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Martin S. Eichenbaum
Federico Puglisi
Sergio Rebelo
Mathias Trabandt

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Banks and the State-Dependent Effects of Monetary Policy
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ABSTRACT

This paper provides empirical evidence that contractionary monetary policy is less powerful in high interest-rate environments. We argue that this state dependence reflects the interaction between bank's net interest margins (the return on banks' assets minus the per-dollar cost of their funds), and households' high marginal propensity to consume out of liquid wealth. We construct a banking model in which social dynamics shape household attentiveness to deposit rates and embed it in a nonlinear heterogeneous-agent New Keynesian model. Estimated versions of the partial and general equilibrium models account well for the observed state dependence in the response of banks' net interest margins and the response of aggregate economic activity to monetary policy shocks.

Martin S. Eichenbaum
Northwestern University
Department of Economics
and NBER
eich@northwestern.edu

Federico Puglisi
Banca d'Italia
federicopuglisi@u.northwestern.edu

Sergio Rebelo
Northwestern University
Kellogg School of Management
Department of Finance
and CEPR
and also NBER
s-rebelo@northwestern.edu

Mathias Trabandt
Goethe University Frankfurt
and IWH
mathias.trabandt@gmail.com

1 Introduction

This paper shows that monetary policy has a smaller impact on aggregate activity when interest rates are high than when they are low. Our empirical analysis finds that real GDP, the stock market, aggregate consumption, and investment decline more sharply when a contractionary policy shock follows a period of low Federal Funds Rates.

We also find that after a period of low Federal Funds Rates, a contractionary policy shock raises banks' net interest margins (NIMs)—the return on banks' assets minus the per-dollar cost of their funds. By contrast, when the shock follows a period of high Federal Funds Rates, NIMs fall. This difference arises mainly from the asymmetric response of banks' funding costs: the pass-through to deposit rates is greater when initial rates are high.

To account for our empirical findings, we build and estimate a general equilibrium model in which state dependence arises from the interaction of two forces: (i) state dependence in the spread between the rate of return on banks' assets and NIMs, and (ii) households' high marginal propensity to consume out of liquid wealth. The basic mechanism in our model is as follows. In high-interest-rate environments, there is greater pass-through from an increase in the policy rate to the interest rate that banks pay depositors. So, other things equal, households' income from savings rises by more in high interest-rate environments. The associated rise in liquid wealth mitigates the decline in aggregate demand relative to the decline that would occur in a low-interest-rate environment. Through this mechanism, state dependence in the response of interest rates on savings to a hike in the policy rate translates into a state-dependent effect on aggregate economic activity.

We proceed in two steps. First, we develop a partial equilibrium banking model and use it to study the mechanisms that generate state dependence in NIM. Second, we embed the banking model in a New Keynesian (NK) dynamic stochastic general equilibrium (DSGE) model in which a subset of households has a high marginal propensity to consume out of liquid wealth. We then use the model to study how state dependence in NIM translates into state dependence in macroeconomic aggregates. The estimated versions of these models account well for the patterns of state dependence observed in the data.

A key feature of our banking model is that at any point in time some households are inattentive to deposit interest rates. The fraction of households that are inattentive to deposit interest rates depends on the level of the interest rate. This relationship arises from social dynamics between attentive and inattentive households.[1] Inattentive households may become attentive after interacting with attentive households, who are more likely to discuss interest rates when rates are high.

[1]For evidence on the role of social dynamics in consumers' financial decisions, see Iyer and Puri [2012], Bailey et al. [2018], and McCartney and Shah [2022]).

Our emphasis on the importance of inattentive depositors in banking is consistent with Financial Conduct Authority [2023], which finds that half of consumers don't know the interest rate that they are earning on their savings account. Similarly, a recent Capital One survey, discussed in Blatt [2025], finds that 57 percent of respondents check their savings account less than once per month or not at all, and 48 percent do not know the interest rate on their savings accounts.

There are three key effects at work in our banking model. First, higher interest rates reduce the present value of future bank profits. Free entry into banking implies that current profits must increase to compensate for this effect. The spread between the Federal Funds Rate and deposit rates widens, thereby increasing NIM. This effect is stronger when interest rates are low because a marginal increase in interest rates has a greater impact on present values.

Second, rising interest rates increase the number of attentive depositors, who receive higher deposit interest rates than inattentive depositors. This effect, which reduces NIM, is stronger when interest rates are high because there are more attentive depositors who can convert inattentive depositors.

Third, expectations of a future rise in the number of attentive depositors reduce banks' expected profits. With free entry, current NIM must increase to offset this effect. This force is stronger at low interest rates because banks weigh future profitability more heavily.

In our estimated partial equilibrium model, NIM rises in response to a positive monetary policy shock that follows a period of low interest rates. The reason is that, according to the model, the first and third effects dominate the second effect, leading to an increase in NIM. In contrast, NIM falls when the same shock occurs after a period of high interest rates. The reason is that, according to our model, the second effect prevails in the high-interest-rate scenario, causing NIM to decline.

In our DSGE model, bank profits flow to people with a much lower MPC out of liquid wealth than those who receive interest income from banks. Because of social dynamics, the share of attentive households is higher after a period of high interest rates. So, the pass-through from an increase in the policy rate to deposit rates is more pronounced than when interest rates are low. This effect increases household income from savings and dampens the contractionary effect on aggregate demand when interest rates are high. As a result, state dependence in NIM translates into state-dependent macroeconomic responses. In the introduction to Section 7 we present data-based calculations to support the view that the differential effect of a policy shock on aggregate demand is large–on the order of $120 billion–due to state dependence in NIM.

The paper is organized as follows. Section 2 outlines our contribution to the literature. Section 3 describes the data and Section 4 presents our empirical results. We discuss the robustness of these results in Section 5. Section 6 introduces our partial equilibrium banking model and the results from estimating that model. Section 7 presents our theoretical and estimated DSGE models. Section 8 concludes.

2 Literature Review

Our paper contributes to four strands of the literature. First, it relates to the extensive empirical and theoretical work on the role of banks in the monetary transmission mechanism. Notable contributions in this area include Cúrdia and Woodford [2010], Driscoll and Judson [2013], Gertler and Karadi [2015], Piazzesi, Rogers, and Schneider [2019], and Bianchi and Bigio [2022]. Our work is particularly related to studies that emphasize the deposit channel of monetary policy and the cyclical behavior of the net interest margin (see, for example, Drechsler, Savov, and Schnabl [2017, 2018, 2021], Bolton et al. [forthcoming], Ulate et al. [2021], Begenau and Stafford [2022]), Abadi et al. [2023], and Bolton et al. [forthcoming]). Our empirical results are consistent with Greenwald et al. [2023], who document a nonlinear relationship between the Federal Funds Rate and deposit interest rates, with pass-through increasing at higher levels of the policy rate. We make two main contributions to this literature: (i) we show that the responses of NIM, deposit spreads, and key macroeconomic aggregates to monetary policy shocks are state-dependent; and (ii) we propose a model that accounts for this state dependence.

Second, we contribute to the empirical literature documenting the state-dependent effects of monetary policy shocks. Alpanda et al. [2021] find that the effectiveness of monetary policy diminishes when household debt is high and real output is below potential. Berger et al. [2021] and Eichenbaum et al. [2022] use U.S. loan-level data to show that households are less likely to refinance their mortgages when the interest rate on their existing loan is lower than the prevailing market rate for new mortgages. As policy rates rise, mortgage rates tend to increase as well, leading many households with fixed-rate mortgages to hold loans at below-market rates. As a result, a given interest rate cut becomes less effective following a series of rate hikes.

Third, our paper is related to the literature on the MPC out of liquid wealth and its macroeconomic implications in models with heterogeneous agents. Key papers in this area include Johnson, Parker, and Souleles [2006], Parker, Souleles, Johnson, and McClelland [2013], Jappelli and Pistaferri [2014], Kaplan and Violante [2014], Debortoli and Galí [2017], Kueng [2018], Auclert, Rognlie, and Straub [forthcoming], Ganong et al. [2020], and Fagereng, Holm, and Natvik [2021]. Our contribution to this literature is to show how households with a high MPC out of liquid wealth create state-dependent responses of aggregate variables to a monetary policy shock.

Fourth, we add to a growing literature on the macroeconomic impact of social interactions.

This body of work includes papers by Carroll [2003], Iyer and Puri [2012], Burnside, Eichenbaum, and Rebelo [2016], Bailey et al. [2018], and McCartney and Shah [2022]. See Carroll and Wang [2023] for an excellent survey. Relative to this work, we show that social dynamics offer a useful framework for modeling shifts in inattention and the resulting effects on banking behavior and the macroeconomic response to monetary policy.

3 Data

Our empirical analysis uses detailed data from the Consolidated Reports of Condition and Income (Call Reports) obtained from the Federal Deposit Insurance Corporation[2]. These reports are filed quarterly by all national banks, state-member banks, insured state-non-member banks, and savings associations. For each financial institution, we obtain data on the following variables from the call reports: total outstanding assets, total income, total outstanding loans, total loan income, total outstanding liabilities, total expenses, total outstanding deposits, total deposits expense, outstanding transaction deposits, transaction deposit expenses, outstanding saving deposits, saving deposit expenses, outstanding time deposits, time deposit expenses, outstanding foreign deposits, and foreign deposit expenses.

Using these data, we construct the following variables: the ratio of total loans to total assets, the ratio of total deposits to total liabilities, the ratio of transaction deposits to total liabilities, the ratio of savings deposits to total liabilities, the ratio of time deposits to total liabilities, and the ratio of foreign deposits to total liabilities. In addition, we construct data on (i) the quarterly interest income rate on assets, measured as the ratio of total interest earned to total outstanding assets, (ii) the average interest expense rate on liabilities, measured as the ratio of total interest expense to total outstanding liabilities, (iii) the average loan interest income rate, measured as the ratio of total interest income from loans to total outstanding loans, (iv) the total deposit expense rate, measured as the ratio of total interest expense on deposits to total outstanding deposits, (v) the total transaction deposit expense rate, measured as the ratio of total interest expense on transaction deposits to total outstanding transaction deposits, (vi) the total savings deposit expense rate, measured as the ratio of total interest expense on savings deposits to total outstanding savings deposits, (vii) the total time deposit expense rate, measured as the ratio of total interest expense on time deposits to total outstanding time deposits, and (viii) the total foreign deposit expense rate, measured as the ratio of total interest expense on foreign deposits to total outstanding foreign deposits.

[2] See the FDIC website.

We compute two measures of NIM: (i) core NIM, which is the difference between the average loan interest income rate and the average deposit interest expense rate, and (ii) overall NIM, which is the difference between the average interest income rate on all assets and the average interest expense rate computed above. Our empirical analysis uses these data aggregated at the national level. To assess robustness, we re-do our analyses using data from only the 50 largest financial institutions. In all cases, we use quarterly data from 1985:1 to 2019:4. We chose this end date to abstract from the effects of COVID-19. In Section 5, we assess the robustness of our results to changes in the sample period.

We use the following data on aggregate variables obtained from FRED: Real GDP (GDPC1), Real Personal Consumption Expenditure (PCCE96) and Prices (PCEPI), Real Gross Private Domestic Investments (GPDIC1), Real Durables Consumption (DDURRA3Q086SBEA), Real Non-Durable Consumption (DNDGRA3Q086SBEA), Real Services Consumption (DSERRA3Q086SBEA), S&P 500 index (SP500), the Federal Funds Rate (FEDFUNDS), 1-Year Treasury Yield (GS1), 2 Years Treasury Yield (GS2), 10 Years Treasury Yield (GS10), the 15-Year Fixed-Rate Mortgage Average (MORTGAGE15US). We obtain the updated excess bond premium time series from the Federal Reserve Board[3].

We use three measures of exogenous shocks to monetary policy. The first is based on the recursive-style identification used in Bernanke and Mihov [1998] and Christiano et al. [1999], among others. In particular, we identify a time t shock to monetary policy as the residual in a regression of the Federal Funds rate on contemporaneous and four lags of real per capita GDP, the PCE price index, the excess bond premium (the part of credit spread not explained by expected default risk), and the yield curve slope.[4] The presence of the contemporaneous variables in our specification reflects two assumptions: (i) the Federal Reserve sees those variables when making its monetary policy decisions; and (ii) those variables are pre-determined relative to the monetary policy shock. The latter assumption is consistent with Friedman and Schwartz [1963] and Friedman [1968]. For convenience, we refer to this measure of a monetary policy shock as the *recursive shock measure*.

The second measure is constructed by Bauer and Swanson [2023] using high-frequency movements in the one-, two-, three-, and four-month-ahead Eurodollar futures contracts in a 30-minute window of time around Federal Open Market Committee (FOMC) announcements.

The third measure, constructed by Jarociński and Karadi [2020], separates monetary policy shocks from contemporaneous information shocks by analyzing the high-frequency co-movement of interest rates and stock prices in a narrow window around the policy announcement.

[3]See FRB Updated Excess Bond Premium data.

[4]See Caldara and Herbst (2019) for the importance of controlling for the lagged values of the excess bond premium.

To conserve space, the main text focuses on the results obtained with the recursive-style identification. We briefly discuss results for the Bauer and Swanson [2023] and Jarociński and Karadi [2020] shock measures in Section 5. The Appendix contains a detailed analysis of the results obtained with these alternative shock measures.

4 Empirical Results

This section examines how the effects of monetary policy shocks on loan rates, deposit rates, core NIM, and aggregate economic activity depend on the level of policy interest rates prior to the shock. We capture this state dependence using an indicator variable that equals one when the average Federal Funds rate (FFR) over the previous six quarters exceeds a threshold $\bar{R}$ equal to 4 percent, and zero, otherwise. The average value of the FFR is 1.47 percent (5.61 percent) when the six-quarter average of the Federal Funds Rate is below (above) than 4 percent. Our threshold choice is broadly consistent with Pfäuti [2025], Table 1, which shows that the public attention to quarterly inflation rises sharply when inflation exceeds roughly 3.2 percent per annum, which corresponds to a nominal interest rate of roughly 4 percent if the real interest rate is one percent. Our results are robust to setting $\bar{R}$ to values slightly higher (4.5 percent) or lower (3.5 percent) than 4 percent (see Section 5).

4.1 Estimating the State-Dependent Response to a Monetary Policy Shock

We estimate the following local projection equation:

$$Y_{t+h} = \alpha_{0,h}+\beta_{0,h}MP_t+\alpha_{1,h}\mathbb{I}_{\{MA(R)>\bar{R}\}}+\beta_{1,h}MP_t\times\mathbb{I}_{\{MA(R)>\bar{R}\}}+A_h(L)Y_t+B_h(L)MP_t+C_h(L)Z_t+\varepsilon_{t+h}. \quad (1)$$

Here, Y_{t+h} is the time $t+h$ value of the variable of interest, i.e., one of our financial outcome variables, aggregate real activity indicators, or a measure of the price level. For the macroeconomic aggregates, h ranges from one to H. In the case of NIM, the index h ranges from zero to H. The variable MP_t denotes the time t value of the monetary policy shock. The variable $\mathbb{I}_{\{MA(R)>\bar{R}\}}$ is an indicator equal to one when the average level of the FFR across the last six quarters exceeds $\bar{R} = 4$ percent, and zero otherwise. We refer to the state when $\mathbb{I}_{\{MA(R)>\bar{R}\}} = 1$ as the *high-interest-rate state* and the state when $\mathbb{I}_{\{MA(R)>\bar{R}\}} = 0$ as the *low-interest-rate state*.

In principle, we do not need to include other control variables in the local projection. But it is common in the literature to do so (see, for example, Bauer and Swanson [2023]). Following this practice, we include other control variables in the local projection. The variables $A_h(L)Y_t$ and

$B_h(L)MP_t$ denote the values of Y_{t-j} and MP_{t-j}, $j = 1, 2, 3, 4$. Since Z_t includes real per capita GDP, consumption, investment, or the excess bond premium, setting $A_h(L) = 0$ is superfluous when these are the outcome variables. The variable $C_h(L)Z_t$ denotes a vector lag polynomial of additional controls: contemporaneous and four lags of real per capita GDP, PCE prices, investment and consumption, four lags of the excess bond premium, and the yield curve slope. Finally, ε_{t+h} denotes the time $t + h$ regression error.

The coefficient $\beta_{0,h}$ measures the effect of a monetary policy shock on Y_{t+h} in the low state, i.e., when the average level of the time t FFR, across the last six quarters, is below $\bar{R} = 4$ percent. The coefficient $\alpha_{1,h}$ captures the fixed effect of a high average value of past interest rates. The coefficient $\beta_{1,h}$ measures the differential effect of a monetary policy shock on Y_{t+h} in the high-interest-rate state. The sum $\beta_{0,h} + \beta_{1,h}$ provides the total response of Y_{t+h} to a monetary policy shock, conditional on the shock occurring in the high-interest-rate-state.[5]

In the following subsections, we summarize our results by plotting the low-interest-rate state responses ($\beta_L = \{\beta_{0,h}\}_{h=0}^{H}$), the high-interest-state responses, $\beta_H = \{\beta_{0,h} + \beta_{1,h}\}_{h=0}^{H}$, and the non-state-dependent responses, $\beta_b = \{\beta_{0,h}\}_{h=0}^{H}$ obtained by setting $\{\alpha_{1,h} = \beta_{1,h} = 0\}_{h=0}^{H}$ in estimating equation (1).[6] In all cases, we also plot 68% and 90% confidence bands.[7]

4.2 The Federal Funds Rate and Financial Variables

In this subsection, we investigate the state-dependent effects of a monetary policy shock on the federal funds rate (FFR) and other financial variables. We report the results of estimating regression (1) for different specifications of the dependent variable. The size of the monetary policy shock is normalized to induce an initial rise of 100-basis-point annualized increase in FFR.

The figures discussed in this section are organized as follows: the first column plots the non-state-dependent responses (β_0), the second and third columns show the responses in the low- and high- interest rate state responses ($\beta_L$and β_H, respectively); and the last column plots the difference between the two state-dependent responses.

Panel A of Figure 1 shows that a contractionary monetary policy shock leads to a persistent increase in the FFR, lasting approximately two years. Notably, there is is relatively little evidence of state dependence in the response of the FFR itself.

[5]Our estimation framework assumes that positive and negative monetary policy shocks have symmetric effects. The state dependence that we document is robust to distinguishing between positive and negative shocks.

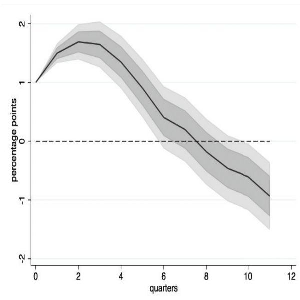
[6]Our specification excludes valuation gains and losses on outstanding long-term assets and loans and long-term liabilities. We do so because Drechsler et al. [2021] forcefully argue on empirical grounds that banks align the interest rate sensitivities of their assets and liabilities, effectively insulating banks from interest rate risk.

[7]We construct the confidence bands under the assumption of zero correlation between $\beta_{0,h}$ and $\beta_{1,h}$. This assumption is standard in the literature, see e.g. Tenreyro and Thwaites [2016].

Figure 1: *Federal Funds Rate and Core NIM*

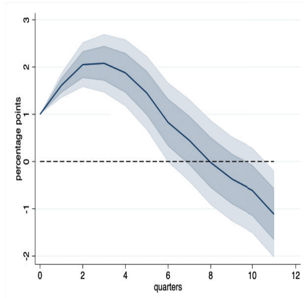
Panel A: Federal Funds Rate

No State-Dependence

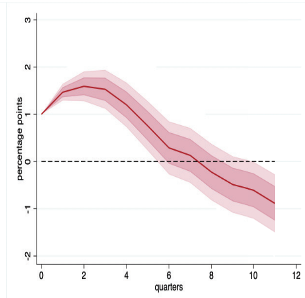


(a) Baseline

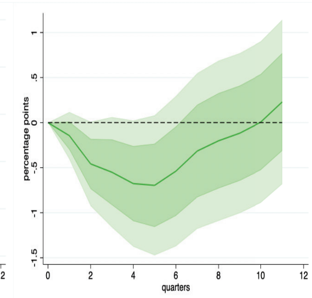
Allowing for State Dependence



(b) Low Rate State

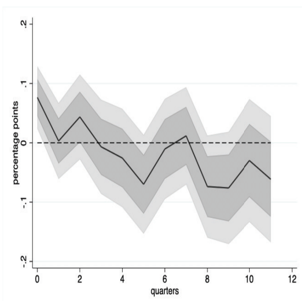


(c) High Rate State

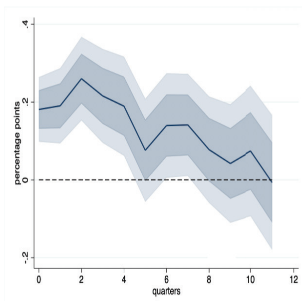


(d) High vs Low

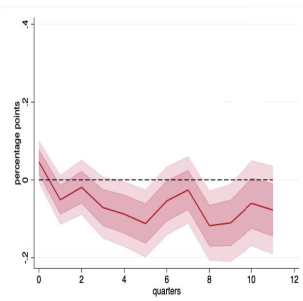
Panel B: Core NIM



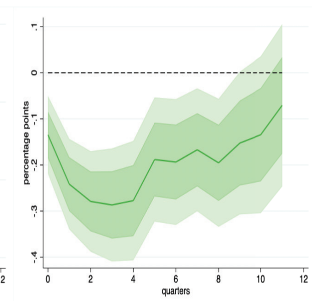
(e) Baseline



(f) Low Rate State



(g) High Rate State



(h) High vs Low

Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Panel B of Figure 1 reports the results for the core net interest margin (NIM) - defined as the difference between the average loan interest income rate and the average deposit interest expense rate). Three results emerge. First, if we do not allow for state dependence, core NIM falls by a modest amount after a contractionary monetary policy shock. The second column shows that in the low-interest-rate state, a contractionary shock leads to a significant and persistent increase in core NIM. In contrast, the third column reveals that the same shock in the high-interest-rate state causes a significant and persistent decline in core NIM. Third, the fourth column shows that the difference in NIM responses across states is statistically significant.

Figure 9 in the Appendix shows how NIM responds to a monetary policy shock. The results are similar to those reported for core NIM in Panel B of Figure 1.

The key drivers of core NIM's response to a monetary policy shock are as follows. First, it is well-documented that interest rates on transaction deposits are relatively unresponsive to policy shocks, while savings and time deposit rates adjust more strongly. Panel A of Figure 2 shows that the spread between time and savings deposit rates increases in a state-dependent manner following a contractionary monetary policy shock. This finding suggests that movements along the intensive margin of deposit rates are a key contributor to the observed state dependence in NIM.[8]

Second, depositors' asset allocations also contribute to the response of core NIM. Panel B of Figure 2 shows that a contractionary monetary policy shock triggers a significant, state-dependent shift from savings to time deposits.

These findings are complementary to Xiao [2020] who finds that depositors shift to higher-yielding money market funds when interest rates are high, but not when rates are low. Approximately half of U.S. money market fund assets are claims on commercial banks, while the remainder are invested outside the banking system (see Aldasoro and Doerr [2023]). The state-dependent flows out of the banking sector documented by Xiao [2020] place additional downward pressure on NIM when interest rates are high.

Panel C of Figure 2 shows that loan rates increase after a contractionary monetary policy shock. However, there is little evidence of state dependence in loan rates. This finding suggests that the state-dependent behavior of core NIM is primarily driven by deposit-side dynamics—namely, interest rate adjustments and the reallocation of funds between deposit types.

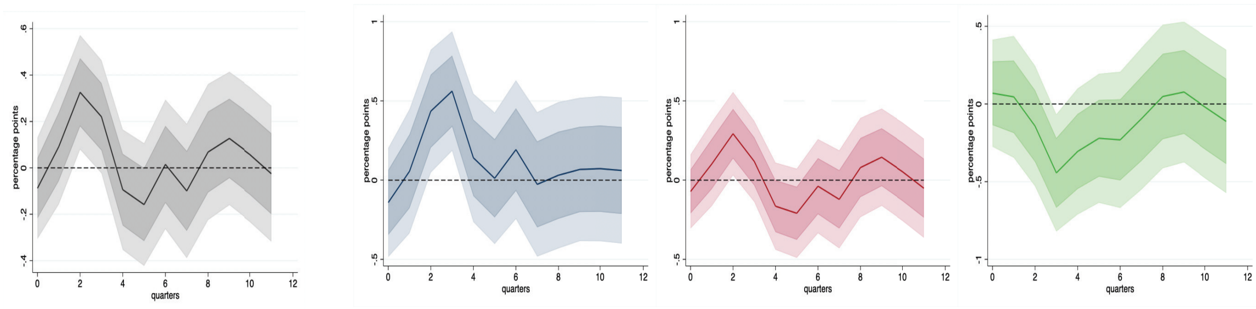
We conclude that the state-dependent response of core NIM to a monetary policy shock is primarily driven by two interacting forces: changes in interest rates on bank liabilities, and the reallocation of funds between savings and time deposits. Together, these forces explain the amplified response of NIM in low-interest-rate environments and its dampened response in high-interest-rate settings.

[8]By intensive margin, we mean the interest rate on savings and checking accounts.

Figure 2: *Core NIM Components*

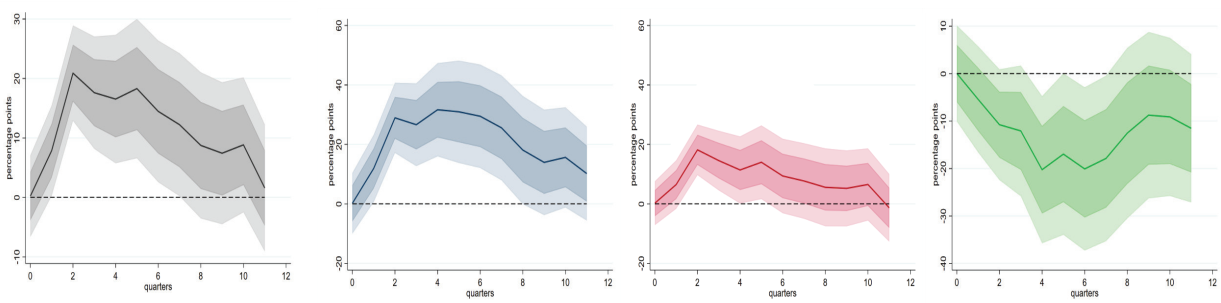
Panel A: Time Deposit Rate minus Saving Deposit Rate

No State-Dependence | Allowing for State Dependence



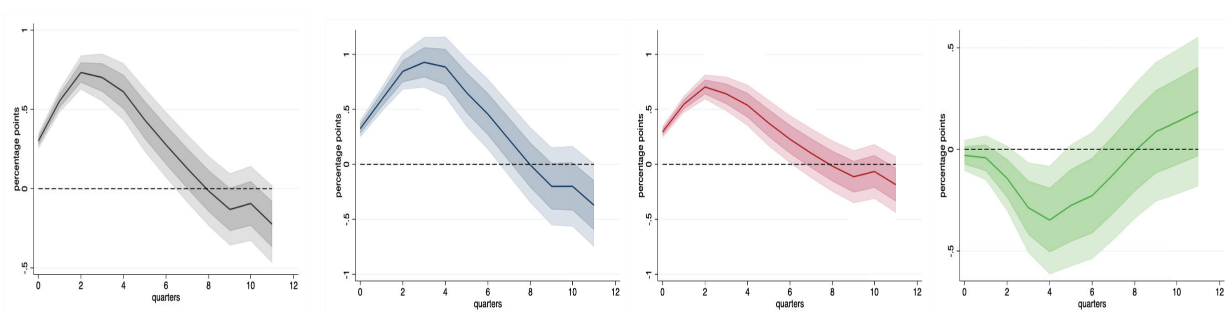
(a) Baseline | (b) Low Rate State | (c) High Rate State | (d) High vs Low

Panel B: Time Deposit Volume over Saving Deposit Volume



(e) Baseline | (f) Low Rate State | (g) High Rate State | (h) High vs Low

Panel C: Loan interest income rate



(i) Baseline | (j) Low Rate State | (k) High Rate State | (l) High vs Low

Note: Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

4.3 Macroeconomic Aggregates

In this subsection, we analyze the state-dependent effects of a monetary policy shock on the stock market, aggregate economic activity, and the logarithm of the price level.

Stock Market Response: panel A of Figure 3 shows that the value of the S&P 500 index declines in response to a contractionary monetary policy shock. The magnitude of this decline is state-dependent: the drop is more pronounced when the shock occurs after a period of low interest rates.

Real Economic Activity: panel B of Figure 3 shows the response of real per capita GDP to a contractionary monetary policy shock. Two features are noteworthy. First, a contractionary shock leads to a persistent decline in GDP lasting approximately two years. Second, the magnitude of the decline is significantly larger in the low-interest-rate state. The difference in responses between low- and high-interest-rate regimes is statistically significant. A similar state-dependent pattern emerges for consumption and investment, though the estimates for those variables are less precise than for GDP (see Figure 9 in the Appendix).

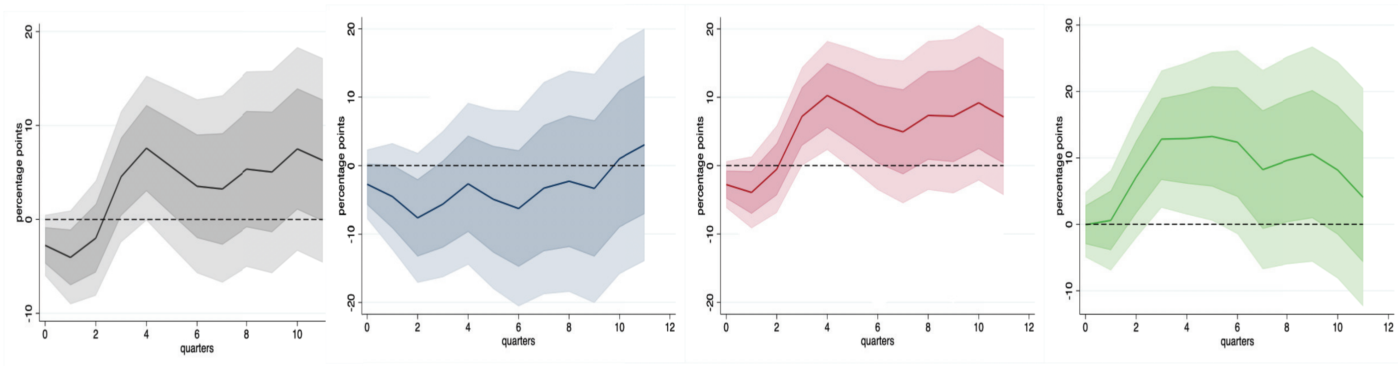
Price Level Response: panel C of Figure 3 displays the response of the personal consumption expenditures (PCE) price index to a contractionary monetary policy shock. In both interest rate states, the contractionary shock does not lead to a statistically significant change in the price level.

In sum, the response of aggregate economic activity and the price level to a contractionary monetary policy shock is broadly consistent with the conventional view: the shock leads to persistent declines in real per capita GDP, consumption, and investment, while having little effect on the price level. However, in contrast to the conventional view, we find clear evidence of state dependence. A contractionary shock leads to a significantly larger drop in economic activity when it follows a period of low interest rates. This pattern mirrors our findings for the core net interest margin (NIM) and related financial variables.

Figure 3: *Aggregate Outcomes*

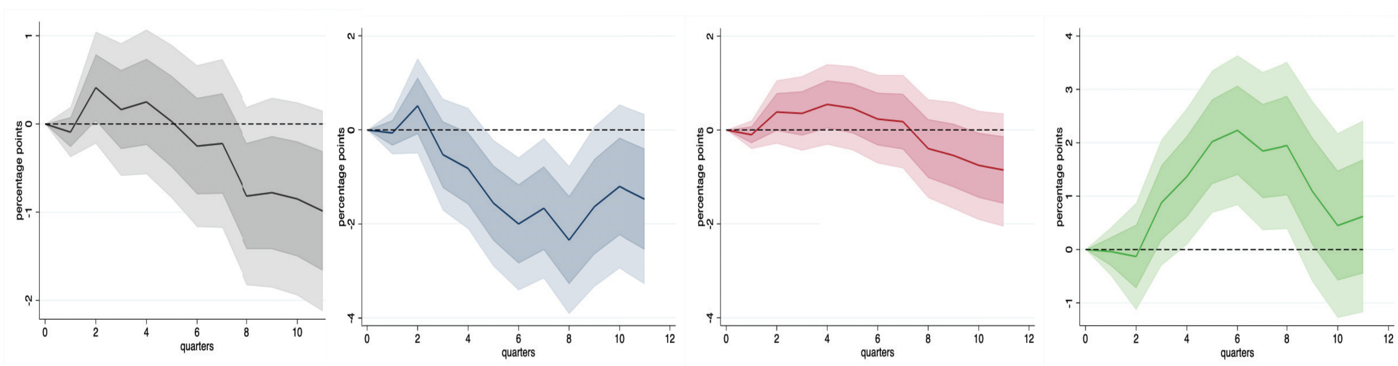
Panel A: Real Log S&P500

No State-Dependence Allowing for State Dependence



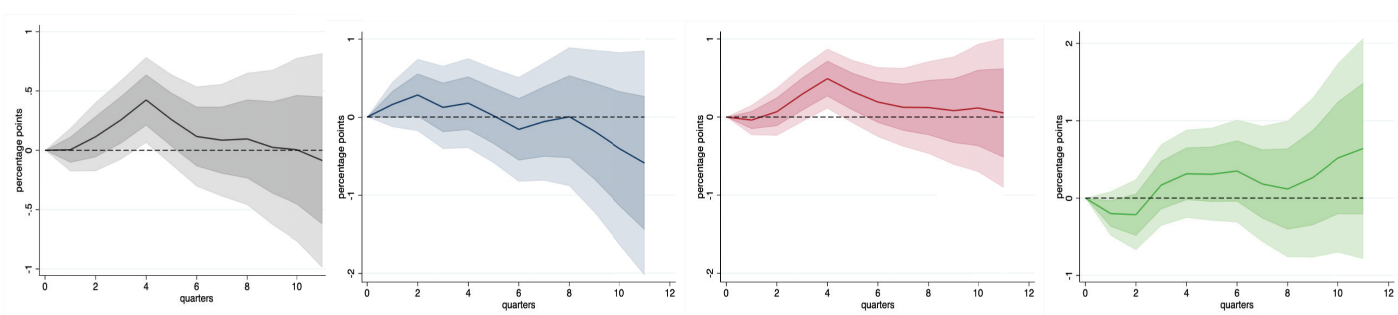
(a) Baseline (b) Low Rate State (c) High Rate State (d) High vs Low

Panel B: Log Real Per Capita GDP



(e) Baseline (f) Low Rate State (g) High Rate State (h) High vs Low

Panel C: Log PCE Price Index



(i) Baseline (j) Low Rate State (k) High Rate State (l) High vs Low

Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

5 Robustness

In this section, we assess the robustness of our empirical findings by varying the sample period, the monetary policy shock measure, the set of control variables used in estimating equation 1, the threshold value of the interest rate, and possible state dependence in the inflation rate.

Sample period The 2008 financial crisis brought major regulatory changes and marked the Fed's shift from a scarce-reserves to an ample-reserves regime. To assess the impact of these changes on our results, we re-do our empirical work using only pre-crisis data (1984Q1–2008Q4). In the Appendix we document the presence of state dependence in the response of the following variables to a monetary shock: core NIM (Panel A of Figure 10), the logarithm of the real value of the S&P 500 (Panels B of Figure 10), the logarithm of real per capita GDP and PCE price index (Panels A and B of Figure 11), the loan interest rate. the spread between the time deposit rate and the savings deposit rate rate (Panels A and B of Figure 12), overall NIM, the logarithm of real per capita consumption, and the logarithm of real per capita investment (Panels A, B and C of Figure 13). In all cases, our results are robust to using the restricted sample. We conclude that the post-crisis regulatory changes do not materially affect our results.

Alternative shock measures Figure 14 and 15 in the Appendix report our results when we re-estimate equation (1) using the shock measures constructed by Bauer and Swanson [2023] and Jarociński and Karadi [2025]. The results for core NIM, the logarithm of the real value of the S&P 500, and the logarithm of real per capita GDP are qualitatively similar to the benchmark results.

Zero lower bound Our benchmark specification does not control for periods in which the zero lower bound (ZLB) is binding. In the Appendix, we control for a binding ZLB using a dummy variable that takes on the value of 1 when FFR is lower than 50 basis point and zero otherwise. Figure 16 in the Appendix shows that the results for core NIM, the logarithm of the real value of the S&P 500 and the logarithm of real per capita GDP are robust to including this dummy variable as well as an interaction term between this dummy and the monetary policy shock.

Threshold interest rate Figures 17 and 18 in the Appendix shows that our results are robust to changing the threshold interest rate from 4 percent to 3.5 and 4.5 percent.

Threshold inflation rate Our results are also robust to including an interaction term that allows the effect of monetary policy shocks to vary when inflation exceeds 3.2 percent. According to Pfäuti [2025], the latter is the threshold for quarterly inflation beyond which individuals become more attentive to inflation. We find that the effect of a monetary policy shock on core NIM, the logarithm of the real value of the S&P 500, and the logarithm of real per capita GDP in the low interest rate state and the high interest rate state is not statistically different (at the 95 percent confidence level) from our benchmark results.

Additional interaction terms Our results are also robust to including an interaction term that allows the effect of a monetary policy shock to vary when (i) quarter on quarter growth of real per capita GDP is higher then its sample average, (ii) the excess bond premium is higher than its sample average or (iii) the slope of the yield curve is higher than its sample average. Specifically we find that the effect of a monetary policy shock on core NIM, the logarithm of the real value of the S&P 500 and the logarithm of real per capita GDP in the low interest rate state and the high interest rate state is not statistically different (at the 95 percent confidence level) from our benchmark results.

6 Partial Equilibrium Model

In this section, we develop a simple competitive banking model that accounts for the key empirical facts about the response of the NIM to a monetary policy shock. The first subsection presents a version of the model that abstracts from social dynamics. This model has two central elements: (i) (i) heterogeneity in household attention to deposit interest rates, with some households being attentive and others inattentive; and (ii) bank valuation of deposits that reflects this heterogeneity. We adopt a matching framework in which competitive banks allocate resources to attract both attentive and inattentive depositors.

There is substantial evidence that social dynamics influence households' behavior in financial markets (see, for example, Iyer and Puri [2012], Bailey et al. [2018], and McCartney and Shah [2022]). Motivated by this evidence, the second subsection introduces social dynamics that govern the evolution of the shares of attentive and inattentive households over time. The third subsection integrates these dynamics into the full banking model. To keep the analysis as transparent as possible, we assume that inflation is zero. We subsequently relax this assumption in the general equilibrium model.

Our banking model has three key properties. First, NIM increases with the policy rate. The interest rate spread between the policy rate and deposit rates is larger for inattentive households than for attentive ones. The marginal effect of a policy rate increase on the interest rate spread is larger when the policy rate is low.

Our benchmark analysis employs a random search matching model in which there are no unmatched deposits in equilibrium. We show in the Appendix that these three properties also hold in a *competitive search* version of the model, where banks post interest rates and households direct their search to the most attractive combination of interest rates and matching probabilities.

We focus on the random search benchmark model in our main analysis for two reasons. First, unlike the competitive search model, the random search model does not generate unmatched deposits in equilibrium - a desirable property in a banking context. Second, the benchmark model yields closed-form solutions for interest rate spreads, which makes it easier to highlight and interpret the core mechanisms of the model.

6.1 A Simple Competitive Banking Model

To isolate the role of the key mechanisms in our model, we abstract from non-competitive behavior by banks. The key forces we emphasize—the impact of interest rates on social dynamics and the interaction between social dynamics and interest rates in shaping the present value of future profits—are also present in models with monopolistic competition and free entry.

6.1.1 Deposits

The economy has two types of households: those who are attentive and those who are inattentive to the interest rate on their bank deposits. The fraction of attentive and inattentive households in the population at time t is given by a_t and i_t, respectively, where $a_t + i_t = 1$. For simplicity, we assume that each household has one dollar of deposits.

There is a continuum of banks with measure one. Each period, a fraction $\delta \in (0, 1)$ of dollar deposits leave their bank due to exogenous factors. As a result, δa_t and δi_t dollars from attentive and inattentive households, respectively, become available for reallocation across banks at time t. Banks that lose deposits must reduce their lending accordingly, to ensure that assets equal liabilities.

Banks can distinguish between attentive and inattentive depositors and invest resources to attract both types of depositors. A representative bank spends $\tau_j v_j$ dollars to attempt to attract v_j dollars of type j deposits, $j = a, i$. It is natural to assume that inattentive depositors are less responsive to bank offers than attentive ones, and therefore more costly to attract: $\tau_i > \tau_a$.

Let m_{at} and m_{it} denote the total matches between banks and attentive and inattentive depositors, respectively. These matches are generated according to the following matching technologies:

$$m_{at} = \mu \left(\delta a_t\right)^{\varsigma} v_{at}^{1-\varsigma} \text{ and } m_{it} = \mu \left(\delta i_t\right)^{\varsigma} v_{it}^{1-\varsigma}$$

where $\mu > 0$ and $\varsigma \in (0, 1)$.

The probability that a bank attracts one dollar of type-j deposits, j =a, i, is $p_{at} = \mu (\delta a_t)^{\varsigma} v_{at}^{1-\varsigma}/v_{at}$ and $p_{it} = \mu (\delta i_t)^{\varsigma} v_{it}^{1-\varsigma}/v_{it}$, respectively.

In equilibrium, all deposits find a match,

$$\delta a_t = \mu (\delta a_t)^{\varsigma} v_{at}^{1-\varsigma} \quad \text{and} \quad \delta i_t = \mu (\delta i_t)^{\varsigma} v_{it}^{1-\varsigma}, \tag{2}$$

so there are no unmatched deposits.

This feature stands in contrast to standard matching models used in labor economics, such as the Diamond-Mortensen-Pissarides (DMP) framework, which feature equilibrium unemployment. It is useful to clarify why our matching framework does not produce an analogous pool of unmatched deposits. In the DMP model, unemployment arises for two main reasons. First, there is a timing friction: workers who lose their jobs must enter an unemployment pool before they can be matched with new employers. Second, wages are determined through Nash bargaining, which often prevents the labor market from clearing, as wages may not adjust fully to equate supply and demand.

These frictions are absent in our banking model. Deposits can be reallocated instantaneously across banks, and banks post deposit rates rather than negotiating them through bargaining. As a result, the market for deposits clears each period, and all deposits are matched in equilibrium.

Solving (2) for v_{at} and v_{it} we obtain,

$$v_{at} = \mu^{-1/(1-\varsigma)} \delta a_t \quad \text{and} \quad v_{it} = \mu^{-1/(1-\varsigma)} \delta i_t.$$

Since households face no opportunity cost of funds within the period, they are willing to accept any non-negative interest rate offered by banks. Let R_{at} and R_{it} denote the gross interest rates on deposits for attentive and inattentive households, respectively. These interest rates are typically non-negative, since deposits generate value for banks.

In equilibrium, the total cost incurred by banks to attract deposits is:

$$\delta \mu^{-1/(1-\varsigma)} (\tau_a a_t + \tau_i i_t).$$

6.1.2 Loans and the Value of Deposits

The monetary authority sets the policy rate, R_t, which also serves as the interbank borrowing and lending rate. We interpret R_t as the gross FFR. Banks use deposits to fund loans to firms that require working capital. The marginal cost of lending one dollar is constant and equal to ε^l. Under perfect competition, the equilibrium lending rate, R_t^l, is

$$R_t^l = R_t + \varepsilon^l. \tag{3}$$

The value to a bank of receiving one dollar in deposits from a household of type $j = a, i$ is

$$V_{j,t} = R_t - R_{jt} + \frac{1-\delta}{R_t} V_{j,t+1}. \tag{4}$$

Here, R_{jt} is the gross interest rate paid to type j depositors. The term $R_t - R_{jt}$ is the spread or profit per dollar of deposits from a type-j household at time t. The continuation value, $V_{j,t+1}$, is discounted at rate R_t and multiplied by $(1-\delta)$ to account for the fraction δ of deposits that leave the bank in the next period.

In equilibrium, the present value of bank profits, net of customer acquisition costs, is zero. So, the cost of attracting one dollar of deposits from either an attentive or inattentive household equals the probability of acquiring a deposit times its value to the bank,

$$\tau_a = \frac{\mu \left(\delta a_t\right)^{\varsigma} v_{at}^{1-\varsigma}}{v_{at}} V_{a,t} \text{ and } \tau_i = \frac{\mu \left(\delta i_t\right)^{\varsigma} v_{it}^{1-\varsigma}}{v_{it}} V_{i,t}.$$

In combination with (2), these conditions imply

$$\tau_a = \mu^{1/(1-\varsigma)} V_{a,t} \text{ and } \tau_i = \mu^{1/(1-\varsigma)} V_{i,t}. \tag{5}$$

To build intuition, consider the case of a constant policy rate, $R_t = R$. The value of one dollar of deposits from a type-j households is then given by

$$V_j = \frac{R}{R-1+\delta} \left(R - R_j\right).$$

Using the equilibrium conditions (5), we obtain the following expressions for interest rate spreads,

$$R - R_j = \frac{\tau_j}{\mu^{1/(1-\varsigma)}} \left(1 - \frac{1-\delta}{R}\right). \tag{6}$$

This expression shows that the spread, $R - R_j$, declines with μ. Intuitively, a higher value of μ makes it less costly for banks to attract depositors. Since equilibrium requires the present value of bank profits to equal customer acquisition costs, a decline in acquisition costs, due to higher μ, must be offset by a smaller spread.

Interest rate spreads have three key properties. First, they are an increasing function of R,

$$\frac{d\left(R - R_j\right)}{dR} = \frac{\tau_j}{\mu^{1/(1-\varsigma)}} (1-\delta) R^{-2} > 0. \tag{7}$$

The intuition for this result is as follows. Higher policy rates reduce the present value of profits, since future profits are more heavily discounted. Because equilibrium requires the present value of profits net of customer acquisition costs to be zero, the current spread must rise to offset the decline in the continuation value. We refer to this effect as the present-value effect.

Second, the response of the spread to a rise in the interest rate is decreasing in R, i.e., the second derivative of the spread with respect to R is negative,

$$\frac{d^2\left(R - R_j\right)}{dR^2} = -2\frac{\tau_j}{\mu^{1/(1-\varsigma)}}(1-\delta)R^{-3} < 0.$$

To see the intuition for this result, consider a perpetuity that pays y per period. The present value of this annuity is $y/(R-1)$. The change in this present value with respect to R rises is $-y\left(R-1\right)^{-2}$, which is lower when R is high.

Third, since $\tau_i > \tau_a$, equation 7 implies that the spread associated with inattentive depositors is more sensitive to changes in the policy rate than the spread for attentive depositors.

The NIM (nim_t) of the representative bank is given by,

$$nim_t = R_t + \varepsilon^l - \left(a_t R_{at} + i_t R_{it}\right),$$

where $R_t + \varepsilon^l$ is the gross income from lending and $a_t R_{at} + i_t R_{it}$ is the total interest paid on deposits. Rewriting this expression in terms of interest rate spreads, we obtain:

$$nim_t = \varepsilon^l + a_t\left(R_t - R_{at}\right) + i_t\left(R_t - R_{it}\right).$$

Substituting the steady-state expressions for deposit spreads from equation (6), yields,

$$nim = \varepsilon^l + \frac{\tau_i - a\left(\tau_i - \tau_a\right)}{\mu^{1/(1-\varsigma)}}\left(1 - \frac{1-\delta}{R}\right). \tag{8}$$

Equation (8) has two key properties. First, nim_t decreases with the share of attentive households since banks earn lower spreads from attentive customers. Second, nim_t increases with the policy rate, due to the present-value effect.

Bank profits, π_t^b are given by,

$$\pi_t^b = R_t - \left(a_t R_{at} + i_t R_{it}\right) - \delta\mu^{-1/(1-\varsigma)}\left(a_t\tau_a + i_t\tau_i\right).$$

Banks earn positive profits in each period as a return on past investments in deposit acquisition. However, under free entry, the present value of profits net of acquisition costs equals zero in equilibrium.

6.2 Social Dynamics

A conventional way to model inattention is to assume that the cost of paying attention varies across depositors. While this approach generates heterogeneity in attentiveness, it does not produce state dependence: a given basis point change in interest rates yields the same same marginal benefit regardless of whether the interest rate environment is low or high. As a result, depositor responses are invariant across rate environments, and the model fails to capture the state-dependent patterns observed in the data.

To generate state dependence, we introduce social dynamics that govern the evolution of the fraction of attentive and inattentive depositors over time. We model changes in attentiveness as the outcome of random social interactions between attentive and inattentive households. Inattentive households can become attentive after interacting with attentive ones. Crucially, the rate of these transitions increases with the policy rate: higher interest rates make conversations about deposit rates more likely, increasing the probability that inattentive households become attentive.

The laws of motion for the fractions of inattentive and attentive households are given by:

$$i_{t+1} = i_t(1-\kappa_i) - \omega(R_t)a_t i_t(1-\kappa_i) + \kappa_a a_t, \tag{9}$$

and

$$a_{t+1} = a_t(1-\kappa_a) + \omega(R_t)a_t i_t(1-\kappa_i) + \kappa_i i_t. \tag{10}$$

where $\omega(R_t)$ is an increasing function of the policy rate, capturing the idea that attentive depositors are more likely to discuss interest rates when these rates are high. Making $\omega(R_t)$ a function of the exogenous interest rate, R_t, greatly simplifies the analysis, and avoids a fixed-point problem in which social dynamics depend on equilibrium deposit rates, which themselves depend on social dynamics. Moreover, making ω a function of R_t is empirically plausible because the policy rate is a salient, widely reported interest rate in the media.

We distinguish between two types of transitions between attention states. Exogenous transitions, which are independent of the policy rate, occur at the end of the period: a fraction κ_a of attentive households become inattentive and a fraction κ_i of inattentive households become become attentive. Endogenous transitions, which are driven by social interactions and depend on the policy rate, occur at the beginning of the period. There are $a_t i_t$ pairwise meetings between attentive and inattentive households. A fraction $\omega(R_t)$ of these meetings result in inattentive households becoming attentive. We assume that $\omega(R_t)$, is an increasing function of the annualized quarterly net interest rate, given by:

$$\omega(R_t) = \chi\left(4R_t - 4\right)^2, \text{where} \quad \chi > 0.$$

Here $(4R_t - 4)$ represents the annualized net interest rate in percentage points.

The number of inattentive households that become attentive in period t is:

$$\omega(R_t)a_t i_t + \left[i_t - \omega(R_t)a_t i_t\right]\kappa_i = \omega(R_t)a_t i_t(1-\kappa_i) + i_t\kappa_i.$$

Therefore, the probability that an inattentive household becomes attentive in period t is $\omega(R_t)a_t(1-\kappa_i)+\kappa_i$.

The change in the number of attentive depositors, $a_{t+1}-a_t$, varies with the current level of attentive depositors, a_t. The derivative is

$$\frac{d\left(a_{t+1}-a_t\right)}{da_t}=\omega(R_t)(1-2a_t)(1-\kappa_i)-\left(\kappa_i+\kappa_a\right).$$

The first term reflects the role of social interactions. It is positive when $R_t>1$ is high and $a_t<0.5$. Under these conditions, there is a large pool of inattentive households who can become attentive. The second term is negative for two reasons. First, when a_t is higher, more attentive households become inattentive. Second, when a_t is higher, fewer inattentive households become attentive via exogenous conversion.

The strength of the social interactions related to R_t is maximized when $a_t=0.5$. When a_t is low, social interactions are not very powerful because there are few attentive individuals to initiate conversations. When a_t is high, social interactions are also limited because there are few inattentive households left to be influenced.

Steady State Suppose the policy rate is constant and equal to zero ($R=1$). In this setting, attentive households do not discuss interest rates in their social interactions ($\omega(1)=0$), and the steady state proportion of attentive households depends only on the exogenous rates at which households switch attention states,

$$a=\frac{1}{1+\kappa_a/\kappa_i}.$$

Suppose instead that the net policy rate is constant and strictly positive ($R>1$). Then the steady state level of a satisfies the quadratic equation

$$0=-a\kappa_a+\omega(R)a\left(1-a\right)\left(1-\kappa_i\right)+\kappa_i\left(1-a\right).$$

The positive root of this equation is

$$a=\frac{\omega(R)(1-\kappa_i)-\kappa_a-\kappa_i+\sqrt{\left[\omega(R)(1-\kappa_i)-\kappa_a-\kappa_i\right]^2+4\omega(R)(1-\kappa_i)\kappa_i}}{2\omega(R)(1-\kappa_i)}.$$

A key implication of the functional form for $\omega(R_t)$ is that the share of attentive households is lower when interest rates have been persistently low, and higher when rates have been persistently high. This property introduces a natural form of state dependence into the model.

6.3 Banking with Social Dynamics

In an economy with social dynamics, the time t value to a bank of holding one dollar of deposits from an attentive household is,

$$V_{a,t} = R_t - R_{at} + \frac{1-\delta}{R_t}\left[\kappa_a V_{i,t+1} + (1-\kappa_a) V_{a,t+1}\right].$$

$V_{a,t}$ reflects the fact that a fraction δ of deposits leaves the bank and the probability, κ_a, that an attentive household becomes inattentive in the next period.

The time t value to a bank of a dollar deposit from an inattentive household is given by

$$V_{i,t} = R_t - R_{it} + \frac{1-\delta}{R_t}\left(\left[\omega(R_t)a_t(1-\kappa_i)+\kappa_i\right]V_{a,t+1} + \left\{1-\left[\omega(R_t)a_t(1-\kappa_i)+\kappa_i\right]\right\}V_{i,t+1}\right).$$

$V_{i,t}$ reflects the fact that a fraction δ of deposits leaves the bank and the probability that inattentive households become attentive either through endogenous social interactions, at rate $\omega(R_t)a_t(1-\kappa_i))$, or through exogenous switching, at rate κ_i.

Recall that in equilibrium, equation (5) holds: the cost of acquiring a deposit of type j equals to the probability of succeeding times the value of this deposit to the bank,

$$\tau_j = \mu^{1/(1-\varsigma)} V_{j,t}.$$

Using this result we obtain

$$\frac{\tau_a}{\mu^{1/(1-\varsigma)}} = R_t - R_{at} + \frac{1-\delta}{R_t}\left[\kappa_a \frac{\tau_i}{\mu^{1/(1-\varsigma)}} + (1-\kappa_a)\frac{\tau_a}{\mu^{1/(1-\varsigma)}}\right],$$

and

$$\frac{\tau_i}{\mu^{1/(1-\varsigma)}} = R_t - R_{it} + \frac{1-\delta}{R_t}\left(\left\{\left[\omega(R_t)a_t(1-\kappa_i)+\kappa_i\right]\frac{\tau_a}{\mu^{1/(1-\varsigma)}} + \left\{1-\left[\omega(R_t)a_t(1-\kappa_i)+\kappa_i\right]\right\}\frac{\tau_i}{\mu^{1/(1-\varsigma)}}\right\}\right).$$

The interest rate spread for attentive depositors is:

$$R_t - R_{at} = \frac{\tau_a}{\mu^{1/(1-\varsigma)}} - \frac{1-\delta}{R_t}\left(\kappa_a \frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}} + \frac{\tau_a}{\mu^{1/(1-\varsigma)}}\right).$$

This spread is smaller than in a version of the model without social dynamics (see equation (6)). The reason is that attentive depositors are more valuable to the bank: with probability κ_a, they become inattentive in the future. In equilibrium, the current spread must fall to offset this increased future value.

The interest rate spread for inattentive depositors is:

$$R_t - R_{it} = \frac{\tau_i}{\mu^{1/(1-\varsigma)}} - \frac{1-\delta}{R_t}\left\{\frac{\tau_i}{\mu^{1/(1-\varsigma)}} - \left[\omega(R_t)a_t(1-\kappa_i)+\kappa_i\right]\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\right\}.$$

This spread is larger than in a model without social dynamics (see equation (6)). The reason is that, in the current model, with probability $\omega(R_t)a_t(1-\kappa_i)+\kappa_i$, inattentive depositors become attentive, and hence less profitable, in the future. So, current spreads must be higher to compensate for this fact. The effect is stronger when the number of attentive households is high because inattentive households are more likely to encounter attentive households and become attentive. The effect is also stronger when interest rates are higher because the conversion rate, $\omega(R_t)$, is higher.

We use the results above to study the impact of social dynamics on nim_t. Recall that nim_t is given by,

$$nim_t = R_t + \varepsilon^l - \left(a_t R_{at} + i_t R_{it}\right).$$

Replacing R_{at} and R_{it} and rewriting we obtain,

$$nim_t = \varepsilon^l + \frac{a_t\tau_a + (1-a_t)\tau_i}{\mu^{1/(1-\varsigma)}}\left(1 - \frac{1-\delta}{R_t}\right) + \frac{1-\delta}{R_t}\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\left(a_{t+1} - a_t\right). \tag{11}$$

The first two terms in this expression correspond to the value of nim_t in an economy without social interactions. We discuss the intuition for those terms after equation (8). The third term captures the impact of social interactions on nim_t. An increase in the number of attentive depositors, $a_{t+1} - a_t$, increases nim_t because the equilibrium spread on inattentive depositors rises to compensate for the higher probability that inattentive depositors will become attentive.

The impact of a change in a_t on nim_t is given by

$$\frac{dnim_t}{da_t} = -\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\left(1 - \frac{1-\delta}{R_t}\right) + \frac{1-\delta}{R_t}\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\left[\omega(R_t)(1-2a_t)(1-\kappa_i) - (\kappa_i + \kappa_a)\right].$$

A change in a_t has two effects. The first effect is negative: an increase in a_t lowers the average interest rate spread because deposit spreads are lower for attentive than for inattentive households. The second effect is positive when $a_t < 0.5$ and R_t is high. In this case, a substantial number of inattentive households will become attentive in the near future. These conversions reduce the future profitability of inattentive deposits. In equilibrium, current spreads rise to offset this effect, increasing nim_t.

The marginal impact of R_t on nim_t is given by

$$\frac{dnim_t}{dR_t} = \frac{a_t\tau_a + (1-a_t)\tau_i}{\mu^{1/(1-\varsigma)}}(1-\delta)R_t^{-2} - R_t^{-2}(1-\delta)\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\left(a_{t+1} - a_t\right) + \frac{1-\delta}{R_t}\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\frac{da_{t+1}}{dR_t}, \tag{12}$$

where

$$\frac{da_{t+1}}{dR_t} = \omega'(R_t)a_t(1-a_t)(1-\kappa_i) = 32\chi(R_t - 1)a_t(1-a_t)(1-\kappa_i).$$

There are three effects to consider. The first is the present value effect of a rise in R_t that we discussed in the model without social dynamics. This effect is positive. An increase in R_t induces a rise in current spreads and NIM. The second effect is negative. When R_t rise, banks discount more heavily the future losses that occur when some inattentive depositors become attentive. So $R_t - R_{it}$ decreases inducing a fall in NIM. The third effect is positive. Since $\omega(R_t)$ is increasing in R_t, higher interest rates raise the rate at which inattentive households become attentive due to social interactions. This effect reduces future profits from inattentive households, so $R_t - R_{it}$ and NIM must rise.

Model estimation We partition the model parameters into two sets. The first set, listed in Table 1, consists of parameters chosen ex ante. The second set is estimated using the Bayesian impulse-response matching procedure discussed in Christiano et al. [2010]. See the Appendix for details.

Table 1: Parameter values set *a priori*

Parameter	Parameter value	Description
ϵ_l	0.008	Cost per dollar of making loans
R_L	1.014	Gross annual interest rate, low interest rate state
R_H	1.056	Gross annual interest rate, high interest rate state

We set $\epsilon_l = 0.008$ so that the model is consistent with the average annual core NIM over our sample period - about four percent. We set $R_L = 1.014$ in the low-interest-rate steady state and $R_H = 1.056$ in the high-interest-rate steady state. These values correspond to the average values of the FFR below and above the four percent threshold, respectively. We assume that social dynamics take place multiple times per day, totaling 200 interactions per quarter. Economic decisions are made at the end of each quarter.

We estimate the following parameters: χ,κ_a,κ_i,δ,$\tau_a/\mu^{\frac{1}{1-\varsigma}}$,$\tau_i/\mu^{\frac{1}{1-\varsigma}}$. In the equilibrium equations, the parameters τ_a, τ_i, μ, and ς only appear as the ratios $\tau_a/\mu^{\frac{1}{1-\varsigma}}$, $\tau_i/\mu^{\frac{1}{1-\varsigma}}$, which is why we estimate those ratios rather than the individual parameters.

We assume the economy begins in either the low- or high-nominal-interest-rate state. Conditional on the initial regime, we feed in a sequence for the nominal interest rate, R_t, corresponding to the first 12 elements of the Cholesky-based impulse response functions of the policy rate from Section 4 (see Figure 1).

The vector ψ denotes the point estimates of the impulse responses of nim_t in the high- and low-interest-rate state discussed in Section 4. Our estimation procedure targets the first 12 quarters of the empirical impulse responses of nim_t. We denote our empirical estimates of ψ by the 24x1 vector $\hat{\psi}$.

We impose uniform priors $U(0,100)$ for $\tau_a/\mu^{\frac{1}{1-\varsigma}}$ and $\tau_i/\mu^{\frac{1}{1-\varsigma}}$ and $U(0,1)$ priors for κ_a,κ_i and δ. We assume a gamma prior for χ with shape parameters (2,1).[9]

Table 2: Priors and Posteriors of Parameters.

Parameter	Prior Distribution	Posterior Distribution
	D, Mean, [2.5-97.5%]	Mode, [2.5-97.5%]
Social dynamics interaction parameter, χ	G, 2.0, [0.051 7.37]	1.3826, [0.9470 5.47]
Rate at which attentive become inattentive, κ_a	U, 0.5, [0.025 0.975]	0.0023, [0.001 0.013]
Rate at which inattentive become attentive, κ_i	U, 0.5, [0.025 0.975]	0.0006, [0.000 0.015]
Fraction of depositors who leave banks, δ	U, 0.5, [0.025 0.975]	0.0132, [0.008 0.025]
Cost of attracting attentive depositors, $\tau_a/\mu^{\frac{1}{1-\varsigma}}$	U, 50 , [2.5 97.5]	0.0213, [0.015 0.062]
Cost of attracting inattentive depositors, $\tau_i/\mu^{\frac{1}{1-\varsigma}}$	U, 50 , [2.5 97.5]	0.1611, [0.076 0.184]

Notes: The posterior mode and parameter distributions are based on a standard MCMC algorithm with 10.5 million draws (3 chains, about 15 percent of draws used for burn-in, draw acceptance rates about 0.22). U denotes the prior for the uniform distribution for which the mean is reported instead of the mode. G denotes the Gamma (2,1) distribution.

Our estimated parameters imply that deposits are highly sticky: only 1.3 percent of deposits leave a bank per period. As emphasized by Drechsler, Savov, and Schnabl [2017, 2018, 2021] and others, the stickiness of deposits is a key determinant of banks' franchise value.

To illustrate the properties of the estimated model, we compute the equilibrium response of nim_t to a temporary increase in the policy rate with parameter values set to their posterior modes. The economy starts from the steady state associated with either the low- or high-interest-rate regime.

Figures 4 and 5 depict the responses of key aggregates to a rise in R, starting from the low- and high-interest-rate steady states, respectively, and evaluating the model at the posterior mode of the estimated parameters. The model does a good job of accounting for the empirical responses. Indeed, once sampling uncertainty is taken into account, we cannot reject the null hypothesis that the model-implied and empirical responses are identical.

[9] We initially experimented with a uniform prior for χ but encountered numerical instabilities. Adopting a gamma prior resolves this issue by assigning low probability to extreme values while retaining sufficient flexibility to reflect diffuse prior beliefs.

Figure 4: Dynamic response to monetary policy shock in low-interest-rate state.

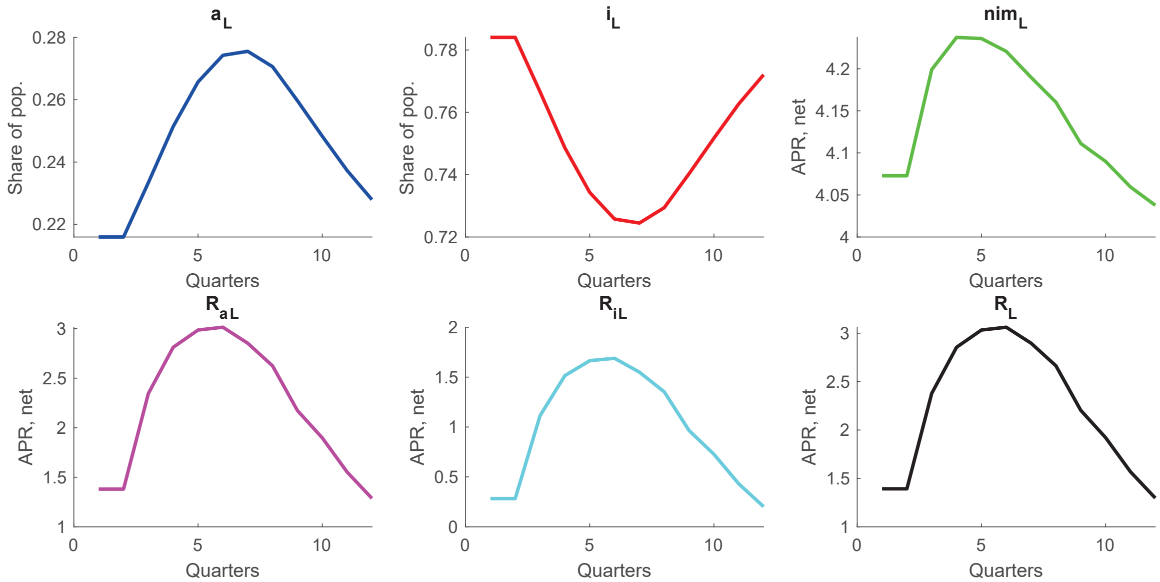
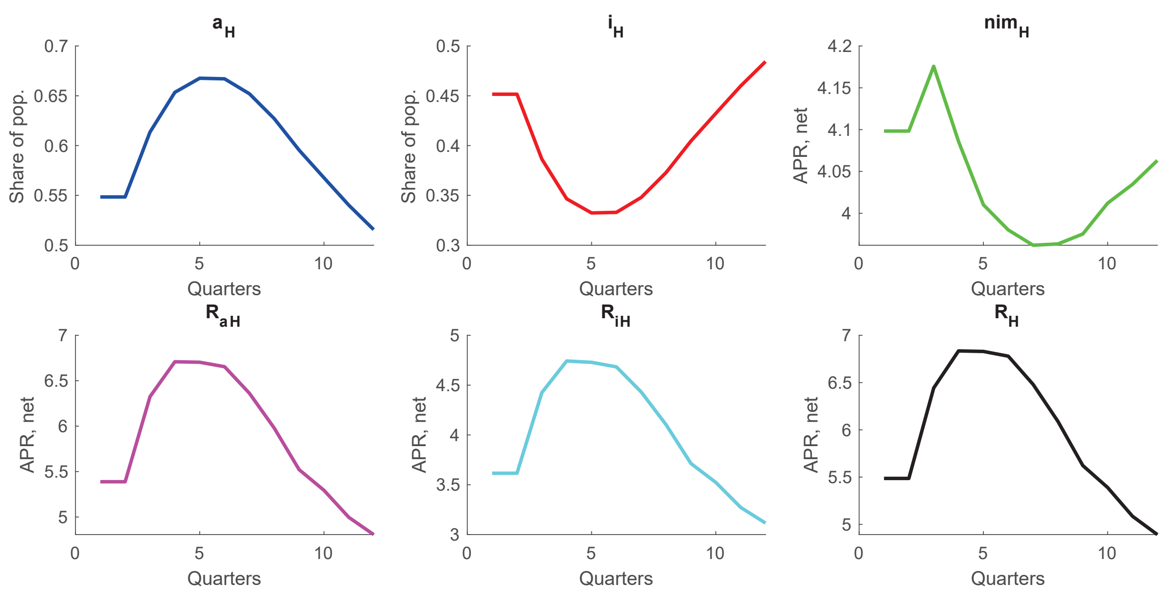


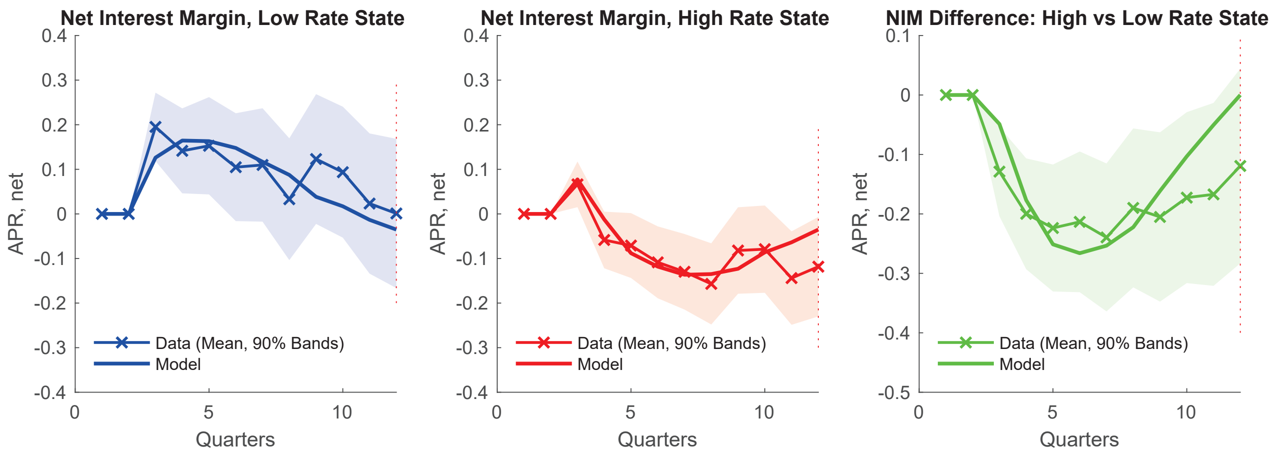
Figure 5: Dynamic response to monetary policy shock in high-interest-rate state.



Our estimated parameter values imply that nim_t rises when a contractionary shock occurs in the low-interest-rate steady state ($R = 1.014$). We infer that the first and third effects dominate the second (see the discussion after equation 12). The second effect is weak because the share of attentive depositors in this regime is low (approximately 20 percent), leading to few interactions between attentive and inattentive agents and consequently, a limited influence from social dynamics.

In contrast, in the steady state with a high interest rate ($R = 1.056$), the fraction of attentive depositors is substantially higher (about 55 percent). This fraction is consistent with survey evidence from high-rate periods showing that roughly half of consumers are unaware of the interest rate on their savings accounts (see Financial Conduct Authority [2023] and Blatt [2025]).

Figure 6: Dynamic response to monetary policy shock: NIM



Note: This figure compares the theoretical impulse response functions from the estimated partial equilibrium banking model with their empirical counterparts discussed in Section 3. Solid lines represent the model-generated IRFs, while solid lines with "x" markers indicate the corresponding empirical IRFs. The shaded areas denote the 90 percent confidence intervals for the empirical IRFs.

Figure 6 shows the responses of nim_t in the high- and low-interest-rate states, as well as the differences between those responses, when the model is evaluated at the estimated posterior mode parameters. The figure compares these model-based responses with their empirical counterparts, obtained using the recursive monetary policy shock measure. The key finding is that the model closely matches the empirical responses. In fact, once sampling uncertainty is taken into account, the null hypothesis that the response functions are identical cannot be rejected.

Panel A of Figure 7 shows the responses of nim_t in the high- and low-interest-rate states as well as the differences between these responses when the model is evaluated at the posterior mode of the estimated parameters, except for χ, which we set to zero. This counterfactual simulation isolates the contribution of endogenous social dynamics to the response of nim_t to a monetary policy shock. Without endogenous social dynamics, the model fails to replicate the empirical responses - particularly the decline in nim_t after a monetary policy shock in the high-interest-rate state.

Panel B of Figure 7 shows the responses of nim_t for a version of the model where $\chi = 0$ is imposed and all other parameters are re-estimated.[10] The new parameter estimates dampen the

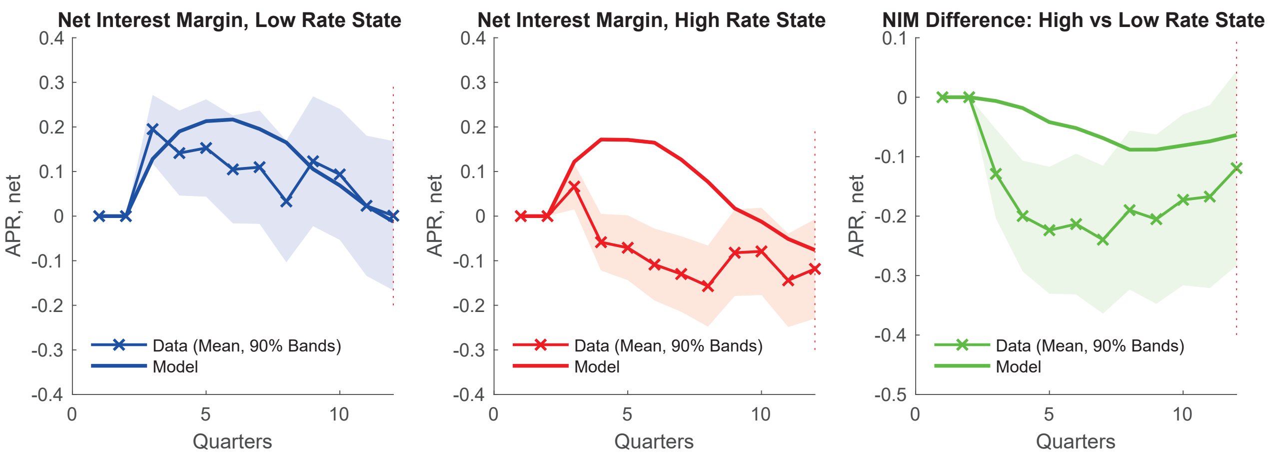
[10] The posterior mode of the estimated parameters is $\kappa_a = 0.00595$, $\kappa_i = 0.06071$, $\delta = 0.08782$, $\tau_a/\mu^{\frac{1}{1-\varsigma}} = 0.02294$,

response of nim_t. Even when re-estimated, the model is unable to account for the dynamics or the state dependence observed in the data: the response of nim_t is nearly identical across the high- and low-interest-rate regimes.

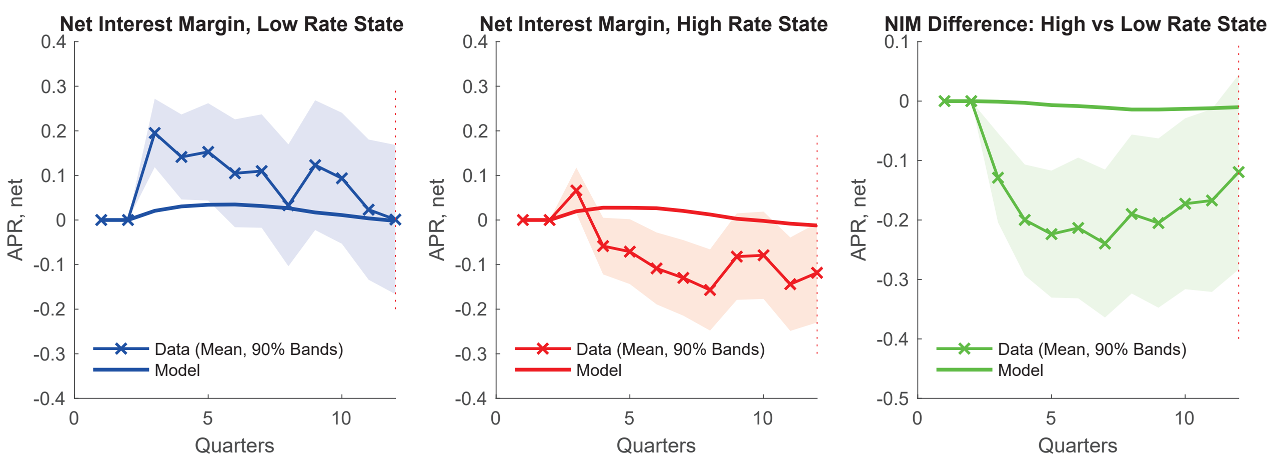
Overall, the results in Figure 7 highlight the critical importance of endogenous social dynamics in explaining the response of nim_t to monetary policy shocks.

Figure 7: NIM response to monetary policy shock *without* endogenous social dynamics.

Panel A: $\chi = 0$, remaining parameters set equal to their baseline values.



Panel B: $\chi = 0$, remaining parameters re-estimated.



Note: This figure compares the theoretical impulse response functions generated from the estimated partial equilibrium banking model without endogenous social interactions to their empirical counterparts discussed in Section 3. Solid lines represent the model IRFs, while solid lines with "x" markers indicate the corresponding empirical IRFs. Shaded areas denote the 90 percent confidence intervals for the empirical IRFs.

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and $\tau_i/\mu^{\frac{1}{1-\varsigma}} = 0.02492$.

7 Connecting Financial Variable and Economic Activity Results

It is useful to quantify how the impact of a monetary policy shock on NIM differs across high and low-interest-rate states. Starting in the low-interest-rate state, the cumulative effect of a monetary policy shock over three years is an increase in NIM-related bank profits–defined as the change in NIM multiplied by commercial banks' total bank assets–of approximately 95 billion dollars. In contrast, when the shock occurs in the high-interest-rate state, NIM-related profits *decline* by 64 billion dollars. So, banks' counterparties save 150 billion dollars in net interest payments when the shock occurs in the high interest rate state rather than the low interest rate state.

A growing body of empirical evidence suggests that the MPC out of liquid wealth is high, typically ranging from 0.20 to 0.60 (see, for example, Carroll et al. [2017] and Ganong et al. [2023]. Assuming an MPC out of liquid wealth of 0.40, these state-dependent effects on wealth translate into a differential swing in aggregate demand of approximately $60 billion.

Twelve quarters after a 100 basis point contractionary monetary policy shock in the low-interest-rate state, the S&P 500 falls by approximately 10 percent. This result is consistent with Bauer and Swanson [2023] and Jarociński and Karadi [2020]. At the end of 2019, the market capitalization of the S&P 500 was approximately $28 trillion. A 10 percent decline following a 100 basis point contractionary monetary policy shock in the low-interest-rate state corresponds to a $2.8 trillion reduction in household wealth. In contrast, the same shock in the high-interest-rate state leads to a more modest 4 percent decline, or roughly $1.2 trillion in lost wealth. Based on estimates by Di Maggio et al. [2020] and Chodorow-Reich et al. [2021], the MPC out of stock market wealth is approximately 3 percent. Applying this estimate yields a differential impact on aggregate demand of roughly $48 billion.

The previous calculations imply a total differential swing in aggregate demand of approximately $120 billion between a contractionary monetary policy shock occurring in the low- versus high-interest-rate state. To put this number in perspective, the corresponding cumulative difference in the decline of GDP over a 12-quarter horizon is roughly $130 billion. Suppose that bank profits accrue disproportionally to people with a much lower MPC out of liquid wealth than those who receive interest income from banks. Then, other things equal, the contraction in aggregate demand would be larger when the policy shock occurs in a low-rate environment. This effect lies at the core of why a state-dependent response of NIM to a monetary policy shock translates into a state-dependent response of aggregate economic activity.

7.1 Banking in a General Equilibrium Model

To explore the quantitative importance of the effect discussed above, we embed the partial-equilibrium banking model into a medium-scale dynamic general equilibrium framework. The latter model incorporates two key components: (i) state-dependent passthrough of policy rate changes to deposit rates, and (ii) the presence of households with a high marginal propensity to consume (MPC) out of liquid wealth.

In practice, many types of households have a high MPC out of liquid wealth. For example, retirees often rely heavily on income from bonds.[11] Other examples include wealthy hand-to-mouth consumers as emphasized by Kaplan et al. [2018] and low-income households facing tight borrowing constraints (see, for example, Bilbiie [2021], and Auclert et al. [forthcoming] among others).

Incorporating all sources of heterogeneity highlighted in the literature is beyond the scope of this paper. Instead, we focus on a parsimonious model designed to capture the interaction between the state-dependent passthrough of bank deposit rates and the presence of high-MPC households. We assume that borrowing constraints are not binding for one group of households, referred to as permanent income (PI) consumers. A second group consists of hand-to-mouth (HTM) consumers. For tractability, we assume that PI households are always attentive, while HTM households transition between attentive and inattentive states according to the social dynamics specified in the partial-equilibrium model.

Importantly, under our timing conventions, households earn interest on their wage income within the period, enabling them to increase consumption when deposit rates rise. This mechanism is particularly relevant for HTM households. The assumption that HTM households receive intra-period interest income serves as a reduced-form representation of the empirical observation that many households exhibit high MPCs out of liquid wealth.

Firms finance wage and capital rental payments by borrowing from banks at the beginning of the period. Households supply labor and deposit wage income in banks at the start of the period. Capital owners also deposit rental income at the beginning of the period. In other respects, the model is a streamlined version of the framework developed by Christiano, Eichenbaum, and Evans [2005].

7.2 Model Description

We now describe the maximization problems for firms and households.

[11] According to the 2022 U.S. Consumer Expenditure Survey, individuals aged 65 and older account for approximately 21 percent of total U.S. consumption.

Final good producers A representative, perfectly competitive firm produces a final homogeneous good, Y_t, using the the following CES aggregation technology:

$$Y_t = \left(\int_0^1 Y_{it}^{\frac{1}{\gamma}} di \right)^{\gamma}, \gamma > 1. \tag{13}$$

The variable Y_{it} denotes the quantity of intermediate input i used by the final goods producer.

Profit maximization implies the following demand schedule for intermediate products:

$$Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\frac{\gamma}{\gamma-1}} Y_t. \tag{14}$$

Here, P_{it} denotes the price of intermediate input i in units of the final good.

The price of output is given by:

$$P_t = \left(\int_0^1 P_{it}^{-\frac{1}{\gamma-1}} dj \right)^{-(\gamma-1)}.$$

The production of the final good, Y_t, can be used for either consumption or investment.

Intermediate goods producers Intermediate good i is produced by a monopolist using labor, N_{it}, and capital services, K_{it}, according to a Cobb-Douglas production function:

$$Y_{it} = (K_{it})^{\alpha} N_{it}^{1-\alpha}. \tag{15}$$

The intermediate goods firm is a monopolist in the product market and takes factor prices as given in competitive input markets. To produce in period t, the firm borrows the nominal wage bill, $W_t N_{it}$, and the nominal capital service bill, $R_t^k K_{it}$, from banks at the beginning of the period. These loans are extended at the gross interest rate R_t^l and are repaid at the end of period using sales revenues.

The firm's real marginal cost is $s_{it} = \partial S_{it} / \partial Y_{it}$ where $S_{it} = \min_{K_{it}, N_{it}} R_t^l [r_t^k K_{it} + w_t N_{it}]$ and Y_{it} is given by (15). Solving the cost minimization problem yields:

$$s_{it} = \frac{R_t^l \left(r_t^k \right)^{\alpha} w_t^{1-\alpha}}{\alpha^{\alpha} (1-\alpha)^{1-\alpha}}.$$

The profits of intermediate-good producer i at time t are:

$$\pi_{it} = P_{it} Y_{it} - P_t s_{it} Y_{it}.$$

In each period, a fraction $1 - \xi$ of firms can re-optimize their price, choosing $\widetilde{P}_t$, and the remaining fraction, ξ, adjusts their price according to the steady state rate of inflation, Π. The law of motion for $P_{it}$is given by,

$$P_{it} = \begin{cases} \Pi P_{i,t-1} & \text{with probability 1-}\xi, \\ \widetilde{P}_t & \text{with probability } \xi. \end{cases} \tag{16}$$

This notation reflects the standard result that in sticky price models like ours, all firms that can re-optimize at time t choose the same price, $\widetilde{P}_t$. We assume that this pricing decision is made prior to the realization of the period-t monetary policy shock.

All intermediate good firms are owned by the representative permanent income household. We denote the time $t+k$ value of a dollar of dividend to these households by v_{t+k}. The firm chooses its optimal time-t price, $\tilde{P}_t$, to maximize:

$$\max_{\tilde{P}_t} E_t \sum_{k=0}^{\infty} (\xi\beta)^k \lambda_{t+k}^P \left(\tilde{P}_t Y_{i,t+k} - P_{t+k} s_{i,t+k} Y_{i,t+k} \right),$$

subject to the demand curve (14). Here, λ_{t+k}^P is the Lagrange multiplier associated with the nominal budget constraint in the PI household's problem. See the Appendix for the first-order conditions associated with this optimization problem.

Wage determination Christiano et al. [2016] show that estimated versions of three models of wage determination produce nearly identical implications for macroeconomic aggregates: the search and matching matching model of labor in Hall and Milgrom [2008], the Calvo-style sticky wage model of Erceg et al. [2000], and a reduced-form specification of real wages dynamics incorporating inertia. Following Christiano et al. [2016], we adopt the following simple real wage rule:

$$ln\left(\frac{w_t}{w}\right) = \vartheta_1 ln\left(\frac{w_{t-1}}{w}\right) + \vartheta_2 ln\left(\frac{N_t}{N}\right).$$

The nominal wage is given by

$$W_t = w_t P_t.$$

Employment is demand-determined. Each household type supplies labor in proportion to its steady-state share in order to satisfy aggregate labor demand,

$$N_{j,t}^H = \frac{N_j^H}{N} N_t \text{ for } j \in \{a, i\}.$$

These steady-state shares, N_j^H/N, are computed using a version of the model with flexible wages and prices. Aggregate labor demand equals aggregate labor supply:

$$N_t = \phi N_t^P + a_t^H N_{a,t}^H + i_t^H N_{i,t}^H.$$

The labor allocation rules for attentive and inattentive hand-to-mouth households, combined with the expression for aggregate labor, yield an implicit rule for the labor supply of PI households.

Households The population consists of two types of households, each comprising a continuum of identical members. A fraction $1-\phi$ are hand-to-mouth (HTM) households. The remaining fraction, ϕ, consists of permanent income (PI) households. The superscript H denotes variables specific to HTM households.

Hand-to-mouth households

Households of type j maximize expected lifetime utility:

$$E_t \sum_{l=0}^{\infty} \beta^t \left\{ \ln(C^H_{j,t+l} - bC^H_{j,t+l-1}) - \psi \frac{(N^H_{j,t+l})^{1+\eta}}{1+\eta} \right\},$$

subject to the budget constraint

$$P_t C^H_{jt} = \left(W_t N^H_{jt} - D^H_{jt}\right) + D^H_{jt} R_{jt},$$

where D^H_{jt} denotes deposits of HTM households of type j. These deposits cannot exceed the funds that households receive at the beginning of the period

$$D^H_{jt} \leq W_t N^H_{jt}. \tag{17}$$

Since wages are deposited at the start of the period and consumption occurs at the end, the opportunity cost of deposits is zero. Given that $R_{jt} \geq 1$, constraint (17) binds, implying:

$$P_t C^H_{jt} = R_{jt} W_t N^H_{jt}.$$

As discussed below, nominal wages are initially at their steady state values and adjust only gradually in response to monetary policy shocks. Since employment is demand-determined and the budget constraint is binding, the preferences of HTM households are irrelevant for equilibrium. That is, HTM households consume all of their income and make no intertemporal consumption choices.

HTM households play an important role in the model because they amplify the response of consumption and aggregate demand to changes in interest rates. In contrast, PI households, discussed below, exhibit much more muted responses to changes in interest income.

Permanent income households

The representative PI households own all firms and the entire stock of physical capital. Each period, the household chooses consumption, physical capital accumulation, the supply of capital services, and bank deposits. For simplicity, we assume all PI households are attentive. Our results are not sensitive to this assumption since PI households respond only modestly to transitory changes to transitory interest rate fluctuations..

PI households maximize their lifetime utility:

$$U_t = E_t \sum_{l=0}^{\infty} \beta^t \left\{ \ln(C_{t+l}^P - bC_{t+l-1}^P) - \psi \frac{(N_{t+l}^P)^{1+\eta}}{1+\eta} \right\}, \tag{18}$$

subject to the budget constraint:

$$P_t \left(C_t^P + I_t \right) + B_{t+1} - R_{t-1} B_t + \Psi_t = \left(W_t N_t^P + R_t^K u_t \bar{K}_t - D_t^P \right) + D_t^P R_{a,t} + \int_0^1 \pi_{jt} dj + \pi_t^b. \tag{19}$$

Here, variable $\bar{K}_t$ denotes the beginning-of-period physical capital stock, Ψ_t are nominal lump-sum taxes, $\int_0^1 \pi_{jt} dj$ are the nominal profits from monopolistically competitive firms, and π_t^b denotes total banking profits. The variable I_t denotes household capital investment. The variable u_t denotes the utilization rate of capital, which is set by the household. Capital services, K_t, depends on the physical stock of capital and the rate of capital utilization according to $K_t = u_t \bar{K}_t$ so that $R_t^K u_t \bar{K}_t$ represents the household's income from from supplying capital services. D_t^P are bank deposits that PI households make at the beginning of the period. These deposits cannot exceed the funds that the household receives at the beginning of the period,

$$D_t^P \leq W_t N_t^P + R_t^K u_t \bar{K}_t. \tag{20}$$

As is the case for HTM households, PI households consume at the end of the period. So, the opportunity cost of holding bank deposits is zero. PI households maximize the value of D_t^P, so equation 20 binds. We can write the resulting budget constraint as

$$P_t \left(C_t^P + I_t \right) + B_{t+1} - R_{t-1} B_t + \Psi_t = R_{at} \left(W_t N_t^P + R_t^K u_t \bar{K}_t \right) + \int_0^1 \pi_{jt} dj + \pi_t^b.$$

The timing of asset investments is as follows. At the beginning of the period, households receive wage payments and capital rental income from firms. These funds are deposited into bank accounts and earn an intra-period interest rate R_{at}. At the end of the period, households use the proceeds from these deposits to finance consumption, capital investment, and bond purchases. Bonds pay interest rate R_t.

The depreciation rate of capital depends on its utilization rate, u_t, according to:

$$\Delta(u_t) = \sigma_0 + \sigma_1(u_t - 1) + \frac{\sigma_2}{2}(u_t - 1)^2.$$

We choose values for the parameters σ_1 and σ_2 so that $u_t = 1$ in the steady state.

The law of motion for the stock of physical capital owned by the PI households is:

$$\bar{K}_{t+1} = \left[1 - \Delta(u_t) \right] \bar{K}_t + F(I_t, I_{t-1}), \tag{21}$$

where $F(.)$ is a function that summarizes the technology for transforming current and past investments into installed capital for use in the following period. As in Christiano et al. [2005], this function is given by[12]

$$F(I_t, I_{t-1}) = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t,$$

where

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{s_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2.$$

Timing It is useful to specify the timing of transactions. At the beginning of each period, firms borrow from banks to cover their wage bill and capital rental costs. Banks issue checks to the firms, which are used to pay households. Households then deposit these funds into bank accounts. By the end of the period, firms repay banks, including interest at rate $R^l - 1$. Banks in turn pay households their deposits plus interest, calculated at rates $R_{at} - 1$ and $R_{it} - 1$ for attentive and inattentive depositors, respectively.

Social dynamics To simplify, we assume that PI households are always attentive.[13] Only HTM households change between attentive and inattentive states. The total number of attentive households, a_t, is given by,

$$a_t = a_t^H + \phi,$$

where a_t^h is the number of attentive HTM households. There are i_t^h inattentive households, all of whom are hand-to-mouth, so that

$$a_t^H + i_t^H + \phi = 1.$$

The equations that describe the social dynamics are as follows,

$$a_{t+1} = \phi + a_t^H(1 - \kappa_a) + \omega(R_t)(\phi + a_t^H)i_t^H(1 - \kappa_i) + \kappa_i i_t^H, \tag{22}$$

$$a_{t+1}^H = a_t^H(1 - \kappa_a) + \omega(R_t)(\phi + a_t^H)i_t^H(1 - \kappa_i) + \kappa_i i_t^H. \tag{23}$$

$$i_{t+1}^H = 0 + i_t^H(1 - \kappa_i) - \omega(R_t)(\phi + a_t^H)i_t^H(1 - \kappa_i) + \kappa_a a_t^H. \tag{24}$$

We can rewrite equation (23) as

$$a_{t+1}^H = a_t^H(1 - \kappa_a) + \omega(R_t)(\phi + a_t^H)(1 - \phi - a_t^H)(1 - \kappa_i) + \kappa_i(1 - \phi - a_t^H). \tag{25}$$

[12] See Eberly et al. [2012] for empirical evidence that favors this investment adjustment cost specification.

[13] Allowing PI households to switch between attention states adds complexity to the model while generating only modest quantitative effects. This is because the resulting changes in consumption reflect the annuitized value of the difference in deposit interest income between attentive and inattentive depositors.

The number of attentive depositors that become inattentive is $\kappa_a a_t^H$. The probability that an attentive depositor becomes inattentive is:

$$\kappa_a \frac{a_t^H}{\phi + a_t^H}.$$

The number of inattentive depositors that become attentive is,

$$\omega(R_t)(\phi + a_t^H) i_t^H (1 - \kappa_i) + \kappa_i i_t^H.$$

The probability that an inattentive depositor becomes attentive is,

$$\omega(R_t)(\phi + a_t^H)(1 - \kappa_i) + \kappa_i.$$

Banking The nominal value to a bank of a deposit from an attentive household corresponding to one unit of output (i.e. P_t dollars) is,

$$V_{at} = P_t (R_t - R_{at}) + E_t \frac{1-\delta}{R_t} \left[\kappa_a \upsilon_t V_{i,t+1} + (1 - \kappa_a \upsilon_t) V_{a,t+1} \right],$$

where

$$\upsilon_t = \frac{a_t^H D_{at}^H}{\phi D_t^p + a_t^H D_{at}^H}.$$

The probability that a dollar of deposits becomes inattentive is lower when there are PI households ($\phi > 0$) because these households never become inattentive. The probability υ_t takes this composition effect into account.

The term $E_t (1 - \delta) / R_t$ embodies the idea that banks are owned by PI households and future proceeds are discounted at the nominal interest rate. Using the PI household Euler equation to replace R_t, yields a standard stochastic discount factor in the expression above.

The nominal value to a bank of a deposit from an inattentive household corresponding to one unit of output (i.e, P_t dollars) is

$$V_{it} = P_t (R_t - R_{it}) + E_t \frac{1-\delta}{R_t} \left(\left[\omega(R_t)(\phi + a_t^H)(1 - \kappa_i) + \kappa_i \right] V_{a,t+1} + \left\{ 1 - \left[\omega(R_t)(\phi + a_t^H)(1 - \kappa_i) + \kappa_i \right] \right\} V_{i,t+1} \right)$$

Since all inattentive deposits are from HTM households, there are no composition effects.

The free-entry conditions are

$$\tau_j = \mu^{1/(1-\varsigma)} \frac{V_{jt}}{P_t},$$

where τ_a and τ_i are the real cost of attracting attentive and inattentive depositors, respectively. Using this result we obtain

$$\frac{\tau_a}{\mu^{1/(1-\varsigma)}} = R_t - R_{at} + E_t \frac{1-\delta}{R_t / \Pi_{t+1}} \left[\kappa_a \upsilon_t \frac{\tau_i}{\mu^{1/(1-\varsigma)}} + (1 - \kappa_a \upsilon_t) \frac{\tau_a}{\mu^{1/(1-\varsigma)}} \right],$$

and

$$\frac{\tau_i}{\mu^{1/(1-\varsigma)}} = R_t - R_{it} + E_t \frac{1-\delta}{R_t/\Pi_{t+1}} \left(\left\{ \left[\omega(R_t)(\phi + a_t^H)(1-\kappa_i) + \kappa_i \right] \frac{\tau_a}{\mu^{1/(1-\varsigma)}} + \left\{ 1 - \left[\omega(R_t)(\phi + a_t^H)(1-\kappa_i) + \kappa_i \right] \right\} \frac{\tau_i}{\mu^{1/(1-\varsigma)}} \right\} \right)$$

The interest rate spread for attentive depositors is:

$$R_t - R_{at} = \frac{\tau_a}{\mu^{1/(1-\varsigma)}} - E_t \frac{1-\delta}{R_t/\Pi_{t+1}} \left[\frac{\tau_a}{\mu^{1/(1-\varsigma)}} + \kappa_a \upsilon_t \frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}} \right].$$

The interest rate spread for inattentive depositors is:

$$R_t - R_{it} = \frac{\tau_i}{\mu^{1/(1-\varsigma)}} - E_t \frac{1-\delta}{R_t/\Pi_{t+1}} \left(\left\{ \frac{\tau_i}{\mu^{1/(1-\varsigma)}} - \left[\omega(R_t)(\phi + a_t^H)(1-\kappa_i) + \kappa_i \right] \frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}} \right\} \right).$$

Banks's net interest income is given by,

$$\left(R_t + \varepsilon^l\right) \left(\phi D_t^p + a_t^H D_{at}^H + i_t^H D_{it}^H\right) - \left[\left(\phi D_t^p + a_t^H D_{at}^H\right) R_{at} + i_t^H D_{i,t}^H R_{it} \right].$$

To compute nim_t we divide this expression by total assets, $\phi D_t^p + a_t^H D_{a,t}^H + i_t^H D_{i,t}^H$, to obtain,

$$nim_t = \varepsilon^l + \frac{\phi D_t^p + a_t^H D_{at}^H}{\phi D_t^p + a_t^H D_{at}^H + i_t^H D_{it}^H} (R_t - R_{at}) + \frac{i_t^H D_{it}^H}{\phi D_t^p + a_t^H D_{at}^H + i_t^H D_{it}^H} (R_t - R_{it}).$$

In equilibrium,

$$\upsilon_{at} = \frac{\delta}{\mu^{1/(1-\varsigma)}} \left(\phi D_t^p + a_t^H D_{at}^H\right) \text{ and } \upsilon_{it} = \frac{\delta}{\mu^{1/(1-\varsigma)}} \left(i_t^H D_{it}^H\right).$$

Nominal banking profits are given by,

$$\begin{aligned} \pi_t^b \; = \; & \left(R_t + \varepsilon^l\right) \left(\phi D_t^p + a_t^H D_{at}^H + i_t^H D_{it}^H\right) - \left[\left(\phi D_t^p + a_t^H D_{at}^H\right) R_{at} + i_t^H D_{it}^H R_{it} \right] \\ & - \varepsilon^l \left(\phi D_t^p + a_t^H D_{at}^H + i_t^H D_{it}^H\right) - \delta \left[\frac{\tau_a}{\mu^{1/(1-\varsigma)}} \left(\phi D_t^p + a_t^H D_{at}^H\right) + \frac{\tau_i}{\mu^{1/(1-\varsigma)}} i_t^H D_{it}^H \right]. \end{aligned}$$

The first term represents lending revenue, the second term is interest paid by banks on deposits, the third term is the operational costs of lending, and the final term represents deposit-acquisition costs.

Re-arranging this expression we obtain,

$$\pi_t^b = \left(\phi D_t^p + a_t^H D_{at}^H\right) \left(R_t - R_{at} - \delta \frac{\tau_a}{\mu^{1/(1-\varsigma)}} \right) + i_t^H D_{it}^H \left(R_t - R_{it} - \delta \frac{\tau_i}{\mu^{1/(1-\varsigma)}} \right).$$

Monetary policy The monetary authority sets the nominal interest rate, R_t, according to a Taylor-type rule:

$$\ln(R_t) = \rho\ln(R_{t-1}) + (1-\rho)\ln(R) + (1-\rho)\left[\theta_\pi ln\left(\frac{\Pi_t}{\bar{\Pi}}\right) + \theta_y ln\left(\frac{GDP_t}{GDP}\right)\right] + \varepsilon_t, \qquad (26)$$

where ε_t is an i.i.d. shock with zero mean and standard deviation σ^r, $\theta_\pi > 1$ and $\theta_y \geq 0$. The variables $\bar{\Pi}$, and R are the target level of inflation and the corresponding steady-state value of the nominal interest rate, respectively. The parameter ρ controls the degree of persistence in the policy rate. GDP_t is given by

$$GDP_t = C_t + I_t + G_t.$$

Fiscal policy Real government spending, G, is assumed to be constant over time. Nominal government expenditures are financed through nominal lump-sum taxes, Ψ. To simplify, we assume that only PI households pay taxes.

Aggregate resource constraint The aggregate resource constraint is given by:

$$Y_t = C_t + I_t + G_t + \tilde{v}_{at}\tau_a + \tilde{v}_{it}\tau_i + \varepsilon^l\left(w_t N_t + r_t^K u_t \bar{K}_t\right),$$

where $\tilde{v}_{at}\tau_a$ and $\tilde{v}_{it}\tau_i$ are the real costs incurred by banks to attract attentive and inattentive depositors, respectively. The term $\varepsilon^l\left(w_t N_t + r_t^K u_t \bar{K}_t\right)$ represents resource costs associated with loan intermediation by banks.

7.3 Model Estimation

We partition the parameters of our model into two sets. The first set consists of parameters chosen *a priori*. With one exception, the second set is estimated using the Bayesian procedure that we applied to the partial equilibrium model.[14]

The parameters that are set *a priori* are listed in Table 3.

[14] The exception is the interest rate paid on deposits by inattentive households in the low interest rate regime. We allow this rate to be slightly negative, subject to a lower bound of –1.5 percent per annum. This assumption improves the model's fit in the high interest rate state. We interpret negative deposit rates as reflecting bank fees rather than negative interest payments.

Table 3: Parameter values set *a priori*

Parameter	Parameter value	Description
ϵ_l	0.008	Cost per dollar of making loans
R_L	1.014	Gross annual nominal interest rate, low nominal interest rate state
R_H	1.056	Gross annual nominal interest rate, high nominal interest rate state
r	1.014	Gross annual real interest rate, low and high nominal interest rate states
β	$1/r^{1/4}$	Discount factor
κ_i	5.4410×10^{-4}	Rate at which inattentive become attentive
ξ	0.95	Price stickiness parameter
γ	1.1	Gross steady state price markup
σ_0	0.025	Depreciation function parameter
σ_1	0.0285	Depreciation function parameter
σ_2	0.001	Depreciation function parameter
α	1/3	Capital share in production
η	1	Curvature disutility of labor
ψ	1	Slope disutility of labor
g/y	0.2	Steady state government consumption to output ratio
ι	1	Price indexation to steady state inflation
ρ	0.75	Persistence coefficient interest rate rule
θ_π	1.5	Inflation coefficient interest rate rule
θ_y	0.125	Output coefficient interest rate rule

We set ϵ_l to 0.008, the same value as in the partial equilibrium model. The steady-state nominal interest rates are set to $R_L = 1.014$ in the low-interest-rate steady state and $R_H = 1.056$ in the high-interest-rate steady state. These values correspond to the average FFR below and above the four percent threshold, respectively.

The annualized steady-state real interest rate, r, is set to 1.4 percent in both regimes, implying a discount factor equal to $1/(1.014)^{1/4}$.[15] Since the real interest rate is constant across regimes, all other real variables are virtually identical in the two steady states. This property allows us to isolate the effects of different levels of nominal interest rates.

We set κ_i to its posterior mode estimate from the partial equilibrium model.[16] The price stickiness parameter ξ is set to 0.95, implying a slope of the linearized New Keynesian Phillips curve of 0.003. The latter value is consistent with post-1990 sample estimates by Del Negro et al. [2020] and Hazell et al. [2022]. We set the steady-state gross price markup γ to 1.1 as in e.g. Harding, Lindé and Trabandt [2022, 2023]. Our results are robust to alternative values of γ.

We now turn to the capital depreciation and utilization parameters. We set σ_0 and σ_1 so

[15] This calibration is consistent with Johannsen and Mertens [2021], who argue that the long-run real interest rate has been constant since 1960.

[16] We encountered numerical difficulties when attempting to estimate this parameter directly.

that the low-nominal-interest rate steady state quarterly capital depreciation rate and the capital-utilization rate, u, are equal to 2.5 percent per quarter and one, respectively. Consistent with Christiano et al. [2005], we set σ_2 to 0.001. This value implies that it is relatively inexpensive to vary capital utilization.

In line with the literature, we set the capital share in production, α, to 1/3 and the steady-state ratio of government consumption to output to 0.2. As in Christiano et al. [2005], we assume quadratic disutility of labor, so η is equal to one. We also set the parameter ψ, which affects the disutility of labor, equal to one. Finally, we set the parameters of the monetary policy rule ρ, θ_π and θ_y to 0.75, 1.5 and 0.125, respectively. These values are consistent with the empirical NK literature.

When solving the model, we assume that social dynamics occur daily, while economic decisions are made at the end of each quarter. The total number of interactions per quarter is set to 200, implying that households have multiple social interactions per day. We estimate the following parameters: χ,κ_a,δ,$\tau_a/\mu^{\frac{1}{1-\varsigma}}$,$\tau_i/\mu^{\frac{1}{1-\varsigma}}$,$\phi$,$b$,$s_I$,$\vartheta_1$ and ϑ_2. In the equilibrium equations, the parameters τ_a, τ_i, μ and ς only appear as the ratios $\tau_a/\mu^{\frac{1}{1-\varsigma}}$, $\tau_i/\mu^{\frac{1}{1-\varsigma}}$ which is why we estimate those ratios rather than the individual parameters.

In our estimation we assume that the economy begins either in the low- or high-nominal-interest rate state. Conditional on the initial state, we feed in exogenous paths for the nominal interest rate R_t, corresponding to the Cholesky-based estimated impulse response function of the policy rate (see Section 4).

We estimate the model by matching data and model-generated impulse response functions for the following variables: real per capita GDP, real per capita consumption, real per capita investment, the real hourly wage rate, and core NIM.

Our computational approach is as follows. We consider two steady states corresponding to a low (R_L) and high (R_H) nominal interest rate. The real interest rate is the same in both steady states. Our specification for R_L and R_H implies two different values for steady state inflation. To simulate the effect of a monetary policy shock, we feed in paths for R_L and R_H equal to estimated impulse response of the FFR to a Cholesky-based monetary policy shock for 12 quarters.[17] After this period, the interest rate path is governed by the Taylor rule.

Recall that the model includes 200 social interactions per quarter. We linearly interpolate the quarterly interest rates to obtain 200 intra-quarter interest rates. The latter are used to compute paths for a^L and a^H. Economic decisions are made at the end of each quarter using the 200th value of a^L and a^H. Using the Fair and Taylor [1983] procedure, we solve two versions of the nonlinear

[17] These paths can be interpreted as resulting from a particular sequence of shocks to the Taylor rule.

model, corresponding to the high and low steady state interest rate. This procedure yields two sets of impulse response functions, which reflect the model's state-dependent dynamics.

Since we are working with the Cholesky monetary shock measure, we impose the restriction that model real quarterly aggregates do not respond contemporaneously to monetary policy shocks.

7.4 Results Baseline

Table 4 reports the priors and posteriors of our estimated parameters.

Table 4: Priors and Posteriors of Parameters.

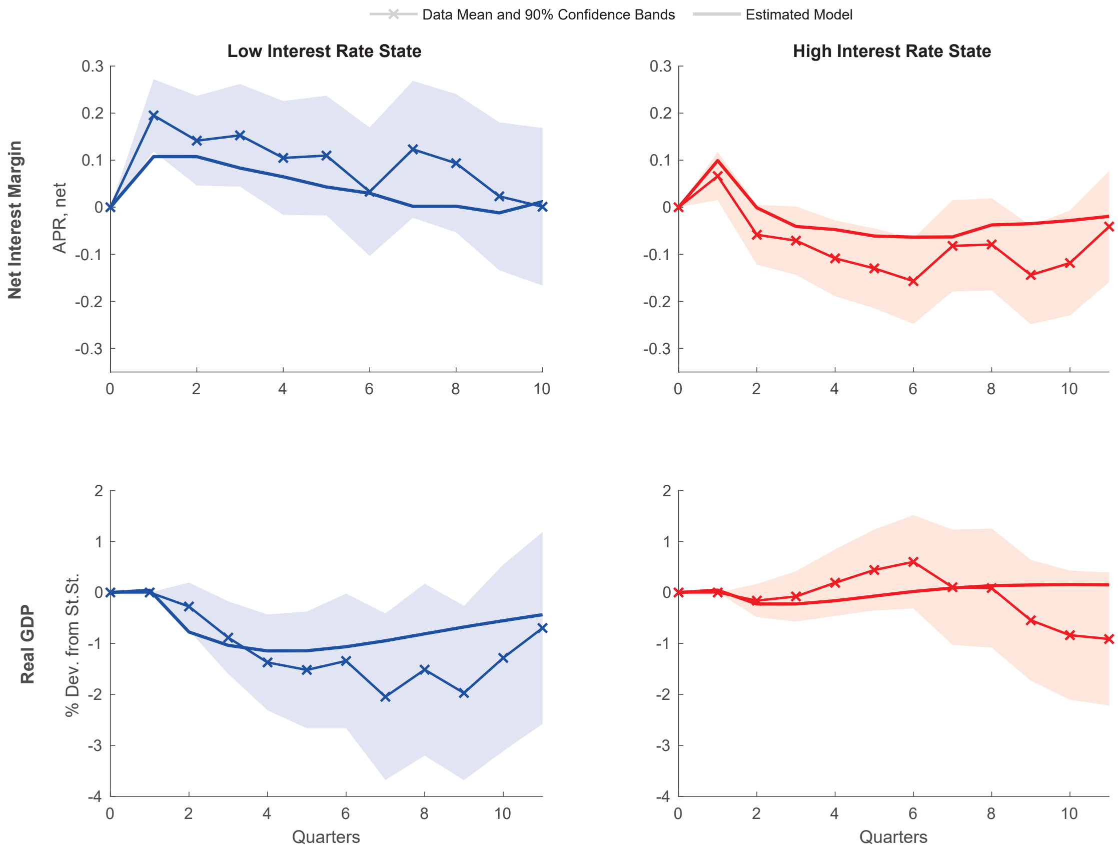
Parameter	Prior Distribution	Posterior Distribution
	Mean, [2.5-97.5%]	Mode, [2.5-97.5%]
Social dynamics interaction parameter, χ	2.0, [0.0506 7.3777]	1.8870, [0.9409 5.0424]
Rate at which attentive become inattentive, κ_a	0.025, [0.000 0.049]	0.0060, [0.0025 0.0217]
Fraction of depositors who leave banks, δ	0.025, [0.000 0.049]	0.0223, [0.0182 0.0489]
Cost of attracting attentive depositors, $\tau_a/\mu^{\frac{1}{1-\varsigma}}$	0.05, [0.000 0.0975]	0.0161, [0.0078 0.0405]
Cost of attracting inattentive depositors, $\tau_i/\mu^{\frac{1}{1-\varsigma}}$	0.50 , [0.025 0.975]	0.2691, [0.1225 0.2954]
Share of PI households, ϕ	0.45, [0.010 0.8775]	0.4972, [0.3273 0.6683]
Consumption habit persistence, b	0.75, [0.615 0.926]	0.8357, [0.6943 0.8658]
adjustment costs, s_I	10.0, [0.103 19.50]	4.9627, [3.3158 17.165]
Real wage rule, persistence, ϑ_1	0.80, [0.615 0.965]	0.9635, [0.7489 0.9901]
Real wage rule, labor demand, ϑ_2	0.50, [0.025 0.975]	0.1083, [0.0522 0.3037]

Notes: T: The posterior mode and parameter distributions are based on a standard MCMC algorithm with a total of 500,000 draws (one chain, with 50,000 draws used for burn-in). The acceptance rate is approximately 0.25. With the exception of the parameter χ, the priors for all parameters take the form of a uniform distribution. In the case of χ, the the prior take the form of a Gamma distribution with shape and scale parameters (2,1).

The point estimates of the banking parameters are broadly consistent with those obtained from the partial equilibrium model. The point estimates of the habit formation parameter, b, and the investment adjustment cost parameter, s_I, are broadly consistent with those used in the literature (see e.g. Christiano et al. [2005] and Smets and Wouters [2007]). The point estimate for ϕ is consistent with the literature surveyed by Carroll et al. [2017]. In line with the data, the estimated wage rule parameters imply a highly inertial response of wages to monetary policy shocks (see, for example, Christiano et al. [2015]).

Figure 8 displays the model-implied impulse responses of nim_t and real GDP to a monetary policy shock along with the corresponding estimated counterparts from Section 4.[18]

Figure 8: Estimated general equilibrium model. Impulse responses to a monetary policy shock of 100 b.p. annualized. NIM and real GDP: data vs. model. Units in deviation from steady state or data baseline, respectively.



Note: This figure compares the theoretical impulse response functions (IRFs) generated from the estimated general equilibrium banking model with their empirical counterparts discussed in Section 3. Solid lines represent the model-generated IRFs. Solid lines with "x" markers depict the corresponding empirical IRFs. The shaded areas represent the 90 percent confidence bands for the empirical IRFs.

Two key results emerge from that figure. First, as in the partial equilibrium model, the response of NIM is state dependent: a monetary policy shock raises NIM when interest rates are low but lowers it when interest rates are high. The intuition for this results is the same as in the partial equilibrium model. Second, the magnitude of the real responses to a monetary policy shock is state dependent for all variables except wages (see the Appendix) and the policy rate. The peak decline in aggregate output is approximately twice as large in the low-interest-rate regime relative to the high-interest-rate regime. The underlying mechanism for this result is discussed in Section 4.4.

We conclude that our general equilibrium model is consistent with the view that state de-

[18]The Appendix reports the impulse response function for consumption, investment and the real wage.

pendence in NIM responses induces a state-dependent response of aggregate economic activity to monetary policy shocks.

8 Conclusion

We show that the effect of monetary policy shocks on the economy depends on whether the shocks occur following periods of low or high nominal interest rates. This state dependence arises from the state-contingent response of banks' net interest margins (NIM) and key macroeconomic variables such as GDP, consumption, and investment.

These patterns cannot be explained by models in which households are inattentive simply because it is costly to monitor interest rates. In such frameworks, a given interest rate change should elicit the same depositor response regardless of the prevailing rate environment, implying no state-dependent effects.

To account for our empirical findings, we develop and estimate a nonlinear New Keynesian general equilibrium model with an explicit banking sector. The model features two central mechanisms. First, a subset of households is inattentive to the interest earned on deposits. Second, the share of inattentive households evolves through social interactions: inattentive depositors may become attentive after interacting with attentive ones. This transition is more likely when interest rates are high, as attentive households are more inclined to discuss interest rates in those conditions. The resulting state dependence in deposit interest rates affects the broader economy because some households exhibit a high marginal propensity to consume out of liquid wealth.

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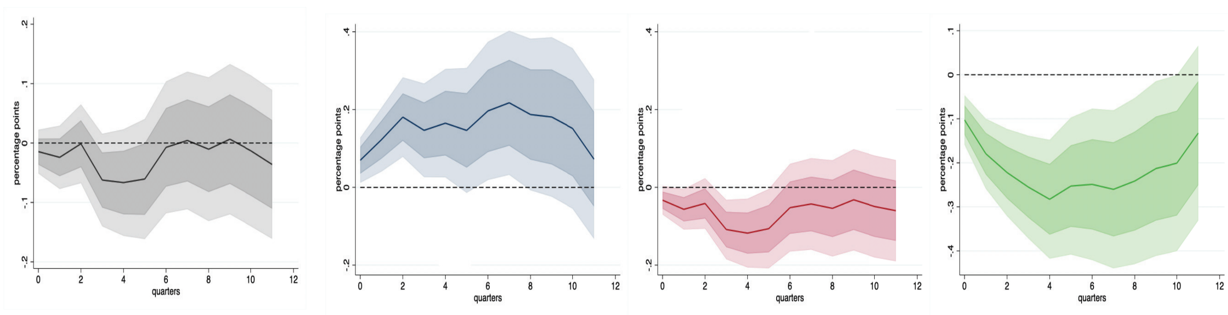
9 Appendix

10 Empirical Robustness

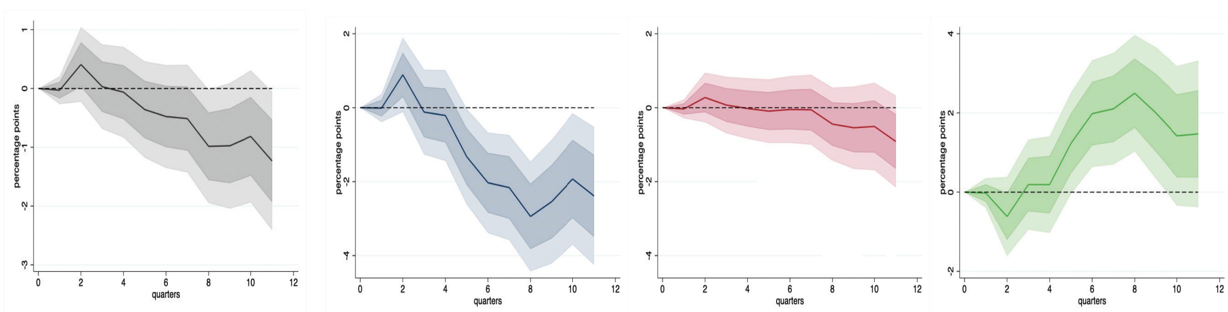
Figure 9: Other outcome variables

Overall NIM



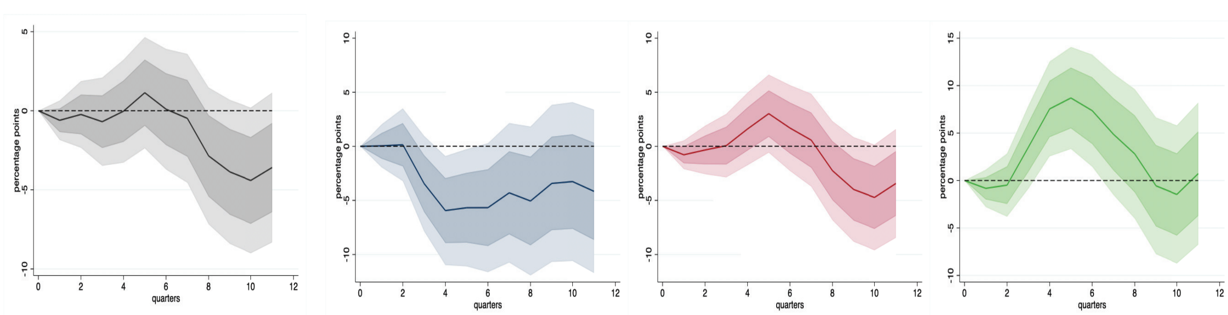
(a) Baseline (b) Low Rate State (c) High Rate State (d) High vs Low

Logarithm of real per capita consumption



(e) Baseline (f) Low Rate State (g) High Rate State (h) High vs Low

Logarithm of real per capita investment



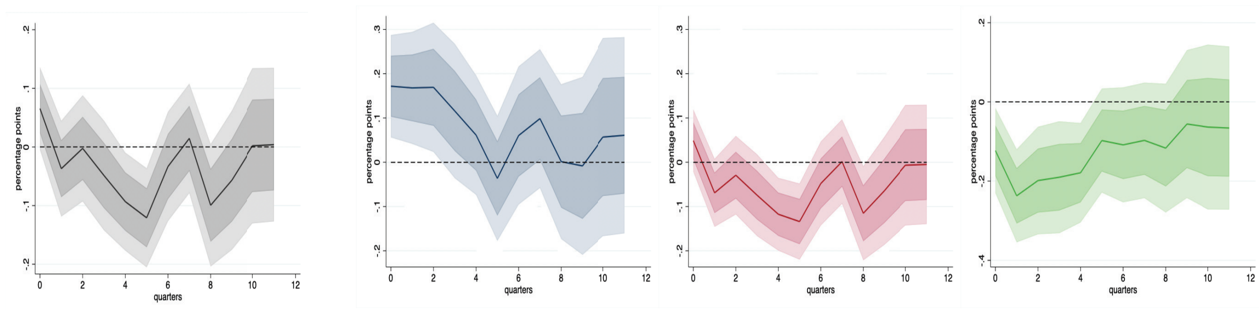
(i) Baseline (j) Low Rate State (k) High Rate State (l) High vs Low

Note: overall NIM is computed as the difference between the average interest income rate on all assets and the average interest expense rate. Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Figure 10: Sample period 1984Q1-2008Q4. core NIM, logarithm of real S&P 500

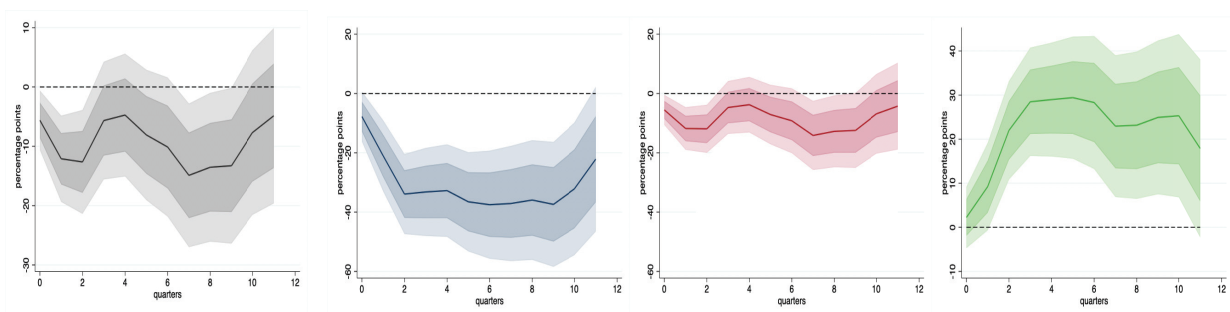
Panel A: Core NIM

No State-Dependence | Allowing for State Dependence



(a) Baseline (b) Low Rate State (c) High Rate State (d) High vs Low

Panel B: Real Log S&P500



(e) Baseline (f) Low Rate State (g) High Rate State (h) High vs Low

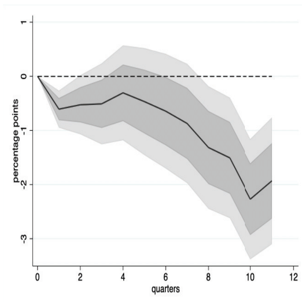
Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Figure 11: Sample period 1984Q1-2008Q4. Logarithm of real per capita GDP and PCE deflator index

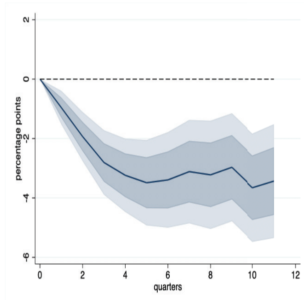
Panel A: Logarithm of real per capita GDP

No State-Dependence

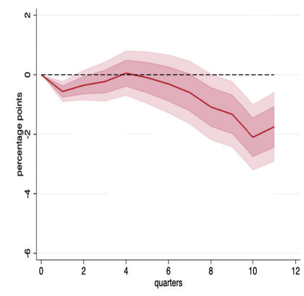
Allowing for State Dependence



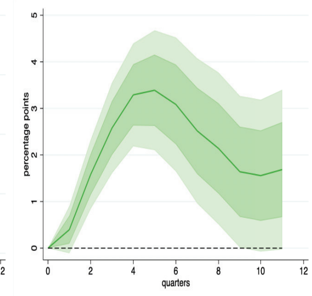
(a) Baseline



(b) Low Rate State

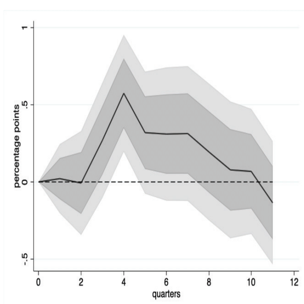


(c) High Rate State

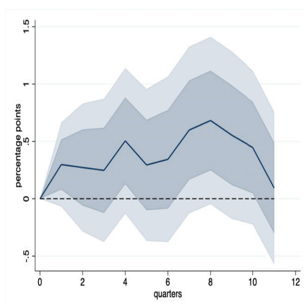


(d) High vs Low

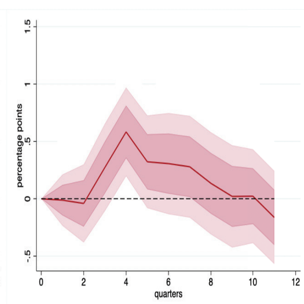
Panel B: Logarithm of PCE deflator index



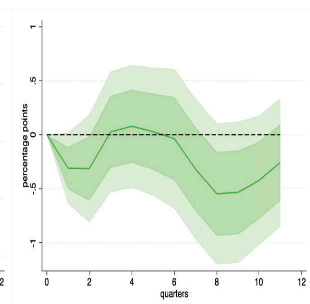
(e) Baseline



(f) Low Rate State



(g) High Rate State



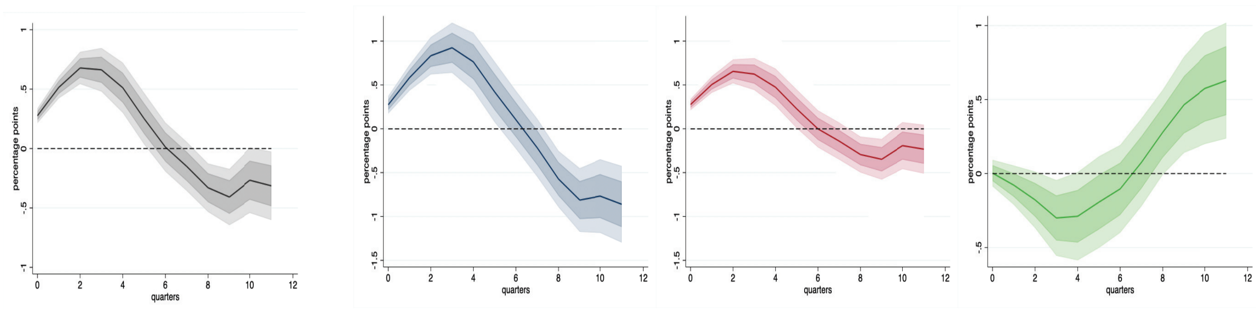
(h) High vs Low

Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Figure 12: Sample period 1984Q1-2008Q4. Loan interest rate and spread between time and deposit rate.

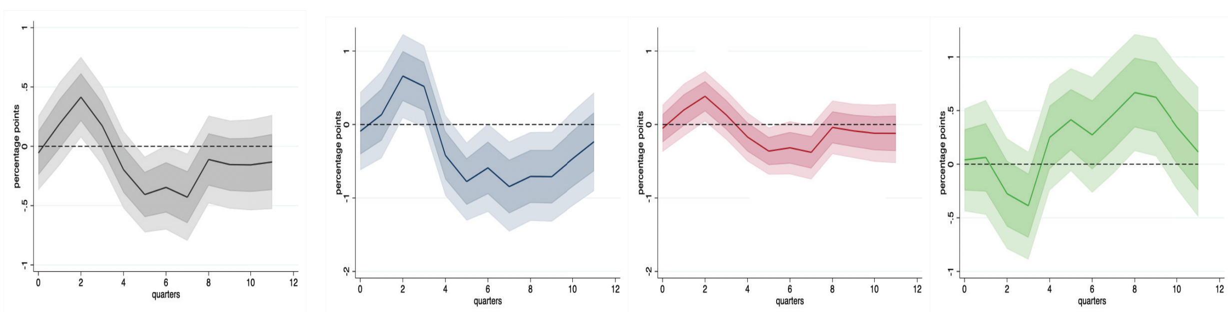
Panel A: Loan Interest Rate

No State-Dependence | Allowing for State Dependence



(a) Baseline | (b) Low Rate State | (c) High Rate State | (d) High vs Low

Panel B: Spread between Time and Saving Deposit Rate

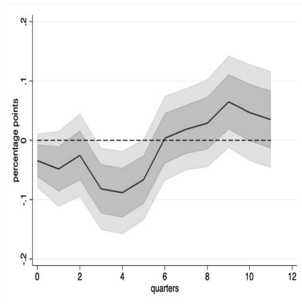


(e) Baseline | (f) Low Rate State | (g) High Rate State | (h) High vs Low

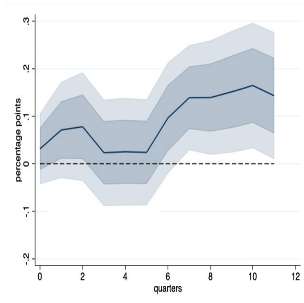
Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Figure 13: Sample period 1984Q1-2008Q4. Overall NIM, logarithm of real per capita Consumption and Investment

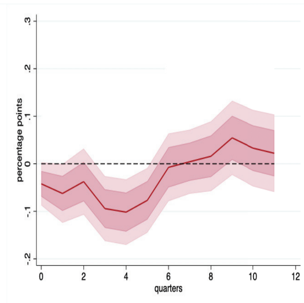
Overall NIM



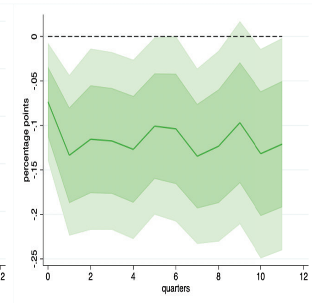
(a) Baseline



(b) Low Rate State

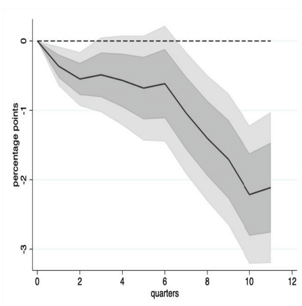


(c) High Rate State

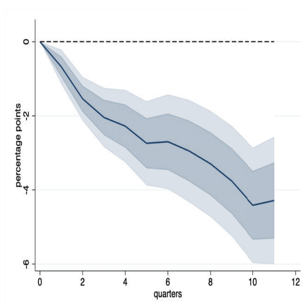


(d) High vs Low

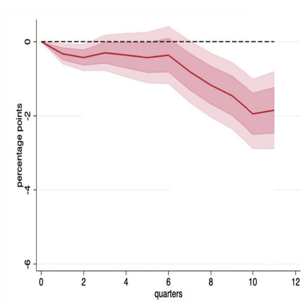
Logarithm of real per capita consumption



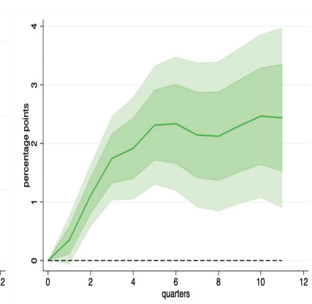
(e) Baseline



(f) Low Rate State

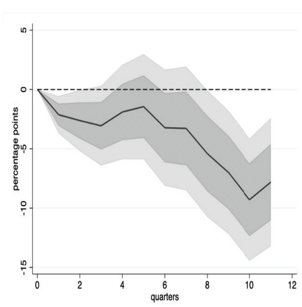


(g) High Rate State

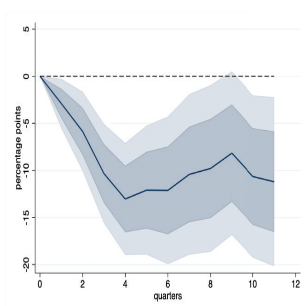


(h) High vs Low

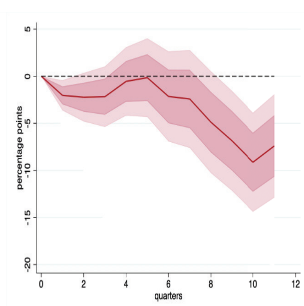
Logarithm of real per capita investment



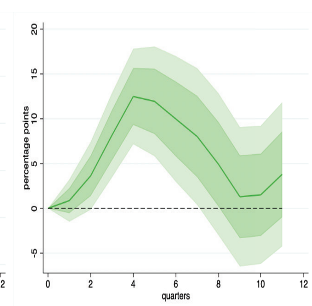
(i) Baseline



(j) Low Rate State



(k) High Rate State



(l) High vs Low

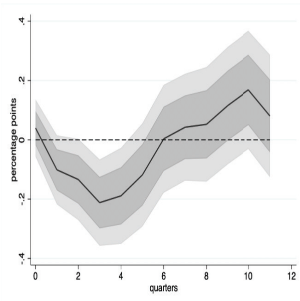
Note: overall NIM is computed as the difference between the average interest income rate on all assets and the average interest expense rate. Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Figure 14: Benchmark specification, Bauer and Swanson (2023) monetary policy measure

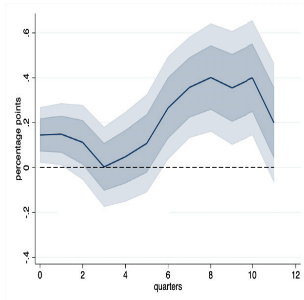
Panel A: Core NIM

No State-Dependence

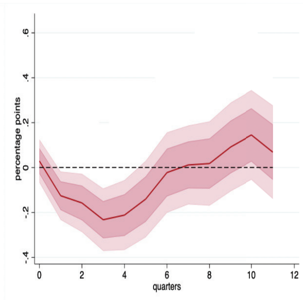
Allowing for State Dependence



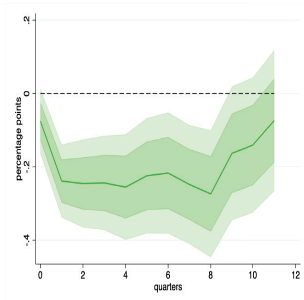
(a) Baseline



(b) Low Rate State

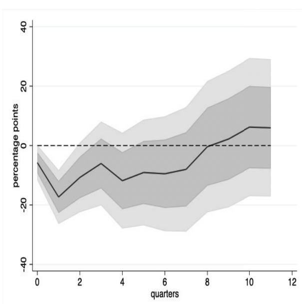


(c) High Rate State

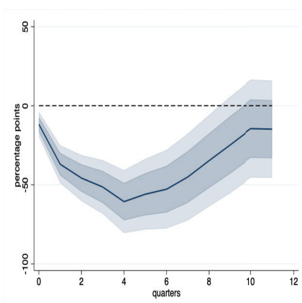


(d) High vs Low

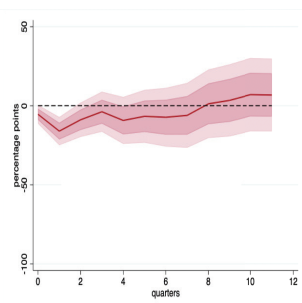
Panel B: Real Log S&P500



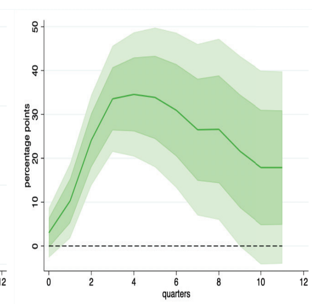
(e) Baseline



(f) Low Rate State

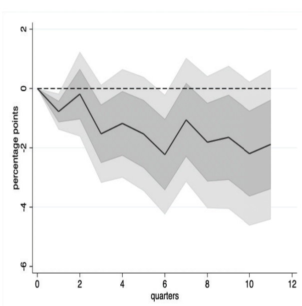


(g) High Rate State

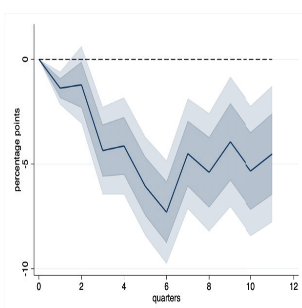


(h) High vs Low

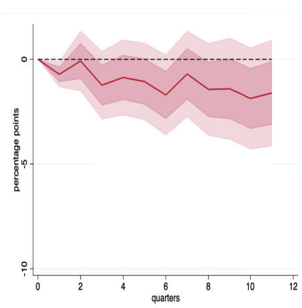
Panel C: Log Real Per Capita GDP



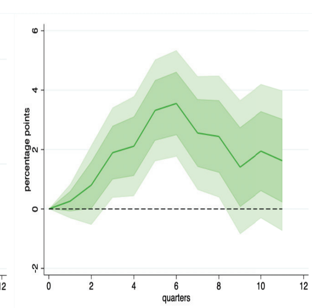
(i) Baseline



(j) Low Rate State



(k) High Rate State



(l) High vs Low

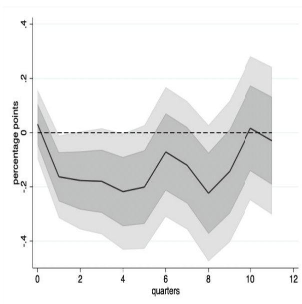
Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Figure 15: Benchmark specification, Jarociński and Karadi (2023) monetary policy measure

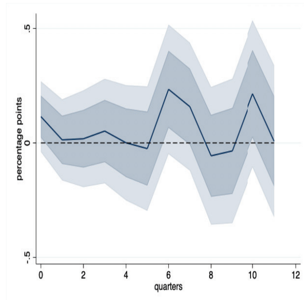
Panel A: Core NIM

No State-Dependence

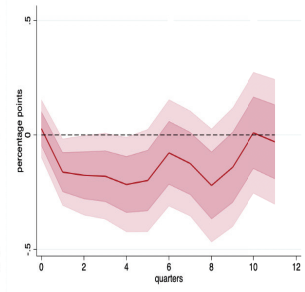
Allowing for State Dependence



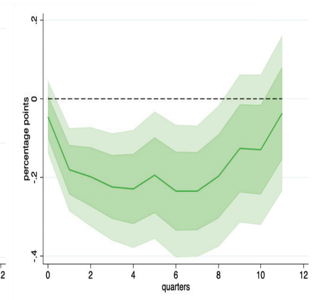
(a) Baseline



(b) Low Rate State

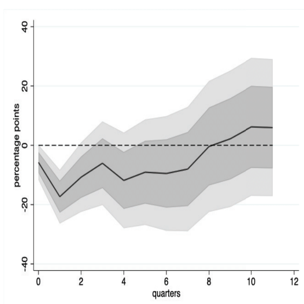


(c) High Rate State

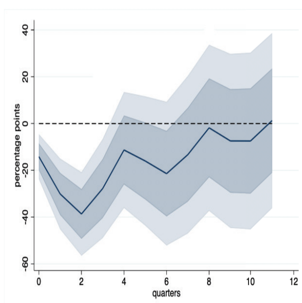


(d) High vs Low

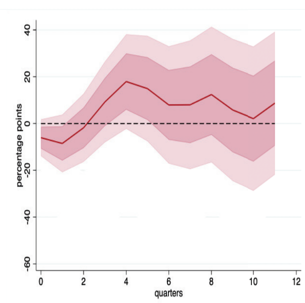
Panel B: Real Log S&P500



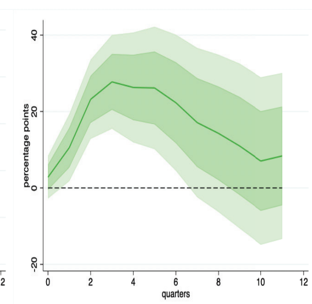
(e) Baseline



(f) Low Rate State

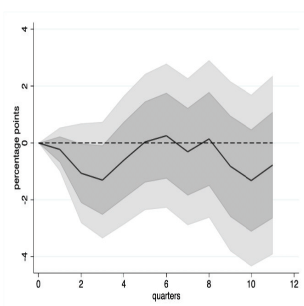


(g) High Rate State

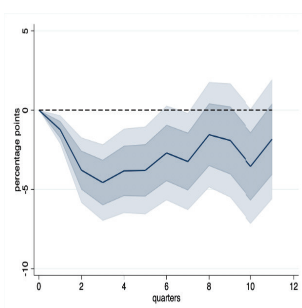


(h) High vs Low

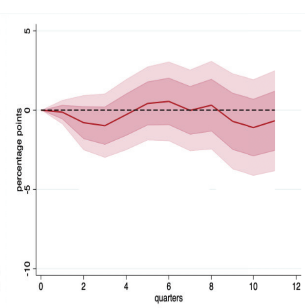
Panel C: Log Real Per Capita GDP



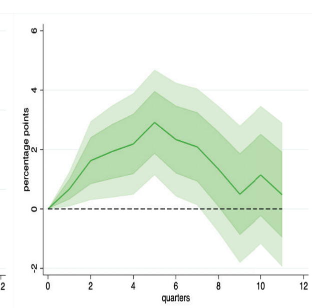
(i) Baseline



(j) Low Rate State



(k) High Rate State



(l) High vs Low

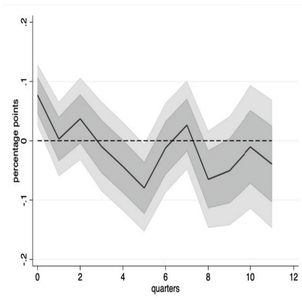
Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

Figure 16: Controlling for the ZLB

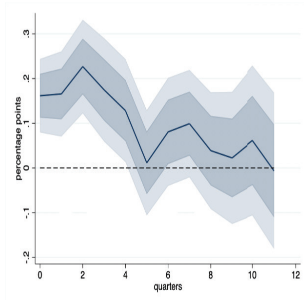
Panel A: Core NIM

No State-Dependence

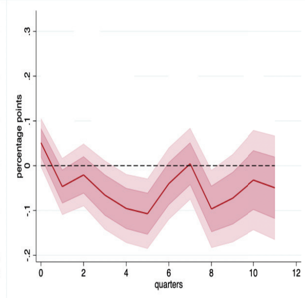
Allowing for State Dependence



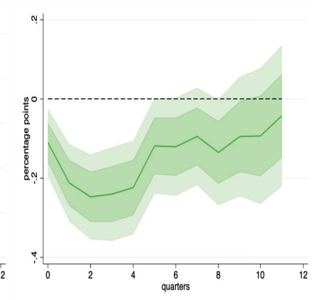
(a) Baseline



(b) Low Rate State

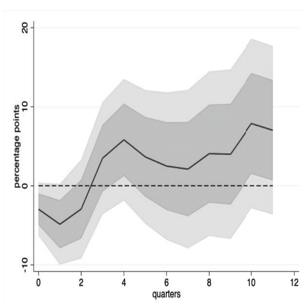


(c) High Rate State

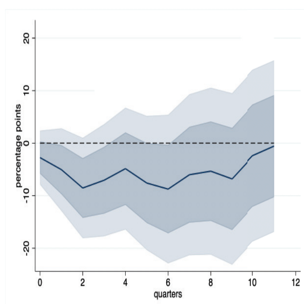


(d) High vs Low

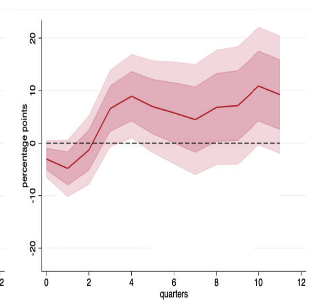
Panel B: Real Log S&P500



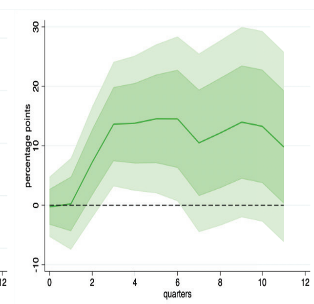
(e) Baseline



(f) Low Rate State

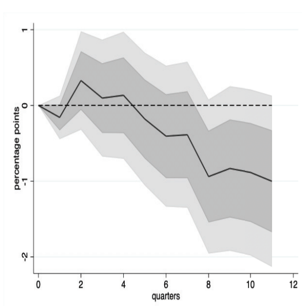


(g) High Rate State

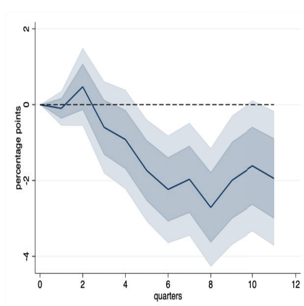


(h) High vs Low

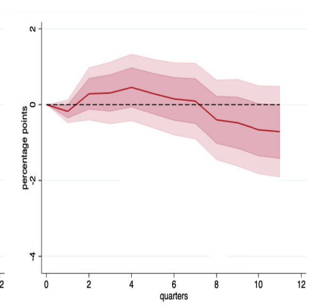
Panel C: Log Real Per Capita GDP



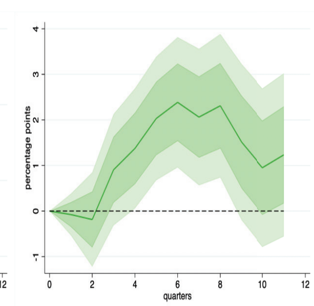
(i) Baseline



(j) Low Rate State



(k) High Rate State



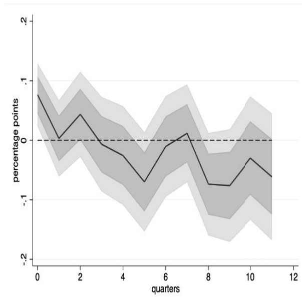
(l) High vs Low

Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

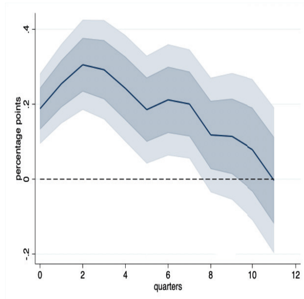
Figure 17: Threshold R equal to 3.5 percent

Panel A: Core NIM

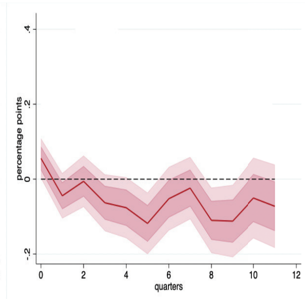
No State-Dependence | Allowing for State Dependence



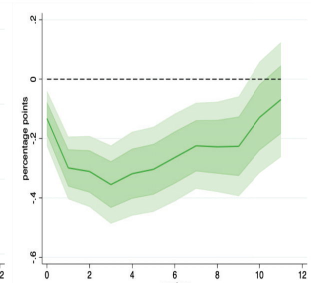
(a) Baseline



(b) Low Rate State

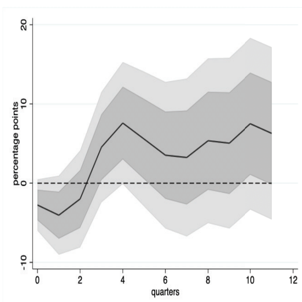


(c) High Rate State

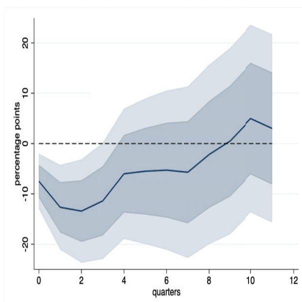


(d) High vs Low

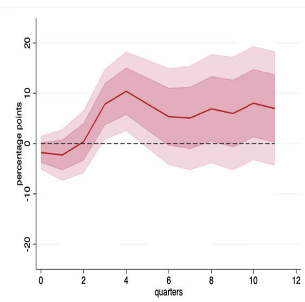
Panel B: Real Log S&P500



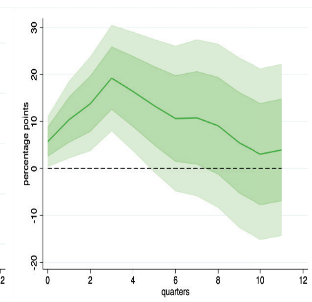
(e) Baseline



(f) Low Rate State

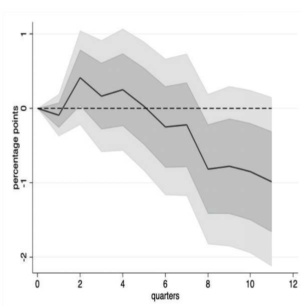


(g) High Rate State

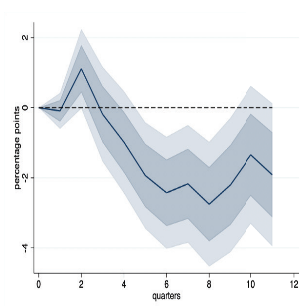


(h) High vs Low

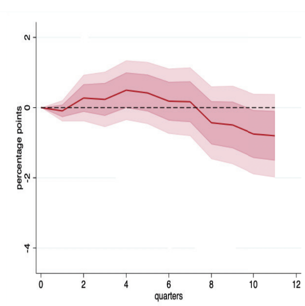
Panel C: Log Real Per Capita GDP



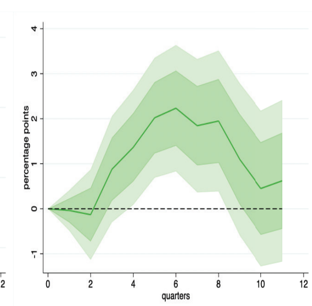
(i) Baseline



(j) Low Rate State



(k) High Rate State



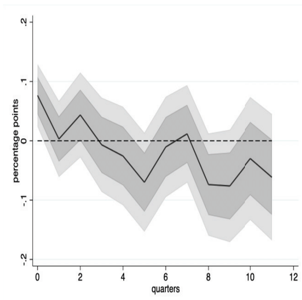
(l) High vs Low

Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

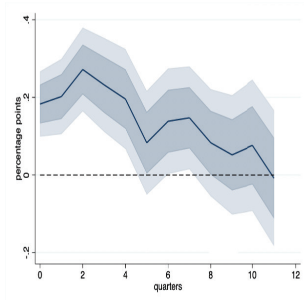
Figure 18: Threshold R equal to 4.5 percent

Panel A: Core NIM

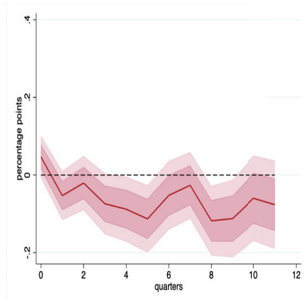
No State-Dependence | Allowing for State Dependence



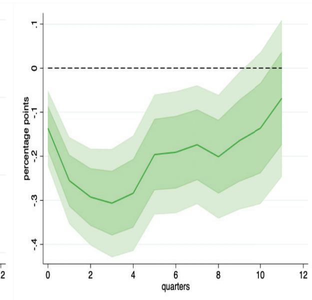
(a) Baseline



(b) Low Rate State

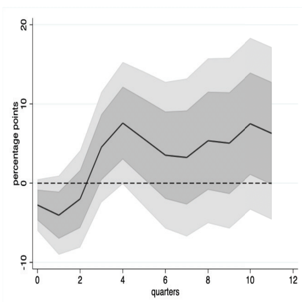


(c) High Rate State

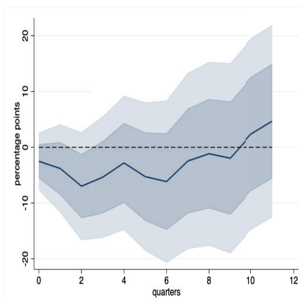


(d) High vs Low

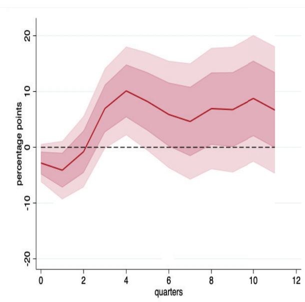
Panel B: Real Log S&P500



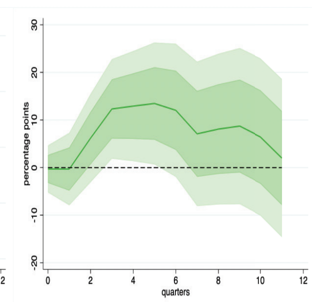
(e) Baseline



(f) Low Rate State

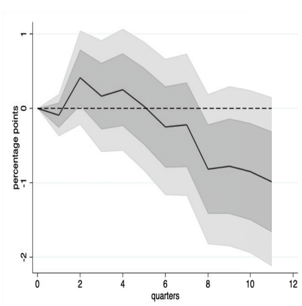


(g) High Rate State

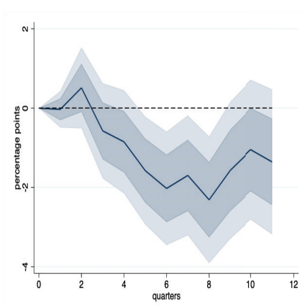


(h) High vs Low

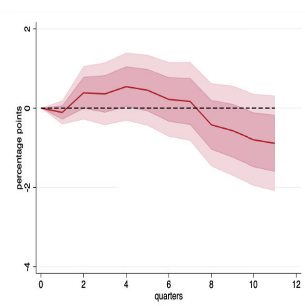
Panel C: Log Real Per Capita GDP



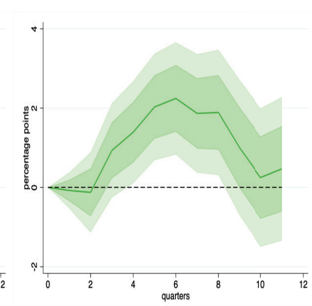
(i) Baseline



(j) Low Rate State



(k) High Rate State



(l) High vs Low

Note: Solid Lines in the first three columns depict point estimates of the response of a variable to a 100 b.p. contractionary shock to monetary policy. The solid line in the fourth column depicts the difference between the point estimates of a variable's response in the low and high rate state. The shaded areas in all figures depict the 68% (darker) and 95% (lighter) confidence intervals.

11 Bayesian Estimation Procedure

To explain the Bayesian estimation procedure, suppose that the structural model is true. Let θ_0 denote the true values of the model parameters and $\psi(\theta)$ the mapping from model parameters to the model-based impulse responses of NIM in the high- and low-interest-rate states. Classical asymptotic sampling theory implies that, when the number of observations, T, is large,

$$\sqrt{T}\left(\hat{\psi} - \psi(\theta_0)\right) \overset{a}{\sim} N(0, W(\theta_0)).$$

It is convenient to express the asymptotic distribution of $\hat{\psi}$ as

$$\hat{\psi} \overset{a}{\sim} N(\psi(\theta_0), V). \tag{27}$$

Here, V is a consistent estimate of the precision matrix $W(\theta_0)/T$. Following Christiano et al. [2010], we assume that V is a diagonal matrix. In our setting, the diagonal elements of that matrix are the estimated variances of the impulse responses of nim_t in the high- and low-interest-rate states.

We specify priors for θ and then compute the posterior distribution for θ given $\hat{\psi}$ using Bayes' rule. This computation requires the likelihood of $\hat{\psi}$ given θ. An asymptotically valid approximation of this likelihood is implied by (27):

$$f\left(\hat{\psi}|\theta, V\right) = (2\pi)^{-\frac{N}{2}} |V|^{-\frac{1}{2}} \exp\left[-0.5\left(\hat{\psi} - \psi(\theta)\right)' V^{-1}\left(\hat{\psi} - \psi(\theta)\right)\right]. \tag{28}$$

The value of θ that maximizes this function is an approximate maximum likelihood estimator of θ. It is approximate for two reasons. First, the central limit theorem underlying (27) only holds exactly as $T \to \infty$. Second, our proxy for V is guaranteed to be correct only for $T \to \infty$.

The Bayesian posterior of θ conditional on $\hat{\psi}$ and V is:

$$f\left(\theta|\hat{\psi}, V\right) = \frac{f\left(\hat{\psi}|\theta, V\right) p(\theta)}{f\left(\hat{\psi}|V\right)}. \tag{29}$$

In practice, we impose an additional constraint, also known as an endogenous prior: when estimating the model, we only consider parameter values θ such that (i) the spreads $R_t - R_{i,t}$, $R_t - R_{a,t}$ are always non-negative; (ii) $R_{i,t}$ and $R_{a,t}$ in the high interest rate state are higher than in the low interest rate state; and (iii) $\tau_i > \tau_a$.

The function $p(\theta)$ denotes the prior distribution of θ, and $f\left(\hat{\psi}|V\right)$ denotes the marginal density of $\hat{\psi}$:

$$f\left(\hat{\psi}|V\right) = \int f\left(\hat{\psi}|\theta, V\right) p(\theta)\, d\theta.$$

Because the denominator is not a function of θ, we can compute the mode of the posterior distribution of θ by maximizing the value of the numerator in (29). We compute the posterior distribution of the parameters using a standard Monte Carlo Markov chain (MCMC) algorithm.

12 Robustness analysis

Bauer and Swanson [2023] follow Nakamura and Steinsson [2018] and use the first principal component of the changes in ED1–ED4 around FOMC announcements rescaled so that a one-unit change in the principal component corresponds to a 1 percentage point change in the ED4 rate. Bauer and Swanson orthogonalize these movements to variables summarizing the information set available to financial markets before the FOMC announcement: a measure of the surprise component of the most recent non-farm payrolls release (as measured by the deviation of the actual outcome from the consensus forecast), employment growth over the last year, the log change in the Standard & Poor's 500 index (S&P 500) from three months before the day of the FOMC announcement, the change in the yield curve slope over the same period, the log change in a commodity price index over the same period, and the option-implied skewness of the 10-year Treasury yield from Bauer and Chernov [2024].

Jarociński and Karadi [2025] identify a monetary policy shock by leveraging (i) the high-frequency co-movement of interest rate and stock price surprises, (ii) the predictability of surprises based on public news, and (iii) heteroskedasticity between FOMC and non-FOMC announcements.

Table 5 reports the standard deviations of our three shock measures over our sample period.

Table 5: Standard deviation of policy shock measures

Shock Measure	Full Sample	Low Rates	High Rates	ZLB	Low Rates and ZLB
Recursive	0.26	0.20	0.20	0.31	0.19
Bauer and Swanson	0.12	0.09	0.11	0.15	0.06
Jarocinski and Karadi	0.12	0.09	0.10	0.14	0.07
Observations	128	42	57	29	71

13 A competitive search model of banking

Our baseline model assumes random search. In this appendix, we consider a version of the banking model with competitive search, following the framework of Moen [1997]. Unlike the baseline case, some deposits remain unmatched, held instead as cash and earning a zero interest rate.

In this framework, there are different submarkets where banks offer interest rates. Depositors direct their search toward the most attractive submarkets. Markets with higher rates draw more depositors, reducing the likelihood that any individual depositor matches with a bank, while increasing the chances that a bank secures a match with a depositor. Banks select submarkets with interest rates that maximize their expected profits. Depositors choose the submarket that maximizes their expected return. In equilibrium, depositors are indifferent among interest rate offers that attract applications.

To simplify, we consider a version of the model with a representative household. For convenience, we describe the model in continuous time, but the same results would hold in discrete time. We focus our analysis on the model's steady state properties.

We show that the interest rate spreads in this model shares the three key properties we highlight in the benchmark model. First, the spreads increase with R, Second, in response to a change in R, interest rate spreads increase more when interest rates are low than when interest rates are high. Third, since $\tau_i > \tau_a$, when R rises, the spread earned by the bank on deposits owned by inattentive households increases more than the corresponding spread for attentive depositors.

A bank in submarket i posts v_i offers to attract depositors. It costs τv_i dollars to pay for v_i posts. The number of dollars of matched deposits in submarket i, m_i, is determined by the following matching function,

$$m_i = \mu u_i^{\varsigma} v_i^{1-\varsigma},$$

where u_i denotes unmatched deposits in submarket i. The probability that an unmatched deposit finds a bank in this submarket is

$$p(\theta_i) = \frac{m_i}{u_i} = \mu u_i^{\varsigma-1} v_i^{1-\varsigma} = \mu \theta_i^{1-\varsigma},$$

where

$$\theta_i = \frac{v_i}{u_i}.$$

The probability that a bank in submarket i fills its posted offer is

$$q(\theta_i) = \frac{m_i}{v_i} = \mu u_i^{\varsigma} v_i^{-\varsigma} = \mu \theta_i^{-\varsigma}.$$

The value of unmatched (U_i) and matched (E_i) deposits in market i are given by

$$rU_i = p(\theta_i)(E_i - U_i) \tag{30}$$

This equation reflects the fact that unmatched deposits earn no interest.

$$rE_i = R_{di} - \delta(E_i - U_i)$$

where r is the net policy rate, δ is the exogenous separation rate, which we assume to be identical in all submarkets, and R_{di} is the gross deposit interest rate in market i.

Solving for E_i and U_i, we obtain,

$$E_i = \frac{R_{di} + \delta U_i}{r + \delta}$$

Combining this equation with equation 30 we obtain

$$rU_i = p(\theta_i) \left(\frac{R_{di} + \delta U_i}{r + \delta} - U_i \right)$$

Solving for U_i,

$$r(r + \delta)U_i = p(\theta_i) \left[R_{di} + \delta U_i - U_i(r + \delta)\right]$$

$$\left[r(r + \delta) - p(\theta_i)\delta + p(\theta_i)(r + \delta)\right] U_i = p(\theta_i)R_{di}$$

$$rU_i = \frac{p(\theta_i)R_{di}}{r + \delta + p(\theta_i)}$$

This equation describes the combinations of deposit rates and matching probabilities that are consistent with a given level of U. Solving for $p(\theta_i)$,

$$rU_i \left[r + \delta + p(\theta_i)\right] = p(\theta_i)R_{di}$$

which yields,

$$p(\theta_i) = \frac{rU_i}{R_{di} - rU_i}(r + \delta) \tag{31}$$

In equilibrium, U_i is identical in all markets with positive depositors. We denote this common value by U, so we write this condition as

$$p(\theta_i) = \frac{rU}{R_{di} - rU}(r + \delta) \tag{32}$$

As is standard in the literature, we assume there is a continuum of submarkets each characterized by a pair of $p(\theta_i)$ and R_{di} consistent with condition (32).

The value of a bank post in market i, B_i, is given by,

$$rB_i = -\tau + q(\theta_i) \left(V_i - B_i\right)$$

where V_i is the value of a one-dollar deposit to a bank, which is given by

$$rV_i = R - R_{di} - \delta V_i$$

Solving for V_i

$$V_i = \frac{R - R_{di}}{r + \delta}$$

Solving for B_i,

$$rB_i = -\tau + q(\theta_i)\left(\frac{R - R_{di}}{r + \delta} - B_i\right)$$

$$B_i = \frac{-\tau + q(\theta_i)\frac{R - R_{di}}{r+\delta}}{r + q(\theta_i)}$$

Each bank maximizes B_i with respect to R_{di} and θ_i subject to the constraint 32, $p(\theta_i) - \frac{rU}{R_{di} - rU}(r + \delta) = 0$.

The first-order conditions for this problem are,

$$\frac{-q(\theta_i)}{[r + q(\theta_i)]\,(r + \delta)} + \lambda \frac{rU}{(R_{di} - rU)^2}(r + \delta) = 0 \tag{33}$$

$$q'(\theta_i)\frac{R - R_{di}}{[r + q(\theta_i)]\,(r + \delta)} - q'(\theta_i)\frac{B_i}{r + q(\theta_i)} + \lambda p'(\theta_i) = 0 \tag{34}$$

Under free entry, $B_i = 0$, so

$$q(\theta_i)\frac{R - R_{di}}{r + \delta} = \tau$$

Using equation 32, we can write equation 33 as,

$$\frac{-q(\theta_i)}{(r + q(\theta_i))(r + \delta)} + \lambda \frac{p(\theta_i)}{R_{di} - rU} = 0 \tag{35}$$

Using the free-entry condition, we can rewrite equation 34 as

$$q'(\theta_i)\frac{R - R_{di}}{[r + q(\theta_i)]\,(r + \delta)} + \lambda p'(\theta_i) = 0 \tag{36}$$

The equations 35, 36, and 32 determine the steady state values of θ_i, R_{di}, and U. Working with these equations we can solve for $R - R_{di}$.

Using the fact that

$$p'(\theta_i) = (1 - \varsigma)\,\mu\theta_i^{-\varsigma},$$

$$q'(\theta_i) = -\varsigma\mu\theta_i^{-\varsigma-1},$$

we obtain

$$\lambda = \frac{\varsigma}{(1-\varsigma)\,\theta_i} \frac{R - R_{di}}{[r + q(\theta_i)]\,(r+\delta)}$$

$$\frac{-q(\theta_i)}{(r+q(\theta_i))(r+\delta)} + \lambda \frac{p(\theta_i)}{R_{di} - rU} = 0$$

$$\frac{-q(\theta_i)}{(r+q(\theta_i))(r+\delta)} + \frac{\varsigma}{(1-\varsigma)\,\theta_i} \frac{R - R_{di}}{[r + q(\theta_i)]\,(r+\delta)} \frac{p(\theta_i)}{R_{di} - rU} = 0$$

$$\frac{q(\theta_i)}{(r+q(\theta_i))(r+\delta)} = \frac{\varsigma}{(1-\varsigma)\,\theta_i} \frac{R - R_{di}}{[r + q(\theta_i)]\,(r+\delta)} \frac{p(\theta_i)}{R_{di} - rU}$$

$$\frac{p(\theta_i)}{q(\theta_i)} = \frac{\mu\theta_i^{1-\varsigma}}{\mu\theta_i^{-\varsigma}} = \theta_i,$$

$$1 = \frac{\varsigma}{(1-\varsigma)} \frac{R - R_{di}}{R_{di} - rU}$$

$$rU = R_{di} - \frac{\varsigma}{(1-\varsigma)}\,(R - R_{di})$$

We now use the constraint

$$p(\theta_i) = \frac{rU}{R_{di} - rU}(r+\delta)$$

$$p(\theta_i) = \frac{R_{di} - \frac{\varsigma}{(1-\varsigma)}\,(R - R_{di})}{\frac{\varsigma}{(1-\varsigma)}\,(R - R_{di})}(r+\delta)$$

$$p(\theta_i) = \frac{1-\varsigma}{\varsigma} \frac{R_{di}}{R - R_{di}}(r+\delta) - (r+\delta)$$

Using the free-entry condition,

$$q(\theta_i) \frac{R - R_{di}}{r+\delta} = \tau$$

$$q(\theta_i) = \mu\theta_i^{-\varsigma} = \frac{\tau}{R - R_{di}}\,(r+\delta)$$

$$\theta_i = \left[\frac{1}{\mu} \frac{\tau}{R - R_{di}}\,(r+\delta) \right]^{-1/\varsigma}$$

Combining,

$$\frac{p(\theta_i)}{q(\theta_i)} = \frac{\frac{1-\varsigma}{\varsigma} \frac{R_{di}}{R - R_{di}}(r+\delta) - (r+\delta)}{\frac{\tau}{R - R_{di}}\,(r+\delta)}$$

$$\frac{p(\theta_i)}{q(\theta_i)} = \frac{\frac{1-\varsigma}{\varsigma}R_{di} - (R - R_{di})}{\tau}$$

$$\frac{p(\theta_i)}{q(\theta_i)} = \theta_i = \frac{\frac{1-\varsigma}{\varsigma}R_{di} - (R - R_{di})}{\tau}$$

$$\left[\frac{1}{\mu}\frac{\tau}{R - R_{di}}(r+\delta)\right]^{-1/\varsigma} = \frac{\frac{1-\varsigma}{\varsigma}R_{di} - (R - R_{di})}{\tau}$$

$$\frac{\varsigma}{1-\varsigma}\tau\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma} = R_{di} - \frac{\varsigma}{1-\varsigma}(R - R_{di})$$

$$R_{di} = \frac{\varsigma}{1-\varsigma}\left[(R - R_{di}) + \tau\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma}\right]$$

$$R_{di} = \varsigma\left[R + \tau\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma}\right]$$

13.1 Properties of the model

The first property is that R_{di} is a decreasing function of τ

$$dR_{di} = \varsigma\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma} d\tau - \tau\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{\tau^2}\frac{R - R_{di}}{r+\delta}d\tau - \tau\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{\tau(r+\delta)}dR_{di}$$

$$dR_{di} = (\varsigma - 1)\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma} d\tau - \left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{(r+\delta)}dR_{di}$$

$$\frac{dR_{di}}{d\tau} = \frac{(\varsigma-1)\left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma}}{1 + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{(r+\delta)}} < 0.$$

Since the cost of attracting an inattentive depositor is higher than that of attracting an attentive depositor, this property implies that the equilibrium interest rate spread is larger for inattentive depositors than for attentive depositors.

The second property is that the interest rate spread $R - R_{di}$ is an increasing function of R

$$R_{di} = \varsigma\left[R + \tau\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma}\right]$$

$$dR_{di} = \varsigma dR + \tau\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{\tau}\frac{dR - dR_{di}}{r+\delta}$$

$$dR_{di} = \varsigma dR + \left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma - 1} \frac{\mu}{r+\delta}(dR - dR_{di})$$

$$dR_{di}\left[1 + \left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma - 1} \frac{\mu}{r+\delta}\right] = \varsigma dR + \left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma - 1} \frac{\mu}{r+\delta} dR$$

$$\frac{dR_{di}}{dR} = \frac{\varsigma + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}}{1 + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}} < 1$$

The third property is that

$$\frac{d^2(R - R_{di})}{d^2 R} < 0$$

$$\frac{d(R - R_{di})}{dR} = 1 - \frac{dR_{di}}{dR} = 1 - \frac{\varsigma + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}}{1 + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}}$$

$$\frac{d(R - R_{di})}{dR} = 1 - \frac{dR_{di}}{dR} = \frac{1 + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}}{1 + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}} - \frac{\varsigma + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}}{1 + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}}$$

$$\frac{d(R - R_{di})}{dR} = 1 - \frac{dR_{di}}{dR} = \frac{1 - \varsigma}{1 + \left(\frac{\mu}{\tau}\frac{R-R_{di}}{r+\delta}\right)^{1/\varsigma-1}\frac{\mu}{r+\delta}}$$

$$\frac{d(R - R_{di})}{dR} = 1 - \frac{dR_{di}}{dR} = (1 - \varsigma)\left[1 + \left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma - 1} \frac{\mu}{r+\delta}\right]^{-1}$$

$$\frac{d^2(R - R_{di})}{d^2 R} = -(1 - \varsigma)\left[1 + \left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma - 1} \frac{\mu}{r+\delta}\right]^{-2}$$
$$\bullet \frac{\mu}{r+\delta}(1/\varsigma - 1)\left(\frac{\mu}{\tau}\frac{R - R_{di}}{r+\delta}\right)^{1/\varsigma - 2} \frac{\mu}{\tau(r+\delta)}\left(1 - \frac{dR_{di}}{dR}\right)$$

Recall that $\frac{dR_{di}}{dR} < 1$, so this expression is negative.

14 General Equilibrium Model

Intermediate goods producers To compute marginal cost, s_{jt}, we solve the following problem,

$$S_{jt} = min_{K_{jt},N_{jt}} R_t^l [r_t^k K_{jt} + w_t N_{jt}]$$

subject to

$$Y_{jt} = (K_{jt})^{\alpha} N_{jt}^{1-\alpha}.$$

The first-order conditions for this problem are,

$$R_t^l r_t^K = s_{jt}\alpha(K_{jt})^{\alpha-1}N_{jt}^{1-\alpha},$$

$$R_t^l w_t = s_{jt}(1-\alpha)(K_{jt})^{\alpha}N_{jt}^{-\alpha}.$$

Combining,

$$\frac{r_t^K}{w_t} = \frac{\alpha N_{jt}}{(1-\alpha)K_{jt}}$$

We can now compute the j^{th} firm's real marginal cost, s_{jt},

$$s_{jt} = \frac{R_t^l \left(r_t^K\right)^{\alpha} w_t^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}$$

The profits of intermediate-good producer j at time t are:

$$\pi_{jt} = P_{jt}Y_{jt} - P_t s_{jt} Y_{jt}.$$

The first-order conditions for optimal price setting are:

$$\begin{aligned}
Z_{1,t} &= \gamma s_t \lambda_t^b P_t Y_t + \beta\xi E_t \left(\frac{\Pi^{\iota}}{\Pi_{t+1}}\right)^{\frac{\gamma}{1-\gamma}} Z_{1,t+1} \\
Z_{2,t} &= \lambda_t^b P_t Y_t + \beta\xi E_t \left(\frac{\Pi^{\iota}}{\Pi_{t+1}}\right)^{\frac{1}{1-\gamma}} Z_{2,t+1} \\
Z_{1,t} &= Z_{2,t} \left(\frac{1-\xi\left(\frac{\Pi^{\iota}}{\Pi_t}\right)^{\frac{1}{1-\gamma}}}{1-\xi}\right)^{(1-\gamma)}.
\end{aligned}$$

The inverse price dispersion term is given by:

$$\breve{p}_t = \left[(1-\xi)\left(\frac{1-\xi\left(\frac{\Pi^{\iota}}{\Pi_t}\right)^{\frac{1}{1-\gamma}}}{1-\xi}\right)^{\gamma} + \xi\frac{\left(\frac{\Pi^{\iota}}{\Pi_t}\right)^{\frac{\gamma}{1-\gamma}}}{\breve{p}_{t-1}}\right]^{-1}.$$

Households *Hand-to-mouth households*

Their labor supply is demand-determined, and their consumption is given by

$$P_t C_{jt}^H = R_{jt} W_t N_{jt}^H.$$

To implement the labor allocation rules above, we need to compute the steady state hours worked for these households in a version of the model with flexible prices and wages,

$$E_t \sum_{l=0}^{\infty} \beta^t \left\{ \ln(C_{j,t+l}^H - bC_{j,t+l-1}^H) - \psi\frac{(N_{j,t+l}^H)^{1+\eta}}{1+\eta} \right\}$$

$$P_t C_{jt}^H = R_{jt} W_t N_{jt}^H.$$

The first-order conditions are,

$$\frac{1}{C_{j,t}^H - bC_{j,t-1}^H} - E_t \frac{\beta b}{C_{j,t+1}^H - bC_{j,t}^H} = \lambda_t^H P_t,$$

$$\psi (N_{jt}^H)^\eta = \lambda_t^H R_{jt} W_t$$

where λ_t^H is the Lagrange multiplier associated with the budget constraint.

Permanent income households

$$U_t = E_t \sum_{l=0}^{\infty} \beta^l \left\{ \ln(C_{t+l}^P - bC_{t+l-1}^P) - \psi \frac{(N_{t+l}^P)^{1+\eta}}{1+\eta} \right\}, \tag{37}$$

subject to

$$P_t \left(C_t^P + I_t\right) + B_{t+1} - R_{t-1} B_t + \Psi_t = \left(W_t N_t^P + R_t^K u_t \bar{K}_t - D_t^P\right) + D_t^P R_{at} + \Phi_t, \tag{38}$$

$$\sigma_0 + \sigma_1 (u_t - 1) + \frac{\sigma_2}{2} (u_t - 1)^2 - \Delta(u_t) = 0,$$

$$\left[1 - \Delta(u_t)\right] \bar{K}_t + \left[1 - \frac{s_I}{2} \left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t - \bar{K}_{t+1} = 0. \tag{39}$$

It is useful to compute

$$\Delta'(u_t) = \sigma_1 + \sigma_2 (u_t - 1).$$

We first need to compute the steady state where they choose their labor supply. The first order condition is:

$$\psi (N_t^P)^\eta = \lambda_t^P R_{jt} W_t.$$

Next, we need to compute all other FOCs:

$$\frac{1}{C_t^P - bC_{t-1}^P} - E_t \frac{\beta b}{C_{t+1}^P - bC_t^P} = \lambda_t^P P_t$$

$$\lambda_t^P = E_t \beta R_t \lambda_{t+1}^P$$

$$-\lambda_t^K + \beta E_t \lambda_{t+1}^K \left[1 - \delta(u_{t+1})\right] + \beta E_t \lambda_{t+1}^P R_{a,t+1} R_{t+1}^K u_{t+1} = 0,$$

$$-\lambda_t^P P_t + \lambda_t^K \left[1 - \frac{s_I}{2} \left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] - \lambda_t^K s_I \left(\frac{I_t}{I_{t-1}} - 1\right) \frac{I_t}{I_{t-1}} + \beta E_t \lambda_{t+1}^K s_I \left(\frac{I_{t+1}}{I_t} - 1\right) \left(\frac{I_{t+1}}{I_t}\right)^2 = 0,$$

$$\lambda_t^P R_{a,t} R_t^K - \lambda_t^K \left[\sigma_1 + \sigma_2 (u_t - 1)\right] = 0$$

Aggregate consumption

Aggregate consumption, C_t, is the average of the consumption of HTM attentive, inattentive, and PI households weighted by their weight in the population,

$$C_t = \phi C_t^P + a_t^H C_{at}^H + i_t^H C_{it}^H.$$

Aggregate resource constraint The aggregate resource constraint is given by:

$$Y_t = \breve{p}_t \left(u_t \bar{K}_t\right)^{\alpha} N_t^{1-\alpha} = C_t + I_t + G_t + \tilde{v}_{at}\tau_a + \tilde{v}_{it}\tau_i + \varepsilon^l \left(w_t N_t + r_t^K u_t \bar{K}_t\right).$$

where $\widetilde{v}_{at}\tau_a + \tilde{v}_{it}\tau_i$ are the costs incurred by banks to attract attentive and inattentive depositors, respectively.

Equilibrium equations After scaling nominal variables, we can write the equilibrium equations as follows

$$a_{t+1}^H = a_t^H(1-\kappa_a) + \omega(R_t)(\phi + a_t^H)(1-\phi-a_t^H)(1-\kappa_i) + \kappa_i(1-\phi-a_t^H)$$

$$\omega(R_t) = \chi\left(4R_t - 4\right)^2$$

$$a_t^H + i_t^H + \phi = 1$$

$$a_t = a_t^H + \phi$$

$$Y_t = C_t + I_t + G_t + \tilde{v}_{at}\tau_a + \tilde{v}_{it}\tau_i + \varepsilon^l \left(w_t N_t + r_t^K u_t \bar{K}_t\right)$$

$$Y_t = \breve{p}_t \left(u_t \bar{K}_t\right)^{\alpha} N_t^{1-\alpha}$$

$$C_t = \phi C_t^P + a_t^H C_{at}^H + i_t^H C_{it}^H$$

$$N_t = \phi N_t^P + a_t^H N_{at}^H + i_t^H N_{it}^H$$

$$\lambda_t^K = \beta E_t \lambda_{t+1}^K \left[1 - \Delta(u_{t+1})\right] + \beta E_t \widetilde{\lambda}_{t+1}^P R_{a,t+1} r_{t+1}^K u_{t+1}$$

$$\tilde{\lambda}_t^P = \beta E_t \frac{R_t}{\Pi_{t+1}} \tilde{\lambda}_{t+1}^P$$

$$-\widetilde{\lambda}_t^P + \lambda_t^K \left[1 - \frac{s_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] - \lambda_t^K s_I \left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} + \beta E_t \lambda_{t+1}^K s_I \left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2 = 0$$

$$\widetilde{\lambda}_t^P R_{at} r_t^K - \lambda_t^K \left[\sigma_1 + \sigma_2(u_t - 1)\right] = 0$$

$$\frac{1}{C_t^P - bC_{t-1}^P} - E_t \frac{\beta b}{C_{t+1}^P - bC_t^P} = \widetilde{\lambda}_t^P$$

$$\bar{K}_{t+1} = \left[1 - \Delta(u_t)\right]\bar{K}_t + \left[1 - \frac{s_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t$$

$$\Delta(u_t) = \sigma_0 + \sigma_1(u_t - 1) + \frac{\sigma_2}{2}(u_t - 1)^2$$

$$C_{at}^H = R_{at} w_t N_{at}^H$$

$$C_{it}^H = R_{it} w_t N_{it}^H$$

$$\breve{p}_t = \left[(1-\xi)\left(\frac{1-\xi\left(\frac{\Pi^\iota}{\Pi_t}\right)^{\frac{1}{1-\gamma}}}{1-\xi}\right)^{\gamma} + \xi\frac{\left(\frac{\Pi^\iota}{\Pi_t}\right)^{\frac{\gamma}{1-\gamma}}}{\breve{p}_{t-1}}\right]^{-1}$$

$$\begin{aligned}
Z_{1t} &= \gamma s_t \widetilde{\lambda}_t^P Y_t + \beta\xi E_t\left(\frac{\Pi^\iota}{\Pi_{t+1}}\right)^{\frac{\gamma}{1-\gamma}} Z_{1,t+1} \\
Z_{2t} &= \widetilde{\lambda}_t^P Y_t + \beta\xi E_t\left(\frac{\Pi^\iota}{\Pi_{t+1}}\right)^{\frac{1}{1-\gamma}} Z_{2,t+1} \\
Z_{1t} &= Z_{2t}\left(\frac{1-\xi\left(\frac{\Pi^\iota}{\Pi_t}\right)^{\frac{1}{1-\gamma}}}{1-\xi}\right)^{(1-\gamma)}
\end{aligned}$$

$$s_t = \frac{R_t^l\left(r_t^K\right)^\alpha w_t^{1-\alpha}}{\alpha^\alpha(1-\alpha)^{1-\alpha}}$$

$$\frac{r_t^K}{w_t} = \frac{\alpha N_t}{(1-\alpha)u_t\bar{K}_t}$$

$$GDP_t = C_t + I_t + G_t$$

$$\ln(R_t) = (1-\rho)\ln(R) + \rho\ln(R_{t-1}) + (1-\rho)\left[\theta_\pi\ln\left(\frac{\Pi_t}{\bar{\Pi}}\right) + \theta_y\ln\left(\frac{GDP_t}{GDP}\right)\right] + \varepsilon_t$$

$$\tau_a\widetilde{\upsilon}_{at} = \frac{\delta\tau_a}{\mu^{1/(1-\varsigma)}}\phi d_t^P + \frac{\delta\tau_a}{\mu^{1/(1-\varsigma)}}a_t^H d_{at}^H$$

$$\tau_i\widetilde{\upsilon}_{it} = \frac{\delta\tau_i}{\mu^{1/(1-\varsigma)}}i_t^H d_{it}^H$$

$$nim_t = \varepsilon^l + \frac{\phi d_t^P + a_t^H d_{at}^H}{\phi d_t^P + a_t^H d_{at}^H + i_t^H d_{it}^H}(R_t - R_{at}) + \frac{i_t^H d_{it}^H}{\phi d_t^P + a_t^H d_{at}^H + i_t^H d_{it}^H}(R_t - R_{it})$$

$$d_t^P = w_t N_t^P + r_t^K u_t \bar{K}_t$$

$$d_{at}^H = w_t N_{at}^H$$

$$d_{it}^H = w_t N_{it}^H$$

$$R_t - R_{it} = \frac{\tau_i}{\mu^{1/(1-\varsigma)}} - E_t\frac{1-\delta}{R_t/\Pi_{t+1}}\left[\frac{\tau_i}{\mu^{1/(1-\varsigma)}} - \left(\omega(R_t)(\phi + a_t^H)(1-\kappa_i) + \kappa_i\right)\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\right]$$

$$R_t - R_{at} = \frac{\tau_a}{\mu^{1/(1-\varsigma)}} - E_t\frac{1-\delta}{R_t/\Pi_{t+1}}\left[\frac{\tau_a}{\mu^{1/(1-\varsigma)}} + \kappa_a\upsilon_t\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\right]$$

$$\upsilon_t = \frac{a_t^H d_{at}^H}{\phi d_t^P + a_t^H d_{at}^H}$$

$$R_t^l = R_t + \varepsilon^l$$

$$G_t = G$$

With flexible prices and wages, we have the following equations for labor supply and the equilibrium wage:

$$\psi(N_t^P)^\eta = \left(\frac{1}{C_t^P - bC_{t-1}^P} - E_t\frac{\beta b}{C_{t+1}^P - bC_t^P}\right) R_{at}w_t$$

$$\psi(N_{at}^H)^\eta = \left(\frac{1}{C_{a,t}^H - bC_{a,t-1}^H} - E_t\frac{\beta b}{C_{a,t+1}^H - bC_{a,t}^H}\right) R_{at}w_t$$

$$\psi(N_{it}^H)^\eta = \left(\frac{1}{C_{i,t}^H - bC_{i,t-1}^H} - E_t\frac{\beta b}{C_{i,t+1}^H - bC_{i,t}^H}\right) R_{it}w_t$$

With sticky prices and wages, the above equations for labor supply and the equilibrium wage are replaced by

$$N_{at}^H = \frac{N_a^H}{N}N_t$$

$$N_{it}^H = \frac{N_i^H}{N}N_t$$

$$ln\left(\frac{w_t}{w}\right) = \vartheta_1 ln\left(\frac{w_{t-1}}{w}\right) + \vartheta_2 ln\left(\frac{N_t}{N}\right).$$

Above, we have made use of the following expressions:

$$\widetilde{\lambda}_t^P = \lambda_t^P P_t$$

$$\widetilde{\upsilon}_{jt} = \frac{\upsilon_{jt}}{P_t}$$

$$W_t = w_t P_t$$

$$d_t^p = \frac{D_t^p}{P_t}$$

$$d_{at}^H = \frac{D_{at}^H}{P_t}$$

$$d_{it}^H = \frac{D_{it}^H}{P_t}$$

We have a system of 39 equations in 39 unknowns:

$$Y_t, C_t, I_t, G_t, \bar{K}_t, GDP_t, N_t, \tau_a\widetilde{\upsilon}_{at}, \tau_i\widetilde{\upsilon}_{it}, \breve{p}_t$$

$$C_t^P, C_{at}^H, C_{it}^H, N_t^P, N_{at}^H, N_{it}^H, u_t, w_t, Z_{1t}, Z_{2t}$$

$$\lambda_t^K, \widetilde{\lambda}_t^P, \Delta(u_t), r_t^K, \Pi_t, s_t, R_{at}, R_{it}, R_t^l, R_t$$

$$nim_t, \upsilon_t, a_t, i_t^H, a_t^H, d_t^P, d_{at}^H, d_{it}^H, \omega(R_t)$$

Steady state Fix a value for the nominal interest rate, R, in steady state. Then,

$$\omega(R) = \chi\left(4R - 4\right)^2$$

The law of motion for a^H can be written as:

$$\left(a^H\right)^2 \omega(R)(1-\kappa_i) - a^H\left[\omega(R)(1-\kappa_i)\left(1-2\phi\right) - \kappa_a - \kappa_i\right] - (1-\phi)\left[\phi\omega(R)(1-\kappa_i) + \kappa_i\right] = 0$$

Solving yields:

$$\begin{aligned} a^H &= \left[\omega(R)(1-\kappa_i)\left(1-2\phi\right) - \kappa_a - \kappa\right]_i / 2\omega(R)(1-\kappa_i) \\ &\pm \left\{\sqrt{\left[\omega(R)(1-\kappa_i)\left(1-2\phi\right) - \kappa_a - \kappa_i\right]^2 + 4\left(1-\phi\right)\omega(R)(1-\kappa_i)\left[\phi\omega(R)(1-\kappa_i) + \kappa_i\right]}\right\} / 2\omega(R)(1-\kappa_i) \end{aligned}$$

Proceed with the positive solution for a^H. Then,

$$i^H = 1 - \phi - a^H$$

$$a = a^H + \phi$$

$$\Pi = \beta R$$

$$R^l = R + \varepsilon^l$$

$$R_i = R - \frac{\tau_i}{\mu^{1/(1-\varsigma)}} + \frac{1-\delta}{R/\Pi}\left[\frac{\tau_i}{\mu^{1/(1-\varsigma)}} - \left(\omega(R)(\phi + a^H)(1-\kappa_i) + \kappa_i\right)\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\right]$$

$$\breve{p} = \frac{1 - \xi\Pi^{\gamma\frac{\iota-1}{1-\gamma}}}{(1-\xi)\left(\frac{1-\xi\Pi^{\frac{\iota-1}{1-\gamma}}}{1-\xi}\right)^{\gamma}}$$

$$s = \frac{1}{\gamma}\quad \frac{1 - \beta\xi\Pi^{\gamma\frac{\iota-1}{1-\gamma}}}{1 - \beta\xi\Pi^{\frac{\iota-1}{1-\gamma}}}\left(\frac{1 - \xi\Pi^{\frac{\iota-1}{1-\gamma}}}{1-\xi}\right)^{(1-\gamma)}$$

Guess a value for υ_t between 0 and 1. Then:

$$R_a = R - \frac{\tau_a}{\mu^{1/(1-\varsigma)}} + \frac{1-\delta}{R/\Pi}\left[\frac{\tau_a}{\mu^{1/(1-\varsigma)}} + \kappa_a\upsilon\frac{\tau_i - \tau_a}{\mu^{1/(1-\varsigma)}}\right]$$

Guess a value for r^k. Then:

$$u = \frac{R_a r^K - \sigma_1}{\sigma_2} + 1$$

Rig parameters $\sigma_0, \sigma_1, \sigma_2$ later on. Also:

$$\Delta(u) = \sigma_0 + \sigma_1(u-1) + \frac{\sigma_2}{2}(u-1)^2$$

$$w=\left[\frac{s\alpha^{\alpha}(1-\alpha)^{1-\alpha}}{R^{l}\left(r^{K}\right)^{\alpha}}\right]^{\frac{1}{1-\alpha}}$$

$$N_{a}^{H}=\left[\frac{1-\beta b}{\psi\left(1-b\right)}\right]^{\frac{1}{1+\eta}}$$

$$N_{i}^{H}=\left[\frac{1-\beta b}{\psi\left(1-b\right)}\right]^{\frac{1}{1+\eta}}$$

$$C_{a}^{H}=R_{a}wN_{a}^{H}$$

$$C_{i}^{H}=R_{i}wN_{i}^{H}$$

$$d_{a}^{H}=wN_{a}^{H}$$

$$d_{i}^{H}=wN_{i}^{H}$$

$$d^{P}=\frac{\left(1-\upsilon\right)a^{H}d_{a}^{H}}{\upsilon\phi}$$

$$\tau_{a}\widetilde{\upsilon}_{a}=\delta\frac{\tau_{a}}{\mu^{1/(1-\varsigma)}}\phi d^{P}+\delta\frac{\tau_{a}}{\mu^{1/(1-\varsigma)}}a^{H}d_{a}^{H}$$

$$\tau_{i}\widetilde{\upsilon}_{i}=\delta\frac{\tau_{i}}{\mu^{1/(1-\varsigma)}}i^{H}d_{i}^{H}$$

Guess a value for N^{P}. Then:

$$N=\phi N^{P}+a^{H}N_{a}^{H}+i^{H}N_{i}^{H}$$

$$\bar{K}=\frac{\alpha Nw}{(1-\alpha)ur^{K}}$$

$$Y=\breve{p}\left(u\bar{K}\right)^{\alpha}N^{1-\alpha}$$

$$I=\Delta(u)\bar{K}$$

$$C^{P}=\frac{1-\beta b}{\left(1-b\right)\psi(N^{P})^{\eta}}R_{a}w$$

$$C=\phi C^{P}+a^{H}C_{a}^{H}+i^{H}C_{i}^{H}$$

$$\widetilde{\lambda}^{P}=\frac{1-\beta b}{\left(1-b\right)C^{P}}$$

$$\lambda^{K}=\widetilde{\lambda}^{P}$$

Finally,

$$Z_{1}=\frac{\gamma s\widetilde{\lambda}^{P}Y}{1-\beta\xi\Pi^{\gamma\frac{\iota-1}{1-\gamma}}}$$

$$Z_{2}=\frac{\widetilde{\lambda}^{P}Y}{1-\beta\xi\Pi^{\frac{\iota-1}{1-\gamma}}}$$

$$nim = \varepsilon^l + \frac{\phi d^P + a^H d_a^H}{\phi d^P + a^H d_a^H + i^H d_i^H} (R - R_a) + \frac{i^H d_i^H}{\phi d^P + a^H d_a^H + i^H d_i^H} (R - R_i)$$

Set G such that G/GDP equals a desired value from the data. Then:

$$GDP = \frac{C + I}{1 - \frac{G}{GDP}}$$

$$G = \frac{G}{GDP} GDP$$

Adjust the three guesses for υ, r^k and N^P so that the following three equations hold with equality:

$$1 = \beta \left[1 - \Delta(u)\right] + \beta R_a r^K u$$

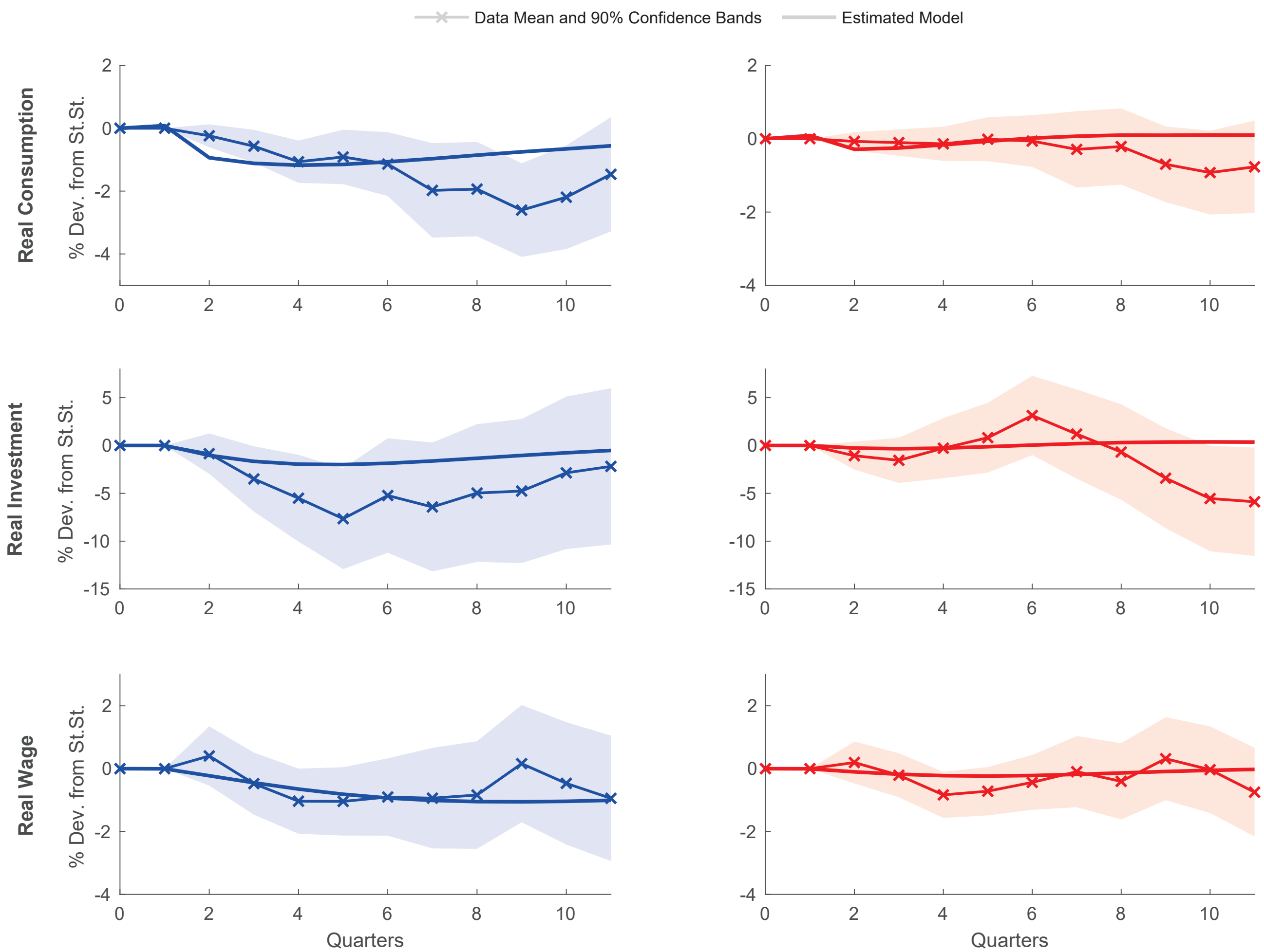
$$d^P = wN^P + r^K u\bar{K}$$

$$Y = C + I + G + \tilde{\upsilon}_a \tau_a + \tilde{\upsilon}_i \tau_i + \varepsilon^l \left(wN + r^K u\bar{K}\right)$$

15 Additional results for GE model

Figure 19 reports the responses of consumption, investment and real wages to a monetary shock.

Figure 19: Estimated general equilibrium model. Impulse responses to a monetary policy shock of 100 b.p., annualized. Consumption, Investment and Real Wages: data vs. model. Units in deviation from steady state or data baseline, respectively.



Note: This figure compares the theoretical impulse response functions (IRFs) generated from the estimated general equilibrium banking model with their empirical counterparts discussed in Section 4. Solid lines represent the model-generated IRFs. Solid lines with "x" markers depict the corresponding empirical IRFs. The shaded areas represent the 90 percent confidence bands for the empirical IRFs.

The response of real wages to a monetary policy shock is muted regardless of which steady state we start from. Consumption and investment display a similar pattern of state dependence.