Uninsured Deposit, Held-to-Maturity Accounting, and Bank Runs

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Abstract

How does the fragility of the banking system to interest rate risks depend on banks' exposure to run-prone funding, such as uninsured deposits, and their portfolio choices between long-term and short-term assets? How does held-to-maturity accounting, aimed to limit the impacts of banks' unrealized capital loss on the regulatory capital measures, affect banks' exposure to deposit run risks when policy rates increase? What would be the implications for regulatory policies on unrealized capital gains or losses in bank accounting? This paper addresses these questions from both empirical and theoretical perspectives. We find that banks with a larger share of uninsured deposits in their total deposits are more sensitive to the policy rate in both deposit rate and quantity. Held-to-maturity accounting encourages banks with higher uninsured deposit shares to classify their long-term assets as held-to-maturity to mitigate the impacts of unrealized losses in bank capital that result from rate hikes. But as an unintended consequence, banks are more prone to run under held-to-maturity accounting because banks hold more long-term assets ex-ante than when all long-term assets are marked to market.

Keywords: Uninsured Deposit, Held-to-Maturity, Marked-to-Market, Interest-rate risks, Bank Run

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1 Introduction

A conventional view on the banking industry is that banks' market power over retail deposits allows them to borrow at rates that are both low and insensitive to the policy interest rates (Drechsler et al., 2017). Such a feature allows banks to engage in maturity transformation while hedging against interest rate risks. The sudden collapses of regional banks such as Silicon Valley Bank (SVB), Signature Bank and First Republic Bank in the first half of 2023 show, however, that the insensitivity of deposit rates to policy interest rates and the stickiness of deposits may not always hold or apply to all banks. According to Acharya et al. (2023), more than 90% of deposits of SVB and Signature Bank were uninsured in 2022. Banks that relied heavily on uninsured deposits were particularly fragile when a sudden increase in the policy interest rate quickly raised their depositors' opportunity cost of holding low-interest-rate transaction deposits. The return-sensitive uninsured depositors thus forced banks to raise the deposit rate to retain them.

Adding to the fragility of the banking system is commercial banks' large exposure to the interest rate risk on the asset side when they hold a large share of their assets in long-term fixed-income securities such as Treasury and Mortgage-backed securities (MBS). Long-term securities faced big unrealized capital losses in their market value when the long-term average interest rate increased. To avoid the unrealized asset losses from being included in the regulatory capital measures, the aforementioned distressed banks reclassified a significant fraction of their long-term assets in the held-to-maturity (HTM) bucket so that these securities are not marked to their market value. Such reclassifications allowed banks to increase the duration of their assets until a run by uninsured depositors forced them to liquidate these securities to meet depositors' liquidity demands.

How does banks' exposure to volatile and run-prone funding, such as uninsured deposit, interact with their portfolio choices between long-term and short-term assets to influence the fragility of banking system to interest rate risks? How does the provision of held-to-maturity accounting to limit the impacts of banks' unrealized capital loss on the regulatory capital measures affect banks' exposure to deposit run risks when policy rates increase? And what would be the implications for regulatory policies on unrealized capital gain or loss in bank accounting?

This paper addresses these questions from both empirical and theoretical perspectives. We find that banks with a larger share of uninsured deposits in their total deposits face higher deposit betas on both rates and flows, which measures the sensitivity of rates and flows to the policy interest rate. Accordingly, the option of held-to-maturity accounting encourages those banks with higher uninsured deposits to put their long-term assets held-to-maturity to mitigate the impacts of unrealized capital loss on bank capital as interest rates increase. As an unintended consequence, a bank run is more likely if long-asset assets are accounted as book value in held-to-maturity. This is because banks hold more ex-ante long-term assets than when all long-term assets are marked-to-market.

Our empirical analysis starts with constructing bank-specific deposit betas on both rates and flows, using bank-level data from U.S. Call Reports. We then employ a difference-in-difference to identify the role of banks uninsured deposit ratios on both deposit betas and banks' portfolio allocation between held-to-maturity and marked-to-market assets. Our main empirical finding is that banks with a higher share of uninsured deposits in total deposits tend to have both larger deposit rate and deposit flow sensitivity to changes in policy interest rates. Moreover, with sufficiently high uninsured deposit ratios, banks tend to hold larger shares of held-to-maturity securities in their total securities as their uninsured deposit keep increasing, especially during the period of monetary tightening.

Disciplined by the above empirical findings, we develop a simple framework of bank runs, in which banks' asset portfolio choices and liquidation decisions jointly determine their vulnerability to uninsured depositor runs when the policy interest rate increases. Our framework contains three new ingredients. The first is heterogeneity in uninsured depositors' outside options, which, together with switching costs, endogenizes the uninsured depositors' deposit withdrawal choices. The second new ingredient is banks' choices of deposit pricing (and, thus, quantity) based on (endogenous) uninsured deposit ratio. The third new ingredient is banks' portfolio choices between short-term and long-term assets and whether to liquidate their long-term assets to meet the liquidity need from deposit withdrawals after the policy rate is realized.

Our theoretical framework delivers the following main results. First, a higher uninsured deposit ratio leads to higher deposit betas on both rates and outflows. The intuition is that uninsured depositors are more sensitive (more likely to run) to interest rate changes. When there are more uninsured depositors, there would be higher deposit outflow when the interest rate is high. In response, banks set higher deposit rates to maintain their deposit base.

Second, banks' uninsured deposit ratio and long-term asset position jointly determine their vulnerability to run risks associated with interest rate hikes. If banks' long-term assets are low, the only equilibrium is the no-run equilibrium, in which banks choose to hold their long-term assets into maturity. When banks accumulate enough long-term assets, a high enough policy interest rate results in a partial-run equilibrium, under which banks liquidate their long-term assets with marked-to-market losses. The threshold policy interest rate that triggers a partial run, moreover, could be lower for banks with higher uninsured deposit ratios. Finally, when banks' long-term assets are sufficiently high, a complete-run equilibrium emerges, in which banks choose to default their deposit at a sufficiently high policy rate. In other words, either higher uninsured deposits or initial long-term asset holding leads to higher financial instability.

Third, given the portfolio choices between short-term and long-term assets, held-to-maturity accounting reduces the probability of partial bank runs, under which banks are forced to liquidate their long-term assets upon deposit withdrawal. However, the provision of held-to-maturity accounting encourages banks' risk-taking by holding more long-term assets. Accordingly, when the policy interest rate increases, bank runs are more likely to occur when long-term assets are accounted as book value than when all long-term assets are marked to market.

Our paper also contributes to the emerging literature on banks' interest rate risks by focusing on how the exposure of the bank's assets and liabilities to interest rate risks depend on the size of uninsured deposits, HTM accounting, and imperfect bank competition. Drechscher et al. (2021) is the pioneer in this line of literature, with a focus on banks' market power on the liability side. On the asset side, Kim et al. (2023) and Granja (2023) found evidence that banks reclassify long-term securities from AFS to HTM when the policy rate hikes. Jiang et al. (2023b) found that mortgage-backed securities expose banks to housing price changes while marked as HTM on banks' balance sheets. Jiang et al. (2023a) found evidence that marked-to-market loss together with a high uninsured deposit ratio led to SVB bank run and financial instability. While the literature on uninsured deposits focuses on the recent episodes of banking crises, we extend the analysis to pre-SVB periods from 2010 to 2020. On the liability side, we find that the uninsured deposit ratio affects banks' deposit betas on both rates and flows. On the asset side, we find that uninsured deposits and HTM accounting can cause banks to adjust the accounting for long-term assets regularly. The reclassification incentives increase with the bank's exposure to uninsured deposits. An exception is Chang et al. (2023). They find evidence that banks better at risk-taking attract more uninsured deposits. Sorting is a long-run phenomenon. We take banks' initial deposit base as given and focus on banks' balance sheet adjustment and manipulation.

Our theoretical work contributes to the literature on uninsured deposit runs by highlighting the interaction between banks' deposit betas and their asset portfolio choices. Motivated by the SVB episode, Drechsler et al. (2023) are the first to study bank runs caused by the imperfect hedge against interest rate risks. They assume banks with greater exposure to uninsured deposits also have greater market power, thus lower deposit rate betas. Jiang et al. (2023a) develops a simple model to show that marked-to-market loss and high uninsured deposit ratio together lead to SVB bank run and financial instability. In both papers, however, bank deposit betas are assumed to be exogenous and independent of uninsured deposit ratios. Moreover, the uninsured deposit withdrawal in both papers is exogenous. Accordingly, both papers are silent on how uninsured deposit affects banks' vulnerability to interest rate risks via the deposit pricing channel. In addition, both papers abstract from asset portfolio choices between short-term and long-term assets and held-to-maturity accounting. By endogenizing both banks' pricing decisions and asset portfolio decisions, our theoretical work emphasises partial bank runs, where banks do not become insolvent but only inefficiently liquidate some of their long-term asset holdings. We show partial bank runs are more likely to occur under HTM accounting and large exposure to uninsured deposits.

This paper is structured as follows. Section 2 describes the data construction and summary statistics. Section 3 presents the empirical evidence on the linkage between uninsured deposit ratio and deposit betas and the linkage between bank's security holding in held-to-maturity accounts and their uninsured deposit ratio. Section 4 sketches a simple model of uninsured deposit runs with endogenous deposit rates and asset portfolio choices. Section 5 characterizes equilibria in which banks experience no runs, partial runs and complete runs by uninsured depositors in response to increases in policy interest rates. Section 7 concludes.

2 Data and Summary Statistics

2.1 Data Sources

We obtained the bank data from U.S. Call Reports provided by the Federal Reserve Bank of Chicago. The data covers quarterly information on all U.S. commercial banks' balance sheets and income statement items, including loan amounts, deposits, interest expenses, assets, bank types, uninsured deposits, securities held to maturity or available for sale (thus marked to market), etc. Using the FDIC bank identifier, we merge Call Reports with data from the Federal Deposit Insurance Corporation (FDIC). The merged data spans from 2010-2020. The sample period starts in 2010 because there was a structural change in uninsured deposit regulation in 2009 that increased deposit insurance limit from 100K USD to 250K USD. As in Figure 1, the total uninsured deposit in the U.S. experienced a sharp drop in 2009 because of the regulatory change. This pattern is also similar for uninsured deposits of large banks. We are working to extend the sample period to 2023 when runs on regional banks took place. Even though the sample ends in 2020 for now, the data offer some insights on the more recent events. We measure the policy rate using the Fed funds effective rate from Federal Reserve Economic Data (FRED).

2.2 Summary Statistics

Table 2 provides summary statistics for our bank-quarter sample (See Appendix A for detailed data definition of variables). Column (1) shows that, on average, uninsured deposits take about 30% of total deposits and 25% of total assets. Columns (2) and (3) show the difference between banks with low and high uninsured deposit (UD) ratios. Banks with higher UD ratios are larger in terms of deposit quantity than those with low UD ratios (18.5 vs. 19.5). Also, the size of available for sales security held by the former is significantly higher than the latter (17.4 vs. 15.9). This is despite the fact that total security quantity held by the two types of banks is similar (17.0 vs. 17.9).

3 Empirical Evidence

In this section, we explore the empirical linkage between banks' uninsured deposit ratio and the sensitivity of their deposit rate or growth to changes in policy interest rates. After that, we explore how banks' security holding in marked-to-market or held-to-maturity account is empirically correlated with their uninsured deposit ratio and policy rates.

3.1 Uninsured Deposit Ratio and Deposit Betas

In this section, we examine how the sensitivities of deposit growth and deposit rates to policy rates vary with the uninsured deposit ratio. We call the sensitivities of deposit growth and deposit rates to policy rates the deposit growth beta and deposit rate beta, respectively. We start with evidence on the correlation between deposit rate beta, deposit growth beta, and uninsured deposit ratio. We then establish the empirical relationship between deposit betas and uninsured deposit ratio, controlling for bank-specific characteristics such as the bank's size, type, and market share.

3.1.1 Correlation between Uninsured Deposit Ratio and Deposit Betas

To obtain the cross-bank correlation between deposit betas and uninsured deposit ratio, we first estimate bank-specific deposit betas by running the following panel regression

$$\Delta y_{it} = \alpha_i + \alpha_y + \alpha_q + \beta_i \Delta FF_t + \epsilon_{it} \tag{1}$$

where Δy_{it} is the change in deposit rate or log difference of deposit quantity for an individual bank i from quarter t to $t+1$. ΔFF_t is the contemporaneous change in the Fed funds effective rate. The coefficient α_i represents the bank fixed effects, controlling for time-invariant unobserved heterogeneity across banks. α_y represents the year fixed effect, controlling for macroeconomic shocks other than monetary policy; and α_q represents the quarter fixed effect to control for seasonal factors. The coefficient β_i captures the sensitivity of deposit rate or quantity of deposit to changes in the Fed funds rate. Depending on the dependent variable, we refer to β_i as either the deposit rate beta or deposit growth beta of bank i.

We study the cumulative effect of policy rate changes on deposit rate or quantity by running the following regression

$$\Delta y_{it} = \alpha_i + \alpha_y + \alpha_q + \sum_{\tau=0}^{3} \beta_{i\tau} \Delta FF_{t-\tau} + \epsilon_{it} \tag{2}$$

The cumulative deposit rate or growth beta for bank i is defined as the sum of the estimated β across four quarters, i.e., $\sum_{\tau=0}^{3} \beta_{i\tau}$.

After we estimate the deposit betas for individual banks, we sort all banks into 20 equal-sized bins according to their uninsured deposit ratio. Each bin contains 208 banks. We then plot the average deposit betas by bins against the uninsured deposit ratio. The top panel of Figure 2 shows that banks with higher uninsured deposit ratios tend to have higher contemporaneous or cumulative deposit rate beta. The correlation between uninsured deposit ratio and contemporaneous deposit rate beta is 0.26 and significant at 1 % (see column 1 of Table 3). By contrast, banks with higher uninsured deposit ratios tend to have lower deposit flow beta. The correlation between the uninsured deposit ratio and deposit growth beta is -0.032 and significant at 1 % (column 3 of Table 3). Intuitively, banks with a higher share of uninsured deposits tend to be more vulnerable to deposit runs when interest rates increase. This shows up as a more negative deposit growth beta as the uninsured deposit ratio increases. To retain rate-sensitive uninsured depositors, banks with larger uninsured deposit ratios adjust more than deposit rates in response to policy rate changes. This shows up as an increase in deposit rate beta as the uninsured deposit ratio increases.

3.1.2 Baseline Regressions on Uninsured Deposit Ratio and Deposit Betas

While the above scattered plots show a positive correlation between deposit beta and uninsured deposit ratio, such a relationship could be confounded by many factors. For example, banks with higher uninsured deposit ratios could have lower deposit market power, thus a higher sensitivity of deposit rate beta to the policy rate. To alleviate the concern for omitted variable bias, we include market concentration for individual banks, measured by the standard Herfindahl-Hirschman index (HHI). Moreover, the relationship between the uninsured deposit ratio and deposit rate beta could be non-linear, as the probability of deposit run is likely to be non-linear in the uninsured deposit ratio. Therefore, we construct a dummy variable that equals one if the uninsured deposit ratio exceeds some threshold value. We then interact it with the policy rate and test whether banks with higher uninsured deposit ratios have higher (lower) deposit rate (growth) beta. We start by running the following regression

$$\begin{aligned}\Delta y_{it} &= \alpha_0 + [\beta_0 + \beta_1 \mathbb{1}(ud_{it-1} > \tau_1))]\, \Delta FF_t + \beta_2 \Delta FF_t * HHI_{it-1} \\ &\quad + \alpha_1 \mathbb{1}(ud_{it-1} > \tau_1) + \alpha_2 Bank\ Size_{it} + \alpha_3 Bank\ Type_{it} + \alpha_4 HHI_{it-1} + \alpha_i + \alpha_y + \alpha_q + \epsilon_{it},\end{aligned}$$

where Δy_{it} is the change in deposit rate or log difference of deposit quantity, ΔFF_t is the change in Fed Funds Target rate, ud_{it} is the share of uninsured deposit in total deposit. τ_1 is a certain threshold, and we set it as the median of uninsured deposits as a benchmark. $\mathbb{1}(ud_{it-1} > \tau_1)$ is a dummy variable that equals one if bank i's uninsured deposit ratio at time $t-1$ is larger than the threshold τ_1. Both HHI and its interaction with Fed funds rate are included as control variables. In addition, we include bank types and bank asset sizes as time-varying bank-specific controls. ϵ_{it} is clustered at bank level. The coefficient of interest is β_1, which measures the impacts of the uninsured deposit ratio on the deposit beta.

Columns (1) and (2) of Table 4 reports the estimation results for deposit rate. It shows that the estimated effects of both Fed funds rate and the uninsured deposit rate on individual banks' deposit rate are positive at the 0.01 significance level. The estimated β_1 is positive at the 0.01 significance level, suggesting banks with higher uninsured deposit ratios have higher deposit rate beta. Our estimated β_1 is robust to including HHI and its interaction with ΔFF_t. Note that the estimated coefficient on the interaction term between changes in Fed funds rate and HHI is negative and significant at 1% level (column 2), which is consistent with the empirical findings of the existing literature (Drechscher et al. (2017)) that banks with higher market concentration are associated with lower deposit (rate) beta.

Columns (3) and (4) of Table 4 report the estimation results for deposit quantity growth. In contrast to the deposit rate, the estimated effects of both the Fed funds rate and its interaction with the uninsured deposit ratio dummy on deposit growth are negative and significant at 1 percent. The estimated β_1 suggests that banks with higher uninsured deposit ratios would experience larger deposit outflow in response to an increase in the Fed funds rate. Interestingly, the estimated β_2 is positive at 1% significance level, which indicates that banks with higher market share would experience less deposit outflow in response to an increase in the Fed funds rate. Again, our estimated deposit quantity betas are robust to the inclusion of HHI and its interaction with Fed funds rates.

We further explore the relationship between deposit beta and uninsured deposit ratio by estimating the deposit beta by quantiles of uninsured deposit ratio. To this end, we construct ten dummy variables corresponding to each quantile of the uninsured deposit ratio and interact these dummies with the Fed funds rate. We run the following regression

$$\Delta y_{it} = \alpha_0 + \sum_{j=1}^{10} \beta_j \Delta FF_t * \mathbb{1}(ud_{it-1} \in \text{jth quantile})$$
$$+ \alpha_1 Bank\ Size_{it} + \alpha_2 Bank\ Type_{it} + \alpha_3 HHI_{it-1} + \alpha_4 \Delta FF_t * HHI_{it-1} + \alpha_i + \alpha_y + \alpha_q + \epsilon_{it},$$

where $\mathbb{1}(ud_{it-1} \in \text{jth quantile})$ is a dummy variable that equal to one if bank i's uninsured deposit ratio ud_{it-1} falls into quantile j. Our coefficients of interest is β_j.

Columns (1) and (2) of Table 5 report the estimated deposit rate beta by quantiles. For both columns, the estimated β_j for all quantiles are positive and significant at 1 percent level, with the magnitude of the point estimates increasing in quantiles (except the bottom one). This suggests that banks in a higher quantile of uninsured deposit ratios have higher deposit rate beta on average. Columns (3) and (4) show that the estimated deposit growth beta is negative for all quantiles and significant at 0.01 significance level. Similar to the pattern of deposit rate beta, the absolute value of deposit quantity beta increases monotonically in quantiles.

To summarize, we find that banks' uninsured deposit ratio has a significant effect on their deposit rate and growth betas. Banks with a higher uninsured deposit ratio experience a larger deposit rate increase and deposit outflow when the Fed funds rate increases. Such an effect is robust to the presence of bank market concentration.

3.2 Uninsured Deposit and Bank Asset Holdings

Having explored the relationship between uninsured deposits and deposit betas, we now switch to the relationship between uninsured deposits and bank asset holdings, particularly whether they are accounted as held-to-maturity (HTM) securities or available-for-sale (AFS, marked-to-market) securities. We study the impacts of the Fed funds rate on banks' tendency to hold HTM securities and how the impact depends on banks' dependence on uninsured deposits as their funding source.

3.2.1 The Role of Interest Rate Risks in Security Value Accounting

We hypothesise that banks tend to increase (reduce) their holding of HTM security when the policy rate increases. With banks holding long-term securities (e.g., MBS or Treasury), an increase in interest rates significantly decreases the market values of those securities. Reclassifying assets from AFS to HTM helps banks avoid recognizing unrealized losses on these securities in their financial statements. This is especially true for those banks with a higher share of uninsured deposits, which are more vulnerable to deposit run risks.

$$\begin{aligned} y_{it} = {} & \alpha_0 + \beta_1 \mathbb{1}(\Delta FF_t > 0) * ud_{it-1} + \\ & + \alpha_1 Bank\ Size_{it} + \alpha_2 Bank\ Type_{it} + \alpha_3 \mathbb{1}(\Delta FF_t > 0) + \alpha_4 ud_{it-1} + \alpha_i + \alpha_y + \alpha_q + \epsilon_{it}, \end{aligned} \tag{3}$$

where y_{it} the log level of securities held in AFS or HTM accounts or the share of HTM security in total security. $\mathbb{1}(\Delta FF_t > 0)$ is a dummy variable that equals one if Fed tightens its monetary policy by increasing the Fed funds rate. β_1 is our coefficient of interest, capturing how banks' holding of a specific security category is related to their reliance on uninsured deposits when the Fed tightens its monetary policy.

Column (1) of Table 6 reports the estimated coefficient for the total security. The estimated coefficient for the uninsured deposit ratio is positive and significant at 1%, which indicates that banks with a higher share of uninsured deposits tend to hold more security. Moreover, during monetary tightening, banks tend to increase their security holding. Columns (2) and (3) show the estimated coefficients for the two security components, AFS security and HTM security. In Column (2), the estimated coefficient on ud_{it-1} is positive, suggesting that banks with a higher share of uninsured deposits tend to increase AFS security during monetary policy easing. Column (3), however, indicates that these banks tend to increase the holding of HTM security when monetary policy is tightened: Both the estimated coefficients on $\mathbb{1}(\Delta FF_t > 0)$ and its interaction with ud_{it-1} are positive and significant at 0.01 level. Consistent with Column (3), the estimated coefficients on $\mathbb{1}(\Delta FF_t > 0)$ and its interaction with ud are positive and significant at 1 % level in column (4) are positive and significant at 1 % level. In other words, during monetary policy tightening periods, banks that rely more on uninsured deposits as their funding sources tend to increase their share of HTM security in total security. Note that the coefficient β_1 for the overall security is insignificant. This indicates no significant correlation between total securities and uninsured deposits during periods of monetary tightening. The increase in HTM securities when the Fed funds rate rises could be attributed to a reclassification from FAS securities to HTM securitiies.

3.2.2 Role of Uninsured Deposits

We would also like to explore whether the correlation between uninsured deposits and banks' security holding is nonlinear in the uninsured deposit ratio. We conjecture that the positive correlation between uninsured deposits and the HTM share is only significant when banks' uninsured deposits are large enough. Banks with large enough uninsured deposits, and thus high deposit rate beta and low deposit growth beta, may be particularly vulnerable to interest rate risks. Accordingly, the correlation between uninsured deposits and the HTM share shall be positive for these banks.

To test the above conjecture, we run the following regression

$$
\begin{aligned}
y_{it} = {} & \alpha_0 + \beta_1 \mathbb{1}(ud_{it-1} > \tau_3) * ud_{it-1} + \\
& + \alpha_1 Bank\ Size_{it} + \alpha_2 Bank\ Type_{it} + \alpha_3 \mathbb{1}(ud_{it-1} > \tau_3) + \alpha_4 ud_{it-1} + \alpha_i + \alpha_y + \alpha_q + \epsilon_{it},
\end{aligned} \tag{4}
$$

where $\mathbb{1}(ud_{it-1} > \tau_3)$ is a dummy variable that equals one if bank i's lagged uninsured deposit ratio is above the median of the sample.

Table 7 reports the estimated results. In Column (1), the estimated coefficients for both α_4 and β_1 are positive and significant at 1% level. This suggests that the positive correlation between the uninsured deposit ratio and banks' security holding is stronger for those banks with sufficiently large uninsured deposits. Columns (2) and (3) suggest that such a non-linear positive correlation is primarily caused by banks' stronger incentive to hold held-to-maturity securities as they rely more on uninsured deposits. As a result, for those with a sufficiently high uninsured deposit ratio, the share of held-to-maturity security in total security is increasing in the uninsured deposit ratio (column (4)).

Our results suggest that banks with a sufficiently large share of uninsured deposits tend to increase the share of held-to-maturity security in total security. This is especially the case during the period of monetary tightening, during which banks face elevated interest rate risks. One possible reason is that reclassifying assets from the AFS account to the held-to-maturity account helps banks, especially those more prone to deposit run risks, to avoid recognizing unrealized losses on these securities.

4 A Model of Uninsured Depositor Runs

We introduce uninsured depositors, imperfect bank competition, interest-rate risk and HTM vs MTM accounting to an otherwise standard banking model (Diamond and Dybvig (1983), Allen and Gale (2009)). The economy is static. It is populated with N banks, a unit measure of depositors, and a competitive money market mutual funds (MMMF) sector. Banks are identical. Each depositor is endowed with a unit of wealth. Some depositors are insured. Others are not. The economy represents a small open region, say a county, in a large country. We compare regions by varying the number of banks that measures bank concentration and the fraction of uninsured depositors.

Depositors There are $1-u$ insured depositors and u uninsured ones. We index depositors by $i \in [0,1]$. All depositors are matched with banks at the beginning of the model period. Both insured and uninsured depositors are matched evenly across banks. So the total deposit quantity is initially 1; each bank has $1/N$ units of deposits, a u fraction of which are uninsured deposits. In the middle of the period, a policy rate shock arrives and is observed by depositors. Depositors then decide whether to withdraw their deposits or not. Insured depositors' outside option is holding cash or depositing money in the checking account, which promises a zero net return. An uninsured depositor i can access money mutual funds at some switching costs. Net of the depositor's accessing cost, the outside option promises an idiosyncratic return, r_i. The return is the depositor's private information so the deposit rate cannot be contingent on it.

$$r_i = \tilde{\beta}_i r - F,$$

where $\tilde{\beta}_i$ is an i.i.d. draw from a uniform distribution $U[0,1]$, and $F > 0$ is a fixed switching cost. An uninsured depositor i remains in the bank if r_i is below the deposit rate r^d. Therefore, the total deposit supply after uninsured depositors' withdrawal decisions is

$$D = 1 - u + u \times \text{Prob}(r^d \geq r_i) \tag{5}$$

The effective deposit rate r^d is weakly negative when banks default due to bank runs.

Banks Banks engage in Cournot competition. At the beginning of the period, bank $n \in \{1, \ldots, N\}$ assigns L_n fraction to long-term assets and $\frac{1}{N} - L_n$ to short-term assets. In the middle of the period, bank n observes the policy rate r and decides on its deposit quantity D_n and whether to liquidate its asset holdings. Table 1 summarizes the timeline of events.

t_1	Depositors deposit money in banks; banks choose asset portfolios.
t_2	Policy rate r is announced.
t_3	Depositors' withdrawal decisions; banks set D_n and make asset liquidation decisions.

Table 1: Timeline.

Denote the return on short-term assets r^S. We assume that it follows:

$$r^S = \begin{cases} r & \text{if held to } t_3 \\ 0 & \text{o.w.} \end{cases}$$

Meanwhile, the return on long-term asset r^L follows:

$$r^L = \begin{cases} R & \text{if held to } t_3 \\ R - \lambda\widehat{r} & \text{o.w.} \end{cases}$$

where R denotes the book return of the long-term asset, and $R - \lambda\widehat{r}$ denotes the mark-to-market return, $\widehat{r}$ is the deviation of the realized policy rate r and a benchmark policy rate $\overline{r}$, $\widehat{r} = r - \overline{r}$. The implied returns from the held-to-maturity value, or book value, and the marked-to-market value coincide at the benchmark interest rate $\overline{r}$. The implied return from the book is determined ex-ante when the bank chooses its asset portfolio.

The mark-the-market return is affected by the capital gain or loss due to the policy rate shock. We assume that the marked-to-market value of long-term assets is sensitive to the policy interest rate changes. A 1% increase in the policy rate leads to $\lambda > 1$ percent loss in the value.

Assumption 1 $\lambda > 1$.

We assume that the implied return from the book value of long-term assets is greater than the short-term rate ex-ante.

Assumption 2 $R > r$.

We also assume that the fixed cost of switching from deposit to MMMF is sufficiently high. Denote $\Lambda \equiv \max\{\lambda, \frac{\lambda}{\lambda-1}\}\overline{r} > 0$. We assume

Assumption 3 $F > \Lambda$.

5 Equilibrium Characterization

This section characterizes the symmetric equilibrium. We first characeterize equilibrium conditions taking banks' portfolios as given and then study the optimal portfolio choice for banks. Based on the asset liquidation decisions of the banks, we categorize the equilibrium into the no-run equilibrium, in which banks do not liquidate long-term assets to meet liquidity needs from deposit withdrawals, and the partial-run equilibrium, in which banks need to liquidate long-term assets to meet liquidity needs from deposit withdrawals. We derive theoretical predictions that are consistent with the empirical evidence.

5.1 Liquidation Decision under HTM Accounting

Denote a bank n's deposit quantity choice D_n and the deposit quantity choice of any other bank D_{-n}. Given the predetermined portfolio decision L_n, bank n chooses its deposit demand to maximize:

$$F(D_n; L_n) = \begin{cases} RL_n + (D_n - L_n)r - r^d(D_n, D_{-n})D_n & D_n \geq L_n \\ RL_n + (D_n - L_n)\lambda\widehat{r} - r^d(D_n, D_{-n})D_n & D_n < L_n \end{cases} \tag{6}$$

where long-term assets are marked-to-market (MTM) when liquidated but are under HTM accounting if held to maturity, $r^d(D_n, D_{-n})$ denotes the demand curve for deposits implied by (5), with total deposit demand $D = D_n + (N-1)D_{n-1}$.

(6) implies that the marginal benefit of deposits depends on whether the bank needs to liquidate the long-term assets, triggering partial runs. When bank n does not need to liquidate long-term assets to meet deposit withdrawals, $D_n \geq L_n$, the marginal benefit of retaining depositor is $r - r^d - D_n \frac{\partial r^d}{\partial D_n}$. On the margin, the bank purchases short-term assets whose return is r, and the marginal cost of retaining a depositor is $r^d + D_n \frac{\partial r^d}{\partial D_n}$.

When the bank liquidates long-term assets to meet deposit withdrawals, $D_n < L_n$, the marginal benefit of retaining depositor is to avoid the capital loss from reclassifying a long-term asset from HTM to MTM and liquidate it, $\lambda\widehat{r}$.

The marginal benefit of deposit transitions discontinuously from $\lambda\widehat{r} - r^d - D_n \frac{\partial r^d}{\partial D_n}$ to $r - r^d - D_n \frac{\partial r^d}{\partial D_n}$ as bank n's deposits increase from L_n^- to L_n^+. For a high enough realized interest rate r, $\lambda\widehat{r} > r$, the objective function $F(D_n; L_n)$ is concave but has a kink at $D_n = L_n$. Corollary 1 characterizes optimal deposit demand D_n^*.

Corollary 1 *The optimal deposit demand D_n^* for bank n satisfies the following properties:*

- $D_n^* > L_n$ *when* $\frac{dF(D_n;L_n)}{dD_n} = 0$ *for some* $D_n > L_n$*;*
- $D_n^* < L_n$ *when* $\frac{dF(D_n;L_n)}{dD_n} = 0$ *for some* $D_n < L_n$*;*
- $D_n^* = L_n$ *when* $\frac{dF(D_n;L_n)}{dD_n} < 0$ *for all* $D_n > L_n$ *and* $\frac{dF(D_n;L_n)}{dD_n} > 0$ *for all* $D_n < L_n$*.*

We focus on the symmetric equilibrium throughout the paper, where banks hold the same deposit quantities.

Definition 1 (Symmetric Equilibrium) *A symmetric equilibrium is $D_n^* = D/N$ such that $F(D_n; L_n)$ is maximized at $D_n^* = D/N$, given other banks' deposit choice $D_{-n}^* = D/N$ and its own long-term asset holding $L_n = L_{-n} = L/N$.*

5.1.1 No-run Equilibrium

In this section, we characterize a no-run equilibrium and the conditions for such an equilibrium.

Definition 2 *A no-run equilibrium is an equilibrium where banks do not liquidate their long-term asset holding in the interim period, $D \geq L$.*

When $r < \max\{F, uNF\}$, the policy rate is so low that all depositors remain in the bank. In this case, $D = 1$ and $r^d = 0$ and it is a no-run equilibrium.

Proposition 1 (No-run Equilibrium) *When the policy rate is low, $r < \max\{F, uNF\}$, there exists a no-run equilibrium where no depositors withdraw deposits $D = 1$, and deposit rate is zero $r^d = 0$. When the policy rate is high, $r > \max\{F, uNF\}$, whether there exists a no-run equilibrium depends on banks' long-term asset holding.*

- *When $L \leq \frac{N}{N+1}$, there exists a no-run equilibrium for any given policy rate r and uninsured deposit ratio u. In this case, $D > L$. Deposit rate r^d and total deposit demand D follow*

$$r^d = \begin{cases} \frac{(N - \frac{1-u}{u})r - F}{N+1} & u > \frac{r}{(N+1)r - F} \\ 0 & u \leq \frac{r}{(N+1)r-F} \end{cases} \tag{7}$$

$$D = \begin{cases} \frac{N}{N+1}\left(1 + u\frac{F}{r}\right) & u > \frac{r}{(N+1)r-F} \\ 1 - u + u\frac{F}{r} & u \leq \frac{r}{(N+1)r-F} \end{cases} \tag{8}$$

- *When $\frac{N}{N+1} < L \leq \frac{N}{N+1/\lambda}$, there exists a no-run equilibrium for any given policy rate r and uninsured deposit ratio u. $D > L$ when*

$$r < r_U^* \equiv \begin{cases} \frac{uF}{\frac{N+1}{N}L - 1} & u > \frac{L}{N} \\ \frac{uF}{L-(1-u)} & 1 - L < u \leq \frac{L}{N} \\ \infty & u \leq 1 - L \end{cases} \tag{9}$$

  In this case, the deposit rate r^d and total deposit demand D follow Equations (7) and (8), respectively. $D = L$ when $r \geq r_U^*$, in which case $r^d = \frac{L-(1-u)}{u}r - F$.

- *When $L > \frac{N}{N+1/\lambda}$, there exists a no-run equilibrium when $r < \max\{r_U^*, r_L^*\}$, where*

$$r_L^* \equiv \begin{cases} \frac{u(F - \lambda\bar{r})}{\frac{N+1}{N}L - 1 + u(1-\lambda)} & u > u_L^* \equiv \frac{-(1-L)N\lambda\bar{r} + FL}{-N\lambda\bar{r} + F\lambda N} \\ \frac{uF}{L-(1-u)} & u \leq u_L^*. \end{cases} \tag{10}$$

$D > L$ when $r < r_U^*$, in which case the deposit rate r^d and total deposit demand D follow Equations (7) and (8), respectively. $D = L$ when $r_U^* < r < \max\{r_U^*, r_L^*\}$, in which case $r^d = \frac{L-(1-u)}{u} r - F$.

Equations (7) and (8) illustrate that banks anticipate heightened deposit withdrawals when there are many uninsured depositors. Banks thus offer a positive deposit rate to retain uninsured depositors and maintain their deposit base.

When $L < \frac{N}{N+1/\lambda}$, a no-run equilibrium exists in the entire (r, u) parameter space. However, if banks hold long-term assets exceeding $\frac{N}{N+1/\lambda}$, there exists a no-run equilibrium only when the policy rate falls below r_U^*. Notably, r_U^* diminishes with an increase in L, indicating that more long-term asset holdings correspond to a smaller no-run region and, therefore, higher probability of liquidating long-term assets.

Given predetermined long-term asset holdings, when $u < 1 - L$, a no-run equilibrium exists throughout the domain. This suggests that a lower uninsured deposit ratio enhances financial stability. As per Proposition 1, r_U^* exhibits a U-shaped relationship with the uninsured deposit ratio u. When $r^d = 0$, an increase in uninsured deposits leads to higher deposit outflow, thereby reducing the no-run region. When $r^d > 0$, banks with higher uninsured deposit ratios internally set higher deposit rates, reducing deposit outflow and, consequently, expanding the no-run region in the (r, u) parameter space.

5.1.2 Partial-run Equilibrium

A partial-run equilibrium is an equilibrium where banks need to liquidate their long-term assets to meet the liquidity demand from deposit withdrawals.

Definition 3 *A partial-run equilibrium is an equilibrium where banks liquidate their long-term asset holdings. That is, the measure of remaining depositors is lower than the ex-ante long-term asset holdings, $D < L$.*

Notice that a bank could face partial runs when it is solvent. We say a bank faces complete runs when it has to liquidate long-term assets and still becomes insolvent. A complete-run equilibrium is a special case of the partial-run equilibrium.

A partial-run equilibrium in which banks are still solvent is important for our empirical analysis. Few banks became insolvent because of the interest rate risks during our sample period from 2010 to 2020. The liquidation of long-term assets when banks are still solvent connects the theory with the empirical evidence.

The next proposition characterizes conditions under which a partial run equilibrium exists.

Proposition 2 (Partial-run Equilibrium)

- *When* $L \leq \frac{N}{N+1/\lambda}$, *there does not exist a partial-run equilibrium.*
- *When* $L > \frac{N}{N+1/\lambda}$, *a partial-run equilibrium exists when* $r > r_L^*$. *Deposit rate* r^d *and total deposit demand* D *follow*

$$r^d = \begin{cases} \frac{N\lambda\hat{r} - \frac{1-u}{u}r - F}{N+1} & u > \frac{r}{N\lambda\hat{r}+r-F} \\ 0 & u \leq \frac{r}{N\lambda\hat{r}+r-F} \end{cases} \tag{11}$$

$$D = \begin{cases} \frac{N}{N+1}\left[1-u+u\frac{F}{r}+u\frac{\lambda\hat{r}}{r}\right] & u > \frac{r}{N\lambda\hat{r}+r-F} \\ 1-u+u\frac{F}{r} & u \leq \frac{r}{N\lambda\hat{r}+r-F} \end{cases} \tag{12}$$

A partial-run equilibrium exists when banks' long-term asset holdings exceed $\frac{N}{N+1/\lambda}$ and the realized policy interest rate exceeds r_L^*. Similar to the no-run equilibrium, banks only offer a positive deposit rate when the proportion of uninsured depositors u exceeds $\frac{r}{N\lambda\hat{r}+r-F}$.

Banks are subject to partial runs when the ex-post policy rate exceeds r_L^*. The threshold policy rate r_L^* is decreasing in long-term asset holding L, suggesting that long-term asset holdings increase the likelihood of liquidation. The threshold r_L^* shows a U-shaped relationship with the uninsured deposit u because higher uninsured deposits incentivize the bank to increase deposit rates to retain depositors.

Proposition 3 *When* $L > \frac{N}{N+1+\frac{F}{\lambda\bar{r}}(1-\lambda)}$, *there are multiple equilibria when* $r_L^* < r < r_U^*$.

Figures 3, 4, and 5 provide an overview of the run regions under HTM accounting. Notably, when $N \leq \frac{N}{N+1}$, $D > L$ across the entire (r,u) domain. Similarly, when $\frac{N}{N+1} < N \leq \frac{N}{N+1/\lambda}$, the no-run region extends across the entire (r,u) domain, with $D > L$ when $r < r_U^*$ and $D = L$ when $r > r_U^*$, as depicted in Figure 3.

For L falling within $\frac{N}{N+1/\lambda} < L \leq \frac{N}{N+1+\frac{F}{\lambda\bar{r}}(1-\lambda)}$, a partial-run equilibrium arises when $r > r_L^*$, where $r_L^* > r_U^*$, ensuring a unique equilibrium for all (r,u) pairs, as per Figure 4. Subsequently, when $L > \frac{N}{N+1+\frac{F}{\lambda\bar{r}}(1-\lambda)}$, the no-run region overlaps with the partial-run region, as indicated by Proposition 3 and Figure 5. Even in this scenario, a unique equilibrium prevails when $u < \frac{L}{N}$. This implies that higher uninsured deposit leads to higher financial instability.

5.1.3 Consistency with Empirical Evidence

The deposit rate beta corresponds to the derivative of the deposit rate to the policy rate $\frac{dr^d}{dr}$. The deposit growth beta corresponds to the derivative of log deposit quantity to the policy rate $\frac{d\log D}{dr}$. The following proposition characterizes how the two betas change with the uninsured deposit ratio u.

Proposition 4 *In both the no-run equilibrium and the partial-run equilibrium, deposit rate beta is positive and deposit growth beta is negative if the equilibrium deposit rate r^d is positive.*

$$\frac{dr^d}{dr} > 0 \; , \; \frac{d\log D}{dr} < 0.$$

The both deposit rate and deposit quantity become more sensitive to the policy rate when uninsured deposit ratio u is high:

$$\frac{d}{du}\left(\frac{dr^d}{dr}\right) > 0 \; , \; \frac{d}{du}\left(\left|\frac{d\log(D)}{dr}\right|\right) \geq 0.$$

Proposition 4 is consistent with the empirical findings on the deposit rate and growth betas in Section 3.1. Banks with higher uninsured deposit ratios expect escalated deposit outflows when the policy rate increases. In response to the rate-sensitive deposit outflow, these banks offer higher deposit rates to retain depositors. This implies that banks with higher uninsured deposits have lower effective market power.

Proposition 5 *In the partial-run equilibrium, an increase in the proportion of uninsured depositors u corresponds to a higher fraction of assets held to maturity relative to long-term assets ($\frac{D}{L}$).*

Proposition 5 is derived from Equation (12). Banks with higher uninsured deposit ratios u offer higher deposit rates and exhibit higher deposit rate beta, resulting in lower market power. Given the increased interest rate risk ($r > r_L^*$), such banks are more inclined to classify long-term assets as HTM. This result aligns with the empirical positive correlation between HTM holdings and uninsured deposits when the policy rate is high, which we document in Section 3.2.

5.1.4 Complete-run Equilibrium

Complete-run equilibrium is a special case of the partial-run equilibrium in which banks become insolvent.

Definition 4 *A complete-run equilibrium is an equilibrium in which banks become insolvent,* $F(D_n; L_n) \leq 0$.

Recall that when the equilibrium lies in the no-run region, banks' profit is always positive. However, when the equilibrium lies in the partial-run region, the profit can be negative, $F(D_n; L_n) \leq 0$, in equilibrium. Since a complete-run equilibrium is a special case of the partial-run equilibrium, a bank's profit is negative only if bank liquidates its long-term assets.

5.2 Portfolio Choice under HTM Accounting

At the beginning of the period, banks choose their long-term asset position L to maximize the expected profit given the prior distribution of policy rates $G(r)$ on $[0, R]$. Denote a banks' profit Π. The expected profit is

$$
\begin{aligned}
&E_r[\Pi, D > L] + E_r[\Pi, D < L] + E_r[\Pi, D = L] \\
=&E_r[(R - r)L + (r - r^d)D, D > L] \\
+&E_r[(R - \lambda\widehat{r})L + (\lambda\widehat{r} - r^d)D, D < L] + E_r[(R - r^d)L, D = L]
\end{aligned}
$$

We assume that $G(r)$ follows the Bernoulli distribution, where

$$
r = \begin{cases} r_h & \text{w.p. } 1 - p \\ r_l & \text{w.p. } p \end{cases} \tag{13}
$$

where $\overline{r} < r_l < F < r_h$. $r_l < F$ guarantees that the equilibrium is always a no-run equilibrium at $r = r_l$, while $r_l > \overline{r}$ guarantees that the book value of the long-term asset is greater than its market value at $r = r_l$.

Proposition 6 *When* $R + \lambda\overline{r} + p\lambda(r_l - \overline{r}) > \lambda\mathbb{E}r + pr_l$ *and* $R + (1-p)F > \mathbb{E}r + (1-p)F\frac{Nr_h}{\overline{r}}$, *the optimal long-term asset holding under HTM accounting* $L^* = 1$.

Proposition 6 suggests that the marginal benefit of holding long-term assets is positive under mild conditions. These conditions are more likely to hold when R or p is high or when the expected return, $\mathbb{E}r = pr_l + (1-p)r_h$, is low. Specifically, when the book value of long-term assets is high, holding more long-term assets results in a higher expected return. Moreover, in scenarios with heightened interest rate risk—characterized by either high p or low $\mathbb{E}r$—the marginal benefit of holding long-term assets is amplified.

6 Counterfactual Analysis

6.1 Marked-to-market Long-term Assets

In previous sections, long-term assets have been accounted for at book value when held to maturity or at market value when liquidated. In this section, we assume that bankers' payoff always depend on the marked-to-market value of the long-term asset so that banks always use MTM accounting. We would like to know whether HTM accounting increases banks' incentive to hold long-term assets.

Similar to the analysis in the previous section, we first consider banks' liquidation decisions given banks' portfolio decisions and subsequently examine the optimal portfolio choice under MTM accounting.

Proposition 7 (Liquidation Decision under MTM Accounting)

- *When the long-term asset holding* $L \leq \frac{N}{N+1}$,
  - *the no-run equilibrium always exists. Deposit rate* r^d *and total deposit demand* D *follow Equations* (7) *and* (8)*, respectively;*
  - *the partial-run equilibrium exists when* $D = 1 - u + u\frac{F}{r} < L$*, in which case the deposit rate* $r^d = 0$*;*
  - *when* $1 - u + u\frac{F}{r} < L$*, the no-run equilibrium and the partial-run equilibrium coexist.*
- *When the long-term asset holding* $L > \frac{N}{N+1}$,
  - *the no-run equilibrium exist when the policy rate* $r < r_U^*$*. Deposit rate* r^d *and total deposit demand* D *follow Equations* (7) *and* (8)*, respectively;*
  - *the partial-run equilibrium exists when* $D = 1 - u + u\frac{F}{r} < L$*, in which case* $r^d = 0$*;*
  - *When* $1 - u + u\frac{F}{r} < L$ *and* $r \geq r_U^*$*, the no-run equilibrium and the partial-run equilibrium coexist.*

Proposition 7 summarizes banks' liquidation decisions under MTM accounting. The no-run equilibrium when $D > L$ remains unchanged, as the marginal benefit of deposits remains constant. In contrast, the partial-run equilibrium holds for all long-term asset holding L, as the marginal benefit of deposits becomes zero. Consequently, with the same portfolio choice as under HTM accounting, the partial-run region expands under MTM accounting. Furthermore, the complete-run region under MTM accounting also expands: banks default as long as the market value of long-term assets is negative. Figures 6 and Figure 7 illustrate the run regions under MTM accounting.

Given the ex-post policy rate distribution as specified in Equation (13), we obtain the optimal long-term asset holding L^{**} in the following proposition.

Proposition 8 (Portfolio Choice when Long-term Assets are MTM) *When $R + \lambda\bar{r} < \lambda\mathbb{E}r + pr_l$, the optimal long-term asset holding under MTM accounting $L^{**} = 0$.*

Proposition 8 indicates that under MTM accounting, the marginal benefit of holding long-term assets is consistently negative. The condition $R + \lambda\bar{r} < \lambda\mathbb{E}r + pr_l$ is more likely to be satisfied when the capital loss for an MTM asset with a rate increase λ is high. An increase in the policy rate leads to a substantial decrease in the market value of long-term assets, consequently diminishing the marginal benefit of holding such assets.

When all long-term assets are marked to market, a bank run never occurs because banks choose to reduce their exposure to long-term assets ex ante, $L^{**} = 0$. Combining Proposition 6 and Proposition 8, we can see that long-term asset holding under HTM accounting ($L^* = 1$) exceeds that under MTM accounting, resulting in a higher likelihood of bank runs. In essence, HTM accounting aims to shield banks from reporting potential losses but, as an unintended consequence, it also incentivize banks to be more exposed to interest rate risk.

7 Conclusion

In this paper, we introduce uninsured depositors and held-to-maturity vs marked-to-market accounting to a banking model with imperfect competition. We find that these new ingredients jointly contribute to the fragility of the banking sector to interest rate risks. A high uninsured deposit share exposes the bank to more deposit outflows and greater run risks when the policy interest rate increases. This causes banks to offer a high deposit rate beta and weakens banks' market power. A high uninsured deposit share also changes banks' asset portfolios. Under held-to-maturity accounting, increasing uninsured deposit share could increase banks' long-term asset holding and incentivise banks to reclassify long-term assets from marked-to-market to held-to-maturity when the policy rate increases. Our theory suggests policymakers should design accounting rules contingent on uninsured deposit share and bank market power. Our empirical evidence using the U.S. Call Reports supports the key predictions of our theory.

Variables	All		Low UD Ratio		High UD Ratio	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Uninsured Deposit (UD) Ratio	0.306	0.147	0.196	0.059	0.416	0.123
Uninsured Deposit to Asset Ratio	0.256	0.120	0.166	0.051	0.346	0.100
Deposit Rate	0.629%	0.004	0.702%	0.004	0.556%	0.004
Domestic Deposit Rate	0.628%	0.004	0.702%	0.004	0.554%	0.004
ln(Total Deposit)	19.0	1.38	18.5	1.03	19.5	1.49
Loan/Deposit	0.727	0.199	0.726	0.188	0.727	0.209
(Loan+HTM)/Deposit	0.759	0.197	0.760	0.188	0.758	0.205
Securities/Assets	23.2%	0.153	23.0%	0.146	23.4%	0.160
HTM/Assets	2.65%	0.075	2.84%	0.077	2.46%	0.074
AFS/Assets	20.5%	0.151	20.1%	0.147	20.9%	0.156
HTM/Securities	11.9%	0.263	13.1%	0.284	10.7%	0.239
Herfindahl-Hirschman Index (HHI)	0.157	0.125	0.167	0.121	0.147	0.128
ln(Asset)	19.2	1.38	18.7	1.05	19.7	1.49
Obs. of Community Banks	179,487		91,216		88,271	
Obs. of Regional Banks	2,492		182		2,310	
Obs. of National Banks	896		39		857	
Obs. of National Member Banks	35,305		15,651		19,654	
Obs. of State Member Banks	27,061		12,362		14,699	
Obs. of State Nonmember Banks	120,509		63,424		57,085	
Obs. (Bank×Quarter)	182,875		91,437		91,438	

Table 2: Summary Statistics

Notes: The table provides summary statistics for the entire sample, as well as sub-samples categorized by high and low uninsured deposit ratios. The data is at the bank-quarter level and covers 2010 to 2020. Data is from Call Reports and FDIC.

Variables	Deposit Rate Beta		Deposit Quantity Beta	
	(1)	(2)	(3)	(4)
	One Quarter	Four Quarter	One Quarter	Four Quarter
Average Uninsured Deposit Ratio	0.264***	0.227***	-0.032***	-0.052***
	[0.013]	[0.023]	[0.008]	[0.010]
Constant	0.055***	0.191***	-0.035***	-0.031***
	[0.004]	[0.008]	[0.003]	[0.003]
Observations	20	20	20	20
R-squared	0.957	0.847	0.480	0.593

Table 3: Correlation between Uninsured Deposit Ratio and Bank-specific Betas

Notes: This table presents deposit rate (or deposit growth) sensitivities towards Fed funds rate growth against bank-level uninsured deposit ratio. We refer the deposit rate (or deposit growth) sensitivities towards Fed funds rate growth as the bank-specific beta. The data is at the bank-quarter level and covers 2010 to 2020. Bank-specific betas are calculated by regressing the change in a bank's interest expense rate (or log of deposit quantity) on the contemporaneous (and three previous quarterly) changes in the Fed funds rate and summing the coefficients. Bank-specific betas are winsorized at 0.5% and 99.5% level to eliminate outliers. We then divide the sample into 20 equal-sized bins according to their uninsured deposit ratios, and calculate the average uninsured deposit ratio and average bank-specific betas in each bin. Lastly, average bank specific betas are regressed on the average uninsured deposit ratio. Columns (1) and (2) show the correlation between uninsured deposit ratio and deposit rate beta, while column (2) uses cumulative deposit rate sensitivity of four quarter as dependent variable. Columns (3) and (4) show the correlation between uninsured deposit ratio and deposit quantity beta, while column (4) uses cumulative deposit quantity sensitivity of four quarter as dependent variable. Data is from Call Reports. *, **, *** stands for significance at 10%, 5%, 1% level, respectively.

VARIABLES	(1) Δ Deposit Rate Variables Demeaned	(2) Δ Deposit Rate Variables Demeaned	(3) Δ ln(Deposit) Variables Demeaned	(4) Δ ln(Deposit) Variables Demeaned
ΔFF_t	0.097***	0.098***	-0.049***	-0.049***
	[0.001]	[0.001]	[0.001]	[0.001]
$\mathbb{1}(ud_{it-1} > \tau_1)$	0.010***	0.010***	-0.011***	-0.011***
	[0.001]	[0.001]	[0.001]	[0.001]
HHI_{it-1}		0.029		0.069*
		[0.024]		[0.041]
$\Delta FF_t * \mathbb{1}(ud_{it-1} > \tau_1)$	0.053***	0.051***	-0.010***	-0.010***
	[0.003]	[0.003]	[0.001]	[0.001]
$\Delta FF_t * HHI_{it-1}$		-0.116***		0.020***
		[0.011]		[0.005]
Observations	178,666	178,666	178,666	178,666
R-squared	0.330	0.331	0.090	0.090
Bank Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Quarter Fixed Effect	Yes	Yes	Yes	Yes
Bank Size Fixed Effect	Yes	Yes	Yes	Yes
Bank Type Fixed Effect	Yes	Yes	Yes	Yes

Table 4: Uninsured Deposit Ratio and Deposit Betas

Notes: This table estimates the effect of high uninsured deposit ratio on deposit betas. We refer the deposit rate (or deposit growth) sensitivities towards Fed funds rate growth as the deposit betas. The data is at the bank-quarter level and covers 2010 to 2020. Columns (1) and (2) show how uninsured deposit ratio affects the deposit rate beta, while columns (3) and (4) show how uninsured deposit ratio affects the deposit quantity beta. Columns (3) and (4) additionally control bank-level HHI (HHI_{it-1}) and its interaction between Fed funds rate growth ΔFF_t. $\mathbb{1}(ud_{it-1} > \tau_1)$ is an indicator that uninsured deposit ratio is above its median. We are interested in the coefficient on $\Delta FF_t * \mathbb{1}(ud_{it-1} > \tau_1)$. The data is from the Call Reports and FDIC. Fixed effects are denoted at the bottom of the table. Standard errors are clustered by bank. *, **, *** stands for significance at 10%, 5%, 1% level, respectively.

VARIABLES	(1) Δ Deposit Rate	(2) Δ Deposit Rate	(3) Δ ln(Deposit)	(4) Δ ln(Deposit)
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 1st quantile)	0.072***	0.075***	-0.028***	-0.029***
	[0.008]	[0.008]	[0.003]	[0.003]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 2nd quantile)	0.062***	0.063***	-0.041***	-0.041***
	[0.004]	[0.004]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 3rd quantile)	0.061***	0.061***	-0.042***	-0.042***
	[0.004]	[0.004]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 4th quantile)	0.074***	0.075***	-0.046***	-0.047***
	[0.004]	[0.004]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 5th quantile)	0.085***	0.085***	-0.051***	-0.051***
	[0.003]	[0.003]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 6th quantile)	0.093***	0.094***	-0.047***	-0.047***
	[0.003]	[0.003]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 7th quantile)	0.099***	0.100***	-0.052***	-0.052***
	[0.003]	[0.003]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 8th quantile)	0.114***	0.114***	-0.055***	-0.055***
	[0.003]	[0.003]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 9th quantile)	0.130***	0.129***	-0.057***	-0.057***
	[0.004]	[0.004]	[0.002]	[0.002]
$\Delta FF_t * \mathbb{1}(ud_{it-1}$ in the 10th quantile)	0.168***	0.164***	-0.061***	-0.060***
	[0.005]	[0.005]	[0.003]	[0.003]
HHI_{it-1}		0.028		0.071*
		[0.023]		[0.042]
$\Delta FF_t * HHI_{it-1}$		-0.097***		0.016***
		[0.011]		[0.005]
Observations	178,666	178,666	178,666	178,666
R-squared	0.332	0.333	0.088	0.088
Bank Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Quarter Fixed Effect	Yes	Yes	Yes	Yes
Bank Size Fixed Effect	Yes	Yes	Yes	Yes
Bank Type Fixed Effect	Yes	Yes	Yes	Yes

Table 5: Deposit Beta and Uninsured Deposit Ratio by Quantiles

Notes: This table presents deposit rate (or deposit growth) sensitivities towards Fed funds rate growth against quantiles of uninsured deposit ratio. We refer the deposit rate (or deposit growth) sensitivities towards Fed funds rate growth as the deposit beta. The data is at the bank-quarter level and covers 2010 to 2020. Columns (1) and (2) show the correlation between different quantiles of uninsured deposit ratio and deposit rate beta, while column (2) additionally controls for bank-level HHI (HHI_{it-1}) and its interaction between Fed funds rate growth ΔFF_t. Columns (3) and (4) show the correlation between different quantiles of uninsured deposit ratio and deposit quantity beta, while column (4) additionally controls for bank-level HHI and its interaction between Fed funds rate growth. Data is from Call Reports. *, **, *** stands for significance at 10%, 5%, 1% level, respectively.

VARIABLES	(1) ln (Securities) Variables Demeaned	(2) ln (Securities AFS) Variables Demeaned	(3) ln (Securities HTM) Variables Demeaned	(4) HTM Share Variables Demeaned
ud_{it-1}	0.629***	0.631*	1.018	0.009
	[0.137]	[0.376]	[0.691]	[0.028]
$\mathbb{1}(\Delta FF_t > 0)$	0.005***	-0.006	0.062***	0.002***
	[0.001]	[0.004]	[0.009]	[0.000]
$ud_{it-1} * \mathbb{1}(\Delta FF_t > 0)$	0.029	-0.081	0.947***	0.024***
	[0.027]	[0.083]	[0.225]	[0.006]
Observations	178,666	178,666	178,666	178,666
R-squared	0.935	0.875	0.803	0.851
Bank Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Quarter Fixed Effect	Yes	Yes	Yes	Yes
Bank Size Fixed Effect	Yes	Yes	Yes	Yes
Bank Type Fixed Effect	Yes	Yes	Yes	Yes

Table 6: Uninsured Deposit Ratio and Securities when FFR Increases

Notes: This table estimates the effect of high uninsured deposit ratio on securities when Fed funds rate increases. The data is at the bank-quarter level and covers 2010 to 2020. Columns (1) - (4) show the correlation between uninsured deposit ratio and log(AFS+1), log(HTM+1), log(securities), and HTM/Securities, respectively. ud_{it-1} is the uninsured deposit ratio for bank i at $t-1$. $\mathbb{1}(\Delta FF_t > 0)$ is an indicator that Fed funds rate is increasing. We are interested in the coefficient on $ud_{it-1} * \mathbb{1}(\Delta FF_t > 0)$. The data is from the Call Reports and FDIC. Fixed effects are denoted at the bottom of the table. Standard errors are clustered by bank. *, **, *** stands for significance at 10%, 5%, 1% level, respectively.

VARIABLES	(1) ln (Securities) Variables Demeaned	(2) ln (Securities AFS) Variables Demeaned	(3) ln (Securities HTM) Variables Demeaned	(4) HTM Share Variables Demeaned
ud_{it-1}	0.474***	0.445	0.503	0.000
	[0.149]	[0.447]	[0.746]	[0.032]
$\mathbb{1}(ud_{it-1} > \tau_3)$	0.027**	0.049	0.081	-0.000
	[0.012]	[0.041]	[0.092]	[0.003]
$ud_{it-1} * \mathbb{1}(ud_{it-1} > \tau_3)$	0.920***	0.627	3.103**	0.103**
	[0.183]	[0.567]	[1.269]	[0.041]
Observations	178,666	178,666	178,666	178,666
R-squared	0.935	0.875	0.803	0.851
Bank Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Quarter Fixed Effect	Yes	Yes	Yes	Yes
Bank Size Fixed Effect	Yes	Yes	Yes	Yes
Bank Type Fixed Effect	Yes	Yes	Yes	Yes

Table 7: Uninsured Deposit Ratio and Securities when Uninsured Deposit Ratio is High

Notes: This table estimates the effect of high uninsured deposit ratio on securities when uninsured deposit ratio is high. The data is at the bank-quarter level and covers 2010 to 2020. Columns (1) - (4) show the correlation between uninsured deposit ratio and log(AFS+1), log(HTM+1), log(securities), and HTM/Securities, respectively. ud_{it-1} is the uninsured deposit ratio for bank i at $t-1$. $\mathbb{1}(ud_{it-1} > \tau_3)$ is an indicator that lag of uninsured deposit is above its median. We are interested in the coefficient on $ud_{it-1} * \mathbb{1}(ud_{it-1} > \tau_3)$. The data is from the Call Reports and FDIC. Fixed effects are denoted at the bottom of the table. Standard errors are clustered by bank. *, **, *** stands for significance at 10%, 5%, 1% level, respectively.

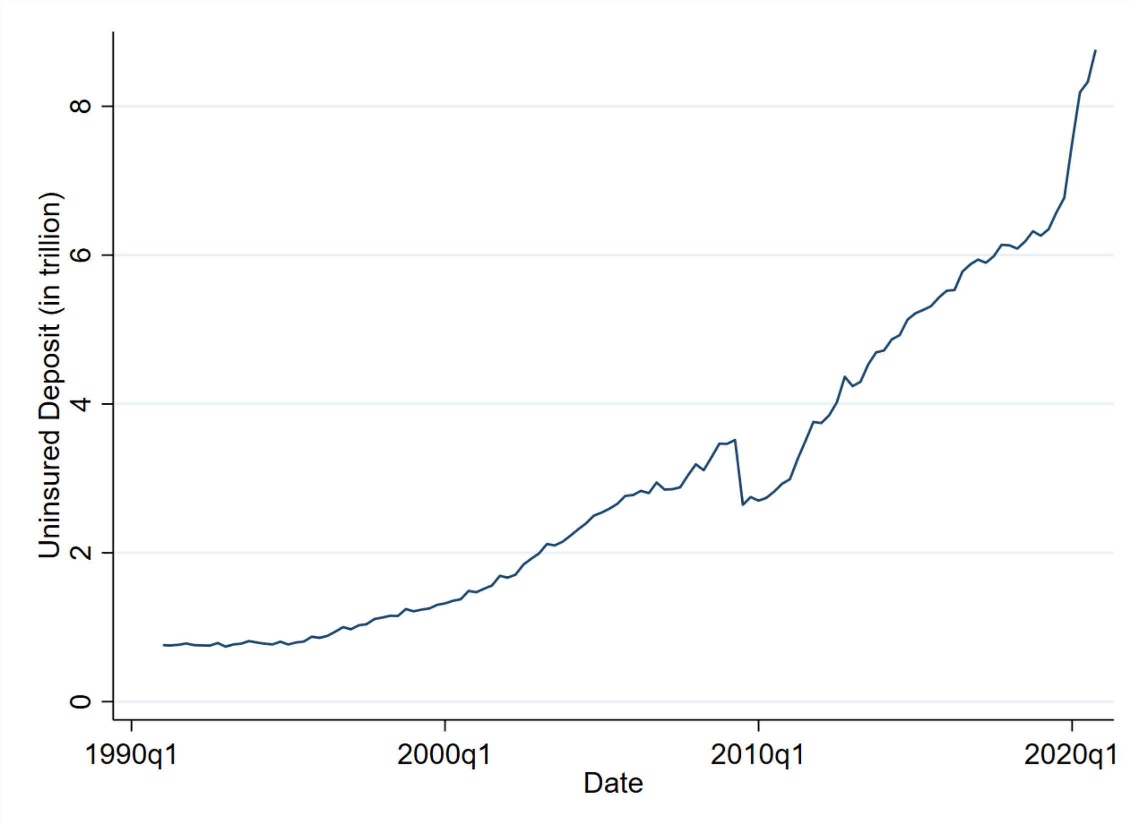
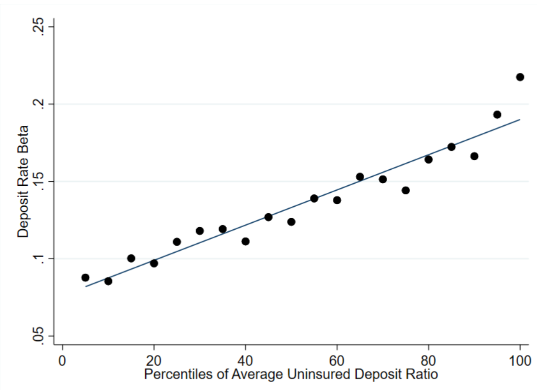
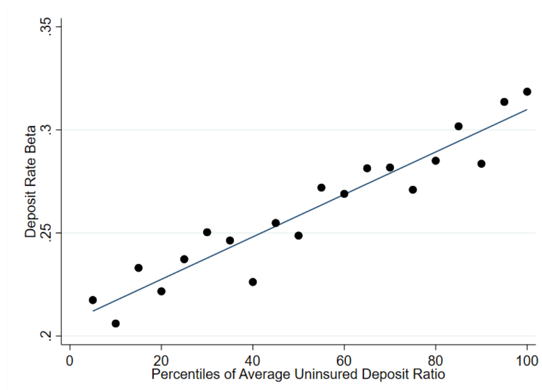


Figure 1: Trends of Uninsured Deposit

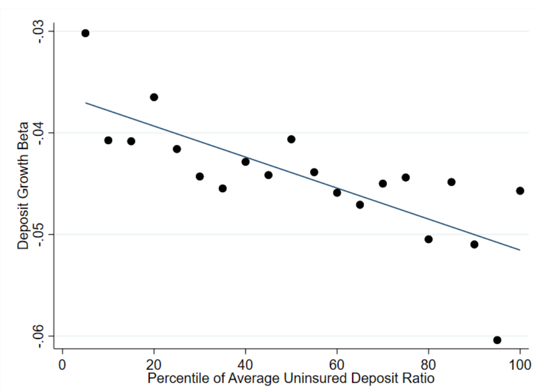
Notes: This plot presents the trend of total uninsured deposits in the U.S. Notice that there is a sharp drop in 2009 because of the regulatory change. Source: Call Report.



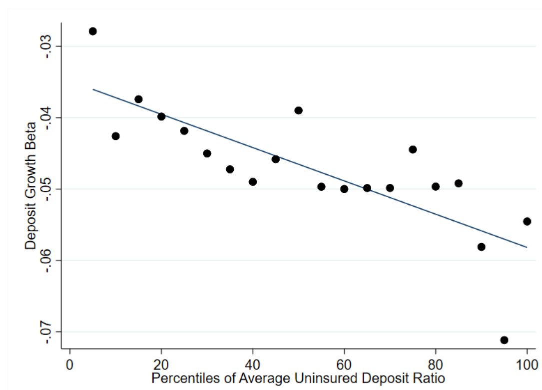
(a) Deposit Rate Beta (One Quarter)



(b) Deposit Rate Beta (Cumulative)



(c) Deposit Growth Beta (One Quarter)



(d) Deposit Growth Beta (Cumulative)

Figure 2: Deposit Rate and Growth Beta

Notes: This figure presents deposit rate (or deposit growth) sensitivities towards Fed funds rate growth against percentiles of uninsured deposit ratio. We refer the deposit rate (or deposit growth) sensitivities towards Fed funds rate growth as the bank-specific beta. The data is at the bank-quarter level and covers 2010 to 2020. Bank-specific betas are calculated by regressing the change in a bank's interest expense rate (or log of deposit quantity) on the contemporaneous (and three previous quarterly) changes in the Fed funds rate and summing the coefficients. Bank-specific betas are winsorized at 0.5% and 99.5% level to eliminate outliers. We then divide the sample into 20 equal-sized bins according to their uninsured deposit ratios, and calculate the average uninsured deposit ratio and average bank-specific betas in each bin. Panels (a) and (b) show the deposit rate betas against percentiles of average uninsured deposit ratio, while panel (b) uses cumulative deposit rate sensitivity of four quarter on Y axis. Panels (c) and (d) show the deposit quantity betas against percentiles of average uninsured deposit ratio, while panel (d) uses cumulative deposit quantity sensitivity of four quarter on Y axis. Data is from Call Reports.

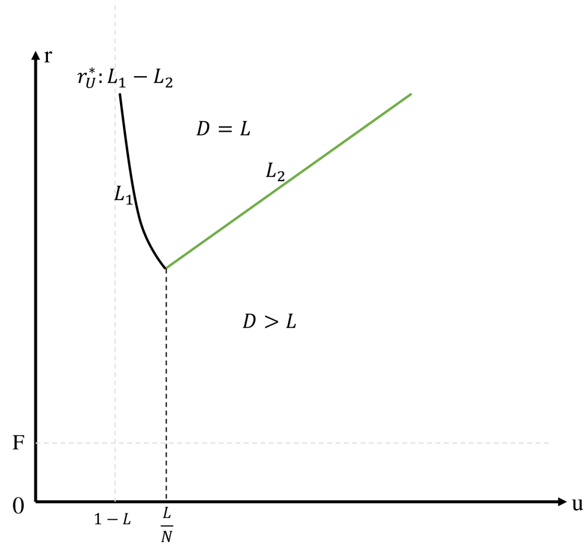


Figure 3: Run Regions under HTM Accounting, when $\frac{N}{N+1} < L \leq \frac{N}{N-1/\beta_M}$

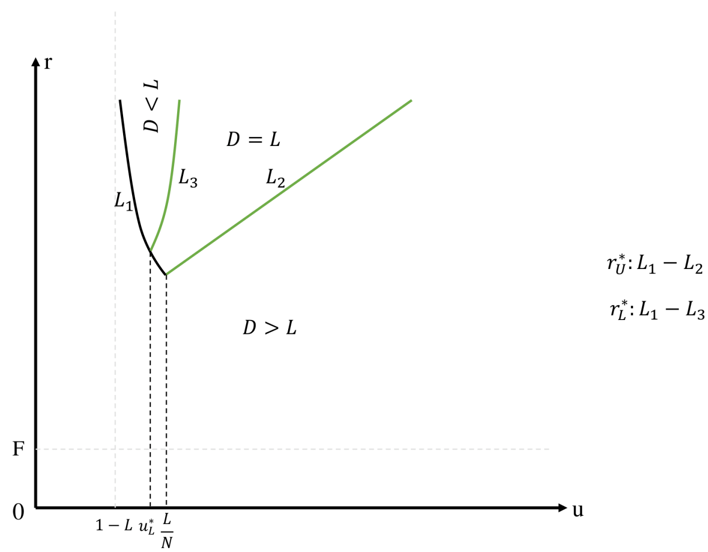


Figure 4: Run Regions under HTM Accounting, when $\frac{N}{N-1/\beta_M} < L < \frac{N}{N+1+\frac{F}{\lambda \bar{r}}(1-\lambda)}$

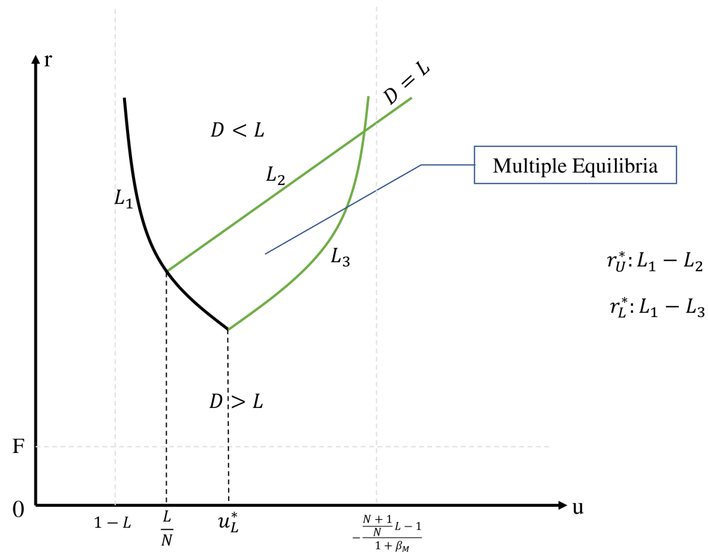


Figure 5: Run Regions under HTM Accounting, when $L > \frac{N}{N+1+\frac{F}{\lambda \bar{r}}(1-\lambda)}$

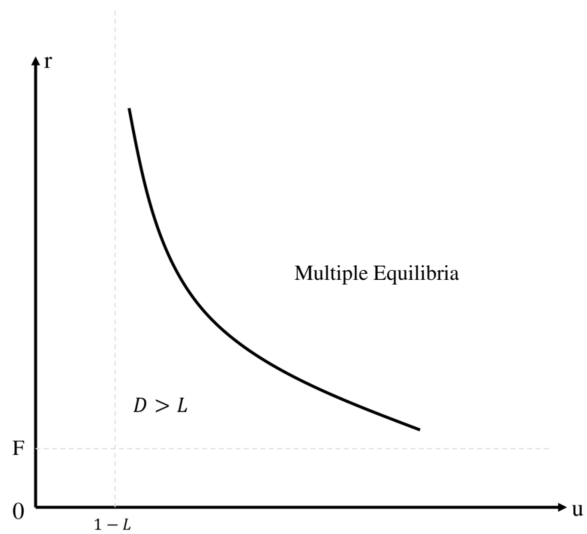


Figure 6: Run Regions under MTM Accounting, when $L \leq \frac{N}{N+1}$

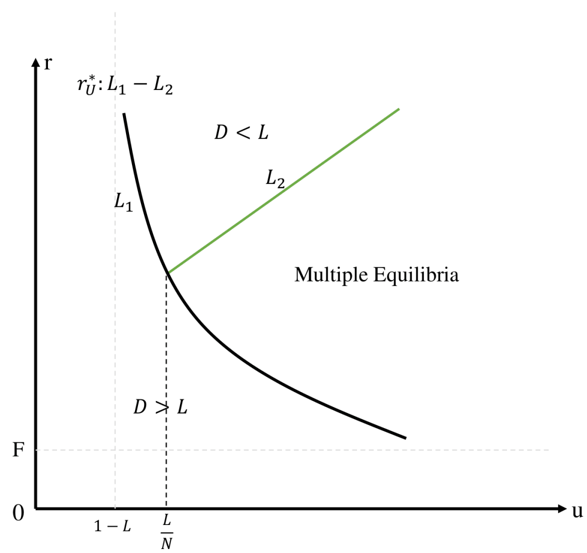


Figure 7: Run Regions under MTM Accounting, when $L > \frac{N}{N+1}$

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Appendices

A Data Description and Sources

- Deposit rate: Interest expense on deposits divided by total deposits. The ratio is winsorized at 0.5% and 99.5% level. Data is from Call Reports.
- Domestic Deposit rate: Interest expense on domestic deposits divided by domestic deposits. The ratio is winsorized at 0.5% and 99.5% level. Data is from Call Reports.
- Uninsured deposit ratio: Uninsured deposits divided by total deposits. Uninsured deposits are defined as deposits greater than $100k$ until 2009 and greater than $250k$ after that. The ratio is winsorized at 0.5% and 99.5% level. Uninsured deposit is from RCON2710 series before 2006Q2, and RCONF051+RCONF047 after 2006Q2. RCONF051 includes amount of deposit accounts (excluding retirement accounts) of more than 250000, while RCONF051 includes amount of deposit accounts in retirement accounts of more than 250000. Data is from Call Reports.
- Uninsured deposit to asset ratio: Uninsured deposits divided by total assets. The ratio is winsorized at 0.5% and 99.5% level. Data is from Call Reports.
- Bank size: Community bank with bank assets less than 10 billion, national bank with bank assets more than 100 billion, and regional bank with bank assets in between. Data is from Call Reports.
- Bank Type is directly obtained from FDIC, which mainly includes national member bank, state member bank, and state nonmember bank.
- Loans: Quarterly average of loans from Call Reports.
- Deposits: Total deposit size. Data is from Call Reports.
- Assets: Total asset size. Data is from Call Reports.
- Securities HTM: Securities held to maturity at amortized cost. Data is from Call Reports.
- Securities AFS: Securities available for sale at fair value. Data is from Call Reports.
- Herfindahl-Hirschman Index: We construct county-level HHI based on branch-level deposit size, and then average it into bank-level HHI using deposits as weights. Data is from FDIC.

B Proofs

Proof for Propositions 1 and 2. Following Corollary 1, there are three cases where $F(D_n; L_n)$ reaches the maximum.

Case 1 ($\frac{dF(D_n;L_n)}{dD_n} = 0$ for $D_n > L_n$.) *When $D_n > L_n$, $F(D_n; L_n)$ is equivalent to:*

$$\left[r - r^d(D_n, D_{-n})\right] D_n \tag{14}$$

From the total deposit supply equation and the market clearing condition, we have:

$$r^d(D_n, D_{-n}) = \frac{\sum_{n=1}^{N} D_n - 1 + u}{u} r - F \tag{15}$$

Combining Equations 14 and 15, $\frac{dF(D_n;L_n)}{dD_n} = 0$ is satisfied in the symmetric equilibrium when:

$$r^d = \frac{(N - \frac{1-u}{u})r - F}{N+1}.$$

Notice that the deposit rate in this case is positive only when $u > \frac{r}{(N+1)r-F}$. Therefore, we obtain:

$$r^d = \begin{cases} \frac{(N-\frac{1-u}{u})r-F}{N+1} & u > \frac{r}{(N+1)r-F} \\ 0 & u \le \frac{r}{(N+1)r-F} \end{cases}$$

The total deposit demand then follows:

$$D = \begin{cases} \frac{N}{N+1}\left(1 + u\frac{F}{r}\right) & u > \frac{r}{(N+1)r-F} \\ 1 - u + u\frac{F}{r} & u \le \frac{r}{(N+1)r-F}, \end{cases}$$

which holds when $D > L$.

When $L \le \frac{N}{N+1}$: when $r^d > 0$, $D > L$ holds as long as $u > \frac{r}{(N+1)r-F}$. When $r^d = 0$, $D > L$ holds as long as $r < \frac{uF}{L-(1-u)}$ and $u \le \frac{r}{(N+1)r-F}$. By calculus, $u \le \frac{r}{(N+1)r-F}$ is equivalent to $r \le \frac{uF}{uN-(1-u)}$. For any given $r > 0$, $\frac{uF}{uN-(1-u)} < \frac{uF}{L-(1-u)}$. Therefore $D > L$ also holds for all $u \le \frac{r}{(N+1)r-F}$. This means that when $L \le \frac{N}{N+1}$, $D > L$ always holds.

When $L > \frac{N}{N+1}$: when $r^d > 0$, $D > L$ holds as long as $r < \frac{uF}{\frac{N+1}{N}L-1}$ and $r > \frac{uF}{uN-(1-u)}$. We obtain that $\frac{uF}{uN-(1-u)} < \frac{uF}{\frac{N+1}{N}L-1}$ as long as $u > \frac{L}{N}$. When $r^d = 0$, $D > L$ holds as long as $u > 1 - L$, $r < \frac{uF}{L-(1-u)}$ and $r < \frac{uF}{uN-(1-u)}$ or $u \le 1 - L$. We obtain that

$\frac{uF}{L-(1-u)} < \frac{uF}{uN-(1-u)}$ *as long as* $1-L < u \leq \frac{L}{N}$*. Therefore, let us define* r_U^* *as*

$$r_U^* = \begin{cases} \frac{uF}{\frac{N+1}{N}L-1} & u > \frac{L}{N} \\ \frac{uF}{L-(1-u)} & 1-L < u \leq \frac{L}{N} \\ \infty & u \leq 1-L \end{cases}$$

This means that $L > \frac{N}{N+1}$*,* $D > L$ *is satisfied when* $r < r_U^*$*.*

Case 2 ($\frac{dF(D_n;L_n)}{dD_n} = 0$ **for** $D_n < L_n$**.)** *When* $D_n < L_n$*,* $F(D_n;L_n)$ *is equivalent to:*

$$\left[\lambda\widehat{r} - r^d(D_n, D_{-n})\right] D_n \tag{16}$$

Combining Equations (15) and (16), $\frac{dF(D_n;L_n)}{dD_n} = 0$ *is satisfied in the symmetric equilibrium when:*

$$r^d = \frac{N\lambda\widehat{r} - \frac{1-u}{u}r - F}{N+1}$$

Notice that the deposit rate in this case is positive only when $u > \frac{r}{N\lambda\widehat{r}+r-F}$*. Therefore, we obtain:*

$$r^d = \begin{cases} \frac{N\lambda\widehat{r} - \frac{1-u}{u}r - F}{N+1} & u > \frac{r}{N\lambda\widehat{r}+r-F} \\ 0 & u \leq \frac{r}{N\lambda\widehat{r}+r-F} \end{cases} \tag{17}$$

The total deposit demand then follows

$$D = \begin{cases} \frac{N}{N+1}\left[1-u+u\frac{F}{r}+u\frac{\lambda\widehat{r}}{r}\right] & u > \frac{r}{N\lambda\widehat{r}+r-F} \\ 1-u+u\frac{F}{r} & u \leq \frac{r}{N\lambda\widehat{r}+r-F} \end{cases} \tag{18}$$

which holds when $D < L$*. By calculus,* $u < \frac{r}{N\lambda\widehat{r}+r-F}$ *is equivalent to* $r < \frac{u(N\lambda\overline{r}+F)}{uN\lambda-(1-u)}$*.*

When $L \leq \frac{N}{N+1}$*: when* $r^d > 0$*,* $D < L$ *never holds. When* $r^d = 0$*,* $D < L$ *holds as long as* $r > \frac{uF}{L-(1-u)}$ *and* $r < \frac{u(N\lambda\overline{r}+F)}{uN\lambda-(1-u)}$*. We obtain that* $\frac{uF}{L-(1-u)} < \frac{u(N\lambda\overline{r}+F)}{uN\lambda-(1-u)}$ *when* $u(N\lambda F - N\lambda\overline{r}) < FL - N\lambda\overline{r}(1-L)$ *and* $\frac{FL-N\lambda\overline{r}(1-L)}{N\lambda F-N\lambda\overline{r}} > 1-L$*. The two conditions are equivalent to* $L > \frac{N}{N+1/\lambda}$*. This means that when* $L \leq \frac{N}{N+1}$*,* $D < L$ *never holds.*

When $\frac{N}{N+1} < L \leq \frac{N}{N+1/\lambda}$*: when* $r^d > 0$*,* $D < L$ *holds as long as* $r > \frac{u(F-\lambda\overline{r})}{\frac{N+1}{N}l-1+u(1-\lambda)}$*,* $r > \frac{u(N\lambda\overline{r}+F)}{uN\lambda-(1-u)}$*, and* $\frac{FL-N\lambda\overline{r}(1-L)}{N\lambda F-N\lambda\overline{r}} < -\frac{\frac{N+1}{N}L-1}{1-\lambda}$*. The three conditions are simultaneously satisfied when* $L > \frac{N}{N+1/\lambda}$*. When* $r^d = 0$*,* $D < L$ *holds only when* $\frac{FL-N\lambda\overline{r}(1-L)}{N\lambda F-N\lambda\overline{r}} > 1-L$*. This condition is also equivalent to* $L > \frac{N}{N+1/\lambda}$*. This means that when* $\frac{N}{N+1} < L \leq \frac{N}{N+1/\lambda}$*,*

$D < L$ never holds.

When $L > \frac{N}{N+1/\lambda}$: when $r^d > 0$, $D < L$ holds as long as $r > \frac{u(F-\lambda\bar{r})}{\frac{N+1}{N}l-1+u(1-\lambda)}$, $r > \frac{u(N\lambda\bar{r}+F)}{uN\lambda-(1-u)}$, and $\frac{FL-N\lambda\bar{r}(1-L)}{N\lambda F-N\lambda\bar{r}} < -\frac{\frac{N+1}{N}L-1}{1-\lambda}$. When $r^d = 0$, $D < L$ holds as long as $\frac{uF}{L-(1-u)} < r < \frac{u(N\lambda\bar{r}+F)}{uN\lambda-(1-u)}$. Let us define $u_L^* = \frac{FL-N\lambda\bar{r}(1-L)}{N\lambda F-N\lambda\bar{r}}$, and r_L^* as

$$r_L^* \equiv \begin{cases} \frac{u(F-\lambda\bar{r})}{\frac{N+1}{N}L-1+u(1-\lambda)} & u > u_L^* \\ \frac{uF}{l-(1-u)} & u \leq u_L^* \end{cases}$$

This means that when $L > \frac{N}{N+1/\lambda}$, $D < L$ holds when $r > r_L^*$.

Case 3 ($\frac{dF(D_n;L_n)}{dD_n} < 0$ for all $D_n > L_n$ and $\frac{dF(D_n;L_n)}{dD_n} > 0$ for all $D_n < L_n$.) *In this case, the optimal solution D_n^* is a corner solution: $D_n = L_n$. The deposit rate is then given by $r^d = \frac{L-(1-u)}{u}r - F$ following the deposit supply equation. $\frac{dF(D_n;L_n)}{dD_n} < 0$ for all $D_n > L_n$ and $\frac{dF(D_n;L_n)}{dD_n} > 0$ for all $D_n < L_n$ when $r < \frac{u(F-\lambda\bar{r})}{\frac{N+1}{N}L-1+u(1-\lambda)}$, $r > \frac{uF}{\frac{N+1}{N}L-1}$, and $r^d > 0$.*

When $L \leq \frac{N}{N+1}$, the above three conditions never simultaneously hold. When $\frac{N}{N+1} < L \leq \frac{N}{N+1/\lambda}$, the three conditions are equivalent to $r > r_U^*$. When $L > \frac{N}{N+1/\lambda}$, the three conditions are equivalent to $r_U^* < r < \max\{r_U^*, r_L^*\}$.

Combining the three cases, we obtain the no-run region and partial-run region as in Proposition 1 and Proposition 2. ■

Proof for Proposition 3. When $L > \frac{N}{N+1/\lambda}$, $u_L^* > \frac{L}{N}$ is satisfied when

$$\begin{aligned} &\frac{FL-N\lambda\bar{r}(1-L)}{N\lambda F-N\lambda\bar{r}} > \frac{L}{N} \\ \Rightarrow &FL-N\lambda\bar{r}(1-L) > L\lambda F-\lambda\bar{r}L \\ \Rightarrow &L > \frac{N\lambda\bar{r}}{(N+1)\lambda\bar{r}+F(1-\lambda)} = \frac{N}{N+1+\frac{F}{\lambda\bar{r}}(1-\lambda)} \end{aligned} \tag{19}$$

Since $(1-\lambda)(\frac{F}{\lambda\bar{r}}-\frac{1}{\lambda}) < 0$, we have $\frac{N}{N+1+\frac{F}{\lambda\bar{r}}(1-\lambda)} > \frac{N}{N+1/\lambda}$. Therefore, multiple equilibria exist when Equation 19 is satisfied. ■

Proof for Proposition 4. When $D > L$, given the optimal deposit rate and deposit quantity, we obtain:

$$\frac{dr^d}{dr} = \frac{N-\frac{1-u}{u}}{N+1} > 0$$

The positive deposit rate beta follows that the deposit rate is positive. The effect of uninsured deposit ratio on the deposit rate beta follows

$$\frac{d^2 r^d}{drdu} = \frac{1}{(N+1)u^2} > 0$$

Moreover, the deposit growth beta follows

$$\begin{aligned}\frac{dlog(D)}{dr} = \frac{dD}{dr}\frac{1}{D} &= -\frac{N}{N+1}\frac{uF}{r^2}\frac{r}{(1-u)r + u(F+r^d)} \\ &= -\frac{N}{N+1}\frac{uF}{r}\frac{1}{(1-u)r + u(F + \frac{(N-\frac{1-u}{u})r - F}{N+1})} \\ &= -\frac{1}{r}\frac{uF}{uF+r} = \frac{1}{r}(\frac{r}{r+uF} - 1) < 0\end{aligned}$$

The above equation implies that when the policy rate increases, there would be deposit outflow. The effect of uninsured deposit ratio on the deposit growth beta follows

$$\frac{d^2 log(D)}{drdu} = -\frac{F}{(r+uF)^2} < 0$$

This proposition implies that the deposit rate beta is positive, but the deposit growth beta is negative. When $D \leq L$, the proof is the same. ■

Proof of Proposition 6. When $L \leq \frac{N}{N+1}$, the equilibrium is always a no-run equilibrium with $D > L$. Banks maximize

$$\max\{p\left[(R - r_l)L + (r_l - r^d)D\right] + (1-p)\left[(R - r_h)L + (r_h - r^d)D\right]\}$$

The marginal benefit of holding long-term asset becomes $p(R - r_l) + (1-p)(R - r_h)$, which is positive.

When $\frac{N}{N+1} < L \leq \frac{N}{N+1/\lambda}$, the equilibrium is always a no-run equilibrium with $D > L$ or $D = L$. When $D > L$ at both $r = r_l$ and $r = r_h$, the marginal benefit of holding long-term assets is still $p(R - r_l) + (1-p)(R - r_h)$, which is still positive. When $D > L$ at $r = r_l$ and $D = L$ at $r = r_h$, the objective condition becomes

$$\max\{p\left[(R - r_l)L + (r_l - r^d)D\right] + (1-p)\left[(R - r^d)L\right]\}$$

Therefore, the marginal benefit of holding long-term assets is

$$\begin{aligned} &p(R - r_l) + (1-p)(R - r^d - \frac{\partial r^d}{\partial L} L) \\ =\ &R - pr_l + (1-p)(F - \frac{2L - 1 + u}{u} r_h) \end{aligned} \tag{20}$$

The minimum of Equation (20) reaches at $u = 1 - L$, and $L = \frac{N}{N+1/\lambda}$. Equation (20) then becomes

$$R + (1-p)F - (1-p)r_h N\lambda - pr_l,$$

which is positive when $R + (1-p)F > (1-p)r_h(N\lambda - 1) + \mathbb{E}r$.

When $L > \frac{N}{N+1/\lambda}$, the equilibrium could be either $D > L$, $D = L$, or $D < L$ at $r = r_h$. However, at $r = r_l$, $D > L$. In the scenario of $D > L$ at $r = r_h$, the marginal benefit of holding long-term asset is $p(R - r_l) + (1-p)(R - r_h) > 0$. In the scenario of $D < L$, the marginal benefit of holding long-term asset $p(R - r_l) + (1-p)(R - \lambda(r_h - \overline{r}))$, which is positive when $R + \lambda\overline{r} + p\lambda(r_l - \overline{r}) > \lambda\mathbb{E}r + pr_l$. In the scenario of $D < L$, the marginal benefit of holding long-term asset is $R - pr_l + (1-p)(F - \frac{2L-1+u}{u} r_h)$, the minimum of which reaches at $u = \min\{\frac{(\frac{N+1}{N}L - 1)\lambda\overline{r}}{(\lambda-1)F}, \frac{\frac{FL}{N} - (1-L)\lambda\overline{r}}{-\lambda\overline{r} + \lambda F}\}$ and $L = 1$. At this point, the marginal benefit of holding long-term asset becomes:

$$R - pr_l + (1-p)F - (1-p)r_h(1 + \max\{\frac{F}{\lambda\overline{r}}N(\lambda - 1), N\lambda - \frac{N\lambda\overline{r}}{F}\}),$$

which is positive when $R + (1-p)F > \mathbb{E}r + (1-p)r_h \max\{\frac{F}{\lambda\overline{r}}N(\lambda-1), N\lambda - \frac{N\lambda\overline{r}}{F}\})$.

Therefore, when $R + \lambda\overline{r} + p\lambda(r_l - \overline{r}) > \lambda\mathbb{E}r + pr_l$ and $R + (1-p)F > \mathbb{E}r + (1-p)r_h \max\{\frac{F}{\lambda\overline{r}}N(\lambda-1), N\lambda - \frac{N\lambda\overline{r}}{F}, N\lambda - 1\})$, the marginal benefit of holding long-term asset is positive, and $L^* = 1$. The sufficient condition for $R + (1-p)F > \mathbb{E}r + (1-p)r_h \max\{\frac{F}{\lambda\overline{r}}N(\lambda-1), N\lambda - \frac{N\lambda\overline{r}}{F}, N\lambda - 1\})$ could be $R + (1-p)F > \mathbb{E}r + (1-p)r_h\frac{NF}{\overline{r}}$. ■

Proof for Proposition 7. When all assets are market-to-market, the case where $D > L$ is not affected since the marginal benefit of deposits remained unchanged. When $D < L$, the objective function is now equivalent to:

$$0 - r^d(D_n, D_{-n})D_n$$

Since the objective function is decreasing, the optimality is achieved when $r^d = 0$, and $D = 1 - u + u\frac{F}{r}$. $D < L$ holds when $r > \frac{uF}{L-(1-u)}$. $D = L$ never holds because $F(D_n, D_{-n})$ is decreasing when $D_n < L_n$. ■

Proof for Proposition 8. When $D > L$ at $r = r_l$, and $D < L$ at $r = r_h$, banks maximize

$$\max\{p\left[(R - \lambda(r_l - \overline{r}) - r_l)L + (r_l - r^d)D\right] + (1-p)\left[(R - \lambda(r_h - \overline{r}))L + (0 - r^d)D\right]\}$$

The marginal benefit of holding long-term assets then becomes $p(R - \lambda(r_l - \overline{r}) - r_l) + (1 - p)(R + \lambda\overline{r} - \lambda r_h) = R + \lambda\overline{r} - \lambda\mathbb{E}r - pr_l$, which is negative as long as $R + \lambda\overline{r} < \lambda\mathbb{E}r + pr_l$.

When $D > L$ for both $r = \overline{r}$ and $r = r_h$, the marginal benefit of holding long-term assets becomes

$$p(R - \lambda(r_l - \overline{r}) - r_l) + (1-p)(R + \lambda\overline{r} - \lambda r_h - r_h) = R + \lambda\overline{r} - (\lambda + 1)\mathbb{E}r,$$

which is negative as long as $R + \lambda\overline{r} < (\lambda + 1)\mathbb{E}r$.

Therefore, when $R + \lambda\overline{r} < \lambda\mathbb{E}r + pr_l$, the marginal benefit of holding long-term asset is negative, $L^{**} = 0$. ■