

Online Appendix for  
Household Debt Overhang and Transmission of  
Monetary Policy

Sami Alpanda\*

Sarah Zubairy†

University of Central Florida

Texas A&M University

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\*University of Central Florida, Department of Economics, College of Business Administration, 4336 Scorpius Street, Orlando, FL 32816. Phone: (407) 823-1575, e-mail: sami.alpanda@ucf.edu.

†Department of Economics, Texas A&M University, 4228 TAMU, College Station, TX, 77843. Phone: (979) 845-7382, e-mail: szubairy@tamu.edu.

## A Appendix on data sources

Table 1: Data Sources

Data	Description	Source
GDP	Nominal GDP	BEA
PGDP	GDP deflator	BEA
Consumption	Nominal Personal consumption expenditures	BEA
Investment	Nominal Gross private investment	BEA
Residential Investment	Nominal Residential investment	BEA
Population	Civilian Noninstitutional Population, 16 and over (CNP16OV)	FRED
Federal funds rate	FFR	FRED
Mortgage debt	Households; Home Mortgages; Liability (HHMSDODNS)	FRED
Household debt	Households; Liability (CMDEBT)	FRED
House price	Real house price index	Robert Shiller's data webpage
Wu and Xia shadow rate		Atlanta Fed website
Home equity loans	Z1/FL893065125.Q	FRB Financial Accounts
Refinancing	Refinancing applications index	Mortgage Bankers Association

Note: Real values of GDP and its expenditure components were all deflated using the GDP deflator.

## B Additional Details about Debt Gap and Monetary Shocks

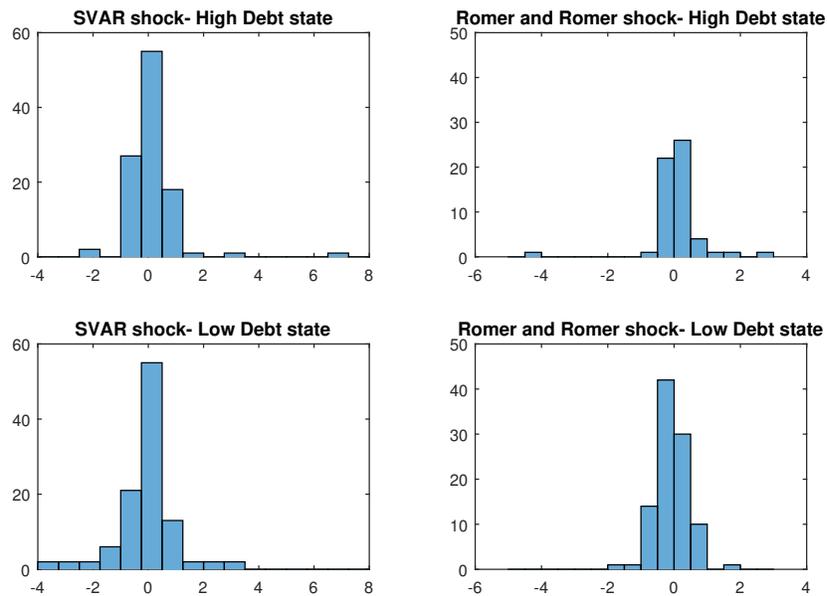


Figure 1: Histograms of SVAR and Romer-Romer monetary policy shocks by household debt state. The top panel shows the distribution of the monetary policy shocks in the high debt state, and the bottom panel shows the low debt state.

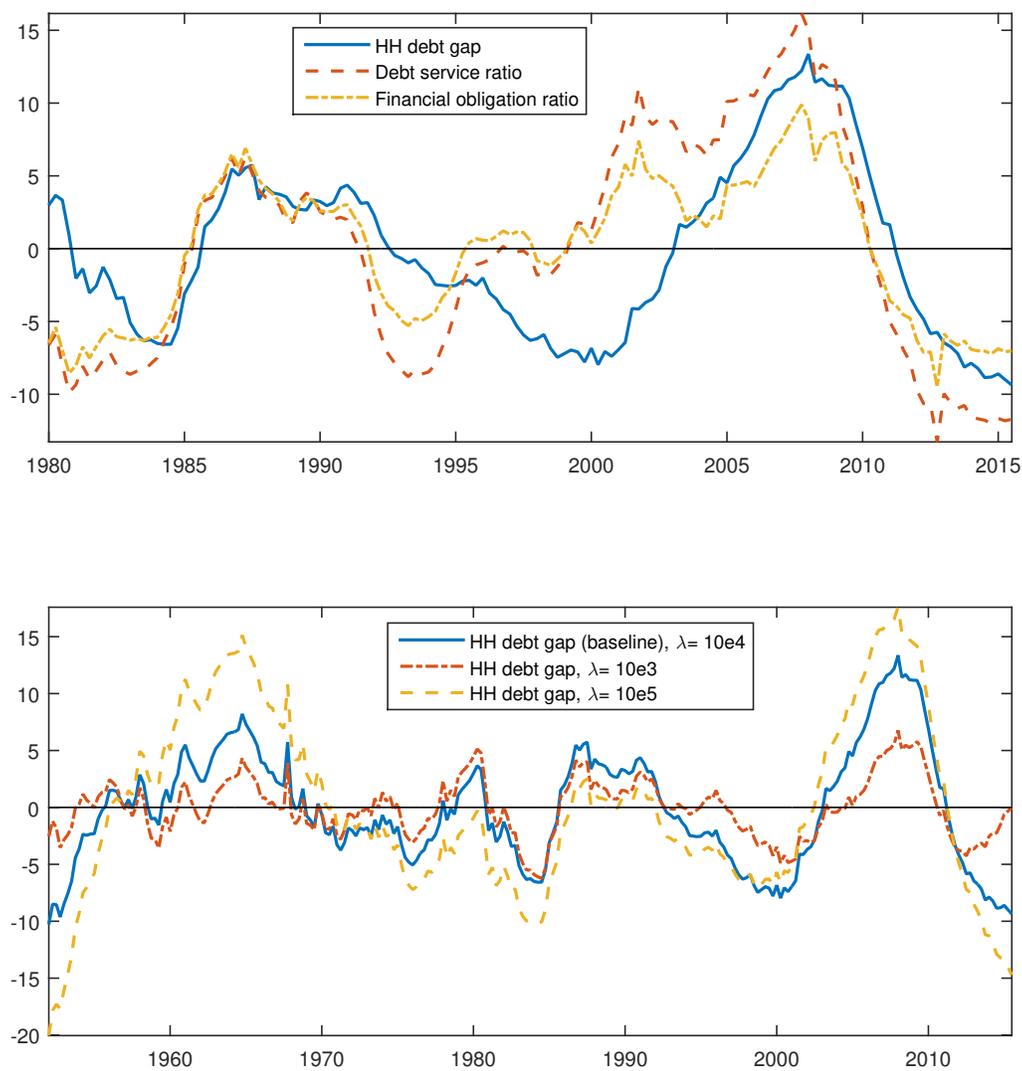


Figure 2: Comparison of the debt gap with alternative measures of debt overhang for the overlapping sample. The first panel of the figure compares our baseline debt gap with the measures of household debt services and financial obligation ratio percent deviations from their respective means. Source: Federal Reserve Board. Note: Household debt service ratio (DSR) is the ratio of total required household debt payments to total disposable income, including required mortgage and scheduled consumer debt payments. The Financial Obligations Ratio (FOR) is a broader measure than the debt service ratio. It includes rent payments on tenant-occupied property, auto lease payments, homeowners' insurance, and property tax payments. The second panel shows the implied debt gap under alternative values of the smoothing parameter,  $\lambda$  in the HP filter.

## C Statistical significance of baseline results

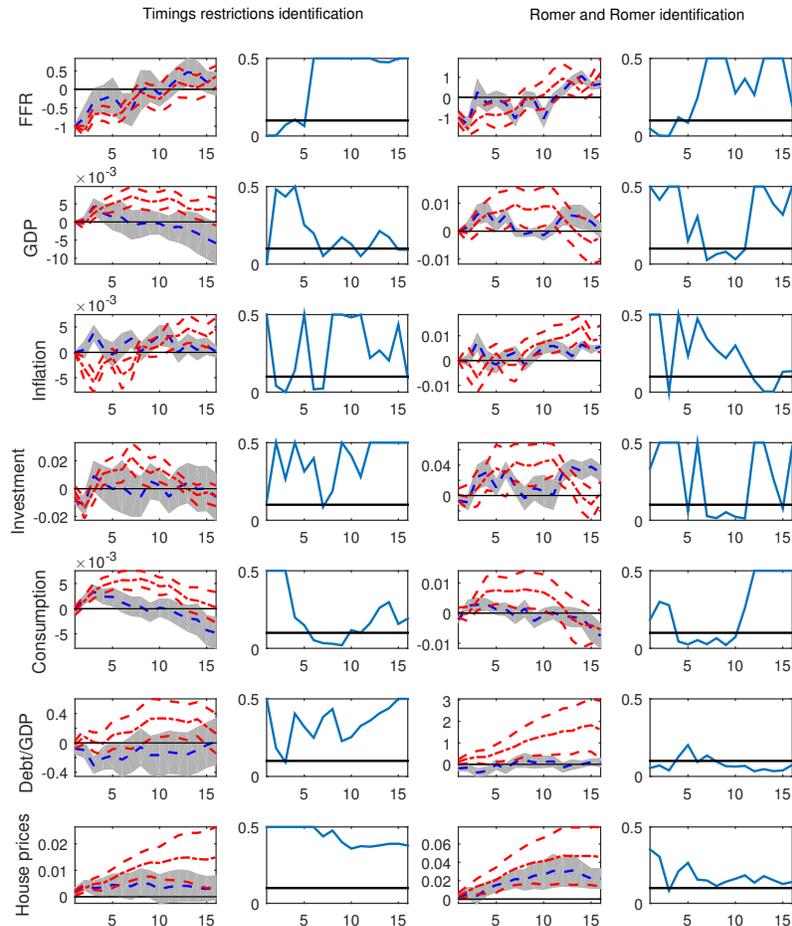


Figure 3: The first and third column shows the impulse response function to a monetary shock in high debt (blue dashed) and low debt (red dot-dashed) state, under the respective identification. The second and last column show the p-value for the null hypothesis that the response in high debt is equal to the response in the low debt state at a given horizon. The p-value are capped at 0.5. The solid black line is at 0.1, at the 10% significance level.

# D Robustness Check: One-sided HP and Band-Pass filters to define debt gap

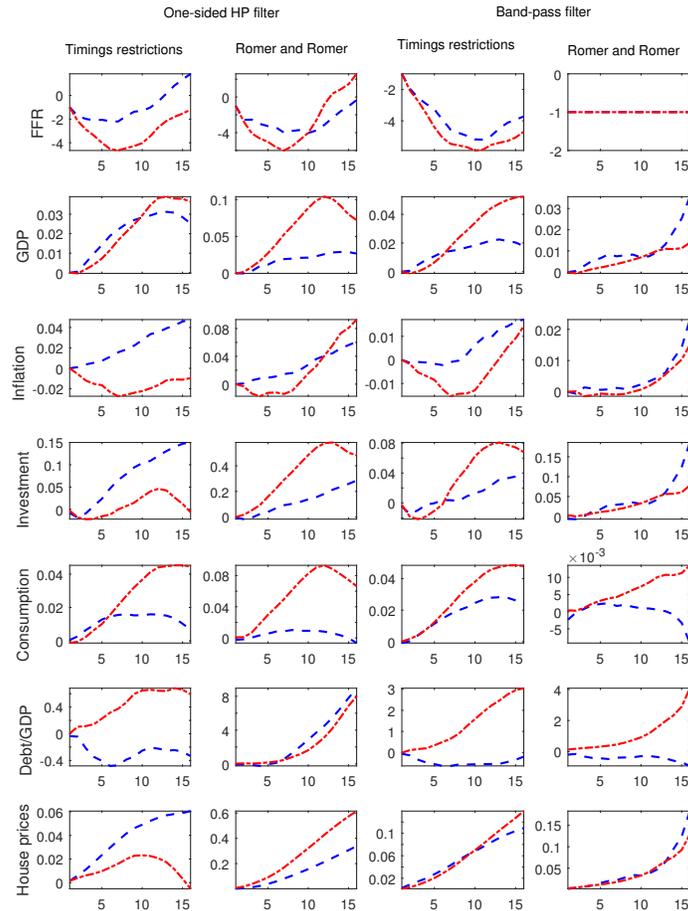


Figure 4: Cumulative effects of a monetary shock under alternative filters to define high and low debt states. The first column shows results for one-sided HP filter with timing restriction identification, and the second column shows it with Romer and Romer shocks. The third column shows the impulse response functions using BP filter with timing restriction identification, and the fourth column shows it with Romer and Romer shocks. All figures show the effects in high debt (blue dashed line) and low debt state (red dot-dashed line).

## E Robustness Check: Threshold VAR

We also consider a threshold VAR, as a robustness check of our baseline empirical results. More specifically, we consider the following threshold VAR to look at the state dependent effects of monetary policy based on household debt:

$$Y_t = I_{t-1}A(L)Y_{t-1} + (1 - I_{t-1})B(L)Y_{t-1} + u_t, \quad (1)$$

where  $u_t \sim N(0, \Omega_t)$ , and  $\Omega = I_{t-1}\Omega_A + (1 - I_{t-1})\Omega_B$ . Here, as before,  $I$  is the dummy variable indicating high-debt state, and  $A(L)$  and  $B(L)$  are polynomials of order 2. In order to identify a monetary shock we order federal funds rate after macroeconomic aggregates such as GDP, consumption, investment and inflation, but before house prices and household debt, before doing a Cholesky decomposition.

While our baseline Jorda method allows for natural transition across states, the VAR methodology assumes that we stay in a given state for a long time. Given that the average duration of both high and low debt states in our sample are around 13 quarters, the short-run impulse response function using the threshold-VAR methodology are consistent with the data.

Figure 5 shows the resulting IRFs in the linear and state dependent case. Note the state dependence results are robust to this different methodology and almost all variables are less responsive to monetary policy in the high-debt state. The state-dependence in investment is weaker than our baseline case, whereas the only exception is the case of house prices, where the state dependence is reversed.

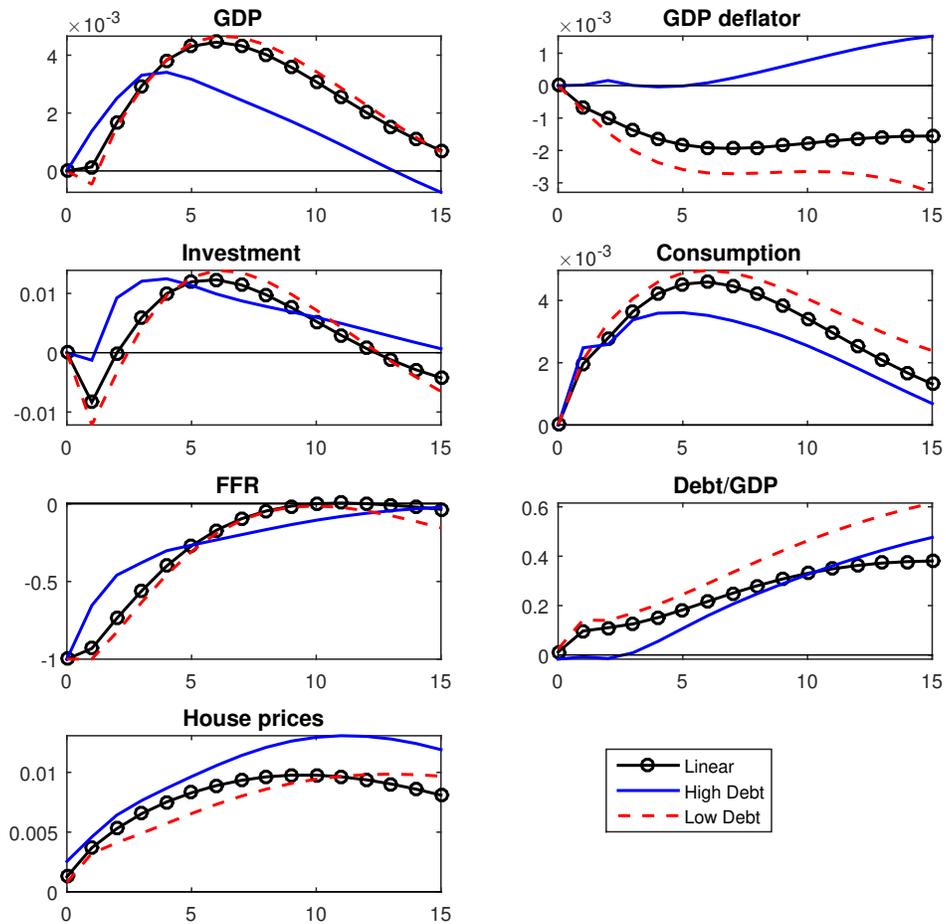
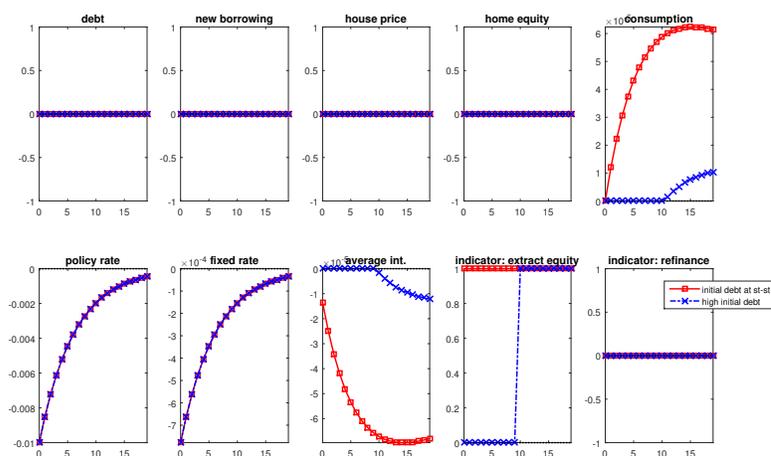


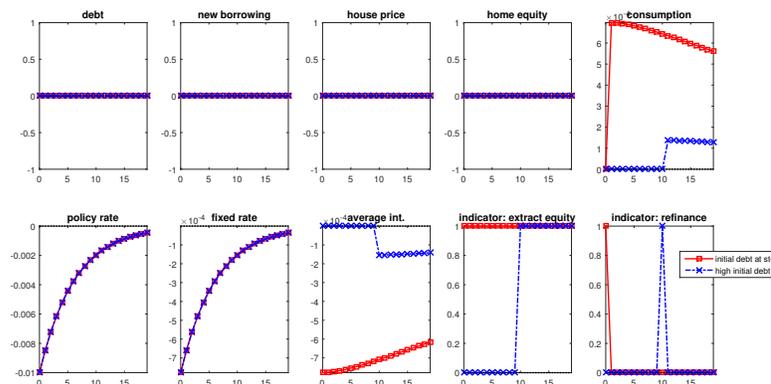
Figure 5: Robustness check: IRFs to a monetary shock using the threshold VAR approach. The figure shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state.

## **F Theoretical responses to a monetary shock: Interest rate channel only**

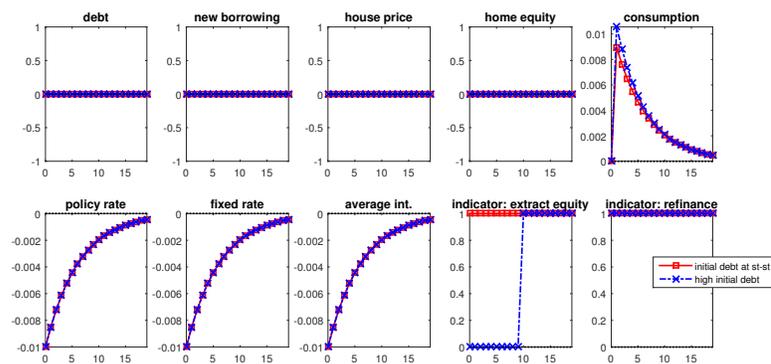
In order to isolate the interest rate channel from the home equity channel, we show the theoretical impulse response functions to a monetary policy in the models considered in Section 4, where we set  $\rho_{qR} = 0$  in Equation (9). The following figures, thus show the analogous responses to a monetary policy shock for the three cases considered, as Figure 14, where we only show the interest rate channel.



(a) Fixed-rate loans with no refinancing



(b) Fixed-rate loans with refinancing option



(c) Adjustable-rate loans

Figure 6: Impulse responses from our theoretical model of model variables to an annualized 100 bps monetary policy shock when we shut down feedback effects to house prices. The figure shows the response for the steady state debt level (red line with circles) and the high debt state (blue line with crosses).

## G General Equilibrium Extension of Theoretical Model

In this Appendix, we extend the partial equilibrium model in Section 4 to include saver households, and consider a general equilibrium version of the model with endogenous labor supply (and income), endogenous house price formation and variable inflation rates. Here, we consider the case of adjustable-rate mortgages. Similar to Iacoviello (2005), the model features two types of agents which differ in terms of their time discount factors. In particular, the impatient households (identified with subscript  $I$ ) discount the future more heavily than the patient households (identified by subscript  $P$ ); hence,  $\beta_P > \beta_I$ . Their period utility functions are identical, and are given by

$$u(c_{i,t}, h_{i,t}, n_{i,t}) = \log c_{i,t} + \xi \log h_{i,t} - \frac{n_{i,t}^{1+\vartheta}}{1+\vartheta}, \text{ for } i \in \{P, I\} \quad (2)$$

where  $\xi$  determines the relative importance of housing in utility,  $n_i$  denotes labor supply, and  $\vartheta$  is the inverse of the Frisch-elasticity of labor supply.

We retain the assumption that there is no residential investment in the model and the aggregate housing level is a constant, but allow housing to be traded across the two types of households; hence,  $h_{P,t} + h_{I,t} = \bar{h}$ . The budget constraint of patient households is given by

$$c_{P,t} + q_t(h_{P,t} - h_{P,t-1}) + \frac{B_t}{P_t} + \frac{L_t}{P_t} \leq w_{P,t}n_{P,t} + (1 + R_{t-1})\frac{B_{t-1}}{P_t} + (R_{t-1} + \kappa)\frac{D_{t-1}}{P_t} + \frac{\Pi_t}{P_t}, \quad (3)$$

where  $B_t$  denoted nominal holdings of 1-period government bonds (assumed to be in zero supply),  $w_{P,t}$  is the wage rate of patient households, and  $\Pi_t$  denotes the pure profits of monopolistically competitive firms, which is transferred to patient households in lump-sum fashion. The budget constraint of impatient households is given by

$$c_{I,t} + q_t(h_{I,t} - h_{I,t-1}) + (R_{t-1} + \kappa)\frac{D_{t-1}}{P_t} \leq w_{I,t}n_{I,t} + \frac{L_t}{P_t}, \quad (4)$$

where  $w_{I,t}$  is the wage rate of impatient households. Their borrowing constraint is now

modified as

$$\frac{L_t}{P_t} = \phi q_t (h_{I,t} - h_{I,t-1}) + \max \left\{ 0, \phi q_t h_{I,t-1} - (1 - \kappa) \frac{D_{t-1}}{P_t} \right\}. \quad (5)$$

Thus, as opposed to the partial equilibrium model, we now allow agents to borrow up to  $\phi$  percent of the housing value at purchase (i.e., first lien), but allow home equity loans (i.e., second lien) only when their home equity level surpasses the threshold level, similar to the partial equilibrium model we analyzed before.

The production part of the model is standard. In particular, we consider a unit of measure of monopolistically competitive intermediate goods producers indexed by  $j$ , that face quadratic price adjustment costs (with a level parameter  $\kappa_p$ ), and produce differentiated output,  $y_t(j)$ , using the following production function

$$y_t(j) = z n_{P,t}(j)^\psi n_{I,t}(j)^{1-\psi} - f, \quad (6)$$

where  $z$  is the level of total factor productivity (TFP),  $\psi$  is the share of patient household labor, and  $f$  denotes the fixed cost in production. The differentiated goods of intermediate goods producers are aggregated by perfectly competitive producers, as is standard in New Keynesian set-ups. In equilibrium, the resource constraint of the economy is given by

$$c_{P,t} + c_{I,t} = y_t - \frac{\kappa_p}{2} \left( \frac{\pi_t}{\pi} - 1 \right)^2 y_t, \quad (7)$$

where  $y_t$  denotes aggregate output, and the inflation rate is determined via a New Keynesian Phillips curve, which can be derived from the first-order conditions of the monopolistically competitive intermediate goods producers as

$$\left( \frac{\pi_t}{\pi} - 1 \right) \frac{\pi_t}{\pi} = E_t \left[ \left( \beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \left( \frac{\pi_{t+1}}{\pi} - 1 \right) \frac{\pi_{t+1}}{\pi} \frac{y_{t+1}}{y_t} \right] - \frac{\eta - 1}{\kappa_p} (1 - \theta \Omega_t), \quad (8)$$

where  $\lambda_P$  denotes the Lagrange multiplier on the patient household budget constraint,  $\eta$  is the elasticity of substitution among the differentiated intermediate goods,  $\theta = \eta/(\eta - 1)$  is the average mark-up that the monopolistically competitive firms charge, and  $\Omega_t$  denotes their marginal cost of production.

Monetary policy is conducted via a Taylor rule that is given by

$$R_t = \rho R_{t-1} + (1 - \rho) \left( R + a_\pi \log \frac{\pi_t}{\pi} \right) + \varepsilon_{R,t}, \quad (9)$$

where  $a_\pi$  denotes the long-run response coefficient with respect to inflation.

## G.1 Parameterization and impulse responses

We set the patient households' discount factor,  $\beta_P$ , to 0.995, which along with the steady-state inflation factor,  $\pi$ , of 1.005, implies a 4 percent nominal interest rate in annualized terms at the steady state, similar to our partial equilibrium model. Similarly, we set the share of debt principal paid out every period,  $\kappa$ , to 0.0125, and the LTV ratio for new housing purchases,  $\phi$ , 0.9 as before.

The discount factor for impatient households,  $\beta_I$ , is set to 0.97, the level parameter for housing in the utility function,  $\xi$ , is set to 0.12, and the share parameter in the production function,  $\psi$ , is set to 0.65, following Iacoviello and Neri (2010). We set  $\vartheta$  to 1, implying a unit Frisch-elasticity of labor supply, and  $\eta$  to 11, implying that firms set a 10 percent average markup when setting prices over their marginal cost. The price stickiness parameter,  $\kappa_p$ , is set to 100, implying that the slope of the New Keynesian Phillips curve is 0.1, in line with estimates in the literature. Finally, for the smoothness parameter on the Taylor rule,  $\rho$ , is set to 0.85, similar to its corresponding value in the partial equilibrium model, and the long-run response coefficient for inflation,  $a_\pi$ , is set to 1.5.

We compute impulse responses using the exact non-linear version of the model and a perfect foresight solution following an unexpected monetary policy shock.<sup>1</sup> In the high-debt

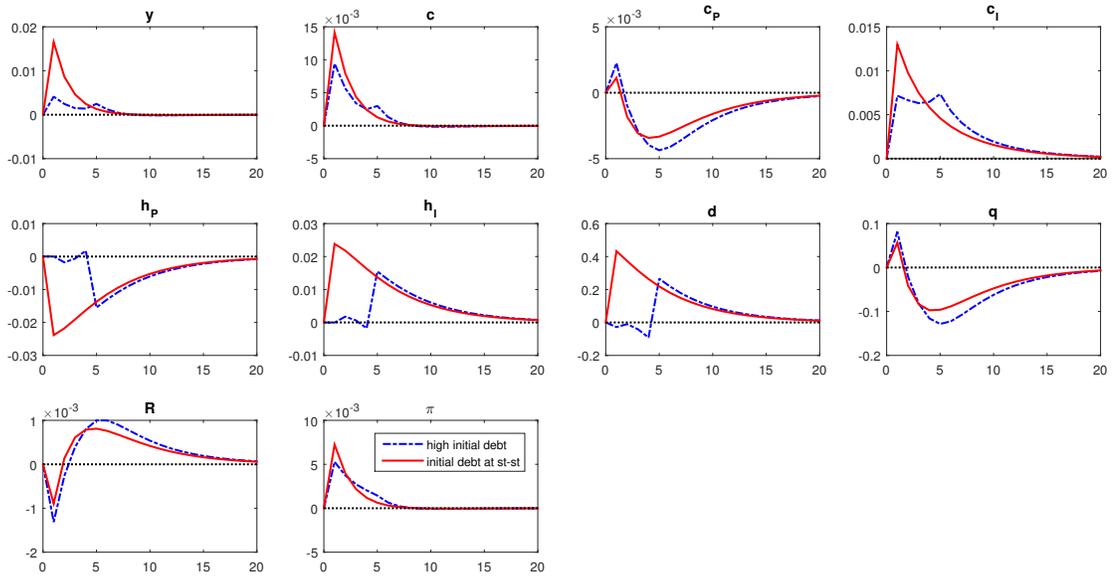


Figure 7: Impulse responses from our theoretical model of model variables to an annualized 100 bps monetary policy shock, in the general equilibrium model. The figure shows the response for the steady state debt level (red solid line) and the high debt state, where initial debt level is assumed to be 10% above the steady state (blue dashed line).

case, we start the model at the steady state for all variables, except for the initial debt level which is assumed to be 10% above the steady state. As can be observed from Figure 7, in this case, the impact of the monetary policy shock is muted for impatient household's real debt stock,  $d$ , in the initial periods following the shock due to the debt overhang effect. Note that inflation increases less in the high debt case, but this effect is not strong enough to reverse the impact of the monetary shock on the real debt profile of borrowers. The smaller increase in borrowing weakens the stimulatory impact of the monetary shock on overall consumption and output. Thus, the results in the general equilibrium model regarding the efficacy of a monetary shock under high debt are by and large similar to those we obtained in the partial equilibrium model.