Household Debt Overhang and Transmission of Monetary Policy*

Sami Alpanda†
University of Central Florida

Sarah Zubairy‡
Texas A&M University

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Abstract

We investigate how the level of household indebtedness affects the monetary transmission mechanism in the U.S. economy. Using state-dependent local projection methods, we find that the effects of monetary policy are less powerful during periods of high household debt. In particular, the impact of monetary policy shocks is smaller on GDP, consumption, residential investment, house prices and household debt during a high-debt state. We then build a partial equilibrium model of borrower households with financial constraints to rationalize these facts. The model points to the weakening of the home-equity loan channel as a possible reason for the decline in monetary policy effectiveness when initial debt levels are high.

Keywords: Household debt, monetary policy, home-equity loans

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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.

1 Introduction

The pace of recovery following the recent recession in the U.S. has been rather tepid. Given the significant amount of monetary (and fiscal) stimulus that was provided to the economy following the crisis, most observers thought at the time that the recovery would materialize much faster and monetary policy would return to normal within the span of a few years. The forecasting models used in central banks and other policy institutions concurred with this view. The actual performance of the economy however, proved to be consistently below expectations. A possible explanation for this discrepancy is that the economy was hit by a series of additional adverse shocks, unanticipated at the time of these projections. More likely however, the effects of monetary policy that are hardwired into these (mostly linear) models capture average effects of policy under normal economic circumstances, while policy effectiveness may in fact be *state-dependent* and change based on factors that prevail when the monetary stimulus is implemented.[1]

A possible candidate for this state-dependence of monetary policy effectiveness is the level of household debt. Standard intuition points to a larger, and not a smaller, impact from monetary policy when initial debt levels are high. For instance, the same rate cut should lead to a larger decline in borrowers' interest burden, and therefore cause a larger increase in their after-interest income and expenditures, when borrowers carry a higher initial debt stock. Furthermore, the *financial accelerator* mechanism of Kiyotaki and Moore (1997) and Bernanke et al. (1999) also points to a potential amplification effect for monetary policy from higher debt. In particular, a rate cut leads to an increase in house prices and borrowers' home equity levels, allowing them to borrow more and at cheaper rates. High household debt is likely to be accompanied by high levels of housing, since the majority of household debt reflects mortgages. Thus, a higher initial debt level should be associated with a higher financial accelerator effect, thereby strengthening the effectiveness of monetary policy. A third possible moderating factor of debt on monetary policy is due to the *debt-deflation* channel of Fisher (1933). In particular, a rate cut would tend to increase the inflation rate, thereby reducing the *real* debt burden of borrowers. Other things equal, this favorable effect is stronger when the initial debt stock is larger, again strengthening the effectiveness of a rate cut.

On the other hand, there are also reasons to think that high debt or in particular, debt higher than what is supported by fundamentals may curtail the effectiveness of monetary policy, reminiscent of a *debt overhang* (Dynan, 2012). For starters, highly-indebted households may be less willing, or less able, to borrow further in response to a rate cut, especially during recessionary periods when agents are facing higher job insecurity and income uncertainty. Mian and Sufi (2014) argue that, after house prices collapsed during the recent recession, households significantly reduced their spending levels for several reasons: (i) they needed to rebuild wealth to recover their lost savings for retirement, (ii) they

[1] Another potential culprit for the weakening of monetary policy effectiveness during the recent recovery is the constraint posed by the zero lower bound (ZLB) on the policy rate. The use of unconventional monetary policies during this period alleviated the effect of the ZLB by providing stimulus through the lowering of long-term interest rates. Sufi (2015), for example, cautions against placing the blame for the slow recovery on the ZLB; in particular, he notes that while the policy rate remained near zero since the end of 2008, the interest rates on 30-year mortgages declined by about 270 basis points (bps).

increased precautionary savings due to the heightened risk on future employment and income (Carroll and Kimball, 1996), (iii) they no longer had sufficient home equity to use as collateral for borrowing, and (iv) they had a hard time refinancing into a lower mortgage rate given the low (or even negative) equity on their mortgages. These likely are also some of the reasons why expansionary monetary policy may have been less effective during the post-crisis period. In particular, the precautionary savings motive increased at the face of heightened income uncertainty, and households were less willing to borrow following the crisis; instead, they were more likely to try to deleverage voluntarily (Koo, 2008; Di Maggio et al., 2015). At the same time, households that were willing to borrow further found it more difficult to do so, since their home equity had dwindled, which made it harder (or impossible) for them to tap into their home equity lines of credit (Bhutta and Keys, 2016) or to refinance into lower mortgage rates (Chen et al., 2013; Beraja et al., 2015). The former effect may have repercussions not only for consumption and residential investment, but also for business investment as well, since many entrepreneurs of small-scale establishments routinely tap into their home equity to finance their businesses (Bhutta and Keys, 2016). The modifying effect of the initial debt stock on monetary policy may be apparent in non-crisis times as well, since higher debt levels imply lower household net worth, all else equal.[2]

In this paper, we investigate how household indebtedness affects the monetary transmission mechanism in the U.S. economy. To answer this question, we first consider the impulse responses of various macroeconomic variables to a monetary policy shock, employing state-dependent local projection methods (Jorda, 2005; Ramey and Zubairy, 2016). In the baseline case, the exogenous monetary policy shocks are identified under the assumption that contemporaneous and lagged output and inflation are in the information set of the monetary authority.[3] We are interested in whether the monetary policy transmission is different in periods of high or low debt gap, which looks at deviations of household debt-to-GDP from a trend. Our results indicate that the effectiveness of monetary policy is curtailed during periods of high household debt. Namely, the impact of a monetary policy shock is significantly smaller on GDP, consumption, residential investment, house prices and household debt during a high-debt state. These results are by and large robust to using an alternative monetary shock series as identified in Romer and Romer (2004), or to the inclusion of the ZLB period (2008q1-2015q3) in the sample using the *shadow* federal funds rate constructed by Wu and Xia (2016).

In the second part of the paper, we build a small-scale, partial-equilibrium, endowment-economy model to illustrate some of the key channels of the monetary policy transmission mechanism that

[2]There are other reasons why high household debt may curtail the effectiveness of monetary policy. For example, to the extent that high household debt is accompanied by an excess supply of housing during a boom, a monetary policy expansion during the bust may become less effective due to the inability to increase construction activity and housing starts. The possibility of future leverage-related financial crises may also moderate the effects of current monetary policy based on the existing level of household debt. For example, if the probability of a future crisis depends positively on the aggregate debt level (or on the debt gap) as in Jorda et al. (2015) and Alpanda and Ueberfeldt (2016), then agents may become more cautious about borrowing and consuming further in periods with high aggregate debt relative to periods with low aggregate debt, even in normal times.

[3]This is the commonly used approach of obtaining monetary policy shocks from a structural vector autoregression (SVAR) identified with Cholesky decomposition, where the federal funds rate is ordered last after output and inflation.

operate through borrower households, and examine how the effectiveness of these channels changes based on the initial debt stock of borrowers. The model is a simplified version of the model in Alpanda and Zubairy (2016), and features long-term debt contracts as in Kydland et al. (2012) and Garriga et al. (2013), distinguishing between the stock and the flow of debt. The model is purposefully kept simple and partial equilibrium to focus on the effects of a policy rate cut on the interest burden of borrowers (i.e., interest rate channel), and their new borrowing through home-equity loans (i.e., home-equity loan channel). We first show that the former channel is stronger when debt levels are higher. The latter channel, however, is operational only when debt levels are relatively low and borrowers hold adequate levels of home equity. Thus, the expansionary impact of a decline in interest rates may be curtailed under high initial debt levels, when the effects of the home-equity channel surpasses those from the interest rate channel. The model thus points to the weakening of the home-equity loan channel as a possible reason for the decline in monetary policy effectiveness when initial debt levels are high.[4]

1.1 Related Literature

The state dependence of the effectiveness of monetary policy has been studied earlier in the literature. Tenreyro and Thwaites (2016) shows in a state-dependent time series model that the effects of monetary policy are less powerful in recessions as opposed to expansions.[5] In contrast, we focus on the state of household debt to capture the potential non-linearity in the responses to monetary policy. Note that high debt episodes in our sample do not necessarily coincide with recessionary episodes. In particular, recession periods are distributed equally between our high debt and low debt episodes; hence, we are capturing a different non-linearity in the responses to monetary policy relative to Tenreyro and Thwaites (2016). Our results are in line with their work however, since, as we show in Section 3.4, monetary policy effects are weakened further when a high debt episode coincides with a recession.

There is also a vast literature looking at the effectiveness of monetary policy particularly in the Great Recession, and some of the channels discussed are through household debt levels. For instance, Sufi (2015) argues that monetary policy since the crisis has been ineffective "because it has channeled interest savings and additional credit to exactly the households that are least likely to change their spending in response. The households that would normally spend most aggressively out of monetary policy shocks are heavily indebted or have seen their credit scores plummet, rendering them either unwilling or unable to boost spending". Beraja et al. (2015) use U.S. loan-level data to show that the expansionary effects of monetary policy following the crisis was weaker in states where collateral values were more depressed. They attribute this to the weakening of the refinancing channel when home equity levels are low. Charles Goodhart (2014), on the other hand, argues that the decline in

[4]In Appendix F, we extend the model to a general equilibrium setup, and show that the baseline results regarding the weakening of monetary policy under high debt levels stand.

[5]Others, such as Angrist et al. (2017) and Barnichon and Matthes (2016) explore non-linearities in the responses to monetary policy by considering whether contractionary policy has different effects from expansionary policy.

monetary policy effectiveness during the Great Recession is mainly due to the weakening in the bank lending and bank capital channels of monetary policy transmission, which became more restricted as a result of the increase in excess reserves and regulatory capital requirements, respectively.

Relatedly, Calza et al. (2013) document that the impact of monetary policy shocks to residential investment and house prices depend on the development of mortgage markets, and the transmission to consumption is stronger in countries where mortgage equity release is common and mortgage contracts are predominantly variable-rate. Note, that while Calza et al. (2016) find that countries with high mortgage debt-to-GDP ratios exhibit larger responses to monetary policy, they are focusing on the level of debt, which can be thought of as a proxy for financial development. In contrast, we focus on the *debt gap*, which is the deviation of household debt-to-GDP from its trend, where financial development might be a factor driving the trend. As our theoretical model in Section 4 illustrates, monetary policy can have a larger impact on the economy when the *trend level* of debt is higher, since the interest rate channel is stronger in this case, consistent with the findings of Calza et al. (2016). Nevertheless, monetary policy can become less effective overall during periods of high *debt gaps*, since home equity extractions may become curtailed. Using data on U.S. states, Albuquerque and Krustev (2015) find that excessive indebtedness exerted a meaningful drag on consumption over and beyond income and wealth effects during the post-crisis recovery, and that indebtedness begins to bite only at high levels, indicating a non-linear relationship between the level of initial household debt and consumption. In departure from the aforementioned studies, our focus is looking at the role of household indebtedness in the transmission of monetary policy in the time series dimension.

There is also a related literature on precautionary savings in the presence of debt and income uncertainty. Banerjee (2011) argues that buying a house is a commitment for future cash outflows. Thus, agents may increase precautionary savings following a house purchase financed by a mortgage, since they now have higher levels of "consumption commitments". Mody et al. (2012) find that at least two-fifths of the increase in household saving between 2007 and 2009 can be attributed to the precautionary savings motive, and highlight the effects of income uncertainty on precautionary savings in a small-scale partial equilibrium model of *saver* households. Our partial equilibrium model is similar to theirs, except that our model features *borrower* households and focuses on the effects of initial debt on borrowing and expenditure.[6]

The next section introduces the econometric model we use to test whether the effectiveness of monetary policy depends on the level of household debt, and Section 3 presents the results from this empirical framework. Section 4 introduces a small-scale partial equilibrium model that illustrates some of the key channels of the monetary policy transmission mechanism that operate through borrower households, and examines how the effectiveness of these channels changes based on the

[6]There is also a related literature that focuses on debt overhang in businesses following Myers (1977). In particular, debt increases the probability of a bankruptcy and therefore loss of collateral (i.e., capital), which has a disincentivizing effect on acquiring new investment goods through debt. In the housing realm, this type of debt overhang can be manifested as households' unwillingness to spend on maintenance and household appliances, which are important components of residential investment and durable consumption expenditures, respectively (Melzer, 2016). There may also be a related adverse impact on household labor supply due to household debt overhang (Bernstein, 2016).

initial debt stock of borrowers. Section 5 concludes.

2 Econometric methodology

We follow the methodology of Ramey and Zubairy (2016) and apply the local projection technique proposed in Jordà (2005) to estimate state-dependent models and calculate impulse responses.[7] The Jordà method simply requires estimation of a series of regressions for each horizon, h, and for each variable. The linear model looks as follows:

$$z_{t+h} = \alpha_h + \psi_h(L)y_t + \beta_h shock_t + \varepsilon_{t+h}, \text{for } h = 0, 1, 2, ... \tag{1}$$

where z is the variable of interest, y is a vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and *shock* is the identified monetary shock. The coefficient β_h gives the response of z at time $t + h$ to the shock at time t. Thus, one constructs the impulse responses as a sequence of the β_h's estimated in a series of separate regressions for each horizon.

This method is easily adapted to estimating a state-dependent model. In particular, we now estimate a set of regressions for each horizon h as follows:

$$\begin{aligned} z_{t+h} = {} & I_{t-1} \left[\alpha_{A,h} + \psi_{A,h}(L)y_t + \beta_{A,h} shock_t\right] \\ & + (1 - I_{t-1}) \left[\alpha_{B,h} + \psi_{B,h}(L)y_t + \beta_{B,h} shock_t\right] + \varepsilon_{t+h}, \end{aligned} \tag{2}$$

where $I_{t-1} \in \{0, 1\}$ is a dummy variable that indicates the *state* of the economy in terms of household indebtedness before the monetary policy shock hits. In particular, I_{t-1} takes a value of 1 in the high-debt state and 0 otherwise. We discuss the construction of this dummy variable in more detail in the next subsection. We allow all the coefficients of the model (other than deterministic trends) to vary according to this state of the economy. One particular complication associated with the Jordà method is the serial correlation in the error terms induced by the successive leading of the dependent variable. Thus, we use the Newey-West correction for our standard errors (Newey and West, 1987).

One of the merits of using the Jordà's local projection methodology is that, in contrast to regime-switching VARs, we do not need to take a stance on how long a given state lasts, and how the economy transitions between high and low debt states, when constructing impulse responses. The coefficients β_h's, in the equations above, capture the average effect of the monetary policy shock based on the initial state, given by high debt or low debt, and thus also embed the average effects of the shock on the change in the state. Additionally, the natural transitions in the data between the two states due to other factors in the economy are captured by the lagged control variables on the right hand side. Ramey and Zubairy (2016) show that these implicit assumptions regarding the

[7] In Appendix E, we use an alternative methodology, namely a threshold vector autoregression (TVAR), as a robustness check on our results.

transition of the state in the local projection methodology versus threshold VARs can potentially lead to very different impulse response functions.

2.1 Defining the high-debt state

In order to test whether the transmission of monetary shocks depends on the initial level of household debt, we first need to define which periods constitute a high-debt state. We base our state variable on the household debt-to-GDP ratio, since this accounts for the effects of population growth and changes in economic conditions. In order to define the high- and low-debt states, we construct a *debt gap* measure by considering the deviation of the debt-to-GDP ratio from a smooth trend. We construct this trend by running a Hodrick and Prescott (1997) (HP) filter with a very high smoothing parameter, $\lambda = 10^4$. This approach is useful in capturing the longer duration of credit cycles, and has been previously used in the literature (e.g. Drehmann and Tsatsaronis, 2014; Bernadini and Peersman, 2016).[8] In particular, our choice of λ assumes that credits cycles are twice as long as business cycles.[9] We show a comparison of the implied debt gap under this definition with alternative measures of debt overhang and alternative values of the smoothing parameter, λ, in Appendix B. Overall, since our approach employs a discrete or dummy variable approach in characterizing high- and low-debt states, these differences in definitions do not yield very different turning points.

Given the well-known endpoint problem of the two-sided HP-filter, we filter the debt-to-GDP series from 1951 to 2015, but exclude both the start and end of this sample in our baseline case and use debt gap data only from 1955 to 2007. Figure 1 shows the the level of household debt-to-GDP ratio for the full sample and the vertical lines indicate the subsample that we employ in our estimation. For the sample period 1952q1-2015q3, we have a positive debt gap (i.e., a high-debt state) in nearly 50 percent of the sample. As shown in Figure 1, the high-debt state corresponds with four distinct periods: 1956q2-1968q4, 1979q1-1980q4, 1985q4-1992q3 and 2003q2-2011q1.[10] The high debt episodes identified coincide with the rise and fall of household debt around the credit crunch of 1966, the savings and loan crisis in the 1980s and the large change in household debt accompanied with the house price boom in the run-up to the Great Recession.

In order to further understand the reason behind considering the gap instead of the level of household debt-to-GDP to define debt states, it is useful to see the evolution of the variable over time. Figure 1 plots the level of household debt-to-GDP ratio from 1951 to 2015, along with its smooth HP-trend. It is apparent that the debt-to-GDP has had an upward trend throughout the

[8]In particular, the BIS assigns credit-to-GDP gap measure a lot of importance as a guide to policymakers, given that it has been shown to be a useful early warning indicator for banking crises.

[9]Typically, λ is set at 1600 when extracting business cycle frequencies up to 8 years. Ravn and Uhlig (2005) show that the filter parameter should be adjusted by multiplying it with the fourth power of the observation frequency ratio. Our choice of 10^4, is close to $1600 \times 2^4 \approx 2.5 \times 10^4$, implying twice the business cycle. BIS tends to use a higher smoothing parameter of 5×10^5, when they construct credit-to-GDP gap, since they use it as an indictor for banking crises, which on average occur every 20 to 25 years in the samples they consider.

[10]In Section 3.3, we also consider an alternative method of filtering using the Baxter and King (1999) bandpass filter, where we isolate frequencies between 4 and 64 quarters. Thus it is twice as long as the standard business cycle frequencies used in the literature, and is largely consistent with our HP-filter smoothing parameter.

sample, except for the large deleveraging episode following the recent financial crisis. The trend level of debt-to-GDP has likely been increasing over time due to financial innovations, such as advances in credit scoring, and technological progress in related fields that have significantly eased the flow of information, reducing frictions between lenders and borrowers. In addition, since the 1980s, there has also been a strengthening in potential fundamentals driving household debt, such as house prices and home-ownership rates, which determine collateral for borrowing, accompanied by a decline in mortgage rates, which determines borrowing costs. Although these developments on the trend level of debt may have also affected monetary policy transmission, our focus here is whether state-dependence of monetary policy is related to the deviations of debt from its fundamental (or trend) level. This choice is also partly informed by our theoretical model in Section 4, which is also consistent with considering the deviation of debt from a steady state level.

2.2 Identifying monetary shocks

In our baseline specification, we identify monetary shocks using residuals from an ordered 3-variable VAR, where the federal funds rate is ordered last after GDP and inflation. This identifying assumption implies that current GDP and inflation are in the information set of the monetary authority, which is a standard identification approach employed in structural VARs that use a Cholesky decomposition to identify shocks.[11] This method of identification allows us to use a sample period spanning 1955q1-2007q4. The start of the sample is characterized by the availability of quarterly data for federal funds rate, and the sample ends in 2007q4 to avoid the ZLB period on the federal funds rate. As noted before, close to 50 percent of the sample is classified as high debt period for this sample period. In Appendix B, we also show that the distribution of these monetary shocks in high- and low-debt states look very similar in terms of sign and size.

We also conduct a robustness check on our results by identifying the monetary policy shocks as in Romer and Romer (2004). These shock series are obtained as residuals from a regression of the first difference of the intended federal funds rate target, identified using a narrative approach, on lagged values of output and inflation and Greenbook forecasts, which are all in the Federal Reserve's information set. As argued by Romer and Romer (2004), the obtained residuals are exogenous with respect to the evolution of economic activity. However, this shock is available for a shorter sample spanning 1969q1-2007q4.[12] For this sample period, close to 36 percent of the sample is classified as a high-debt period.

[11] Note, this is equivalent to using the contemporaneous federal funds rate as the shock in Equations (1) and (2), and ensuring that the contemporaneous and the lagged values of GDP and inflation, along with the lagged values of federal funds rate, are part of y_t in Equations (1) and (2).

[12] We use the updated Romer-Romer shock series up to 2007q4 from Johannes Wieland's website.

3 Empirical Results

In this section, we report results from the state-dependent model on the effects of monetary policy shocks, first for the case where the monetary shock is identified under timing restrictions (i.e., Cholesky decomposition), and then for a shorter sample and with the alternative identification of monetary shocks following Romer and Romer (2004). Note that in both cases we consider our baseline definition of household debt gap based on HP filtering. We then conduct several robustness checks based on the definition of the state and threshold, as well as sample choice. We also explore how the results are affected if the high-debt states and recessions interact.

3.1 Identification of monetary shock under timing restrictions

The source and the exact definition of the data series used in the analysis are given in Appendix A. In our baseline model, we use two lags of GDP, inflation and federal funds rate as control variables, as suggested by both the Akaike and Schwartz information criteria.[13] In addition, for each variable of interest, we also add two lags of the variable itself to the set of controls.

Figure 2 shows the impulse response functions to a 100 basis points (bps) expansionary shock to the federal funds rate for our baseline specification. We first consider results from the linear model, as shown in the second column. In response to an expansionary monetary shock, we observe a rise in GDP, investment and consumption, where the responses peak between 8 to 10 quarters after impact. The response of inflation, on the other hand, is negative on impact and increases above the initial position with a delay of few quarters, and is thus subject to the well documented *price puzzle*. In response to an expansionary monetary shock, we also see a rise in the debt-to-GDP ratio and house prices.

The third column of Figure 2 shows the impulse response functions to a monetary shock for both the high debt (blue dashed) and low debt (red dot-dashed) states. Note that the responses of GDP, investment, consumption, debt-to-GDP and house prices are significantly positive in the low-debt state. They are also shaped similar to the linear case, and are typically of larger magnitude relative to the linear model. In particular, the GDP response peaks at 0.7 percent in response to a 100 bps shock to the federal funds rate in the low-debt state, relative to 0.5 percent in the linear model. The price puzzle is also worse in the low-debt state relative to the linear case. In contrast, in the high-debt state, the responses of all the variables, including GDP, consumption, investment and debt-to-GDP are muted, and not significantly different from zero, at most horizons.[14]

We then consider the responses of subcomponents of consumption and investment to the monetary policy shock in Figure 3. In the linear case, we see that in response to a expansionary shock, there are positive and hump-shaped responses for durable and services consumption as well as for residential investment, whereas non-durable consumption and non-residential investment increase

[13] We choose lag length based on the zero horizon ($h = 0$) equation for GDP and the federal funds rate.

[14] In Appendix C, we formally test whether the impulse responses in the high debt state are statistically different from responses in the low debt states. The GDP response is statistically different across states for various horizons between 6 and 12 at the 10 percent significance level.

with a delay. The state-dependent responses show that, in general, all components of consumption and investment have more robust responses in the low-debt state. Durable consumption has a significantly higher response in the low-debt state across almost all horizons after impact, and thus seems to be a major driver for the difference in the total consumption responses across the two states. Residential investment also has a significantly larger response in the low-debt state for 6 to 8 quarters after impact, and is driving the difference across states in terms of gross investment.

The state dependent responses reveal differences in the propagation of monetary policy shocks under the high- and low-debt states at different horizons. In order to further assess the total effectiveness of monetary policy in each state, we also compute the *cumulative* impulse responses. Figure 4 shows the cumulative effects of each variable in the high- and low-debt states, computed using the integral of the corresponding impulse response function. The cumulative effects clearly illustrate that, for all real variables, there is a much larger positive impact during the low-debt state relative to the high-debt state. The only exception is for inflation, where the effects are reversed, and this is due to the worsening of the prize puzzle in the low-debt state as mentioned above. The first panel, however, shows that the federal funds rate also responds differently after impact, and overall falls much less in the low-debt state. In order to verify whether the weaker response of the federal funds rate might be responsible for the more robust response of other variables in the low-debt state, we show the normalized cumulative responses of all the variables by the cumulative response of the federal funds rate. As the second column of Figure 4 shows, even after controlling for the response of the federal funds rate, the cumulative effects of a monetary shock are much larger in the low-debt state than in the high-debt state. The only exception is the effect of monetary policy shocks on house prices, which seem to be of comparable size in the two states following this normalization.

Overall, these results lead us to conclude that the effectiveness of monetary policy in stimulating the economy is reduced when households are highly indebted. These effects can be explained by a relatively muted response of both consumption and investment. Overall, consumption and residential investment seem to be playing a big role in driving the differences in the GDP responses between high and low debt states. In addition, we also document that the responses of household debt-to-GDP, which comprises mostly of mortgage debt, and house prices also have smaller responses in the high-debt state.

3.2 Identification of monetary shock as in Romer and Romer (2004)

Next, we conduct the same analysis as in the previous subsection, but use the extended series for the Romer and Romer (2004) monetary shock instead. As mentioned earlier, under this specification, due to the availability of Greenbook forecasts, we start the sample at a later date in 1969. Hence, in this specification, we are dropping the 1956q2-1968q4 high debt episode used in the previous section, when our data had started in 1955.

Figure 5 shows the impulse response functions to a Romer and Romer monetary shock. In the linear model, shown in the middle column, GDP, consumption and investment again have hump shaped responses, peaking at around 8-10 quarters after the shock hits the economy. The inflation response is muted on impact, and starts rising with a delay. With this identification specification and the shorter sample, the price puzzle is no longer a pronounced issue. Similar to the alternative identification scheme, both debt-to-GDP and house prices respond positively to an expansionary monetary shock.

The last column of Figure 5 shows the state-dependent responses to the monetary shock. Once again the responses in the low-debt state (red dot-dashed) tend to be more robust than the responses to a shock hitting the economy in a high-debt state (blue dashed). This is especially evident in the case of consumption, debt-to-GDP and between horizons 6 to 12 quarters for GDP and investment. Figure 6 shows the impulse response functions of the sub-components of consumption and investment. All components of consumption and residential investment have larger responses in the low-debt state.

Figure 7 shows the *cumulative* effects of the monetary shocks in the two states. The left panel shows that the cumulative effects on GDP, consumption, investment and debt-to-GDP are much larger in the low-debt state. Once we normalize for the effects of the federal funds rate, the differences across the two states become much smaller, particularly relative to the differences we obtained using the baseline identification and sample in the previous subsection. However, there is still evidence to suggest a significant deviation in the cumulative effects on consumption and debt-to-GDP based on the state.

To sum up, under this alternative identification scheme for the monetary shock following Romer and Romer (2004) and a shorter sub-sample, we find slightly weaker, but still positive, evidence of state-dependence in the responses of variables to a monetary shock based on the level of household debt. Namely, in this case too, GDP, its components and debt-to-GDP have a muted response and are stimulated to a much smaller degree in response to a monetary shock when the economy is in a high-debt state.

3.3 Robustness checks

In this section, we consider various robustness checks on our baseline specification. We consider alternative definitions for our state variable, the threshold used to construct the state variable, and also consider a different sample. For these robustness checks, we use our baseline (i.e., VAR-based) identification scheme for the monetary shock, unless otherwise indicated.

3.3.1 Debt gap constructed using bandpass filter

We now construct the debt gap using a bandpass filter instead of the HP filter. The implied debt gap from this alternative method of filtering is shown in the top panel of Figure 8. Note that when we use the bandpass filter to construct high and low debt states, we have a few additional very short duration high debt periods in the mid 1970s and 1990s.

Figure 9 shows the impulse response functions using this alternative debt gap measure to construct the high and low debt states. Overall, the results look very similar to those in Figure 2, where we had used the HP filter to construct the debt gap. In particular, we again find evidence of stronger and more robust responses of GDP, investment, consumption and deb-to-GDP in the low-debt state, and relatively muted responses in the high-debt state. In Appendix D, we also show that the *cumulative* effects of a monetary policy shock under this alternative debt gap definition are very similar to our baseline case in Figure 4.

Figure 10 shows the impulse response functions when we use the bandpass filter to construct the high and low debt states, as well as employ the Romer and Romer identification for the monetary policy shock. Again the results are very similar to our baseline case shown in Figure 5. The responses of most real variables are larger with an expansionary monetary policy shock in the low-debt state relative to the high-debt state.

3.3.2 Using only mortgage debt to construct the state variable

In our baseline specification, we had considered the gap in the *total* household debt-to-GDP as our state variable. We check the robustness of our results to the use of only mortgage debt (as a ratio to GDP) instead, using the same HP-filter smoothing parameter of 10^4. On average, mortgage debt accounts for 66 percent of the total household debt. Figure 8 shows the resulting mortgage debt gap in this case, which lines up fairly closely with our baseline definition using the total household debt gap measure. Figure 11 shows the impulse response when we use this alternative debt gap as the state variable. Note that, we again find that output has a much more robust response to expansionary monetary policy.

3.3.3 Alternative debt threshold

In the baseline case, our debt gap threshold to divide the sample into two was effectively 0. If, however, we want to focus only on very high debt periods, we could instead define periods of high debt as when the debt gap is larger than the median (i.e., when the debt-to-GDP ratio is at least 2 percent above trend). This results in 36 percent of the sample be characterized as high debt, shown in Figure 8.

Figure 12 summarizes the impulse responses when we use this alternative debt threshold. The response of GDP in the low debt (red dot-dashed line) state is much larger in response to a monetary shock. In particular, we again find that GDP has a positive and robust response in the low-debt state.

3.3.4 Controlling for lagged debt

When we identified the monetary policy shocks in our baseline case with timing restrictions, we assumed that GDP and inflation were in the information set of the monetary authority. We now allow for the possibility that the monetary authority also takes into account information regarding household debt. In particular, we now include lagged household debt as an additional control variable in our baseline specification, when we construct the responses of the fed funds rate, GDP and inflation. The results are shown in Figure 13. Note that the results in this case look similar to our baseline case, and the response of GDP is much larger in the low-debt state than the high-debt state.

3.3.5 Accounting for the price puzzle

As noted earlier, our baseline specification in Figure 2 gives rise to the price puzzle, an issue encountered in the related literature as well. In particular, in our linear model, the response of inflation to an expansionary monetary policy shock is negative in the first few quarters, and is statistically significantly negative during the quarter after the shock hits the economy. We also note that in our state-dependent model, the price puzzle is worsened during the low-debt state, while the response of inflation is positive in the high-debt state.

In order to overcome the price puzzle, we follow the literature and include the logarithm of commodity prices as a control variable in our baseline specification, and allow both lags and the contemporaneous values of this variable in the information set of the monetary authority (Christiano et. al, 1999). Figure 14 shows the responses of federal funds rate, GDP and inflation when we include this variable in our analysis. There are three things to note. First, as the middle panel for inflation reveals, the addition of commodity prices certainly helps mitigate the price puzzle in the linear model. The response of inflation is statistically insignificant for the first few quarters and then turns positive. Second, as shown in the last panel for inflation, the price puzzle now weakens in the low-debt state, but the response of inflation is still negative for a few quarters (while remaining positive in the high-debt state). Finally, note that the addition of commodity prices as a control variable does not affect the main state-dependent results for GDP. In particular, the response of GDP to an expansionary monetary shock is much more positive and robust during the low-debt state, relative to the high-debt state.[15]

3.3.6 Importance of each high-debt episode

We want to assess whether a particular high-debt episode is the major driver of our baseline results regarding the state dependence of monetary policy shocks' effects on the economy, based on household indebtedness. In order to examine this systematically, we reclassify each of our four high debt episodes in our baseline case as low debt periods, one by one and conduct the analysis.

Figure 15 shows the response of GDP in both the high-debt and the low-debt state to a monetary policy shock for each of the four cases. First, note that the response of GDP in the low-debt state (red dot-dashed line) remains larger than the response in the high-debt state (blue dashed line) at most horizons in all cases. Second, note that the responses of GDP across the two states look very similar to our baseline results. The only exception is the case when we remove 1979q1-1980q4 from

[15] The literature has noted that excluding the pre-1984 sample helps to mitigate the prize puzzle. When we conduct the analysis excluding the pre-1984 sample, we still find evidence of larger effects of monetary policy in the low debt state on GDP.

the high-debt state. In that case the response of GDP is in fact negative in the high-debt state, but the 90 percent confidence bands are also larger. Overall, this suggests that our results are not driven by one particular outlier episode.

3.3.7 Extending the sample to include the Great Recession

While we have data available for all real variables, we are forced to end our sample in 2007q4 in the baseline case, since the federal funds rate is subject to the ZLB in the subsequent period. In order to additionally consider the sample period 2008q1-2015q3, we employ the *shadow* federal funds rate constructed by Wu and Xia (2016) for this sub-period. Note that in this case, our sample includes the Great Recession. In addition, as is apparent from Figure 1, our last high debt episode is now longer and lasts until 2011. Figure 16 shows the results from running the linear and the state-dependent models using our baseline monetary shock identification and specification over this longer sample period. The second column shows that for this longer sample, GDP, consumption and investment respond to the monetary policy shock with a persistent hump-shape. Also, both the debt-to-GDP ratio and house prices rise in response to the expansionary monetary shock. The last column shows the state-dependent responses. For horizons between 5- 10 quarters, the responses of GDP and its components are statistically significantly larger in the low-debt state than the high-debt state. Debt-to-GDP also rises more robustly in the low-debt state, and has a muted response in the high-debt state. The response of house prices however is virtually the same across the two different states.

3.4 Interaction of high debt periods with recessions

In this section, we dig deeper into our baseline findings about the state-dependent effects of monetary policy shocks, and consider whether the state of the economy plays an additional moderating role. Figure 1 shows the household debt-to-GDP ratio (solid line) and its trend (dashed line), and the grey shaded areas indicate the NBER recessions. It is clear that the recessionary episodes are distributed almost equally through both the high- and low-debt periods. Out of the nine recessionary episodes in the sample running until 2007q4, only three recessions occur completely in the high-debt state. If we extend the sample to the end of 2015, then the last episode, the Great Recession, occurs during the high-debt state. Tenreyro and Thwaites (2016) find empirical evidence that the effects of monetary policy on macroeconomic variables are more powerful in expansions than in recessions.[16] However, given the distribution of recessions across the two debt states, we can conclude that the results about the effectiveness of monetary policy being dependent on household indebtedness is not driven solely by the state of the economy.[17]

[16] They consider a sample period of 1969-2007, and identify shocks based on Romer and Romer (2004).

[17] Tenreyro and Thwaites (2016) also find that the effects of contractionary monetary policy shocks are larger than the effects of expansionary shocks. Figure 23 in the Appendix shows the distribution of both types of monetary shocks used in our analysis, and shows that we have rather similar looking distribution of shocks across the high and low debt states. This suggests that the specific distribution of shocks is also not driving our main results on state-dependence.

One might conjecture, though, that if the high-debt state occurs during a recession, then the effects could be exacerbated. This would mean that the relative effectiveness of monetary policy might worsen further during periods that are characterized as both a high-debt state and a recession. In order to test this conjecture, we run our state-dependent model, where we assume that the dummy variable I_{t-1} takes a value of 1 in Equation (2) when we are in the high-debt state *and* in an NBER recession, and 0 otherwise. For this exercise, we consider the longer sample, running until 2015q3, as described above among the robustness checks, in order to include additional high debt observations occurring during a recession. Note that only about 8 percent of observations constitute a high-debt and recession state.[18]

Figure 17 shows the impulse response functions using this new definition of the state, where we interact high debt and recession. The last column shows the state-dependent results, where the response to monetary shock in a high-debt/recession state are given by the blue dashed lines, and otherwise are given by the red dashed-dotted lines. In response to an expansionary shock, we now observe that GDP *falls* in the high debt/recession state, while it rises otherwise. This is also particularly striking in light of the federal funds rate response, which returns to steady state within a couple quarters in the high-debt/recession state. On the other hand, in the other state, federal funds rate has a much more persistent response and stays negative for longer. Consumption and investment also falls after a few quarters in the high debt/recession state. Debt-to-GDP and house prices have relatively muted responses in the high debt/recession state versus otherwise. Overall, this suggests that when we consider high debt states which are also characterized by a recession, the effectiveness of monetary policy is further reduced significantly.

In order to quantify the role of recessions, we compare the *cumulative* effects of monetary policy in the high-debt state, both for the case where we distinguish between recessions and where we do not. More precisely, Figure 18 shows the cumulative effects of monetary policy in the high-debt state (blue dashed line), where we do not draw any distinction between recessions and expansions.[19] In addition, Figure 18 also shows the cumulative effects in the high-debt/recession state (black dot-dashed line). The first column shows that, for all real variables with the exception of the debt-to-GDP ratio, the effects are smaller in the high debt/recession state. In particular, for GDP, consumption and investment, the cumulative effects are negative at longer horizons following an expansionary monetary shock. Note however, that the cumulative effects on the federal funds rate are also different in the two cases. Thus, in the second column we normalize for the effects on the federal funds rate. In that case too, however, we see that the cumulative effects on real variables are much smaller, particularly at longer horizons, in the high-debt/recession state versus the high-debt state.

We established earlier that the effectiveness of monetary policy is limited during a high-debt state. The results in this section show that this ineffectiveness is further exacerbated when the

[18] For the sample period 1955-2007, this constitutes only 6 percent of the sample.

[19] Note, these are the same cumulative effects as in the high debt state shown in Figure 4, except that we are now considering a longer sample that runs until the end of 2015.

high-debt state coincides with a recession. In fact, if the state of the economy characterized by both high level of indebtedness and recession, expansionary monetary policy can have negative effects on GDP.

4 Small-scale model with debt overhang

In this section, we build a small-scale, partial-equilibrium, endowment-economy model to illustrate some of the key channels of the monetary policy transmission mechanism that operate through *borrower* households, and examine how the effectiveness of these channels change based on the initial debt stock of borrowers. The model features long-term mortgage contracts as in Kydland et al. (2012), and allows for home equity extraction within this set-up similar to Alpanda and Zubairy (2016). The model is purposefully kept simple and partial equilibrium to focus on the effects of a policy rate cut on the interest burden of borrowers (i.e., interest rate channel), and their new borrowing through home-equity loans (i.e., home-equity loan channel). In Appendix F, we present an extension of the model in a general equilibrium setup, and show that the baseline results regarding the weakening of monetary policy under high debt levels still stand.

4.1 A partial equilibrium model

The borrowers' period budget constraint is given by

$$c_t + q_t \left(h_t - h_{t-1}\right) + \left(R_{t-1} + \kappa\right) \frac{D_{t-1}}{P_t} \leq y + \frac{L_t}{P_t}, \tag{3}$$

where c_t and h_t denote real consumption and housing, respectively, and q_t is the relative price of housing. D_{t-1} denotes the nominal stock of debt carried from the previous period, and P_t is the price level. For simplicity, we assume that the price level increases at a constant rate of π, and the real endowment income level, y, is a constant each period. Borrowers pay a pre-determined interest rate of R_{t-1} on their debt, along with a κ percent of its principal each period. L_t is the amount of new borrowing in nominal terms, and is related to the stock of debt as

$$D_t = \left(1 - \kappa\right) D_{t-1} + L_t. \tag{4}$$

We assume that borrowers are allowed to extract from their housing equity; hence they face a borrowing constraint of the form

$$L_t \leq \max\left\{0, \phi P_t q_t h_t - \left(1 - \kappa\right) D_{t-1}\right\}, \tag{5}$$

where the max operator captures the notion that agents become borrowing constrained when they do not have adequate equity in their houses. Note that $1 - \phi$ percent of the house value has been pledged as collateral for the original mortgage, and thus cannot be pledged against home equity loans taken on top of the first lien.[20]

The borrowers' preferences are represented by the period utility function $u(c_t, h_t)$, and they discount the future at a rate of $\beta < 1$. For simplicity, we abstract from residential investment in our model by assuming that housing does not depreciate and its supply is a constant, $\overline{h}$. Hence, in equilibrium, we will have $h_t = \overline{h}$ for all t.

To close the model, we specify stochastic processes for the interest rate and house prices. We assume that the policy rate follows an AR(1) process with a persistence parameter ρ_R:

$$R_t = (1 - \rho_R) R + \rho_R R_{t-1} + \varepsilon_{R,t}. \tag{6}$$

House prices also follow an AR(1) process, but we allow for a feedback effect from interest rates to house prices as

$$\log q_t = \rho_q \log q_{t-1} + \varepsilon_{q,t} - \rho_{qR} \left(R_{t-1} - \overline{R} \right), \tag{7}$$

where ρ_{qR} captures the notion that an expansionary policy shock would also lead to an increase in house prices with a lag.[21]

4.2 Solution of the model

Assuming the utility function obeys the usual conditions (e.g., strictly increasing and concave), the borrowing constraint binds every period as long as agents discount the future sufficiently (i.e., $\beta << 1/(1+R)$). We follow Iacoviello (2005), and assume this holds. The law of motion of debt in (4) and the borrowing constraint in (5) can now be combined to solve for the policy functions for the debt stock in equilibrium:

$$d_t = \begin{cases} \frac{1-\kappa}{\pi} d_{t-1} \text{ if } d_{t-1} > \frac{\pi\phi}{1-\kappa} q_t h \\ \phi q_t h \quad \text{ if } d_{t-1} \leq \frac{\pi\phi}{1-\kappa} q_t h \end{cases}, \tag{8}$$

where $d_t = D_t/P_t$ denotes the real stock of debt. In particular, when debt levels are sufficiently high, agents cannot borrow more, so they start to slowly deleverage by paying off a portion of their principal each period, reminiscent of a debt overhang. When debt levels are low however, they borrow against housing equity up to the allowed loan-to-value ratio, ϕ. This implies that the response of debt to a change in house prices in our model will be asymmetric, conditional on the existing level of debt and home equity. This asymmetry is similar to that assumed in Justiniano et al. (2015), but here depends on the debt level (instead of the change in house prices) and is derived explicitly using long-term mortgage contracts.

The consumption level of agents can now be solved using their budget constraint in (3). Note

[20]Similarly, if agents build home equity through a house price increase, they cannot pledge more than ϕ percent of this increase as collateral when extracting equity.

[21]Note that in the above formulation, we have also assumed, without loss of generality, that the steady-state value of house prices, q, is equal to 1.

that the asymmetry in the debt evolution of agents will affect their consumption profile as well:

$$c_t = \begin{cases} y - \frac{R_{t-1}+\kappa}{\pi} d_{t-1} & \text{if } d_{t-1} > \frac{\pi\phi}{1-\kappa} q_t h \\ y + \phi q_t h - \frac{1+R_{t-1}}{\pi} d_{t-1} & \text{if } d_{t-1} \leq \frac{\pi\phi}{1-\kappa} q_t h \end{cases} . \tag{9}$$

We can now investigate how an expansionary monetary policy shock would affect borrowers' consumption in this simple set-up. At the impact period $t = 0$, there is no change in consumption, since the interest paid on the debt is pre-determined and the interest rate is assumed to affect house prices only with a lag (see equation 7). For periods following the impact period, the derivative of consumption with respect to the policy rate is given by

$$\frac{\partial c_t}{\partial R_{t-1}} = \begin{cases} -\frac{1}{\pi} d_{t-1} & \text{if } d_{t-1} > \frac{\pi\phi}{1-\kappa} q_t h \\ -\frac{1}{\pi} d_{t-1} + \phi h \frac{\partial q_t}{\partial R_{t-1}} & \text{if } d_{t-1} \leq \frac{\pi\phi}{1-\kappa} q_t h \end{cases} \quad \text{for } t > 0. \tag{10}$$

This highlights that the effects on consumption are through two channels. First, the decline in interest rates have a direct income effect by reducing the interest burden of borrowers. This channel is stronger when the initial debt stock is larger, since the same rate cut would lead to a larger decline in the borrowers' interest burden. The second channel is due to the effect of interest rates on house values, whereby a decline in rates increases the home equity of agents, allowing them to borrow further. This channel is not operational however when debt levels are high; thus, the effectiveness of monetary policy can be curtailed with high levels of existing debt, reminiscent of a debt overhang on borrower households.[22]

4.3 Parameterization and impulse responses

To illustrate the aforementioned channels quantitatively, we first parameterize our model, and then present the impulse responses to a 25 bps (i.e., 100 bps in annualized terms) monetary policy shock.

We set the structural parameters to fairly standard values. The steady-state interest rate, R, is set 0.01, reflecting a 4 percent nominal interest rate in annualized terms. The constant inflation factor, π, is set to 1.005, reflecting 2 percent annual inflation. Without loss of generality, the level of output, y, is normalized to 1. The share of debt principal paid out every period, κ, is set to 0.01, reflecting an average loan duration of 25 years. The LTV ratio for new housing purchases, ϕ, is set to 90 percent . These values imply that the borrowers' steady-state housing-to-income and debt-to-income ratios in annualized terms are 1 and 0.9, respectively. Finally, for the exogenous processes on interest rates and house prices, we set the persistence parameters as 0.85 and 0.5, respectively, while we set the response coefficient of house prices to interest rates, ρ_{qR}, to 0, to isolate the effects

[22]Our borrowing constraint formulation above assumes a constant cost of borrowing up to the limit, after which no further borrowing is allowed (i.e., an infinite cost of borrowing). In fact, all that is required for the above results to go through is an increasing and convex cost function, which would generate an increase in the marginal cost of borrowing as initial debt levels rise. This may be motivated, for example, by an increase in the default risk premium charged by lenders as the borrower gets more leveraged, similar to the agency cost models of Carlstrom and Fuerst (1997) and Bernanke et al. (1999).

of the interest rate channel. Later, we set this latter parameter to 4 in our simulations to ensure that an annualized 100 bps decline in policy rates leads to a peak response in house prices of 1.4 percent, as found in the empirical analysis in Section 3.

Figure 19 plots the impulse responses of model variables to an annualized 100 bps innovation in the monetary policy shock in the absence of feedback effects to house prices (i.e., $\rho_{qR} = 0$).[23] In this case, the home equity channel is completely shut off, and only the interest rate channel is operational. We compare the impulse responses starting from two initial levels of debt; the first is the steady state level of debt, corresponding to an initial debt-to-annual income ratio of 1 , and the second is a case where the initial debt level is 20 percent above the steady state. Since there is no change in house prices, the expansionary monetary policy shock does not lead to additional borrowing. (Note that borrowing levels are positive, but there is no new *additional* borrowing as a result of the monetary shock.) The increase in consumption is simply due to the increase in disposable income, given the decline in the interest burden of debt. As expected, in this case, monetary policy is more effective when the initial level of debt is higher, since the decline in the interest rate leads to a larger income effect, and therefore, to a bigger boost in consumption.

When house prices respond to the interest rate (i.e., $\rho_{qR} = 4$), the home equity channel is also operational, but only when initial debt levels are low and the agent carries adequate home equity. In our example, this channel more than compensates for the stronger effect of the interest rate channel under high debt (see Figure 20). In particular, now, the increase in house prices leads to an increase in new borrowing and consumption, but only in the low debt case. With high initial debt, this channel is not operational (at least for the first 10 quarters following the shock) despite the increase in home equity, and therefore the impact of a monetary policy shock on consumption is lower. With high initial debt, the agents de-leverage for the first 10 quarters and build enough equity so as to be able to start borrowing again, but by that time the impact of monetary shock is already muted. Note that, in fact, the equilibrium level of home equity increases more in the high initial debt case relative to low initial debt, since, in the latter case, part of the increase in home equity is extracted through home equity loans. Note also that the stronger response of consumption under low initial debt lasts for several periods, but consumption slowly declines below the high initial debt case in the following periods, as the new debt accumulated in the former case now needs to be paid back with interest.

4.4 Considering a distribution over initial debt levels

In the discussion above, we only considered two initial debt levels, but the results are unaltered if we instead consider the whole distribution of initial debt across borrowers shifting to the right. In particular, suppose initial debt across agents is distributed normally with mean μ and a standard

[23] The impulse responses from different initial debt levels are computed by simulating the model separately with and without the monetary shock, and then taking the difference of these paths (i.e., "shock minus control"). Thus, the transition path to steady state implied under the no shock scenario has already been excluded from the impulse responses.

deviation of σ. Given our calibration, the threshold debt level that determines whether an agent can extract home equity or not is given by $\frac{\pi\phi}{1-\kappa}qh$, which is equal to 3.65 at the steady state with $q = 1$ (which corresponds to a debt-to-income ratio of 0.914 in annualized terms). In what follows, we fix the standard deviation of the initial debt distribution, σ, to 10% of this threshold, and compare how the impulse responses of *aggregate* variables differ as we change the mean of the initial debt distribution, μ. In particular, we consider a low mean of $\mu_L = 3.65$, corresponding to the debt threshold calculated above, and a high mean of $\mu_H = 4.39$, which is 20% above μ_L.

Figure 21 compares the impulse responses of variables, aggregated over all agents in the distribution, when $\mu = \mu_L$ versus $\mu = \mu_H$; thus, we are considering a 10% increase in debt levels across the board. Overall, the results are similar to those we obtained previously. In particular, the responses of borrowing and consumption are weaker under μ_H due to the higher share of agents that cannot extract home equity (shown in the last panel of the figure). In particular, with μ_L, 50% of agents have enough home equity to borrow further at the impact period of the shock, while with μ_H, a far smaller share of agents can extract equity initially. Over time, agents build equity, and the share of agents extracting equity rises to 1, as the economy converges to the steady state. During the transition path however, some agents are fully constrained and cannot extract equity under both μ_L and μ_H, but much more so under μ_H.

4.5 Discussion

Our partial equilibrium model described above is illustrative, and abstracts from other channels that may also be potentially important. First, in our set-up, all debt is adjustable rate, which likely exaggerates the favorable impact of the interest rate channel. If mortgage contracts carry fixed interest rates, the interest burden of existing mortgage borrowers would not decline unless refinancing is allowed and can be undertaken at a low cost. This refinancing channel would also become weaker when households carry a large initial debt burden, since refinancing becomes costlier (or outright impossible) when borrowers have low or negative levels of home equity (Beraja et al., 2015). Thus, a more elaborate set-up with fixed mortgage rates and refinancing would have similar, if not stronger, implications regarding the weakening of monetary policy under high initial debt relative to our set-up above.

Second, in the partial equilibrium set-up, we have assumed an exogenous relationship between interest rates and house prices, but this link could crucially depend on the amount of housing demand. If existing levels of high debt restricts this demand coming from borrower households, the impact on house prices would likely be muted as well. This, in turn, would lead to a further weakening in the home equity channel, and thus lower monetary policy effectiveness, as initial debt levels grow. This suggests that endogenizing house price formation in our set-up would likely not overturn the main conclusion, and may even strengthen it.

Third, a rate cut would also lead to a small increase in the inflation rate, thereby reducing the *real* debt burden of borrowers through the debt-deflation effect (Fisher, 1933). Other things equal, this favorable effect would be stronger when the initial debt stock is larger, thereby increasing the effectiveness of a rate cut. We abstract from this channel by setting the inflation rate to a constant. Note however that the evidence for monetary policy's impact on inflation is rather mixed. In particular, many VAR studies, as well as our empirical analysis in sections 2 and 3, point to an initial decrease in inflation following monetary easing, a notion that has been dubbed as the "price puzzle". Incorporating this initial decrease in inflation would slightly strengthen our results for the short term by further weakening the effectiveness of monetary policy under high initial debt levels, but this would also weaken our results in the medium term. Instead, we assume a constant inflation rate in our model, and abstract from the debt-deflation effect altogether.

Fourth, in our simple model, we assumed that the borrowing constraint would always bind since agents discount the future more than the prevailing interest rate. Thus, in equilibrium agents borrow up to the limit of their home equity line of credit as long as this limit is positive. Empirical data however suggests that agents tend to build some equity over time, and not all available home equity is extracted (Greenspan and Kennedy, 2005; 2007). Our results would likely become weaker if the home equity extraction rate is less than 1.

Fifth, the model also abstracts from residential investment, and does not allow for new mortgage lending except for home equity loans taken on top of the first lien. In a world where home equity loans can also be used to finance residential investment expenditures (e.g., to cover maintenance costs or to finance the down-payment on a secondary home or an investment property), the effects of monetary policy on residential investment will also become more muted as initial debt levels increase.

Sixth, there are possible interactions with housing-related fiscal policy that may attenuate the effects of monetary policy. For instance, as interest rates fall, agents would be able to deduct less mortgage interest, which would increase their overall tax burden on their income. This adverse effect will be larger when existing debt levels are high.[24]

Finally, the model abstracts from "saver" households which would provide the financing to the borrowers in our model. The decline in interest rates would also impact the consumption smoothing and investment patterns of these households. In particular, the resulting decline in the interest income of savers and the increase in house prices would likely offset some of the increase in demand coming from borrower households, and this adverse effect would likely be stronger as the existing stock of debt is higher.[25]

In Appendix E, we consider a general equilibrium version of the model to incorporate some of these considerations into our model. In particular, the general equilibrium model features saver households who provide the financing to borrowers, and features endogenous house price formation

[24]Similarly, property tax payments increase along with the increase in house prices. If the existing levels of debt and housing stocks are correlated, this effect by itself could also attenuate the effectiveness of monetary policy under high levels of debt.

[25]Transmission of monetary policy operates through many other channels that our model abstracts from (such as the exchange rates), but it is unlikely that the strength of these transmission mechanisms would be modified based on the degree of existing household debt.

and variable (and endogenously determined) inflation rates. Our results indicate that our main conclusions are robust to these changes in the model.

4.6 Additional evidence on the home-equity channel

Our theoretical model presented above suggests that the weakening of the home-equity loan channel may be a possible reason for the decline in monetary policy effectiveness when initial debt levels are high. In this subsection, we empirically test this idea using the state-dependent model of Section 2, and explore whether the impulse response of home-equity extractions to a monetary shock features state-dependence with respect to household debt. Since a considerable portion of home-equity extractions are associated with refinancing activity, we also explore state dependence with respect to refinancing (Alpanda and Zubairy, 2016).

Note that the available data we have on home-equity loans and refinancing activity are limited, with a shorter time series spanning 1990-2015. In what follows, we conduct our baseline analysis over this shorter sample period. Figure 22 shows the impulse responses of federal funds rate, GDP and inflation in the first three rows, and also shows the responses of home-equity loans (HE loans), which is defined as home-equity loans as a ratio of total household debt, and refinancing, which is data on all refinancing mortgage originations from the Mortgage Bankers Association.

The middle column shows impulse responses from the linear model. Note that in this shorter sample of 1990-2015, in response to a monetary policy shock, we see a muted response of GDP, which is in fact negative at many horizons.[26] The response of home-equity loans is negative on impact and rises slowly, while refinancing goes up on impact. The last column shows the responses from the state-dependent model. In the high-debt state (blue dashed response), the response of GDP is once again smaller than the response in the low-debt state (red dot-dashed), and is in fact negative, while it is positive in the low-debt state. The state-dependent responses also suggest that in response to expansionary monetary policy, both home equity loans and refinancing activity increase much more in the low-debt state relative to the high-debt state, where the difference in the home-equity loan response is in the longer horizons, and the difference in the refinancing response is on impact and at shorter horizons.

Given the short sample and the problems associated with identification of monetary policy shocks in the more recent samples discussed above, we view this exercise as suggestive evidence that supports the basic transmission mechanism we highlight, but deserves further attention that is beyond the scope of this paper.

[26]This is consistent with findings in other papers that focus on this period. For example, Ramey (2016) shows that for this and shorter sample periods starting in 1990s, expansionary monetary policy shocks under some identifications can have negative effects on GDP. In order to deal with this identification issue, which possibly arises due to expectations regarding monetary policy changes, some papers use high frequency identification methods (Gertler and Karadi, 2015).

5 Conclusion

In this paper, we use a state-dependent time-series model to find that the effectiveness of monetary policy in the U.S. is curtailed during periods of high household debt. These results are robust to alternative definitions of high- and low-debt periods, and two leading methodologies of identification of monetary policy shocks. Our small-scale theoretical set-up highlights one possible channel as to why this may occur; namely that higher initial debt levels may slow down the increase in home equity extractions when policy rates are cut.

Our results indicate that the effectiveness of monetary policy was likely hindered during the recent recession, given the significant amount of debt households had accumulated previously. Our results also suggest that, in general, when high levels of leverage accompany recessions, alternative tools to monetary policy should also be considered in order to stimulate the economy.

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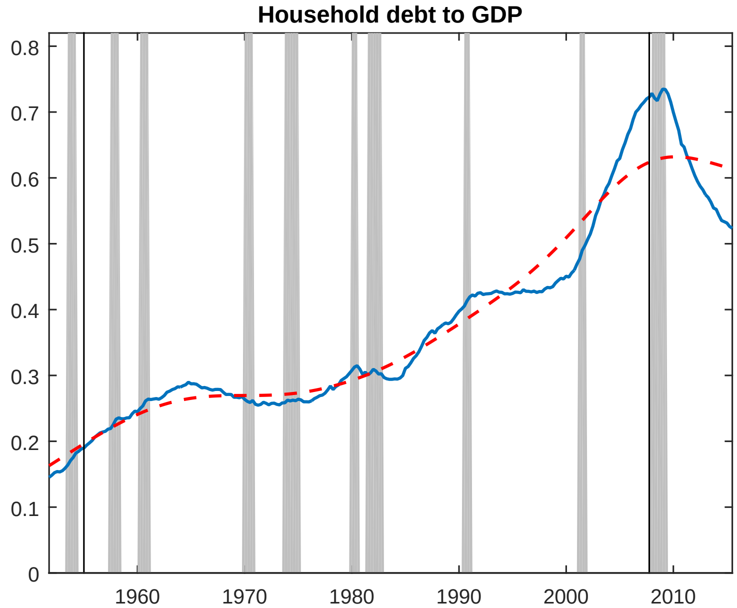

Figure 1: Household debt to GDP ratio, for the full sample, 1951q2-2015q3. The trend (red dashed) is constructed by running a HP filter with a very high smoothing parameter, 10^4. The vertical lines mark 1955q1, start of the sample and 2007q4, the end of the sample used in the baseline estimation. The grey shaded regions indicate NBER recession dates.

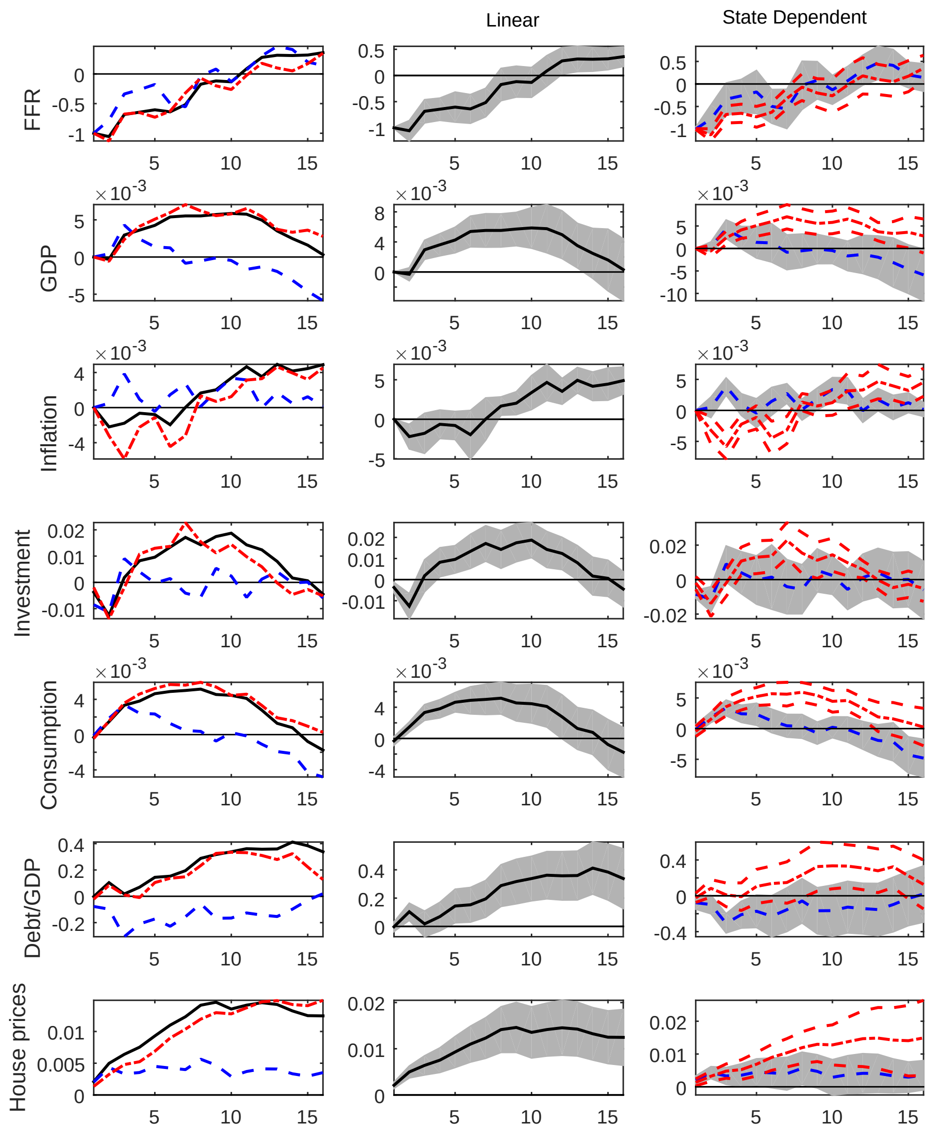

Figure 2: IRFs to a monetary shock identified with timing restrictions. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

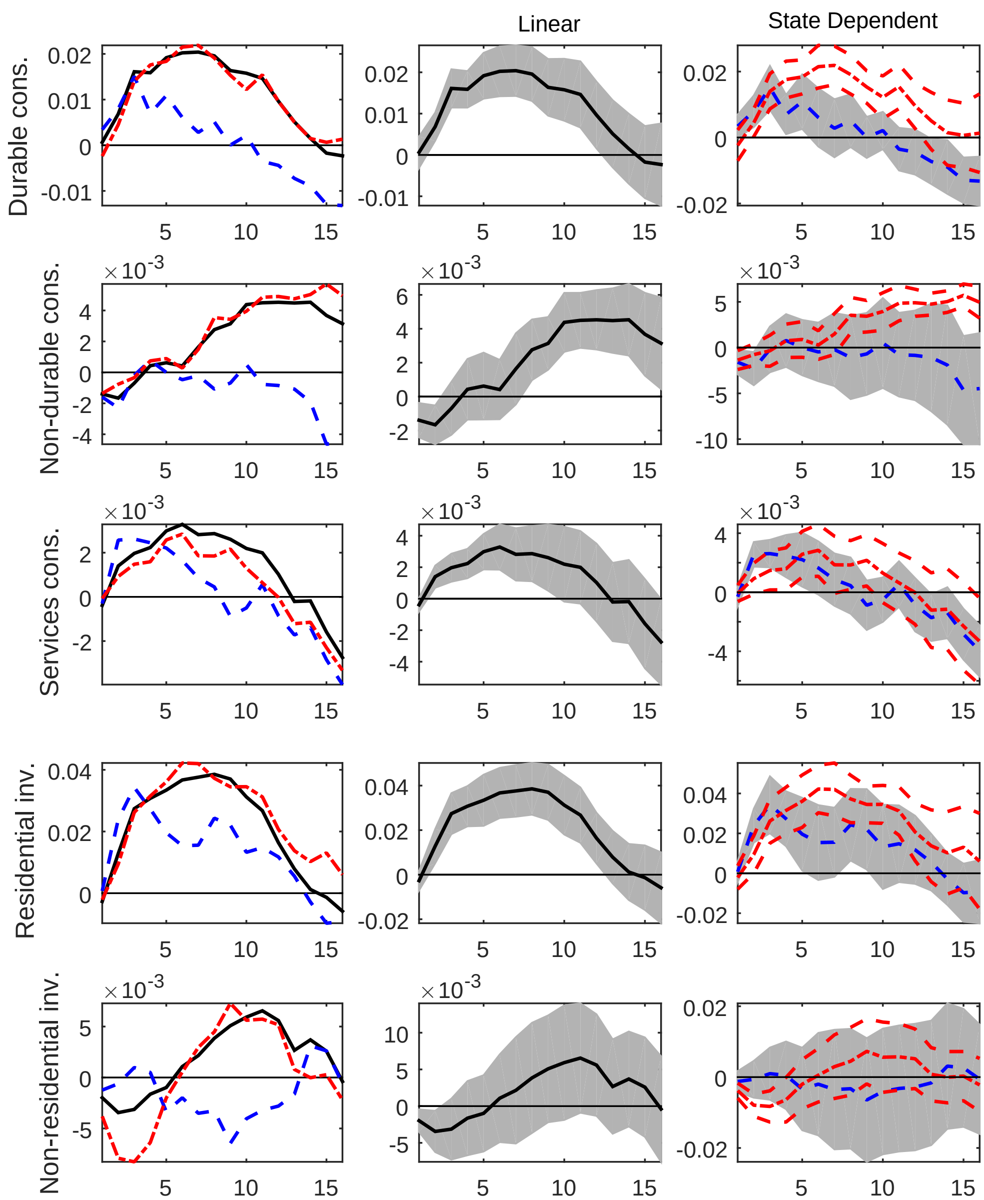

Figure 3: IRFs to a monetary shock identified with timing restrictions. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

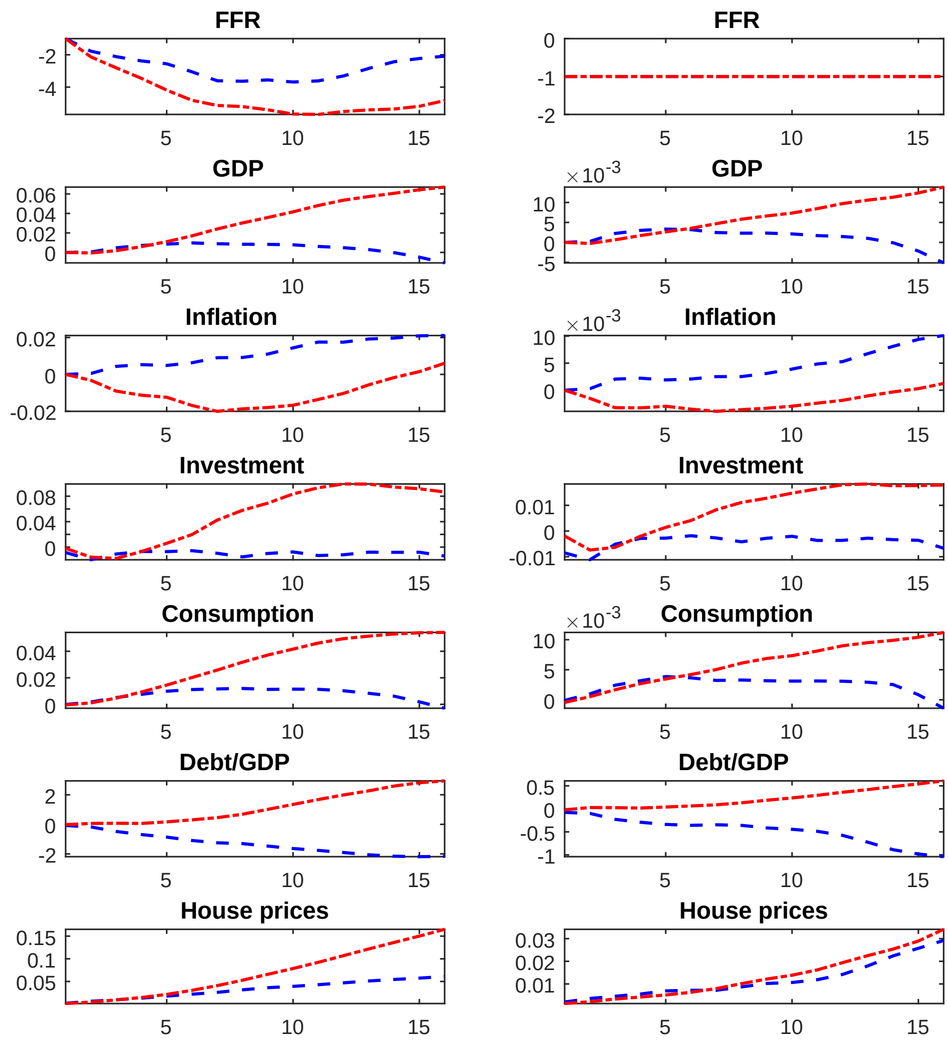

Figure 4: Cumulative effects of a monetary shock identified with timing restrictions. The first column shows the cumulative effects of a monetary shock on a variable in high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the cumulative effect of a monetary shock on a variable normalized by the cumulative response of federal funds rate in that particular state, for high debt (blue dashed) and low debt (red dot-dashed) state.

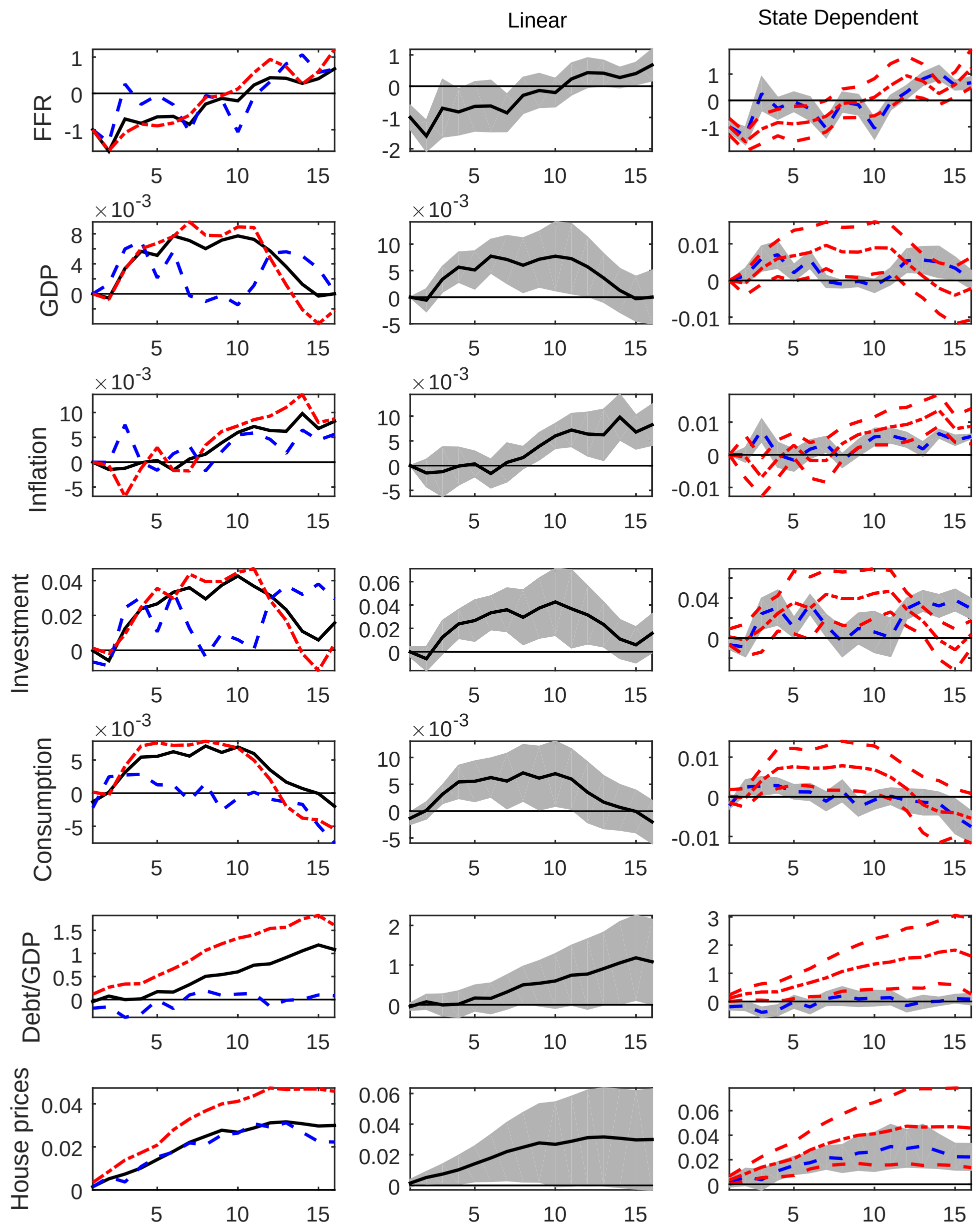

Figure 5: IRFs to a monetary shock identified as in Romer and Romer (2004), for the sample 1969q1-2007q4. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

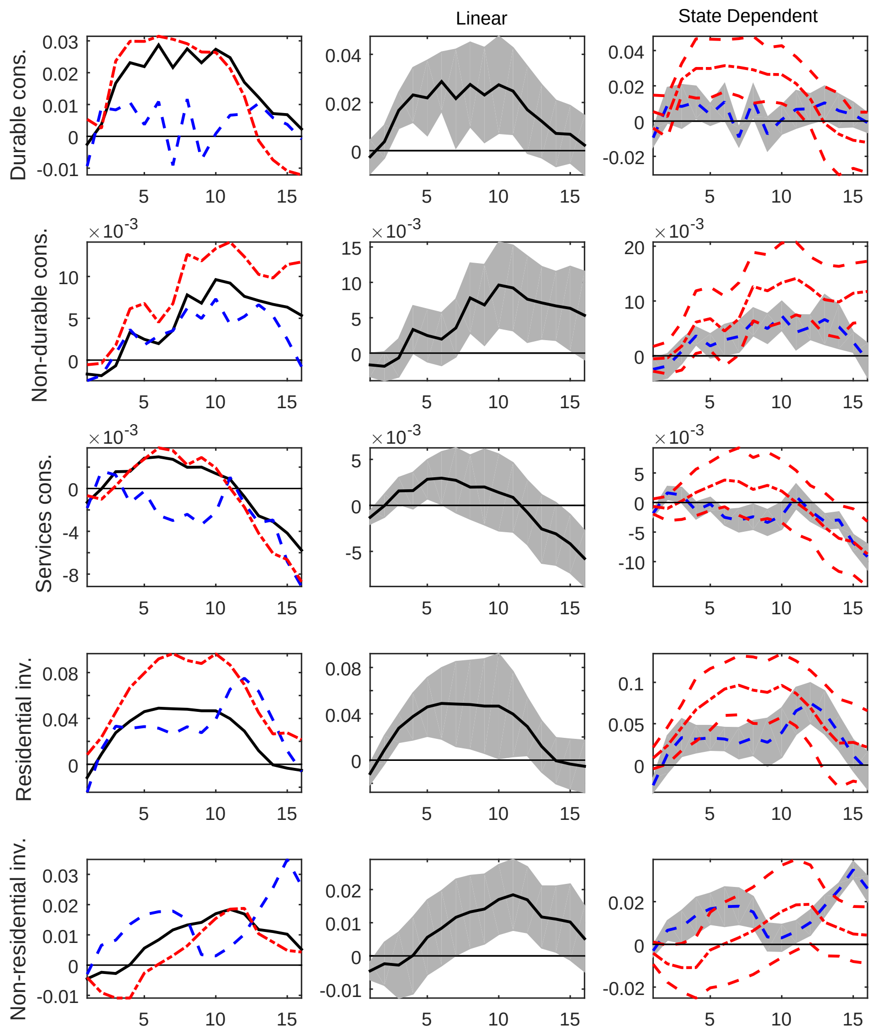

Figure 6: IRFs to a monetary shock identified as in Romer and Romer (2004), for the sample 1969q1-2007q4. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

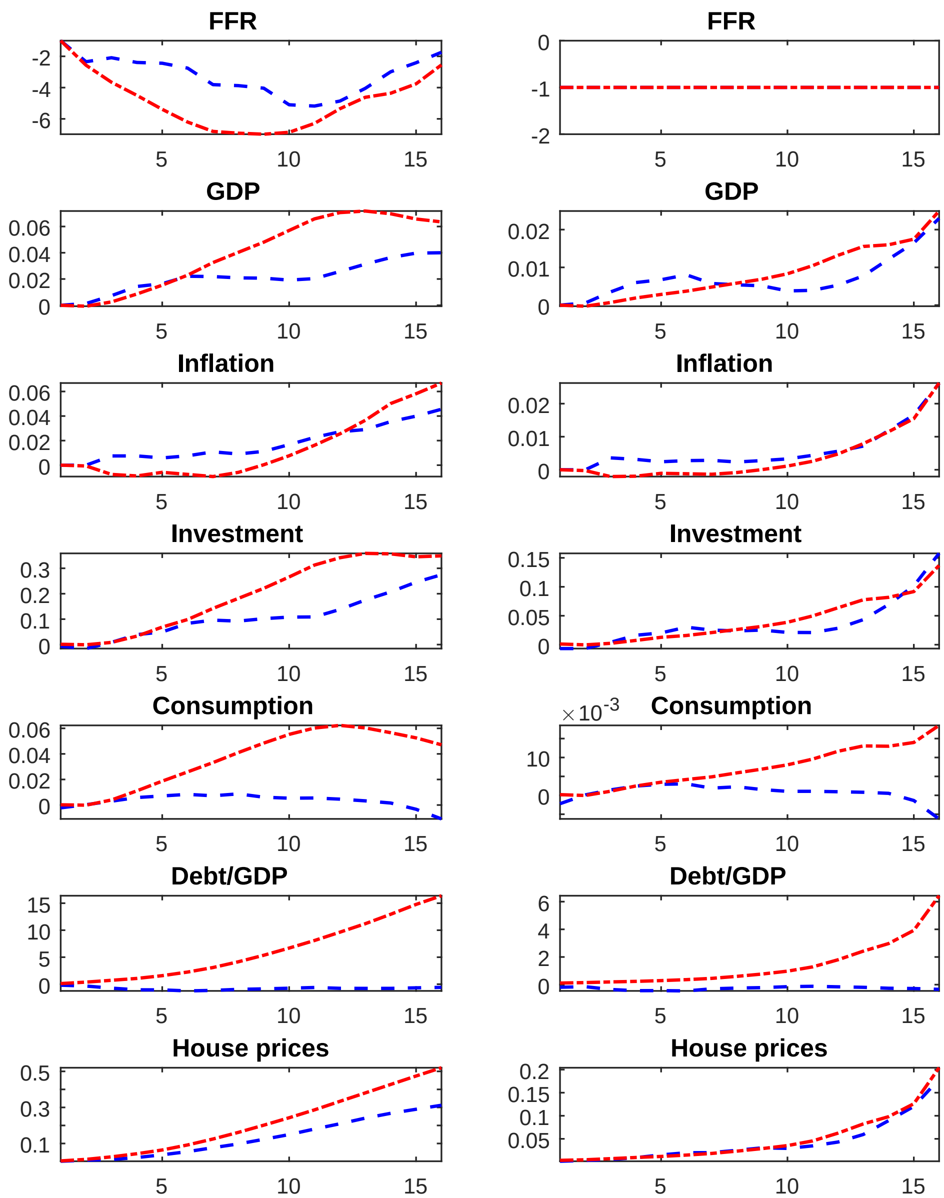

Figure 7: Cumulative effects of a monetary shock identified as in Romer and Romer (2004), for the sample 1969q1-2007q4. The first column shows the cumulative effects of a monetary shock on a variable in high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the cumulative effect of a monetary shock on a variable normalized by the cumulative response of federal funds rate in that particular state, for high debt (blue dashed) and low debt (red dot-dashed) state.

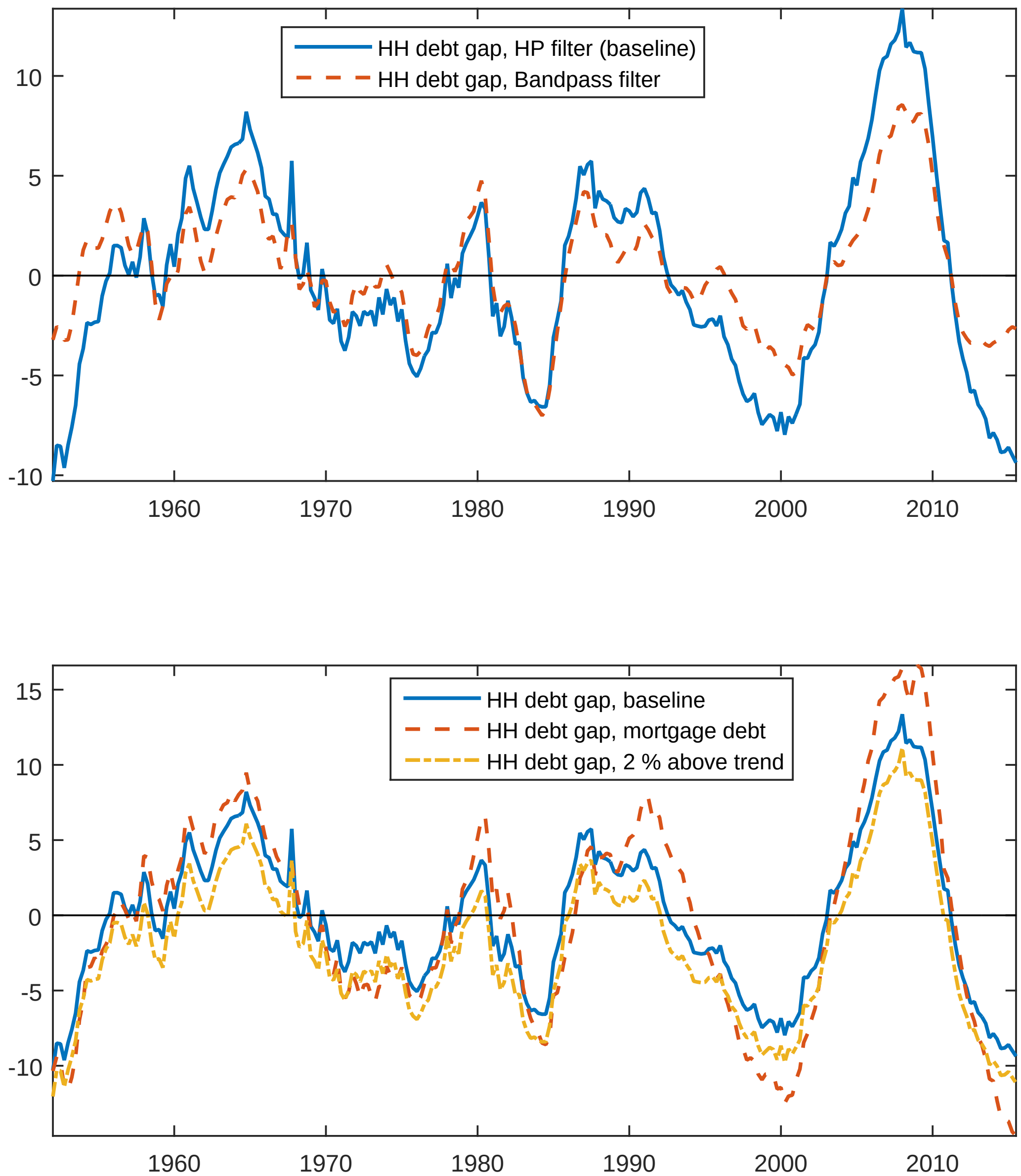

Figure 8: Robustness check: Comparing our baseline debt gap with alternative definitions of the debt gap. The top panel shows the baseline debt gap (solid line), constructed using the HP filter with $\lambda = 10^4$ and an alternative measure of debt gap using a bandpass filter (dashed line), with frequencies between 4 and 64 quarters. The bottom panel shows the baseline debt gap (solid line), debt gap with mortgage debt as state variable instead of total household debt (dashed line) and debt gap with high debt state defined as being 2 percent above our baseline trend (dot-dashed line).

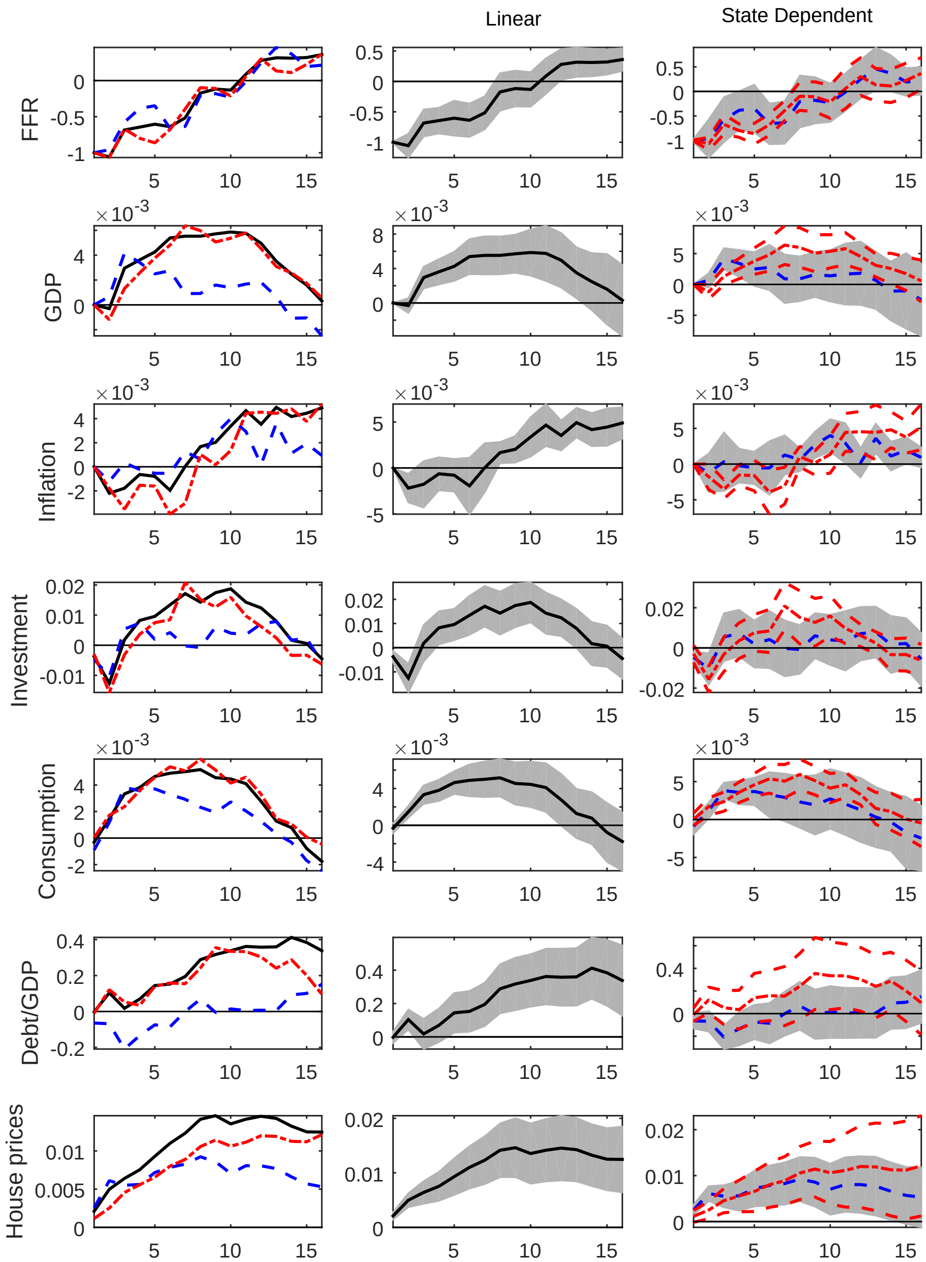

Figure 9: Robustness check: IRFs to a monetary shock identified with timing restrictions, using BP filter to get high and low debt states. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

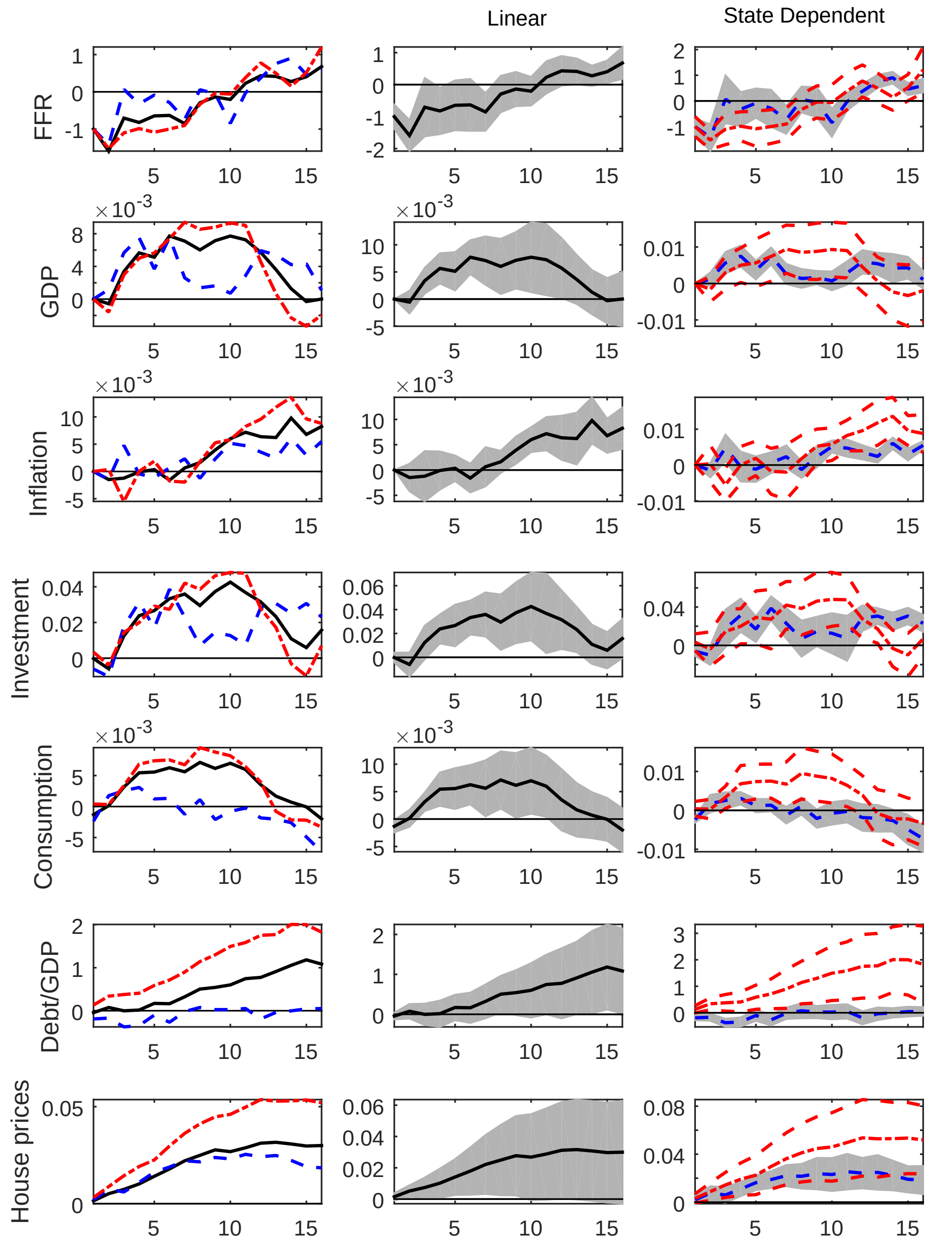

Figure 10: Robustness check: IRFs to a monetary shock identified as in Romer and Romer (2004), for the sample 1969q1-2007q4, using BP filter to get high and low debt states. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

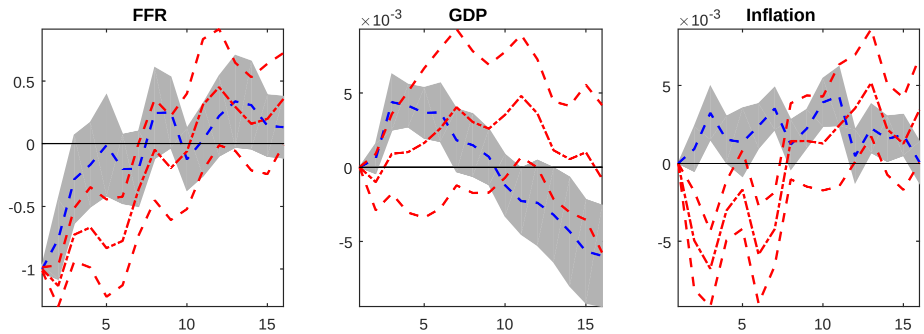

Figure 11: Robustness check: IRFs to a monetary shock with mortgage debt as a state variable. The figure shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

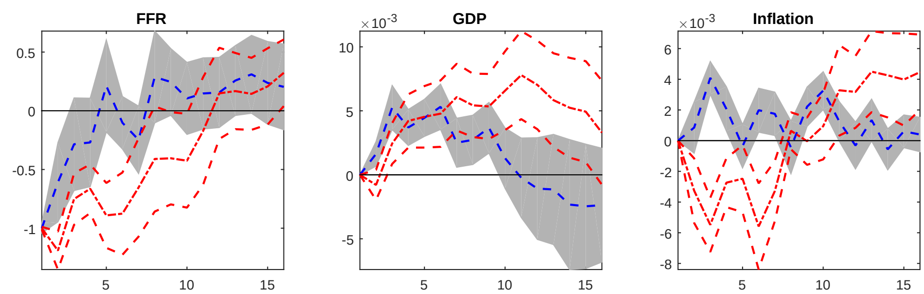

Figure 12: Robustness check: IRFs to a monetary shock with high debt state defined as being 2 percent above trend. The figure shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

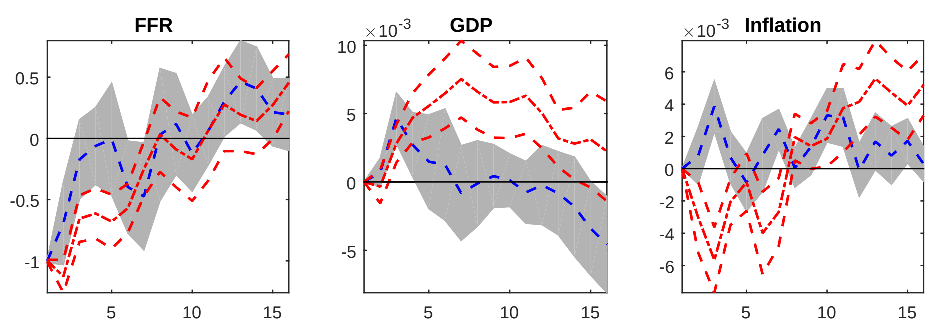

Figure 13: Robustness check: IRFs to a monetary shock with debt as control variables. The figure shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

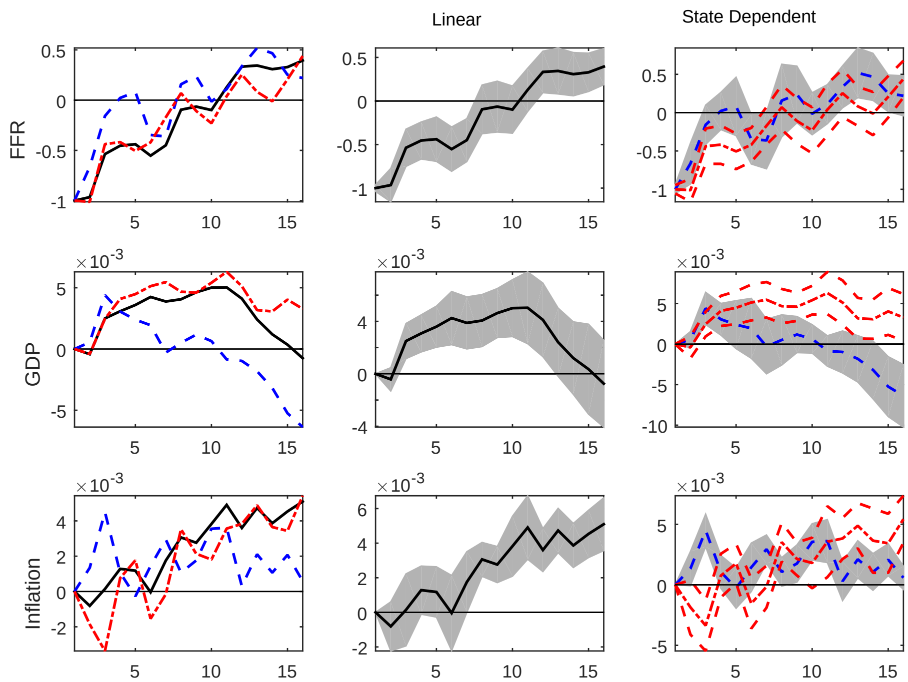

Figure 14: Robustness check: IRFs to a monetary shock with commodity prices as an additional control for dealing with price puzzle. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

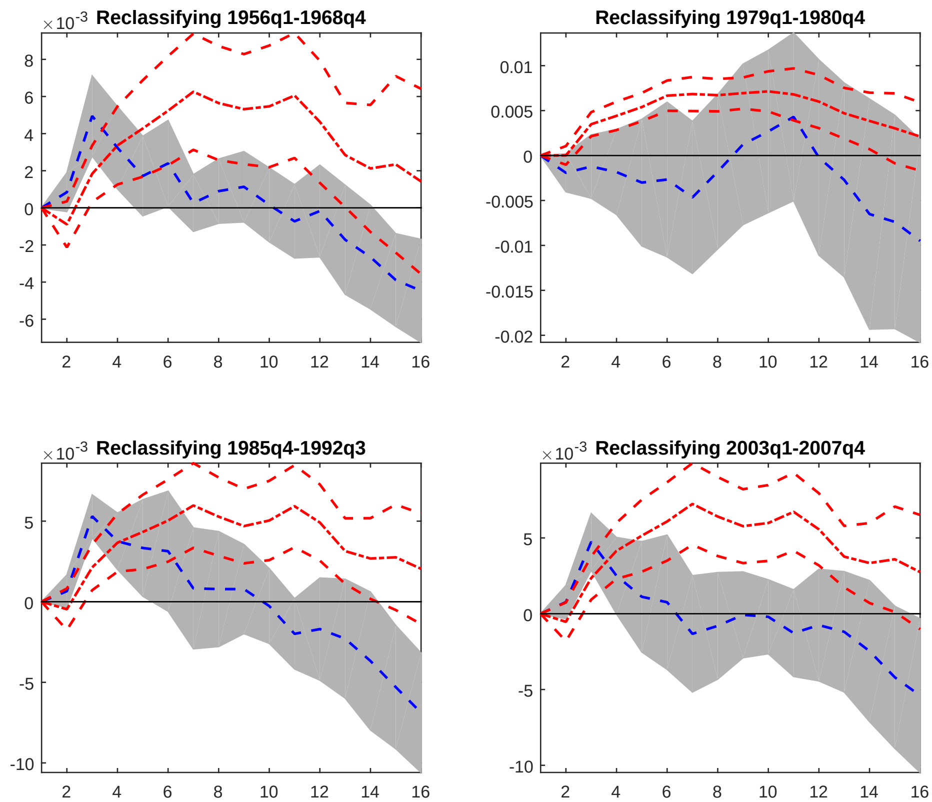

Figure 15: Robustness check: IRFs of GDP to a monetary shock in the high debt (blue dashed) and low debt (red dot-dashed) state for the sample where we re-classify the specified period from a high debt state to a low debt state. The state dependent IRFs are shown with their respective 90% confidence band.

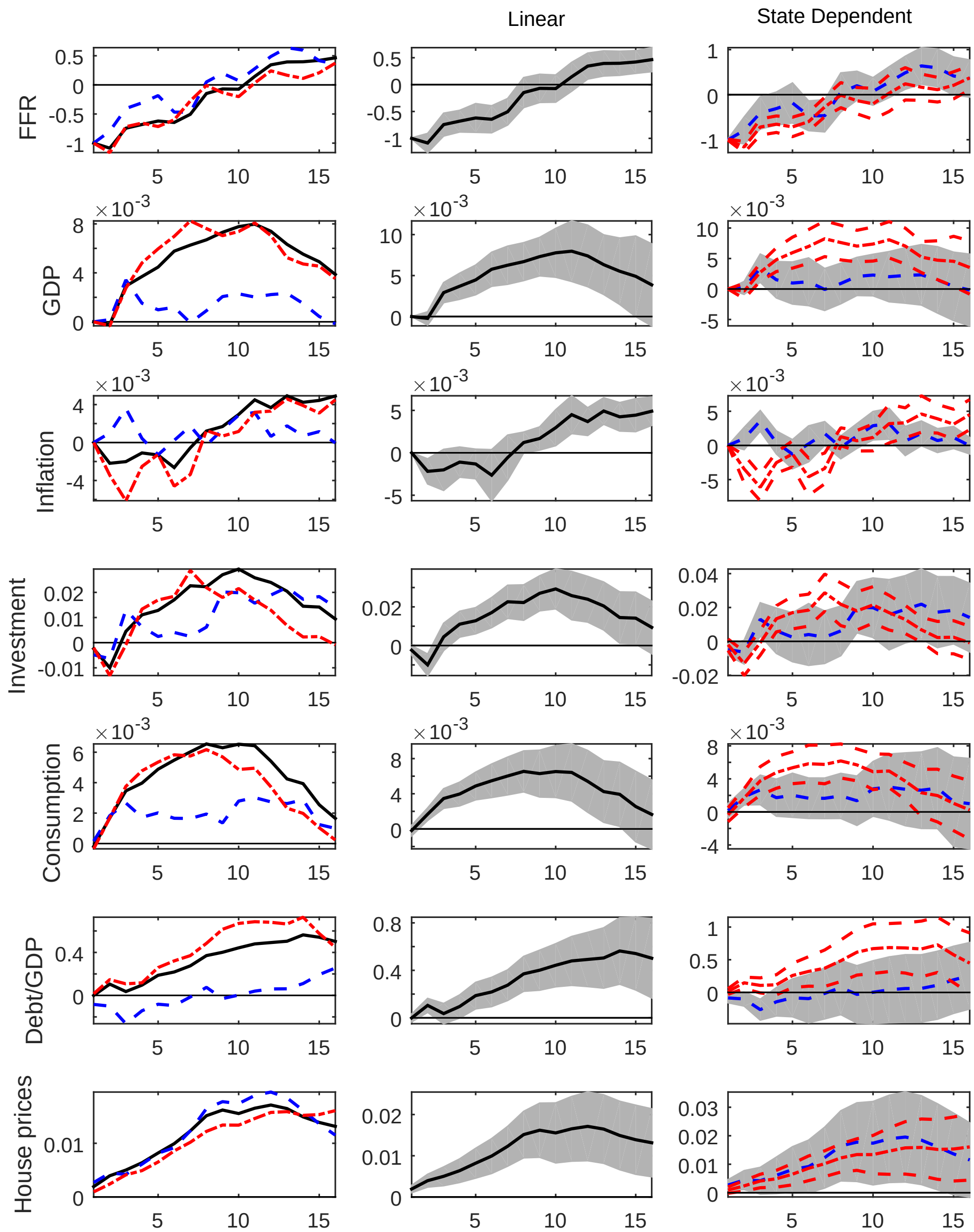

Figure 16: Robustness check: IRFs to a monetary shock with our baseline specification, for a longer sample, 1955q1-2015q3. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

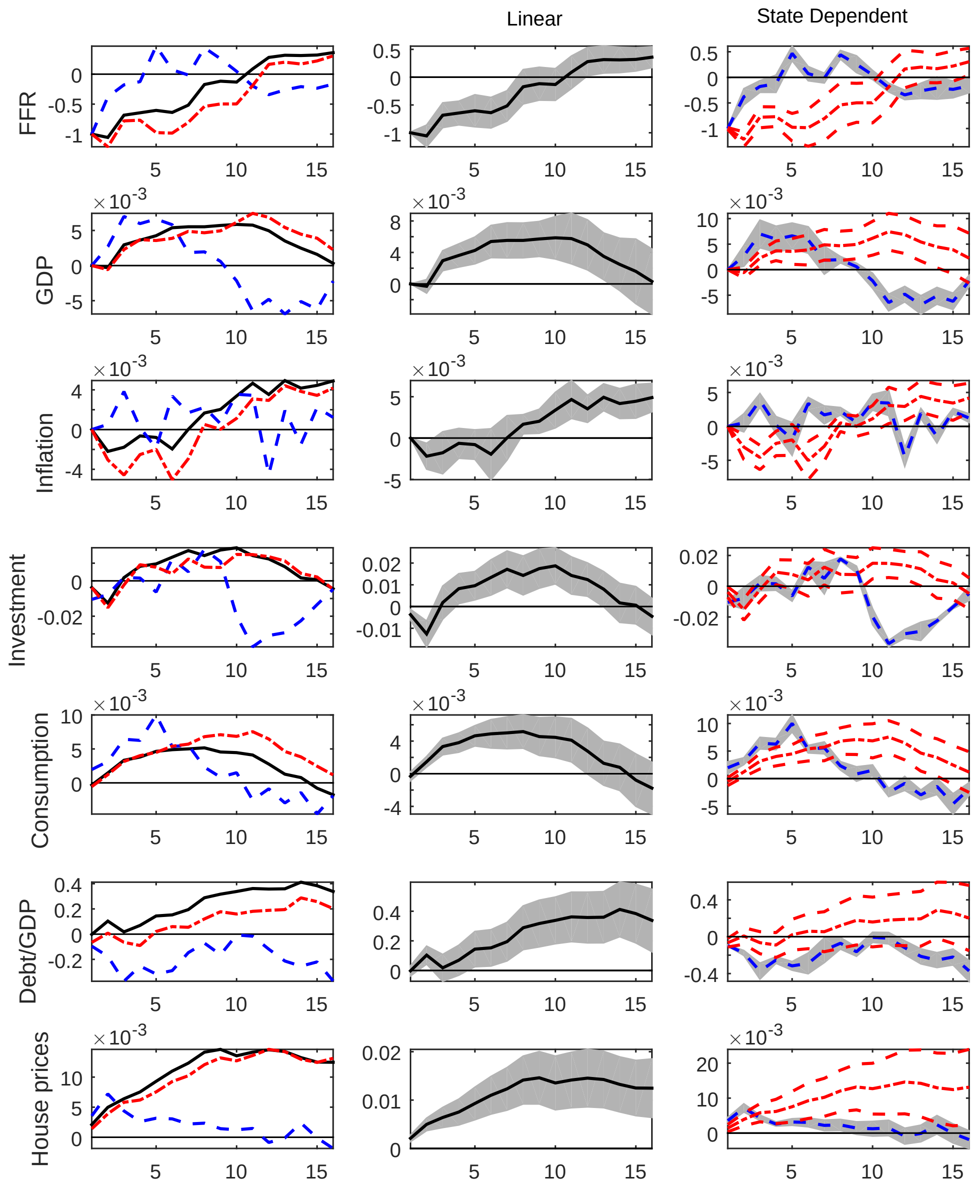

Figure 17: Robustness check: IRFs to a monetary shock for high debt states coinciding with recession and otherwise, for a longer sample, 1955q1-2015q3. The first column shows the point estimate for IRFs in linear (black solid), high debt and recession (blue dashed) and otherwise (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band.

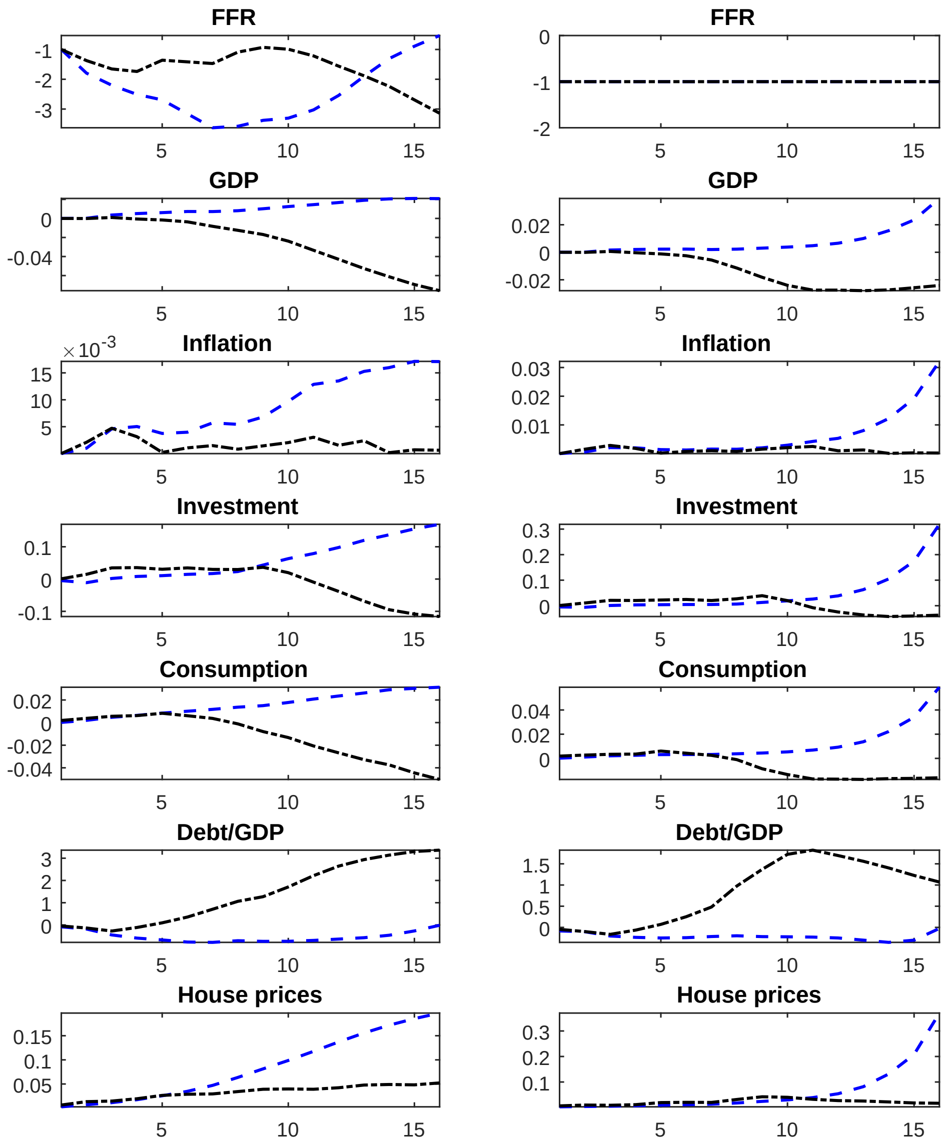

Figure 18: Cumulative effects of a monetary shock for a longer sample, 1955q1-2015q3. The first column shows the cumulative effects of a monetary shock on a variable in high debt (blue dashed) and high debt state coinciding with recession (black dot-dashed) state. The second column shows the cumulative effect of a monetary shock on a variable normalized by the cumulative response of federal funds rate in that particular state, for high debt (blue dashed) and high debt state coinciding with recession (black dot-dashed) state.

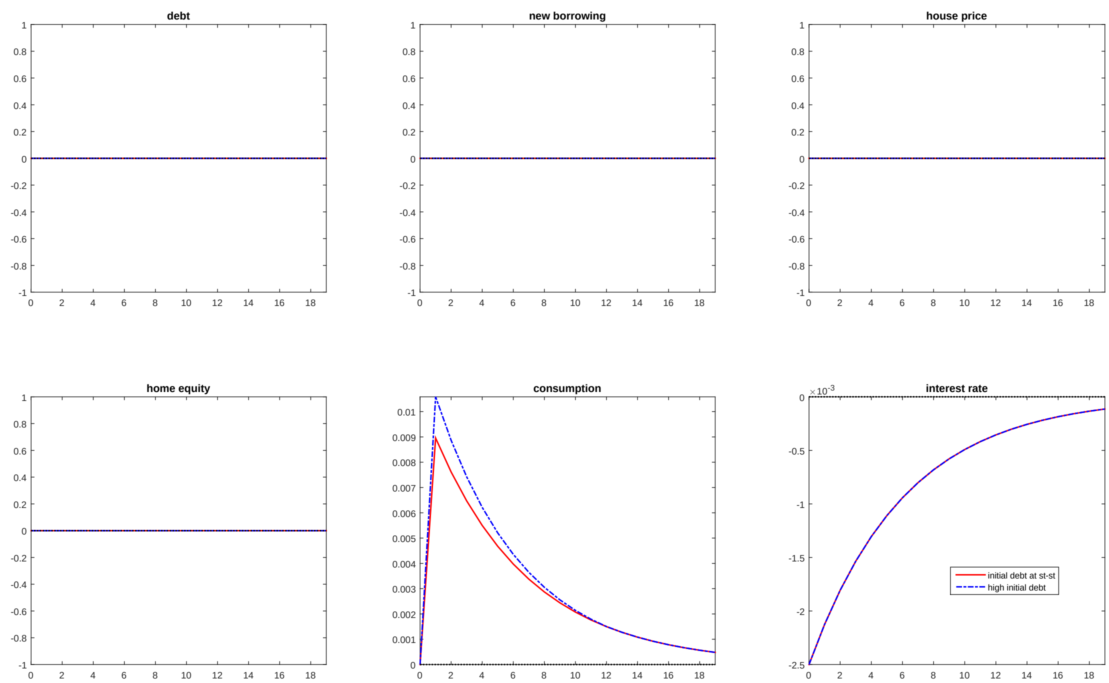

Figure 19: Impulse responses from our theoretical model of model variables to an annualized 100 bps monetary policy shock in the absence of feedback effects to house prices (i.e., $\rho_{qR} = 0$). The figure shows the response for the steady state debt level (red solid line) and the high debt state (blue dashed line).

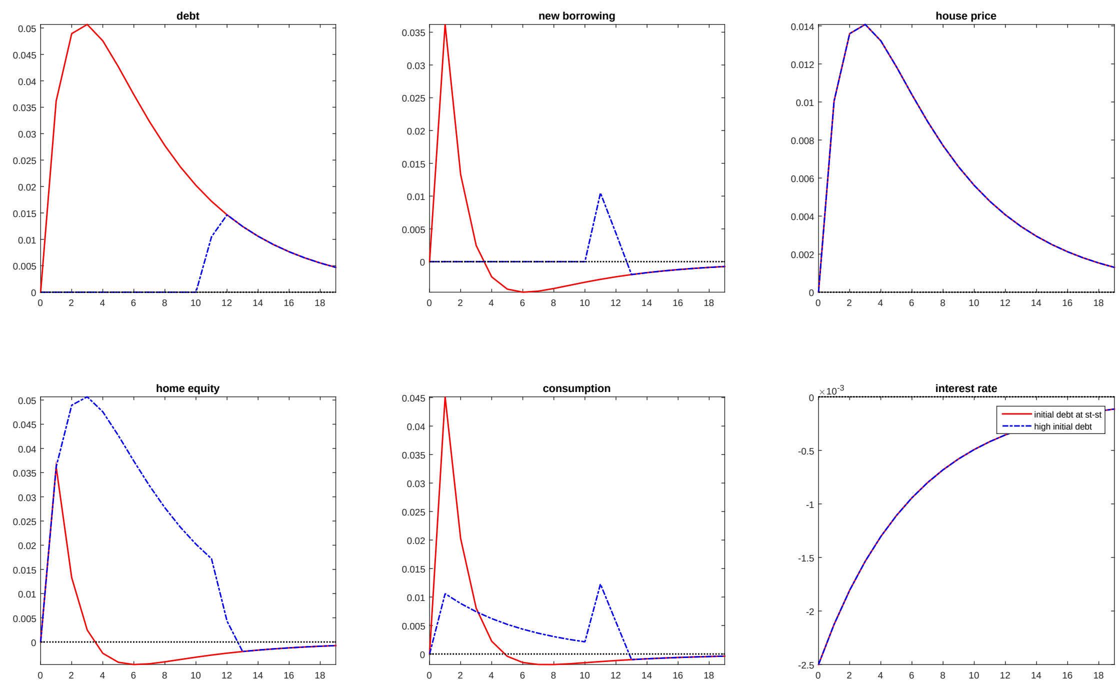

Figure 20: Impulse responses from our theoretical model of model variables to an annualized 100 bps monetary policy shock when we additionally allow feedback effects to house prices. The figure shows the response for the steady state debt level (red solid line) and the high debt state (blue dashed line).

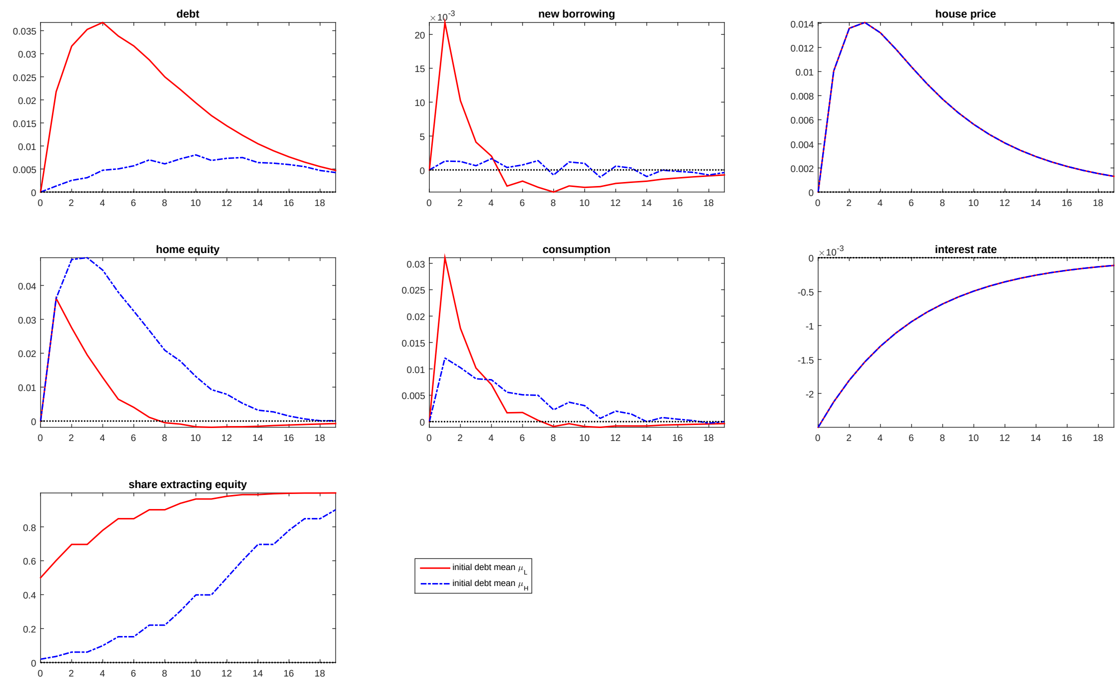

Figure 21: Impulse responses from our theoretical model of model variables to an annualized 100 bps monetary policy shock, when we aggregate over a distribution of households, when $\mu = \mu_L$ versus $\mu = \mu_H$. The figure shows the response for the low debt households, $\mu = \mu_L$, (red solid line) and the high debt households, with $\mu = \mu_H$ (blue dashed line).

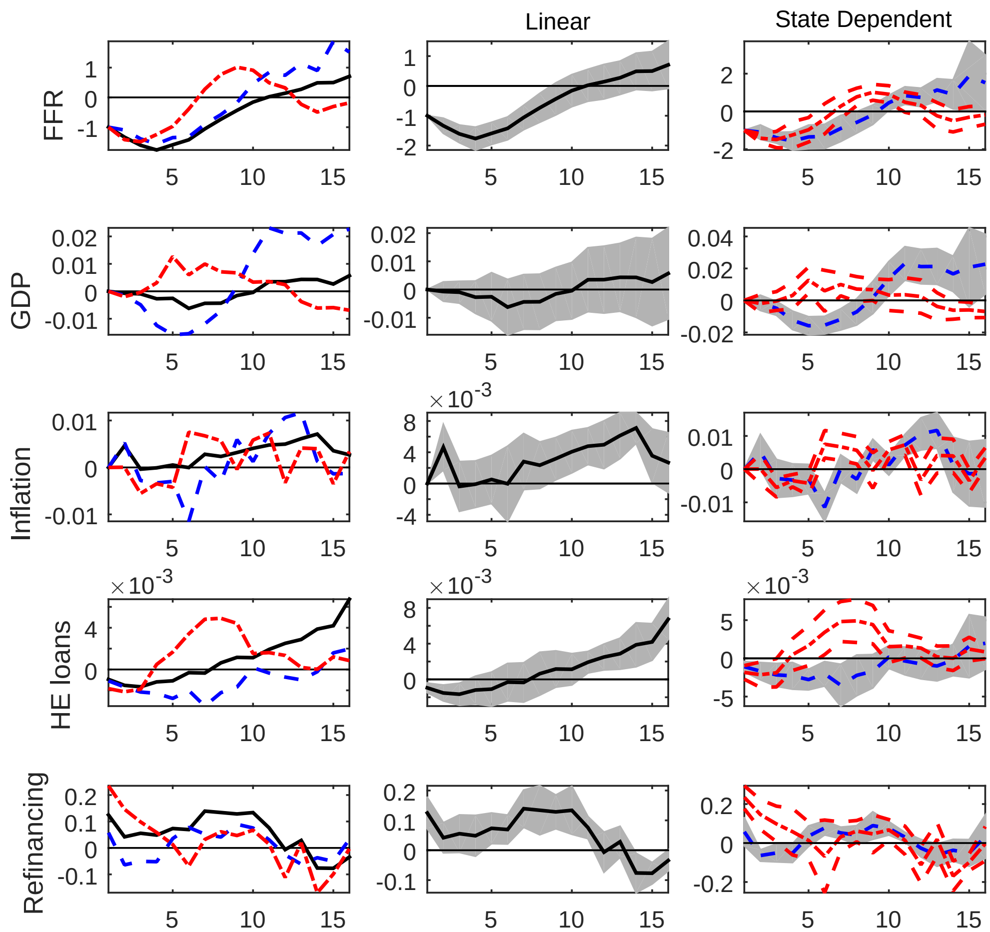

Figure 22: IRFs of home equity loans (HE loans), refinancing and other variables to a monetary shock, for the sample period: 1990q4-2015q3. The first column shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the IRFs in the linear case with 90% confidence band. The third column shows state-dependent IRFS for the high debt state (blue dashed line) and low debt state (red dot-dashed line), with their respective 90% confidence band. Note: We use home equity loans as a share of total household debt.

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

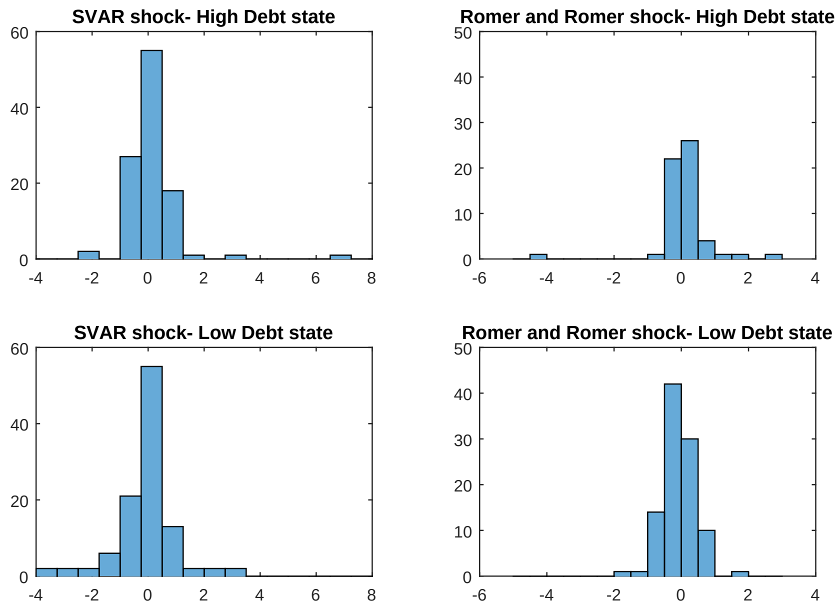

Figure 23: Histograms of SVAR and Romer-Romer monetary policy shocks by household debt state. The top panel shows the distribution of the monetary policy shocks in the high debt state, and the bottom panel shows the low debt state.

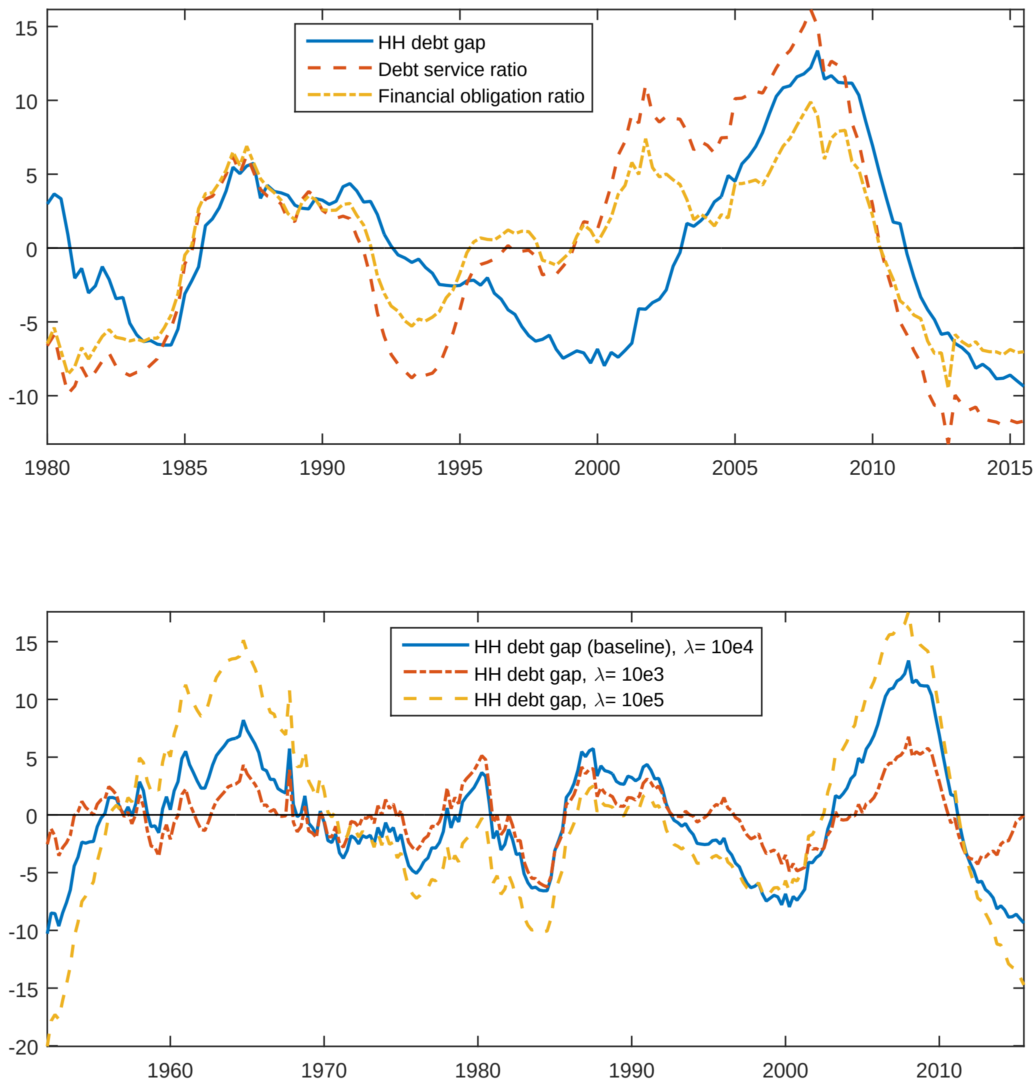

Figure 24: Comparison of the debt gap with alternative measures of debt overhang for the overlapping sample. The first panel of the figure compares our baseline debt gap with the measures of household debt services and financial obligation ratio percent deviations from their respective means. Source: 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, λ in the HP filter.

C Statistical significance of baseline results

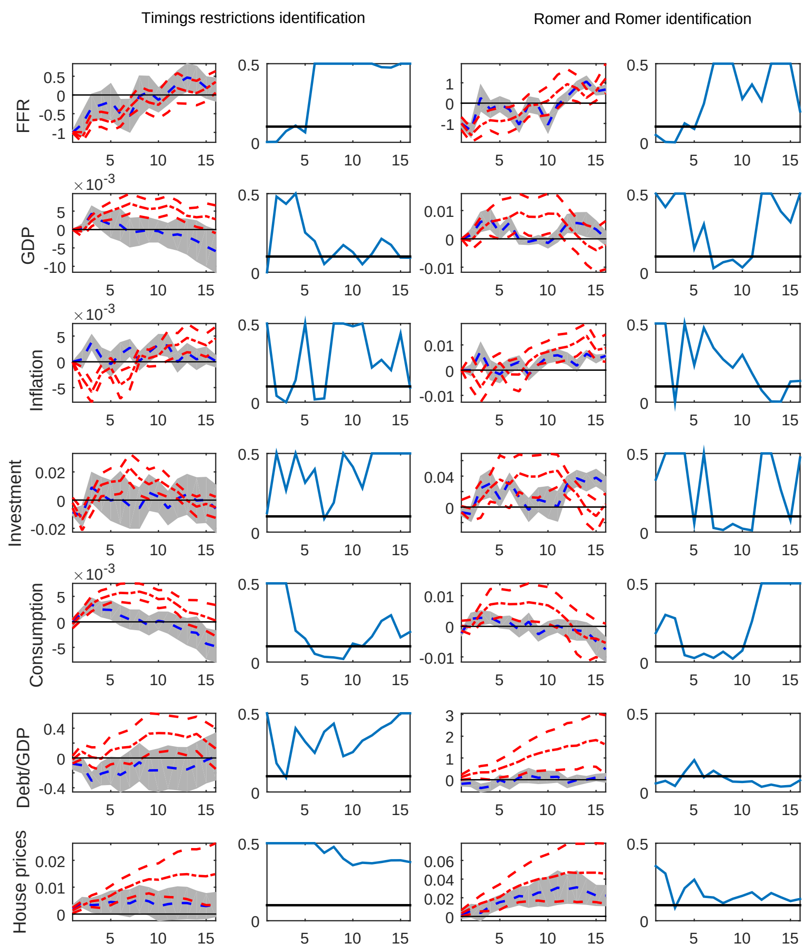

Figure 25: The first and third column shows the impulse response function to a monetary shock in high debt (blue dashed) and low debt (red dot-dashed) state, under the respective identification. The second and last column show the p-value for the null hypothesis that the response in high debt is equal 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 Additional results from using bandpass filter

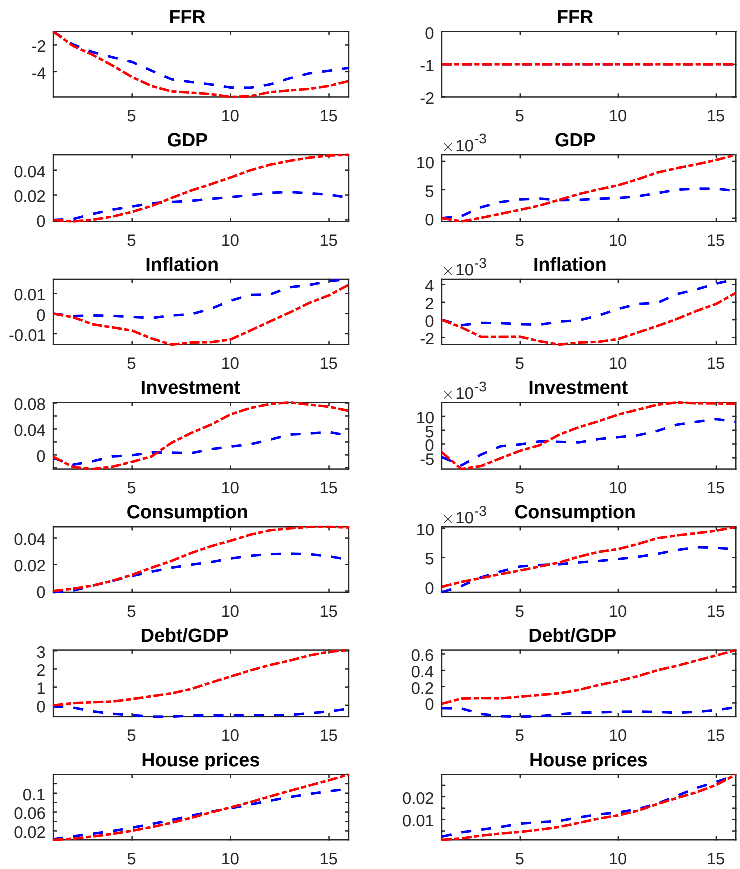

Figure 26: Cumulative effects of a monetary shock identified using timing restrictions, using BP filter to get high and low debt states. The first column shows the cumulative effects of a monetary shock on a variable in high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the cumulative effect of a monetary shock on a variable normalized by the cumulative response of federal funds rate in that particular state, for high debt (blue dashed) and low debt (red dot-dashed) state.

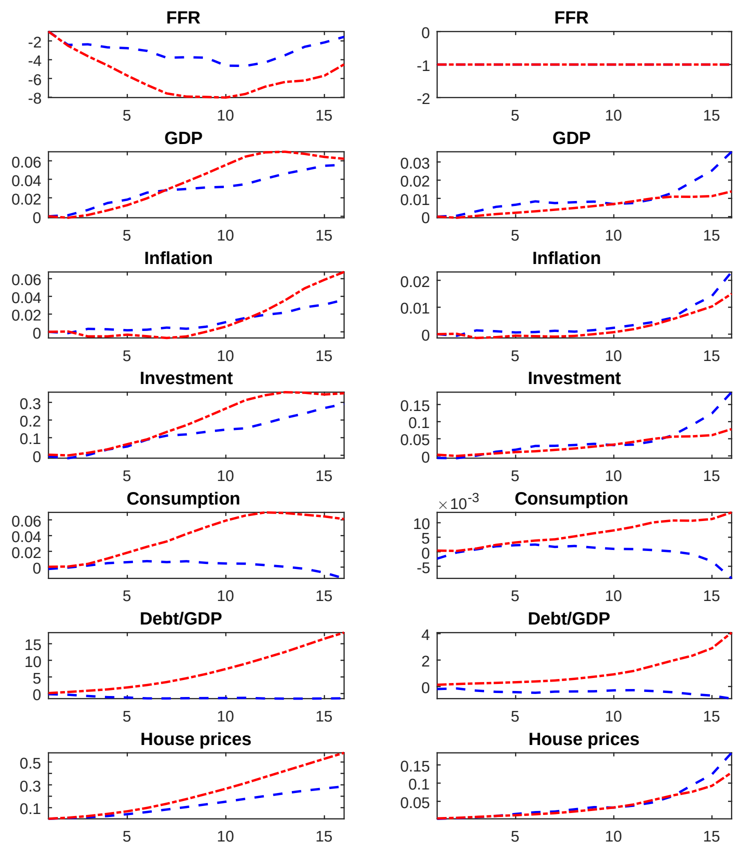

Figure 27: Cumulative effects of a monetary shock identified as in Romer and Romer (2004), for the sample 1969q1-2007q4, using BP filter to get high and low debt states. The first column shows the cumulative effects of a monetary shock on a variable in high debt (blue dashed) and low debt (red dot-dashed) state. The second column shows the cumulative effect of a monetary shock on a variable normalized by the cumulative response of federal funds rate in that particular state, for high debt (blue dashed) and low debt (red dot-dashed) state.

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:

$$Y_t = I_{t-1}A(L)Y_{t-1} + (1 - I_{t-1})B(L)Y_{t-1} + u_t, \tag{11}$$

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 28 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.

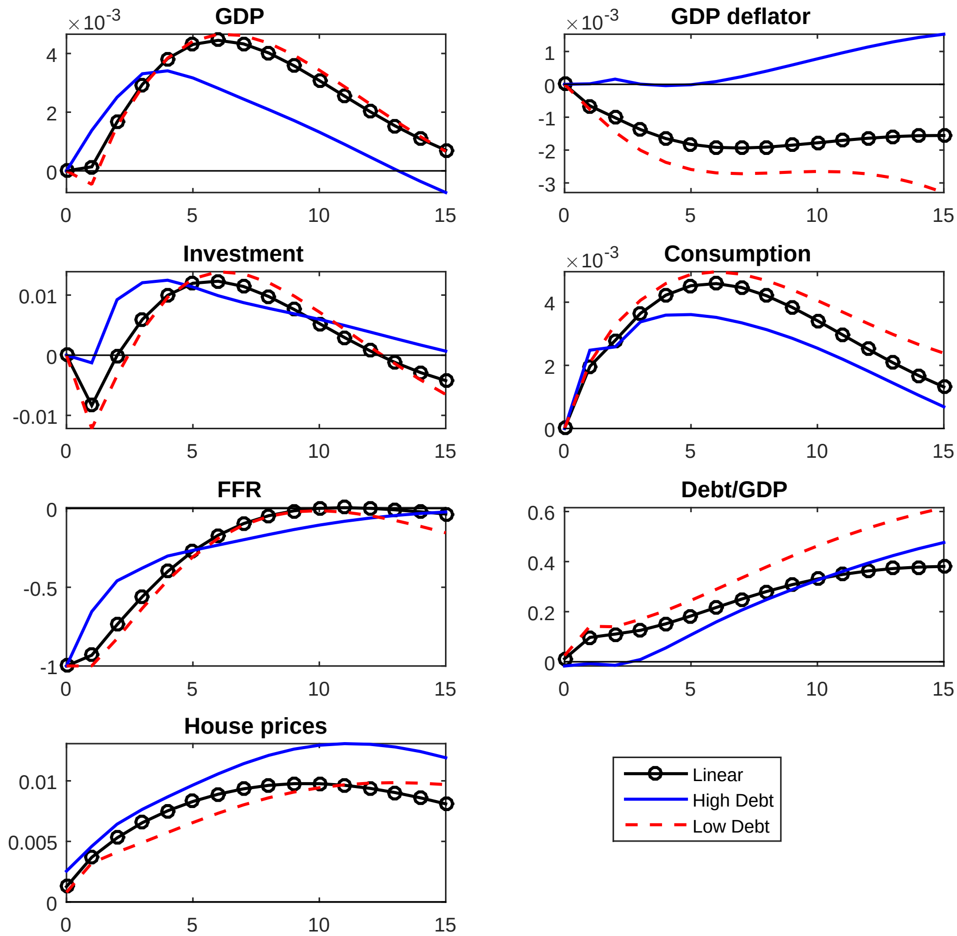

Figure 28: Robustness check: IRFs to a monetary shock using the threshold VAR approach. The figure shows the point estimate for IRFs in linear (black solid), high debt (blue dashed) and low debt (red dot-dashed) state.

F 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. 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 given by

$$u\left(c_{i,t}, h_{i,t}, n_{i,t}\right) = \log c_{i,t} + \xi \log h_{i,t} - \frac{n_{i,t}^{1+\vartheta}}{1+\vartheta}, \text{ for } i \in \{P, I\} \tag{12}$$

where ξ determines the relative importance of housing in utility, n_i denotes labor supply, and ϑ 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, $h_{P,t} + h_{I,t} = \overline{h}$. The budget constraint of patient households is given by

$$c_{P,t} + q_t\left(h_{P,t} - h_{P,t-1}\right) + \frac{B_t}{P_t} + \frac{L_t}{P_t} \leq w_{P,t} n_{P,t} + \left(1 + R_{t-1}\right)\frac{B_{t-1}}{P_t} + \left(R_{t-1} + \kappa\right)\frac{D_{t-1}}{P_t} + \frac{\Pi_t}{P_t}, \tag{13}$$

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 Π_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

$$c_{I,t} + q_t\left(h_{I,t} - h_{I,t-1}\right) + \left(R_{t-1} + \kappa\right)\frac{D_{t-1}}{P_t} \leq w_{I,t} n_{I,t} + \frac{L_t}{P_t}, \tag{14}$$

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

$$\frac{L_t}{P_t} = \phi q_t\left(h_{I,t} - h_{I,t-1}\right) + \max\left\{0, \phi q_t h_{I,t-1} - (1-\kappa)\frac{D_{t-1}}{P_t}\right\}. \tag{15}$$

Thus, as opposed to the partial equilibrium model, we now allow agents to borrow up to ϕ 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 κ_p), and produce differentiated output, $y_t(j)$, using the following production function

$$y_t(j) = n_{P,t}(j)^{\psi}\, n_{I,t}(j)^{1-\psi} - f, \tag{16}$$

where ψ 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

$$c_{P,t} + c_{I,t} = y_t - \frac{\kappa_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 y_t, \tag{17}$$

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

$$\left(\frac{\pi_t}{\pi} - 1\right)\frac{\pi_t}{\pi} = E_t\left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right)\left(\frac{\pi_{t+1}}{\pi} - 1\right)\frac{\pi_{t+1}}{\pi}\frac{y_{t+1}}{y_t}\right] - \frac{\eta - 1}{\kappa_p}\left(1 - \theta\Omega_t\right), \tag{18}$$

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

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

$$R_t = \rho R_{t-1} + (1 - \rho)\left(R + a_\pi \log\frac{\pi_t}{\pi}\right) + \varepsilon_{R,t}, \tag{19}$$

where a_π and a_y denote the long-run response coefficients with respect to inflation and output gap, respectively.

F.1 Parameterization and impulse responses

We set the patient households' discount factor, β_P, to 0.995, which along with the steady-state inflation factor, π, 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, κ, to 0.01, and the LTV ratio for new housing purchases, ϕ, 0.9 as before.

The discount factor for impatient households, β_I, is set to 0.97, the level parameter for housing in the utility function, ξ, is set to 0.12, and the share parameter in the production function, ψ, is set to 0.65, following Iacoviello and Neri (2010). We set ϑ to 1, implying a unit Frisch-elasticity of labor supply, and η to 10, implying that firms set a 10 percent average markup when setting prices over their marginal cost. The price stickiness parameter, κ_p, is set to 100, implying that the slope of the New Keynesian Phillips curve is 0.9, in line with estimates in the literature. Finally, for the smoothness parameter on the Taylor rule, ρ, is set to 0.85, similar to its corresponding value in the partial equilibrium model, and the long-run response coefficient for inflation, a_π, 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.[27] In the high-debt case, we start

[27]To compute the transition path from the initial to the terminal steady state, we use the Matlab routines available

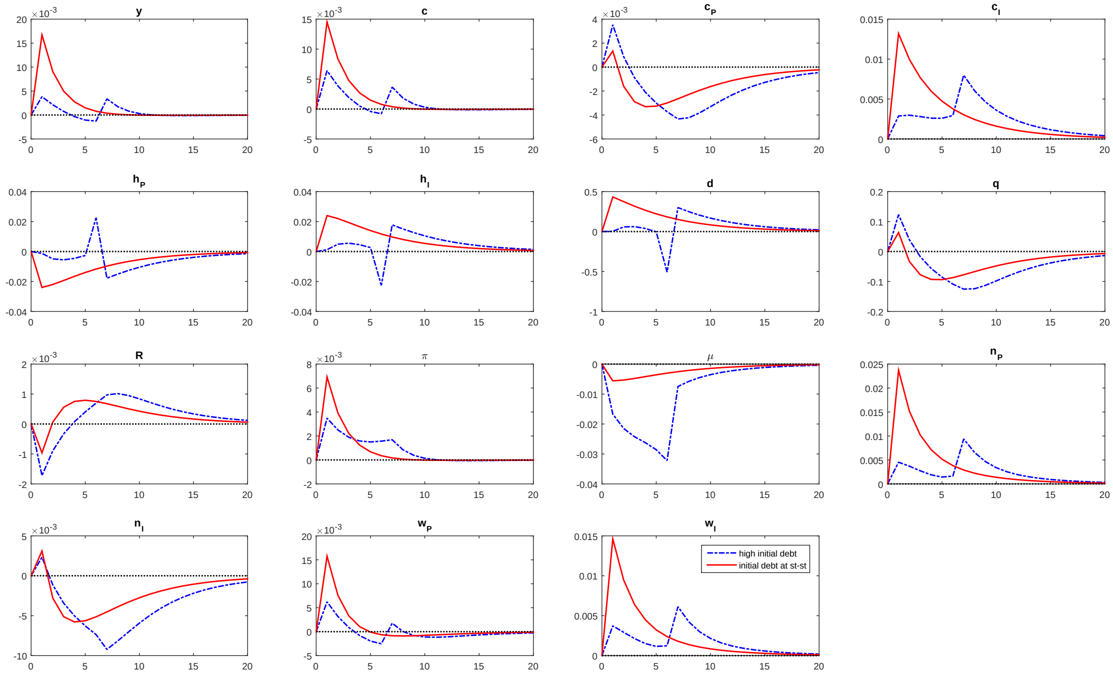

Figure 29: Impulse responses from our theoretical model of model variables to an annualized 100 bps monetary policy shock, in the general equilibrium model. The figure shows the response for the steady state debt level (red solid line) and the high debt state, where initial debt level is assumed to be 10% above the steady state (blue dashed line).

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 29, 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.

in *Dynare*. The model converges to the terminal steady state after 1,000 periods, corresponding to 250 years. The transition path is computed by imposing the initial and terminal values and simultaneously solving a system of nonlinear equations that characterize equilibrium in all periods using a Newton method.