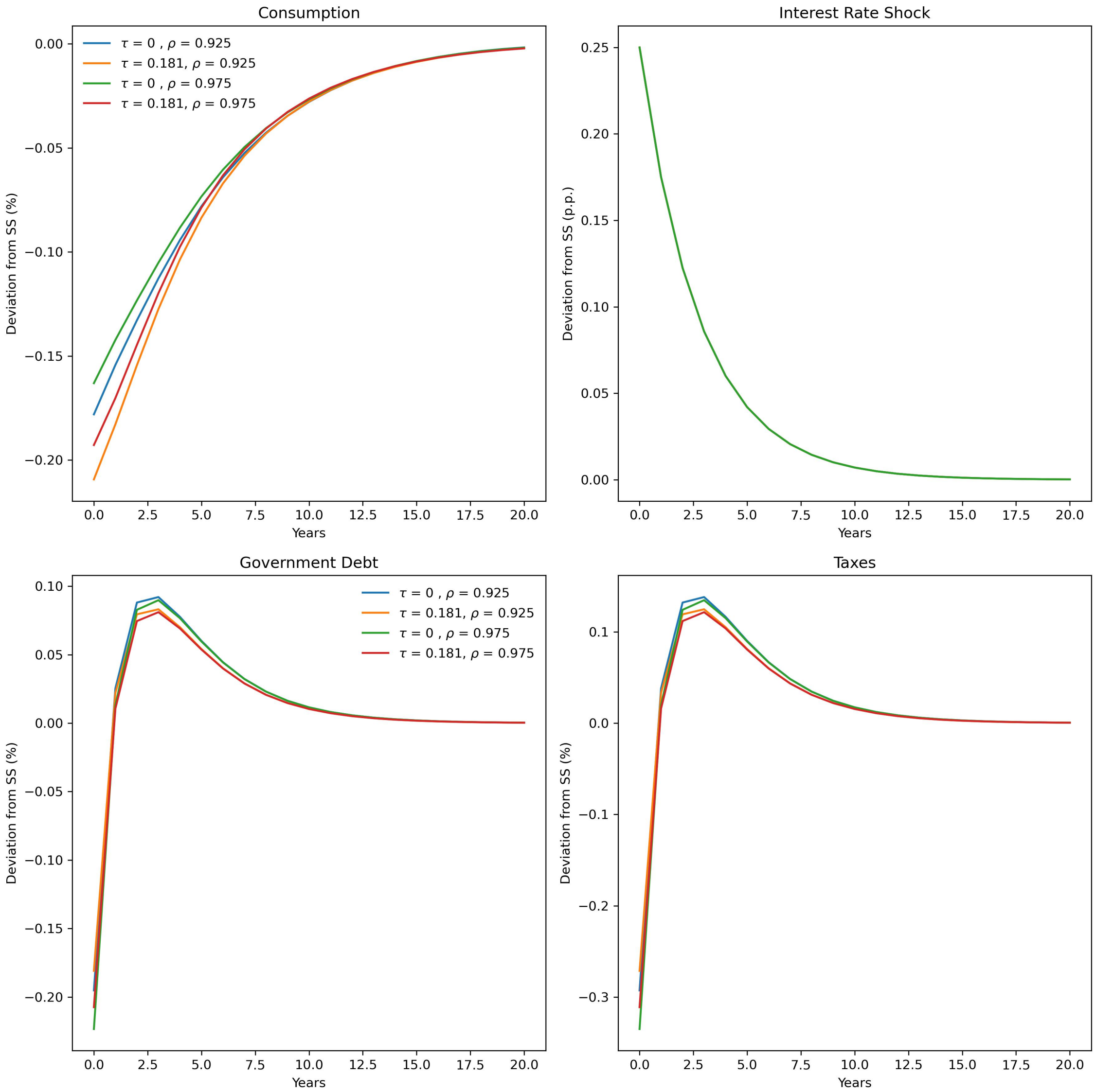

Figure 8: Impulse responses to a 25bps real interest rate increase in the two-asset HANK model with long-term government debt ($\nu^{LT} = 0.85$) for different tax progressivities and long-term debt durations.

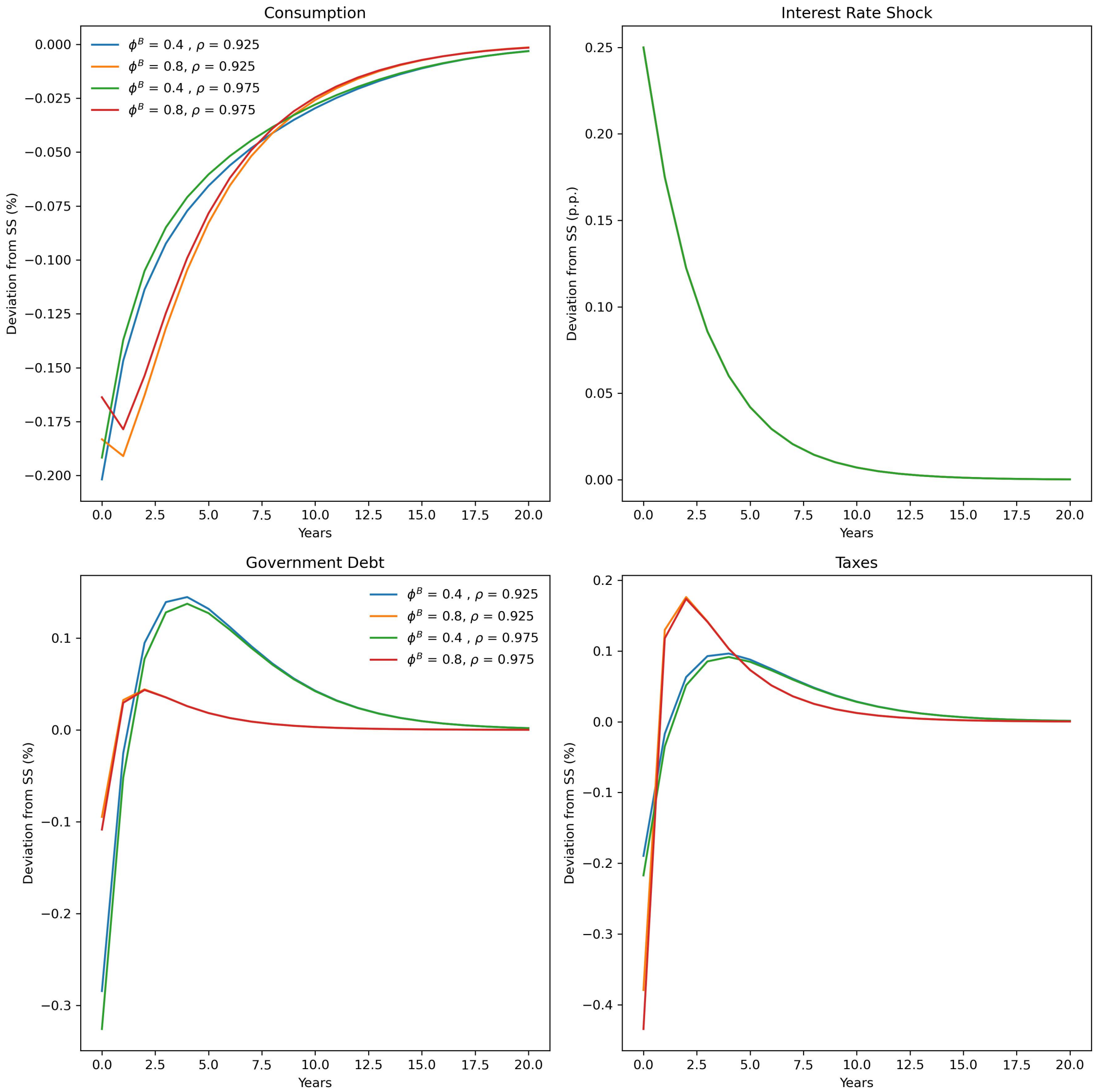

Figure 9: Impulse responses to a 25bps real interest rate increase in the two-asset HANK model with long-term government debt ($\nu^{LT} = 0.85$) for different tax progressivities and fiscal rules.

5 Conclusion

This paper shows that, in models with heterogeneous households, the introduction of long-term government debt gives rise to fiscal-monetary interactions which can dampen the aggregate and distributional effects of monetary policy. In both a THANK and a HANK model in which the government issues liquid short-term and illiquid long-term debt, the impulse responses show that a longer debt maturity profile generates greater fiscal space following a rise in short-term real interest rates. It is therefore the interactions between the maturity of government debt and the design of fiscal policy which determines the effect of monetary policy on aggregate consumption and consumption inequality. A longer government debt maturity leads to the most significant dampening of monetary policy when the share of long-term government debt is higher, when the tax system is less progressive, and when the fiscal rule is more responsive to the level of government debt.

While this paper highlights the role of the maturity structure of government debt for monetary transmission, the main results are applicable to the interactions between monetary policy and alternative features of the government debt stock. These could include the government's choice to issue index-linked or purely nominal government bonds, or to borrow in domestic or foreign currency. As with debt maturity, these debt management choices will impact the effect of monetary policy on the government's fiscal space and the level of taxation. As a result, the structure of government debt and the stance of the fiscal authority must be a key consideration for the central bank in understanding the monetary transmission mechanism.

References

Felipe Alves, Greg Kaplan, Benjamin Moll, and Giovanni L Violante. A further look at the propagation of monetary policy shocks in hank. *Journal of Money, Credit and Banking*, 52(S2):521–559, 2020.

Adrien Auclert. Monetary policy and the redistribution channel. *American Economic Review*, 109(6):2333–67, 2019.

Adrien Auclert, Matthew Rognlie, and Ludwig Straub. The intertemporal Keynesian cross. Technical report, National Bureau of Economic Research, 2018.

Adrien Auclert, Bence Bardóczy, Matthew Rognlie, and Ludwig Straub. Using the sequence-space jacobian to solve and estimate heterogeneous-agent models. *Econometrica*, 89(5):2375–2408, 2021.

Michael Batty, Jesse Bricker, Joseph Briggs, Sarah Friedman, Danielle Nemschoff, Eric Nielsen, Kamila Sommer, and Alice Henriques Volz. The distributional financial accounts of the united states. *Measuring Distribution and Mobility of Income and Wealth*, page 641, 2020.

Florin O Bilbiie. Monetary policy and heterogeneity: An analytical framework. Technical report, CEPR Working Paper, 2018.

Florin O Bilbiie. The New Keynesian cross. *Journal of Monetary Economics*, 114:90–108, 2020.

Florin O Bilbiie, Tommaso Monacelli, and Roberto Perotti. Stabilization vs. redistribution: the optimal monetary-fiscal mix. 2020.

Florin O Bilbiie, Diego R Känzig, and Paolo Surico. Capital and income inequality: An aggregate-demand complementarity. *Journal of Monetary Economics*, 126:154–169, 2022.

Cristiano Cantore and Edoardo Leonardi. Monetary-fiscal interaction and the liquidity of government debt. Technical report, 2024.

Cristiano Cantore and Pascal Meichtry. Unwinding quantitative easing: state dependency and household heterogeneity. 2023.

Nicolas Caramp and Ethan Feilich. Monetary policy and government debt. 2022.

Nicolas Caramp and Dejanir H Silva. Fiscal policy and the monetary transmission mechanism. *Review of Economic Dynamics*, 51:716–746, 2023.

Ferre De Graeve and Giulio Mazzolini. The maturity composition of government debt: A comprehensive database. *European Economic Review*, 154:104438, 2023.

Elisa Faraglia, Albert Marcet, Rigas Oikonomou, and Andrew Scott. Government debt management: The long and the short of it. *The Review of Economic Studies*, 86(6): 2554–2604, 2019.

Robin Greenwood, Samuel G Hanson, and Jeremy C Stein. A comparative-advantage approach to government debt maturity. *The Journal of Finance*, 70(4):1683–1722, 2015.

Richard Harrison. Asset purchase policy at the effective lower bound for interest rates. 2012.

Jonathan Heathcote, Kjetil Storesletten, and Giovanni L Violante. Optimal tax progressivity: An analytical framework. *The Quarterly Journal of Economics*, 132(4): 1693–1754, 2017.

Greg Kaplan, Benjamin Moll, and Giovanni L Violante. Monetary policy according to HANK. *American Economic Review*, 108(3):697–743, 2018.

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

Alessandro Missale and Olivier Blanchard. The debt burden and debt structure. *American Economic Review*, 84:309–319, 1994.

Julio J Rotemberg. Sticky prices in the united states. *Journal of political economy*, 90 (6):1187–1211, 1982.

US Treasury. Fiscal service, federal debt held by private investors [fdhbpin]. Retrieved from FRED, Federal Reserve Bank of St. Louis, September 2023.

Michael Woodford. Fiscal requirements for price stability, 2001.

A Appendices: Illiquid Long-Term Debt

A.1 THANK Steady State

The model is loglinearised around a steady state with zero inflation and profit, with steady-state output normalised to one ($Y = 1, \Pi = 1, D = 0$). The derivation of the steady state closely follows the short-term debt case derived in Appendix D of Bilbiie (2018).

The steady-state levels of short- and long-term government debt can be expressed as:

$$B^{LT} = \nu^{LT} B$$
$$B^{ST} = (1 - \nu^{LT}) B.$$

The government budget constraint gives taxes as:

$$T = \left[(R^{LT} - 1)\nu^{LT} + (R - 1)(1 - \nu^{LT})\right] B.$$

With uniform taxation, household budget constraints are:

$$C^S + \frac{B}{1-\lambda} = Y^S - T + \frac{1}{1-\lambda}\left[Rs(1 - \nu^{LT}) + R^{LT}\nu^{LT}\right] B$$
$$C^H = Y^H - T + R\frac{1-s}{\lambda}(1 - \nu^{LT})B.$$

Using the equation for aggregate income, $Y = \lambda Y^H + (1-\lambda)Y^S$, and defining steady-state income inequality as $\Gamma \equiv \frac{Y^S}{Y^H}$, we can express steady-state incomes as:

$$Y^H = \frac{1}{1 + (1-\lambda)(\Gamma - 1)}$$
$$Y^S = \frac{\Gamma}{1 + (1-\lambda)(\Gamma - 1)}.$$

Following Bilbiie (2018), we can substitute these equations into the steady-state self-insurance Euler equation. This yields an expression for steady-state bond demand:

$$B = \frac{\frac{1}{1+\frac{1-\lambda}{1-s}\left(\frac{1}{\beta R}-1\right)} - \frac{1}{1+(1-\lambda)(\Gamma-1)}}{(1-\nu^{LT})\left(\frac{1-s}{\lambda}-1\right)R + 1 - \nu^{LT}R^{LT}}.$$

When the government only issues short-term debt ($\nu^{LT} = 0$), this is the same as the expression for steady-state bond demand in Bilbiie (2018).

The Euler equation for long-term debt gives $R^{LT} = \frac{1}{\beta}$. The short-term real interest rate is obtained using the self-insurance Euler equation:

$$R = \frac{\frac{1}{\beta}}{s + (1-s)\frac{C^S}{C^H}}.$$

This shows that there is a steady-state liquidity premium ($R < R^{LT}$) when there is steady-state consumption inequality ($C^S > C^H$).

Substituting the steady-state bond demand into the household budget constraints gives steady-state consumption:

$$C^S = \frac{1}{1-\lambda} - \frac{\lambda}{1-\lambda}\frac{1}{1+\frac{1-\lambda}{1-s}\left(\frac{1}{\beta R}-1\right)}$$
$$C^H = \frac{1}{1+\frac{1-\lambda}{1-s}\left(\frac{1}{\beta R}-1\right)}.$$

The steady state with no consumption inequality can be obtained through the same revenue-neutral steady-state transfers as in Bilbiie (2018). A transfer of $1 - \frac{1}{1+\frac{1-\lambda}{1-s}\left(\frac{1}{\beta R}-1\right)}$ to the hand-to-mouth delivers $C^H = 1$. The corresponding tax $\frac{\lambda}{1-\lambda}\left[1 - \frac{1}{1+\frac{1-\lambda}{1-s}\left(\frac{1}{\beta R}-1\right)}\right]$ collected from savers ensures that $C^S = 1$.

A.2 THANK Loglinearised Equilibrium Conditions

The THANK model with short-term and long-term government debt is loglinearised around a steady state with zero inflation and equal consumption across income states ($C^S = C^H$). The loglinearised equilibrium conditions are as follows:

1. H budget constraint

$$c_t^H = w_t + n_t^H + \frac{\tau^D}{\lambda}d_t - \frac{\alpha}{\lambda}t_t + \frac{1-s}{\lambda}RB_Y^{ST}r_t + \frac{1-s}{\lambda}Rb_t^{ST}$$

2. H labour supply

$$\varphi n_t^H = w_t - \frac{1}{\sigma} c_t^H$$

3. Aggregate labour supply

$$\varphi n_t = w_t - \frac{1}{\sigma} c_t$$

4. Consumption inequality

$$\gamma_t = c_t^S - c_t^H$$

5. Long-term debt Euler equation

$$c_t^S = \mathbb{E}_t c_{t+1}^S - \sigma r_{t+1}^{LT}$$

6. Short-term debt (self-insurance) Euler equation

$$c_t^S = s\mathbb{E}_t c_{t+1}^S + (1-s)\mathbb{E}_t c_{t+1}^H - \sigma r_{t+1}$$

7. Fisher parity

$$i_t = r_t + E_t \pi_{t+1}$$

8. Long-term real rate

$$r_t^{LT} = \beta\rho q_t - q_{t-1}$$

9. Profit

$$d_t = -w_t$$

10. Production and goods market clearing

$$n_t = c_t$$

11. Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + \kappa w_t$$

12. Taylor rule

$$i_t = \phi^{\pi}\pi_t + \varepsilon_t^i$$

13. Monetary policy shock process

$$\varepsilon_t = \rho^M \varepsilon_{t-1} + \nu_t^M$$

14. Government budget constraint

$$b_{t+1} = Rb_t^{ST} + R^{LT}b_t^{LT} + RB_Y^{ST}r_t + R^{LT}B_Y^{LT}r_t^{LT} - t_t$$

15. Fiscal rule

$$t_t = \phi^B \left(Rb_t^{ST} + RB_Y^{ST}r_t + R^{LT}b_t^{LT} + R^{LT}B_Y^{LT}r_t^{LT}\right)$$

16. Total government debt

$$b_{t+1} = b_{t+1}^{ST} + b_{t+1}^{LT}$$

17. Debt management rule

$$b_{t+1}^{LT} = B_Y^{LT}q_t.$$

A.3 Calibration of THANK and HANK

A.3.1 Aggregate MPC and Hand-to-Mouth Share

The HANK model is calibrated to achieve a 41% average annual MPC, as obtained in the baseline two-asset HANK model developed by Alves et al. (2020). For the US-style calibration with $\nu^{LT} = 0.65$, this ensures that the share of hand-to-mouth households in the model (40%) is close to the value in the data (41%). To ensure consistency across the THANK and HANK models, I therefore set λ, the hand-to-mouth share in the THANK model, equal to 40%. As the λ hand-to-mouth households have a MPC of 1 and the $1-\lambda$ savers have a MPC of $1-\beta$, setting $\lambda = 0.4$ also ensures that the aggregate MPCs are very similar across models (0.406 in the THANK model compared to 0.41 in the HANK).

A.3.2 Income Process

The HANK model takes the persistence and standard deviation of the income process from Auclert et al. (2018). The values chosen ($\rho_e = 0.91, \sigma_e = 0.92$) give the following Markov transition matrix for the three-state income process:

$$\Pi = \begin{pmatrix} 0.912 & 0.0860 & 0.00203 \\ 0.0430 & 0.914 & 0.0430 \\ 0.00203 & 0.0860 & 0.912 \end{pmatrix}.$$

The transition matrix for the income states in the THANK model is given by:

$$\begin{pmatrix} h & 1-h \\ 1-s & s \end{pmatrix}.$$

Bilbiie (2018) shows that the first-order correlation of the income process in the THANK model is given by:

$$Corr(\log(Y_{t+1}^j), \log Y_t^j) = s + h - 1 = 1 - \frac{1-s}{\lambda}.$$

I therefore choose the value of s to match the autocorrelation of income across the THANK and HANK models.

A.4 HANK Steady-State Objects

A.4.1 Asset Distribution

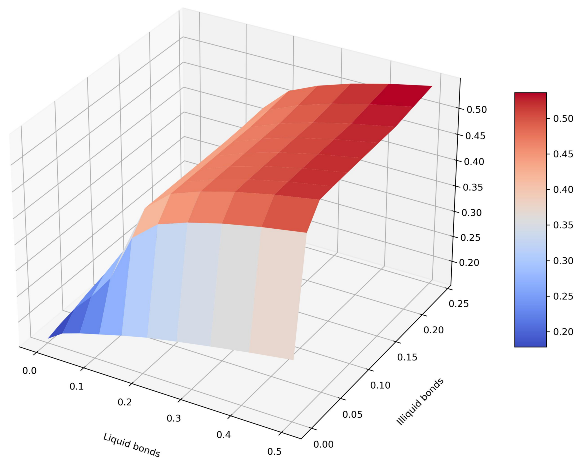

Figure 10: The cumulative distribution of government debt holdings for the two-asset HANK model in which 65% of government debt is short term.

A.4.2 Consumption and Saving Policy Functions

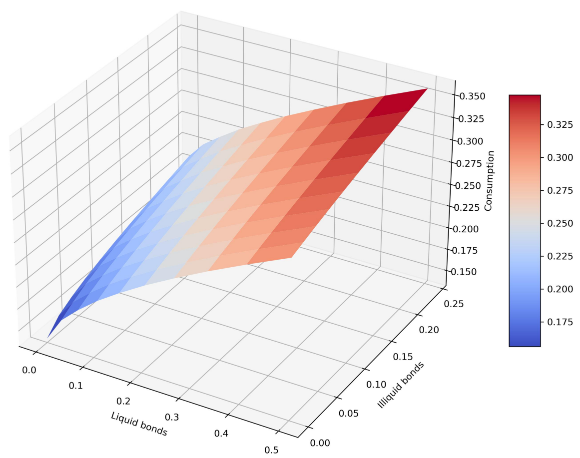

Figure 11: The consumption policy function for a household in the lowest income state in the HANK model in which 65% of government debt is short term.

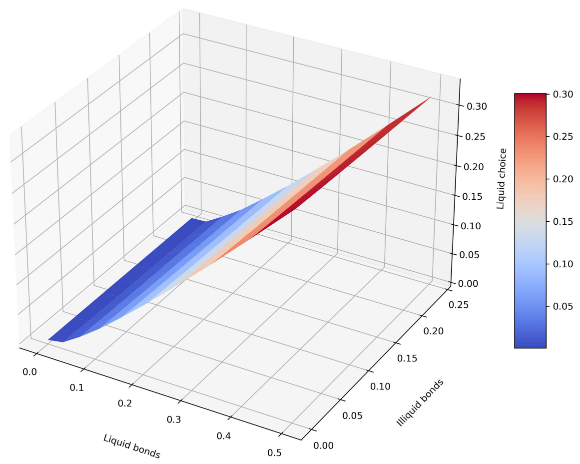

Figure 12: The liquid savings policy function for a household in the lowest income state in the HANK model in which 65% of government debt is short term.

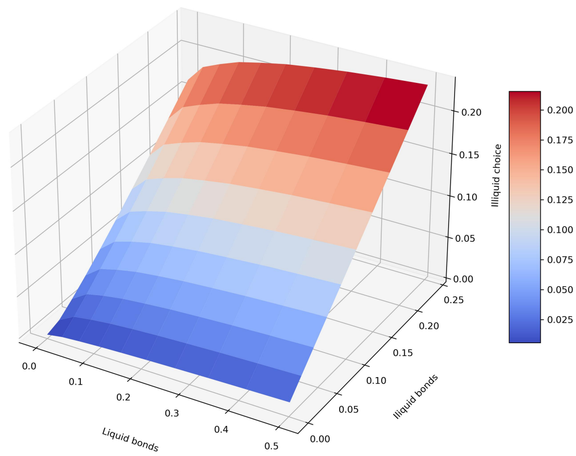

Figure 13: The illiquid savings policy function for a household in the lowest income state in the HANK model in which 65% of government debt is short term.

B Liquid Long-Term Government Debt and Monetary Policy Transmission

In the main body of this paper, long-term government debt is illiquid. As a result, long-term government bonds are not used for self-insurance, and households have a lower marginal propensity to consume out of changes in the value of long-term bonds. The fiscal effects of monetary policy therefore determine the degree to which monetary policy is dampened by a longer maturity profile.

However, if long-term government bonds are liquid, some households do respond to the downward revaluation of their bond holdings by reducing their consumption.[11] The magnitude of this household wealth effect and its implications for consumption are driven by the interactions between government debt maturity, the distribution of debt ownership, and fiscal policy. When the duration of government debt is longer, a rise in interest rates leads to a larger fall in government bond prices, and households are exposed to a greater downward revaluation of their assets. The aggregate consumption effects of this revaluation are greatest when a larger share of government debt is held by households with a high marginal propensity to consume. The design of the tax system determines the degree to which the fiscal effects of monetary policy offset the household balance sheet effects, and therefore whether monetary policy is amplified or dampened by the introduction of long-term debt.

A THANK Model with Liquid Long-Term Debt

In the THANK model with liquid long-term government debt, both short- and long-term government bonds can be used for self-insurance. The loglinearised household budget constraints are therefore given by:

$$c_t^H = w_t + n_t^H + \frac{\tau^D}{\lambda} d_t - \frac{\alpha}{\lambda} t_t + \frac{1-s}{\lambda} R \left[B_Y^{ST} r_t + b_t^{ST} + B_Y^{LT} r_t^{LT} + b_t^{LT} \right]$$

$$c_t^S + \frac{1}{1-\lambda}(b_{t+1}^{ST} + b_{t+1}^{LT}) = w_t + n_t^S + \frac{1-\tau^D}{1-\lambda} d_t - \frac{1-\alpha}{1-\lambda} t_t + \frac{s}{1-\lambda} R \left[B_Y^{ST} r_t + b_t^{ST} + B_Y^{LT} r_t^{LT} + b_t^{LT} \right].$$

Long-term government debt holdings now appear in the budget constraint of hand-to-mouth households. This reflects the fact that a share $1-s$ of saver households become

[11] It is this revaluation of households' assets which amplifies monetary policy in the model developed Caramp and Feilich (2022).

hand-to-mouth in each period, and take their long-term government debt savings with them to the hand-to-mouth income state.

The Euler equations for short-term and long-term government bonds are now identical:

$$c_t^S = s\mathbb{E}_t c_{t+1}^S + (1-s)\mathbb{E}_t c_{t+1}^H - \sigma r_{t+1}$$
$$c_t^S = s\mathbb{E}_t c_{t+1}^S + (1-s)\mathbb{E}_t c_{t+1}^H - \sigma r_{t+1}^{LT}$$

which means that the ex-ante returns on the bonds are equal.

We can follow Bilbiie (2018) to obtain the aggregate Euler equation, the key aggregate demand equation for the THANK model. Substituting the equations for intratemporal optimality and profits into the hand-to-mouth budget gives:

$$c_t^H = \chi c_t + z\left[\frac{1-s}{\lambda}R\left(B_Y^{ST} + B_Y^{LT} + b_t^{ST} + b_t^{LT}\right) - \frac{\alpha}{\lambda}t_t\right]$$

where $\chi \equiv 1 + \varphi\left(1 - \frac{\tau^D}{\lambda}\right)$ is the cyclicality of income inequality, and $z \equiv \frac{1}{1+\frac{1}{\varphi\sigma}}$. Substituting this expression into the aggregate demand equation allows to to write the saver's consumption as:

$$c_t^S = \frac{1-\lambda\chi}{1-\lambda}c_t - \frac{z}{1-\lambda}\left[(1-s)R\left(B_Y^{ST} + B_Y^{LT} + b_t^{ST} + b_t^{LT}\right) - \alpha t_t\right].$$

Substitute c_t^H and c_t^S into the self-insurance Euler equation to obtain the aggregate Euler equation:

$$\begin{aligned} c_t = {} & \delta\mathbb{E}_t c_{t+1} - \sigma\frac{1-\lambda}{1-\lambda\chi}r_{t+1} - \frac{\alpha z}{1-\lambda\chi}\left(t_t + \frac{1-s-\lambda}{\lambda}t_{t+1}\right) \\ & + z\frac{1-s}{1-\lambda\chi}R\left(b_t + B_Y^{ST}r_t + B_Y^{LT}r_t^{LT}\right) + z\frac{1-s}{\lambda}\frac{1-s-\lambda}{1-\lambda\chi}R\left(b_{t+1} + B_Y r_{t+1}\right). \end{aligned}$$

Importantly, long-term government bonds are subject to duration risk. Recall that the loglinearised definition of the ex-post real return on long-term debt is given by:

$$r_t^{LT} = \beta\rho q_t - q_{t-1}.$$

Arbitrage between short- and long-term government bonds equalises the ex-ante returns. That is:

$$r_{t+1} = \rho q_{t+1} - q_t.$$

Forward iteration allows us to express the long-term government bond price in terms of the short-term real interest rate:

$$q_t = -\sum_{j=0}^{\infty} \rho^j \mathbb{E}_t r_{t+1+j}.$$

When the short-term real interest rate rises, the price of the long-term government bond falls. Unanticipated monetary contractions therefore reduce the ex-post return on the long-term government bonds held by households:

$$r_t^{LT} = -\beta\rho \sum_{j=0}^{\infty} \rho^j \mathbb{E}_t r_{t+1+j} - q_{t-1}.$$

Substituting this expression for r_t^{LT} into the aggregate Euler equation yields:

$$c_t = \delta \mathbb{E}_t c_{t+1} - \left(\sigma \frac{1-\lambda}{1-\lambda\chi} + z \frac{1-s}{1-\lambda\chi} \rho B_Y^{LT} \right) r_{t+1} - \frac{\alpha z}{1-\lambda\chi} \left(t_t + \frac{1-s-\lambda}{\lambda} t_{t+1} \right)$$
$$+ z \frac{1-s}{1-\lambda\chi} R \left(b_t + B_Y^{ST} r_t - \beta \sum_{j=1}^{\infty} \rho^j \mathbb{E}_t r_{t+1+j} - q_{t-1} \right) + z \frac{1-s}{\lambda} \frac{1-s-\lambda}{1-\lambda\chi} R \left(b_{t+1} + B_Y r_{t+1} \right).$$

This shows that the introduction of *liquid* long-term debt leads to a larger coefficient on the real interest rate r_{t+1}, and can therefore *amplify* monetary contractions. This amplification operates through the balance sheets of hand-to-mouth households. When monetary tightening causes a rise in the short-term real-interest rate, the price of long-term bonds falls. his fall in the government bond price reduces the value of the long-term government debt outstanding on household balance sheets. Due to this downward revaluation of their assets, hand-to-mouth households respond by reducing their consumption further, deepening the effects of the monetary contraction.

The additional coefficient on the bond price is increasing in ρ, B_Y and $1-s$. This shows that it is households' exposure to changes in the value of government debt which determines the degree of amplification. A larger value of ρ indicates that government bonds have a longer duration. The longer is the duration of government bonds, the more responsive is the bond price to changes in the interest rate. Hence, when the duration of bonds is longer, a rise in real interest rates leads to a stronger downward revaluation of households' government debt holdings. This generates a larger negative wealth effect, and a deeper fall in consumption. Similarly, a larger value of B_Y^{LT}, the steady-state long-term government debt ratio, means that households hold a larger quantity of long-term government debt. When government bond prices fall due to a monetary contraction, increased household exposure to government debt leads to stronger household wealth effects. This means that the fall in aggregate consumption when government bonds are revalued will be greater.

Lastly, the term $1 - s$ represents the degree of idiosyncratic risk in the THANK model, the probability of becoming hand-to-mouth conditional upon being a saver. As only savers choose to purchase government bonds, the share of government debt owned by the hand-to-mouth household is given by $1 - s$, the share of savers who suffer an adverse shock. A higher degree of idiosyncratic risk therefore means that a larger share of government debt will be owned by hand-to-mouth households. As these households have a unit marginal propensity to consume, the revaluation of government debt generates a larger fall in aggregate consumption when the share of government debt owned by hand-to-mouth households is larger. Consequently, the interactions between government debt maturity and the distribution of government debt ownership play an important role in monetary transmission in the THANK model with long-term government debt. When high-MPC households have greater exposure to changes in the value of government debt, monetary policy can be amplified through household balance sheet effects. These hand-to mouth balance sheet effects would not be present in models without liquid long-term government debt.

As was the case in the THANK model with illiquid long-term government debt, fiscal policy remains a key determinant of the degree of amplification or dampening of monetary policy. When the revaluation of long-term government debt loosens the government budget constraint, this provides the fiscal authority with the headroom to reduce taxes. The design of fiscal policy therefore determines the extent to which this reduction in taxes offsets the amplification generated by the household wealth effect. When the fiscal rule is more responsive to the value of government debt, and when the tax system is less progressive, the government responds with a larger reduction in taxes for high-MPC households. This dampens the effect of monetary policy. Conversely, if the fiscal rule is less-responsive to government debt, and if the tax system is more progressive, the fiscal effects of monetary policy are less effective in offsetting the household wealth effects from bond revaluation. In this case, the addition of liquid long-term government debt amplifies the contractionary effects of monetary tightening.

Figures 14 and 15 show the impulse responses to a 25 basis-point monetary contraction for the THANK model in which long-term government debt is liquid and the share of hand-to-mouth households is 20%.[12] In figure 14, the probability of remaining a saver is $s = 0.95$ and the responsiveness of the fiscal rule is $\phi^B = 0.6$. The impulse responses show that, due to the fiscal effects of monetary policy, the aggregate consumption effect

[12]The wealth effects from long-term bond revaluation have a larger impact on aggregate consumption when λ is smaller such that each hand-to-mouth household holds a larger quantity of government debt.

of monetary policy on consumption is dampened. However, due to the liquidity of government debt, this dampening is less significant than in the case with illiquid long-term debt discussed in the main body of the paper. In figure 15, I increase the level of idiosyncratic risk by setting $s = 0.8$ and halve the responsiveness of the fiscal rule to $\phi^B = 0.3$. The introduction of a longer government debt maturity profile now leads to amplification of monetary policy. This amplification is driven by the downward revaluation of government debt, 20% of which is held by hand-to-mouth households with unit MPC. Due to the reduced responsiveness of the fiscal rule under this parameterisation, the fiscal effects of monetary policy do not fully offset these wealth effects, meaning that the effect of the monetary contraction on aggregate consumption and consumption inequality are amplified. This illustrates that the interactions between debt maturity, household exposure to government debt, and the design of fiscal policy can play an important role in monetary transmission in models with liquid government debt and heterogeneous households.

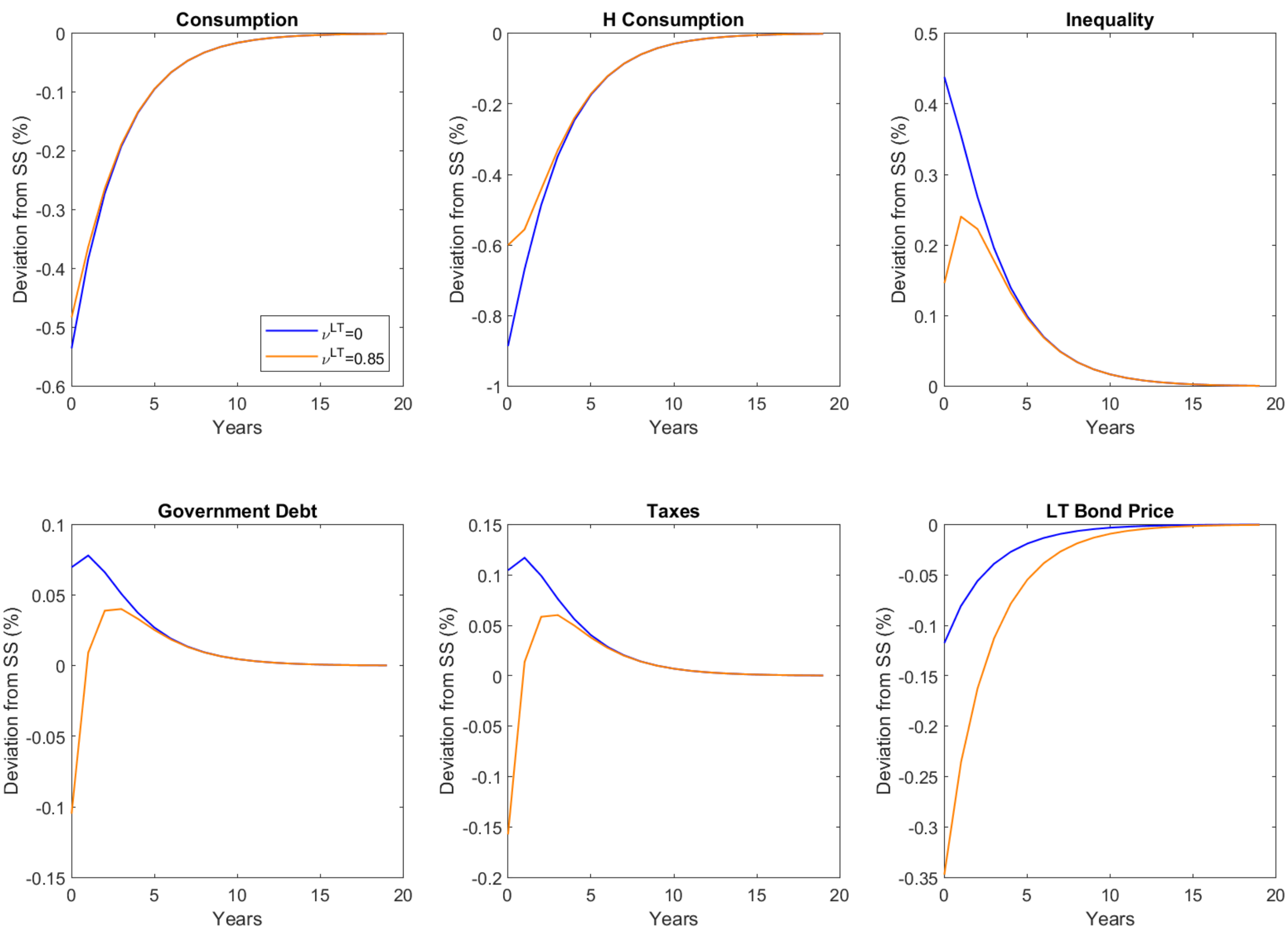

Figure 14: Impulse responses to a 25 bps monetary contraction for the THANK model with liquid short-and long-term debt. $s = 0.95$, $\phi^B = 0.6$, $\alpha = 0.4$, $\lambda = 0.2$.

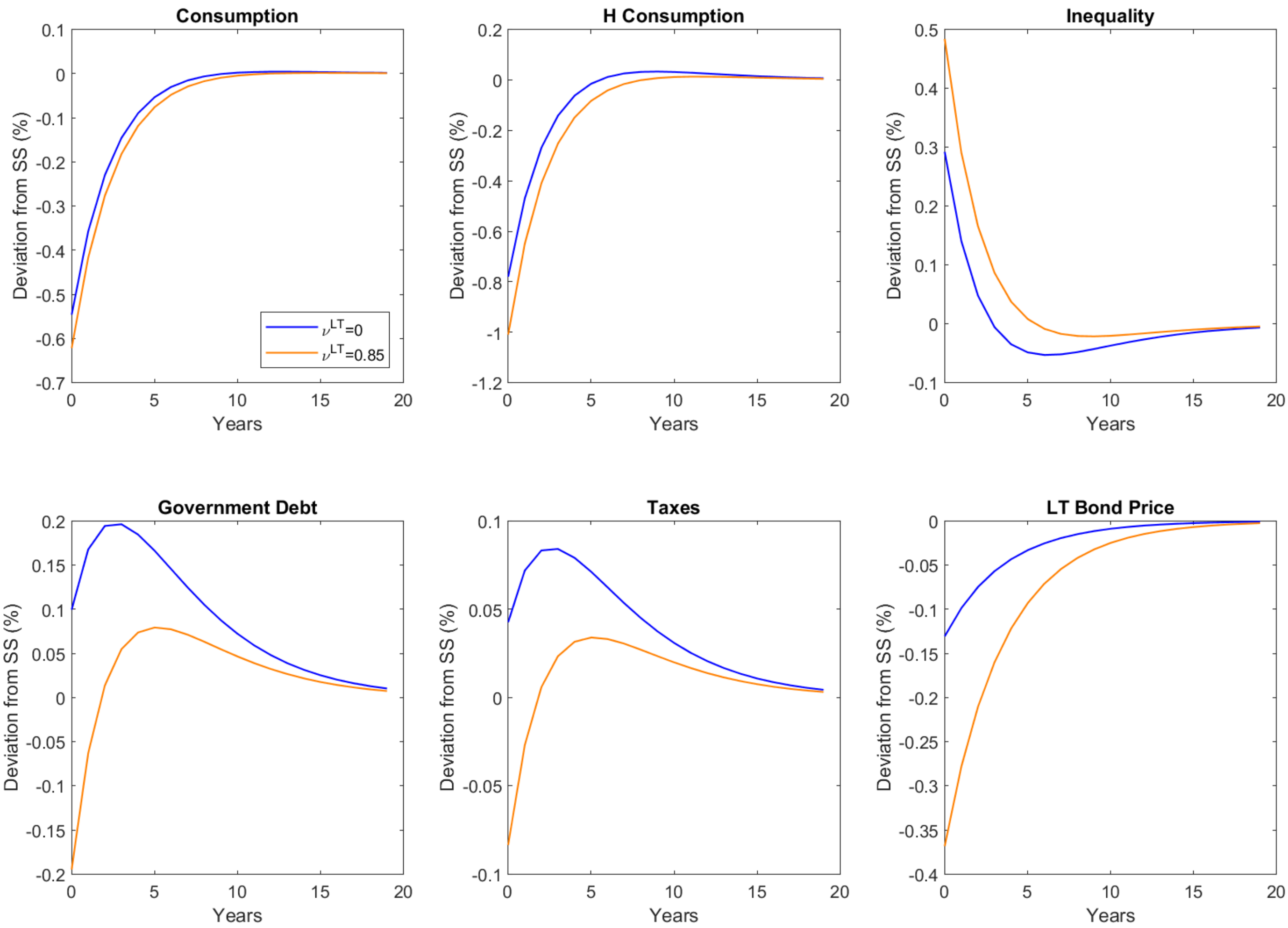

Figure 15: Impulse responses to a 25 bps monetary contraction for the THANK model with liquid short-and long-term debt.$s = 0.8$, $\phi^B = 0.3$, $\alpha = 0.4$, $\lambda = 0.2$.

A HANK model with Liquid Long-Term Debt

Figure 16 shows the impulse responses to a monetary policy contraction for a one-asset HANK model in which households can only self-insure using liquid government debt. As in the THANK model, it is the interactions between government debt maturity and the design of fiscal policy which determines the amplification or dampening of monetary policy. When the fiscal rule is less responsive to the value of government debt ($\phi^B = 0.3$), the IRFs show that a longer debt maturity amplifies monetary policy due to the reduction in household wealth caused by the downward revaluation of government debt. However, when the fiscal rule is more responsive ($\phi^B = 0.6$), the government responds to the monetary contraction by with a larger reduction in taxes. This tax reduction offsets the household wealth effect, meaning that a longer debt maturity dampens the effect of monetary tightening on aggregate consumption.

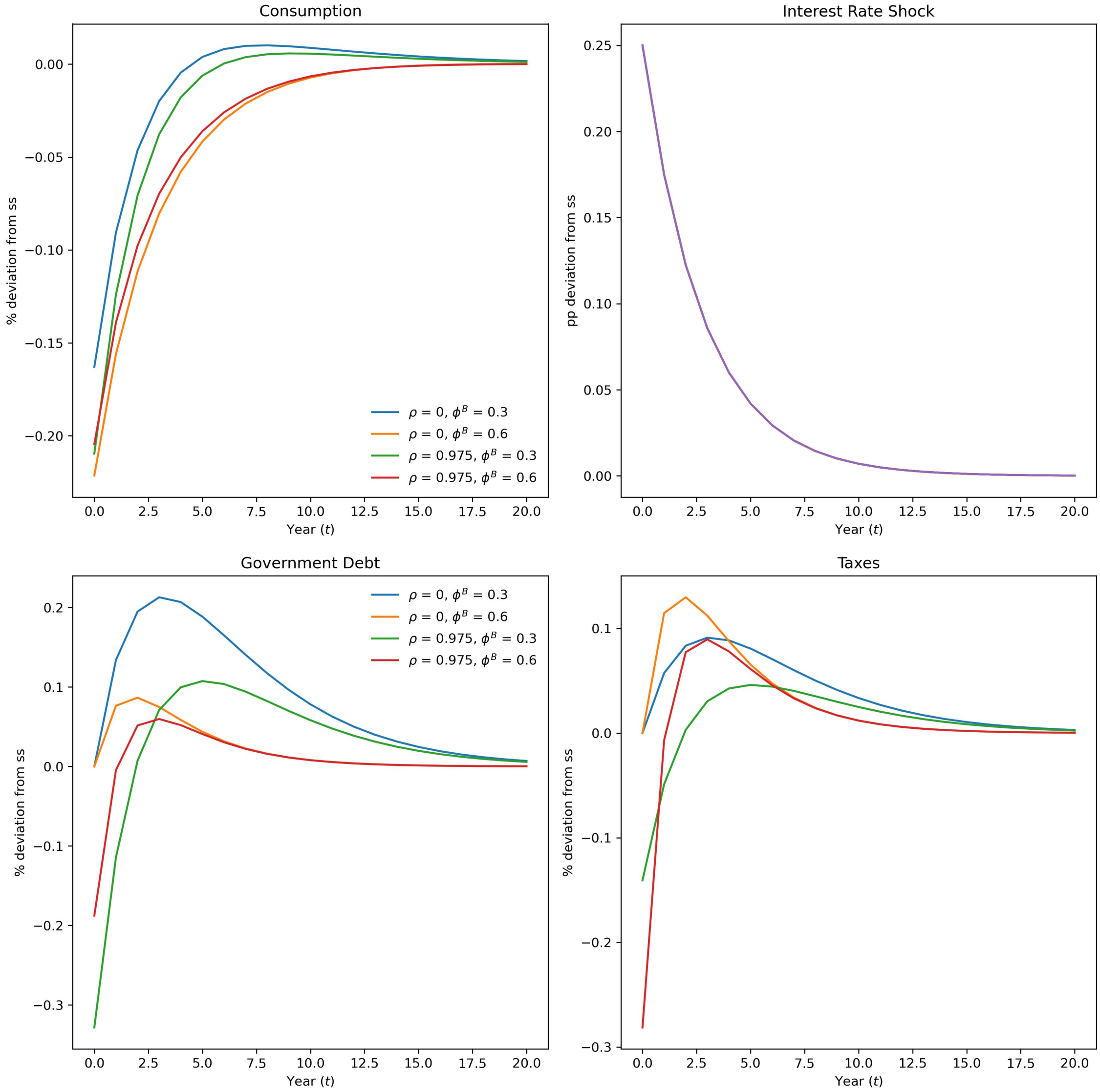

Figure 16:

Empirical Evidence

In the (T)HANK models with liquid long-term government debt, the distribution of household exposure to government debt is a key determinant of the amplification or dampening of monetary policy. Data from the United States suggests that household ownership of domestic government debt has risen over the past decade. The share of US government debt held by domestic private investors rose from a low of 32% at the end of Q1 2014 to 47% at the end of Q3 2022 (US Treasury, 2023). This suggests that domestic households have played an important role in absorbing increased government debt issuance. In addition, the Distributional Financial Accounts show that low-income households' exposure to government debt has increased. Since the onset of the global financial crisis in Q1 2007, the share of domestically-owned US government bonds held by the bottom 20% of the income distribution has increased from just 0.7% to 3.7% in Q2 2023 (Batty et al., 2020). This increase in low-income household exposure is shown in Figure 17.

However, the Distributional Financial Accounts include government bonds held both directly and indirectly by households, potentially including government debt held in illiquid pension or investment accounts. Furthermore, the Distributional Financial Accounts also show that the share of government debt held by the bottom 50% of the net worth distribution has fallen significantly as wealth inequality has widened since the 1990s. This suggests that high-MPC households are unlikely to have large exposure to changes in the value of long-term government bonds. As a result, the models with illiquid long-term government debt are likely to offer a more realistic view of the role of impact of debt maturity on monetary transmission.

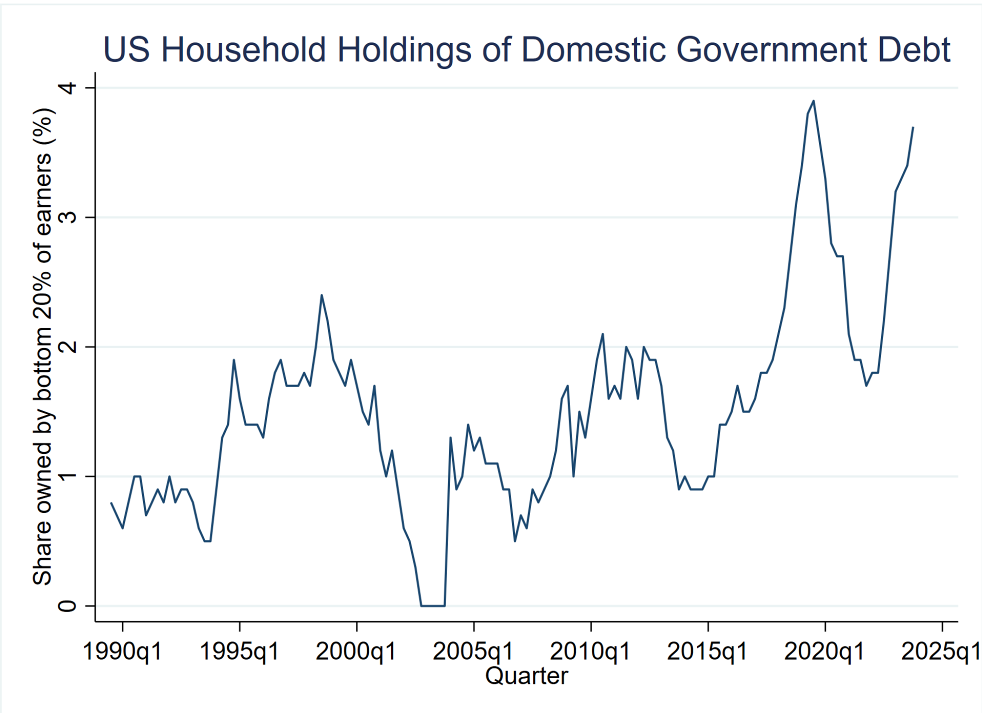

Figure 17: Share of domestic government debt owned (directly and indirectly) by households in the bottom quintile of the US income distribution. Sourced from the Distributional Financial Accounts.

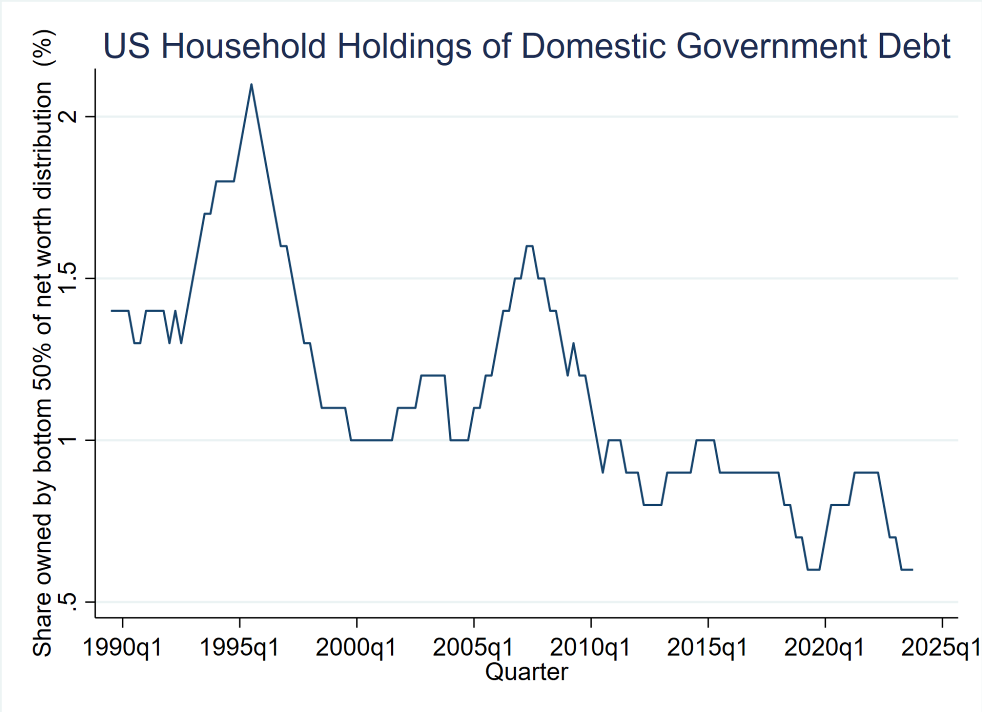

Figure 18: Share of domestic government debt owned (directly and indirectly) by households in the bottom half of the US net worth distribution. Sourced from the Distributional Financial Accounts.