State Dependence of Monetary Policy Across Business, Credit and Interest Rate Cycles*

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Abstract

We investigate how the business, credit and interest rate cycles affect the monetary transmission mechanism, using state-dependent local projection methods and data from 18 advanced economies. We exploit the time-series variation within countries, as well as cross-sectional variation across countries, to investigate this issue. We find that the impact of monetary policy shocks on output and most other macroeconomic and financial variables is smaller during periods of economic downturns, high household debt, and high interest rates. We then build a small-scale theoretical model to rationalize these facts. The model highlights the presence of collateral and debt-service constraints on household borrowing and refinancing as a potential cause for state dependence in monetary policy with respect to the business, credit, and interest rate cycles.

Keywords: Monetary Policy, Household Debt, Local Projections

J.E.L. Codes: E21, E32, E52

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1 Introduction

The tepid recovery experienced by many advanced economies following the financial crisis has cast doubt on the effectiveness of monetary policy to stimulate the economy. Against this background, we investigate whether the transmission of monetary policy is affected by the degree of economic slack, the level of household indebtedness, or the level of interest rates relative to the past. In particular, we explore whether the impact of monetary policy shocks on output, credit and other macroeconomic and financial variables are less pronounced during periods of economic downturns, high household debt, or high prevailing interest rates.

In the first part of the paper, we employ *state*-dependent local projection methods as in Jordà (2005) and Ramey and Zubairy (2018) on a panel data set from 18 advanced economies to empirically detect possible non-linearities and asymmetries in the transmission of monetary policy shocks over the business cycle, the credit cycle, and the interest rate cycle. Exploiting the cross-country as well as the time series dimension of our dataset allows us to sharpen our inference for the impulse responses across states. In our state-dependent regressions, we identify the "slump" periods for the business cycle as periods of negative output gap. Similarly, "high-debt" periods for the credit cycle are identified as periods in which the household debt-to-GDP ratio is significantly above its trend. Finally, "high interest rate" periods (or tightening cycles) for the interest rate cycle are identified as periods in which the current long-term interest rate is above its 5-year lagged moving average.

Our baseline results indicate that monetary policy effectiveness for stimulating output is significantly weakened during periods of economics slumps and high household indebtedness. These results are also by and large robust to alternative identifications of the business cycle or the credit cycle states. For the interest rate cycle, our baseline results also point to a weakening in the effectiveness of monetary policy during tightening cycles; however, the differences between the two states along the interest rate cycle are not statistically significant, and these results are not as robust to alternative identifications of the states.

Our paper contributes to the literature investigating state dependence in the transmission of monetary policy shocks. The findings in the literature regarding the effectiveness of monetary policy over phases of the business cycle are mixed. Weise (1999) shows that shocks to the money supply have a stronger effect on US output when output growth is low. Using a regime switching model, Lo and Piger (2005) find significant time variation in the response of U.S. output to monetary policy interventions. They classify these responses into "high response" and "low response" regimes, and link the periods of high response to recessions, thereby concluding that monetary policy actions have stronger effects during recessions than during expansions. A similar result is obtained by Peersman and Smets (2002), who study the effectiveness of monetary policy in the Euro Area. More recently, Tenreyro and Thwaites (2016) use a smooth-transition local projection approach, and find that the response of U.S. output to monetary policy shocks are stronger in an expansion relative to a recession, mainly due to larger responses of consumer durables and business investment expenditures during booms. Our findings are also in line with Jordà et al. (2019) who document a weaker response of output to monetary policy shocks during slumps than during booms while analyzing a sample of 17 advanced economies, employing a longer sample period but annual data.

A growing number of papers in the literature investigate how leverage affects the effectiveness of monetary policy. Consistent with our findings, Aikman et al. (2016) and Alpanda and Zubairy (2019) document that U.S. monetary policy shocks have a smaller impact on output when the household debt gap is high. Jordà et al. (2019) find that output responds more to a monetary policy shock during credit booms, and they argue that mortgage credit, rather than total credit, generates the state dependence in the transmission of monetary policy. Harding and Klein (2018) focus on phases of expansions (leveraging) and contractions (deleveraging) of the home mortgages-to-real estate ratio, and find that monetary policy shocks in the U.S. have had stronger effects on economic activity during periods of household deleveraging.

There are also a few recent papers that have investigated state-dependence of monetary policy based on the interest rate cycle. Eichenbaum et al. (2018) and Berger et al. (2018) use U.S. loan-level data to document that households are less likely to refinance their mortgages when the current interest rate on their outstanding loan is lower than the market rate on new mortgages. When the policy rate has been rising, and therefore mortgage rates have also been climbing, households with fixed rate mortgages might face a mortgage rate lower than the current rate. This implies that a given interest rate cut would be less powerful after a sequence of interest rate hikes.

In contrast to the existing literature cited above, we consider the state dependence of monetary policy along all three cycles (i.e., business cycles, credit cycles, and interest rate cycles) using the same quarterly dataset. Moreover, rather than focusing on one single country, we consider a cross-section of countries in our empirical investigation, which allows us to exploit a larger number of recessionary, high debt or high interest rate periods across time, and sharpens the inference on the estimated parameters across the different states. Pooling across countries is crucial: first, some states are infrequent in a single country or might coincide with specific episodes. For example, the US has experienced only one high debt episode which correspond with the financial crisis. Second, pooling ensures that we have enough variation so that we can identify different states separately, so that two states do not always coincide, i.e. high debt periods do not always occur when the economy is operating below potential. Third, we can also examine the response of macroeconomic variables to expansionary monetary policy shocks during combinations of states: for example, during periods of economic slumps and low prevailing interest rates compared with periods of slumps and high interest rates.

The second contribution of the paper is to rationalize these empirical findings in a unified framework through the lens of a stylized model, which can simultaneously generate the three state dependencies described above. To this end, we build a small-scale partial equilibrium model featuring long term fixed-rate or adjustable rate mortgage debt contracts. Households face debt-service-ratio (DSR) and loan-to-value (LTV) constraints on their new borrowing, which lead to state dependence in the effects of monetary policy. For state dependence with respect to the business cycle, note that the borrower's income level is a moderating factor for the effects of the new mortgage rate on the debt limit implied by the DSR constraint. In particular, the same decline in the fixed rate results in a larger relaxation of the DSR constraint when incomes are high versus when they are low. Given that incomes are higher at the boom phase of the business cycle relative to the slump phase, the effects of monetary policy are also stronger during booms. Similarly, for the state dependence of the credit channel with respect to the credit cycle, existing indebtedness affects the tightness of both the LTV and the DSR constraints. At high levels of debt, the agent is unable to satisfy either the LTV or the DSR constraint (or both), and therefore, will not be able to borrow at the margin despite the rate cut, while the same rate cut would induce new borrowing when the agent's existing level of debt is low. In the aggregate, this would render monetary policy to be state dependent with respect to the credit cycle. Finally, for state dependence with respect to the interest rate cycle, note that the borrower's DSR constraint is relaxed further when the agent is able to refinance her existing debt, which is exercised only when the current mortgage rate is below the borrower's average interest burden on existing debt. In the aggregate, there would be more refinancing during a loosening cycle relative to a tightening cycle of interest rates, which thus renders the credit channel relatively less effective in a tightening cycle. In summary, this illustrative model highlights the weakening of the credit and refinancing channels as potential channels for the decline in monetary policy effectiveness during periods of economic slump, high household debt, and high interest rates.

The rest of the paper is organized as follows: Section 2 presents the econometric framework and the definition of states, Section 3 summarizes the empirical results, Section 4 describes the simple theoretical model used to rationalize the empirical results, and Section 5 concludes.

2 Econometric Methodology

We apply the local projection technique proposed in Jordà (2005) to estimate linear as well as state-dependent models and calculate impulse responses to exogenous monetary policy innovations. The Jordà method simply requires estimation of a series of regressions for each horizon, h, and for each variable of interest. The linear model looks like the following panel local projections:

$$z_{i,t+h} = \alpha_{i,h} + \psi_h(L)y_{i,t} + \beta_h x_{i,t} + \varepsilon_{i,t+h}, \quad \text{for} \quad h = 0, 1, 2, ... \tag{1}$$

where $i = 1, ...N$ denotes the country under consideration.[1] Here z is the variable of interest, y is a vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and x is the identified monetary shock. Notice that $\alpha_{i,h}$ is a country fixed effect, which captures time invariant country heterogeneity, such as labor market institutions etc. The coefficient β_h gives the response of z at time $t + h$ to the shock occurring 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. By pooling the regression coefficients β_h, we consider the average response to the shock across all countries and time. In the regressions, we cluster the standard errors by country.

When we present the results, we consider z to be the logarithm of real output growth, logarithm of CPI, logarithm of real house prices and the debt-to-GDP ratio in deviations relative to their initial value before the shock hits the economy, while short term rates and long term rates are measured in units of percentage points. In the baseline case, $\psi(L)$ is a polynomial of order 2. The set of controls includes log of real output, log of CPI all items, log of real house prices, the debt-to-GDP ratio, a short term interest rate and a long term interest rate.

The linear projection model in (1) can be easily extended to a non-linear, state-dependent model by allowing the parameters to change according to the state of the economy:

$$z_{i,t+h} = I_{i,t-1}\left[\alpha^A_{i,h} + \psi^A_h(L)y_{i,t} + \beta^A_h x_{i,t}\right] + (1 - I_{i,t-1})\left[\alpha^B_{i,h} + \psi^B_h(L)y_{i,t} + \beta^B_h x_{i,t}\right] + \varepsilon_{i,t+h} \qquad (2)$$

where $I_{i,t-1} \in \{0, 1\}$ represents the state of the economy in country i when the shock hits. In particular, $I_{i,t-1}$ takes the value of 1 in "perilous" times (i.e., economic slumps, high debt states, or high interest rates), and 0 in "tranquil" times (i.e., economic booms, low debt states, or low interest rates). We will describe how the states are identified in the next subsection.

State dependent local projections have recently been used by Tenreyro and Thwaites (2016), Ramey and Zubairy (2018), Harding and Klein (2018) Auer et al. (2019) and Alpanda and Zubairy (2019), among others to analyze the state-dependent effects of fiscal and monetary policy shocks. Although Plagborg-Møller and Wolf (2019) show that in general local projections and vector autoregression (VAR) models estimate the same impulse response in population, in our non-linear context, the local projection methodology offers several advantages over VARs. First, they are more robust to misspecifications, as they do not impose dynamic restrictions which are implicit in VAR models. Second, they provide a simple way to account for state-dependence, especially in a panel framework. Finally, unlike regime-switching VARs, they do not require one to take a stand on the duration of a given state or on the mechanism triggering the transition between regimes. Therefore, the coefficients β^A_h and β^B_h represent the average effects of the monetary policy innova-

[1]The eighteen countries included in our sample are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States.

tions conditional on the initial state, and capture the possible change in state occurring during the projection horizon.

2.1 Definition of States

In order to proceed with the estimation of the regression model in (2), we first need to identify which episodes constitute perilous states. With respect to the business cycle, we distinguish between periods in which the economy is operating above or below its potential level. Following Jordà et al. (2019), we identify slumps (booms) as periods in which real output is below (above) potential output, where the latter is constructed with a two-sided HP (Hodrick and Prescott, 1997) trend using the usual smoothing parameter when defining business cycle phases at the quarterly frequency, i.e., $\lambda = 1,600$. Figure 1 shows the slump periods over time and across countries, plotted against the logarithm of real output.

INSERT FIGURE 1 HERE

With regards to high versus low debt states, we base our definition on leverage, measured by the household debt-to-GDP ratio.[2] For this, we first construct a debt gap measure as the deviation of the household debt-to-GDP ratio from its smooth trend, obtained using an HP filter with a large smoothing parameter, $\lambda = 4\times10^5$.[3] The resulting trend is thus very slow moving, accounting for the fact that credit cycles are characterized by a longer duration and a larger amplitude than traditional business cycles (Aikman et al. 2015, Aikman et al. 2016). This choice of the smoothing parameter is also consistent with the one adopted under Basel III for the implementation of countercyclical capital buffers (Drehmann 2013), and those used in the previous literature (Bauer and Granziera 2017, Aikman et al. 2016). Second, we define high debt states as periods in which the gap is above the 75-*th* percentile of the debt-gap distribution, which corresponds to a household debt-GDP gap of about 5%. This threshold is chosen to identify periods in which households are financially constrained as in the stylized model described in Section 4.[4] Therefore, our definition of high debt states identifies periods of excessive leverage, during which economies might be less resilient to shocks and have lower loss-absorption capacities.[5] In fact, a large increase in debt-to-GDP above

[2]We focus on household credit primarily because our theoretical small-scale model focuses on household borrowing. Also, Jordà et al. (2019) show that differences in impulse responses to monetary policy shocks are larger when mortgage credit is growing than when it is decreasing, while differences are not significant with non-mortgage credit.

[3]The data for all countries in our analysis are collected by the Bank for International Settlements (BIS). The series we use is the (end-of-period) market value of credit to household and non-profit institutions serving households from all sectors. Data availability for these series is shorter than for total credit (see Table A.1 in the Appendix).

[4]For robustness, we also try a different threshold and define as periods of high debt quarters in which the debt gap is positive. With this alternative classification, we find that the effects of monetary policy are still weaker in high debt states. However, the differences are not statistically significant.

[5]Other studies consider the non-linear effects of monetary policy during credit booms vs busts, identified as periods of rapid growth in mortgage credit over GDP (Jordà et al. 2019) or household leveraging vs deleveraging

trend can represent widespread optimism (for example, extrapolative expectations on house prices) and elevated risk appetite of homebuyers, which might lead banks to underwrite poor quality loans and seek risk. Figure 2 shows the high debt states together with the household debt-to-GDP ratio for each country over the sample 1975Q1-2018Q3. In most countries, the debt-to-GDP ratio exhibits an upward trend, which is generally attributed to financial deepening, as financial innovations granted access to credit markets for previously under-served households.

INSERT FIGURE 2 HERE

Finally, motivated by the analysis in Eichenbaum et al. (2018), we base our definition of tightening cycles on a measure of the interest rate gap. In particular, we identify tightening cycles as periods in which the long term rate is higher than the average of long term rates in the previous five years. The use of the long term rate is preferred to the short term rate, as the former can be considered a better proxy for the mortgage rate. After a sequence of interest rate hikes, many homeowners are likely to face a mortgage rate lower than the current market rate, and might not have an incentive to refinance in response to an unexpected rate cut, thereby weakening the effects of monetary policy. The distribution of tightening cycles across time and countries together with the long term rate is shown in Figure 3. Note also, that instead of distinguishing between positive and negative monetary shocks, which can be perceived as surprises in the monetary policy actions on the upside or the downside respectively, we are interested in testing a more relevant hypothesis in our perspective of whether where we are in the interest rate cycle or when the surprise occurs relative to interest rate trend matters.

INSERT FIGURE 3 HERE

Table 1 shows some descriptive statistics regarding the states. While booms and slumps are almost equal both in frequency and duration, high debt states or tightening cycles occur much less frequently than low debt states or loosening cycles (25% versus 75%). On average, low debt states are more than twice as persistent as high debt states, while loosening states are almost three times more longer lasting than tightening states. All perilous states display a lower growth rate of real output, as well as lower growth of real household debt and house prices, than tranquil states. The difference in output, household debt and house prices is more marked for low vs high debt states, indicating that our classification captures quite extreme episodes. Interest rates, both short and long term, are much higher during tightening than loosening cycles, while they are quite similar across the other states.

cycles (Harding and Klein 2018). We focus on high vs low debt gap to capture the notion of financially constrained vs unconstrained households, which is consistent with the non-linearities of the transmission mechanism outlined in our theoretical model.

INSERT TABLE 1 HERE

Figure 4 shows that the occurrence of the three states changes substantially across countries and time. For example, some countries, like Italy, Ireland and Spain, experienced a combination of economic slump, high debt and high long term interest rates in the periods following the financial crisis while others, like Canada, Finland, the UK and Norway in the late eighties or early nineties. Also, there is no discernable pattern regarding whether a state leads or follows another state (e.g. low interest rates anticipating high debt).

INSERT FIGURE 4 HERE

Table 2 reports the proportion of observations in which the economy is jointly experiencing two (panel A) or three (panel B) states. Only 3% of observations are contemporaneously periods of economic slump, high debt and high interest rates, while 27% of the observations identify good times across all states, i.e. booms, low debt and loosening states. Looking at the joint frequency of two states, only 14% of observations are both high debt and slumps, 8% are high debt and tightening, and 9% are slumps and tightening. The figure and the table highlight that the three definitions of perilous states do not identify the same periods, and therefore, they are pointing at different fragilities in the economic environment.

INSERT TABLE 2 HERE

2.2 Identification of monetary shocks

In order to obtain impulse responses from the regression models outlined above, we need to specify the assumptions necessary to identify the monetary policy shocks. We follow the literature and assume that no variable responds contemporaneously to the monetary policy shock, except for the short and long term interest rates. This can also be interpreted as assuming that current output, prices and the debt-to-GDP ratio are included in the information set of the monetary authority. These assumptions are also equivalent to the standard identification of monetary policy shocks in structural VAR models, where short term rates are ordered last and the mapping between reduced form shocks and structural shocks is obtained through a Cholesky decomposition of the variance-covariance matrix of the reduced form errors. This is implemented in our model by using the contemporaneous short term rate as the shock $x_{i,t}$ in Equations (1) and (2), and ensuring that the contemporaneous and lagged values of GDP, inflation, and debt-to-GDP along with the lagged values of short and long terms rates, are part of the control vector $y_{i,t}$.

The short term rate is the three month risk free rate, while the long term rate is the ten year government bond yield. To overcome the issues associated with the period associated with the zero lower bound, we substitute the short term rate with the shadow rate for the US, the EMU countries, the UK and Japan for the relevant years.[6] We also consider alternative monetary policy identification schemes, discussed in the robustness Section 3.3.

3 Empirical Results

3.1 Linear Effects of Monetary Policy Shocks

We first report the results for the linear model in (1). The impulse responses to a 100 basis points (bp) expansionary monetary policy shock are shown in Figure (5). Given our definition of the outcome variable $z_{i,t}$, the responses for log of output, log of CPI index, household debt-to-GDP ratio and log of house prices represent their cumulative impulse responses. The responses are shown with a one standard error band, where the standard errors are estimated using a clustered-robust covariance matrix estimator.

INSERT FIGURE 5 HERE

After an unexpected loosening, output rises and peaks at 14 quarters; CPI initially drops, consistent with the well documented price puzzle, but the decrease is feeble, short-lived and followed by a rise in inflation. The interest rate response is quite persistent with the short term rate going back to its initial value about 20 periods after the initial shock, while the response of debt-to-GDP ratio is not significantly different from zero for the first two years, but eventually, an unexpected loosening increases household leverage by 0.7 percent. The long term rate initially falls by about 30 bp on impact, and the response over subsequent periods resembles the shape of the short term response, while real house prices rise substantially and persistently, peaking at about 2.2% after 4 years.

Overall, the impulse responses are consistent with results available in the literature. Alpanda and Zubairy (2019) and Harding and Klein (2018) find similar responses applying a similar linear projection model and identification assumptions for the analysis of the U.S. economy. Bauer and Granziera (2017) use a panel VAR on the same set of countries, identify monetary policy shocks with sign restrictions, and find similar dynamics for the response of the debt-to-GDP gap. The responses in this paper are also comparable to the ones obtained in Jordà, Schularick and Taylor (2019), which employs the same panel of countries, but uses annual data and a longer sample which starts in 1870.

[6] The shadow rates for the US, the EMU area and the UK are taken from Wu and Xia (2016, 2017), while the series for Japan was kindly provided by the Bank of Japan.

3.2 State-Dependent Effects of Monetary Policy Shocks

We next estimate the non-linear model in (2). Figures 6 through 8 show the state-dependent impulse response functions to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points on impact.

3.2.1 Business Cycles

We first consider the responses to monetary policy shocks across different business cycle phases, where the responses during slumps (booms) are denoted by a solid blue (red dashed) line in Figure 6. While the response of the short term rate is almost identical across states, the response of GDP is radically different: during slumps the response is flat and not statistically different from zero, while during booms output rises substantially, by about 1%. For CPI the responses are very similar across states, although the price puzzle is slightly more pronounced during booms. The responses of the debt-to-GDP ratio and house prices are more muted during slumps than during booms. For the debt-to-GDP ratio, the difference in the response across states is significant only after 12 quarters, while the response of house prices start to diverge after 7 quarters. Overall, these results point to a weaker effect of monetary policy during slumps. This is consistent with the results in Tenreyro and Thwaites (2016) and Jordà, Schularick and Taylor (2019), who find that monetary policy is less powerful in recessions for the US and for a panel of countries, respectively.

INSERT FIGURE 6 HERE

3.2.2 Credit Cycles

We next consider the responses to monetary policy shocks across household credit cycle phases. Results for the state dependent model based on the household debt gap are shown in Figure 7, in which the solid blue (red dashed) lines denotes the responses for the high (low) debt states. For real output, the shape of the responses is similar to the linear case in both states, but the size of the responses is much larger in the low debt state relative to the high debt states. The responses start to diverge only after 6 quarters, but the differences persist to the end of the horizons considered.[7] Regarding CPI, the price puzzle is worse in the low debt state relative to the linear model, while there is no price puzzle in the high debt state. In the long run, the cumulative response of prices is weaker in the high debt state, though the responses are not statistically significantly different. The response of the debt-to-GDP ratio is muted in the high debt state; however, the difference is not statistically significant. For house prices the opposite holds, as the peak response is larger in high

[7] For completeness, we also investigate the state dependence of monetary policy during leveraging vs de-leveraging cycles, following Harding and Klein (2018). We confirm the empirical finding documented by the authors for the U.S. that monetary policy is less effective during periods of household leveraging.

debt states than low debt states, but the responses are not statistically different here as well. The responses of output, debt-to-gdp and house prices confirm for a panel of countries the empirical findings that Alpanda and Zubairy (2019) document for the US.

INSERT FIGURE 7 HERE

3.2.3 Interest Rate Cycles

Finally, the impulse responses for tightening (blue) versus loosening (red) cycles are reported in Figure 8. The responses in this case exhibit smaller differences across states for the macroeconomic variables. GDP has a larger positive point-wise response to monetary easing during a loosening cycle than a tightening cycle, at longer horizons. However, these responses along with the responses of other variables are not statistically significantly different across the two states. The short term rate response is the only response statistically significantly different across states, and tends to be more persistent during tightening cycles.

INSERT FIGURE 8 HERE

The results overall point to a reduced effectiveness of monetary policy in stimulating output when the economy is operating below potential or when households are highly indebted. Moreover, during slumps or during periods of high household debt, a contractionary monetary policy shock might be ineffective in decreasing household indebtedness.

3.3 Robustness checks

In this section we run a set of experiments to assess the robustness of our results. This includes considering alternative definitions for the states identified in Section 2.1, considering sub-samples and alternative monetary policy identification as described in Section 2.2.[8]

3.3.1 Alternative definitions of business cycle

For the business cycle, we consider the OECD classification of business cycle phases in recessions and expansions. The OECD recessionary episodes and the impulse responses obtained using these definitions are shown in Figure A.1 of the Appendix and panel a) of Figure 9 respectively. The response of output is weaker in recessions than expansions, although the difference is smaller than

[8]Note that the nominal output series for Ireland exhibits a large jump in 2015Q1. The reason behing this sizable increase is that due to changes in corporate tax rates a number of large corporations decided to relocate their activity to Ireland. Therefore, as a further robustness check we tried running our linear and state dependent analysis dropping Ireland from our sample. We confirm that our results are unaltered for the business cycle analysis and we find slightly stronger results for the credit and interest rate cycle. In particular, at longer horizons the impulse responses remain significantly different across states.

when the classification is based on the two-sided HP filter. We also provide results for the case in which booms (busts) are defined as periods in which output is above (below) trend, computed as in Hamilton (2018). Figure A2 of the Appendix shows the classification of booms and busts obtained using this alternative definition, while panel b) of Figure 9 reports the impulse response functions. To further test the robustness of our results, we repeat the analysis for periods of economic slack identified as: (i) periods of negative output gaps obtained using a one-sided HP filter, (ii) two consecutive periods of negative output growth, and (iii) periods of unemployment greater than the natural rate of unemployment, constructed using a one- or two-sided HP-trend of the unemployment rate. The results are robust to the different recession/slump definitions.

INSERT FIGURE 9 HERE

3.3.2 Alternative definitions of credit cycle

For the credit cycle, we consider a threshold classification based on the household debt service ratio, computed as the ratio of interest payments plus amortization to income.[9] Therefore, the debt service ratio reflects the borrowers' ability to pay the annual obligations arising from their debt, given a particular level of income. An already high debt service ratio might prevent the household from taking on more debt, as suggested by the DSR constraint in the theoretical setup in Section 4. We define the high debt state as periods in which the debt service gap is above the 60th percentile, where the gap is computed as the difference between the debt service ratio and the two-sided HP-trend with the same smoothing parameter used for the computation of the household debt-to-GDP trend; i.e., $\lambda = 4 \times 10^5$. Figure A3 shows the classification of high debt service states together with the debt service ratio, while panel c) of Figure 9 reports the impulse responses. Similar to the high debt states, the high debt service ratio states are also infrequent, but long-lived. Consistent with the response of output in the baseline classification of high/low debt states, we find that the response of output is larger when the debt service ratio is low.

3.3.3 Interaction of interest rate cycles with fixed and variable rate mortgages

We motivated the definition of tightening cycles based on long-term rates by tying it to mortgage rates, since mortgage debt typically constitutes the largest component of household debt. These baseline results do not point toward statistically significant differences between tightening and loosening cycles. Note that the type of mortgage is in many instances a choice variable for households, and the share of adjustable versus fixed-rate mortgages within each country is arguably an equilibrium outcome. Furthermore, the interest burden of borrowers responds more to policy rate changes

[9]The data is available from the BIS on a quarterly basis starting in 1999Q4. Earlier data is taken from Drehmann et al. (2018). Data availability is listed in Table A1.

in countries where adjustable rate mortgages are relatively more prevalent. Bearing this in mind, we now condition *jointly* on the interest rate cycle and whether a country has primarily fixed or variable rate mortgages.[10]

INSERT FIGURE 10 HERE

The top panel of Figure 10 shows the state dependent responses for tightening (blue solid) versus loosening (red dashed) cycles for countries with predominantly variable rate mortgages, and the bottom panel shows the responses in the case of fixed rates. Note that the response of GDP is statistically significantly larger in the loosening state than a tightening state, when mortgages are more likely to be variable or adjustable rate. Note that household debt-to-GDP has a much larger response in the loosening state, whereas it is flat in the tightening state. This lines up with our initial hypothesis of larger effects in a loosening cycle, where we can think of adjustable-rate states as one where refinancing can occur every period. The results in the case of fixed rates, shown in the bottom panel, are just the opposite and the response of GDP is much larger in a tightening cycle than a loosening cycle.[11]

3.3.4 Alternative subsamples

One might be concerned that the results regarding state dependence over the credit cycle might be driven by the financial crisis of 2007-08, as most countries experienced elevated household indebtedness during the recession following the crisis. Similarly, concerns might arise that the zero lower bound may affect the transmission of monetary policy. Therefore, to address those issues we repeat the analysis dropping the observations past 2006Q4. The impulse responses for this shorter sample are reported in Figure 11. The state dependent results for slumps versus booms are robust to employing this shorter sample period. The response of real output is again weaker in the case of high debt states. However, because of the smaller number of observations, the confidence bands for the high debt states are much wider, and therefore, the responses are not statistically significantly different across states until the last 3 quarters considered. Results for the tightening versus loosening states are unaltered.

INSERT FIGURE 11 HERE

Finally, monetary policy regimes and instruments have changed substantially over time. Therefore, we repeat our estimation starting from 1990Q1, when inflation targeting was officially adopted

[10] See details on this classification in Table A1 of the Appendix.

[11] For completeness, we repeat the analysis interacting the business and the credit cycle with the mortgage rate characteristics. Results are reported in Figures A4 and A5. For business cycles, we confirm that monetary policy is more effective in booms than in slumps. Also, during recessions output is more responsive to monetary policy shocks when rates are adjustable than when they are fixed. In the case of the credit cycle, we confirm that the response of output is stronger during low debt states, and this holds for both fixed and variable rates.

in several advanced economies. Figure 12 shows the impulse responses for the three state classifications considered. Restricting the estimation to this shorter sample leaves the results for the business cycle more or less unchanged in terms of the output responses, while it strengthens the differences across phases of the credit cycle and the interest rate cycle.

INSERT FIGURE 12 HERE

3.3.5 Joint State Analysis

In the previous sections we analyze each state dependence separately. But one might be interested in understanding whether for example the effectiveness of monetary policy during busts is affected by the level of household indebtedness. Pooling across countries is therefore essential to increase the number of observations and allow us to analyze the joint dependence across states.

Figure 13, top panel shows the IRFs to a monetary policy shock distinguishing between booms versus busts and whether they occur during high vs low household debt. From the picture it is clear that during booms, low household indebtedness can amplify the positive effects of an expansionary monetary policy on growth. It also shows that monetary policy is slightly more effective in stimulating GDP during slumps if household indebtedness is low.

INSERT FIGURE 13 HERE

Figure 13, middle panel analyzes the case of boom vs bust episodes which occur during tightening vs loosening cycles. Here, when the economy is experiencing a boom, the increase in output will be larger and more protracted over time if interest rates are low rather than high when an expansionary monetary policy shock hits the economy.

Finally, the bottom panel of Figure 13 shows the IRFs during high vs low debt periods when they are paired with high vs low prevailing interest rates. Overall, the differences across the four states are not statistically significantly different. Monetary policy tends to be more effective when debt is low (red lines), confirming the results in our baseline analysis. In the short run the effects of an unexpected expansionary shock will be stronger if interest rates were high before impact. However, these positive effects tend to decrease in the long run.

3.3.6 Considering LP-IV and alternative monetary policy identification

In our baseline estimation, we assume that current output and prices are included in the information set of the monetary authority when identifying a monetary policy shock, and estimate our impulse responses function in a one-step panel LP-OLS (local projection - ordinary least squares) approach. Jordà et al. (2019) show that in their particular treatment of monetary policy shocks, there is attenuation bias in the case of LP-OLS compared with LP-IV, local projections with instrumental variables approach. In order to test if our results are sensitive, we conduct some robustness checks with the LP-IV approach.

First, we identify monetary shocks by running a 4-variable panel VAR with GDP, CPI, short term and long term interest rates, and similar to our baseline case, assume current output and prices are in the information set (i.e., order them before the short term rate and do a Cholesky decomposition).[12] Since this is now a constructed regressor, we now get state dependent responses employing a LP-IV approach, where we instrument the short term rate with this shock.

INSERT FIGURE 14 HERE

Panel a) of Figure 14 shows that under this alternative estimation approach, monetary policy shocks have a statistically significantly larger effect on GDP in booms than in slumps. This is consistent with our baseline results. Panel b) of Figure 14 shows that, while the pointwise GDP response is smaller in the high debt state than the low debt state, the differences are not statistically significantly different for GDP.[13] As mentioned above, since the weak instrument issue is rather severe in the tightening state, it leads to very large confidence bands across tightening states and thus those impulse response functions are not shown.

We also consider an alternative identification approach for monetary policy shocks. This approach employs a combination of zero and sign restrictions. In particular, we consider a 3-variable panel VAR with GDP, CPI and the short term interest rate, and impose zero impact response for GDP while restricting the impact response of inflation to be negative. We again use this shock in an LP-IV to back out the state dependent responses.[14] Note that in this case, to be consistent with the identifying assumption we only have contemporaneous values of GDP on the right hand side and lags of all other variables. Linear responses under this alternative identification are fairly similar to our baseline case and are shown in the Appendix.

INSERT FIGURE 15 HERE

Panel a) of Figure 15 shows that under this alternative identification approach, monetary policy shocks again have larger effects on GDP in booms than in slumps. Note however that inflation has a larger (positive) response in slumps than in booms. Panel b) of Figure 15 shows that under this approach, while the GDP response in the low debt state is larger than the response in the high

[12] We check whether our instrument is weak using the Kleibergen-Paap test. The test statistics are as follows for the Cholesky identification: 11.22 and 71.96 across slumps and booms respectively, 66.46 and 51.41 across high and low debt state respectively, and 0.70 and 85.53 across tightening and loosening states respectively.

[13] We also consider an alternative, where we estimate monetary shocks by running the same 4 variable VAR for each country one-by-one. Results are very similar to the pooled VAR shock and are shown in the Appendix.

[14] In this case of sign and zero restrictions, the Kleibergen-Paap test statistics for strength of the instrument are: 14.44 and 57.98 across slumps and booms respectively, 74.20 and 59.20 across high and low debt state respectively, and 2.74 and 110.50 across tightening and loosening states, respectively.

debt state at short horizons, they are not statistically significantly different at longer horizons.[15] Again because of weak instrument issues, we do not report state dependent impulse response across tightening and loosening states.

4 Small Scale Model with State Dependence

In this section, we construct a small-scale model to illustrate some of the key channels of monetary policy transmission that operate through borrower households, such as the home equity extraction, interest burden, and refinancing channels. The model is purposefully kept simple and partial equilibrium to examine how the effectiveness of these channels can change conditional on the existing levels of the borrowers' income, debt, and average interest burden when the monetary policy is implemented, thus tying monetary effectiveness to the three cycles we considered in the previous sections: namely, the business cycle, the credit cycle, and the interest rate cycle. Note that the objective of this model is to highlight potential transmission mechanisms at play, and not to provide a quantitative explanation.

The model features long-term, fixed or adjustable-rate mortgage contracts as in Kydland et al. (2016) and Garriga et al. (2017), and allows for home equity extraction and refinancing within this set-up similar to Alpanda and Zubairy (2017). The model extends Alpanda and Zubairy (2019) by featuring a debt service ratio (DSR) constraint along with a loan-to-value (LTV) constraint, which apply when agents want to take out home equity loans and/or refinance their existing loans. As will be made clear later, the presence of the DSR and LTV constraints render monetary policy state dependent with respect to the business and credit cycles, while the refinancing option generates state dependence with respect to the interest rate cycle.

4.1 Model Description

Consider a borrower household, whose preferences are represented by a period utility function $u(c_t, n_t, h_t)$, where c_t, n_t, and h_t denote real consumption, labor services and housing, respectively. The household is assumed to be infinitely-lived, and discounts future utility with a factor $\beta < 1$. For simplicity, we assume that borrowers supply labor services inelastically; hence, $n_t = 1$ for all t. Furthermore, we assume that the borrower already owns a constant $\overline{h}$ units of housing, which is not traded and does not depreciate over time (i.e., $h_t = \overline{h}$ for all t). The borrowers' period budget constraint is thus given by:

$$c_t + \left(R^m_{t-1} + \kappa\right) \frac{D_{t-1}}{P_t} \leq \frac{W_t}{P_t} n_t + \frac{L_t}{P_t}, \tag{3}$$

[15] We also consider monetary policy shocks obtained with country-by-country estimation with this approach. The results overall are similar, but the confidence bands are much larger and so we do not see statistically significantly different results for most horizons.

where P_t denotes the aggregate price level, D_{t-1} is the stock of nominal debt brought from the previous period, L_t is new borrrowing in period t, and W_t is nominal wage income received. R_{t-1}^m denotes the average (net) interest on the borrower's existing mortgage debt, and κ is the proportion of debt that the borrower pays as principal each period. For simplicity, we assume that the rate of inflation $\pi_t = P_t/P_{t-1}$ is constant over time (i.e., $\pi_t = \pi$ for all t).

The borrower's stock of debt evolves according to the following law of motion:

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

where new borrowing, L_t, is taken in the form of a home equity loan. Consequently, the borrower's average interest rate on the stock of debt, R_t^m, evolves over time as:

$$R_t^m D_t = R_{t-1}^m (1-\Phi_t)(1-\kappa)\, D_{t-1} + R_t^f \left[L_t + \Phi_t (1-\kappa)\, D_{t-1}\right] \tag{5}$$

where R_t^f is the current interest rate on new fixed-rate long-term loans, and $\Phi_t \in \{0,1\}$ is an indicator function denoting whether the stock of debt brought from the previous period, $(1-\kappa)\, D_{t-1}$, is refinanced in period t with this new fixed rate. Note that one can shut off the refinancing option in the above formulation by setting $\Phi_t = 0$ for all t, which implies $R_t^m D_t = R_{t-1}^m (1-\kappa)\, D_{t-1} + R_t^f L_t$. In this case, the current fixed rate affects the overall average interest burden only through new loans. Similarly, one can consider adjustable rate mortgages by setting $\Phi_t = 1$ for all t, which implies $R_t^m = R_t^f$.

Home equity extraction and refinancing by the borrower are subject to a loan-to-value (LTV) as well as a debt service ratio (DSR) constraint. The LTV constraint is given by

$$L_t \leq \max\left\{0, \phi P_t q_t \overline{h} - (1-\kappa)\, D_{t-1}\right\} \tag{6}$$

where ϕ is the regulatory loan-to-value (LTV) ratio and q_t denotes the relative (real) price of housing. Thus, the borrower is required to have a minimum level of equity in the house to be able to extract home equity or to refinance existing loans.[16] Similarly, the DSR constraint is given by

$$\left(R_t^f + \kappa\right) L_t \leq \max\left\{0, \theta W_t - \left[\Phi_t R_t^f + (1-\Phi_t)\, R_{t-1}^m + \kappa\right](1-\kappa)\, D_{t-1}\right\}, \tag{7}$$

where θ is the regulatory debt service ratio. Thus, the total debt service obligations of the agent in the next period in the form of interest and principal payments, including the debt service for existing debt, cannot exceed a θ fraction of the borrower's current income, W_t. The formulation

[16]Note that $1-\phi$ of the house value has already been pledged as collateral for the original mortgage, and thus cannot be pledged against home equity loans taken on top of the first lien. Similarly, if agents build home equity through a house price increase, they cannot pledge more than ϕ fraction of this increase as collateral when extracting equity.

above takes into account that with refinancing, the average interest paid on total debt next period would be equal to R_t^f, while in the absence of refinancing, the average interest on total debt would be equal to R_t^m as implied by equation (5).

4.1.1 Determination of interest rates and other exogenous variables

We assume that the policy rate set by the central bank, R_t, follows an AR(1) process with a persistence parameter ρ_R:

$$R_t = (1 - \rho_R) R + \rho_R R_{t-1} + \varepsilon_{R,t}, \tag{8}$$

where R denotes the steady-state level of the policy rate, ρ_R is the persistence parameter, and $\varepsilon_{R,t}$ is an *i.i.d.* monetary policy shock. The current interest rate on fixed-rate long-term loans, R_t^f, is then determined by a weighted sum of current and future policy rates based on the expectations hypothesis plus a constant term, τ, capturing the risk premium on mortgages relative to government bonds as

$$R_t^f = \kappa \sum_{s=0}^{\infty} (1 - \kappa)^s R_{t+s} + \tau, \tag{9}$$

since the duration of the loans is (approximately) $1/\kappa$. When the loans are adjustable-rate, we set $R_t^f = R_t$ for all t, and thus, changes in the policy rate pass through to the current borrowing rate fully.[17]

Similar to Alpanda and Zubairy (2019), we assume that there is a lagged feedback effect from the policy rate to house prices as:

$$\log q_t = \rho_q \log q_{t-1} - \rho_{qR} (R_{t-1} - R), \tag{10}$$

where ρ_{qR} denotes a pass-through parameter.[18] This feedback effect is important to generate a credit channel for monetary policy transmission when the LTV constraint is binding. In particular, a policy rate cut would increase the house price, relaxing the borrowers' LTV constraint and thus inducing them to borrow further.[19]

Finally, we assume that there is a lagged feedback effect from the policy rate to real wages as:

$$\log w_t = (1 - \rho_w) \log w + \rho_w \log w_{t-1} - \rho_{wR} (R_{t-1} - R), \tag{11}$$

[17] In Alpanda and Zubairy (2017), this follows from the arbitrage condition between the saver households' incentives to give adjustable-rate long-term loans to borrowers versus purchasing 1-period government bonds.

[18] Thus, we have assumed, without loss of generality, that the steady-state value for the relative price of housing, q, is equal to 1.

[19] Note that our empirical results show state-dependent responses of house prices to monetary shocks, notably across slumps and booms. If we allow that, it would help strengthen the channel of transmission but we keep it linear in this exercise to keep things simple and clarify the main credit channel at work.

where $w_t = W_t/P_t$ denotes the real wage rate with a steady-state level of w, and ρ_{wR} regulates the pass-through from the policy rate to real wages. A policy rate cut increases wages, relaxing borrowers' DSR constraint and allowing them to borrow more. Note that (10) and (11) are reduced form ways to capture general equilibrium effects of monetary policy shocks on house prices and wages.

4.2 Model Solution

Assuming the utility function obeys the usual regularity conditions (e.g., strictly increasing and concave), either the LTV or the DSR constraint will bind every period as long as the households discount the future sufficiently (i.e., $\beta << 1/(1+R)$). Thus, the equilibrium amount of new loans taken by the borrower in real terms, $l_t = L_t/P_t$, is given by

$$l_t = \max\left\{0, \min\left\{\phi q_t \overline{h} - \frac{1-\kappa}{\pi}d_{t-1}, \frac{\theta w_t}{R_t^f+\kappa} - \frac{\left[\Phi_t R_t^f + (1-\Phi_t)R_{t-1}^m + \kappa\right]}{R_t^f+\kappa}\frac{1-\kappa}{\pi}d_{t-1}\right\}\right\}, \quad (12)$$

where $d_t = D_t/P_t$ denotes the real stock of debt. Thus, if either the LTV or the DSR constraint is not satisfied, the agent cannot extract any equity and cannot refinance existing loans (i.e., $l_t = 0$ and $\Phi_t = 0$). The agent would thus simply pay off the interest and principal on existing debt, and consume the rest of his/her wage income as determined by the budget constraint

$$c_t = w_t - \frac{R_{t-1}^m+\kappa}{\pi}d_{t-1}, \quad (13)$$

while deleveraging his/her stock of debt as

$$d_t = \frac{1-\kappa}{\pi}d_{t-1}, \quad (14)$$

with his/her average interest burden staying the same as in the previous period (i.e., $R_t^m = R_{t-1}^m$).

If the agent satisfies both the LTV and the DSR constraints, then the level of new borrowing is determined by whichever constraint is more stringent:

$$l_t = \min\left\{\phi q_t \overline{h} - \frac{1-\kappa}{\pi}d_{t-1}, \frac{\theta w_t}{R_t^f+\kappa} - \frac{\left[\Phi_t R_t^f + (1-\Phi_t)R_{t-1}^m + \kappa\right]}{R_t^f+\kappa}\frac{1-\kappa}{\pi}d_{t-1}\right\} \quad (15)$$

with the agent choosing to refinance (i.e., $\Phi_t = 1$) when the current fixed rate on loans is lower than his/her existing average interest burden (i.e., $R_t^f < R_{t-1}^m$), and choosing not to refinance (i.e., $\Phi_t = 0$) when $R_t^f \geq R_{t-1}^m$. The equilibrium levels for the debt stock, average interest burden, and consumption are then determined, respectively, as

$$d_t = \frac{1-\kappa}{\pi} d_{t-1} + l_t, \tag{16}$$

$$R_t^m = (1-\Phi_t)\frac{1-\kappa}{\pi}\frac{d_{t-1}}{d_t} R_{t-1}^m + \left(\frac{l_t}{d_t} + \Phi_t \frac{1-\kappa}{\pi}\frac{d_{t-1}}{d_t}\right) R_t^f, \tag{17}$$

and

$$c_t = w_t + l_t - \frac{R_{t-1}^m + \kappa}{\pi} d_{t-1}. \tag{18}$$

4.3 Transmission and state dependence of monetary policy

The components on the right hand side of the equilibrium consumption expression in (18) indicate that the transmission of a monetary policy shock on consumption demand works through three distinct channels in the model: namely, wage, credit, and interest burden channels. As will be discussed below, refinancing affects both the credit and the interest burden channels.

The wage channel of monetary transmission refers to the effect of a rate cut on the real wage rate, w_t. This generates an (indirect) income effect on consumption demand, whose strength depends on the pass-through parameter, ρ_{wR}, in the wage equation (11). Note that the model solution above indicates that the effects of this wage channel of monetary transmission in the model is not state dependent. In particular, the agent's existing levels of income, debt, and average interest burden do not affect the efficacy of this channel, and thus, regardless of initial conditions, the policy rate generates the same effect on wages and therefore consumption.[20]

The second channel of monetary transmission is the credit channel, whereby a rate cut induces agents to take out more new loans, l_t, since both the LTV and the DSR constraints are relaxed as a result of the rate cut. In particular, a decrease in the policy rate relaxes the LTV constraint by raising the price of housing, q_t, while it relaxes the DSR constraint by increasing the agent's wage income and lowering his/her interest burden on the new debt acquired, R_t^f (see equation (15)). Note that, when the agent can refinance, the DSR constraint would be relaxed even further since the interest rate on existing debt is also lowered to R_t^f in this case.

Unlike the wage channel discussed above, the efficacy of the credit channel of monetary transmission is state dependent with respect to all the three aggregate cycles we are considering. For

[20]This is likely a simplification given our partial equilibrium setup. In a general equilibrium setting, the change in the wage rate may be a function of aggregate demand, and if the effects of monetary policy on aggregate demand is state dependent in general, then its effects on the wage rate would also be state dependent. Our simple partial equilibrium model abstracts from this subtle issue. Endogenizing this would only strengthen our results, and is therefore not attempted here.

state dependence with respect to the business cycle, note that the level of the agent's wage income, w_t, is a moderating factor for the effects of the fixed mortgage rate on the debt limit implied by the DSR constraint. In particular, the same decline in R_t^f would result in a higher relaxation of the DSR constraint when w_t is high versus when it is low. Given that real wages and incomes are higher at the expansion phase of the business cycle relative to the contraction phase, the effects of monetary policy would be stronger during expansions versus recessions. Similarly, for the state dependence of the credit channel with respect to the credit cycle, observe that the level of existing debt, d_{t-1} affects the tightness of both the LTV and the DSR constraints. At high levels of debt, the agent is unable to satisfy either the LTV or the DSR constraint (or both), and therefore, will not be able to borrow at the margin or to refinance despite the rate cut, while the same rate cut would induce new borrowing when the agent's existing level of debt is low. In the aggregate, this would render monetary policy to be state dependent with respect to the credit cycle. Finally, for the state dependence of the credit channel with respect to the interest rate cycle, observe that the borrower's DSR constraint is relaxed further when the agent is able to refinance her existing debt, which occurs only when $R_t^f < R_{t-1}^m$. In the aggregate, there will be more refinancing in a loosening cycle relative to a tightening cycle of interest rates, which thus renders the credit channel relatively less effective in a tightening cycle. To summarize, the solution of the model indicates that the efficacy of the credit channel of monetary policy, which affects consumption demand through new borrowing, l_t, is likely to be state dependent in the aggregate with respect to all the three major cycles we are considering in this paper.

The third channel of monetary transmission is captured by the last term in the consumption expression in (18), and is due to the policy rate's effect on the average interest burden of the borrower. In particular, a rate cut reduces the average interest burden of the borrower in future periods, and this effect is stronger if the agent is also able to refinance existing loans to a lower rate as well as reducing the cost of new borrowing on the margin. The solution of the model suggests that this interest burden channel of monetary transmission is also state dependent, at least with respect to the credit and interest rate cycles. In particular, the same decline in the interest rate would result in bigger interest cost savings when the borrower's existing level of debt is high. Thus, unlike the credit channel, the interest burden channel would imply a stronger effect of monetary policy on consumption when existing levels of debt are high. Note however that the possibility of refinancing may actually revert this result, or generate a non-linear effect of monetary policy on the interest burden. In particular, at low and medium levels of debt, the agent would also be able to lower the interest burden on her existing debt through refinancing, while this is not possible at high levels of debt due to the LTV and DSR constraints on refinancing. Thus, the interest burden channel of monetary policy is also likely to be weaker at high levels of initial debt, complementing the state dependence of the credit channel with respect to the credit cycle discussed above. As the discussion above suggests, the interest burden channel is also state dependent with respect to the interest rate cycle given the higher likelihood of refinancing in a loosening cycle relative to a tightening cycle.

4.4 Theoretical impulse responses to a monetary policy shock

Impulse responses of key model variables to monetary policy shocks simulated from our model illustrate the aforementioned channels quantitatively. We first discuss the choice of the simulation parameters, which are mostly taken from Alpanda and Zubairy (2019). The policy rate at the steady state, R, is set to 0.01, reflecting a 4 percent nominal policy rate in annualized terms, while the constant inflation factor, π, is set to 1.005, for an annual inflation rate of 2 percent. The share of debt principal paid out every period, κ, is set to 0.0125, reflecting an average loan duration of 20 years, and τ is set to 0.005 to reflect a constant 2% risk premium on mortgages. The LTV ratio for housing loans, ϕ, is set to 80%, and the DSR ratio, θ, is set to 36%, following Greenwald (2018). Without loss of generality, the steady state level of wages, w, is normalized to 1, while the housing quantity parameter, $\bar{h}$, is set equal to 16. These parameters imply that the borrower's steady-state housing-to-income and debt-to-income ratios in annualized terms are 4 and 3.2, respectively.[21] Finally, for the exogenous processes on interest rates, house prices, and wages, we set the persistence parameters ρ_R, ρ_q, and ρ_w to 0.85, 0.95, and 0.95 respectively. The response coefficient of house prices to interest rates, ρ_{qR}, is set equal to 1 to ensure that an annualized 100 bps decline in policy rates leads to a peak response in house prices of 1%, while we abstract from the wage channel in what follows by setting the pass-through parameter ρ_{wR} in (11) equal to 0.

INSERT FIGURE 16 HERE

Figure 16 plots a borrower's impulse responses to an annualized 100 bps innovation in the monetary policy shock conditional on the initial state of the business cycle. In particular, in the "high initial income" case, the initial level of wages, w_{-1}, is set to its steady state level of 1 (thus, $w_t = 1$ for all t in this baseline case), while in the "low initial income" case, the initial level of wages, w_{-1}, is 10% below the steady state level (i.e., $w_{-1} = 0.9$), but approaches the steady state level of 1 over time given persistence parameter $\rho_w = 0.95$. For each case, the impulse responses are computed by simulating the model separately with and without the monetary shock, and then taking the difference of these paths.[22] We also assume that agents are able to extract only a

[21] Note that at the steady state, the LTV constraint is more stringent than the DSR constraint since $\phi \frac{qh}{y} < \frac{\theta}{R^f + \kappa}$.

[22] Thus, in the "low income" case, we start the simulations off the steady state only for the initial level of income, while setting the initial policy rate before the shock, the price of housing, and the initial debt levels to their steady-state values. Note that the control simulations in the absence of the monetary shock still imply transitional dynamics, but our "shock minus control" approach here isolates these dynamics from the impulse responses. We use a similar approach for all the impulse responses that follow.

fraction (5%) of their available home equity each period. This spreads out the impact of the home equity credit channel across more periods, and, although not crucial for the key message here, helps generate more persistent impulse responses for consumption, more in line with the empirical estimates presented in Section 3 of the paper.[23]

The impulse responses in the "high initial income" case are standard. In this case, the agent satisfies both the LTV and the DSR constraints when the monetary policy shock hits, but the LTV constraint is slightly more stringent and therefore binding. The decrease in the policy rate, R_t, reduces the rate at which the agents can borrow at the margin and refinance existing loans (i.e., R_t^f), which then reduces their average interest burden (i.e., R_t^m) in future periods. The decrease in the interest rate also leads to an increase in house prices, relaxing the LTV constraint, which allows the agent to increase new borrowing at the margin and thereby increase consumption.[24] In the "low initial income" case however, the agent does not satisfy the DSR constraint initially, and thus cannot extract any equity and cannot refinance the interest on existing debt despite the decline in interest rates. Thus, the agent is forced to delever during the first 3 periods, and monetary policy shock has no effect on the agent's consumption level.[25] The agent satisfies the DSR constraint at the 4th period, and can therefore lower the interest on existing debt through refinancing and also start extracting equity at the lower interest rate. Both these credit and interest rate channels help the agent increase his/her consumption levels, but the effects of the monetary shock are delayed and muted relative to the "high initial income" case, at least for the first 2 years following the shock. Consumption in the "high initial income" case slowly declines below the "low initial income" case in the following periods, as the higher level of new debt accumulated in the interim needs to be paid back with interest. In summary, the results suggest that the presence of the DSR constraint can generate state dependence for the effects of monetary policy with respect to the business cycle, since wages are lower during recessions relative to expansions, which then makes the DSR constraint more stringent.

INSERT FIGURE 17 HERE

Figure 17 repeats the same exercise but now plots the effects of the monetary policy shock

[23] Partial extraction of available home equity is also consistent with the empirical evidence on home equity extraction rates in the data (Alpanda and Zubairy, 2017).

[24] Note that, at the impact period $t = 0$, there is no change in consumption unless the DSR constraint is binding (and therefore more stringent than the LTV constraint) initially. This is because the interest paid on existing debt, R_{-1}^m, is pre-determined (thus, refinancing does not affect current period interest payments), and the policy rate is assumed to affect house prices only with a lag. A decline in R_0 would reduce R_0^f relaxing the DSR constraint, which then would increase consumption in the current period, if the DSR constraint was more stringent than the LTV constraint at the steady state.

[25] Note that the impulse response for the debt stock is shown as 0 during these 3 periods, since the same deleveraging occurs in both the "shock" and the "control" scenarios, with no additional impact of the monetary policy shock on the debt stock. Note also that the equilibrium level of home equity increases further 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.

conditional on the initial state of the credit cycle. In particular, in the “low initial debt” case, the initial level of debt, d_{-1}, is set to its steady state level of 12.8, while in the “high initial debt” case, the initial level of wages, d_{-1}, is 10% above the steady state level. The baseline low initial debt case is equivalent to the high income case before. In the “high initial debt” case, the agent does not satisfy the DSR constraint for 4 and the LTV constraint for 5 periods since its debt level and debt service burden are too high. Thus, the agent cannot extract any equity and cannot refinance the interest rate on her existing debt despite the decline in interest rates. As a result, the agent is forced to delever during the first 5 periods this time, and monetary policy shock has no effect on the agent’s consumption level during these periods. The effects of the monetary shock on borrowing and consumption are again delayed, and muted in a cumulative sense, relative to the “low initial debt” case. The results thus suggest that monetary policy effects with respect to the credit cycle can be state dependent due to the DSR (or the LTV) constraint, with lower impact during high initial debt situations.[26]

INSERT FIGURE 18 HERE

Finally, Figure 18 plots impulse responses for an annualized 100 bps points rate cut versus a rate increase, assuming that the initial interest burden and the initial policy rate prior to the shock are both at their respective steady state levels. The impulse responses for the rate increase case are reversed for variables in the first two rows of the figure to facilitate easier comparison of magnitudes with the rate cut case. The “rate cut” case is equivalent to the baseline cases discussed before. In the “rate increase” case, the current mortgage rate is greater than the average interest burden of the borrower (i.e., $R_t^f > R_{t-1}^m$), and thus the agent chooses not to refinance existing loans. This implies that the magnitude of the change in the interest burden in the rate cut versus the rate increase cases are significantly different. In particular, the agent is able to reduce his/her average interest burden significantly in the rate cut case, while in the rate increase case, the increased interest rate only applies to the newly acquired debt and not to the existing stock of debt brought from prior to the monetary policy shock. As a result, the average burden increases in the latter case, but not to a large extent. Thus, the adverse effects of monetary tightening on consumption through a rate increase is also smaller than the expansionary effects of monetary loosening on consumption through a rate cut, although quantitatively the differences are small. Note that, in both cases the LTV constraint is more stringent than the DSR constraint, and therefore the refinancing choice does not directly impact the credit channel. The conditionality with respect to the tightening

[26] Alpanda and Zubairy (2019) shows that the LTV constraint can also lead to state dependence with respect to the financial cycle. Also note that the analysis above considered only two initial income levels or two initial debt levels, but similar results would be obtained if we instead consider a distribution of initial income and debt across borrowers, only a fraction of which satisfy either the LTV or the DSR constraint or both initially, and examine how monetary policy effectiveness would change as income and debt distributions are shifted to the left or to the right, respectively.

versus loosening cycle of monetary policy arises solely from the refinancing's impact on the interest rate channel.

5 Conclusions

Understanding the transmission mechanism and assessing the effectiveness of stabilization policies is essential for the conduct of monetary policy. In this paper, we provide new insights on both fronts. First, we document stylized facts regarding the ability of monetary authorities to stimulate the economy. We use a state-dependent time-series model to find that the effectiveness of monetary policy in boosting GDP is curtailed during bad times, namely periods of economic slack, high household debt and high interest rates for a panel of advanced countries. Our findings are robust to alternative definition of states, identification of monetary policy shocks and subsample analysis. These results could explain why after the Great Recession many countries have experienced a weak recovery despite accommodative monetary measures.

Second, we show in a simple model that different transmission channels are sensitive to phases of the business, credit and interest rate cycles. Our small-scale theoretical set-up highlights the role of the credit channel arising from the collateral and debt service constraints faced by households, as well as the possibility of refinancing existing mortgages, as possible drivers of our empirical results.

Our analysis suggests that during downturns, monetary authority might need to be more aggressive and need larger discretionary actions to have a given size effect on GDP, that might be achieved with smaller shocks in good times. Also, since the effectiveness of monetary policy is at times curtailed, our results indicate that the use of alternative tools to monetary policy should also be considered in perilous times.

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Table 1. Characteristics of States

	States Classification					
	Business Cycle		Credit Cycle		Interest Rate Cycle	
	Slumps	Booms	High Debt	Low Debt	Tightening	Loosening
Frequency and Duration						
proportion of quarters	0.53	0.47	0.24	0.76	0.25	0.75
quarters in state	6	7	18	44	7	19
number of episodes	264	262	49	62	113	130
Macro Variables						
real output growth qoq (%)	0.34	0.80	0.16	0.67	0.22	0.64
inflation rate qoq (%)	0.89	1.01	0.76	0.82	1.50	0.52
real hh debt growth qoq (%)	0.96	1.18	0.75	1.16	0.75	1.13
nominal short term rate	5.82	6.38	5.07	5.61	9.68	4.35
nominal long term rate	6.87	6.82	5.92	6.39	9.67	5.33
house price growth qoq (%)	0.21	0.63	-0.35	0.69	-0.26	0.67

Note: The table shows some descriptive statistics for selected variables during the states classification defined in Section 2.1.

Table 2. Frequency of Joint States

Panel A. States Classification: 2 States

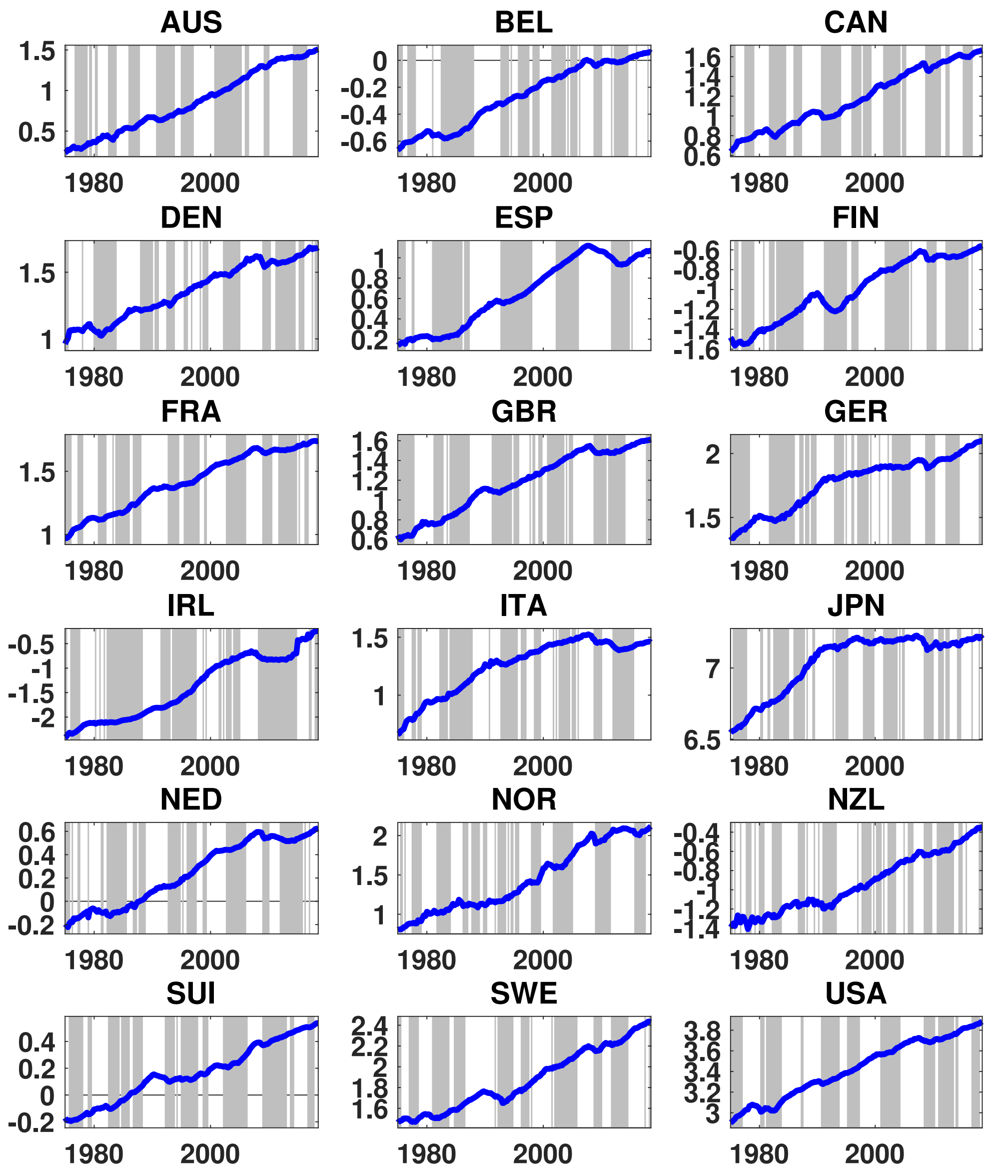
Slumps		Booms	
High Debt	Low Debt	High Debt	Low Debt
0.14	0.39	0.10	0.37
Slumps		**Booms**	
Tightening	Loosening	Tightening	Loosening
0.09	0.43	0.16	0.32
High Debt		**Low Debt**	
Tightening	Loosening	Tightening	Loosening
0.08	0.17	0.16	0.59

Panel B. States Classification: 3 States

Slumps				Booms			
High Debt		Low Debt		High Debt		Low Debt	
Tightening	Loosening	Tightening	Loosening	Tightening	Loosening	Tightening	Loosening
0.03	0.11	0.06	0.32	0.05	0.06	0.10	0.27

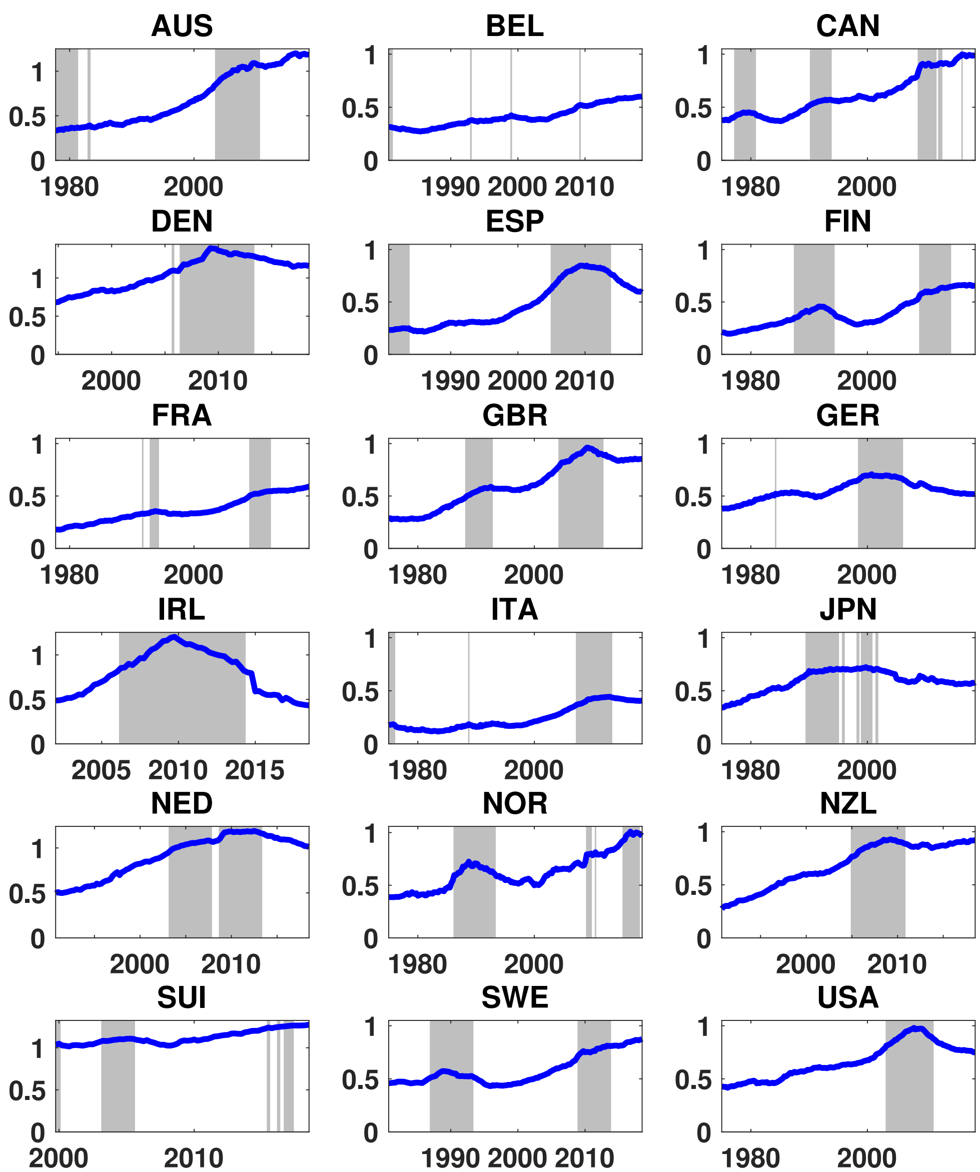
Note: The table shows the proportion of observations in each state given the state classification defined in Section 2.1.

Figure 1: Log Real GDP and Slumps



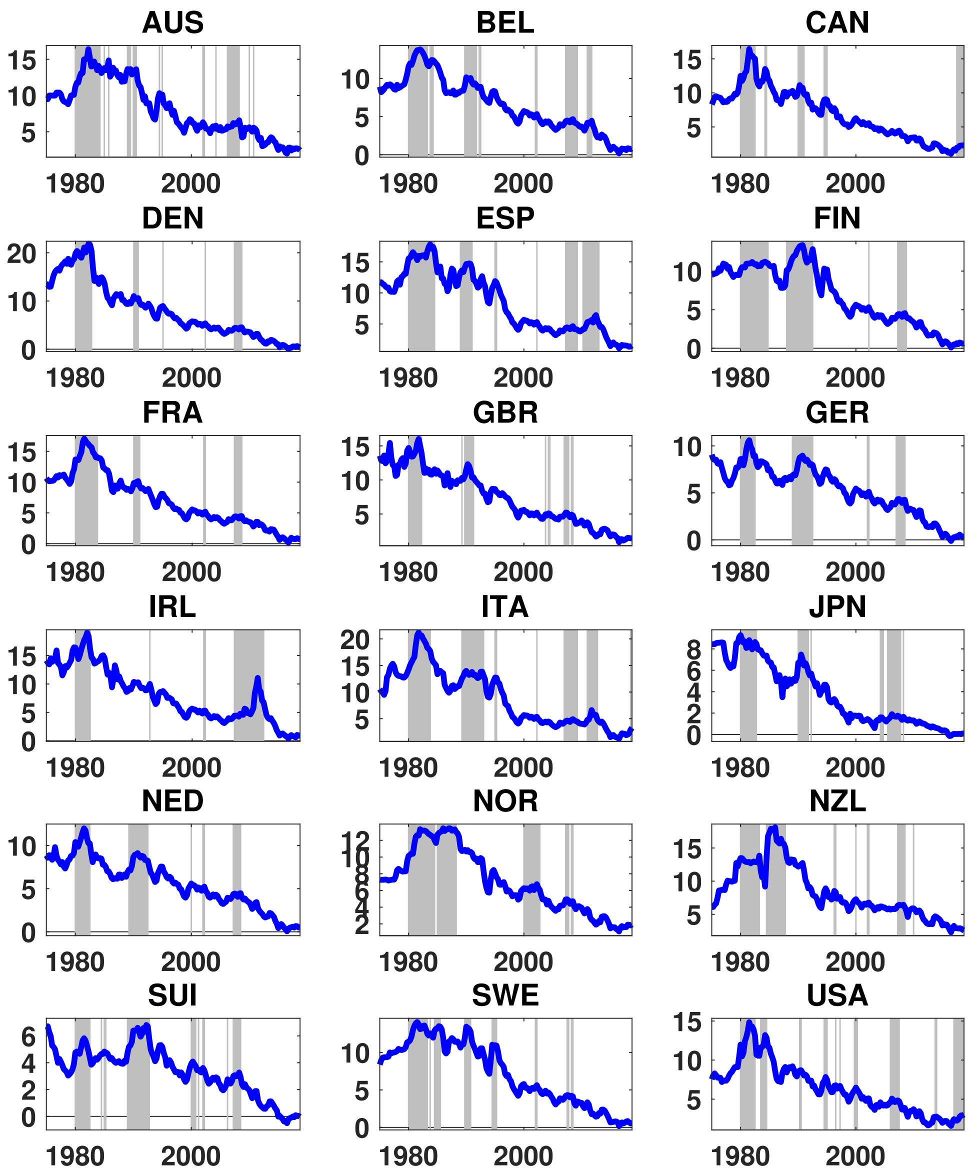
Note: The figure shows the log of real GDP (line) and the recession dates (shaded areas) identified as negative output gap, where the gap is constructed as deviation from two-sided HP filter trend obtained using as smoothing parameter λ=1600.

Figure 2: Debt-to-GDP Ratio and High Debt States



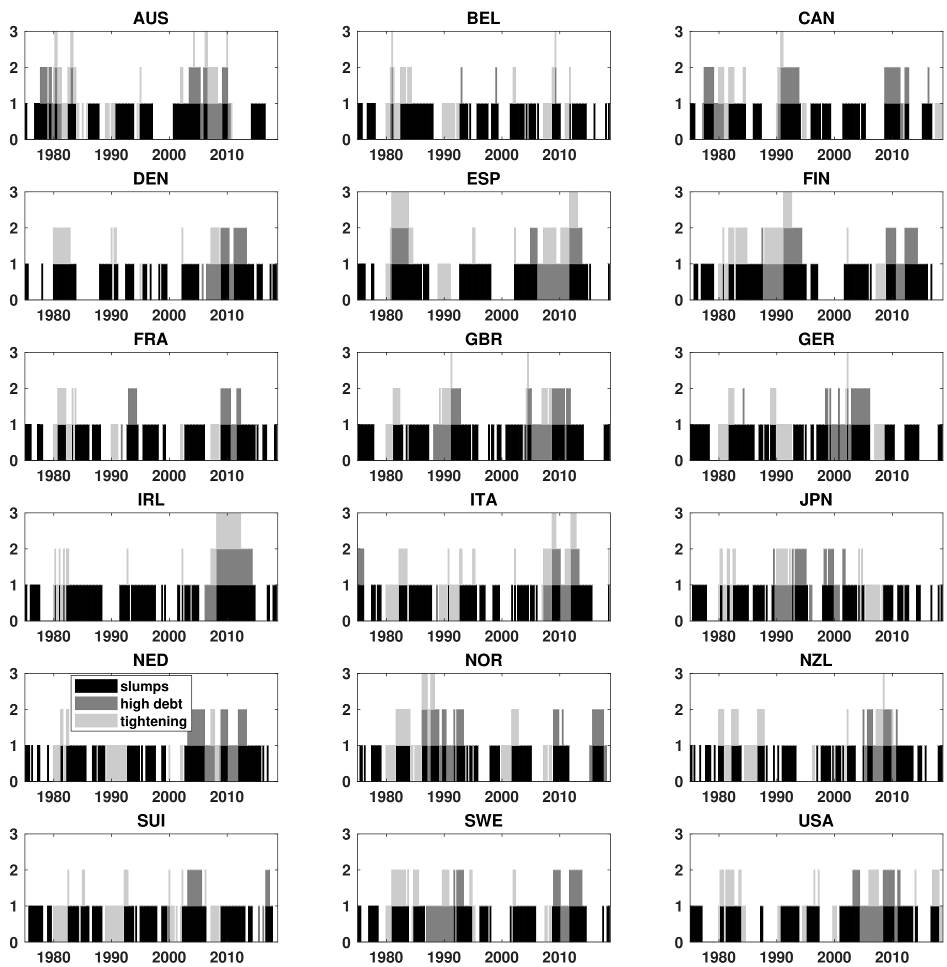
Note: Household debt-to-GDP ratio (line) and high debt states (shaded areas). High debt states are defined as periods in which household debt to GDP gap is above the 75th percentile of the gap distribution, where the gap is constructed subtracting from the debt to GDP series the two sided hp filtered trend obtained using as smoothing parameter λ=400000.

Figure 3: Long Term Rates and Interest Rate Hikes



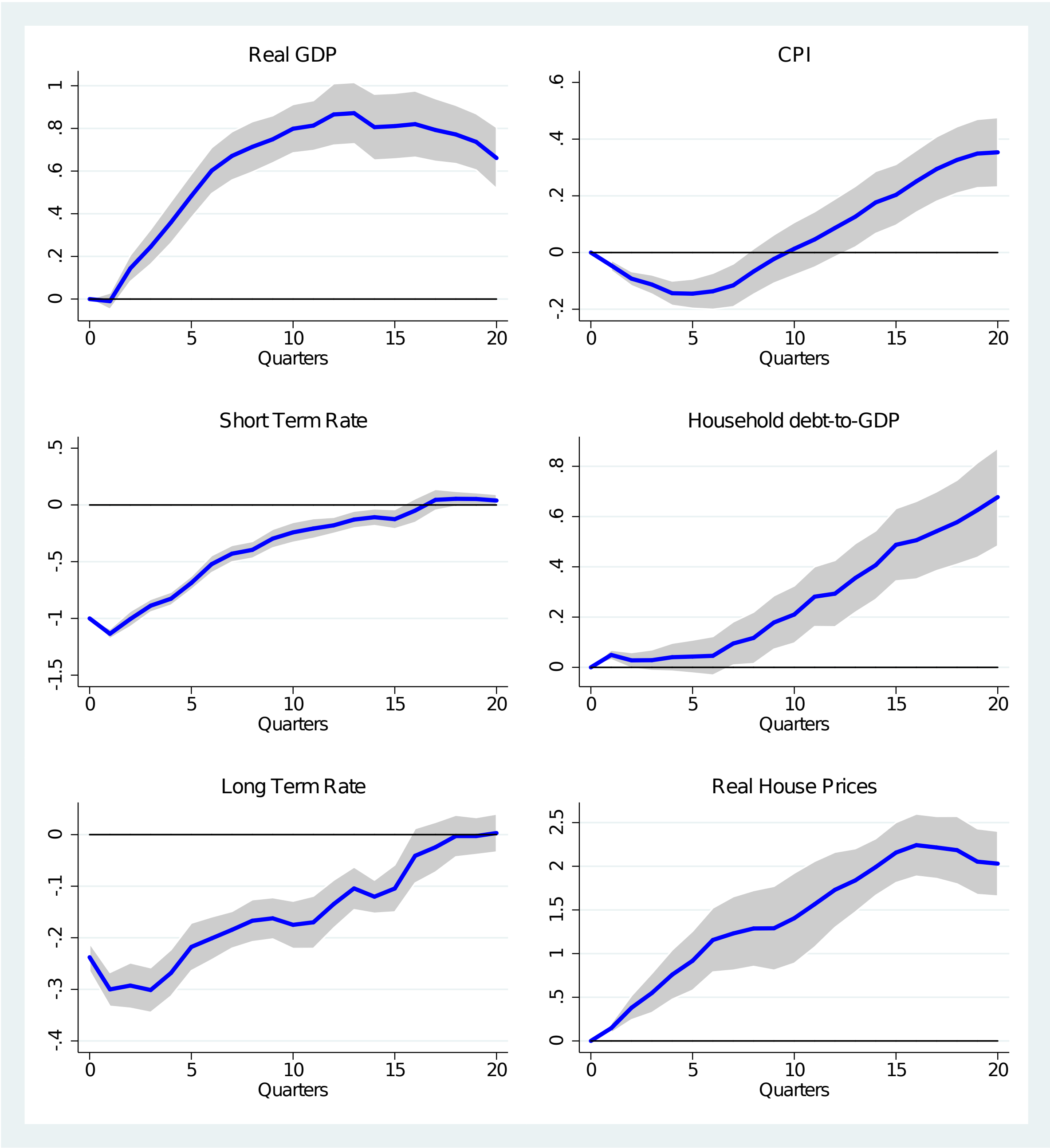
Note: Nominal long term interest rates (line) and high interest states (shaded areas). High interest states are defined as periods in which the long term rate is above the average of the previous five years.

Figure 4: "Perilous" States Across Countries and Time



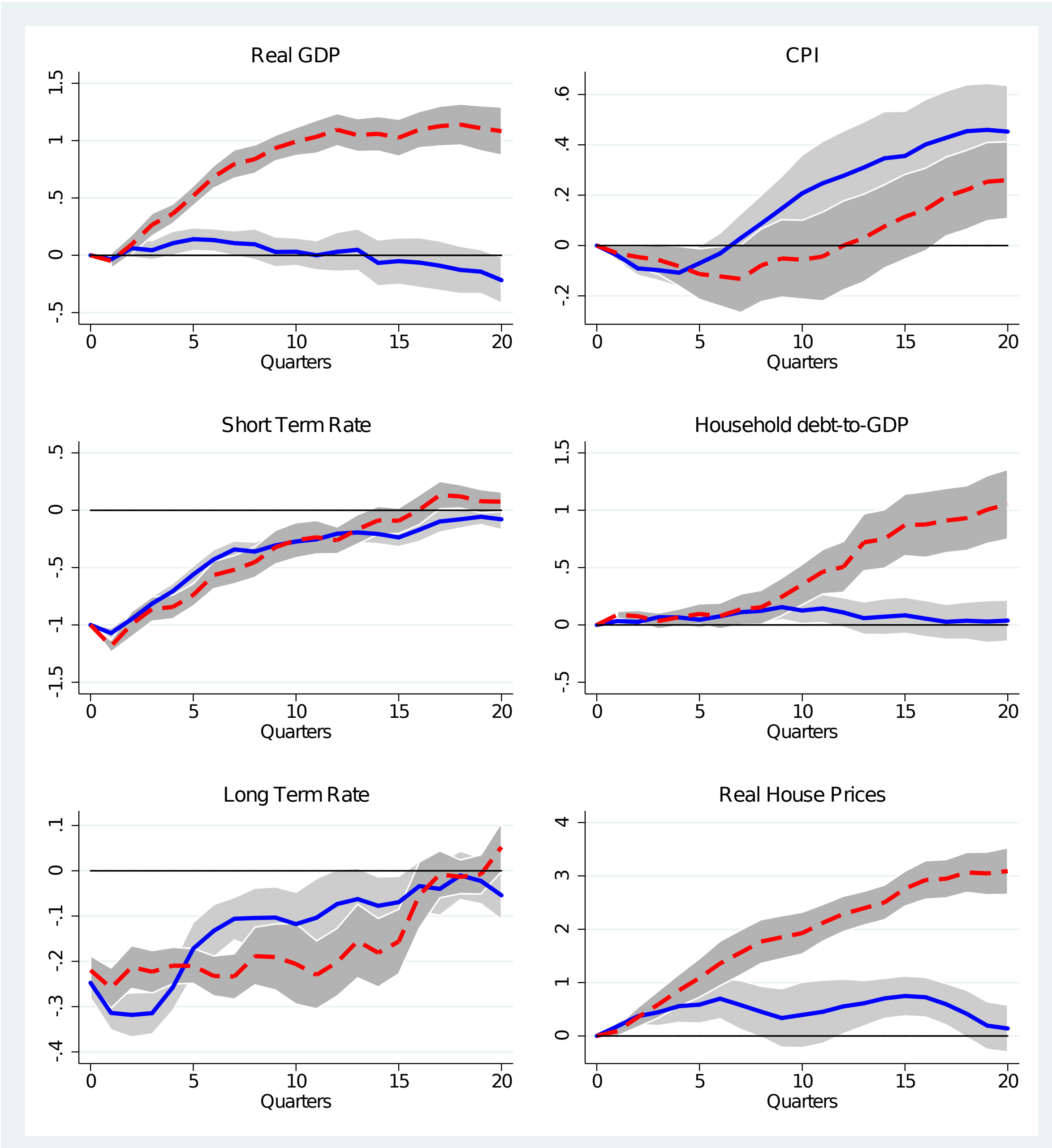
Note: The figure shows for every quarter whether a country was in a slump (black), high debt state (dark grey) or tightening cycle (light grey).

Figure 5: Linear Impulse Responses to a Monetary Shock



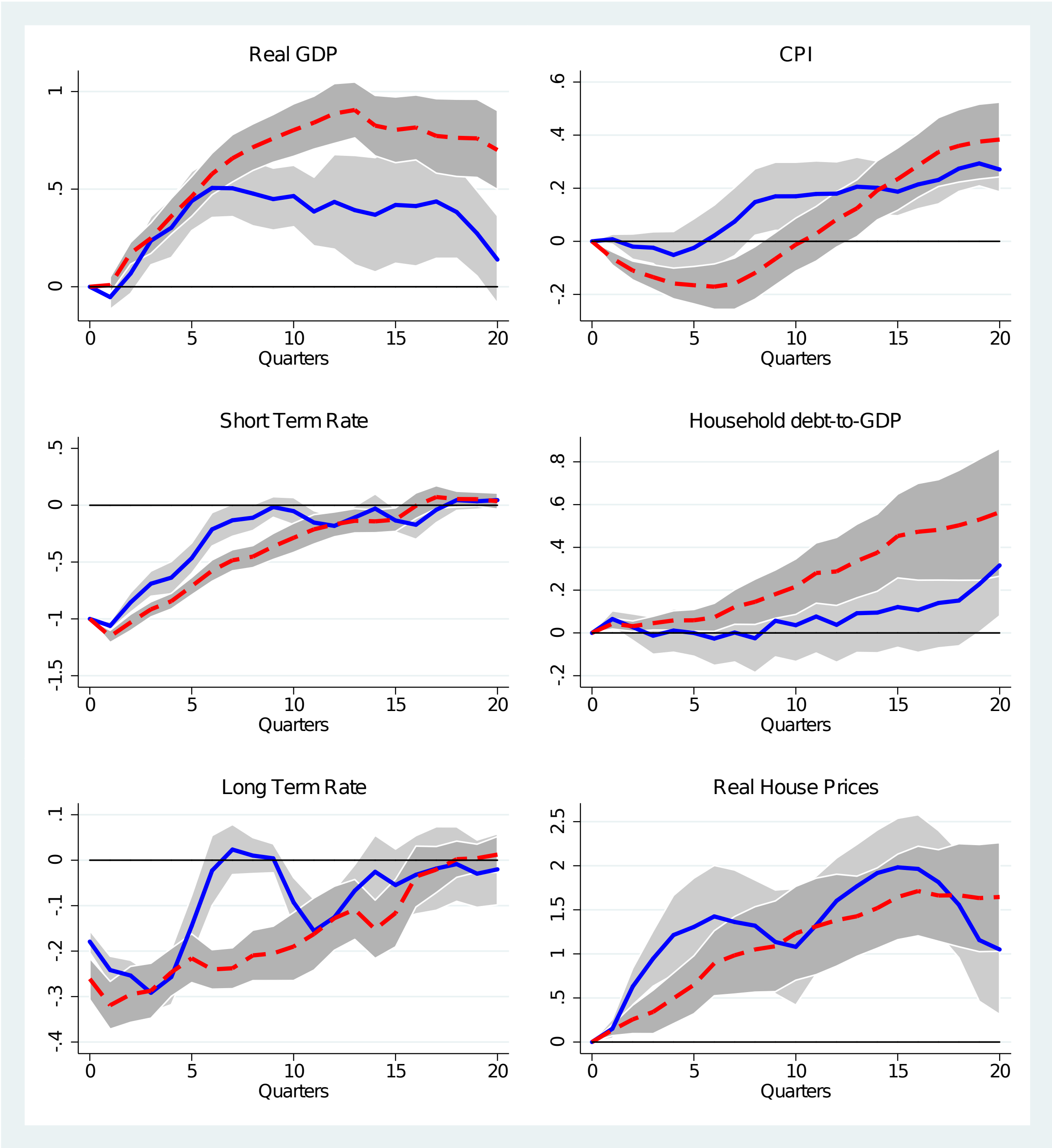
Note: The figure shows the impulse responses of the variables to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points. Shaded areas denote one standard error confidence bands. Responses for the short and long term rates are in levels, for the debt-to-gdp ratio are in cumulative changes, for the remaining variables are cumulative change in logarithms.

Figure 6: State Dependent Impulse Responses: Slumps vs Booms



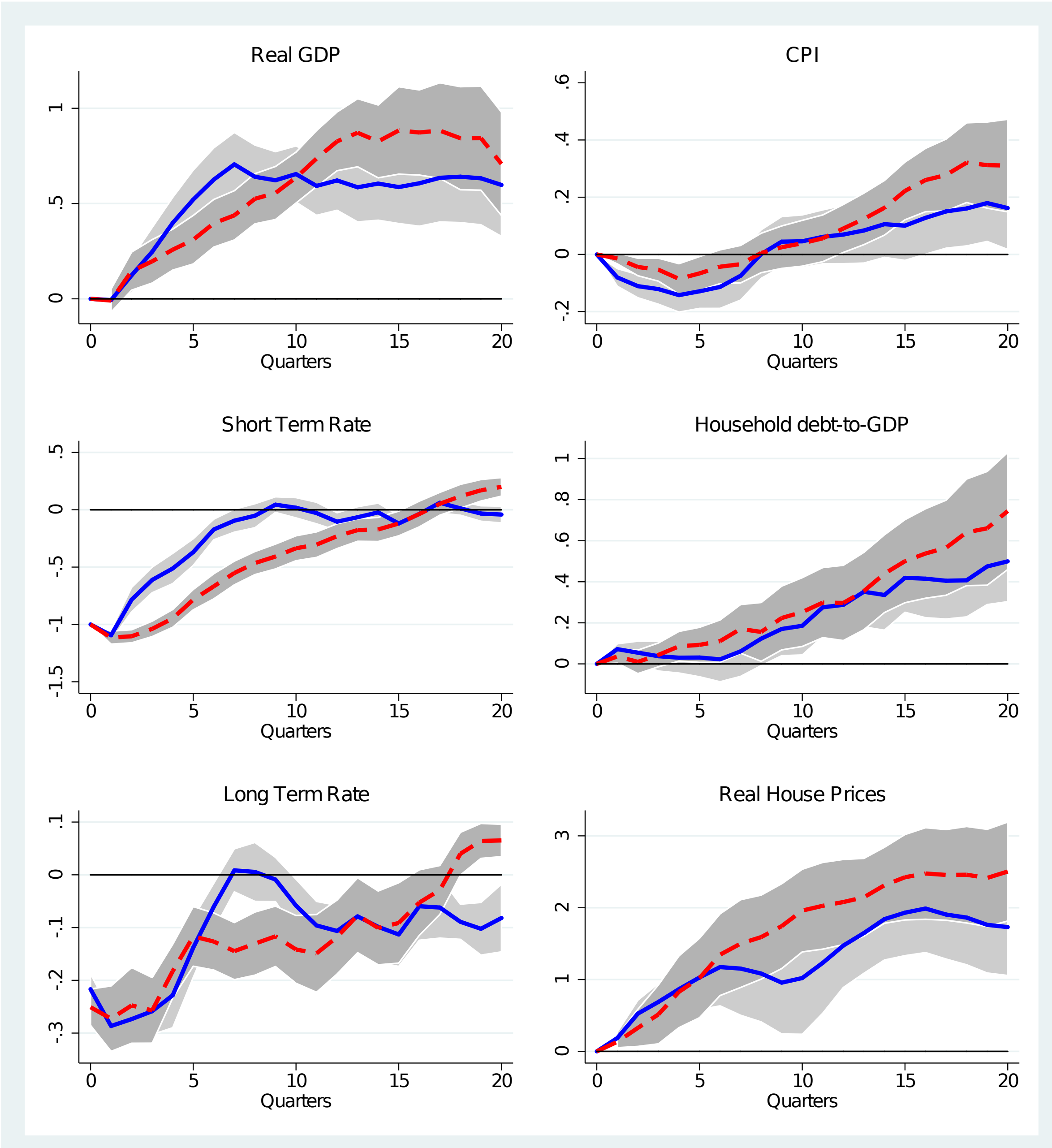
Note: The figure shows the impulse responses of the variables to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points. Solid blue (red) lines denote the responses during slumps (booms). Shaded areas denote one standard error confidence bands. Responses for the short and long term rates are in levels, for the debt-to-gdp ratio are in cumulative changes, for the remaining variables are cumulative change in logarithms.

Figure 7: State Dependent Impulse Responses: High vs Low Debt



Note: The figure shows the impulse responses of the variables to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points. Solid blue (red) lines denote the responses during high debt (low debt). Shaded areas denote one standard error confidence bands. Responses for the short and long term rates are in levels, for the debt-to-gdp ratio are in cumulative changes, for the remaining variables are cumulative change in logarithms.

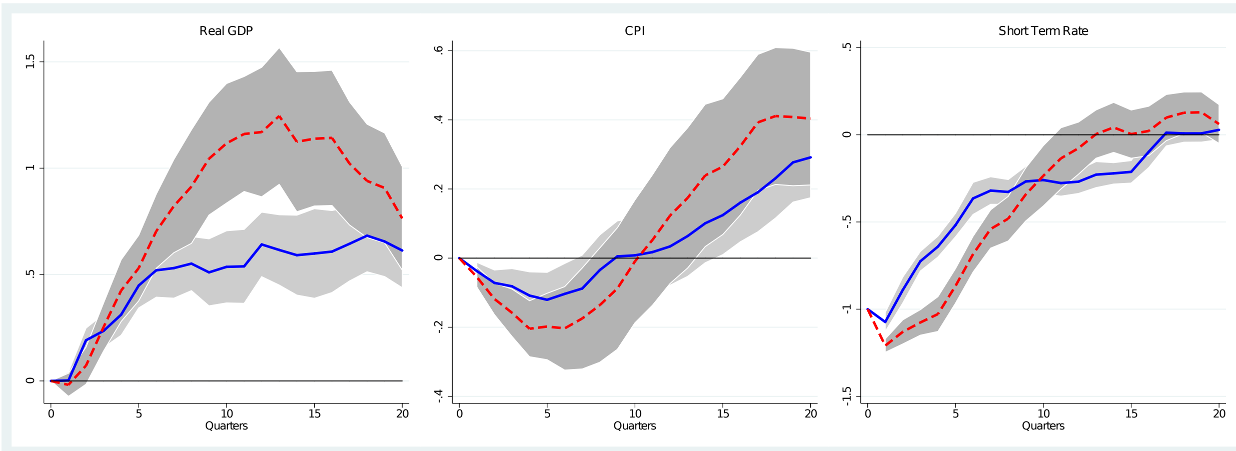
Figure 8: State Dependent Impulse Responses: Tightening vs Loosening



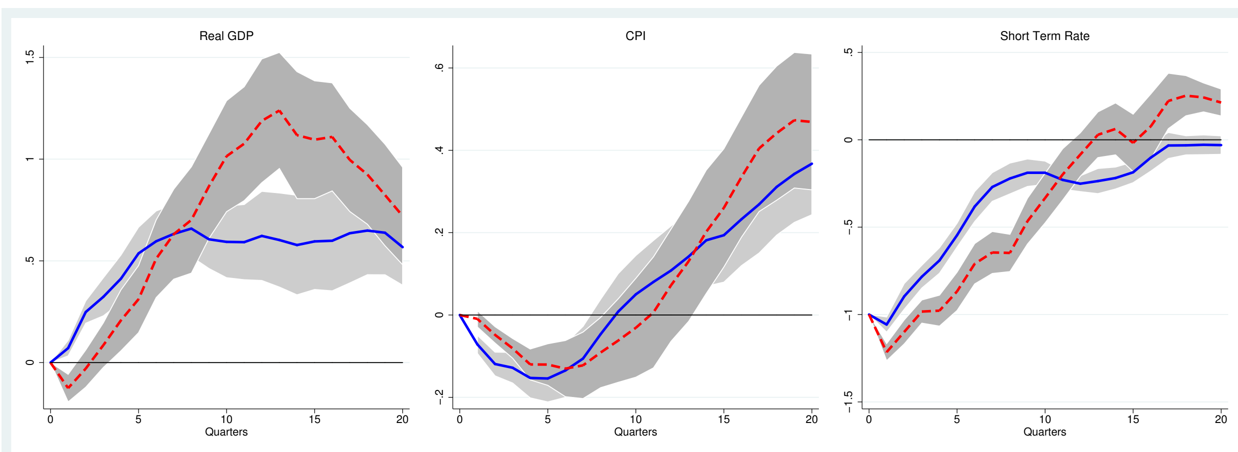
Note: The figure shows the impulse responses of the variables to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points. Solid blue (red) lines denote the responses during tightening (loosening). Shaded areas denote one standard error confidence bands. Responses for the short and long term rates are in levels, for the debt-to-gdp ratio are in cumulative changes, for the remaining variables are cumulative change in logarithms.

Figure 9: State Dependent Impulse Responses: Alternative State Definition

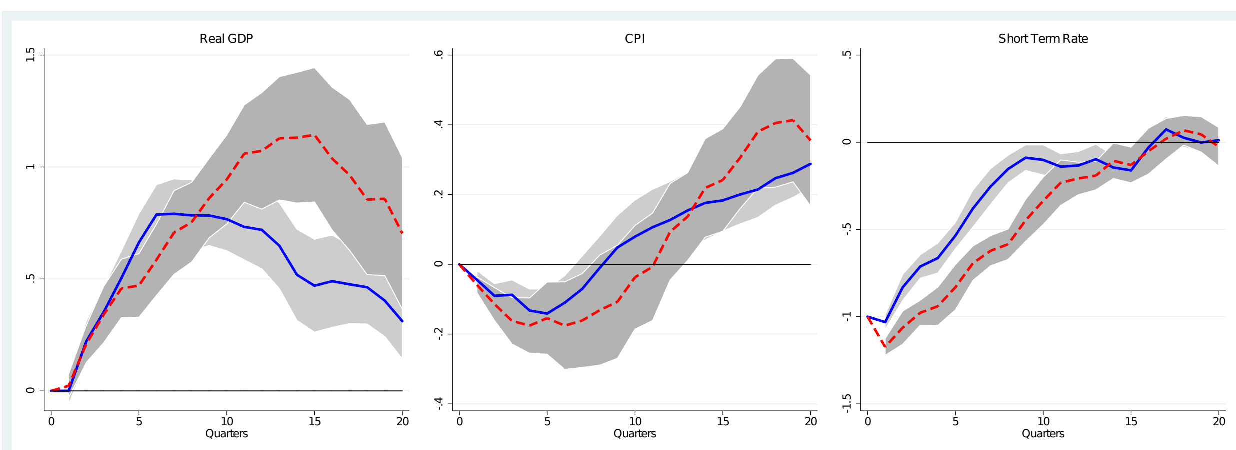
(a) OECD Recessions vs Expansions



(b) Hamilton (2018) filter to define booms and slumps

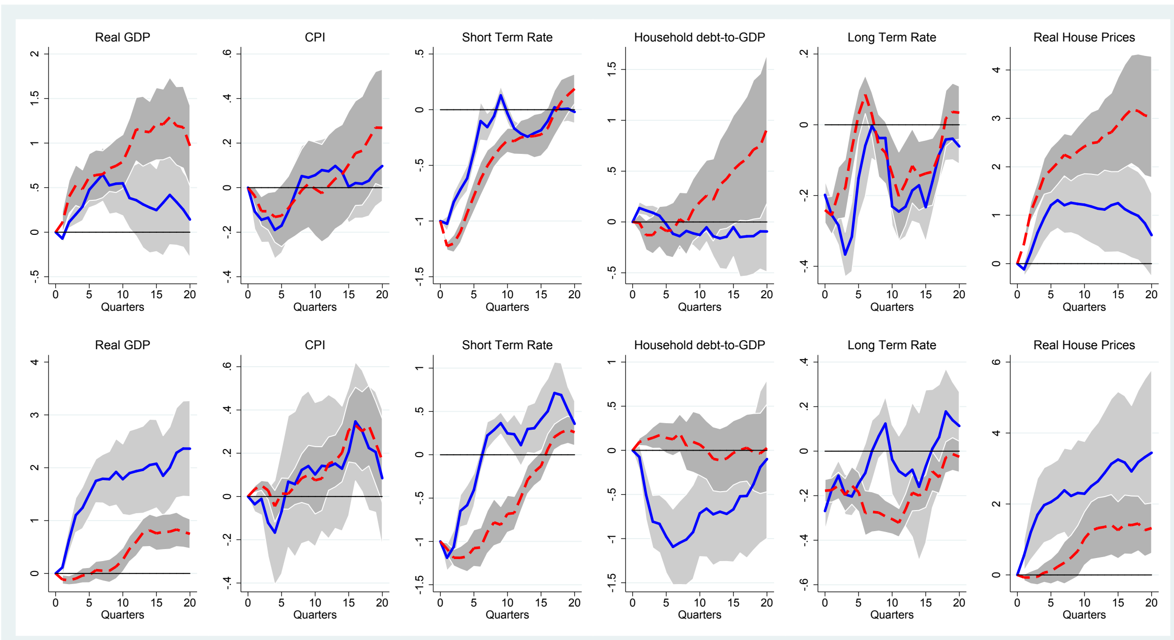


(c) High vs Low Debt Service Ratio



Note: Solid blue (red dashed) lines denote the responses during slumps (booms) in the top two panels and high (low) debt service ratio in the bottom panel.

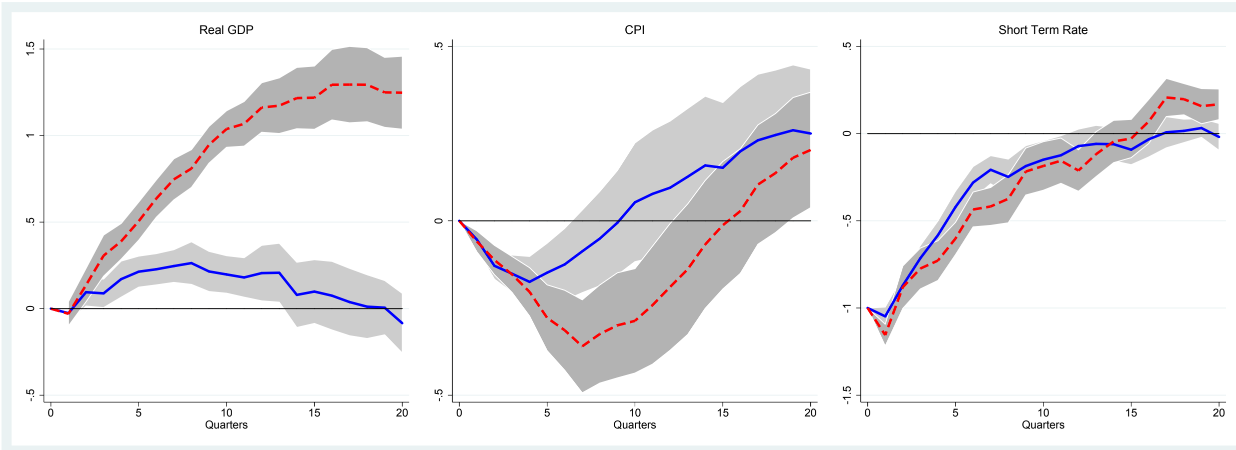
Figure 10: State Dependent Impulse Responses: Tightening vs Loosening across Fixed and Variable Rate Mortgages



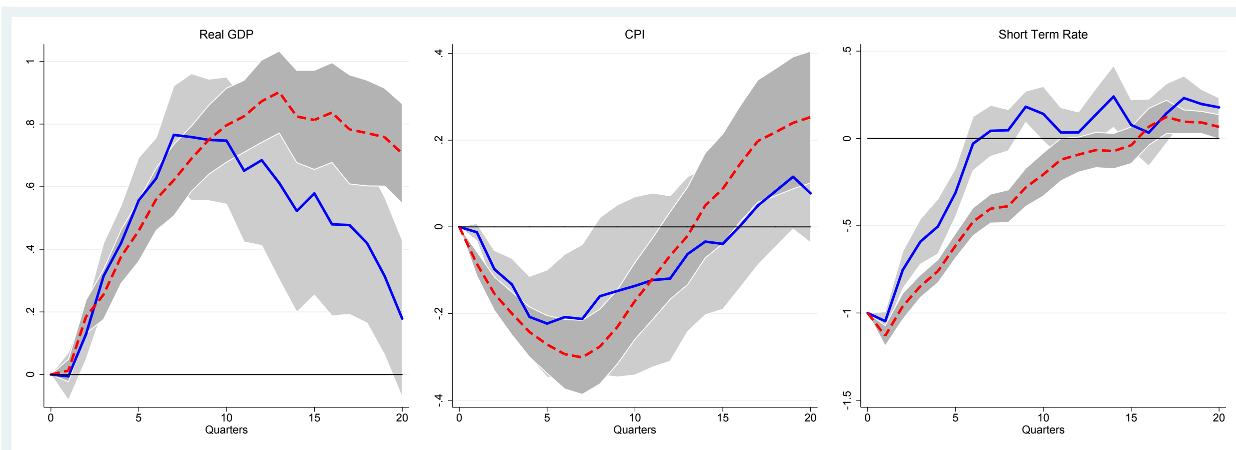
Note: The figure shows the impulse responses of the variables to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points. The top panel shows the variable mortgage rates and the bottom panel shows fixed rate case. In both panels, solid blue (red dashed) lines denote the responses during tightening (loosening) cycles. Shaded areas denote one standard error confidence bands. Responses for the short and long term rates are in levels, for the household debt-to-gdp ratio are in cumulative changes and for the remaining variables are cumulative change in logarithms.

Figure 11: State Dependent Impulse Responses: Sample up to 2006Q4

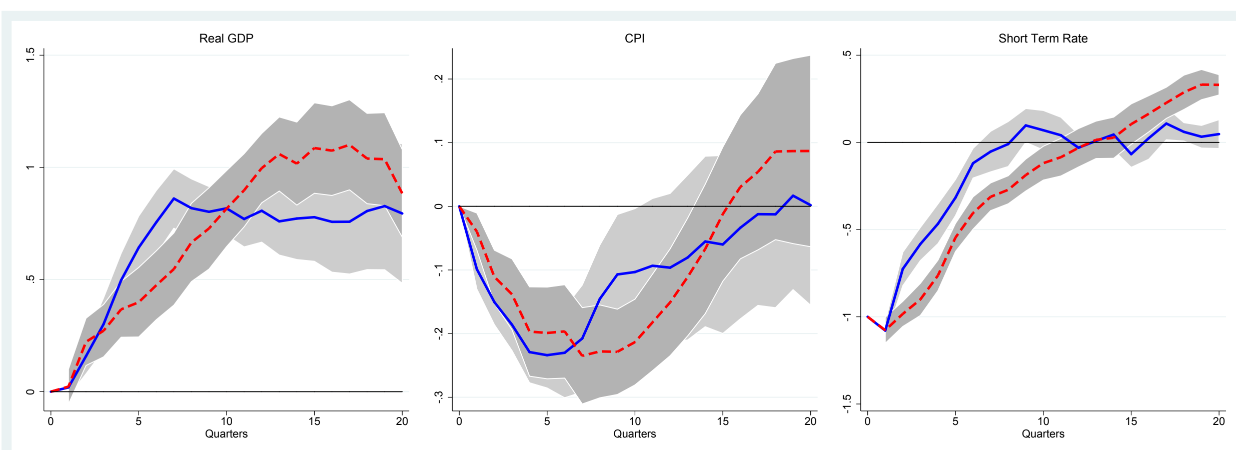
(a) Slumps vs Booms



(b) High vs Low Debt



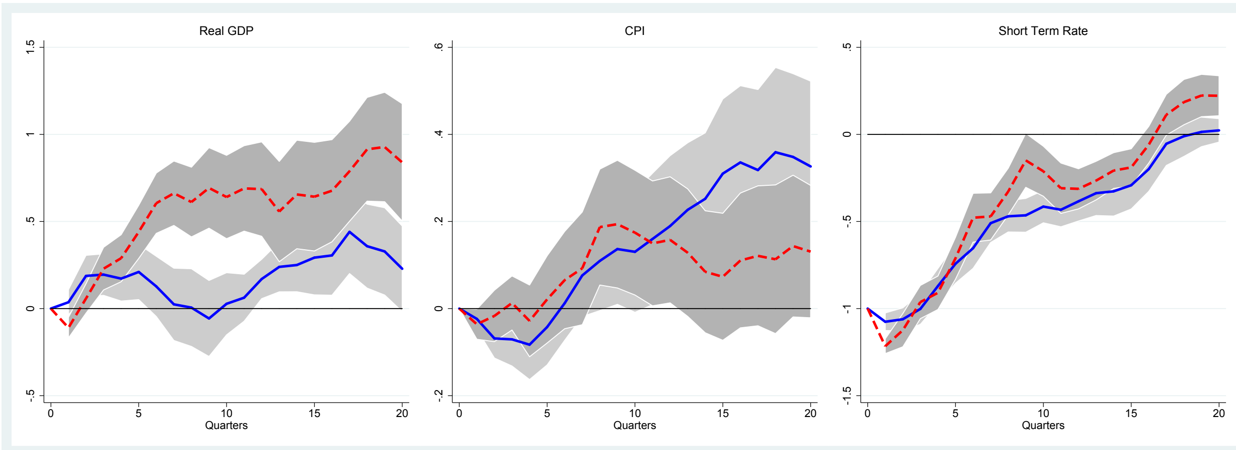
(c) Tightening vs Loosening



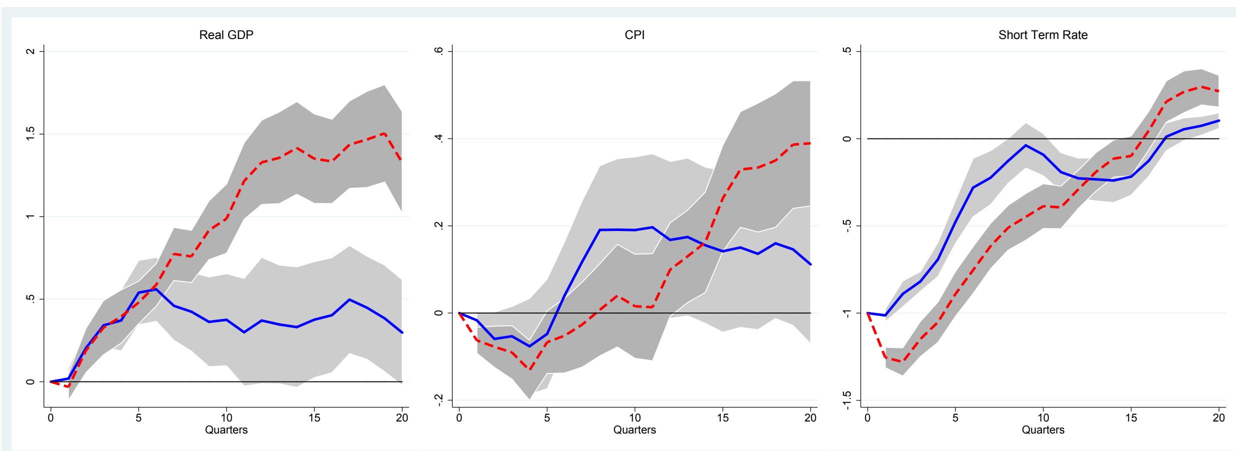
Note: Solid blue (red dashed) lines denote the responses during slumps (booms)in the top panel, high (low) debt in the second panel and tightening (loosening) in the bottom panel.

Figure 12: State Dependent Impulse Responses: Sample from 1990Q1

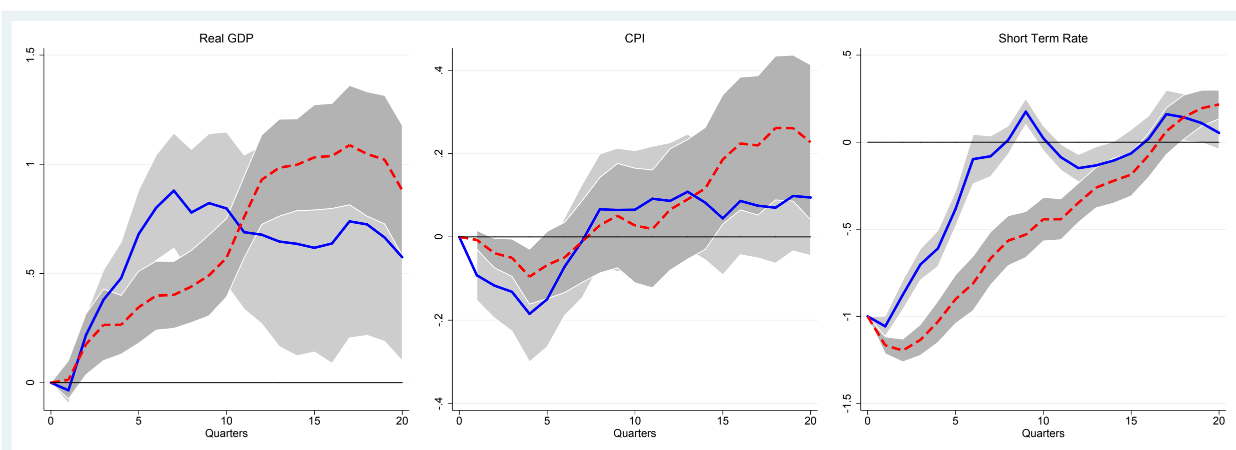
(a) Slumps vs Booms



(b) High vs Low Debt



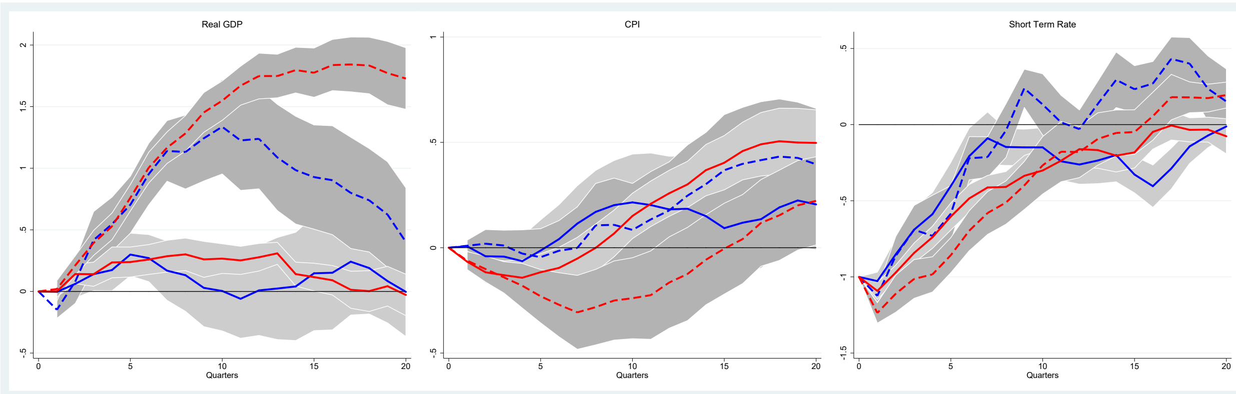
(c) Tightening vs Loosening



Note: Solid blue (red dashed) lines denote the responses during slumps (booms)in the top panel, high (low) debt in the second panel and tightening (loosening) in the bottom panel.

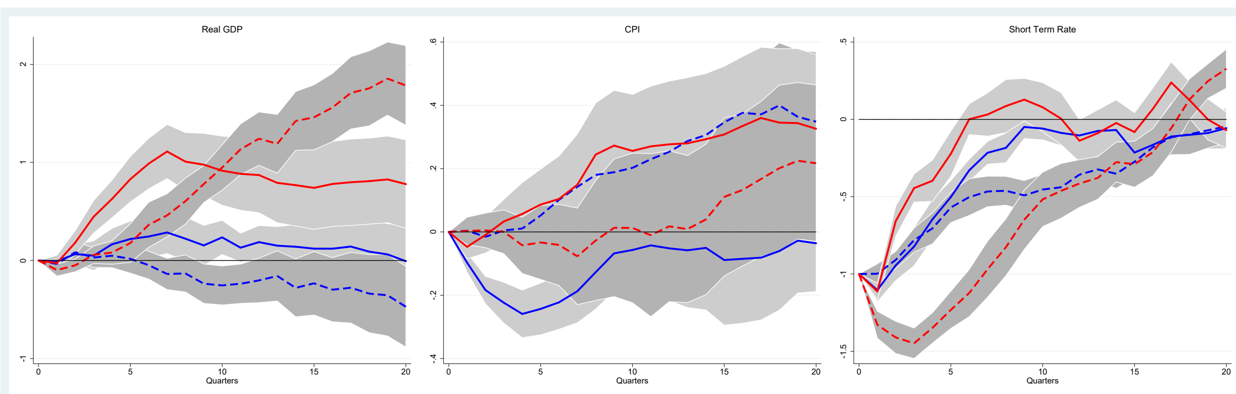
Figure 13: State Dependent Impulse Responses: Considering joint states

(a) High vs Low Debt with Slumps vs Booms



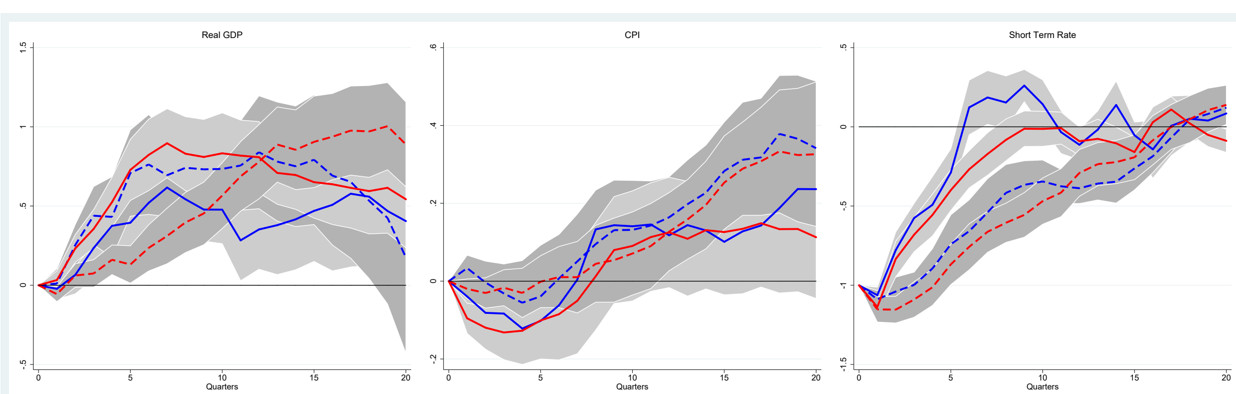
Note: high debt + slumps (blue solid), high debt + booms (blue dashed), low debt + slumps (red solid), low debt + booms (red dashed)

(b) Slumps vs Booms with Tightening vs Loosening



Note: slumps + tight (blue solid), slumps + loose (blue dashed), booms + tight (red solid), booms + loose (red dashed)

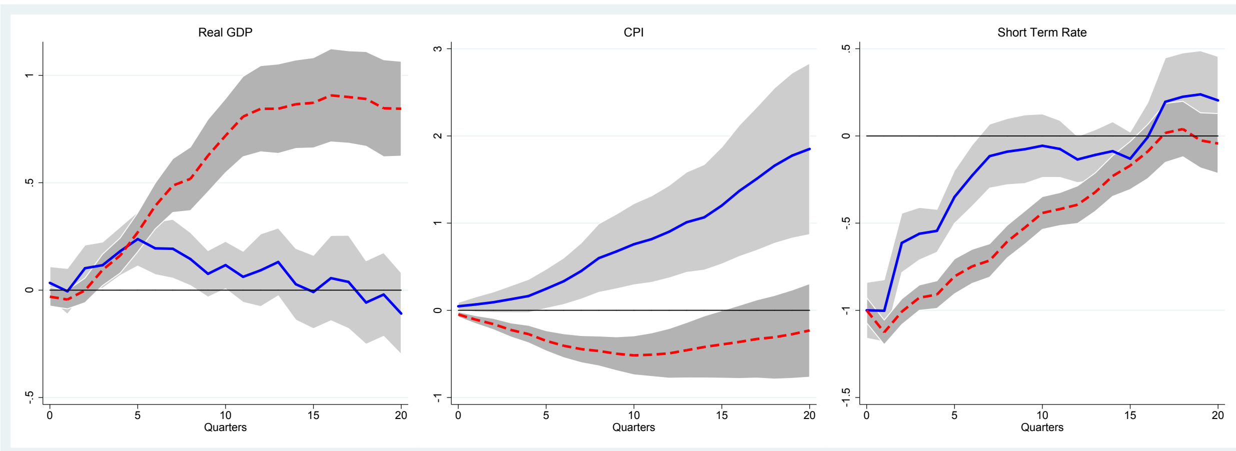
(c) High vs Low Debt with Tightening vs Loosening



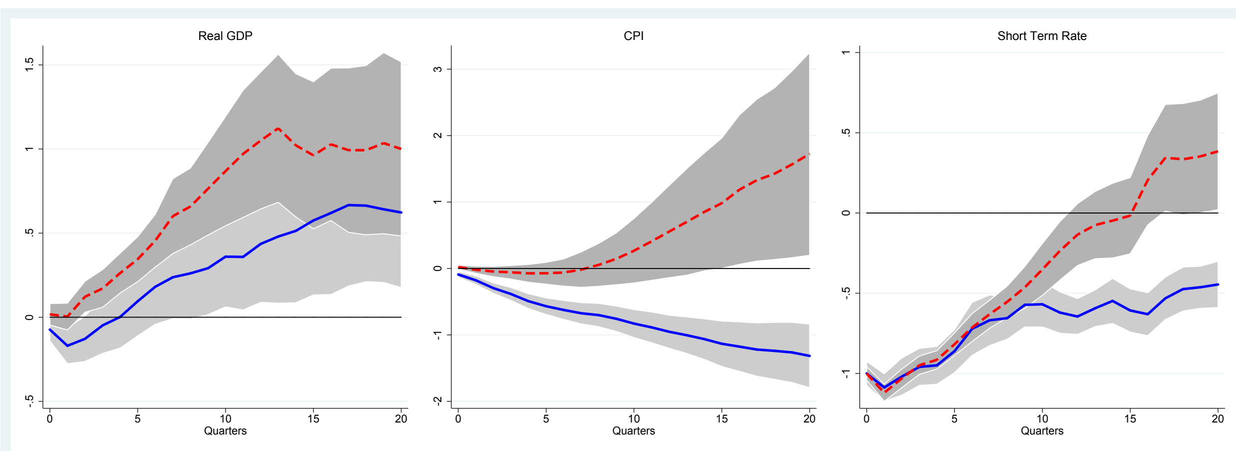
Note: high debt + tight (blue solid), high debt + loose (blue dashed), low debt + tight (red solid), low debt + loose (red dashed)

Figure 14: State Dependent Impulse Responses with LP-IV: Baseline Identification

(a) Slumps vs Booms



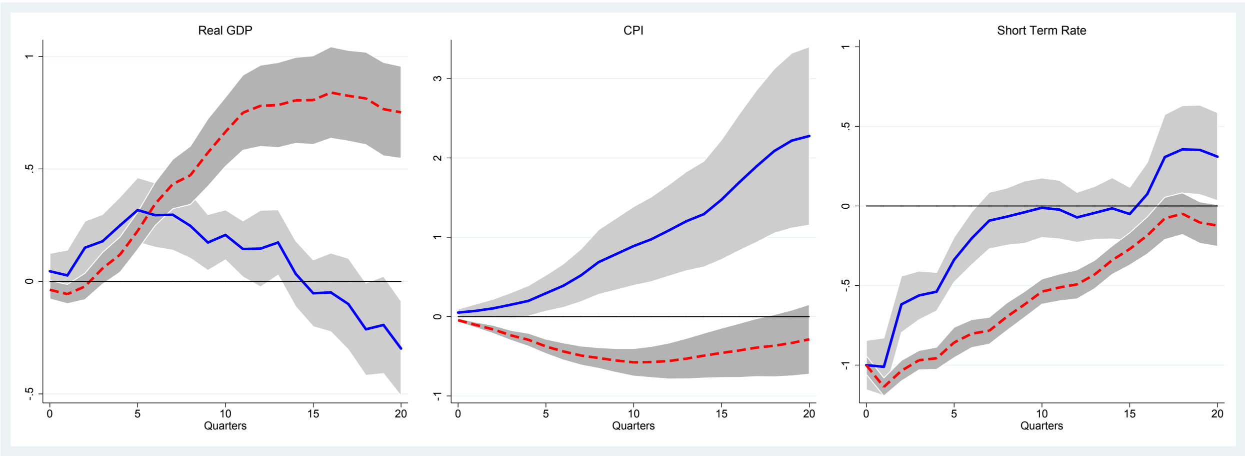
(b) High vs Low Debt



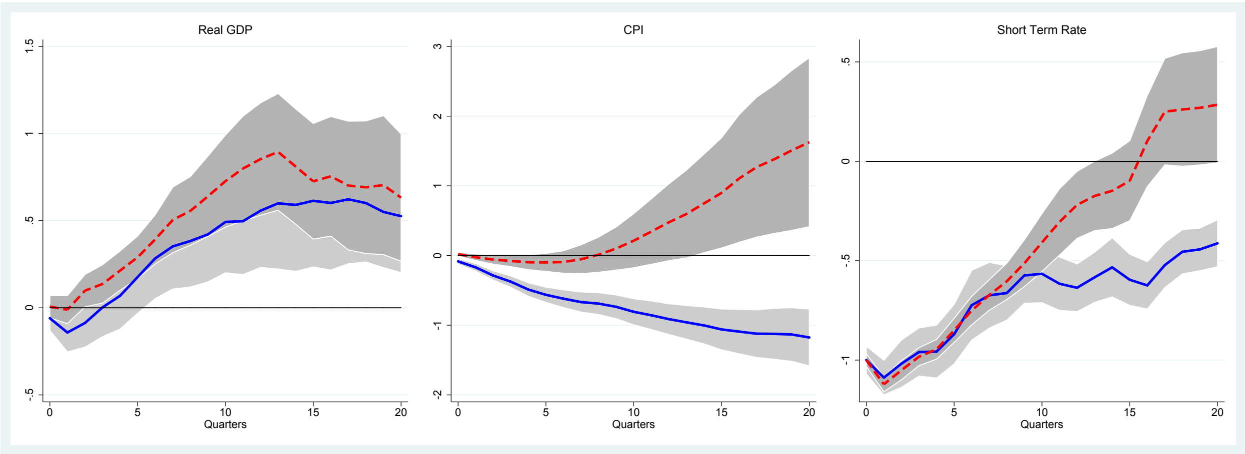
Note: The results are for the case where monetary shocks are identified in a 4 variables VAR with ordering restrictions and IRFs are estimated using LP-IV. Solid blue (red dashed) lines denote the responses during slumps (booms) in the top panel and high (low) debt in bottom panel.

Figure 15: State Dependent Impulse Responses with LP-IV: Sign and Zero Restriction Identification

(a) Slumps vs Booms

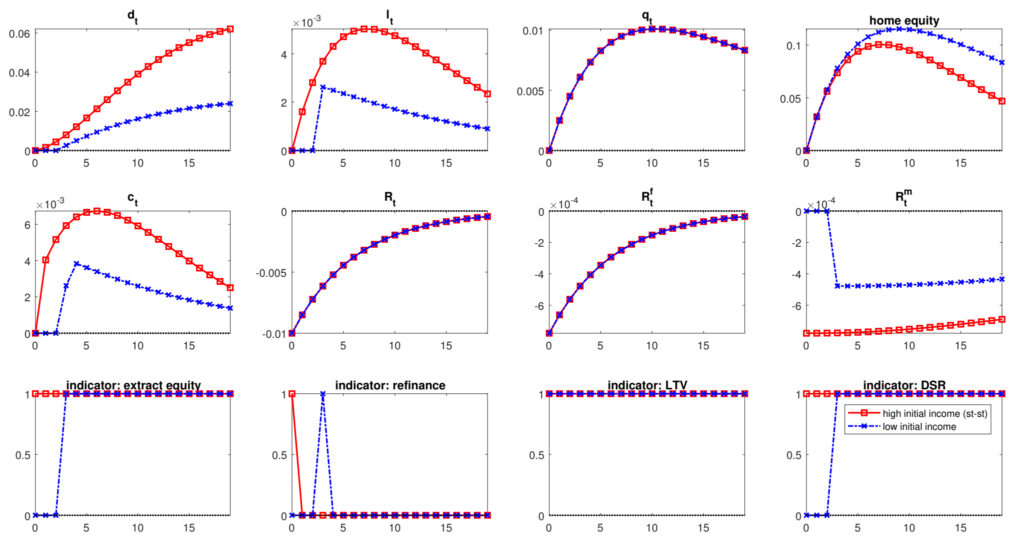


(b) High vs Low Debt



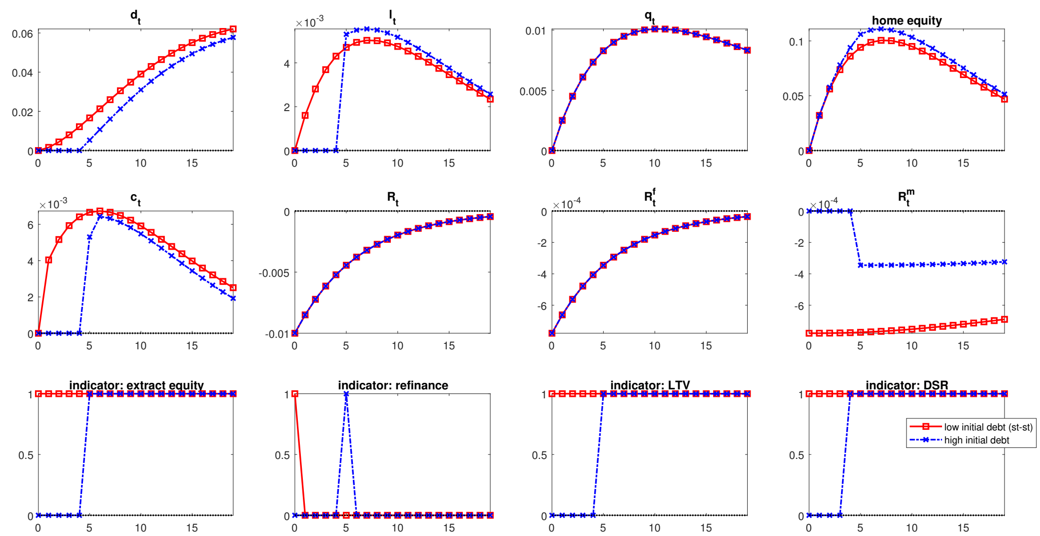
Note: The results are for the case where monetary shocks are identified with zero and sign restrictions and IRFs are estimated using LP-IV. Solid blue (red dashed) lines denote the responses during slumps (booms) in the top panel and high (low) debt in bottom panel.

Figure 16: Simulated IRFs: State Dependence wrt the Business Cycle



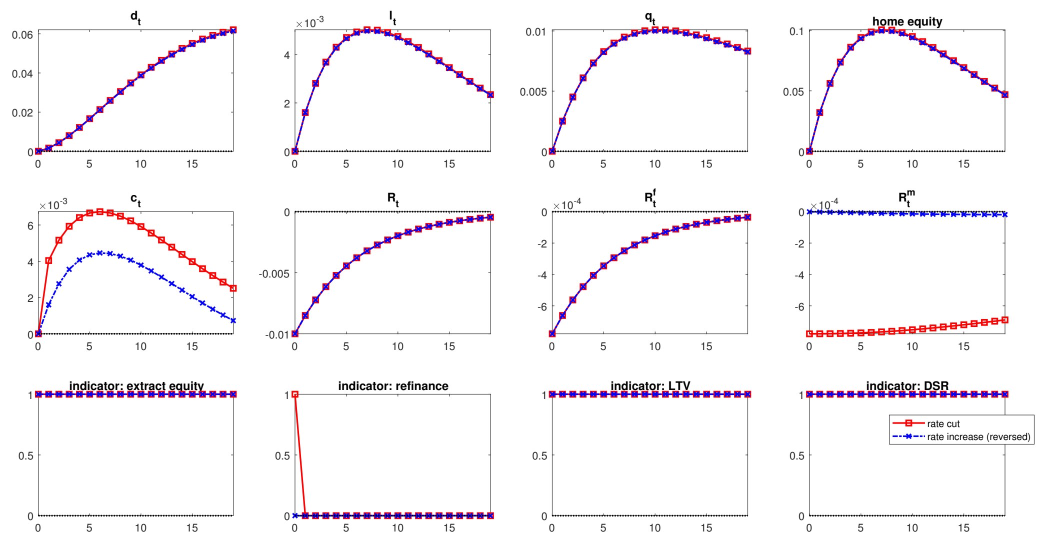
Note: Impulse responses of model variables to an annualized 100 bps expansionary monetary policy shock conditional on initial income level. In the high income case (red line with boxes), the agent's initial income when the shock occurs is at the steady state level. In the low income case (blue line with crosses), the agent's initial income level is 10% lower than the steady state. The simulations assume that the agent can extract at most 5% of home equity each period. The labels are consistent with the notation in Section 4: "d_t" is the real stock of debt, "l_t" the amount of new loans in real terms, "q_t" real house prices, "c_t" consumption in real terms, "R_t" the policy rate, "R_t^f" the interest rate on fixed-rate long-term loans, "R_{t-1}^m" the average interest rate on the borrower's existing mortgage.

Figure 17: Simulated IRFs: State Dependence wrt the Credit Cycle



Note: Impulse responses of model variables to an annualized 100 bps expansionary monetary policy shock conditional on initial income level. In the low debt case (red line with boxes), the agent's initial debt when the shock occurs is at the steady state level. In the high debt case (blue line with crosses), the agent's initial debt level is 10% lower than the steady state. The simulations assume that the agent can extract at most 5% of home equity each period. The labels are consistent with the notation in Section 4: "d_t" is the real stock of debt, "l_t" the amount of new loans in real terms, "q_t" real house prices, "c_t" consumption in real terms, "R_t" the policy rate, "R_t^f" the interest rate on fixed-rate long-term loans, "R_{t-1}^m" the average interest rate on the borrower's existing mortgage.

Figure 18: Simulated IRFs: State Dependence wrt Interest Rate Cycle



Note: Impulse responses of model variables to an annualized 100 bps expansionary versus contractionary monetary policy shock. In both the rate cut case (red line with boxes), and the rate increase case (blue line with crosses), the agent's initial interest burden and the policy rate are assumed to be at the steady state. The simulations assume that the agent can extract at most 5% of home equity each period. The labels are consistent with the notation in Section 4: "d_t" is the real stock of debt, "l_t" the amount of new loans in real terms, "q_t" real house prices, "c_t" consumption in real terms, "R_t" the policy rate, "R_t^f" the interest rate on fixed-rate long-term loans, "R_{t-1}^m" the average interest rate on the borrower's existing mortgage.

A Appendix

Table A1. Credit Data and Mortgage Market Characteristics

	Household Debt	Total Credit	DSR	Mortgage Rate
Australia	1977Q4	1975Q1	1977Q4	V
Belgium	1980Q4	1975Q1	1980Q4	F
Canada	1975Q1	1975Q1	1975Q1	F
Denmark	1994Q4	1975Q1	1999Q1	F
Spain	1980Q4	1975Q1	1999Q1	V
Finland	1975Q1	1975Q1	1978Q2	V
France	1977Q4	1975Q1	1980Q4	F
Great Britain	1975Q1	1975Q1	1975Q1	V
Germany	1975Q1	1975Q1	1991Q4	F
Ireland	2002Q1	1975Q1	2002Q1	V
Italy	1975Q1	1975Q1	1975Q1	V
Japan	1975Q1	1975Q1	1994Q4	F
Netherlands	1990Q4	1975Q1	1990Q4	F
Norway	1975Q1	1975Q1	1995Q4	V
New Zealand	1990Q4	1975Q1	1990Q4	V
Switzerland	1999Q4	1975Q1	1999Q1	F
Sweden	1980Q4	1975Q1	1980Q4	V
US	1975Q1	1975Q1	1975Q1	F
Total # Observations	2,629	3,132	2,297	

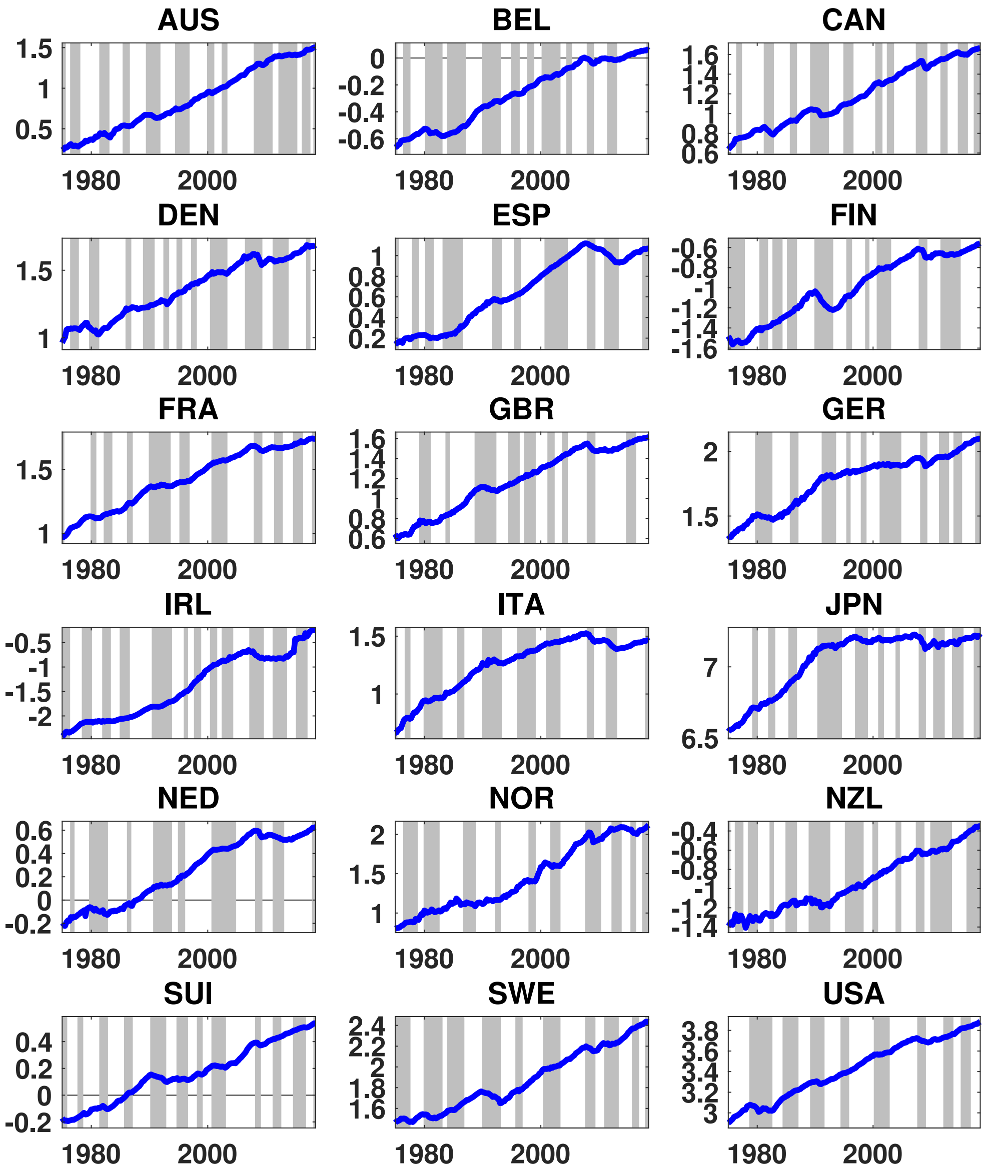
Note: Availability of credit data for each country. Entries denote the first quarter for which the data is available. Last observation is 2018Q3 for all series and all countries. The classification of mortgage market rates into fixed (F) or adjustable (V) is base on Tsatsaronis and Zhu (2004) for all countries except Italy, New Zealand and Switzerland. For Italy, the reference is the ECB Occasional paper titled "Housing Finance in the Euro Area", for New Zealand the Reserve Bank of New Zealand Financial Stability Report, November 2005 and for Switzerland the CGFS paper on "Housing Finance in the Global Financial Market".

Table A2. Characteristics of States

	States Classification			
	Business Cycle		Credit Cycle	
	OECD Recessions	Expansions	High DSR	Low DSR
Frequency and Duration				
proportion of quarters	0.45	0.55	0.40	0.60
quarters in state	7	10	13	15
number of episodes	184	182	79	76
Macro Variables				
real output growth qoq (%)	0.14	0.90	0.25	0.72
inflation rate qoq (%)	1.03	0.87	0.83	0.68
real hh debt growth qoq (%)	0.82	1.26	0.85	1.15
nominal short term rate	6.80	5.49	5.86	4.35
nominal long term rate	7.17	6.57	6.35	5.53
house price growth qoq (%)	-0.06	0.79	-0.00	0.81

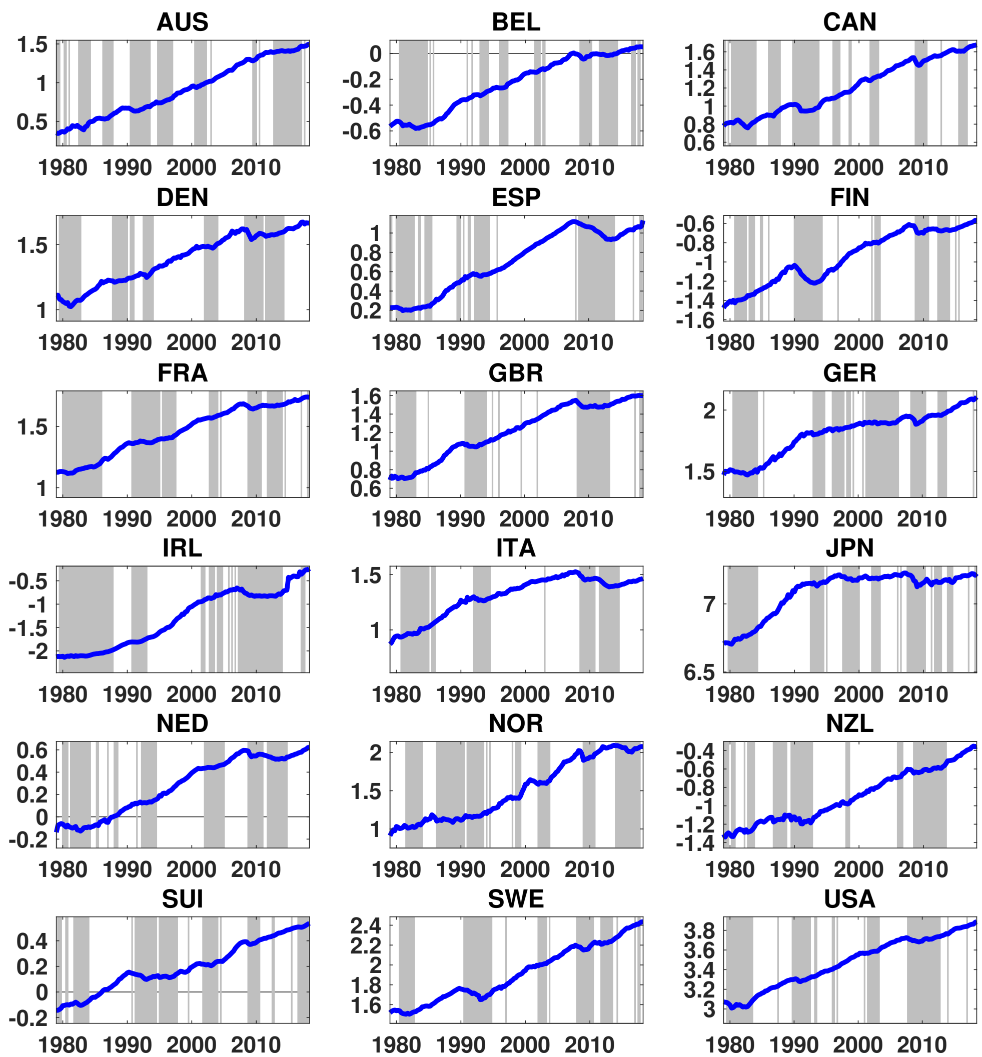
Note: The table shows some descriptive statistics for selected variables during the states classification defined in Section 3.3.

Figure A.1: OECD Recessions



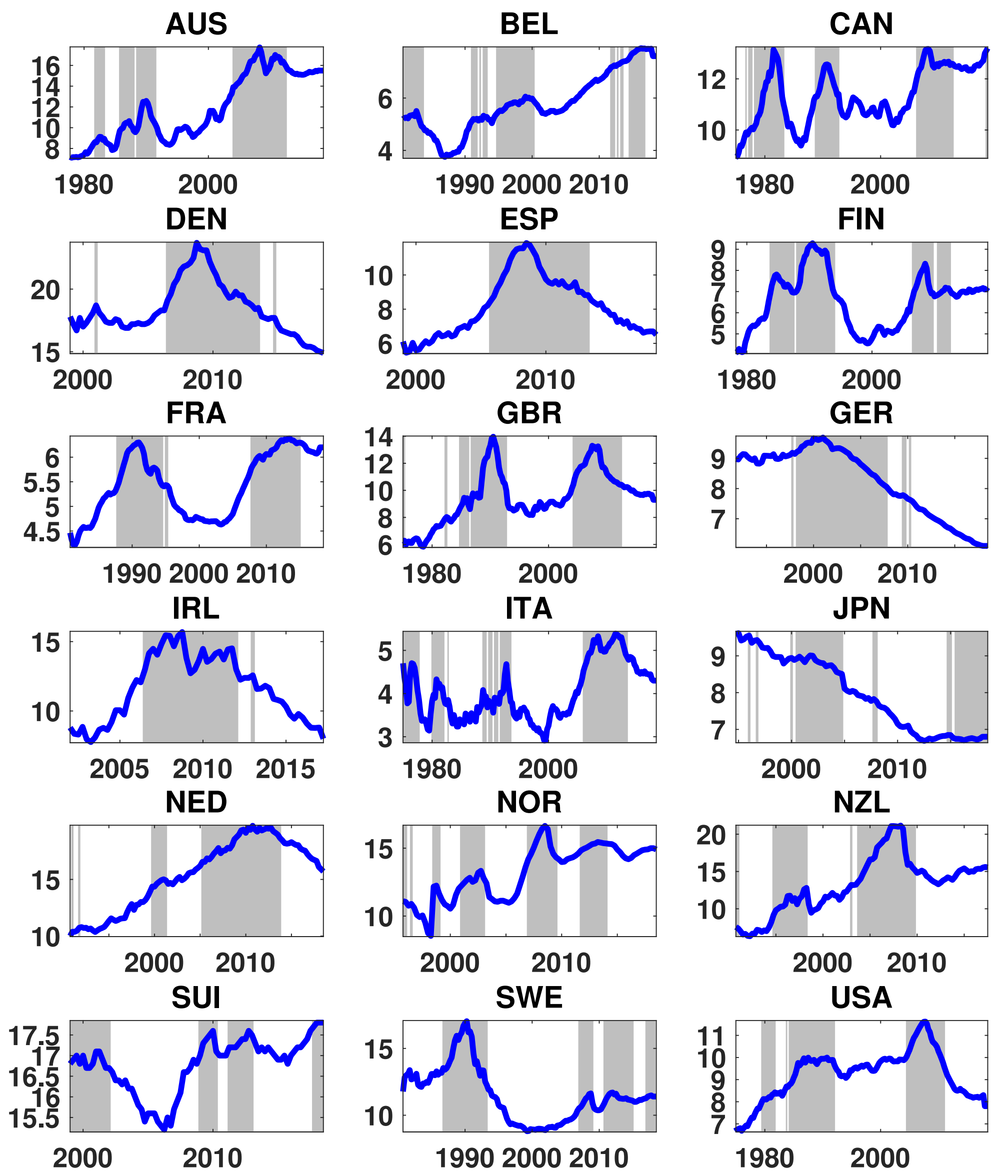
Note: The figure shows the log of real GDP (line) and the OECD recession dates (shaded areas).

Figure A.2: Booms vs Slumps (Hamilton filter)



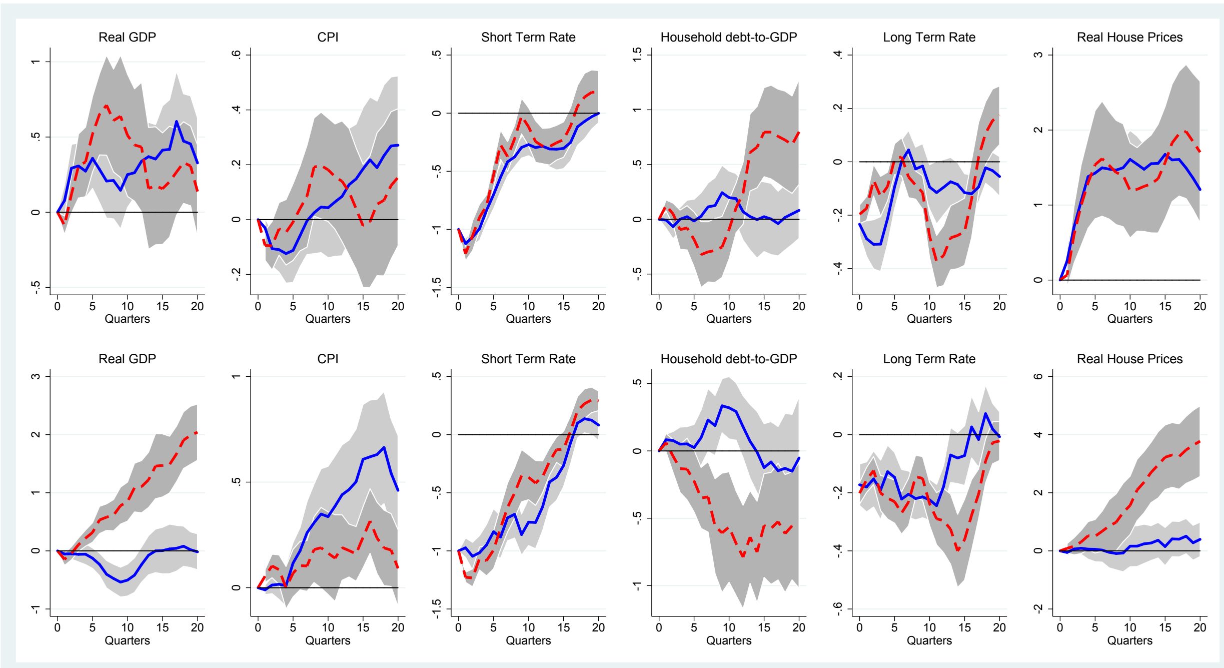
Note: The figure shows the log of real GDP (line) and the boom and slumps episodes (shaded areas) identified with the Hamilton (2018) filter.

Figure A.3: Debt Service Ratio



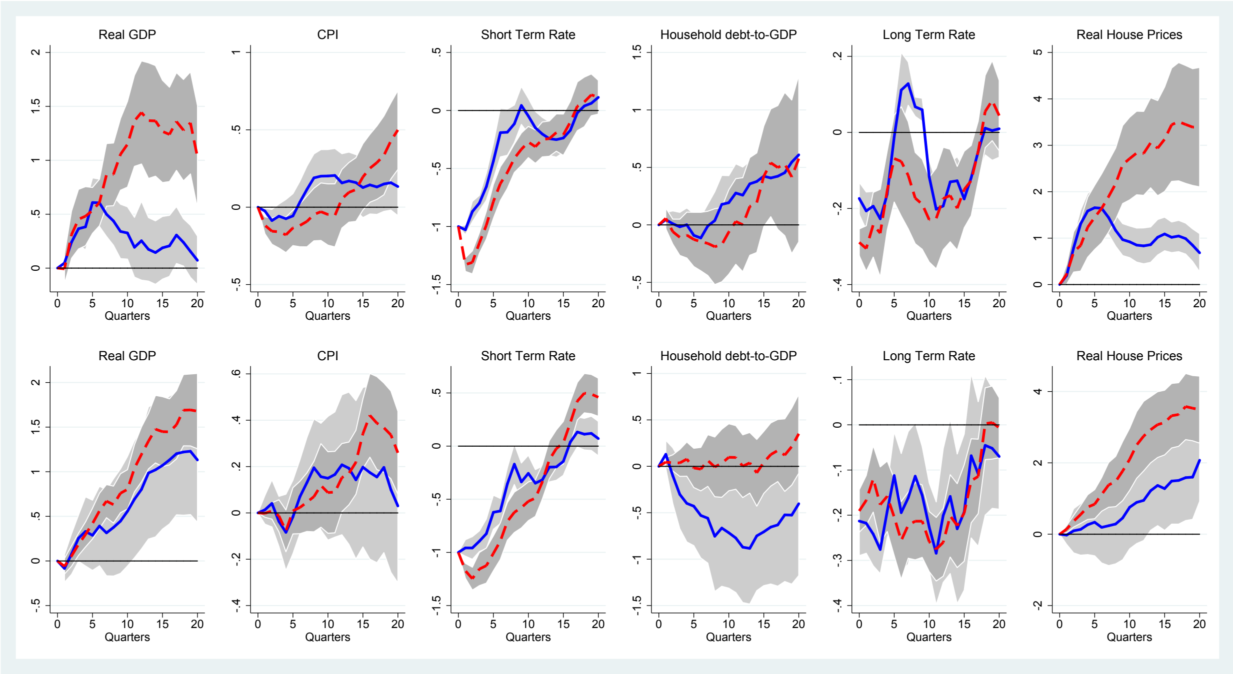
Note: The figure shows the debt service ratio (solid line) and periods of high debt service ratio (shaded areas). High debt states are defined as periods in which household debt service gap is above the 60th percentile of the gap distribution, where the gap is constructed subtracting from the debt service ratio the two sided hp filtered trend obtained using as smoothing parameter λ=400000.

Figure A.4: State Dependent Impulse Responses: Slumps vs Booms across Fixed and Variable Rate Mortgages



Note: The figure shows the impulse responses of the variables to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points. The top panel shows the variable mortgage rates and the bottom panel shows fixed rate case. In both panels, solid blue (red dashed) lines denote the responses during slumps (booms). Shaded areas denote one standard error confidence bands. Responses for the short and long term rates are in levels, for the household debt-to-gdp ratio are in cumulative changes and for the remaining variables are cumulative change in logarithms.

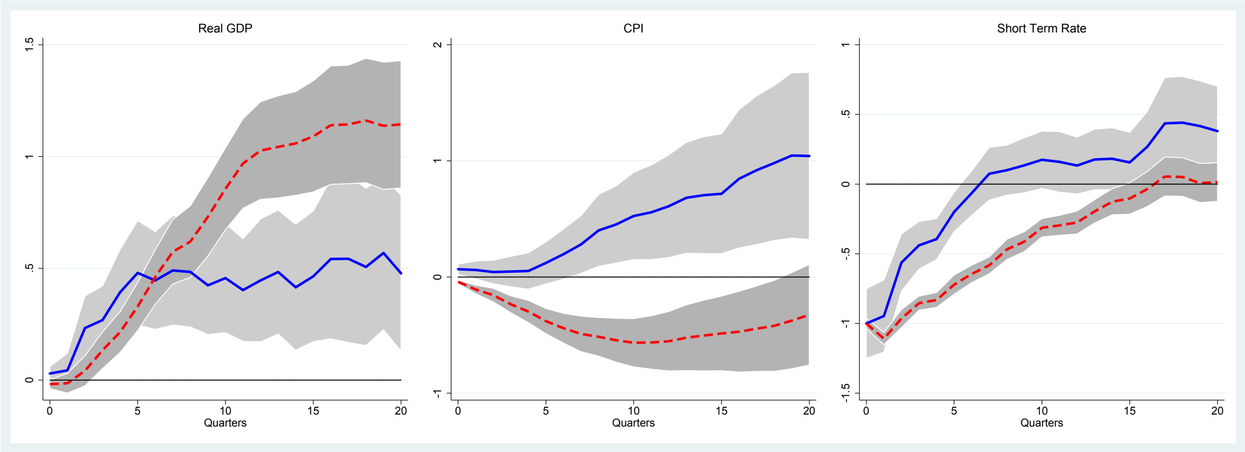
Figure A.5: State Dependent Impulse Responses: High vs Low Debt across Fixed and Variable Rate Mortgages



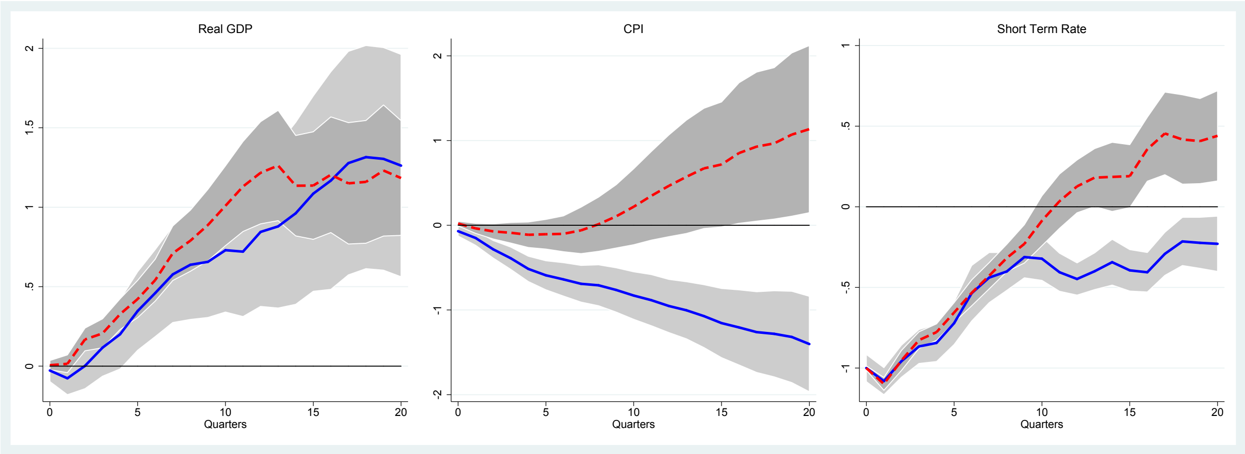
Note: The figure shows the impulse responses of the variables to an expansionary monetary policy shock normalized to decrease the short term rate by 100 basis points. The top panel shows the variable mortgage rates and the bottom panel shows fixed rate case. In both panels, solid blue (red dashed) lines denote the responses during slumps (booms). Shaded areas denote one standard error confidence bands. Responses for the short and long term rates are in levels, for the household debt-to-gdp ratio are in cumulative changes and for the remaining variables are cumulative change in logarithms.

Figure A.6: State Dependent Impulse Responses with LP-IV: Cholesky, Single Country

(a) Slumps vs Booms



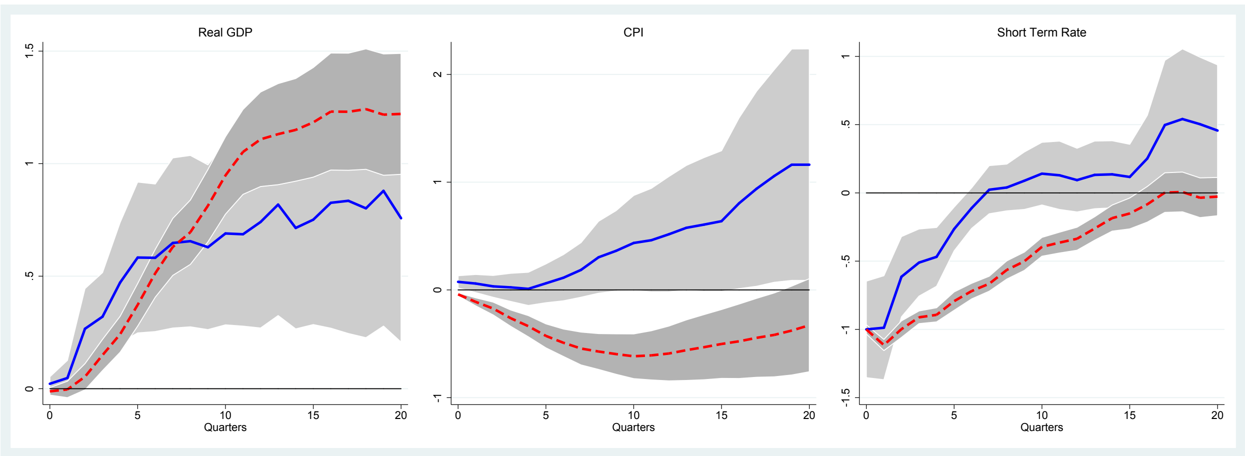
(b) High vs Low Debt



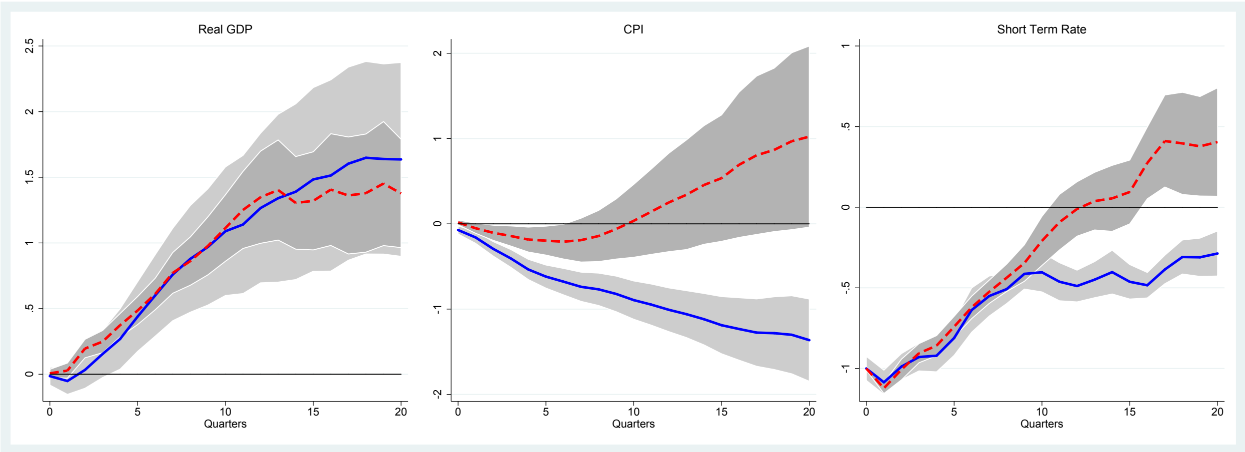
Note: The results are for the case where monetary shocks are identified in a 4 variables VAR with ordering restrictions and IRFs are estimated using LP-IV. The VAR is estimated country-by-country. Solid blue (red dashed) lines denote the responses during slumps (booms) in the top panel and high (low) debt in bottom panel.

Figure A.7: State Dependent Impulse Responses with LP-IV: Sign and Zero Restrictions, Single Country

(a) Slumps vs Booms



(b) High vs Low Debt



Note: The results are for the case where monetary shocks are identified in a 4 variables VAR with sign and zero restrictions and IRFs are estimated using LP-IV. The VAR is estimated country-by-country. Solid blue (red dashed) lines denote the responses during slumps (booms) in the top panel and high (low) debt in bottom panel.