Why Is Monetary Policy Less Effective at Low Interest Rates: The Role of Banking Sector

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Abstract

This paper investigates the effectiveness of monetary policy in a low-interest-rate environment, focusing on how loan and deposit rates respond to changes in nominal interest rates. Using U.S. bank data, I show that deposit rates reach zero when the policy rate falls to about 2 percent, with both deposit and loan rates becoming unresponsive to further cuts below the threshold. Net interest margins do not shrink, preserving banks' equity and lending capacity to additional policy rate cut. Monetary transmission thus weakens well above the zero lower bound, muting the stimulus to loan demand rather than eroding banks' lending capacity. Stabilizing demand-driven recessions near this threshold requires earlier fiscal coordination.

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1. Introduction

Banks' deposit and loan rates are important channels through which monetary policy is transmitted to the economy. Bank deposits are the primary savings vehicle for many households, so deposit rates directly affect returns on savings, while loan rates shape households' intertemporal borrowing decisions and firms' investment spending. For banks, these two rates determine profitability, as the spread between them is a main source of earnings and, consequently, accumulated equity, which determines their lending capacity. The effectiveness of monetary policy therefore depends on how deposit and loan rates adjust to changes in the policy rate, since these adjustments affect not only the decisions of households and firms but also banks' capacity to create credit.

The literature on monetary policy transmission through the banking sector predicts that low or negative policy rates can undermine the effectiveness of monetary policy, as the pass-through from the policy rate to deposit rates breaks down and lending capacity is ultimately eroded.[1] Because cash offers a zero nominal return, negative deposit rates would prompt households to withdraw their deposits and hold cash instead, which places a lower bound of zero on deposit rates. Because banks set deposit rates below the policy rate by exercising market power as highlighted in Drechsler et al. (2017), this bound binds while the policy rate is still positive, making it distinct from the lower bound on the policy rate. Given this constraint, the conventional view holds that, as the policy rate declines, deposit rates remain stuck at zero while banks continue to lower lending rates. This compresses loan-deposit margins and erodes bank equity through reduced profits. Ulate (2021), Abadi et al. (2023), and Balloch and Koby (2023) formalize this channel, showing that the resulting compression of net interest margins slows the accumulation of bank equity and ultimately reduces lending capacity.[2] Abadi et al. (2023) extend this logic and shows that, once interest rates fall below a certain threshold, known as the reversal interest rate, expansionary monetary policy becomes contractionary.

In this paper, I propose an alternative mechanism through which monetary policy loses effectiveness in low-interest-rate environments: the breakdown of loan-rate pass-through. I provide evidence for this novel mechanism using U.S. bank-level data and exogenous monetary policy shocks. The U.S. banking sector provides a useful setting because the effective lower bound on deposit rates, a key condition underlying the conventional mechanism, can bind even while the

[1] Wang (2025) examine how the pass-through from the *real* rate to loan and deposit rates varies with the level of the real rate and analyze its short-run and long-run effect while do not model the deposit-rate lower bound.

[2] Although these papers study negative nominal interest rate policy, the mechanism begins to operate as soon as the deposit-rate lower bound binds, even while the policy rate is still positive. Beyond this net interest margin channel, the literature identifies several others, including a balance-sheet channel in which falling returns on liquid assets such as reserves and government bonds reduce bank profitability (Eggertsson et al. 2023), household portfolio diversification and bank funding substitution (Onofri et al. 2023), and signaling effects (de Groot and Haas 2023).

policy rate remains positive. Therefore, the adoption of a negative nominal interest rate policy is not necessary to examine this mechanism. Moreover, U.S. banks experienced a prolonged period of low interest rates and accommodative monetary policy, allowing me to examine how banks' deposit and loan rates respond once this bound becomes binding. This mechanism differs from explanations based on weakened bank balance sheets because monetary policy loses effectiveness when further rate cuts no longer reduce borrowing costs, rather than when banks' lending capacity contracts.

To examine how banks respond to expansionary monetary policy shocks when the deposit rate bound is binding, I first estimate a threshold regression to identify the level of the policy rate below which deposit rates cease to respond even as the policy rate continues to decline. Ulate (2021) uses cross-country bank-level data and actual changes in policy rates to estimate the threshold to be approximately 0.5%. In contrast, I estimate the threshold directly using a threshold regression following Hansen (2000) and exogenous monetary policy shocks constructed by Bauer and Swanson (2023), Nakamura and Steinsson (2018), and Acosta et al. (2025). The estimates show that deposit rates cease to respond once the federal funds rate falls below approximately 2%.

I then examine the responses of loan rates using panel local projections (Jordà 2005; Jordà et al. 2022), which allow these responses to vary across regimes. Specifically, I interact monetary policy shocks with indicator variables for whether the federal funds rate is above or below 2% to estimate their effects in each regime. Using the same exogenous monetary policy shocks as in the threshold estimation, I find that both deposit and loan rates cease to respond to monetary policy shocks once the policy rate falls below 2%, even though the policy rate itself continues to decline. These findings are robust to the possibility that low interest rates coincide with other macroeconomic conditions or bank characteristics, such as uncertainty, lending standards, or bank balance-sheet conditions, that may independently affect banks' pricing decisions. The results remain unchanged when these factors and their interactions with monetary policy shocks are included jointly alongside the interactions between the regime indicators and monetary policy shocks. The results are also robust to alternative specifications based on Ramey and Zubairy (2018).

Consistent with the muted responses of loan and deposit rates in the low-interest-rate regime, I find that the loan-deposit spread does not shrink following further expansionary monetary policy shocks and instead remains stable.[3] A direct examination of net interest margins confirms that they

[3]In an independent work, Eichenbaum et al. (2025) study the state-dependent response of bank net interest margins (NIM) to monetary policy shocks but find a different pattern. They report that NIM declines after an expansionary shock in a low policy rate regime, whereas I show that it remains stable across regimes. The discrepancy mainly reflects two differences. First, they define low-rate regimes as periods when the average policy rate is below 4%, following the level at which public attention to *inflation* rises (Pfäuti 2025). By contrast, I estimate the policy-rate threshold at which deposit-rate pass through breaks down. Second, their baseline relies on recursively identified

do not decline in response to expansionary monetary policy shocks, contrary to the conventional view that low interest rates impair bank balance sheets. This result is consistent with Drechsler et al. (2021), who show that U.S. banks' net interest margins remain stable across interest rate cycles, and with Genay et al. (2014), who find that low interest rates have only negligible effects on U.S. bank profitability. The same result holds for other measures of profitability, including return on assets (ROA) and return on equity (ROE).

Next, I find limited evidence that expansionary monetary policy shocks in the low-rate regime weaken bank equity or increase leverage, contrary to the conventional view that low interest rates impair bank balance sheets. Equity remains stable across both book-based and market-based measures, while leverage shows no meaningful increase, suggesting that leverage constraints are unlikely to become binding. This is consistent with U.S. evidence in English et al. (2018), who show that bank stock prices decline following unanticipated increases in the level or slope of the yield curve, implying that monetary easing tends to support bank valuations.[4]

Finally, I test whether the response of lending exhibit policy rate level dependence. Because loan rates do not fall, one would expect lending to fail to expand even though lending capacity remains intact. Consistent with this prediction, the stock of loans on banks' balance sheets ceases to accumulate, and loan applications no longer respond to expansionary monetary policy in the low-rate regime.[5]

To evaluate how the banking sector's state-dependent response affects the effectiveness of monetary policy, I develop a general equilibrium model in which banks intermediate between households that supply deposits and firms that demand loans. Following the money-in-the-utility-function approach of Feenstra (1986) and Krishnamurthy and Vissing-Jorgensen (2012), households derive utility from holding deposits as well as from consumption. This feature allows households to hold deposits alongside risk-free assets that earn the policy rate, generating an endogenous spread between the policy rate and the deposit rate as in Wang (2025) and Jamilov and Monacelli (2025). Firms produce using labor and capital and finance their capital through bank loans. Banks fund loans by issuing deposits and are constrained by the equity they carry into each period. When setting loan rates, banks account for both their deposit funding costs and the cost of leverage.

When calibrated to the U.S. economy, the model reproduces the empirically estimated impulse

monetary policy shocks. Instead, I use high-frequency identified monetary policy shocks. Section 4.2.2 discusses these differences in detail.

[4] Evidence from Europe is more mixed. While Altavilla et al. (2018) show, using monetary policy surprises, that easing shocks improve euro-area bank stock prices, Basten and Mariathasan (2023) and Ampudia and Van den Heuvel (2022) find that low or negative rates in the euro area are associated with weaker bank equity outcomes and reduced lending. See also Claessens et al. (2018), Eisenshmidt and Smets (2019), Lopez et al. (2020), and Eggertsson et al. (2023).

[5] While theoretical papers share a core mechanism in which compressed net interest margins and eroded equity dampen monetary policy effectiveness, the empirical evidence is mixed; see Balloch et al. (2022) and Brandao-Marques et al. (2024) for comprehensive reviews.

responses of banking-sector variables, retail rates, loan, and equity, to monetary policy shocks. The model implies that monetary policy becomes less effective in low-rate environments because pass-through from the policy rate to loan rates collapses even without an erosion of bank equity. The model predicts that the output response to an exogenous monetary policy shock depends on the level of the policy rate, with the response nearly halved in the low-rate regime. This attenuation is less severe when firms rely on bonds as well as bank loans because pass-through from the policy rate to corporate bond rates remains intact, allowing monetary easing to continue reducing firms' borrowing costs. In the extended model, where bond financing accounts for 40% of firms' funding, consistent with the aggregate funding structure of U.S. nonfinancial firms, monetary policy retains about two-thirds of its high-rate effectiveness, implying that the loss is reduced from one-half to one-third but remains economically sizable.

This weakening of monetary policy effectiveness in low-interest-rate environments is particularly pronounced during recessions. Following a recessionary shock modeled as a household preference shock, the Taylor rule calls for a reduction in the policy rate, but the effectiveness of this response depends on the *level* of the policy rate. If the recession occurs in the high-rate regime, deposit rates remain responsive, and policy rate cuts reduce banks' funding costs and loan rates, cushioning the declines in lending and output. However, if the recession occurs in the low-rate regime, the monetary policy response is not transmitted to either the deposit rate or the loan rate, resulting in a more severe recession and larger output losses than in the high-rate regime. Consequently, increasing the responsiveness of the Taylor rule to the output gap cannot restore the effectiveness of monetary policy and provides only limited additional stabilization.

When the model incorporates a simple government spending rule that responds to the output gap, fiscal stabilization partly offsets the weakened transmission of monetary policy and supports the recovery from recession. The gains from fiscal intervention are modest when monetary policy remains sufficiently effective to counteract recessionary forces, but become substantially larger in the low-rate regime.

These results have implications for *when* coordination between monetary and fiscal policy is required, suggesting that such coordination is needed even when the policy rate is above the zero lower bound. Much of the existing literature argues that fiscal policy becomes necessary when monetary policy loses effectiveness at the zero lower bound for the policy rate. For example, Eggertsson and Woodford (2003) argue that stabilization at the lower bound requires a more active role for fiscal instruments, while Christiano et al. (2011) show that the government spending multiplier is substantially larger when the zero lower bound binds. This paper suggests, however, that the need for fiscal support may arise well before the policy rate reaches zero. Because monetary transmission through the banking sector can weaken once deposit rates reach their own lower bound, monetary policy may become constrained at a positive policy rate once the banking sector is taken into account. Therefore, fiscal and monetary policy coordination may be particularly valuable not only at the zero lower bound, but also when the policy rate itself remains unconstrained while its transmission through the banking sector is dampened.

Roadmap. The rest of this paper is organized as follows. Section 2 describes the data and monetary policy shock measures. Section 3 presents the threshold regression and state-dependent panel local projection methodology. Section 4 reports the empirical results for bank interest rates, profitability, equity, leverage, and lending activity, together with robustness checks. Section 5 develops the general equilibrium model. Section 6 presents the calibration and evaluates the model's quantitative performance, the loss of monetary policy effectiveness during recessions, the stabilizing role of fiscal policy, and the extension incorporating bond financing. Section 7 concludes.

2. Data

In this paper, I use data from several datasets to analyze the response of bank variables to monetary policy shocks and test their dependence on the policy rate level.

2.1. Bank-level Data

Bank-level data is from Consolidated Reports of Condition and Income (Call Reports) of U.S. banks provided by Wharton Research Data Services (WRDS).[6] The data span from 1986:Q1 to 2019:Q4 and include quarterly observations of U.S. commercial banks' balance sheets and income statements.[7] For publicly traded banks, Call Report data are matched to equity prices from the Center for Research in Security Prices (CRSP) using code provided by the Federal Reserve Bank of New York.[8] Bank default probabilities are estimated using the indices constructed by Nagel and Purnanandam (2020) and also merged to Call Report data.

[6] I follow the data cleaning process code from Drechsler et al. (2017, 2021)

[7] The sample is restricted to banks reporting at least 20 quarterly observations between 1986 and 2019. Drechsler et al. (2017) restricted their sample to banks reporting more than 60 quarters for estimating interest income beta and interest expense beta. The local projection horizon considered here is 16 quarters, and I use a minimum of 20 quarters. The results are robust to using 40 or 60 quarters.

[8] https://www.newyorkfed.org/research/banking_research/datasets

2.2. Aggregate-level Data

Aggregate time series data are obtained from the Federal Reserve Economic Data (FRED) database and include the effective federal funds rate, market yields on U.S. Treasury securities with various maturities (2, 5, and 10 years), real GDP, CPI, the unemployment rate, and the NBER Recession Indicator. For financial market data, I use the excess bond premium constructed by Gilchrist and Zakrajšek (2012). The Macroeconomic/Financial Market Uncertainty index developed by Ludvigson et al. (2021) are drawn from WRDS. Monetary policy uncertainty, as developed by Baker et al. (2016), is obtained from their website. Finally, quarterly aggregate-level bank profile data are from the FDIC Historical Bank Data.[9]

2.3. Monetary Policy Shock Series

Throughout the analysis, I use monetary policy shocks constructed using high-frequency identification strategies. The baseline monetary policy shock is constructed by Bauer and Swanson (2023), who address both the exogeneity and relevance of monetary policy surprises as instruments.[10] For robustness, I use the shock series constructed by Nakamura and Steinsson (2018) and extended by Acosta (2023). I also use the shocks constructed by Acosta et al. (2025).

3. Empirical Methodology

To examine whether banks respond differently to monetary policy across interest rate environments, I proceed in two steps. First, following Hansen (2000), I estimate the policy rate threshold below which further rate cuts no longer pass through to deposit rates. I then use panel local projections to compare the responses of bank interest rates and balance-sheet variables to monetary policy shocks above and below this threshold.

3.1. Threshold Regression Model

I estimate the policy rate level where the monetary policy shock no longer affects the deposit rates. I utilized the exogenous monetary policy shock series and find the threshold where the pass-through of monetary policy shock to deposit rate changes based on the algorithm suggested

[9] https://www.fdic.gov/quarterly-banking-profile

[10] Bauer and Swanson (2023) include speeches by the Fed Chair, thereby doubling the number and importance of announcements (Swanson and Jayawickrema 2023). They also account for the "Fed response to news" channel by orthogonalizing the surprises with respect to macroeconomic and financial data that predate each announcement.

by Hansen (2000).[11] Hansen (2000) provides an asymptotic distribution theory for the threshold estimate and constructs asymptotic confidence intervals by inverting the likelihood ratio statistic. The regression specification estimated is

$$i^D_{t+h} = \begin{cases} \alpha_L + \beta_L \varepsilon_t + \mathbf{X}'_{t-1}\Gamma_L + \zeta_{t+h}, & \text{if} \quad i_{t-1} < \gamma \\ \alpha_H + \beta_H \varepsilon_t + \mathbf{X}'_{t-1}\Gamma_H + \zeta_{t+h} & \text{if} \quad i_{t-1} \geq \gamma. \end{cases} \tag{1}$$

The left-hand side variable, i^D_{t+h}, denotes the deposit rate at time $t+h$, and ε_t on the right-hand side represents the monetary policy shock. X_{t-1} captures other macroeconomic variables, including the lagged inflation rate, unemployment rate, excess bond premium, and the lagged value of the deposit rate. Given a wide and fine grid support, $\Gamma \in [0, 10]$, the regression tests $\beta_L = \beta_H$ by estimating the likelihood ratio statistic, $LR(\gamma)$, at a given $\gamma \in \Gamma$, and checking whether it is less than or equal to the critical value c.

Table 1. Threshold (γ) Estimation Result

Shock	Bauer and Swanson (2023)	Nakamura and Steinsson (2018)	Acosta et al. (2025)
Deposit Rate	**2.40**	**2.40**	**2.40**
($h = 0$)	[1.75, 3.05]	[2.40, 2.40]	[1.75, 2.40]
Deposit Rate	**2.40**	**2.40**	**2.13**
($h = 1$)	[2.22, 2.47]	[2.19, 2.40]	[1.94, 2.47]
Deposit Rate	**1.92**	**1.25**	**1.25**
($h = 4$)	[1.3, 3.06]	[1.01, 1.25]	[1.02, 1.43]

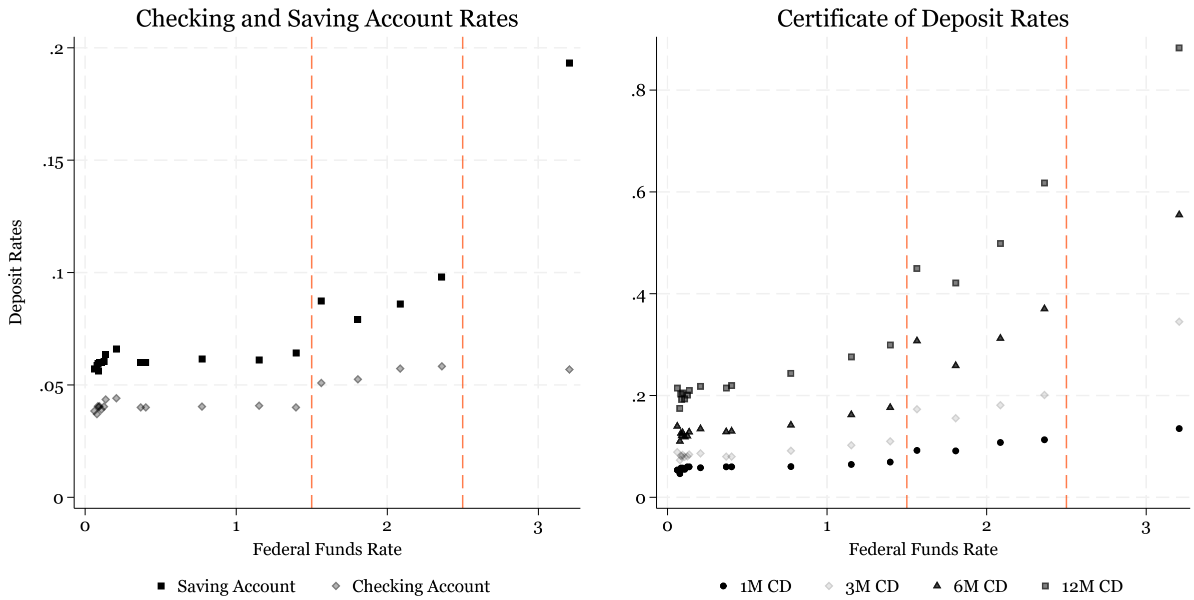
Note. This table displays the point estimate with 95% confidence interval of equation (1) using Hansen (2000) algorithm. The first three rows are estimation result using deposit rate with different leads ($h = 0$, 1, and 4).

Table 1 reports the threshold estimates and their 95% confidence intervals across different monetary policy shock measures and horizons. The horizons correspond to the impact period, one quarter ahead, and one year ahead, allowing sufficient time for the deposit rate to adjust. The estimated thresholds remain broadly stable across the different shock measures and horizons. Accordingly, the baseline analysis sets γ at 2%, while the robustness checks use alternative values within the estimated confidence intervals, such as 1.8% and 2.4%.

Real-time deposit rates setting dynamics confirm the estimation results. Figure 1 plots deposit rate levels, including checking accounts, savings accounts, and certificates of deposit with maturities ranging from one to 12 months, against the federal funds rate. Despite differences across maturities, deposit rates begin to deviate from their lower bound when the federal funds rate rises above 1.5–2%, which is consistent with the threshold estimation results.

[11] Ulate (2021) conducted threshold estimation based on Hansen (1999) under the panel data setting and used policy rate level directly because of the absence of monetary policy shock for each country in data sample.

Figure 1. Deposit Rates and Federal Funds Rates



Note. The figure plots the aggregate national time series of deposit rates from the FDIC against the federal funds rate on the x-axis. Loan rates are calculated as interest income from loans divided by net loans, and deposit rates are calculated as interest expense for deposits divided by total deposits. The data are sourced from the FDIC National Rates and Rate Caps, which are available monthly starting in 2009.

3.2. State-dependent Panel Local Projection

To examine how U.S. banking-sector dynamics respond to exogenous monetary policy shocks and whether these responses differ above and below the estimated policy rate threshold, I employ panel local projections à la Jordà (2005) using a rich panel dataset.

The main specification is as follows.

$$y_{t+h,b} = \beta_h^H \cdot \mathbb{I}\left[i_{t-1} > \gamma\right] \cdot \varepsilon_t + \beta_h^L \cdot \mathbb{I}\left[i_{t-1} \leq \gamma\right] \cdot \varepsilon_t + \mathbf{X}'_{b,t-1}\Gamma_h + \alpha_{b,h} + e_{b,t+h} \tag{2}$$

The left-hand side variable of equation (2), $y_{t+h,b}$, captures the variable of interest at $t+h$, where b denotes the bank index. The indicator functions $\mathbb{I}[i_{t-1} > \gamma]$ and $\mathbb{I}[i_{t-1} \leq \gamma]$ tells whether the policy rate level is higher or lower than the threshold γ or not. Therefore, $\mathbb{I}[i_{t-1} > \gamma]$ indicates the policy rate level where the further policy rate decline is not translated into the cut of deposit rate. The coefficients β_h^H and β_h^L estimate how the monetary policy shock, ε_t, affects the behavior of the outcome in different regime after h quarters the shock. $\mathbf{X}_{b,t-1}$ includes constant, the indicator $\mathbb{I}[i_{t-1} > \gamma]$, the lagged value of the outcome ($y_{t-1,b}$) and both aggregate level economy environment and bank level characteristics that the literature has shown which can simultaneously affect banks' decision. In case of aggregate-level economy environment, I includes lagged value of inflation rate, unemployment rate, the slope of the yield curve, and quarter dummies. In addition, I include recession indicator to control the recessionary effect during the low interest rate environment. The bank-characteristics I control are logarithm level of total assets (size of the bank), security ratio that measures the liquidity of the bank (which is security/asset), and deposit share (which is deposit/liability) emphasized in Eggertsson et al. (2023). $\alpha_{b,h}$ denotes horizon h specific bank fixed effects. The monetary policy shock, ε_t, is normalized so that a positive value corresponds to an expansionary shock. The shock's size is also normalized to induce a decrease in the federal funds rate of 100 basis points on impact.

4. Estimation Results

This section reports the estimated coefficients, β_h^H and β_h^L, for the policy rate, banking variables, and real economy outcomes at horizons $h = 0, \ldots, 16$ of equation (2).

4.1. Policy Rate Response

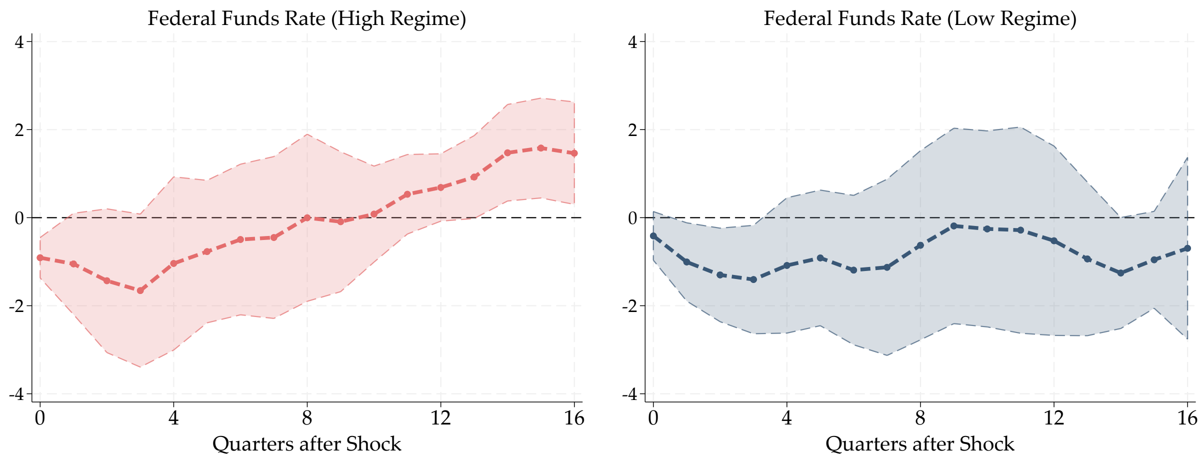
I first estimate the response of the policy rate to test whether the policy rate itself exhibits dependence on its own level. The left panel of Figure 2 describes the estimate of $\{\beta_h^H\}_{h=0}^{16}$ and the right panel illustrates the estimate of $\{\beta_h^L\}_{h=0}^{16}$ of equation (2) for the federal funds rate.[12]

In both regime, the policy rate declines by 100 basis points within one quarter: in the high-interest-rate regime, the policy rate falls by 100 basis points on impact, and in the low-interest-rate regime, the same decline occurs with a one-quarter later and continues to fall for an additional two to three quarters. When the policy rate normalizes after the shocks, it converges more quickly when the initial rate is above the threshold, but remains persistently lower for a longer period when the policy rate environment is below the threshold. In other words, the policy rate exerts stronger and more prolonged downward pressure on the interest rates faced by banks in a low-rate environment, reflecting the Zero Lower Bound (ZLB) periods that the U.S. economy experienced for an extended duration.

As shown in Appendix B, alternative monetary policy shocks constructed by Nakamura and Steinsson (2018) and Acosta et al. (2025) also indicate that policy rate responses do not depend on the prevailing level of the policy rate.

[12]While equation (2) is specified for bank-level data, I estimate the same regression using aggregate data, omitting bank fixed effects and bank-level balance-sheet information from $\mathbf{X}_{t-1}$.

Figure 2. Impulse Responses of Federal Funds Rate to Monetary Policy Shock



Note. The estimated regression equation is $FedFundsRate_{t+h} = \beta_h^H \times \mathbb{I}[i_{t-1} > \gamma] \times \varepsilon_t + \beta_h^L \times \mathbb{I}[i_{t-1} \leq \gamma] \times \varepsilon_t + \Gamma_h' \mathbf{X}_{t-1} + e_{t+h}$ for each horizon $h \in \{0, 1, \ldots, 16\}$ where γ set to be 2%. The upper panels illustrate the sequences of $\{\beta^h\}_{h=0}^H$ and lower panels show sequences of $\{\beta^h\}_{h=0}^H$ with 90% confidence bands. Standard errors are two-way clustered by bank and quarter.

4.2. Loan Rate, Deposit Rate, and Loan-Deposit Spread

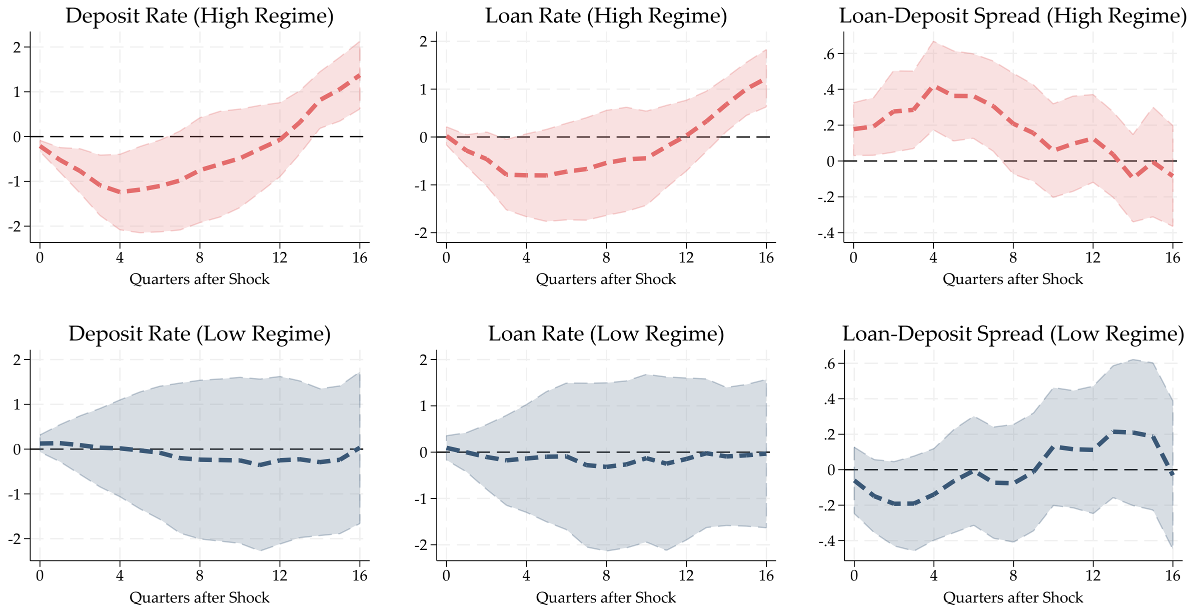
After confirming that the policy rate declines in both regimes, I examine the responses of bank variables, beginning with loan rates, deposit rates, and the loan-deposit spread. The upper panels of Figure 3 present the estimates of β_h^H for each variable, while the lower panels show the corresponding estimates of β_h^L at each horizon h. The left panels of Figure 3 report results for the loan rate, the middle panels for the deposit rate, and the right panels for the loan–deposit spread.

As shown in the upper panels of Figure 3, when the policy rate is set to above 2%, an expansionary monetary policy shock that lowers the policy rate by 100 basis points on impact leads to gradual declines in both lending and deposit rates. After four to five quarters, the loan rate falls by about 80 basis points, while the deposit rate declines by nearly 100 basis points. Consequently, the loan-deposit spread widens by approximately 20 basis points during the first four quarters before returning to its pre-shock level and remaining stable, consistent with Drechsler et al. (2021).[13]

The results for the low-interest-rate regime are displayed in the lower panels of Figure 3. As shown in the lower-left panel, deposit rates remain unresponsive to an expansionary monetary policy shock. This confirms that the estimated threshold properly identifies the policy rate level

[13]Empirical analysis on the effect of policy rate changes to loan-deposit spread is mixed. Literature, including Drechsler et al. (2021) and Ennis et al. (2016), shows there exists weak correlation between net interest margin, measured by the gap between the asset income rate and liability cost rate, and the policy rate dynamics. Taking into account the fact banks usually hold long-term fixed-rate assets (including loans) and floating rate liabilities, a decline of policy rate could lead to an rise of the net interest margin (Paul 2022).

Figure 3. Impulse Responses of Deposit Rate, Loan Rate, and Loan-Deposit Spread to Monetary Policy Shock



Note. The estimated regression equation is $y_{t+h,b} = \beta_h^H \times \mathbb{I}[i_{t-1} > \gamma] \times \varepsilon_t + \beta_h^L \times \mathbb{I}[i_{t-1} \leq \gamma] \times \varepsilon_t + \Gamma_h' \mathbf{X}_{t-1} + \alpha_{b,h} + e_{b,t+h}$ for each horizon $h \in \{0, 1, \ldots, 16\}$ where γ set to be 2%. The upper panels illustrate the sequences of $\{\beta^h\}_{h=0}^H$ and lower panels show sequences of $\{\beta^h\}_{h=0}^H$ with 90% confidence bands. Standard errors are two-way clustered by bank and quarter.

at which the pass-through from the policy rate to deposit rates collapses and aligns with the literature estimation (Greenwald et al. 2023; Emin et al. 2025).

The main results are the estimated coefficients for the loan rate response, displayed in the lower-middle panel. Unlike the assumptions in the literature, loan rates, like deposit rates, cease to respond to expansionary monetary policy even as the policy rate continues to decline, as shown in Figure 2. One possible explanation for the muted response during the first few quarters is that many loan contracts, particularly fixed-rate contracts such as mortgages, have relatively long maturities. Another potential concern is that loan rates are calculated from balance sheet and income statement data and thus capture the average rate on outstanding loans. However, as discussed in relation to the advantages of LP, loan rates remain unresponsive even when their medium-term responses are traced over 16 quarters. Moreover, this result also holds for rates on newly originated loans, as discussed shortly.

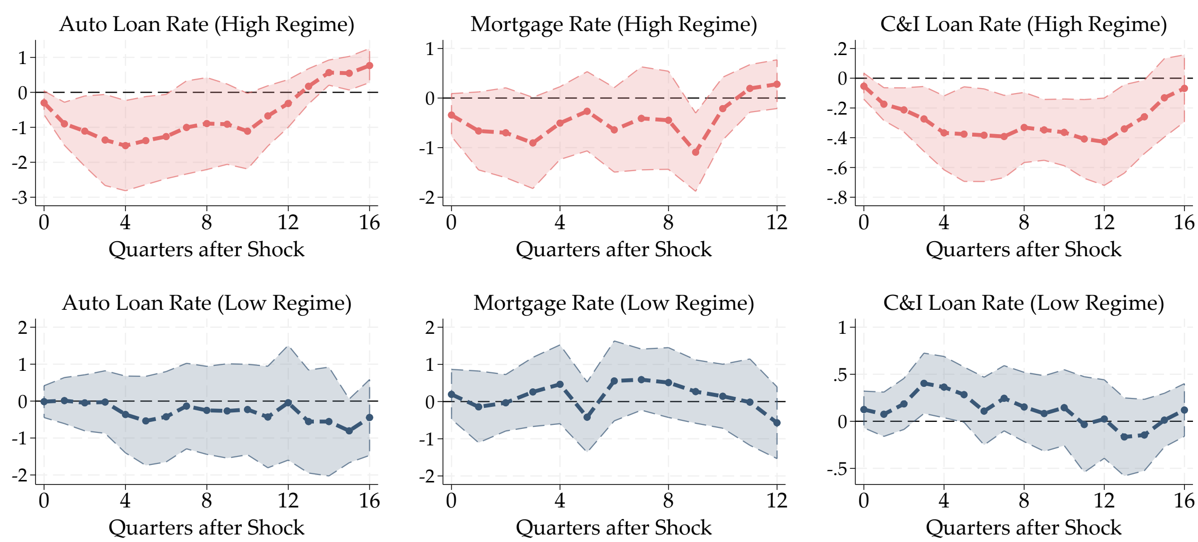
This lack of adjustment in both loan and deposit rates results in a stable loan–deposit spread, as shown in the lower-right panel in Figure 2. The estimated coefficients for loan-deposit rate margin indicate that the null hypothesis that the spread responses are equal to zero cannot be rejected.

This finding implies that the primary source of profits on which banks rely to build lending capacity is preserved, despite the downward pressure from the policy rate and the prolonged period during which banks could have lowered loan rates while deposit rates remained at zero.

4.2.1. Evidence from Loan Rates on Newly Originated Loans.

The primary data consist of balance sheet and income statement information, from which loan and deposit rates are measured as average rates on outstanding balances. Drechsler et al. (2021) documents that while deposits have relatively short maturities, loans have an average maturity of four years. A potential concern is that the estimated responses, particularly those of loan rates, may reflect changes in the composition of outstanding and newly originated loans on banks' balance sheets. To address this concern, I estimate the responses of interest rates on newly originated mortgage, auto, and commercial and industrial (C&I) loans.[14]

FIGURE 4. Impulse Responses of Loan Rate for Newly Originated Loans to Monetary Policy Shock



Note. The estimated regression equation is $FedFundsRate_{t+h} = \beta_h^H \times \mathbb{I}[i_{t-1} > \gamma] \times \varepsilon_t + \beta_h^L \times \mathbb{I}[i_{t-1} \leq \gamma] \times \varepsilon_t + \Gamma_h' \mathbf{X}_{t-1} + e_{t+h}$ for each horizon $h \in \{0, 1, \ldots, 16\}$ where γ set to be 2%. The upper panels illustrate the sequences of $\{\beta^h\}_{h=0}^H$ and lower panels show sequences of $\{\beta^h\}_{h=0}^H$ with 90% confidence bands. Standard errors are two-way clustered by bank and quarter.

[14]For mortgage rates, I use the 30-Year Fixed Rate Mortgage Average in the United States (MORTGAGE30US). For auto loan rates, I use the Finance Rate on Consumer Installment Loans at Commercial Banks, New Autos 48-Month Loan (TERMCBAUTO48NS). For C&I loan rates, I use historical data from Table E.2 of the Survey of Terms of Business Lending, which reports the spread between C&I loan rates and the intended federal funds rate from 1986:Q1 to 2017:Q2 (https://www.federalreserve.gov/releases/e2/e2chart.htm). I recover the C&I loan rate by adding the federal funds rate to this spread.

Figure 4 presents the responses of the three loan-rate series in the high- and low-interest-rate regimes. As shown in the upper panels, all rates on newly originated loans decline significantly following an expansionary monetary policy shock when deposit rates adjust accordingly. In contrast, the lower panels show that these loan rates remain unresponsive when the deposit rate lower bound binds, consistent with the baseline results.

4.2.2. Relationship with Eichenbaum et al. (2025).

Eichenbaum et al. (2025), a contemporaneous and independent study, also employ policy-rate-level-dependent local projections and conclude that a 100 basis point cut in the federal funds rate in a low–policy-rate environment leads to a roughly 30-basis-point *decline* in the loan-deposit spread (named as core NIM in Eichenbaum et al. (2025)) two quarters after the cut, an effect that is statistically significant.

Differences in Specifications There are three main differences between the specifications of their paper and this paper. First, I characterize a low-interest-rate regime based on whether the federal funds rate lagged by one quarter is below 2%. This threshold is estimated from the observed change in the empirical relationship between the deposit rate and monetary policy shocks, as explained in Section 3.1. By contrast, Eichenbaum et al. (2025) characterize a low-interest-rate regime based on whether the six-quarter moving average of the federal funds rate is below 4%. They motivate this threshold using the evidence in Pfäuti (2025) that people pay less attention to inflation when it is below 3.2%, which implies a policy rate of approximately 4% under the assumption of a 1% real interest rate.

Second, Eichenbaum et al. (2025) use three measures of monetary policy shocks, one of which are also used in this paper. Their main shock series is the residual from a regression of the federal funds rate on macroeconomic variables, following Christiano et al. (1999), and it yields a 30-basis-point decline in the net interest margin. The other two shocks are those constructed by Bauer and Swanson (2023) and Jarociński and Karadi (2020). Eichenbaum et al. (2025) show that the net interest margin declines by 40 basis points with statistical significance at the 90% confidence level following the Bauer and Swanson (2023) shock, whereas the Jarociński and Karadi (2020) shock does not produce a statistically significant response. This paper utilizes Bauer and Swanson (2023) as the baseline shock and complements the results using Nakamura and Steinsson (2018) and Acosta et al. (2025).

Third, Eichenbaum et al. (2025) aggregate the panel Call Report data into a single aggregate series and estimate aggregate-level LPs that include other macroeconomic variables. In contrast, this paper uses the panel-level data without aggregation and estimates panel LPs, controlling not only for the macroeconomic environment but also for banks' balance-sheet conditions and heterogeneity.

Sources of the Differences in Results To identify which factors drive the differences in results between the two papers, I begin by establishing a benchmark through a replication of the baseline results of Eichenbaum et al. (2025) using their original specification. Starting from this benchmark, I sequentially replace their monetary policy shocks and threshold definition with those used in this paper, while deliberately retaining their aggregate specification to isolate the contributions of the shock measure and the regime definition. The IRF results are relegated to the Appendix A.

Benchmark Replication. I begin by establishing a benchmark by replicating the baseline results of Eichenbaum et al. (2025) using their original specification and three measures of monetary policy shocks. Figure A.1 shows the response of the net interest margin to an expansionary monetary policy shock when the average policy rate is below 4%, based on the main specification and shock measures used by Eichenbaum et al. (2025). Overall, I obtain broadly similar results. Using their SVAR residual shock, I find that, in the low-interest-rate regime defined by an average federal funds rate below 4%, a 100-basis-point cut in the federal funds rate is followed six quarters later by a statistically significant 21-basis-point decline in the net interest margin, although the timing of the peak response differs. For the other shock measures, I reproduce the statistically significant 40-basis-point decline reported by Eichenbaum et al. (2025) only when using the unorthogonalized version of the Bauer and Swanson (2023) shock. Finally, the Jarociński and Karadi (2020) shock produces a statistically insignificant 33-basis-point decline after seven quarters, similar to the result reported by Eichenbaum et al. (2025).

Changing Shocks. Next, holding their specification and threshold definition fixed, I examine whether the construction and selection of monetary policy shocks account for the differences in the results. I use the orthogonalized monetary policy shock constructed by Bauer and Swanson (2023), as recommended by the authors and used in this paper, along with the shocks constructed by Nakamura and Steinsson (2018) and Acosta et al. (2025). Figure A.2 presents the results. Once the Bauer and Swanson (2023) shock is orthogonalized, the net interest margin no longer exhibits a statistically significant decline. The additional shocks likewise produce no statistically significant decline in the net interest margin.

Changing the Threshold. I then replace the 4% threshold used by Eichenbaum et al. (2025) with the 2% threshold for the lagged federal funds rate estimated in this paper. Figure A.3 presents the results. Under this alternative threshold, the SVAR shock predicts an immediate decline in the net interest margin, but the effect subsequently vanishes. Neither the unorthogonalized nor the orthogonalized version of the Bauer and Swanson (2023) shock generates a decline in the spread. The remaining high-frequency identified shocks constructed by Jarociński and Karadi (2020), Nakamura and Steinsson (2018), and Acosta et al. (2025) also produce no decline.

Key Takeaway. These exercises show that both the type of monetary policy shock and the threshold defining the low-interest-rate regime matter for evaluating the state-dependent effects of monetary policy on banks. The results of Eichenbaum et al. (2025) can be recovered using recursively identified shocks, but several high-frequency-identified shocks produce no shrinkage under their threshold definition. This finding is consistent with the concern raised by Rudebusch (1998) that monetary policy shocks constructed as residuals from federal funds rate regressions may be structurally fragile. Taken together, the evidence indicates that a cut in the policy rate does not result in a decline in the loan-deposit spread in a low-interest-rate environment, in particular when the deposit rate hits its own lower bound.

4.3. Equity and Leverage

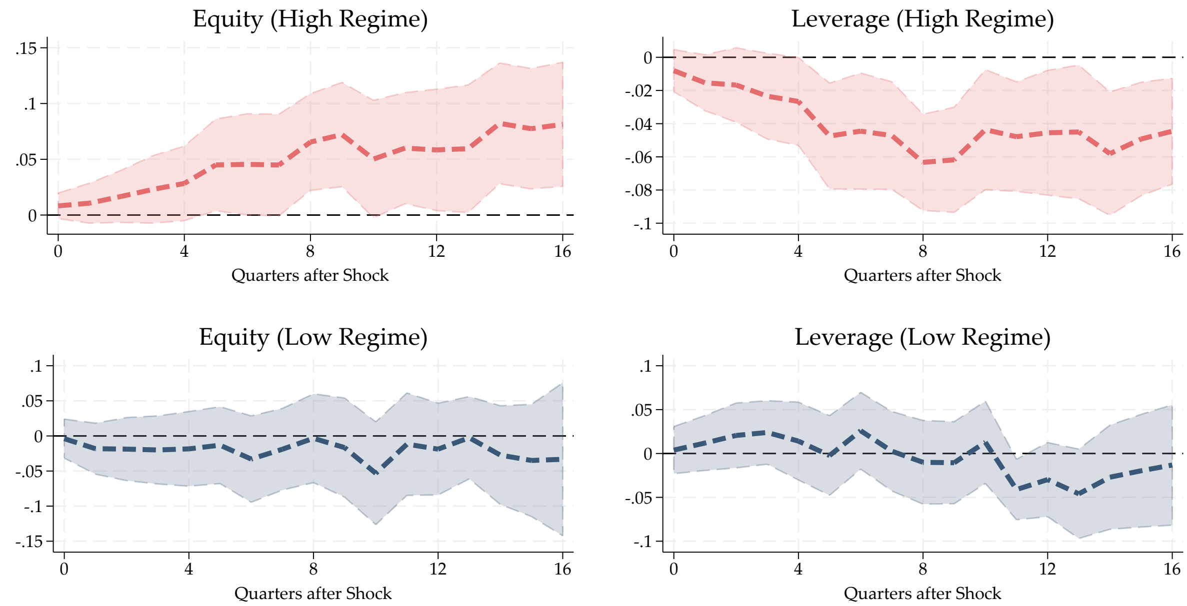
Next, I estimate the responses of bank equity and leverage, both of which the literature identifies as important determinants of lending volumes.[15] According to the mechanism emphasized in this literature, a compression of the loan-deposit spread in a low-interest-rate environment reduces bank profits and erodes equity. The resulting increase in leverage raises the likelihood that regulatory capital constraints become binding. Once these constraints bind, Abadi et al. (2023) shows banks' capacity to extend credit is limited and may even contract. Although the U.S. economy did not adopt negative policy rates, this mechanism should still be observable if it is driven by the effective lower bound on deposit rates, since U.S. deposit rates became unresponsive while the policy rate remained positive and banks experienced a prolonged period of low interest rates and accommodative monetary policy.

The upper panels of Figure 5 show the responses of book equity and leverage when the policy rate is above the threshold, whereas the lower panels report the corresponding estimates when the policy rate is below the threshold. The left panels present the results for book equity, and the right panels present those for leverage. Book equity increases following an expansionary monetary policy shock when the policy rate is above the threshold. This finding is consistent with the expansion of loans and deposits, documented in the following section, combined with the preservation or slight increase of the loan–deposit spread. Together, these responses allow banks to accumulate equity and reduce leverage.[16] Consistent with this mechanism, leverage declines

[15] Heider et al. (2019), for instance, show that when policy rates entered negative territory, banks that relied more heavily on deposits and consequently experienced larger declines in profitability reduced lending relative to other banks, while increasing their risk taking. Bittner et al. (2022) similarly find that bank net worth was an important determinant of lending by Germany and Portugal banks during the negative-rate period.

[16] Another channel through which an expansionary monetary policy shock may contribute to equity accumulation

Figure 5. Impulse Responses of Equity and Leverage (Book Value) to Monetary Policy Shock



Note. The estimated regression equation is $y_{t+h,b} = \beta_h^H \times \mathbb{I}[i_{t-1} > \gamma] \times \varepsilon_t + \beta_h^L \times \mathbb{I}[i_{t-1} \leq \gamma] \times \varepsilon_t + \Gamma_h' \mathbf{X}_{t-1} + \alpha_{b,h} + e_{b,t+h}$ for each horizon $h \in \{0, 1, \ldots, 16\}$ where γ set to be 2%. The upper panels illustrate the sequences of $\{\beta^h\}_{h=0}^H$ and lower panels show sequences of $\{\beta^h\}_{h=0}^H$ with 90% confidence bands. Standard errors are two-way clustered by bank and quarter.

following an expansionary monetary policy shock, which is consistent with Uppal (2025).

When the policy rate is below the threshold, as shown in the lower panels, there is no statistically significant evidence that expansionary monetary policy erodes book equity or increases leverage. Rather, leverage declines beginning nine quarters after the shock with statistical significance. Thus, the results do not support the hypothesis that expansionary monetary policy in a low-interest-rate environment increases the likelihood that banks' capital constraints become binding.[17] These results are robust to the alternative controls, shocks, and local projection specifications discussed in Section 4.5.

Other Profit Measures. Ulate (2021) has examined bank profitability using various measures such as Return on Equity (ROE) and Return on Assets (ROA). In addition, net interest income, the dollar amount accrued for equity accumulation and dividend distribution, is another important

is a reduction in loan losses (Uppal 2025).

[17]One might suggest that banks could maintain their book equity by realizing capital gains from securities sales or adjusting noninterest income and fees. Nevertheless, the majority of banks' profits are generated through net interest income.

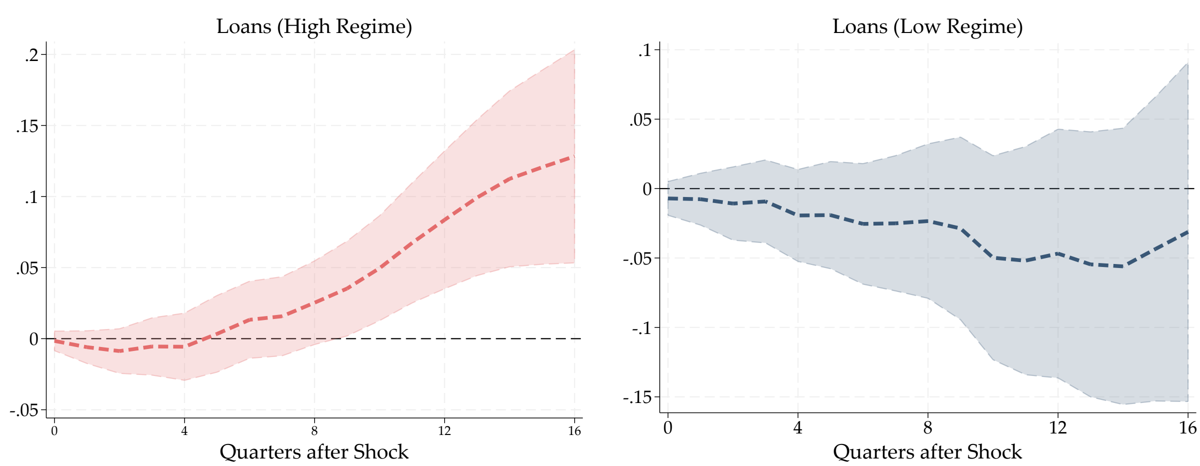
indicator. The analysis of ROE, net interest income, and loan loss provision reveals a pattern similar to that observed for equity. Both ROE and net interest income improve when the policy rate is above the threshold. However, when the policy rate is below the threshold, these measures remain relatively stable in response to an expansionary monetary policy shock. The findings are shown in Appendix B.3.

Market Value. As Nuno and Thomas (2017) and Li (2022) point out, book-value equity and leverage are appropriate measures for analyzing banks' decisions, and their use is consistent with real-world policy frameworks, including those governing lending. However, English et al. (2018) and Ampudia and Van den Heuvel (2022) examine the responses of equity and leverage using market values. For a robustness check, I also examine market-value equity and leverage and obtain similar results. Market-value equity does not decline, nor does market-value leverage increase, when the policy rate is below the threshold. Appendix B.4 presents the results.

4.4. Loan Volume and Loan Application

Now, I estimate the final interest outcome, the loan volume reported in the banks' balance sheet. Figure 6 displayed the estimated coefficients $\{\beta_h^H\}_{h=0}^{16}$ and $\{\beta_h^L\}_{h=0}^{16}$.

Figure 6. Impulse Responses of Outstanding Loan to Monetary Shocks

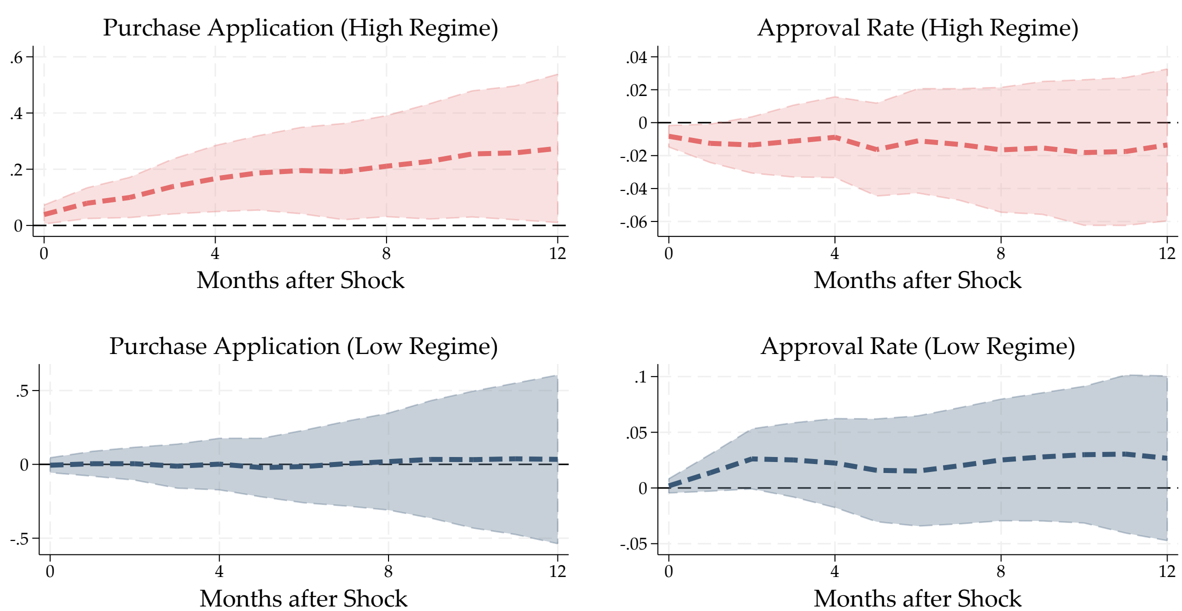


Note. The estimated regression equation is $y_{t+h,b} = \beta_h^H \times \mathbb{I}[i_{t-1} > \gamma] \times \varepsilon_t + \beta_h^L \times \mathbb{I}[i_{t-1} \leq \gamma] \times \varepsilon_t + \Gamma_h' \mathbf{X}_{t-1} + \alpha_{b,h} + e_{b,t+h}$ for each horizon $h \in \{0, 1, \ldots, 16\}$ where γ set to be 2%. The upper panels illustrate the sequences of $\{\beta^h\}_{h=0}^H$ and lower panels show sequences of $\{\beta^h\}_{h=0}^H$ with 90% confidence bands. Standard errors are two-way clustered by bank and quarter.

As shown in the left panel, bank lending increases by 15% over the 16 quarters following the shock. In the low-interest-rate regime, however, the right panel shows that an expansionary monetary policy shock that lowers the policy rate by 1 percentage point does not induce a statistically significant increase in bank lending, as it does in the high-interest-rate regime. Instead, the stock of loans on banks' balance sheets declines mildly.

Because balance sheets report the *stock* of loans, they do not distinguish among previously originated loans, newly originated loans, and repayments. To address this concern, I use monthly Home Mortgage Disclosure Act data on mortgage applications and originations from 1994 to 2021.[18] These data allow me to distinguish mortgage demand from banks' lending stance, with the approval rate serving as a proxy for the latter. If applications and originations exhibit similar state dependence while the approval rate remains unchanged, the results are likely driven by the state-dependent response of loan rates. Conversely, if originations and approval rates exhibit similar state dependence while applications do not, the results are likely driven by banks' lending stance.

Figure 7. Impulse Responses of Loan Application and Approavl Rate to Monetary Monetary Shocks



Note. The estimated regression equation is $y_{t+h} = \beta_h^H \times \mathbb{I}[i_{t-1} > \gamma] \times \varepsilon_t + \beta_h^L \times \mathbb{I}[i_{t-1} \leq \gamma] \times \varepsilon_t + \Gamma_h' \mathbf{X}_{t-1} + \alpha + e_{t+h}$ for each horizon $h \in \{0, 1, \ldots, 16\}$ where γ set to be 2%. The upper panels illustrate the sequences of $\{\beta^h\}_{h=0}^H$ and lower panels show sequences of $\{\beta^h\}_{h=0}^H$ with 90% confidence bands. Standard errors are corrected by the Newey-West correction.

Figure 7 shows that mortgage applications exhibit a pattern similar to that of loan volumes in Figure 6. The approval rate declines by 1 percentage point on impact in the high-interest-rate regime but increases by approximately 2 percentage points in the low-interest-rate regime. Thus,

[18]The data are available at https://sites.google.com/site/neilbhutta/data.

the lack of loan growth in the low-interest-rate regime cannot be attributed to a tightening of banks' lending stance. Instead, the results are consistent with the hypothesis that the unresponsiveness of loan rates suppresses loan demand while protecting banks from the profit contraction that lower policy rates might otherwise induce.

4.5. Robustness Checks

This section describes a battery of robustness checks performed on the baseline results. The results for each exercise are presented in Appendix B.

4.5.1. Alternative Shocks

I repeat the estimation from the previous section using alternative monetary policy shock series: those constructed by Nakamura and Steinsson (2018) and extended by Acosta (2023) (spans from 1995:Q1 to 2019:Q4), as well as those from Acosta et al. (2025) which employ a different identification strategy and cover a different time horizon. Appendix B.1 contains the results and key findings also hold in the case where I use different monetary policy shock series with different time period.

4.5.2. Alternative Specifications

(a) Different Threshold. Taking into account the confidence interval for DZLB based on the threshold estimation exercise, which is $\hat{\Gamma} = [1.7, 2.4]$, I set different values of DZLB (γ) for estimating main specification equation (2). The results for $\gamma = 1.8\%$ and 2.4% are displayed in Appendix B.5 and Appendix B.6, respectively.

(b) Indirect Term. To check the level dependency directly, I instead include an interaction term between the monetary policy shock and the level of the policy rate, rather than using a dummy variable that divides the sample into two, as in the equation (2)

$$y_{t+h,b} = \beta_h^{Direct} \times \varepsilon_t + \beta_h^{Indirect} \times i_{t-1} \times \varepsilon_t + \mathbf{X}'_{b,t-1}\Gamma_h + \alpha_{b,h} + e_{b,t+h} \tag{3}$$

In this exercise, $\beta_h^{Indirect}$ is the primary focus. Under an expansionary monetary policy shock, $\beta_h^{Indirect} < 0$ implies that the outcome decreases more in response to the expansionary monetary policy change when interest rates are higher. Conversely, $\beta_h^{Indirect} > 0$ implies that the outcome increases more in response to the expansionary monetary policy change when interest rates are higher.

The outcome is displayed in Appendix B.7. The results show that both loan and deposit rates exhibit negative values for $\beta_h^{Indirect}$, which implies that both rates fall more when the policy rate environment is set to a higher level. Equity and loan display positive $\beta_h^{Indirect}$ values, which denotes that they increase more in response to an expansionary monetary policy when the policy rate is set to a higher level. Leverage takes a negative value. The spread takes a statistically insignificant value, which is well aligned with the results when using the dummy variable specification.

(c) Confounding Effect. Because the policy rate level can be highly correlated with other economic conditions or bank characteristics that might affect banks' decisions, it's crucial to control for these potentially confounding factors. To do so, I include covariates ($C_{b,t-1}$) and interaction terms between these covariates and the monetary policy variable, $(C_{b,t-1}) \times \varepsilon_t$. By including both covariates and interaction terms, I isolate the true effect of the policy rate on bank behavior while accounting for other potentially confounding factors and specifically testing whether that effect changes depending on whether the policy rate is below the DZLB.

$$\begin{aligned} y_{t+h,b} = &\beta_h^H \cdot \mathbb{I}\left[i_{t-1} > \gamma\right] \cdot \varepsilon_t + \beta_h^L \cdot \mathbb{I}\left[i_{t-1} \leq \gamma\right] \cdot \varepsilon_t \\ &\underbrace{+\gamma_h \cdot C_{b,t-1}}_{\text{Confounding Factor } \varepsilon_t} + \underbrace{\gamma_h^C \cdot C_{b,t-1} \cdot \varepsilon_t}_{\text{Interaction Term with } \varepsilon_t} + \mathbf{X}'_{b,t-1}\Gamma_h + \alpha_{b,h} + e_{b,t+h} \end{aligned} \tag{4}$$

Under the specification of equation (4), I reestimate β_h^H and β_h^L for each variable's response. The possible economic situations that can affect the banks' decisions ($C_{b,t-1}$) are

- Excess bond premium (Gilchrist and Zakrajšek 2012) – Appendix B.8.1
- Recession indicator – Appendix B.8.2
- Great Financial Crisis period indicator – B.8.3
- Macro and Financial uncertainty (Ludvigson et al. 2021) – Appendix B.8.4 and B.8.5
- Monetary Policy Uncertainty (Baker et al. 2016) – Appendix B.8.6
- Bank-level Loan loss provision – Appendix B.8.7

In case of Bank-level Loan loss provision, I standardize the loss provision within bank, which captures the given bank's loan loss status is higher or lower than average following Ottonello and Winberry (2020). The baseline results are qualitatively and quantitatively robust to this confounding effect and deliver the same message.

(d) Ramey and Zubairy (2018)-Type Local Projection. To allow the other covariates, including both aggregate-level economic environments and bank characteristics, to affect the bank's decisions differently based on the policy rate environment, I utilize state-dependent local projection à la Ramey and Zubairy (2018).

$$y_{t+h,b} = \mathbb{I}[i_{t-1} > \gamma] \cdot \left[\beta_h^H \varepsilon_t + \mathbf{X}'_{b,t-1}\Gamma_h^H\right] + \mathbb{I}[i_{t-1} \leq \gamma] \cdot \left[\beta_h^L \varepsilon_t + \mathbf{X}'_{b,t-1}\Gamma_h^L\right] + \alpha_{b,h} + e_{b,t+h}$$

The impulse responses of key variables are described in the Appendix B.9, and they are similar to the benchmark, supporting the findings in a more quantitative way: when the deposit rate lower bound is binding, the loan-deposit spread and loan growth rate remain stable, and book value equity and leverage also remain stable.

5. Model

The central question of this paper is the extent to which the banking sector dampens the effectiveness of monetary policy and whether this attenuation becomes stronger when the policy rate is already low. This issue is particularly important when a recession begins in a low-rate environment. During a recession, the central bank typically lowers the policy rate to reduce borrowing costs, stimulate consumption and investment, and support the recovery of output. The preceding results, however, show that when the policy rate is already low, further rate cuts pass through only weakly to bank loan rates and do little to encourage banks to expand lending. As deposit rates approach their effective lower bound, bank funding costs become less responsive to additional policy rate cuts, leading banks to preserve their net interest margins rather than reduce loan rates one for one. A recession that occurs when rates are already low may therefore leave the central bank with a weaker transmission mechanism precisely when monetary stimulus is needed most.

To quantify this mechanism, I develop a New Keynesian model with financial intermediation and an effective lower bound on deposit rates. Time is discrete and infinite. The economy is populated by a representative household, a continuum of intermediate-good firms, competitive capital producers, capital suppliers, a representative bank, and the government. The model distinguishes among the policy rate, the deposit rate, and the loan rate. Their differential responses determine how the level of the policy rate affects bank lending conditions and, ultimately, the effectiveness of monetary policy in mitigating a recession.

5.1. Banking Sector

The banking sector mainly follows Cúrdia and Woodford (2011). I assume a financial intermediary sector consisting of identical and perfectly competitive banks. Banks issue one-period deposits, D_t, promising a gross nominal deposit return R_t^D, and extend one-period loans, L_t, at the gross nominal loan rate R_t^L in nominal terms. Each bank enters period t with a predetermined stock of real equity, E_t, and takes both contractual rates as given. Its balance sheet satisfies

$$L_t = D_t + E_t. \tag{5}$$

Dynamic Bank Problem The loan and deposit contracts chosen in period t are settled in period $t+1$. After receiving loan repayments, repaying depositors, and paying intermediation costs, the bank distributes a fixed fraction $\gamma \in (0,1)$ of the remaining resources as dividends and retains the fraction $1-\gamma$ as next period's equity. Banks cannot issue external equity. Bank equity therefore evolves according to

$$E_{t+1} = (1-\gamma)(R_t^L L_t - R_t^D D_t - \Xi(L_t, E_t)). \tag{6}$$

The representative household is the residual owner of the bank and receives its dividends. Bank dividends and continuation values are therefore evaluated using the household stochastic discount factor, $\Lambda_{t,t+1} \equiv \beta\Lambda_{t+1}/\Lambda_t$, which will be introduced in the household problem.

After rescaling the bank's ex-dividend value by the constant retention rate $1-\gamma$, let $V_t(E_t)$ denote $(1-\gamma)$ times the unscaled value of a bank entering period t with equity E_t. Subject to (5) and (6), the representative bank solves

$$V_t(E_t) = \max_{\{L_t, D_t\}\geq 0} \mathbb{E}_t\left[\Lambda_{t,t+1}\left(\gamma E_{t+1} + V_{t+1}(E_{t+1})\right)\right]. \tag{7}$$

The first term inside the expectation is the dividend expressed in normalized value units. The corresponding unscaled dividend is then $\gamma E_{t+1}/(1-\gamma)$. Intermediation costs are paid before the bank divides its end-of-period resources between dividends and retained equity.

Intermediation Costs and Loan Pricing The function $\Xi(L_t, E_t)$ captures monitoring expenses as in Cúrdia and Woodford (2011) and Eggertsson et al. (2023).[19] Its total value reduces the resources available for dividends and retained equity, while its marginal value determines the cost of supplying an additional loan. I assume that marginal intermediation costs are nonnegative and

[19] The introduction of intermediation can also be microfounded, such as the presence of a leverage constraint (Eggertsson et al. 2023). The dependence of costs on a bank's equity, or net worth, is microfounded in Gertler and Kiyotaki (2010).

weakly increasing in bank leverage, and that greater bank equity weakly lowers the marginal cost of lending. The functional form used in the quantitative analysis is specified in the calibration section.

Using the balance-sheet identity, an additional unit of lending is financed by an additional unit of deposits. The bank's lending condition is therefore

$$R_t^L = R_t^D + \Xi_L(L_t, E_t). \tag{8}$$

Thus, the loan rate equals the sum of the marginal deposit-funding cost and the marginal cost of intermediation captured by Ξ. The capital-supplier block determines loan demand. Together, the bank's lending condition and the capital supplier's optimality condition determine the equilibrium loan rate.

5.2. Households

The representative household derives utility from consumption, C_t, disutility from labor, N_t, and utility from the liquidity services provided by bank deposits, D_t. The household can save in two vehicles: one-period bank deposits and government bonds, B_t. Government bonds are risk-free investments but provide no liquidity services and earn the policy rate, R_t. The household maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \mathcal{U}\left(C_t, N_t, \frac{D_t}{P_t}\right)\xi_t, \tag{9}$$

where $\beta \in (0, 1)$ is the discount factor. ξ_t denotes a time-preference shock, which is used to generate demand-driven recession scenarios. Preferences feature external habit formation in consumption, a separable disutility of labor, and additively separable utility from deposit holdings:

$$\mathcal{U}\left(C_t, N_t, \frac{D_t}{P_t}\right) = u\big(C_t - h\bar{C}_{t-1}\big) - \chi_N \frac{N_t^{1+\varphi}}{1+\varphi} + \chi_D v(D_t/P_t),$$

where $\bar{C}_{t-1}$ is lagged aggregate consumption, which the household takes as given when making its period-t choices. The parameter h governs external consumption habits, φ is the inverse Frisch elasticity of labor supply, and χ_N and χ_D capture, respectively, the disutility of labor and the weight the household places on deposit holdings. The quantitative implementation uses

$$u(X_t) = \frac{X_t^{1-\sigma}}{1-\sigma}, \qquad v(D_t/P_t) = \frac{(D_t/P_t)^{1-\nu}}{1-\nu}. \tag{10}$$

where $X_t = C_t - h\bar{C}_{t-1}$. The presence of deposits in the utility function captures the role of deposits in household portfolios. Beyond their deposit-rate return, deposits provide payment, transaction, and liquidity services that close substitutes such as government bonds do not offer.[20] Modeling these services as a direct, additively separable contribution to period utility follows the money-in-utility tradition and, more closely, the deposits-in-utility approach of Jamilov and Monacelli (2025), who employ the same device to rationalize why households are willing to hold deposits at rates below the risk-free rate.

The household maximizes utility subject to

$$P_t C_t + D_t + B_t = W_t N_t + R^D_{t-1} D_{t-1} + R_{t-1} B_{t-1} + T_t,$$

where W_t is the nominal wage, R^D_t is the gross deposit rate, and T_t collects lump-sum transfers and distributed profits, including dividends paid by the non-finanical intermediaries and bank to the representative household.

Let Λ_t denote the marginal utility of consumption. Under external habit, $\Lambda_t = u'\left(C_t - h\bar{C}_{t-1}\right) = \left(C_t - h\bar{C}_{t-1}\right)^{-\sigma}$. The first-order condition for government bond holdings is

$$R_t = \left[\mathbb{E}_t\left(\frac{\Lambda_{t,t+1}}{\Pi_{t+1}}\right)\right]^{-1}, \tag{11}$$

where $\Lambda_{t,t+1} \equiv \beta\Lambda_{t+1}/\Lambda_t$ denotes the stochastic discount factor. The first-order condition for bank deposits, combined with equation (11), yields the latent deposit rate that would prevail in the absence of a lower bound:

$$R^{D*}_t = R_t\left(1 - \frac{U_{D/P,t}}{U_{C,t}}\right), \tag{12}$$

where $\mathcal{U}_{C,t} = \Lambda_t$ and $\mathcal{U}_{D/P,t} = \chi_D v'(D_t/P_t) = \chi_D (D_t/P_t)^{-\nu}$. The term $\mathcal{U}_{D/P,t}/\mathcal{U}_{C,t}$ captures the marginal liquidity value and the latent deposit rate lies below the policy rate because deposits provide liquidity services that government bonds do not. At the margin, the household is willing to forgo pecuniary return in exchange for liquidity utility. The deposit markdown then can be expressed as

$$\mu^D_t \equiv \frac{R^{D*}_t}{R_t} = 1 - \frac{\mathcal{U}_{D/P,t}}{\mathcal{U}_{C,t}} \leq 1.$$

If $\chi_D = 0$, deposits and government bonds are perfect substitutes, the markdown collapses to unity, and the latent deposit rate equals the policy rate.

[20]The specification is also consistent with evidence on the convenience yield of safe and liquid assets and with the deposits channel of monetary policy (Krishnamurthy and Vissing-Jorgensen 2012; Drechsler et al. 2017; Di Tella and Kurlat 2021; Wang 2025).

Crucially, I impose an effective lower bound on the observed deposit rate.[21]

$$R_t^D = \max\left\{1, R_t^{D*}\right\} \tag{13}$$

When the constraint is slack, movements in the policy rate pass through to the deposit rate via the portfolio condition (12). Once the constraint binds, however, further reductions in the latent deposit rate no longer lower the observed deposit rate.

5.3. Non-Financial Firms

The production side consists of intermediate-good producers, a representative final-good producer, and competitive capital-producing firms.

Intermediate-Good and Final-Good Producers Intermediate-good firm i produces using capital and labor according to

$$Y_t(i) = K_t(i)^{\alpha} N_t(i)^{1-\alpha}, \qquad 0 < \alpha < 1. \tag{14}$$

Let r_t^k denote the real return on capital and w_t the real wage. Cost minimization yields

$$r_t^k = \alpha mc_t \frac{Y_t(i)}{K_t(i)}, \qquad w_t = (1-\alpha) mc_t \frac{Y_t(i)}{N_t(i)}, \tag{15}$$

where mc_t denotes real marginal cost. A representative, perfectly competitive final-good producer aggregates the differentiated intermediate goods. Price setting by intermediate-good firms is subject to Calvo rigidity (Calvo 1983) and yields a standard New Keynesian Phillips curve.

Capital-Producing Firms Competitive capital-producing firms produce new capital subject to adjustment costs. Aggregate capital evolves according to

$$K_{t+1} = (1-\delta)K_t + I_t. \tag{16}$$

[21] The lower bound can be microfounded by introducing cash as an outside option for savers. Because cash provides liquidity services comparable to those of deposits at a fixed nominal return, the deposit rate cannot fall sufficiently below the return on cash without triggering substitution out of deposits. While it is in principle possible to embed cash explicitly into the deposits-in-utility framework, along the lines of Di Tella and Kurlat (2021) and Wang (2025), I abstract from this extension and impose the resulting floor in reduced form.

The value of new capital is Q_t in nominal term. A representative capital-producing firm chooses investment to maximize

$$\frac{Q_t}{P_t}I_t - I_t - \frac{\widetilde{\phi}}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t, \tag{17}$$

where $\widetilde{\phi} > 0$ governs investment adjustment costs. The first-order condition for investment is

$$\frac{Q_t}{P_t} = 1 + \widetilde{\phi}\left(\frac{I_t}{K_t} - \delta\right). \tag{18}$$

Capital Financing and Loan Demand Intermediate-good firms borrow from banks to finance their capital purchases (Ulate 2021). The value of capital financed in period t satisfies

$$L_t = Q_t K_{t+1}. \tag{19}$$

A unit of capital purchased at price Q_t generates the return r^k_{t+1} and retains the value $(1-\delta)q_{t+1}$ in period $t+1$. Optimal capital demand therefore requires

$$R^L_t \frac{Q_t}{P_t} = \mathbb{E}_t\left[\frac{P_{t+1}}{P_t}\left(r^k_{t+1} + (1-\delta)\frac{Q_{t+1}}{P_{t+1}}\right)\right]. \tag{20}$$

Thus, the expected nominal return on capital equals the contractual cost of bank borrowing. While the baseline model restricts nonfinancial firms to bank financing, I extend the model by allowing firms to issue bonds alongside bank loans as in De Fiore and Uhlig (2011) and Crouzet (2018) in Section 6.5.

5.4. Monetary Policy

The central bank sets the policy rate according to an inertial Taylor rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_R}\left[\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi_\pi}\left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y}\right]^{1-\rho_R}\exp\left(\varepsilon_{m,t}\right), \tag{21}$$

where ρ_R governs interest-rate smoothing, ϕ_π and ϕ_y gauge the responses to inflation and output, and $\varepsilon_{m,t}$ denotes a monetary policy shock.

5.5. Fiscal Policy

The government purchases final goods, denoted by G_t, and finances them through lump-sum taxes or transfers.

In the baseline model, government spending follows an exogenous process given by

$$G_t = \bar{G}^{1-\rho_G} G_{t-1}^{\rho_G} \exp\left(\varepsilon_{g,t}\right), \tag{22}$$

where $\bar{G}$ denotes steady-state government spending, $\rho_G \in [0, 1)$ governs its persistence, and $\varepsilon_{g,t}$ is an exogenous government-spending shock.

In the fiscal-policy experiment, I allow government spending to respond automatically to the output gap according to

$$G_t = \bar{G}^{1-\rho_G} G_{t-1}^{\rho_G} \left(\frac{Y_t}{\bar{Y}}\right)^{-\phi_G} \exp\left(\varepsilon_{g,t}\right), \tag{23}$$

where Y_t^n denotes the natural level of output and $\phi_G \geq 0$ governs the strength of the automatic fiscal response. When output falls below its natural level, $Y_t/\bar{Y} < 1$, and government spending increases. Setting $\phi_G = 0$ reduces this rule to the baseline specification.

5.6. Market Clearing and Equilibrium

Because bank intermediation costs are real resource costs, goods-market clearing requires

$$Y_t = C_t + I_t + G_t + \frac{\Xi_t}{P_t}. \tag{24}$$

Government purchases are present in the steady state of every experiment; absent fiscal shocks, their log deviation is zero, and the fiscal-policy experiment activates the automatic stabilizer.

Equilibrium in the loan market requires

$$L_t = Q_t K_{t+1}. \tag{25}$$

Government bonds are in zero net supply and are eliminated from the quantitative system after using their first-order condition to obtain the household Euler equation.

Equilibrium An equilibrium consists of an allocation $\{C_t, N_t, Y_t, I_t, K_{t+1}, G_t, D_t/P_t, B_t/P_t, L_t/P_t, E_t/P_t\}$ and a price system $\{w_t, r_t^k, q_t, \Pi_t, R_t, R_t^D, R_t^L\}$ such that: (i) the allocation solves the decision problems of the household, intermediate-good firms, capital producers, capital suppliers, and the bank, (ii) bank equity accumulates according to (6), (iii) the policy rate satisfies the monetary-policy rule, the observed deposit rate satisfies the effective lower bound in (13), and government spending satisfies (22) in the baseline fiscal block, and (iv) the goods, loan, labor, and zero-net-supply bond markets clear.

6. Calibration and Model Performance

6.1. Calibration

The model is calibrated at a quarterly frequency. I consider two regimes. In the high-rate regime, the deposit-rate lower bound is slack, and the observed deposit rate responds to monetary policy shocks through the portfolio condition (12). In the low-rate regime, the observed deposit rate is at its lower bound and remains fixed following an expansionary monetary policy shock. The household discount factor is calibrated separately in each regime so as to anchor that regime's steady-state policy rate. All remaining structural parameters remain common across the two regimes.

Externally Calibrated Parameters Preference and technology parameters take standard values from the literature. The inverse intertemporal elasticity of substitution is $\sigma = 1$, so momentary utility is logarithmic in consumption. Following Gertler and Karadi (2011), I set the external-habit parameter to $h = 0.81$. The inverse Frisch elasticity is $\varphi = 1$, consistent with Chetty et al. (2011), and the curvature of deposit utility is normalized to $\nu = 1$. On the production side, I follow Gertler and Karadi (2011) and set the capital share to $\alpha = 0.36$ and the quarterly depreciation rate to $\delta = 0.025$. The investment-adjustment-cost parameter is $\phi = 0.25$, as in Bernanke et al. (1999). I set the elasticity of substitution across intermediate goods to $\theta = 6$ following Galí (2008), implying a steady-state markup of 20 percent. Finally, following the estimate in Hazell et al. (2022), the slope of the New Keynesian Phillips curve is set to $\kappa = 0.0062$.

The intermediation cost takes the constant-elasticity form $\Xi(L_t, E_t) = \zeta \left(L_t/\bar{L}\right)^{\eta} \left(E_t/\bar{E}\right)^{-\iota}$, following Eggertsson et al. (2023), where $\bar{L}$ and $\bar{E}$ denote steady-state loans and equity in the high-rate regime, so that the scale ζ equals the steady-state level of the cost. Under this functional form, higher leverage widens the spread while additional bank capital compresses it,[22] This specification is consistent with the regulatory, funding, and risk-bearing costs of leverage emphasized by Van den Heuvel (2008); Begenau (2020); Adrian and Shin (2014). I set the cost elasticities to $\eta = 4.5$ and $\iota = 2.28$ following Eggertsson et al. (2023). The scale ζ is calibrated internally (see below) so that the steady-state marginal cost equals the high-rate loan–deposit spread.[23]

In the policy block, I follow Galí (2008) and set the interest-rate smoothing parameter to $\rho_R = 0.8$. The inflation response is $\phi_\pi = 2.11$ and the output response is $\phi_y = 0.26$, following

[22] In log deviations the loan–deposit spread satisfies $\hat{R}^L_t - \hat{R}^D_t = (\eta - 1)\hat{L}_t - \iota \hat{E}_t$: the marginal cost of lending responds to loans with elasticity $\eta - 1$ and to equity with elasticity $-\iota$.

[23] Because the cost function is not homogeneous of degree one ($\eta - \iota \neq 1$), the coefficient of the unnormalized form $\Xi = \zeta \bar{L}^{-\eta} \bar{E}^{\iota} L^{\eta}_t E^{-\iota}_t$ depends on the level normalization of the economy and is not interpretable on its own; the calibration therefore reports the normalized scale ζ.

Hofmann et al. (2024). On the fiscal side, the steady-state government-purchase share is $\bar{G}/\bar{Y} = 0.20$, and government spending follows an AR(1) process with persistence $\rho_G = 0.90$.

Table 2. Externally Calibrated Parameters

Parameter	Description	Value	Source
Household Block			
σ	Inverse intertemporal elasticity	1	Wang (2025)
ν	Curvature of deposit utility	1	Wang (2025)
h	External consumption habit	0.81	Gertler and Karadi (2011)
φ	Inverse Frisch elasticity	1	Chetty et al. (2011)
Non-financial Intermediary Block			
α	Capital share	0.36	Gertler and Karadi (2011)
δ	Quarterly depreciation rate	0.025	Gertler and Karadi (2011)
κ	Phillips-curve slope	0.0062	Hazell et al. (2022)
ϕ	Investment-adjustment coefficient	0.25	Bernanke et al. (1999)
θ	Elasticity across intermediate goods	6	Galí (2008)
Banking Sector Block			
η	Intermediation-cost elasticity in loans	4.5	Eggertsson et al. (2023)
ι	Intermediation-cost elasticity in equity	2.28	Eggertsson et al. (2023)
Policy Block			
ρ_R	Interest-rate smoothing	0.8	Galí (2008)
ϕ_π	Inflation response	2.11	Hofmann et al. (2024)
ϕ_y	Output response	0.26	Hofmann et al. (2024)

Internally Calibrated Parameters All interest-rate targets are specified as annual net rates and converted to gross quarterly rates within the calibration. In the high-rate regime the policy, deposit, and loan rates are 4%, 1%, and 5% as I observe at the aggregate level data. In the low-rate regime the policy rate is 2% and the deposit rate sits at its zero lower bound, so it supplies no additional identifying restriction.

Conditional on the externally assigned parameters and the regime-specific discount factors, four steady-state conditions identify four structural parameters. The deposit-portfolio condition pins down the deposit-utility scale χ_D. The loan-pricing condition pins down the intermediation-cost scale ζ given the targeted high-rate leverage. The stationary bank-equity condition then pins down the dividend-payout rate γ. Finally, the labor-supply condition pins down the labor-disutility scale χ_N under the normalization $\bar{N}_H = 1$.

Table 3. Internally Calibrated Parameters and Conditions

Parameter	Calibration target	Value	Identifying condition
χ_D	Deposit rate	1%	Deposit-portfolio condition
χ_N	High-rate labor, $\bar{N}_H$	1	Labor-supply condition
ζ	High-rate loan rate	5%	Loan-pricing condition
γ	High-rate loan-to-equity ratio	10.5	Stationary bank-equity condition

Note. The first three rows are quantitative steady-state targets; the final row is a normalization rather than an empirical moment. Identification is triangular: the loan-pricing condition determines ζ given the targeted high-rate leverage, after which the bank-equity condition determines γ.

Table 4 reports the resulting values. Given the borrowed elasticities $\eta = 4.5$ and $\iota = 2.28$, the high-rate loan–deposit spread pins down the intermediation-cost scale through $\zeta = 0.057$. Given the cost function, the bank-equity stationarity condition selects the payout rate γ that sustains this leverage through retained earnings.

Table 4. Internally Calibrated Structural Parameters

Parameter	Description	Value	Identifying condition
χ_D	Deposit-utility scale	0.481	Deposit-portfolio condition (high regime)
χ_N	Labor-disutility scale	4.829	Labor-supply condition ($\bar{N}_H = 1$)
ζ	Intermediation-cost scale	0.057	Loan-pricing condition (high regime)
γ	Dividend-payout rate	0.076	Stationary bank-equity condition

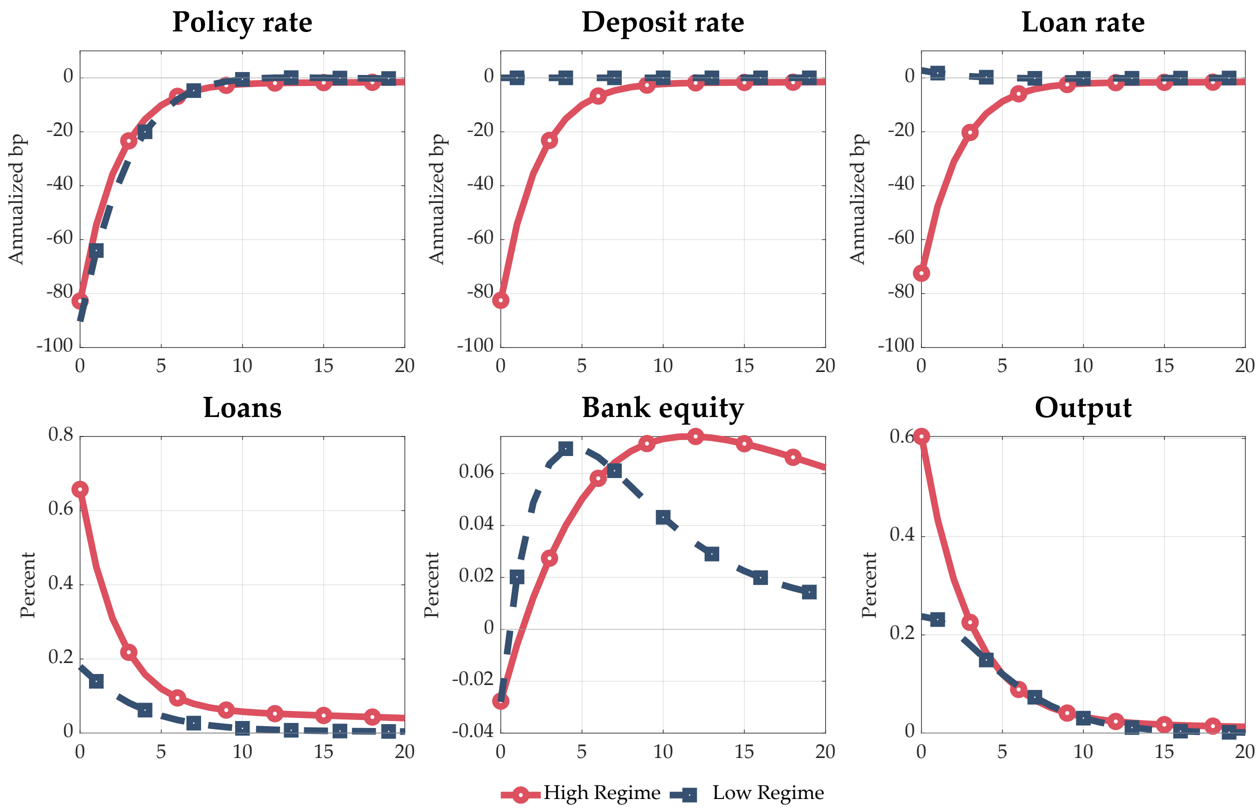
6.2. Model Performance

To evaluate the model's performance, I trace the transmission of an expansionary monetary policy innovation in the high- and low-rate regimes. Figure 8 reports the responses of six variables. The upper row traces the bank-rate transmission mechanism from the policy rate to the deposit and loan rates, while the lower row reports the resulting responses of output, loans, and bank equity. These responses are qualitatively consistent with the state-dependent patterns documented in the empirical analysis.

The monetary policy innovation is set to a quarterly decline of 25 basis points, corresponding to a 100-basis-point annualized policy innovation. The policy rate falls on impact in both high-rate regime and the low-rate regime. The similarity of the two policy-rate responses is consistent with the empirical finding that the policy-rate adjustment itself displays little state dependence.

The deposit- and loan-rate panels reveal the source of the difference in transmission. In the high-rate regime, the deposit rate falls by 82.5 annualized basis points and the loan rate falls by

Figure 8. Responses to an Expansionary Monetary Policy Shock



Note. Impulse responses to an expansionary monetary policy innovation in the high-rate regime (blue) and the low-rate regime (red). Rates are expressed in annualized basis points. Loans, bank equity, and output are percent deviations from their regime-specific steady states.

72.4 basis points on impact. In the low-rate regime, the deposit rate remains fixed at its lower bound, and the loan rate response is also muted, which reproduces the empirical finding that retail-rate pass-through operates normally away from the deposit-rate floor but largely disappears when the floor binds.

The loan and bank-equity responses are qualitatively consistent with the state-dependent patterns documented in the empirical analysis. In the high-rate regime, loans increase by around 0.6 percent on impact and remain persistently above their steady-state level. At the deposit-rate floor, the loan response is only 0.2 percent, approximately one-third of its high-rate counterpart, and dissipates more rapidly. Bank equity exhibits the same state dependence. In the high-rate regime, the sustained expansion in lending leads bank equity to accumulate gradually and remain elevated throughout the reported horizon. At the low-rate regime, while bank equity does not accumulate as persistently as in the high-rate regime, it does not produce a lasting deterioration in bank capitalization or erode the bank's lending capacity. Monetary easing therefore continues to support the bank's balance sheet in the low interest rate regime.

The final panel shows the output response induced by this state-dependent banking channel. Output increases by around 0.6 percent in the high-rate regime but by only 0.2 percent at the deposit-rate floor. Thus, despite similar policy-rate responses, the output effect of monetary easing is substantially weaker at the floor because the policy-rate reduction is not transmitted to deposit and loan rates, limiting the expansion of bank credit.

6.3. Loss of Monetary Policy Effectiveness during Recessions

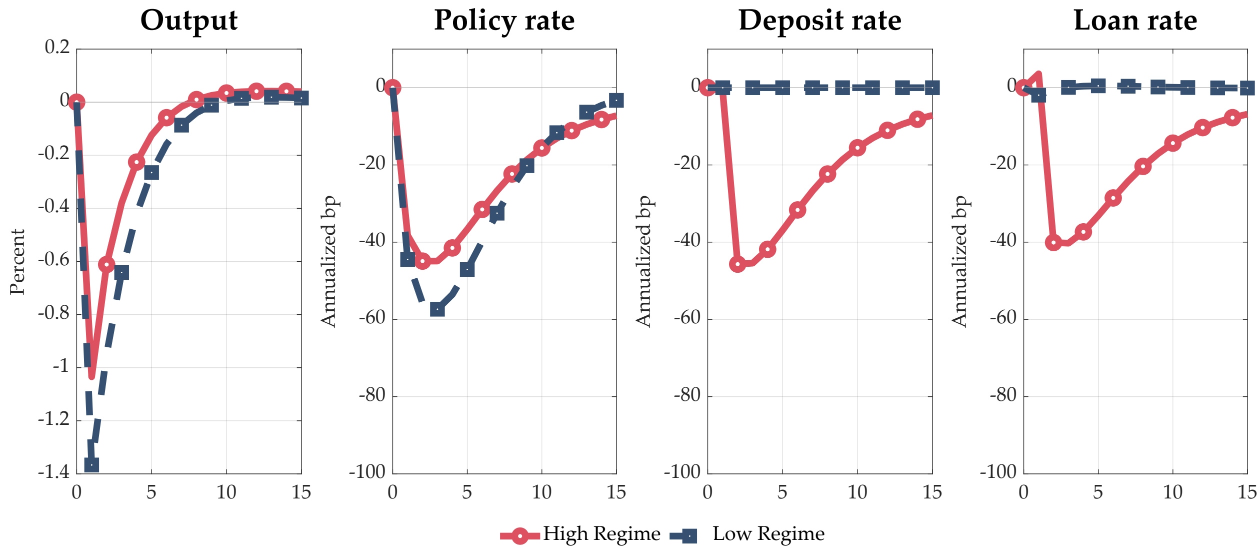
In this section, I evaluate the effectiveness of monetary policy during recessions by introducing a contractionary household preference shock, ξ_t, in equation (9) following Eggertsson et al. (2023). Both regimes are subjected to the same shock, while the central bank responds through the Taylor rule. The shock is calibrated once so that the output decline in the high-rate regime under the benchmark rule is approximately one percent at the trough. Figure 9 reports, from left to right, the responses of output, the policy rate, the deposit rate, and the loan rate.

The key finding is that the recession is deeper at the deposit-rate floor. Output falls by about 1.0 percent in the high-rate regime but by about 1.4 percent in the low-rate regime. This difference arises despite a larger reduction in the policy rate in the low-rate regime. If the recession occurs when the deposit rate lower bound is not binding, monetary easing passes through to both deposit and loan rates and cushions the contraction. However, when the deposit rate lower bound binds, the deposit rate remains fixed and the loan rate response is also muted. The larger policy-rate reduction therefore does not translate into a comparable decline in borrowing costs, causing the same demand shock to generate a deeper and more persistent recession.

One concern is whether a stronger response of the Taylor rule to the output gap can restore the effectiveness of monetary policy in the low-rate regime. To examine this, I vary the coefficient on the output gap, ϕ_Y, while holding the recession shock and all other parameters fixed. For each value of ϕ_Y, I solve the model in both regimes with the zero lower bound on the policy rate and compare two measures of the recession. Figure 10 reports the results. The left panel shows the output trough, while the right panel shows the cumulative output response over sixteen quarters. More negative values indicate a deeper or more persistent recession. The open red markers in the right panel indicate the values of ϕ_Y for which the zero lower bound binds in the low-rate regime.

Figure 10 shows that a stronger response to the output gap does not fully restore monetary policy effectiveness for two reasons. First, increasing ϕ_Y reduces the size of the recession in both regimes, but the difference between the two regimes remains. At the benchmark value $\phi_Y = 0.26$, the output trough is -1.03 percent in the high-rate regime and -1.37 percent in the low-rate regime. The cumulative output responses are -2.14 and -3.83 percent-quarters, respectively. As ϕ_Y increases, both output declines become smaller. However, even at $\phi_Y = 2$, the output trough in

Figure 9. Recession Dynamics across Interest-Rate Regimes



Note. Responses to the same contractionary household preference shock under the benchmark monetary policy rule. The shock occurs at $t = 1$. Output is expressed as a percent deviation from its regime-specific steady state; interest rates are expressed in annualized basis points.

the low-rate regime is −0.93 percent, while it is only −0.5 percent in the high-rate regime. The cumulative output loss in the low-rate regime also remains more than twice as large. Therefore, a more aggressive monetary policy response can reduce the recession, but it cannot eliminate the difference created by the weak pass-through to deposit and loan rates.

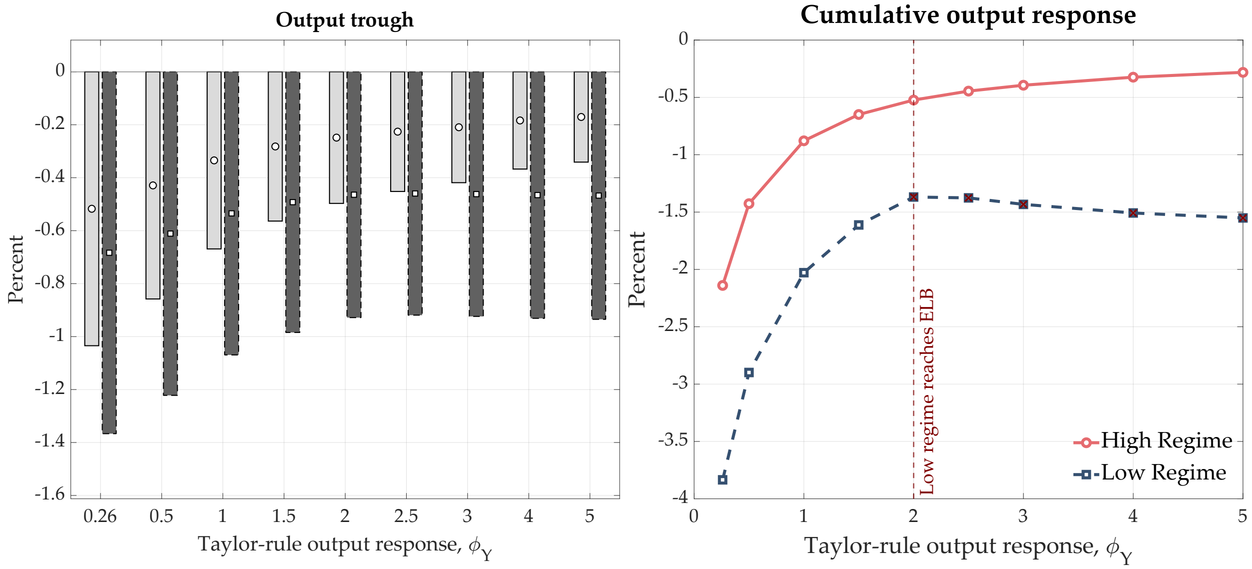
Second, a more aggressive rule eventually reaches the zero lower bound on the policy rate. Since the policy rate starts from a lower level in the low-rate regime, the policy rate reaches zero at around $\phi_Y = 2$ under the current shock size and Taylor rule.[24] Once the zero lower bound binds, a further increase in ϕ_Y requires additional policy-rate cuts that cannot be implemented. As a result, the output trough in the low-rate regime no longer improves, and the cumulative output loss starts to increase. In contrast, both measures continue to improve in the high-rate regime. Therefore, monetary policy faces two limits in the low-rate regime. The deposit-rate floor weakens the transmission of policy-rate cuts to borrowing costs, while the zero lower bound eventually limits the amount of policy-rate cuts that can be implemented.

6.4. The Stabilizing Effects of Monetary–Fiscal Policy Coordination

I then examine whether fiscal policy can stabilize the economy when conventional monetary policy becomes less effective at the deposit-rate floor. I repeat the same low-rate recession under

[24] This implies that, as the shock becomes larger, the threshold value of ϕ_Y at which the policy rate reaches the zero lower bound becomes lower.

FIGURE 10. Limits of a More Aggressive Taylor Rule



Note. The left panel reports the output trough for each value of the Taylor-rule output coefficient ϕ_Y; all troughs are plotted as negative percent deviations. The right panel reports the cumulative output response over sixteen quarters, in percent-quarters, under the same recession shock. The policy rate is subject to a zero lower bound in both regimes. Blue denotes the high-rate regime and red the low-rate regime. Open red markers indicate values of ϕ_Y at which the policy-rate lower bound binds in the low-rate regime.

three policy configurations. The first is the benchmark monetary rule, the second is an aggressive monetary rule with $\phi_Y = 0.50$, and the third is a fiscal stabilizer with $\phi_G = 3$ combined with the benchmark monetary rule. Table 5 reports the results.

TABLE 5. Stabilization at the Deposit-Rate Floor

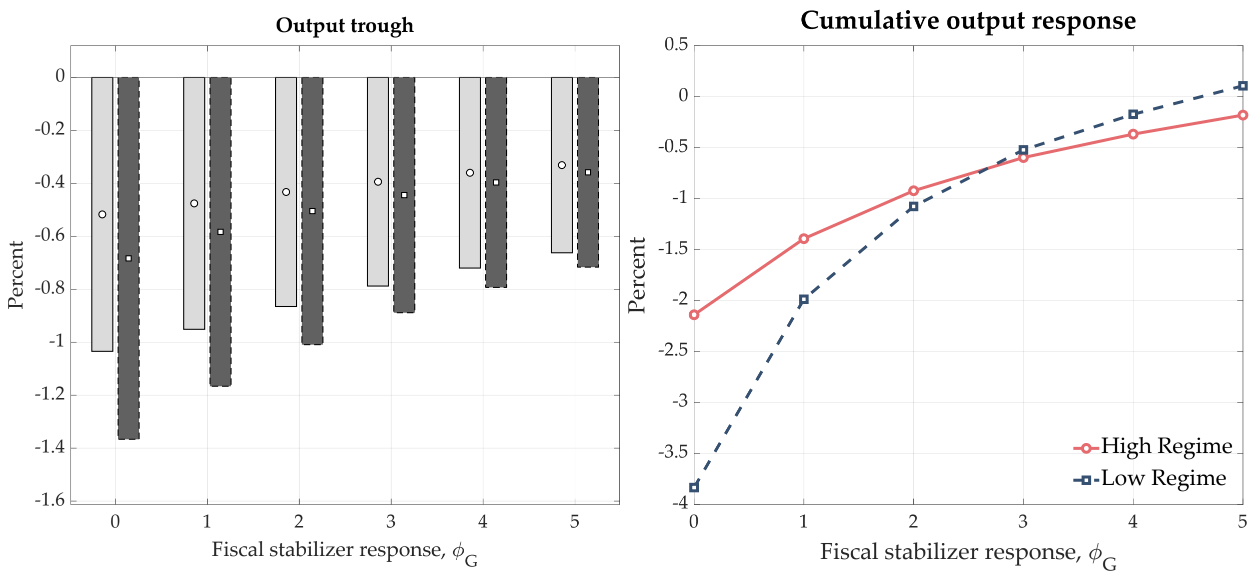
Policy mix	Monetary rule (ϕ_Y)	Fiscal rule (ϕ_G)	Output trough	Cumulative output
Benchmark	0.26	0	−1.367%	−3.835
Aggressive MP	0.50	0	−1.222%	−2.899
Fiscal stabilizer	0.26	3	−0.889%	−0.522

Note. All configurations are evaluated in the low-rate regime using the same recession shock. Cumulative output is the signed sum of the output deviation over sixteen quarters, measured in percent-quarters. Less negative values indicate smaller cumulative output losses.

Increasing the monetary policy response from $\phi_Y = 0.26$ to $\phi_Y = 0.50$ reduces the output trough by approximately 11 percent and the cumulative loss by approximately 24 percent. However, the fiscal stabilizer reduces the output trough by approximately 35 percent and the cumulative loss by approximately 86 percent. The effect on the output trough is about 3.3 times larger than that of the aggressive monetary rule. This is because fiscal policy directly supports aggregate demand, while additional monetary easing still relies on the impaired pass-through from the policy rate to bank retail rates.

I then vary ϕ_G from zero to five while holding the monetary rule at its benchmark to examine whether this result holds for different degrees of fiscal intervention. Figure 11 reports the results. The left panel shows the output trough, while the right panel shows the cumulative output response over sixteen quarters. As ϕ_G increases, both measures improve in the low-rate regime. At $\phi_G = 3$, the output trough improves from -1.37 percent to -0.89 percent, while the cumulative output loss falls from -3.83 to -0.52 percent-quarters. The cumulative gap between the two regimes is almost closed, while the trough gap also continues to decline. This differs from Figure 10, where increasing the Taylor rule response does not eliminate the gap between the two regimes. Therefore, fiscal policy can stabilize the low-rate recession even when additional conventional monetary easing becomes less effective.

FIGURE 11. Fiscal Stabilization beyond Monetary Policy Constraints



Note. The left panel reports the output trough for fiscal-stabilizer coefficients between zero and five; all troughs are plotted as negative percent deviations. The right panel reports the cumulative output response over sixteen quarters, in percent-quarters, under the same recession shock as Figure 10. The monetary-policy rule is held at its benchmark, $\phi_Y = 0.26$, and the policy-rate lower bound is imposed in both regimes. Blue denotes the high-rate regime and red the low-rate regime. A less negative value indicates a milder recession.

The broader implication is about the timing of fiscal–monetary coordination. Fiscal support does not become important only after the policy rate reaches zero, as emphasized by Eggertsson and Woodford (2003) and Christiano et al. (2011). It becomes relevant once the deposit-rate floor binds, even when the policy rate remains positive. This is because the effective constraint on monetary policy arises from weak pass-through to retail rates before the policy rate itself reaches zero. Therefore, fiscal stabilization becomes more important already in low-rate environments.

6.5. Model Extension: Bond Financing Channel

In the baseline model, firms rely only on bank loans. However, market-based debt is also quantitatively important in the United States, as documented by Crouzet (2018). Based on the Federal Reserve's Financial Accounts, debt securities account for approximately 40 percent of total nonfinancial business debt when I aggregate the nonfinancial corporate and noncorporate business sectors. These sectors together include publicly traded firms, privately held corporations, and unincorporated businesses, including many small and medium-sized businesses.

I therefore extend the baseline model by allowing firms to issue bonds in addition to borrowing from banks, following De Fiore and Uhlig (2011). Firms aggregate bank loans and bonds using a CES formulation to finance capital purchases. This allows firms to substitute toward bond financing when bank credit becomes more costly or less available.[25] The firm problem is presented in Appendix C.

Table 6 compares the baseline model and the extended model that allows firms to finance with bonds. Panel A reports the monetary policy shock experiment. In the high-rate regime, the output response changes only slightly, from 0.60 percent to 0.58 percent once bond financing is allowed. However, the difference is larger in the low-rate regime. The impact output response increases from 0.24 percent to 0.38 percent, by 14 basis points. Bond finance therefore recovers about 42 percent of the transmission loss in the baseline model. This is because firms substitute toward bonds when monetary easing no longer lowers bank loan rates in the low-rate regime. This provides an additional financing channel through which monetary policy affects output.

Panel B reports the recession experiment. The extended model does not show much difference in the high-rate regime. In the low-rate regime, however, bond finance reduces the decline in output. Under the benchmark monetary rule, the output trough improves from −1.37 percent to −1.19 percent. Under the aggressive monetary rule, the low-rate trough improves from −1.22 percent to −1.02 percent, while the regime gap falls from 0.36 to 0.16 percentage point. Therefore, bond finance reduces the stabilization gap between the two regimes by more than one-half under both monetary policy rules.

The fiscal stabilizer experiment shows a similar pattern. In the high-rate regime, the output trough remains around −0.79 percent in both models. In the low-rate regime, bond finance improves the output trough from −0.89 percent to −0.82 percent. The gap between the low- and high-rate regimes therefore falls from 0.10 percentage point in the baseline model to 0.04 percentage point

[25] The two sources of financing are not assumed to be perfect substitutes. Bond financing is concentrated among large firms, while small and medium-sized firms remain substantially dependent on bank lending. Because the model represents the aggregate corporate sector rather than individual firms, I set the benchmark elasticity of substitution to 0.5 and consider 0.25, 1, and 2 in the sensitivity analysis.

Table 6. Baseline Model and Bond-Finance Extension

Experiment and policy	Regime	Baseline	Bond finance
Panel A. Output response to an expansionary monetary-policy shock			
Impact response	High-rate	0.604	0.580
Impact response	Low-rate	0.238	0.378
Low/high response ratio	–	39.4	65.1
Panel B. Output trough under the common recession shock			
	High-rate	−1.034	−1.039
Benchmark MP	Low-rate	−1.367	−1.186
	Low–high gap	**-0.332**	**-0.147**
	High-rate	−0.858	−0.862
Aggressive MP	Low-rate	−1.222	−1.018
	Low–high gap	**-0.364**	**-0.156**
	High-rate	−0.788	−0.785
Fiscal stabilizer	Low-rate	−0.889	−0.822
	Low–high gap	**-0.101**	**-0.037**

Note. Panel A reports the impact output response, in percent, to the same expansionary monetary-policy shock. The low/high response ratio is expressed in percent. Panel B reports the output trough, in percent, under the same recession shock. The low−high gap is the low-rate trough minus the high-rate trough. The aggressive monetary rule sets $\phi_Y = 0.50$, the fiscal stabilizer sets $\phi_G = 3$, and the bond-finance extension sets the elasticity of substitution between bank loans and bonds to 0.5.

with bond finance. Fiscal policy remains effective even after bond finance is introduced, while bond finance further reduces the difference between the two regimes.

Overall, bond finance matters mainly in the low-rate regime. When the deposit-rate floor prevents bank loan rates from declining further, firms substitute part of their bank borrowing with bonds. This reduces the loss of monetary policy transmission and makes the recession less severe. However, bank loans and bonds are imperfect substitutes, so bond finance cannot fully replace bank lending. Therefore, the extension weakens but does not eliminate the main result.

7. Conclusion

This paper shows that monetary policy can lose its effectiveness in a low but positive policy rate regime through the banking sector. I show that once the policy rate gets low enough to induce banks to set the deposit rate to 0% and further policy rate cuts are no longer translated into declines in the deposit rate, the loan rate also stops responding to further policy rate cuts. Then, the net interest margin remains stable in response to an additional monetary policy shock, while bank equity and leverage also remain stable. However, as the loan rate does not decline, loan demand is not stimulated. Therefore, while banks can maintain their equity and lending capacity, the effectiveness of monetary policy gets dampened as demand through lending is not stimulated.

This paper has two policy implications. First, it highlights coordination between monetary policy and fiscal policy, rather than the macroprudential policy suggested in the literature. The main mechanism through which monetary policy loses its effectiveness in the low-interest-rate regime has been understood as the erosion of the banking sector stemming from a narrowed net interest margin. In this mechanism, the loan rate is assumed to respond to policy rate changes while the deposit rate is stuck at its own lower bound. Therefore, the policy implication drawn from this margin is coordination between monetary policy and bank regulation that makes banks more buffered to prevent depletion of capital in the low-interest-rate regime and to maintain the effectiveness of monetary policy. However, this paper shows that the loan rate does not decline and banks keep their lending capacity safe while loan demand is not stimulated. Therefore, this paper instead calls for coordination between monetary policy and other stimulus policies such as government spending.

Second, it highlights that the need for policy coordination arises earlier than suggested in the literature. Under the bank equity erosion mechanism, monetary policy loses its effectiveness below the policy rate zero lower bound. This is because the policy rate has to be low, even negative enough, so that bank equity is depleted enough to lose its effectiveness. However, this paper highlights that this happens much earlier, even above the zero lower bound, because the pass-through from the policy rate to the deposit rate collapses well above zero, around 2% in the case of the U.S., and the loan rate response also stops as the deposit rate stops responding. This implies that policy coordination should be discussed earlier, well above the zero lower bound.

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ONLINE APPENDIX

Appendix A. Comparison with Eichenbaum et al. (2025)

In this section, I replicate the results of Eichenbaum et al. (2025) on the responses of the net interest margin (the gap between the loan rate and deposit rate) to monetary policy shocks in the low-interest-rate regime. Then, I compare the response of the net interest margin under different specifications and different shocks.

A.1. Replicating Eichenbaum et al. (2025) Results

First, I replicate the results reported by Eichenbaum et al. (2025) using their specification. I run the SVAR documented in Eichenbaum et al. (2025) and obtain the residuals as the SVAR-identified shock, which is their main shock. Then, I run state-dependent local projections using the aggregate data as Eichenbaum et al. (2025) explain, using i) the SVAR-identified shock, ii) the Bauer and Swanson (2023) shock, and iii) the Jarociński and Karadi (2020) shock, to estimate the response of the net interest margin in the low-interest-rate regime. The low-interest-rate regime is defined as the average federal funds rate over the past 6 quarters being below 4%.

Figure A.1. IRFs of NIM to Monetary Policy Shock in the Low-Interest-Rate Regime
Replicating Eichenbaum et al. (2025) Results

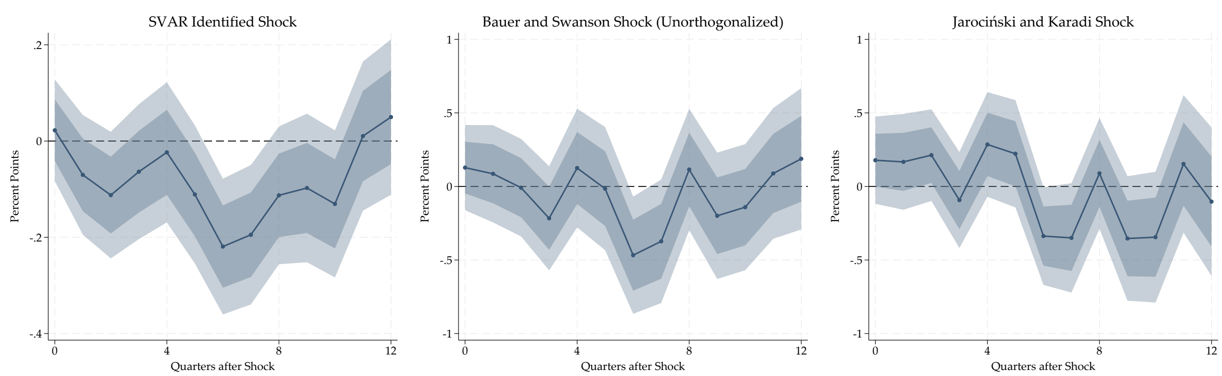


Figure A.1 shows the results. For the SVAR-identified shock and Bauer and Swanson (2023) shock cases, the net interest margin shrinks after 6 quarters. In the case of the SVAR-identified shock, it shrinks by 21 basis points, and for the Bauer and Swanson (2023) shock, it narrows by 51 basis points. Note that the Bauer and Swanson (2023) shock that replicates Eichenbaum et al. (2025) is the unorthogonalized shock, whereas the orthogonalized version does not show a statistically significant response, which is reported in the next section. Shocks constructed by Jarociński and Karadi (2020) do not show the response that Eichenbaum et al. (2025) documented.

Then, under the Eichenbaum et al. (2025) specification, I change the monetary policy shocks to the orthogonalized Bauer and Swanson (2023) shocks and other high-frequency identified shocks, Nakamura and Steinsson (2018) and Acosta et al. (2025).

FIGURE A.2. IRFs of NIM to Monetary Policy Shock in the Low-Interest-Rate Regime
Other HFI Monetary Policy Shocks

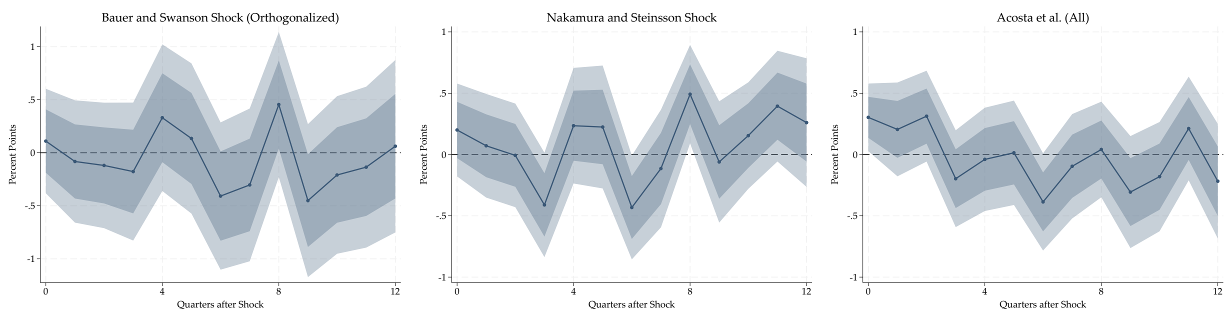


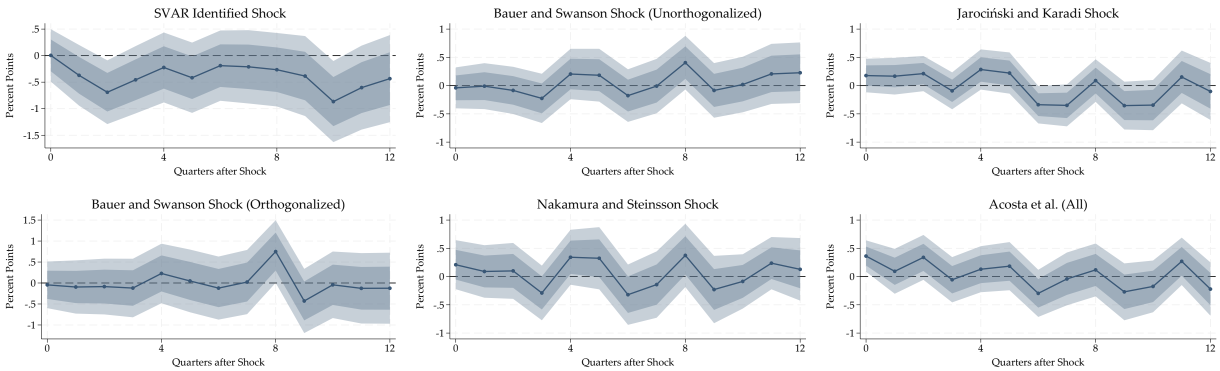
Figure A.2 shows the results. Once the shocks are substituted with other high-frequency identified shocks, the net interest margin does not shrink. The results show that while the point estimates of the net interest margin decline, the impulse response functions do not exhibit systematic responses to the shocks. This implies that the choice of shock matters for identifying the response of the net interest margin.

Finally, I change the threshold from the Eichenbaum et al. (2025) low-interest-rate regime to the definition in this paper, which is a one-quarter federal funds rate below 2%, while holding the other specifications the same as in Eichenbaum et al. (2025). Then, I estimate the response of the net interest margin to the 6 shocks that I consider here, including the shocks utilized by Eichenbaum et al. (2025) and the other high-frequency identified shocks.

Figure A.3 shows the results. Once the threshold definition changes, the SVAR-identified shock shows that the net interest margin shrinks after the second quarter following the shock and again in the 10th quarter. However, for the rest of the high-frequency identified shocks, including the unorthogonalized Bauer and Swanson (2023) shock and the Jarociński and Karadi (2020) shock, the net interest margin does not shrink.

Therefore, this section shows that both the monetary policy shocks and the definition of the threshold contribute to the difference between the results of Eichenbaum et al. (2025) and this paper.

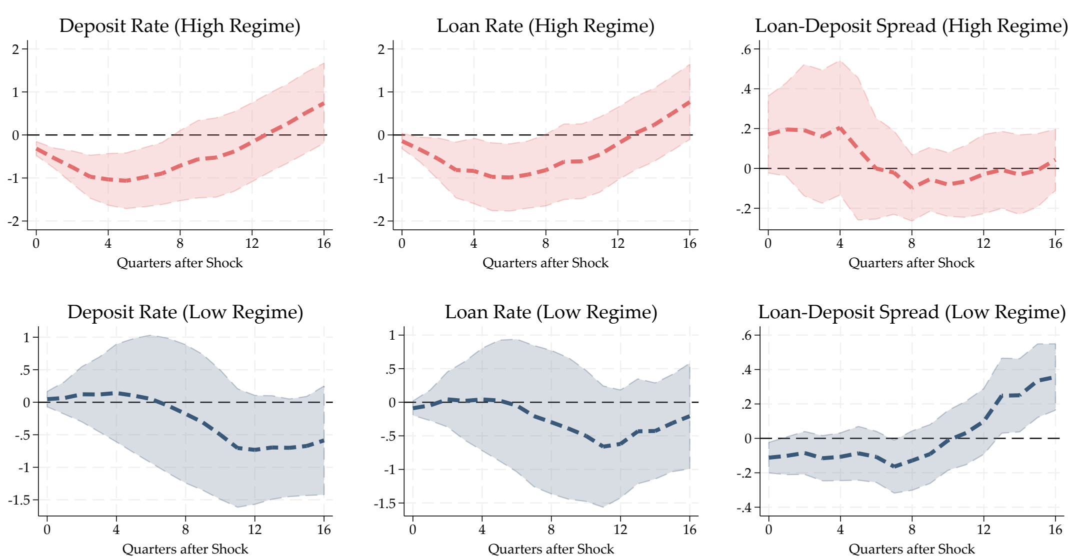
Figure A.3. IRFs of NIM to Monetary Policy Shock in the Low-Interest-Rate Regime
2% Threshold

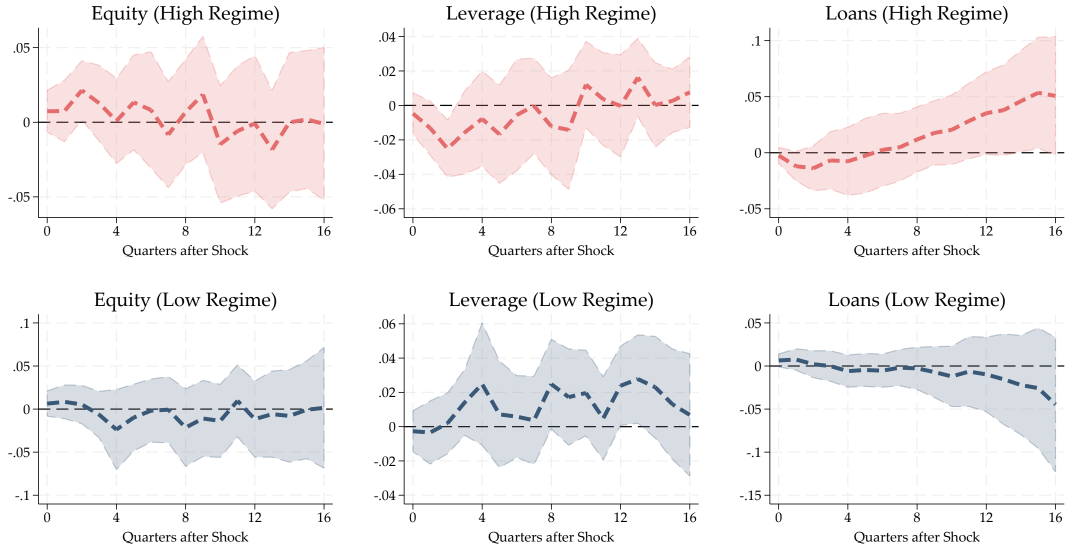


Appendix B. Robustness Check

B.1. Nakamura and Steinsson (2018) Shock

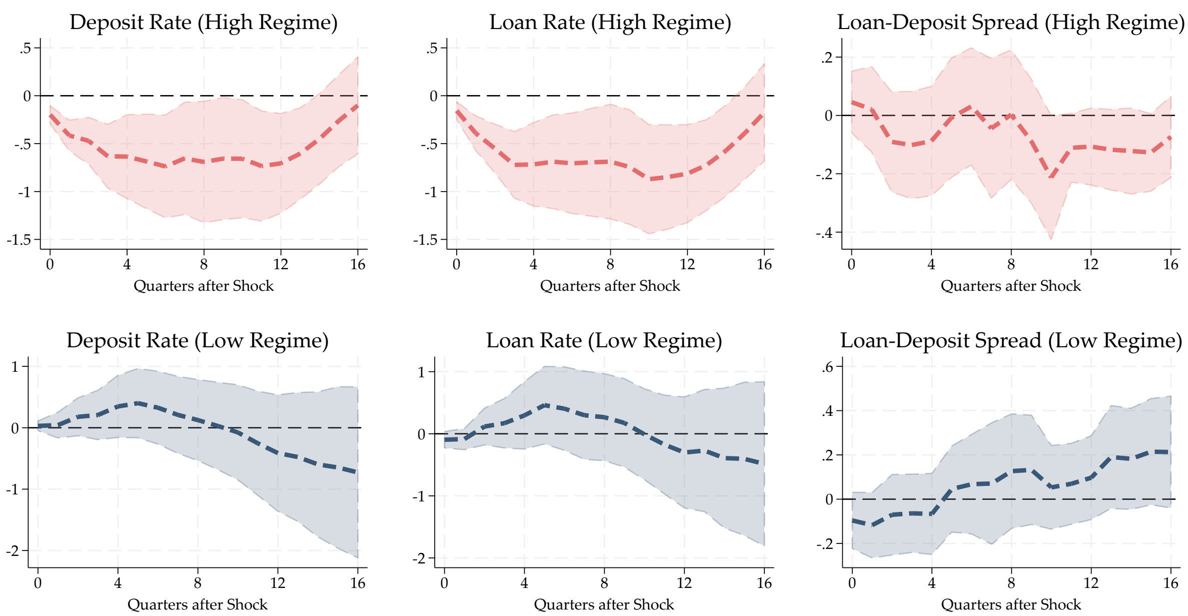
In this section, I utilize Nakamura and Steinsson (2018) shock and presents the impulse responses of each variable of equation (2).

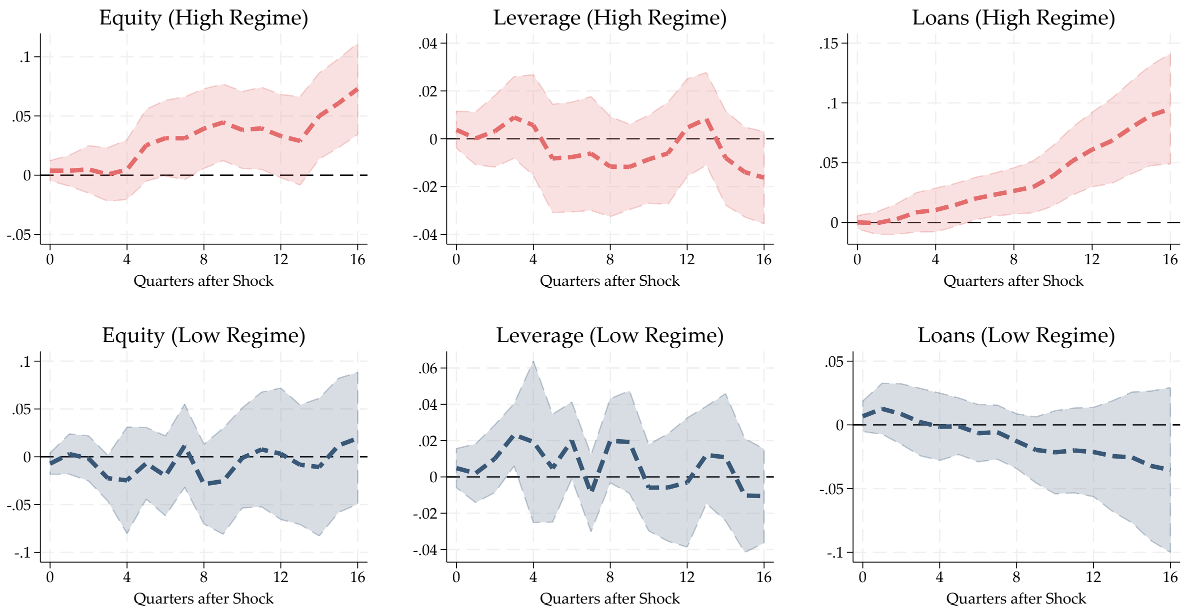




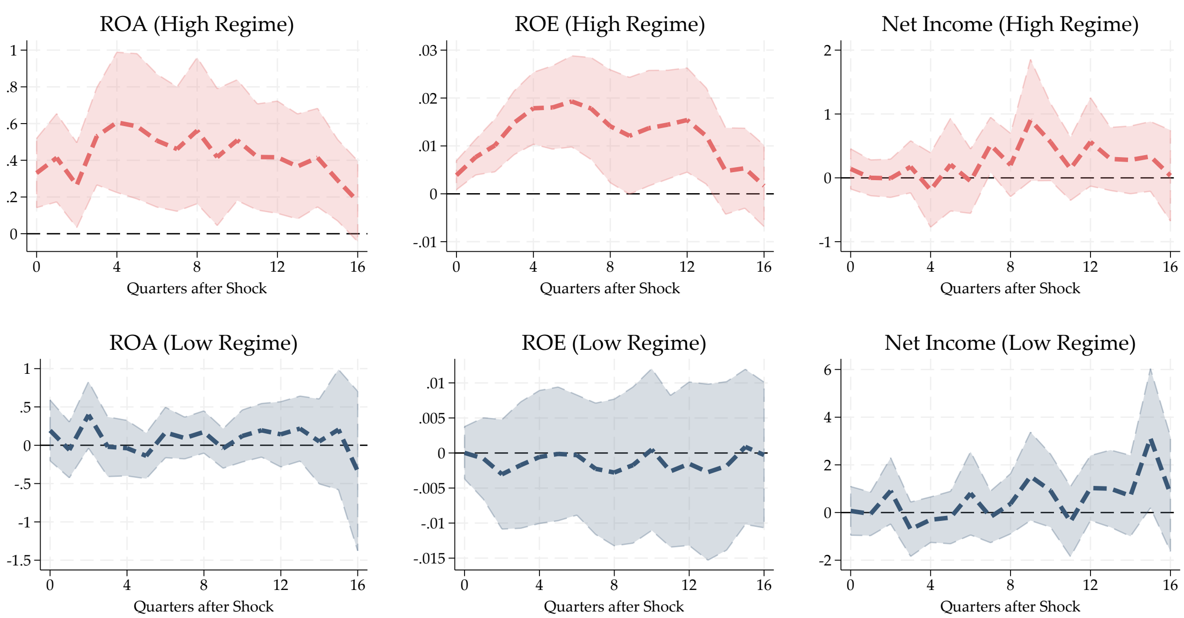
B.2. Acosta et al. (2025) Shock

In this section, I utilize Acosta et al. (2025) shock and presents the impulse responses of each variable of equation (2).



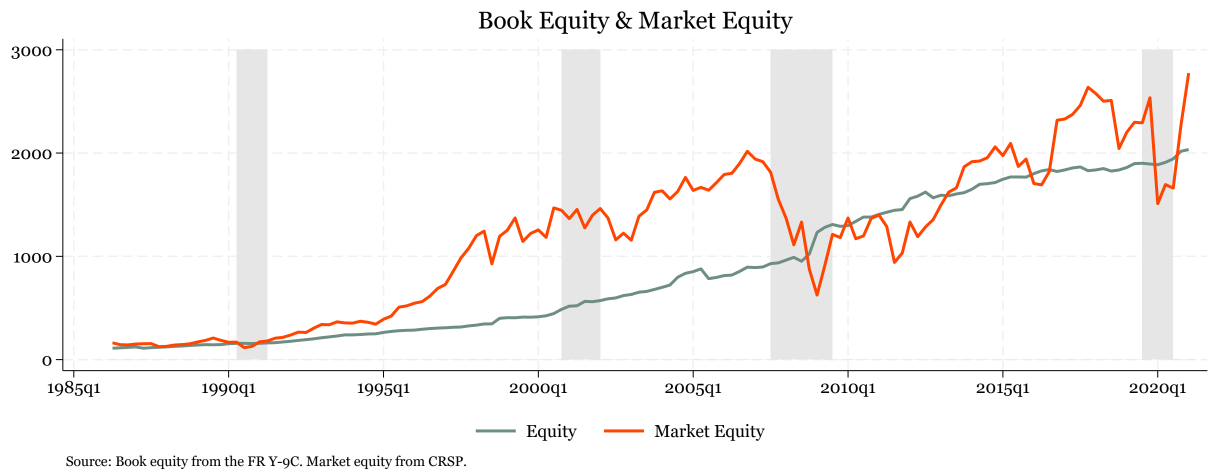


B.3. Other - ROE and Net Income



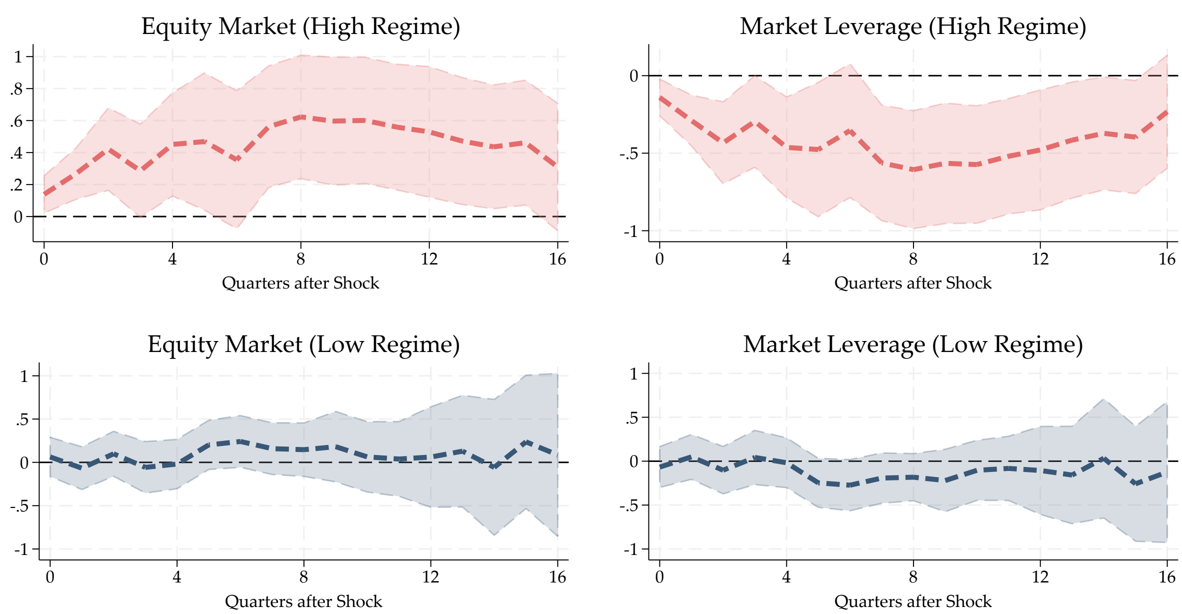
B.4. Other - Market Value

FIGURE A.1. Book Valued Equity and Market Valued Equity

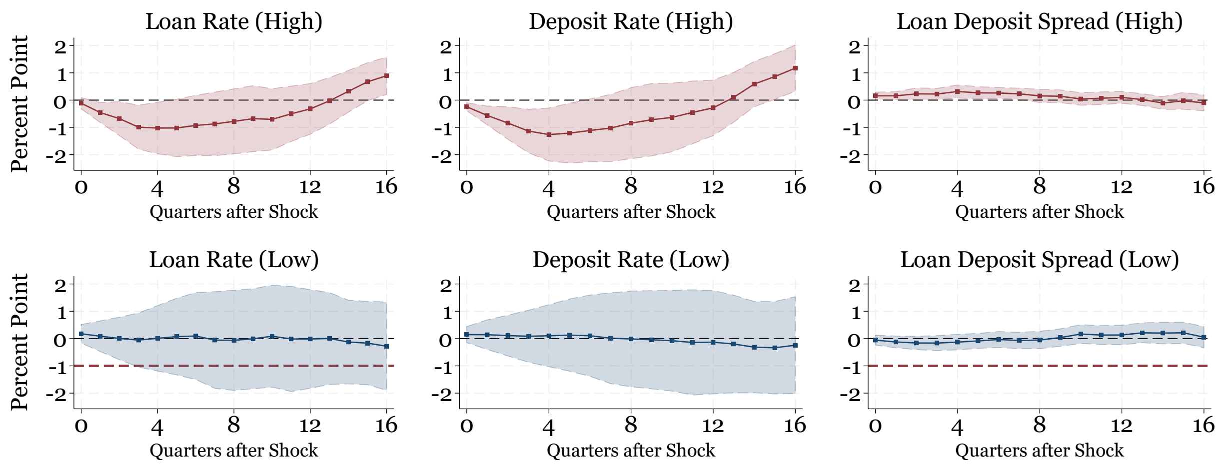


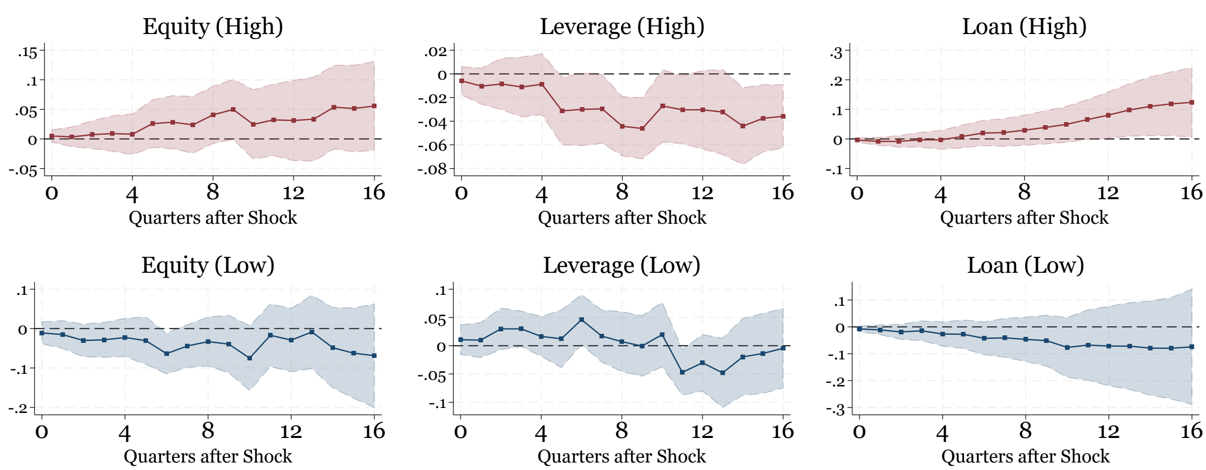
Note. These figures show data on book equity and market equity for an aggregate sample of publicly traded BHCs. Book equity are from the FR Y-9C. Market equity is from CRSP. Market equity equals shares outstanding times the share price, aggregated across publicly traded BHCs.

FIGURE A.2. Impulse Response of Market Value Equity and Leverage

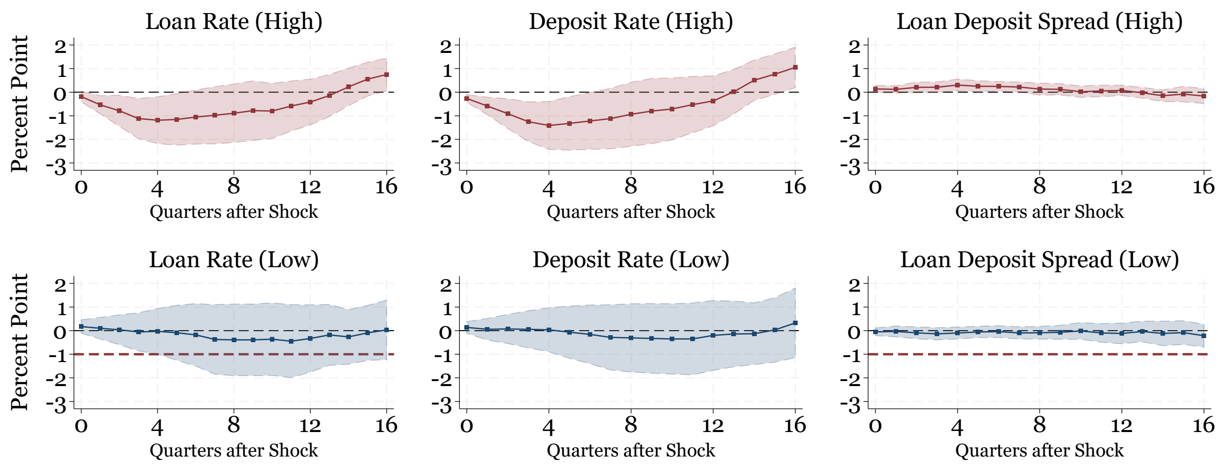


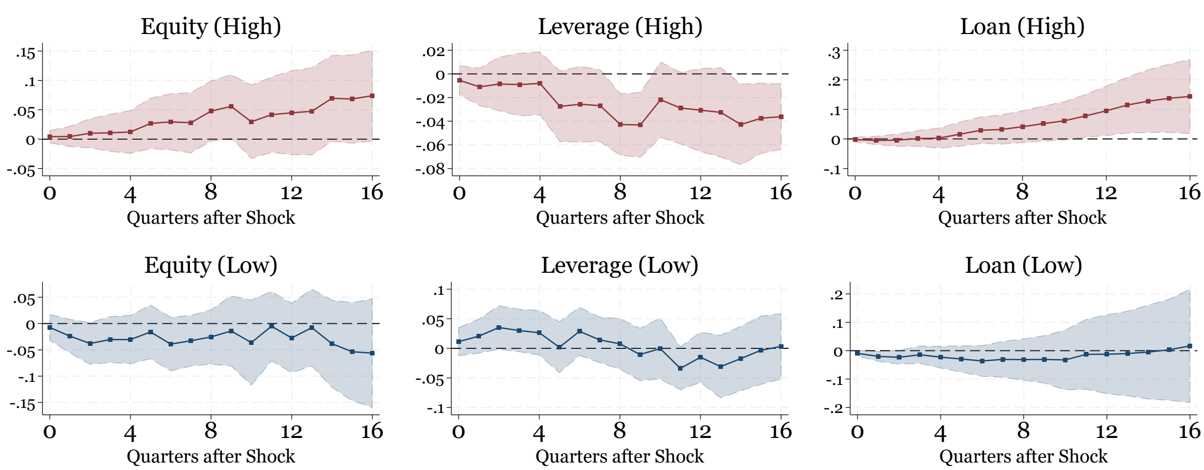
B.5. Different Cutoff: $\gamma = 1.8\%$





B.6. Different Cutoff: $\gamma = 2.4\%$





B.7. Interaction Term

$$y_{t+h,b} = \beta_h^{Direct} \times \varepsilon_t + \beta_h^{Indirect} \times i_{t-1} \times \varepsilon_t + \mathbf{X}'_{b,t-1}\Gamma_h + \alpha_{b,h} + e_{b,t+h} \tag{B.1}$$

Each figure displays $\beta_h^{Indirect}$ from equation (B.1) for each variable. $\beta_h^{Indirect} < 0$ implies that the outcome decreases more in response to the expansionary monetary policy change when interest rates are higher. Conversely, $\beta_h^{Indirect} > 0$ implies that the outcome increases more in response to the expansionary monetary policy change when interest rates are higher.

FIGURE A.3. Loan Rate, Deposit Rate, and Spread

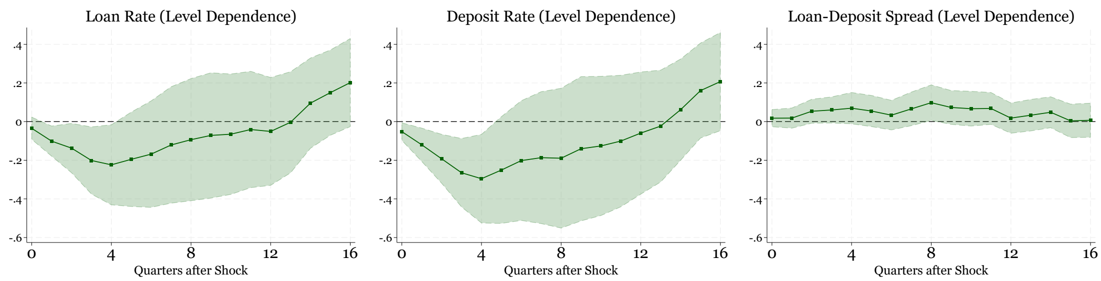


FIGURE A.4. Equity, Leverage, and Loan

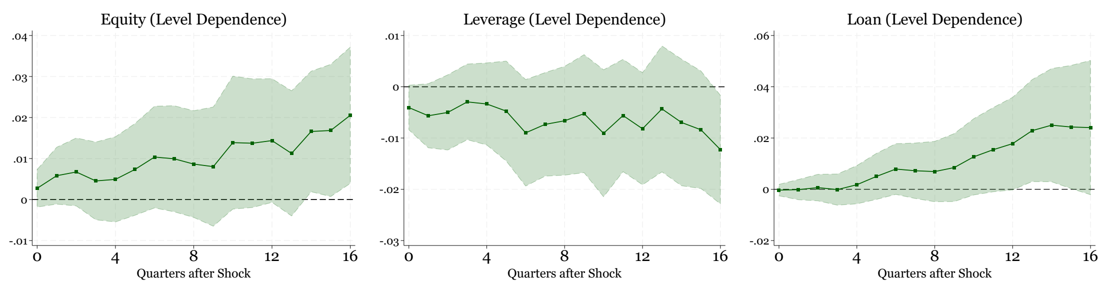
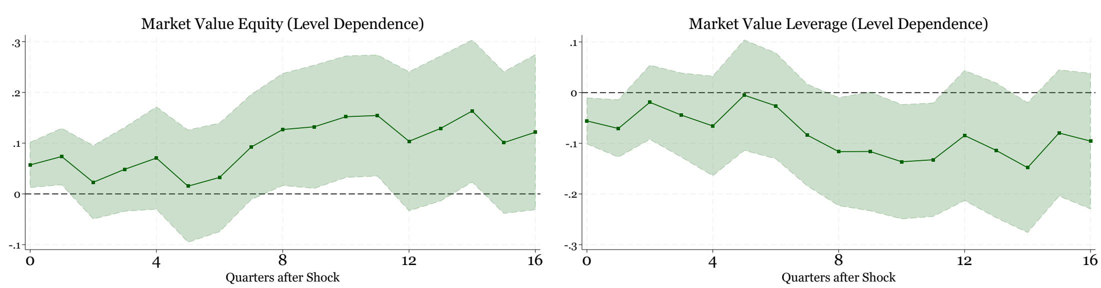


FIGURE A.5. Market Value Equity and Leverage

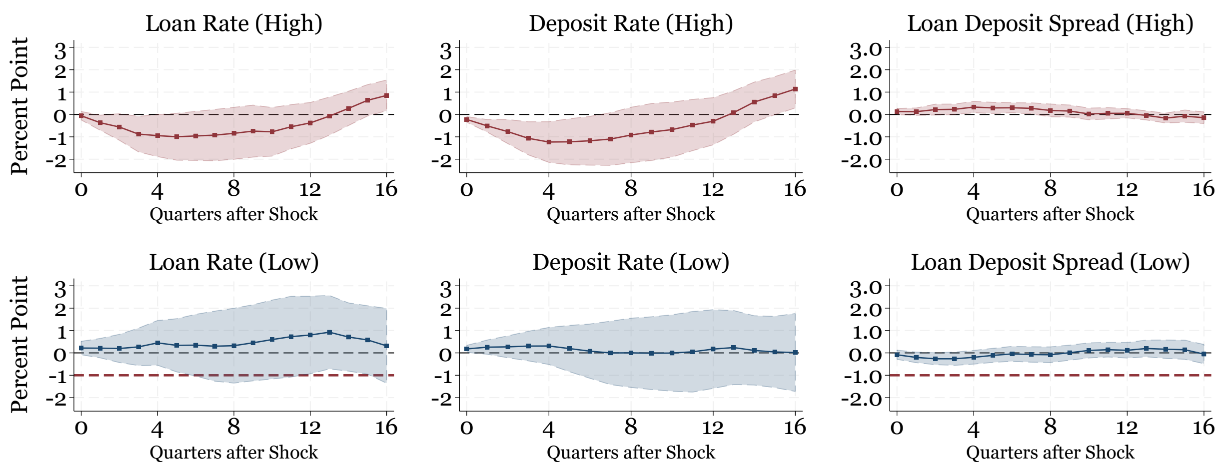


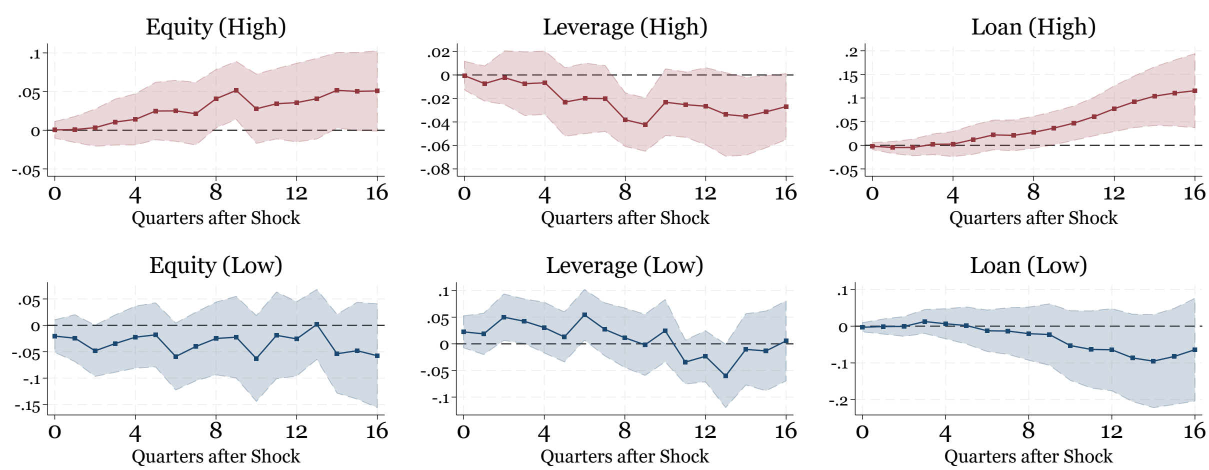
B.8. Controlling Confounding Effect

$$
\begin{aligned}
y_{t+h,b} = \beta_h^H \times \mathbb{I}\left[i_{t-1} > \gamma\right] \times \varepsilon_t + \beta_h^L \times \mathbb{I}\left[i_{t-1} \le \gamma\right] \times \varepsilon_t \\
\underbrace{+\gamma_h \times C_{b,t-1}}_{\text{Confounding Factor } \varepsilon_t} + \underbrace{\gamma_h^C \times C_{b,t-1} \times \varepsilon_t}_{\text{Interaction Term with } \varepsilon_t} + \mathbf{X}'_{b,t-1}\Gamma_h + \alpha_{b,h} + e_{b,t+h}
\end{aligned}
\tag{B.2}
$$

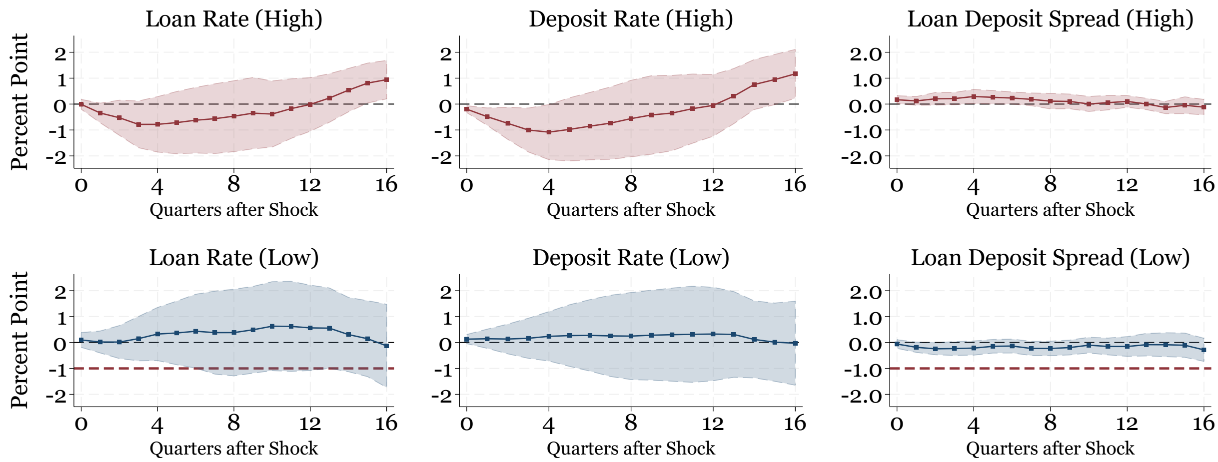
This section displays the re-estimated results of β_h^H and β_h^L of equation (B.2) after including covariates ($C_{b,t-1}$) and interaction terms between these covariates and the monetary policy variable, $(C_{b,t-1}) \times \varepsilon_t$. This approach aims to isolate the true effect of the policy rate on bank behavior while accounting for other potentially confounding factors.

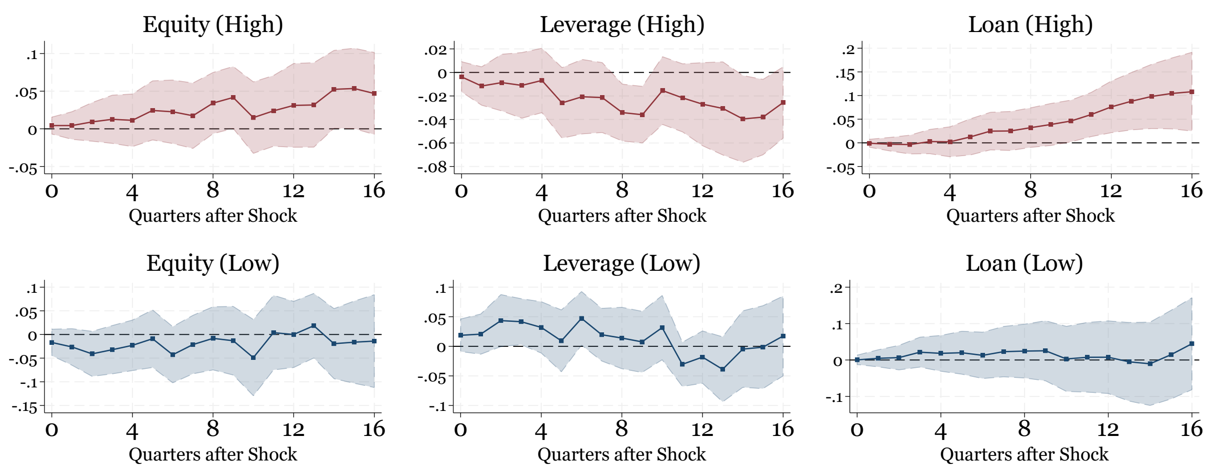
B.8.1. $C_{b,t-1}$: Excess Bond Premium by Gilchrist and Zakrajšek (2012)



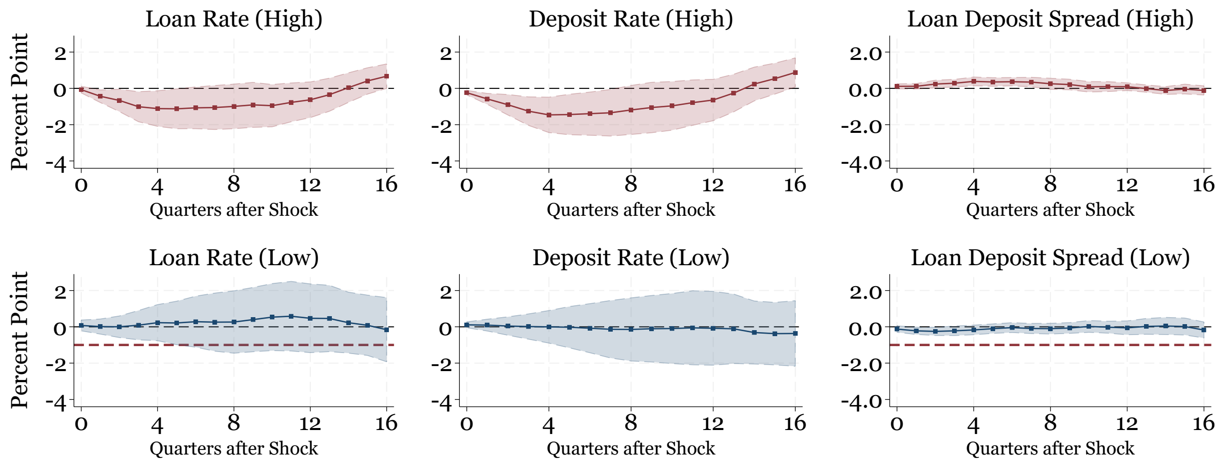


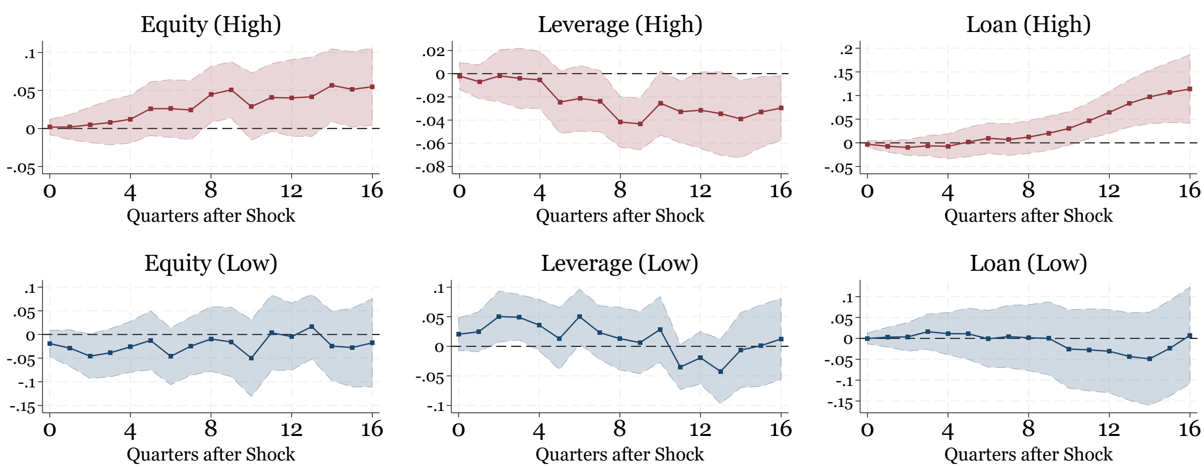
B.8.2. $C_{b,t-1}$: Recession Indicator



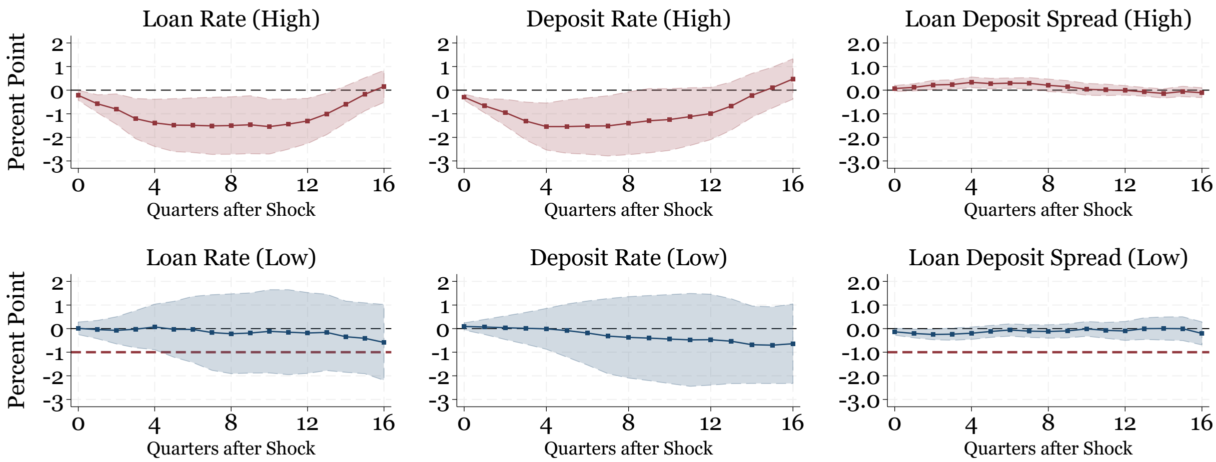


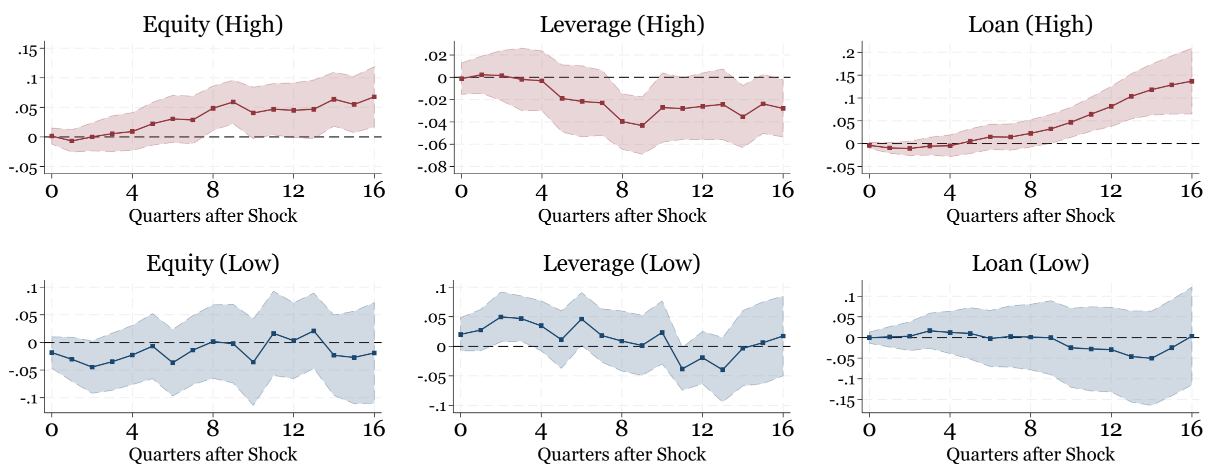
B.8.3. $C_{b,t-1}$: Great Financial Crisis Period



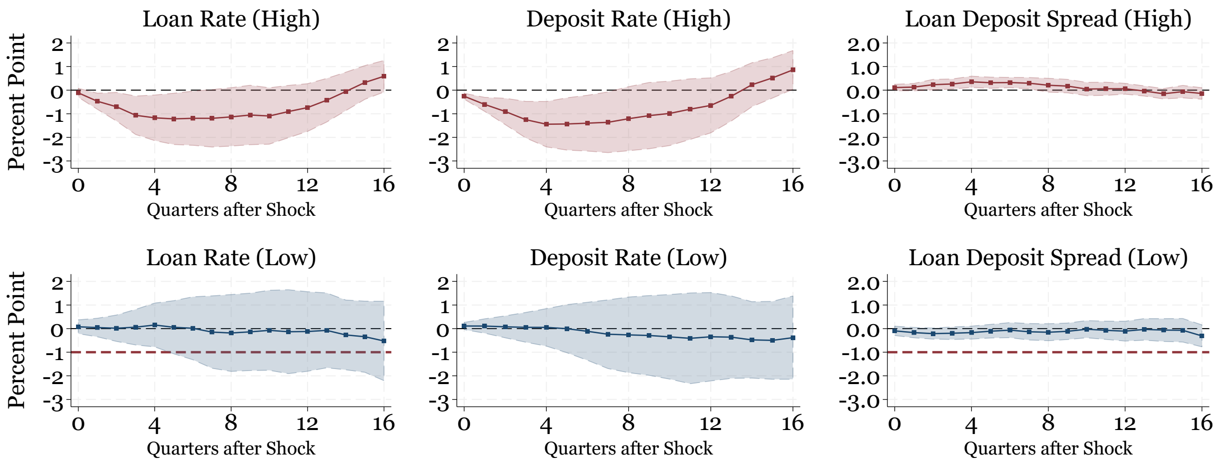


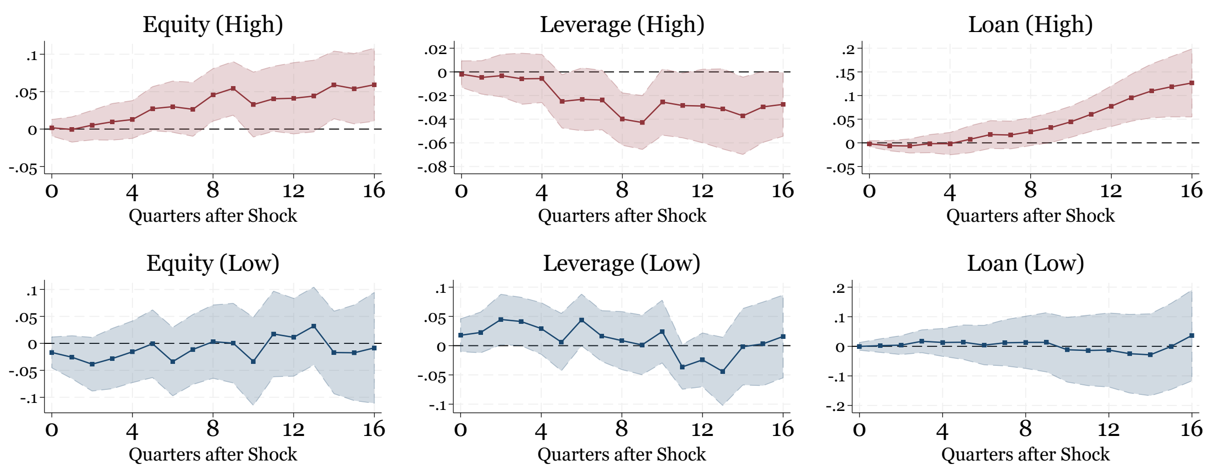
B.8.4. $C_{b,t-1}$: Total Macro Uncertainty by Ludvigson et al. (2021)



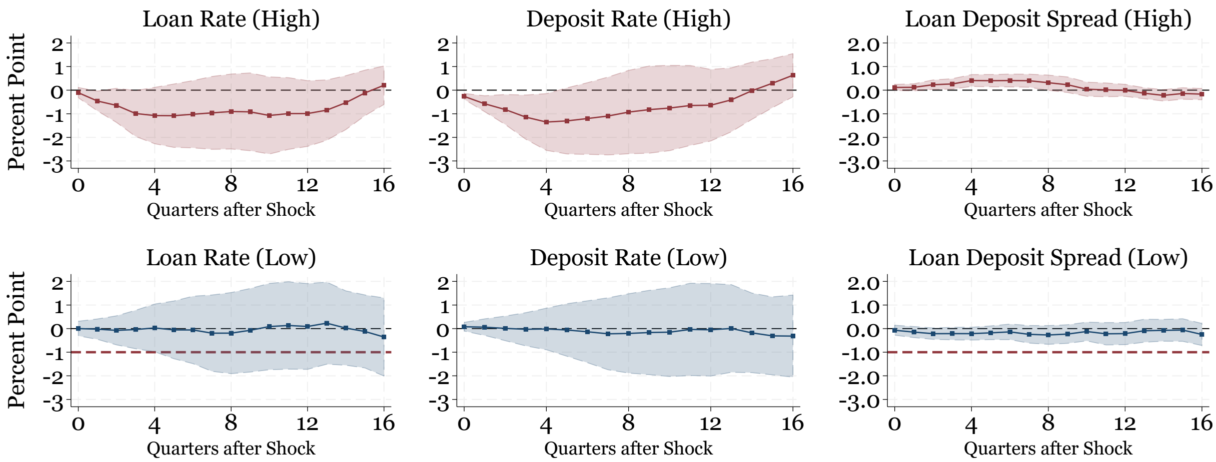


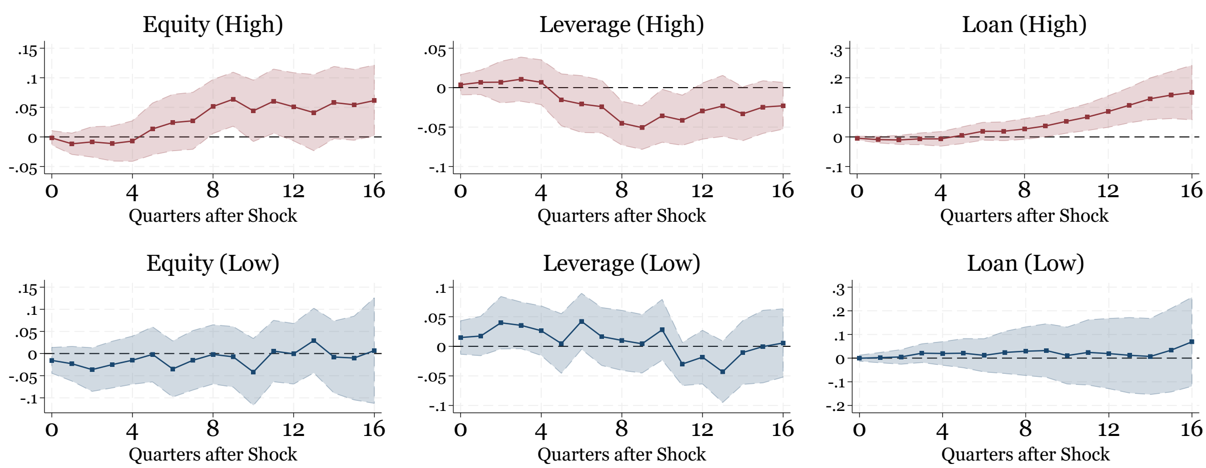
B.8.5. $C_{b,t-1}$: Total Financial Market Uncertainty by Ludvigson et al. (2021)



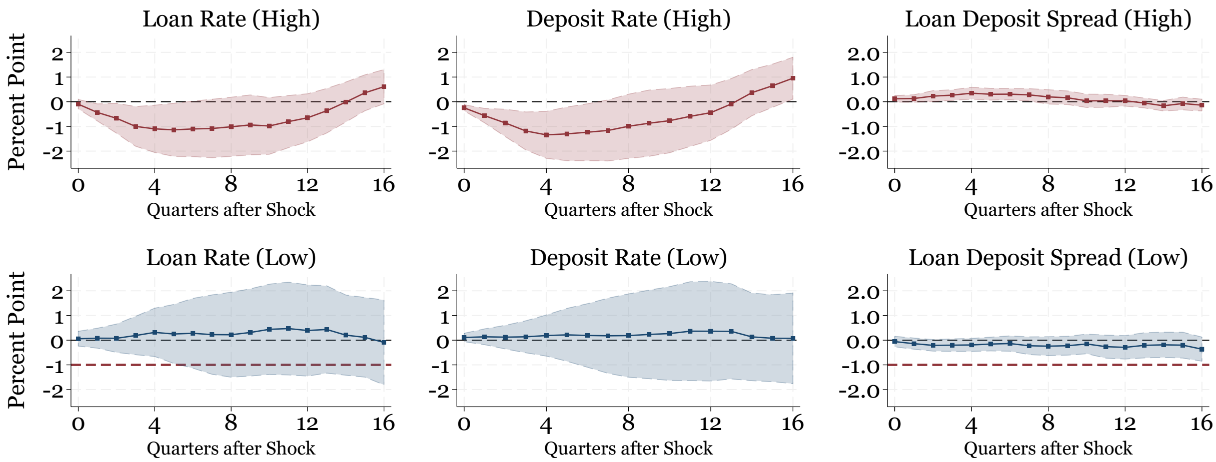


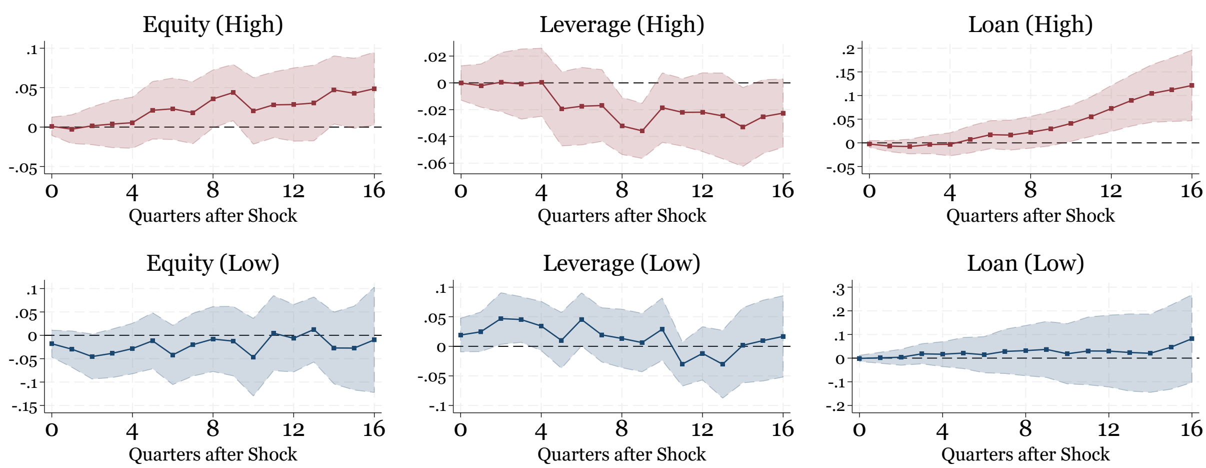
B.8.6. $C_{b,t-1}$: Monetary Policy Uncertainty by Baker et al. (2016)





B.8.7. $C_{b,t-1}$: Loss Provision

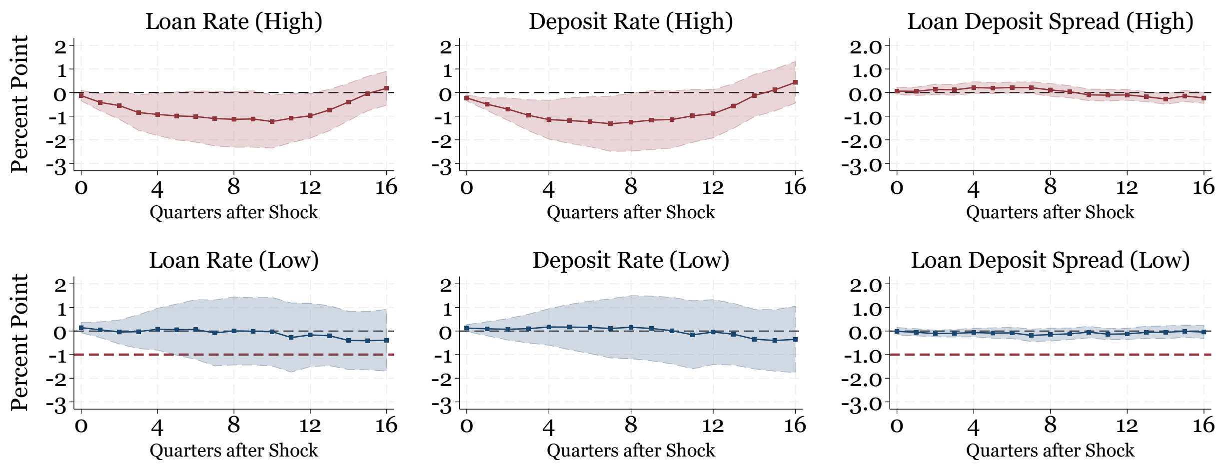


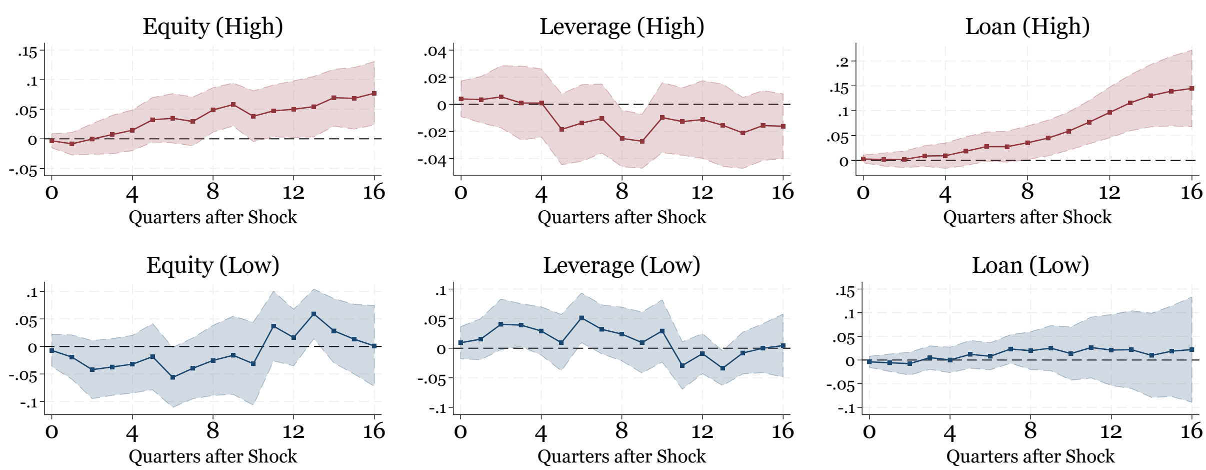


B.9. Ramey and Zubairy (2018) Local Projection

$$y_{t+h,t-1,b} = \mathbb{I}[i_{t-1} > \gamma\%] \times \left[\boldsymbol{\beta_h^H} \boldsymbol{\varepsilon_t} + \Gamma_h^{H'} \boldsymbol{X}_{b,t-1} \right] + \mathbb{I}[i_{t-1} \leq \gamma\%] \times \left[\boldsymbol{\beta_h^L} \boldsymbol{\varepsilon_t} + \Gamma_h^{L'} \boldsymbol{X}_{b,t-1} \right] + \alpha_{b,h} + e_{b,t+h} \tag{B.3}$$

This section displays the reestimated results of β_h^H and β_h^L of equation (B.3), which allows the covariates I consider in both aggregate level and bank level to affect the outcome differently following Ramey and Zubairy (2018).





Appendix C. Firm Financing with Bank Loans and Corporate Bonds

This appendix extends the baseline model by allowing nonfinancial firms to finance capital with corporate bonds as well as bank loans. The extension changes the composition and effective cost of firm financing.

Let B_t denote the quantity of corporate bonds issued in period t, R_t^B denote the gross corporate-bond rate, and X_t denote the effective amount of external finance available for capital purchases. Bank loans and corporate bonds provide imperfectly substitutable financing services, following De Fiore and Uhlig (2011), according to

$$X_t = \left[\omega_L^{1/\sigma_X} L_t^{(\sigma_X-1)/\sigma_X} + (1-\omega_L)^{1/\sigma_X} (B_t)^{(\sigma_X-1)/\sigma_X}\right]^{\sigma_X/(\sigma_X-1)}, \tag{C.1}$$

where $\omega_L \in (0,1)$ is the weight on bank loans and $\sigma_X > 0$ is the elasticity of substitution between the two financing sources.

The finite elasticity captures the limited access of small and medium-sized firms to public debt markets and the relationship-specific services associated with bank lending, as discussed in De Fiore and Uhlig (2011); Crouzet (2018). Thus, the CES block provides an aggregate representation of these financing segments.

C.1. Firm problem

The firm's problem can be written in two stages. Conditional on obtaining X_t units of effective external finance, the firm chooses loans and bonds to minimize its contractual repayment

$$C_t(X_t) = \min_{L_t, B_t \geq 0} \left\{R_t^L L_t + R_t^B B_t\right\} \quad \text{subject to} \quad F(L_t, B_t) \geq X_t, \tag{C.2}$$

where $F(\cdot)$ is the CES aggregator in equation (C.1). Let R_t^X denote the multiplier on the financing requirement. Because the aggregator has constant returns to scale, R_t^X is both the shadow price and the unit cost of effective finance, so that

$$C_t(X_t) = R_t^X X_t. \tag{C.3}$$

Solving the first-order conditions gives the relative financing demand

$$\frac{L_t}{B_t} = \frac{\omega_L}{1-\omega_L}\left(\frac{R_t^L}{R_t^B}\right)^{-\sigma_X}. \tag{C.4}$$

Substituting the first-order conditions into the financing requirement gives the CES unit-cost index

$$R_t^X = \left[\omega_L (R_t^L)^{1-\sigma_X} + (1-\omega_L)(R_t^B)^{1-\sigma_X}\right]^{1/(1-\sigma_X)}, \qquad \sigma_X \neq 1. \tag{C.5}$$

The conditional demands for each financing source are

$$L_t = \omega_L X_t \left(\frac{R_t^L}{R_t^X}\right)^{-\sigma_X}, \qquad B_t = (1-\omega_L) X_t \left(\frac{R_t^B}{R_t^X}\right)^{-\sigma_X}. \tag{C.6}$$

As in the baseline model, capital purchased in period t must be externally financed

$$X_t = q_t K_{t+1}. \tag{C.7}$$

A unit of capital yields rental income r_{t+1}^k and an undepreciated resale value $(1-\delta)q_{t+1}$ in period $t+1$. After substituting the minimized financing cost from equation (C.3), the capital choice is

$$\max_{K_{t+1}\geq 0} \left\{\mathbb{E}_t\left[\Pi_{t+1}\left(r_{t+1}^k + (1-\delta)q_{t+1}\right)K_{t+1}\right] - R_t^X q_t K_{t+1}\right\}. \tag{C.8}$$

In equilibrium,

$$R_t^X q_t = \mathbb{E}_t\left[\Pi_{t+1}\left(r_{t+1}^k + (1-\delta)q_{t+1}\right)\right] \tag{C.9}$$

holds. This condition is identical to the baseline capital-demand condition except that the loan rate R_t^L is replaced by the effective financing rate R_t^X.

The loan expenditure share can then be expressed as

$$s_t^L \equiv \frac{R_t^L L_t}{R_t^X X_t} = \omega_L \left(\frac{R_t^L}{R_t^X}\right)^{1-\sigma_X}, \qquad s_t^B = 1 - s_t^L. \tag{C.10}$$

The calibration targets a high-rate steady-state loan expenditure share of $\bar{s}_H^L = 0.60$, so corporate bonds account for the remaining 40 percent of firm financing expenditure. For a given value of σ_X, define $\bar{q}_R \equiv \bar{R}_H^L / \bar{R}_H^B$. The distribution parameter that reproduces the target share is

$$\omega_L(\sigma_X) = \frac{\bar{s}_H^L}{\bar{s}_H^L + (1-\bar{s}_H^L)\bar{q}_R^{\,1-\sigma_X}}. \tag{C.11}$$

Recalibrating ω_L in this way ensures that changes in σ_X alter the substitution elasticity without mechanically changing the targeted high-rate financing share. The benchmark uses $\sigma_X = 0.50$. The distribution parameter is fixed across interest-rate regimes, while the endogenous steady-state loan share can change as the relative loan and bond rates change.