Private Sector Debt, Financial Constraints, and the Effects of Monetary Policy: Evidence from the US

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Abstract

We characterize the response of U.S. real GDP to monetary policy shocks conditional on the level of private sector debt and the degree to which financial constraints are binding. To incorporate state-dependent effects of monetary policy, we use the local projection framework. We find that although the amount of private sector debt potentially weakens the monetary policy transmission mechanism, policy shocks exert substantially larger effects on output when high private debt coincides with binding financial constraints.

I. Introduction

Is the economy more sensitive to changes in monetary policy if the private sector is indebted? Theoretically, the level of private debt may influence the monetary transmission mechanism through several channels. The most direct link is the effect of changes in interest rates on the disposable income of households with variable rate loans, and hence, their spending decisions (Di Maggio et al., 2017; Cloyne, Ferreira and Surico, 2018). A similar effect is also conceivable for firms through interest expenses and investment decisions (Ippolito, Ozdagli and Perez-Orive, 2018). Firms’ balance sheets and the net worth of households in the presence of binding credit constraints and collateral requirements represent another channel through which monetary policy is transmitted to the real economy (Bernanke and Gertler, 1995). If a monetary expansion, for instance, raises the value of the collateral, it increases the availability of credit, which in turn influences spending and investment decisions. Using household level data, Mian and Sufi (2011) demonstrate that home equity plays a crucial role in this context as it is primarily the spending of homeowners with mortgage debt that responds to changes in house prices (see also Mian and Sufi, 2014). Guerrieri and Iacoviello (2017) develop and estimate a DSGE model with occasionally binding constraints. In their model, shocks to house prices exert larger effects on consumption when the level of household debt is higher and borrowing constraints are binding. Although a higher overall level of private debt implies that these effects should

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1 A related, albeit distinct, branch of the literature studies nonlinearities in the labour market. Petrosky-Nadeau and Zhang (2017) and Pizzinelli, Theodoridis and Zanetti (2018) show nonlinearities in labour market variables across different phases of the business cycle.
become more relevant to the aggregate, resulting in more pronounced effects of policy shocks, a high debt level could also weaken the transmission mechanism, if it is associated with exhausted borrowing capacities (Sufi, 2015; Alpanda and Zubairy, 2019).

To explore how the level of debt interacts with the availability of credit, we condition the effect of policy shocks not only on private sector debt, but also on the extent to which financial constraints are binding as in Rüth (2017). Consider, for instance, a monetary contraction that reduces the value of collateral, and hence, the availability of credit. During financially tranquil periods, households and firms may still have a ready access to loans, even if the level of existing debt is relatively high. In contrast, if the monetary contraction occurs at a time when financial constraints are tight, the effect may be more pronounced if households and firms are highly indebted.

To study these potential nonlinear effects associated with the level of debt and the availability of credit, we estimate state-dependent responses of U.S. real GDP to monetary policy shocks for the sample 1973Q1 to 2017Q4 using the local projection method introduced in Jordà (2005) and apply the Romer and Romer (2004) approach to identify exogenous monetary policy shocks. Since monetary policy was partially implemented through unconventional measures during our sample period, we use the shadow short rate developed in Krippner (2015) instead of the Federal Funds rate target after 2008Q4 for the estimation of monetary policy shocks. To distinguish between high and low debt states, we use the private sector debt-to-GDP ratio relative to its Hodrick–Prescott (HP) trend. We proxy financial constraints by the excess bond premium (EBP), introduced by Gilchrist and Zakrajšek (2012), which captures dynamics in bond prices that are purged from expected losses in the corporate bond market. Gilchrist and Zakrajšek (2012) argue that this residual component proxies the supply of credit as it represents investors willingness to provide funds on credit markets.

Our paper is closely related to Alpanda and Zubairy (2019), who study how private sector leverage influences the transmission of monetary policy shocks and Harding and Klein (2018), who analyse the effects of policy shocks during periods of deleveraging. In this paper, we complement these contributions by explicitly taking into account how the interaction between private sector debt and financial constraints influences the real effects of monetary policy shocks.

When we condition the response of output to policy shocks only on the amount of private sector debt, we find that the response is more pronounced in the low debt state, which is consistent with Alpanda and Zubairy (2019). However, when we also consider the extent to which financial constraints are binding, we find that contractionary monetary policy shocks exert significantly larger effects if high private debt coincides with tight financial constraints. These results are robust across a broad set of robustness checks including alternative state definitions, model specifications, and samples.

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2 We show in a robustness analysis that using the shadow rate provided by Wu and Xia (2016) gives essentially the same results.
3 Klein (2017), Alpanda and Zubairy (2019) and Bernardini and Peersman (2018) also define debt states in terms of deviations from the HP trend.
4 The EBP is a frequently used measure to proxy financial constraints (see e.g. Caldara et al., 2016; Görtz, Tsoukalas and Zanetti, 2018).
The remainder of the paper is structured as follows: Section II describes our empirical approach, the data, and the definition of the states. Section III presents our main findings and in Section IV, we consider the effects of monetary policy shocks on variables other than real GDP. Section V present a number of robustness checks and Section VI concludes the paper.

II. Methodology and data

We study the dynamic effects of monetary policy shocks conditional on private sector debt and financial constraints using the Jordà (2005) local projection method, which allows us to estimate state-dependent impulse response functions in a parsimonious and flexible way that is less prone to mis-specification (see also Kilian and Kim, 2011).

As a first analysis, we study the response of real GDP to monetary policy shocks during periods of low and high private debt. Specifically, we estimate

$$\log(RGDP_{t+h}) = \alpha_{A,h} + \beta_{A,h}MP_t + \gamma_{A,h}(L)x_{t-1}$$

$$+ I_{B,t-1}[\alpha_{B,h} + \beta_{B,h}MP_t + \gamma_{B,h}(L)x_{t-1}]$$

$$+ \lambda_{1,h}t + \lambda_{2,h}t^2 + \epsilon_{t+h},$$

for each forecast horizon $h \in 0, \ldots, H$. $MP_t$ is an exogenous monetary policy shock, which we estimate according to Romer and Romer (2004). $\alpha_{A,h}$ and $\alpha_{B,h}$ are intercepts and $\gamma_{A,h}$ and $\gamma_{B,h}$ are polynomials in the lag operator $L$. The coefficients vary across states $A$ and $B$, where the base category $A$ captures periods of low private debt.

As in Alpanda and Zubairy (2019) and Klein (2017), we set the state indicator $I_{B,t} = 1$ if the deviation of private debt from its HP trend, calculated with a smoothing parameter of $10^4$, is positive, and $I_{B,t} = 0$ otherwise. Accordingly, the $\beta_{A,h}$ and $\beta_{B,h}$ give the response of real GDP to contractionary policy shocks conditional on low private debt at lead $h$, and $\beta_{A,h} + \beta_{B,h}$ is the corresponding response in the high debt state, where $\beta_{B,h}$ is the interaction effect. To address potential endogeneity issues, we follow the literature and lag the state indicator by one quarter (see e.g. Klein, 2017; Bernardini and Peersman, 2018).

Analogously to standard monetary VARs the vector of control variables, $x_{t-1}$, includes lags of the dependent variable, consumer prices and the Federal Funds rate. We control for a linear and quadratic time trend.

To take financial constraints into account, we augment equation (1) to allow the response of real GDP to vary across private debt as well as financial constraint states:

$$\log(RGDP)_{t+h} = \alpha_{A,h} + \beta_{A,h}MP_t + \gamma_{A,h}(L)x_{t-1}$$

$$+ I_{B,t-1}[\alpha_{B,h} + \beta_{B,h}MP_t + \gamma_{B,h}(L)x_{t-1}]$$

$$+ I_{C,t-1}[\alpha_{C,h} + \beta_{C,h}MP_t + \gamma_{C,h}(L)x_{t-1}]$$

$$+ I_{B,t-1}I_{C,t-1}[\alpha_{BC,h} + \beta_{BC,h}MP_t + \gamma_{BC,h}(L)x_{t-1}]$$

$$+ \lambda_{1,h}t + \lambda_{2,h}t^2 + \epsilon_{t+h},$$

The extremely smooth HP trend takes into account that the financial cycle has a longer duration than the business cycle (Drehmann and Tsatsaronis, 2014; Drehmann, Borio and Tsatsaronis, 2012). This procedure allocates 74 observation to the high debt state and 79 observations to the low debt state.
where $I_{B,t}$ is defined as above and $I_{C,t}$ indicates states characterized by binding financial constraints. We set $I_{C,t} = 1$ if the 7-quarter lagged moving average of the EBP (Gilchrist and Zakrajsek, 2012), calculated from $t$ to $t - 6$, is above its median value in period $t$, and $I_{C,t} = 0$ otherwise.

In equation (2), the base category $A$ captures episodes in which private debt is relatively low and financial constraints are relatively weak. Hence, the estimates of $\beta_{A,h}$ give the response of real GDP to contractionary policy shocks in this neutral state. In the state where private debt is high relative to the threshold and financial constraints are loose, the response is $\beta_{A,h} + \beta_{B,C,h}$. In the state characterized by binding financial constraints and low private sector debt, the response is $\beta_{A,h} + \beta_{C,h}$. And finally, during periods when private debt is high and financial constraints are tight, the response of real GDP to monetary policy shocks is $\beta_{A,h} + \beta_{B,h} + \beta_{C,h} + \beta_{BC,h}$, where $\beta_{BC,h}$ captures the additional nonlinear effect of monetary policy that arises if high debt levels coincide with tight constraints.

In our baseline estimation, the sample runs from 1973Q1 to 2017Q4. We obtain data on real GDP, consumer prices and the Federal Funds rate from the Federal Reserve Bank of St. Louis database, Federal Reserve Economic Data. Private debts are loans and leases in bank credit reported in the H.8 table, which we obtain from the Board of Governors of the Federal Reserve System, divided by nominal GDP. In additional estimations, we also consider different dependent variables, such as house prices, housing construction, households’ net worth, and corporate business’ net worth, as well as different loan categories and the loan to value ratio to define the private debt state.6

With the exception of the interest rate, all variables enter the estimations in logs. According to the Schwartz Bayesian information criteria, calculated for different forecast horizons, we set $L = 2$. To account for the serial correlation in the error terms resulting from the sequential leads of the dependent variable (see Jordà, 2005), we apply the Newey–West correction (Newey and West, 1987). In a robustness analysis, which we report in Section V, we show that our findings are robust to different assumptions about time trends, first differences, alternative lag lengths, and different sets of control variables.

Figure 1 shows private debt as a ratio of GDP, the HP trend, and the state dummy variable in Panel (a) and the EBP, the 7-quarter lagged moving average together with the corresponding state dummy in Panel (b). We see that private debt exceeds its HP trend during the mid-1970s, around 1990, 2000, and from 2006 onwards. Financial constraints were relatively tight during the mid-1970s, early 1980s, around 1990, during the mid-2000s, and during the recent financial crisis.

While several periods in the sample are characterized by both, high private debt and tight financial constraints, the two states generally occur in a rather unrelated fashion. Of the 74 periods that we classify as high private debt periods, 45 periods coincide with periods of tight credit constraints, and 48 periods of the 79 low private debt observations coincide with relatively loose financial constraints. The correlation between the two state variables is only 0.22.7

To identify exogenous monetary policy actions, we follow Romer and Romer (2004), and purge intended Federal Funds rate changes from endogenous adjustments in the target

6 See Table A.1 in the Online Appendix for detailed descriptions of the variables and the data sources.
7 For the EBP and the HP-filtered debt-to-GDP ratio the correlation is 0.52.
Figure 1. State variables (1973Q1–2017Q4)

Notes: The solid lines in Panel (a) and (b) are the private debt-to-GDP ratio and the EBP, reported in Gilchrist and Zakrajsek (2012). The dashed lines are the Hodrick–Prescott trend, using a smoothing parameter $\lambda = 10,000$, and the 7-quarter lagged moving average of the excess bond premium, respectively. The grey areas indicate the periods of high private debt and tight financial constraints.

rate. Romer and Romer (2004) regress intended Federal Funds rate changes at FOMC meetings on Greenbook forecasts to control for current economic conditions and the future economic outlook:8

$$\Delta ff_m = \alpha + \beta_{ffb} + \sum_{i=-1}^{2} \gamma_i \widetilde{\Delta y}_{m,i} + \sum_{i=-1}^{2} \lambda_i (\Delta \widetilde{y}_{m,i} - \Delta \widetilde{y}_{m-1,i}) + \sum_{i=-1}^{2} \phi_i \widetilde{\pi}_{m,i}$$

$$+ \sum_{i=-1}^{2} \theta_i (\widetilde{\pi}_{m,i} - \widetilde{\pi}_{m-1,i}) + \rho \tilde{u}_{m0} + \epsilon_m,$$

where $m$ indexes the FOMC meetings, $\Delta ff_m$ is the intended Federal Funds rate change, $\beta_{ffb}$ is the current interest target going into meeting $m$, $\Delta \widetilde{y}_{m,i}$, $\widetilde{\pi}_{m,i}$, and $\tilde{u}_{m0}$ are Greenbook forecasts of real output growth, inflation, and the unemployment rate for the previous ($i = -1$), current ($i = 0$), and subsequent ($i = 1, 2$) quarters prepared for FOMC meeting $m$.

We estimate equation (3) using data from 400 FOMC meetings over the period from 1969 through 2012.9 To take into account the constraints imposed on monetary policy by the zero lower bound, we use the shadow short rate developed in Krippner (2015) instead of the Federal Funds rate target after 2008Q4. The shadow short rate is a measure of the monetary policy stance when the zero lower bound is binding and the Fed conducts monetary policy through quantitative easing and forward guidance.10 To obtain a series of quarterly policy shocks $MP_t$, we sum the estimated innovations $\hat{\epsilon}_m$ from equation (3) within each quarter (see Coibion et al., 2017; Romer and Romer, 2004).

8 Greenbook forecasts are realtime-forecasts of U.S. economic aggregates that are prepared for each FOMC meeting.

9 Although the sample for our main analysis starts in 1973Q1 and ends in 2017Q4, we use a slightly earlier start date for the estimation of the policy shocks to take advantage of the available data and improve the estimation. The end of the policy shocks series is determined by the availability of the Greenbook forecast, but does not limit our sample for the main analysis as we consider a forecasting lead of $h = 20$ quarters.

10 In a robustness analysis, we re-estimate equation (3) using the shadow short rate provided by [Wu and Xia (2016)]. See Table A.2 in the Online Appendix for detailed descriptions of the variables and the data sources.
III. Results

In this section, we present our main results. We show how private debt and financial constraints influence the effects of monetary policy. We also explore how the business cycle, the zero lower bound, deleveraging periods, and potentially nonlinear effects associated with the size and the sign of the policy shock affect the transmission mechanism. And we present results based on alternative definitions of the state variable and a smooth transition version of our main specification.

III.1. Private sector debt and the effects of monetary policy

Figure 2 shows the response of real GDP to a monetary policy shock over a horizon of five years conditional on low private debt in subfigure (a) and conditional on the high private debt state in subfigure (b). The solid lines show the impulse response functions and the grey areas are 95% confidence intervals. Subfigure (c) displays $t$-values for the null hypothesis that the state-dependent impulse responses do not differ at forecast horizon $h$, and the grey area indicates a critical-value of 1.96, corresponding to a 5% significance level.

We see that real GDP declines in response to a contractionary monetary policy shock in both states. Nevertheless, the magnitude differs across states. In the low-debt state, the maximum decline of real GDP is roughly 1.6% after four years in response to a one percentage point monetary policy shock. If private debt is high, the maximum decline is about 0.7%. In the third column we see that the responses are significantly different on impact and marginally significant between periods 15 and 20. Thus, it appears that the effects of monetary policy on real GDP are less pronounced when the economy is in the high debt state, which is in line with the results reported in Alpanda and Zubairy (2019).

III.2. Private debt and financial constraints

Figure 3 shows the impulse response functions obtained from equation (2), where we condition on private sector debt as well as financial constraints, together with the $t$-statistics for pairwise comparisons.

When estimating a linear version of the model, we find that real GDP declines on average by roughly 0.6% after 3 years before it recovers back to its pre-shock level. This size of the decline is of a similar order of magnitude as in Tenreyro and Thwaites (2016).
Subfigures (a) and (b) in the first line show the responses of real GDP in the two private debt states conditional on loose financial constraints. We see that the responses are generally of similar orders of magnitude and do not differ significantly. The two subfigures (d) and (e) in the second line show the responses of real GDP in high and low debt states, conditional on tight financial constraints. Subfigure (d) shows that as long as debt is low, the response of real GDP is insignificant and does not differ significantly from the response obtained for low debt and loose constraints state. Thus, tight financial constraints by themselves do not appear to influence the effects of monetary policy as long as debt is low, which may suggest that the borrowing capacity of the private sector is impaired to such an extent in this state that monetary policy has only a minor influence on the availability of credit (see Sufi, 2015).

Subfigure (e), in contrast, shows that real GDP declines persistently and significantly from period 8 onwards, if private debt is relatively high and financial constraints are tight. In this state, the maximum decline of real GDP is 3% after 13 quarters, whereas the responses are unsystematic in the remaining states. Thus, monetary policy exerts the largest effects on output if private sector debt is relatively high and if financial constraints are tight.

While our results support the view that private debt amplifies the effects of monetary policy, we find that this is only the case if financial constraints are binding. In other

12 This result is line with models that emphasize the role of nonlinearities in the transmission of shocks resulting from borrowing constraints (see e.g. Guerrieri and Iacoviello, 2017).
words, our results are only consistent with the interpretation that firms’ balance sheets and households’ net worth are an important element of the monetary transmission mechanism during times of tight financial constraints.

III.3. Do the effects differ over the business cycle?

Tenreyro and Thwaites (2016) show that the effects of monetary policy on output vary over the phases of the business cycle. Thus, if private sector debt and financial constraints change systematically over the business cycle, then our findings could be spuriously driven by the influence of the business cycle. To take the effect of the business cycle into account, we re-estimate equation (2) augmented with an additional dummy $I_{E,t}$, which we define as $I_{E,t} = 1$ if the U.S. economy enters a recession in period $t$ according to the NBER’s Business Cycle Dating Committee, and $I_{D,t} = 0$ otherwise (Bernardini and Peersman, 2018):\footnote{In Section III.4., we also consider a continuous state measure for the business cycle, as defined in Tenreyro and Thwaites (2016).}

\[
\begin{align*}
\log(RGDP)_{t+h} &= \alpha \beta + \beta A MP_t + \gamma A (L)x_{t-1} \\
&+ I_{B,t-1}[\alpha + \beta B MP_t + \gamma B (L)x_{t-1}] \\
&+ I_{C,t-1}[\alpha + \beta C MP_t + \gamma C (L)x_{t-1}] \\
&+ I_{D,t-1}[\alpha + \beta D MP_t + \gamma D (L)x_{t-1}] \\
&+ \lambda_1 h + \lambda_2 h^2 + \epsilon_{t+h}.
\end{align*}
\]

The neutral state $A$ captures periods in which private debt is relatively low, financial constraints are relatively loose, and the U.S. economy is in an expansion phase. $I_{B,t}$ and $I_{C,t}$ are defined as in the previous estimations.

Figure 4 shows the responses conditional on recessions ($I_{D,t} = 1$).\footnote{Figure A.1 in the Online Appendix shows the corresponding responses during expansion periods ($I_{D,t} = 0$).} Although the responses are somewhat less pronounced during recessions, we still find that monetary policy exerts the largest effects on output when private debt is relatively high and when financial constraints are tight.

III.4. Continuous state variables

We now redefine the state variables as continuous variables using smooth transition functions (Granger and Teräsvirta, 1993) and estimate equation (2) as a smooth transition local projection, which was originally introduced by Auerbach and Gorodnichenko (2012) and Ramey and Zubairy (2018). Specifically, we define the private debt and financial constraint state based on the process

\[
Q(z_t) = \exp \left( \frac{\theta(z_t - c)}{\sigma_z} \right) \left[ 1 + \exp \left( \frac{\theta(z_t - c)}{\sigma_z} \right) \right]^{-1},
\]

where $Q(z_t)$ lies between 0 and 1, $\theta$ determines how violently the state variable changes between high (tight) and low (loose) private debt (financial constraints), and $c$ specifies $\sigma_z$...
the share of observations in each state. For the financial constraint state we follow Rüth (2017) and use the 7-quarter lagged moving average of the EBP as $z_t$, set $\theta = 3$, and choose $c$ such that observations are roughly equally distributed across states. In case of the private debt state $z_t$ represents the 7-quarter lagged moving average of the growth rate of private debt. The results, which are displayed in Figure 5, show again that policy shocks exert the largest effects on output if high private sector debt coincides with tight financial constraints. Although the confidence bands become wider when we estimate smooth transition models, the output effect in the high debt and tight financial constraint state is still significantly larger at least at the 10% level at various horizons.

We also define the business cycle state variable as a smooth transition function $Q(z_t)$ (see Tenreyro and Thwaites, 2016), where $z_t$ is the 7-quarter lagged moving average of real GDP growth. Again, we set $\theta = 3$ and $c$ such that observations are equally distributed across both states. The results for recessions are shown in Figure 6 and confirm the results reported in Section III.3.

Since smoothing the cyclical component of private debt, which is obtained using an extremely smooth HP trend, does not have a straightforward interpretation, we use the growth rate of private debt for this analysis. To account for longer durations of the financial cycle, we also consider an estimation where we take a 14-quarter lagged moving average of credit growth (see Figure A.6 in the Online Appendix). Furthermore, we conduct estimations with two alternative values for $\theta$, namely $\theta = 1$, and $\theta = 10$ for the private debt state (see Figures A.7 and A.8 in the Online Appendix).

Figure A.2 in the Online Appendix shows the responses during expansion periods.

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Figure 4. Responses of real GDP to monetary policy shocks during recessions

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Figure 5. Responses of real GDP to monetary policy shocks conditional on private sector debt and financial constraints (continuous state variables)

(a) Low Debt & Loose Const.: $\beta_{A,h}$

(b) High Debt & Loose Const.: $\beta_{A,h} + \beta_{B,h}$

(c) Test Difference $H_0: \beta_{B,h} = 0$

(d) Low Debt & Tight Const.: $\beta_{A,h} + \beta_{C,h}$

(e) High Debt & Tight Const.: $\beta_{A,h} + \beta_{B,h} + \beta_{C,h} + \beta_{BC,h}$

(f) Test Difference $H_0: \beta_{B,h} + \beta_{BC,h} = 0$

(g) Test Difference $H_0: \beta_{C,h} = 0$

(h) Test Difference $H_0: \beta_{C,h} + \beta_{BC,h} = 0$

(i) Test Difference $H_0: \beta_{B,h} + \beta_{C,h} + \beta_{BC,h} = 0$

Figure 6. Responses of real GDP to monetary policy shocks during recessions

(a) Low Debt & Loose Const.: $\beta_{A,h} + \beta_{D,h}$

(b) High Debt & Loose Const.: $\beta_{A,h} + \beta_{B,h} + \beta_{D,h}$

(c) Test Difference $H_0: \beta_{B,h} = 0$

(d) Low Debt & Tight Const.: $\beta_{A,h} + \beta_{C,h} + \beta_{D,h}$

(e) High Debt & Tight Const.: $\beta_{A,h} + \beta_{B,h} + \beta_{C,h} + \beta_{BC,h} + \beta_{D,h}$

(f) Test Difference $H_0: \beta_{B,h} + \beta_{BC,h} = 0$

(g) Test Difference $H_0: \beta_{C,h} = 0$

(h) Test Difference $H_0: \beta_{C,h} + \beta_{BC,h} = 0$

(i) Test Difference $H_0: \beta_{B,h} + \beta_{C,h} + \beta_{BC,h} = 0$
III.5. Does the zero lower bound influence the results?

As an additional analysis, we take into account that the transmission mechanism, and therefore the effects of policy shocks on output, may have changed between 2009Q1 and 2015Q4, when the Federal Funds rate remained close to zero.\textsuperscript{18} To account for potentially different dynamics we estimate

\[
\log(RGDP)_{t+h} = \alpha_{A,h} + \beta_{A,h} MP_t + \gamma_{A,h}(L)x_{t-1} \\
+ I_{B,t-1}[\alpha_{B,h} + \beta_{B,h} MP_t + \gamma_{B,h}(L)x_{t-1}] \\
+ I_{C,t-1}[\alpha_{C,h} + \beta_{C,h} MP_t + \gamma_{C,h}(L)x_{t-1}] \\
+ I_{B,t-1}I_{C,t-1}[\alpha_{BC,h} + \beta_{BC,h} MP_t + \gamma_{BC,h}(L)x_{t-1}] \\
+ I_{E,t-1}[\alpha_{E,h} + \beta_{E,h} MP_t + \gamma_{E,h}(L)x_{t-1}] \\
+ \lambda_1 h t + \lambda_2 h t^2 + \epsilon_{t+h},
\]

(6)

where \(I_{E,t} = 1\) during the zero lower bound period, and dummies \(I_{B,t}\) and \(I_{C,t}\) are defined as in the baseline estimations. Therefore, the neutral state \(A\) captures periods in which private debt is relatively low, financial constraints are relatively loose, and the policy rate is not close to the zero lower bound.

Figure 7 shows the responses of real GDP in the debt and financial constraint states during the zero lower bound period (\(I_{E,t} = 1\)). We see that although the responses are somewhat weaker after 2008, the results generally resemble our baseline results.\textsuperscript{19}

III.6. Deleveraging states

Harding and Klein (2018) show that monetary policy shocks exert more pronounced effects on the U.S. economy during periods of household deleveraging, i.e. during periods when private sector debt declines. To take deleveraging into account, we augment equation (2) again with an additional state variable \(I_{F,t}\) that indicates the deleveraging states according to Harding and Klein (2018):\textsuperscript{20}

\[
\log(RGDP)_{t+h} = \alpha_{A,h} + \beta_{A,h} MP_t + \gamma_{A,h}(L)x_{t-1} \\
+ I_{B,t-1}[\alpha_{B,h} + \beta_{B,h} MP_t + \gamma_{B,h}(L)x_{t-1}] \\
+ I_{C,t-1}[\alpha_{C,h} + \beta_{C,h} MP_t + \gamma_{C,h}(L)x_{t-1}] \\
+ I_{B,t-1}I_{C,t-1}[\alpha_{BC,h} + \beta_{BC,h} MP_t + \gamma_{BC,h}(L)x_{t-1}] \\
+ I_{F,t-1}[\alpha_{F,h} + \beta_{F,h} MP_t + \gamma_{F,h}(L)x_{t-1}] \\
+ \lambda_1 h t + \lambda_2 h t^2 + \epsilon_{t+h}.
\]

(7)

\textsuperscript{18}Liu \textit{et al.} (2019) show that the impulse responses of key macroeconomic variables to identified shocks have changed during this period.

\textsuperscript{19}Figure A.3 in the Online Appendix shows the responses before the zero lower bound period (\(I_{E,t} = 0\)).

\textsuperscript{20}\(I_{F,t} = 1\) during four specific episodes: 1975Q1–1983Q2, 1998Q1–2001Q2, 2004Q2–2006Q1, and 2010Q1–2015Q1. Only 12 periods of all 68 deleveraging periods in our sample coincide with high private debt and tight financial constraints. In 25 periods, we observe deleveraging and tight financial constraints and in 26 periods we observe deleveraging and high private debt.
The dummies $I_{B,t}$ and $I_{C,t}$ are defined as in the previous estimations. In this specification, the neutral state $A$ captures periods in which private debt is low, financial constraints are loose, and the economy is in the leveraging state.

Figure 8 shows the results conditional on the deleveraging state. The combination of high private sector debt and tight financial constraints amplifies the effects of monetary policy shocks. Nevertheless, since the responses are slightly more pronounced in deleveraging states, we may also conclude that the effects exerted by contractionary policy shocks during deleveraging periods are not fully accounted for by the debt level and financial constraints.

III.7. Alternative definitions of the state indicators

Do the effects of policy shock differ if private sector debt is extraordinarily high and financial constraints are strongly binding? To address this question, we re-estimate equation (2) and set $I_{B,t} = 1$ if the cyclical component of private debt lies above the 70th percentile, and $I_{B,t} = 0$ otherwise. Similarly, we set $I_{C,t} = 1$ if the moving average of EBP is above the 70th percentile, and $I_{C,t} = 0$ otherwise.

Figure 9 shows the results. While we still observe the same qualitative patterns as in Figure 3, output declines already on impact and persistently if debt is particularly high and financial constraints are especially tight, whereas the decline occurs with a delay in the baseline estimation.

21 Figure A.4 in the Online Appendix shows the responses during leveraging periods.
Figure 8. Responses of real GDP to monetary policy shocks during deleveraging periods

Figure 9. Responses of real GDP to monetary policy shocks when states are defined with higher cut-offs
III.8. Do the size and the sign of the policy shock matter?

Since the economy potentially responds particularly strongly to relatively large policy shocks, our estimations may pick up the effects of large shocks rather than the influence of debt levels and financial constraints if large shocks occur during episodes of high debt levels and tight constraints. To address this issue, we control for the size of the shock by adding $MP^3_t$ to our baseline specification:

$$
\begin{align*}
\log(RGDP)_{t+h} &= x_{A,h} + \beta_{A,h}MP_t + \gamma_{A,h}(L)x_{t-1} \\
&+ I_{B,t-1}[x_{B,h} + \beta_{B,h}MP_t + \gamma_{B,h}(L)x_{t-1}] \\
&+ I_{C,t-1}[x_{C,h} + \beta_{C,h}MP_t + \gamma_{C,h}(L)x_{t-1}] \\
&+ I_{B,t-1}I_{C,t-1}[x_{BC,h} + \beta_{BC,h}MP_t + \gamma_{BC,h}(L)x_{t-1}] \\
&+ \lambda_{1,h}MP^3_t + \lambda_{2,h}t + \lambda_{3,h}t^2 + \epsilon_{t+h}.
\end{align*}
$$

(8)

Figure 10 shows that policy shocks exert significantly larger effects if private sector debt is above trend and financial constraints are relatively tight.\(^{22}\)

Angrist, Jordà and Kuersteiner (2018) and Barnichon and Matthes (2016) show that contractionary policy shocks exert stronger effects on economic activity than expansionary shocks. Thus, if high private debt levels and tight financial constraints coincide with

\(^{22}\)Note that we find expansionary effects, albeit small and short-lived, in response to the contractionary monetary policy shock in Panel (b) of Figure 10. Such expansionary effects can be rationalized by the information channel of monetary policy shocks (see Jarociński and Karadi, 2018; Andrade and Ferroni, 2016).
Figure 11. Responses of real GDP to only contractionary monetary policy shocks

Contractionary policy actions, we may capture nonlinearities arising from the sign of the policy shock rather than from the initial state of the economy. Therefore, we add a state variable $I_G,t$ to equation (2):

\[
\begin{align*}
\log(RGDP)_{t+h} &= \alpha_{A,h} + \beta_{A,h}MP_t + \gamma_{A,h}(L)x_{t-1} \\
&\quad + I_{B,t-1}[\alpha_{B,h} + \beta_{B,h}MP_t + \gamma_{B,h}(L)x_{t-1}] \\
&\quad + I_{C,t-1}[\alpha_{C,h} + \beta_{C,h}MP_t + \gamma_{C,h}(L)x_{t-1}] \\
&\quad + I_{B,t-1}I_{C,t-1}[\alpha_{BC,h} + \beta_{BC,h}MP_t + \gamma_{BC,h}(L)x_{t-1}] \\
&\quad + I_{G,t}[\alpha_{G,h} + \beta_{G,h}MP_t + \gamma_{G,h}(L)x_{t-1}] \\
&\quad + \lambda_{1,h}t + \lambda_{2,h}t^2 + \epsilon_{t+h},
\end{align*}
\]

where $I_{G,t} = 1$ if the policy shock is strictly positive, and $I_{G,t} = 0$ otherwise. Since the states $I_B$ and $I_C$ are defined as in the previous estimations, the neutral state $A$ captures the effects of expansionary monetary policy shocks during periods of low private debt and loose financial constraints.

Figure 11 shows the responses conditional on contractionary shocks ($I_{G,t} = 1$). We still observe that output effects are amplified, when both, private debt and financial constraints are high.23

In Figure 12, we consider an additional type of asymmetry. Here we study whether monetary contractions and expansions exert different effects depending on whether financial

23 Figure A.5 in the Online Appendix shows the responses conditional on expansionary shocks ($I_{G,t} = 0$).
constraints are tight or not. Guerrieri and Iacoviello (2017) argue that financial constraints amplify adverse shocks to a greater extent. Specifically, we estimate

\[ \log(\text{RGDP})_{t+h} = \alpha_{A,h} + \beta_{A,h}MP_t + \gamma_{A,h}(L)x_{t-1} + I_{C,t-1}[\alpha_{C,h} + \beta_{C,h}MP_t + \gamma_{C,h}(L)x_{t-1}] + I_{G,t-1}[\alpha_{G,h} + \beta_{G,h}MP_t + \gamma_{G,h}(L)x_{t-1}] + \hat{\lambda}_{A,h}t + \hat{\lambda}_{2,h}t^2 + \epsilon_{t+h}, \]

where the states \( I_{C,t} \) and \( I_{G,t} \) are defined as before, and the neutral State \( A \) captures periods of expansionary monetary policy shocks and loose financial constraints.

Figure 12 shows the response of real GDP to expansionary and contractionary policy shocks that occur under loose constraints (first row) and tight constraints (second row). We find the strongest reaction of real GDP to contractionary shocks under tight constraints. However, it has to be noted that the responses are generally insignificant. Thus, we find only weak evidence in favour of such an asymmetry.

IV. Alternative-dependent variables

A number of contributions point out that the housing market plays a key role for the transmission of monetary policy (see e.g. Mian and Sufi, 2011, 2014). Therefore, we study...
Figure 13. Responses of house prices to monetary policy shocks conditional on private sector debt and financial constraints

Figure 14. Responses of housing construction to monetary policy shocks conditional on private sector debt and financial constraints
Figure 15. Responses of households’ net worth to monetary policy shocks conditional on private sector debt and financial constraints

Figure 16. Responses of corporate businesses’ net worth to monetary policy shocks conditional on private sector debt and financial constraints

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Figure 17. Responses of real GDP to monetary policy shocks conditional on private sector debt and financial constraints (loan to value ratio)

Figure 18. Responses of real GDP to monetary policy shocks conditional on private sector debt and financial constraints (real estate loans)
Figure 19. Responses of real GDP to monetary policy shocks conditional on private sector debt and financial constraints (commercial and industrial loans)

Figure 20. Responses of real GDP to monetary policy shocks conditional on private sector debt and financial constraints (consumer loans)
the responses of house prices in Figure 13 and of housing construction in Figure 14.\textsuperscript{24} We find that house prices and housing construction decline significantly only when private debt is high and financial constraints are tight. Thus, our results are consistent with the view that changes in housing wealth are a key element of the monetary transmission mechanism.

Next, we consider net worth in a broader sense. Figure 15 shows that households’ net worth (total assets minus total liabilities) declines markedly and significantly only in the high debt and tight financial constraints state, which may mirror the effects of house prices on households’ net worth. While the net worth of corporate businesses also declines when high debt coincides with tight constraints as shown in Figure 16, we also observe a rather strong decline in low debt and tight constraint state. This result indicates that the net worth of corporate businesses declines whenever financial constraints are tight. Since tight financial constraints are likely to coincide with increased interest rate costs, the declining net worth may be the result of increasing interest costs.

We also consider the loan to value ratio as well as different loan categories as alternative indicators of indebtedness and define debt states accordingly. The results are displayed in Figures 17 (loan to value ratio), 18 (real estate loans), 19 (commercial and industrial loans), and 20 (consumer loans). The results are generally similar to our baseline results. The state-dependent effects turn out to be most significant in case of commercial and industrial loans. However, in terms of magnitude and timing, the results are rather similar across the different estimations.

\textsuperscript{24}The house price index for the US starts only in 1975Q1.
Finally, we consider the response of the Federal Funds rate to characterize the dynamics of systematic monetary policy in the aftermath of a policy shock. We see from Figure 21 that the responses of the interest rate are fairly similar on impact. In fact, we can reject the null hypothesis of equal responses only in the low debt and loose constraints state and the low debt and tight constraint state at the 5% level. Although the dynamics differ across states over time, the differences do not appear to be systematically related to the output response. For instance, the output response is more pronounced in the high debt and tight constraint state relative to the low debt and tight constraint state, whereas the interest rate responses are rather similar and do not differ significantly across these two states.

V. Robustness analysis

V.1. Covariates and sample

As a first robustness check, we take into account that the policy reaction function may also depend on the level of private debt and financial constraints (see Tenreyro and Thwaites, 2016). To do so, we augment equation (3) and estimate

$$
\Delta f_{m} = \alpha + X_m \Gamma_A + I_{B,m-1} [\alpha_B + X_m \Gamma_B] + I_{C,m-1} [\alpha_C + X_m \Gamma_C] + I_{B,m-1} I_{C,m-1} [\alpha_{BC} + X_m \Gamma_{BC}] + \epsilon_m
$$

(11)

where $X_m = [f b_m, \Delta y_{m,i}, (\Delta y_{m,i} - \Delta y_{m-1,i}), \tilde{\pi}_{m,i}, (\tilde{\pi}_{m,i} - \tilde{\pi}_{m-1,i}), \tilde{u}_{m0}]$, with $i = -1, 0, 1, 2$, as in equation (3), and $A, \Gamma_B, \Gamma_C$ and $\Gamma_{BC}$ are column vectors of the corresponding coefficients in the four different states. We set $I_{B,m} = 1$ and $I_{C,m} = 1$ accordingly to the quarterly dummies $I_{B,t} = 1$ and $I_{C,t} = 1$, as defined in our baseline estimation. That is, we set $I_{B,m} = 1$ if private debt exceeds its HP trend in the corresponding quarter, and $I_{B,m} = 0$ otherwise. $I_{C,m} = 1$ if the 7-quarter lagged moving average of the EBP lies above its median value in the corresponding quarter, and $I_{C,m} = 0$ otherwise. The quarterly policy shocks $MP_t$ are again the quarterly sums of $\hat{\epsilon}_m$.

We also consider an estimation where we use the shadow short rate provided by Wu and Xia (2016) instead of the one obtained from Krippner (2015) to estimate monetary policy shocks based on equation (3). Next, we apply a higher smoothing parameter of $10^6$ (see Bernardini and Peersman, 2018), rather than $10^4$, to define the debt states and re-estimate equation (2). Then we also define the private debt state analogously to the financial constraint state. In other words, we set $I_{B,t} = 1$ when the 7-quarter lagged moving average of the growth rate of private debt exceeds its sample median. We also consider a specification in which we exclude the price level and the Federal Funds rate to preserve degrees of freedom. And finally we exclude data from the Great Recession and end the sample in 2007Q3 as macroeconomic dynamics may have changed when the zero lower bound on the nominal interest rate became binding (see Liu et al., 2019).

Figure 22 summarizes the different robustness checks and shows that the impulse responses in the four different states are qualitatively similar to the baseline results.

V.2. Alternative specifications

Figure 23 shows impulse responses obtained from estimations in log levels with a linear time trend, without any time trends, an estimation in first log-differences, and an estimation
Figure 22. Responses of real GDP to monetary policy shocks (summary robustness of covariates and sample)

Notes: The solid lines in subfigures (a), (b), (d), and (e) show state-dependent impulse responses of real GDP to monetary policy shocks across different estimations. The estimations are: the baseline (black), an estimation in which we consider non-linear monetary policy shocks Tenreyro and Thwaites (2016) following (blue), an estimation in which we substitute Krippner’s (2015) shadow short rate with Wu and Xia’s (2016) shadow rate (green); an estimation applying a higher smoothing parameter to obtain the private debt state Bernardini and Peersman (2018) as in [purple], private debt state is defined analogously to financial constraints based on a lagged moving average (red), an estimation excluding the control variables (orange), and an estimation in which the sample ends in 2007Q3 (gold). The gray areas in subfigures (a), (b), (d), and (e) show 95 percent confidence intervals from the benchmark regression.

using monthly data. For easy comparisons with the baseline results, we show cumulated impulse responses for the estimation in first differences, which we obtain by regressing the $h^{th}$ difference of $\log(RGDP)$ as the dependent variable as in Klein (2017):

$$
\log(RGDP)_{t+h} - \log(RGDP)_{t-1} = \alpha_{A,h} + \beta_{A,h}MP_t + \gamma_{A,h}(L)x_{t-1} + I_{B,t-1}[^{[\alpha_{B,h} + \beta_{B,h}MP_t + \gamma_{B,h}(L)x_{t-1}]} + I_{C,t-1}[^{[\alpha_{C,h} + \beta_{C,h}MP_t + \gamma_{C,h}(L)x_{t-1}]} + (I_{B,t-1}-I_{C,t-1})[^{[\alpha_{BC,h} + \beta_{BC,h}MP_t + \gamma_{BC,h}(L)x_{t-1}]}] + \lambda_{1,h}t + \lambda_{2,h}t^2 + \epsilon_{t+h},
$$

where the control variables real GDP and prices, captured in $x_{t-1}$, enter the regression in first log differences.

When we estimate the main specification (see equation (2)) with monthly data, we consider 6 lags for the control variables to account for the higher frequency of monthly data. While consumer prices and the Federal Funds rate are also available on a monthly frequency, we use industrial production for the output measure and obtain monthly policy

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shocks, by summing the estimated innovations \( \hat{\varepsilon}_m \) from equation (3) within each month. To obtain monthly state variables, we simply set \( I_{B,t} = 1 \) and \( I_{C,t} = 1 \) whenever their quarterly counterparts equal 1. To compare the results with our baseline estimation in Figure 23 we show quarterly averages of the impulse responses and the \( t \)-values. The gray areas in subfigures (a), (b), (d), and (e) show 95 percent confidence intervals from the benchmark regression.

In line with our baseline results, we see that higher private debt or tighter financial constraints only amplify the effects of monetary policy if they occur simultaneously.

V.3. Different lag structure

In our baseline specification, we determine the lag length according to the Schwartz Bayesian information criteria. To evaluate whether our findings are sensitive to the selected lag length, we also consider estimations with one, four and six lags of the control variables. Furthermore, we consider an additional specification where we include the state variables contemporaneously. And finally, we also estimate a version of the model, where we additionally consider a lag of the monetary policy shock.

Figure 24 shows that these sensitivity checks support our conclusions. The strongest effects of monetary policy materialize if private debt is high and financial constraints are tight.

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VI. Concluding remarks

In this paper, we apply the local projection method to study whether private sector debt influences the monetary transmission mechanism. We find that although monetary policy exerts larger effects on real GDP when private sector debt is relatively high, we also find that this amplification effect is only present if high levels of private sector debt coincide with tight financial constraints.

From a policy point of view, our results suggest that monetary policy actions have rather different implications depending on the state of the economy. The adverse macroeconomic effects associated with a monetary contraction are likely to be more severe, if the contraction occurs at a time when the private sector is highly indebted and financial constraints are tight. By the same token, the central bank’s ability to stimulate the economy in the face of adverse shocks is enhanced when the private sector is highly indebted and financial constraints are binding.

To the extent that the Great Recession was characterized by high levels of private debt and tight financial constraints, our results suggest that monetary policy should have been particularly effective during this period and somewhat less effective during the recovery when debt levels declined and financial constraints loosened.

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**Supporting Information**

Additional supporting information may be found in the online version of this article:

Appendix S1. Supplementary materials.