# Monetary Tightening and U.S. Bank Fragility in 2023: Mark-to-Market Losses and Uninsured Depositor Runs?*

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**Abstract**

We develop an empirical methodology and conceptual framework to analyze the effect of rising interest rates on the value of U.S. bank assets and bank stability. We mark-to-market losses on banks' assets due to interest rate increases from Q1 2022 to Q1 2023. Asset values declined on average by 10%, and the $2.2 trillion aggregate decline was on the order of aggregate bank capital. We present a model of *solvency runs*, which illustrates that interest rate increases can lead to self-fulfilling solvency bank runs even when banks' assets are fully liquid. The model identifies banks with asset losses, low capital, and critically, high uninsured leverage as being most fragile. A case study of the recently failed Silicon Valley Bank (SVB) confirms the model insights. 10 percent of banks have larger unrecognized losses and lower capital than SVB. On the other hand, SVB had a disproportional share of uninsured funding: only 1 percent of banks had higher uninsured leverage. Combined, losses and uninsured leverage provided incentives for an SVB uninsured depositor run. We compute new empirical measures of bank fragility for the sample of all U.S. banks. Even if only half of uninsured depositors had decided to withdraw, almost 190 banks with assets of $300 billion are at a potential risk of insolvency, meaning that the mark-to-market value of their remaining assets after these withdrawals would be insufficient to repay all insured deposits. We briefly discuss events and subsequent research following our paper's release on March 13, 2023. We see these as providing validity to our approach and findings.

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## 1. Introduction

Silicon Valley Bank (SVB) failed in a "run" on March 10 of 2023 following a sharp tightening of monetary policy from March 2022. The idea that rising interest rates can lead to bank stability is intuitive and has historic precedent in the S&L crisis.[1] Tighter monetary policy has a significant negative impact on the value of long-term assets on bank balance sheets. If banks' asset values decline relative to liabilities, then such declines can lead to bank instability through two channels. First, a bank can become fundamentally insolvent if asset values exceed the value of its liabilities. This is particularly likely for banks that have limited deposit franchise and need to increase deposit rates as interest rates rise.[2] Second, uninsured depositors may run on the bank, causing it to fail; this is especially the case because uninsured depositors comprise about half of bank deposits (Egan et al 2017). On the other hand, it is far from clear that asset losses induced by monetary tightening are sufficiently large to induce self-fulfilling runs by uninsured depositors. Moreover, while S&L's assets were illiquid, the current banking environment liquid assets represent a significant part of bank balance sheets. This makes it difficult for runs to arise in the canonical framework of Diamond and Dybvig (1983) in which asset illiquidity is paramount.

We develop an empirical methodology and conceptual framework to analyze the effect of rising interest rates on the value of U.S. bank assets and bank stability when bank assets are liquid. In the first part of the paper, we measure the losses due to interest rate increases from Q1 2022 to Q1 2023. Because bank call reports do not mark significant parts of their assets to their market values, we provide a mark-to-market calculation of these losses using tradable and liquid market indexes. Using the case of SVB, we show that the asset side alone cannot explain its failure. SVB was not an extreme outlier from the perspective of asset losses but was an outlier from the perspective of its liabilities. 92.5% of its deposits were uninsured, leading to significant withdrawals that ultimately resulted in the bank's collapse within two days. In other words, despite its liquid balance sheet, the SVB failure had the characteristics of a run by uninsured depositors. In the second part of the paper, we present a model, which illustrates that banks can become exposed to self-fulfilling *solvency runs* when monetary policy tightens. We model the existence of solvency runs, which arise even if banks' assets are fully liquid. This differentiates the model from liquidity run models. The model builds on the idea of solvency runs of Egan et al. (2017) but extends it to study the role of maturity transformation: banks invest in long and short maturity assets, exposing banks to asset declines due to monetary policy and fund with demandable deposits. We then use the insights from the model to compute new empirical measures of bank fragility for the sample of all U.S. banks.

Long dated assets experiences significant value declines following the monetary tightening from Q1:2022 onwards. In response to high inflation, the Federal Reserve Bank severely tightened monetary policy. From March 07, 2022, to March 6, 2023, the federal funds rate rose sharply from 0.08% to 4.57% (Figure 1A). As a result, long-dated assets experienced significant value declines. For instance, the exchange-traded fund that tracks the market value of residential mortgages (SPDR Portfolio Mortgage-Backed Bond ETF—SPMB) declined by more than 10% (Figure 1B)

[1] In the 1980s and 1990s, nearly one-third of savings and loan institutions (S&L) failed due to losses incurred from long-term fixed-rate mortgages that declined in value when interest rates surged.

[2] Banks in concentrated markets and with stronger deposit franchise can be slower to raise their deposit rates in response to raising interest rates (e.g., Hannan and Berger 1991; Neumark and Sharpe 1992; Drechsler et al. 2017; Egan et al. 2017). This can reduce the market value of their liabilities (Drechsler et al. 2021).

from 2022:Q1 to 2023:Q1. Similarly, the market value of commercial mortgages indicated by the iShares CMBS ETF declined by more than 10% during this time. Long maturity treasury bonds were particularly affected by monetary policy tightening, with 10-20 year and 20+ year Treasury bonds losing about 25% and 30% of their market value, respectively, as suggested by iShares Treasury ETF (see Figure 1C). Overall, long duration assets similar to those held on bank balance sheets experienced very significant declines during the FED's monetary policy tightening.

We mark-to-market losses on banks' assets due to interest rate increases from Q1 2022 to Q1 2023 using market-level prices of long-duration assets.[3] Our analysis proceeds in multiple stages. Firstly, we examine losses on banks' assets including their loan portfolios held to maturity, which have not been marked-to-market, as well as securities linked to real estate (such as mortgage-backed securities (MBS), commercial mortgage-backed securities (CMBS), US Treasuries, and other asset-backed securities (ABS)). These assets comprise more than two-thirds of bank assets (72% of $24 trillion dollars). Adjusting these assets to their market values, our findings indicate that by March 2023 bank assets declined on average by 10%. There are large differences in losses, with the bottom 5th percentile experiencing a decline of approximately 20%. In aggregate, the market value of U.S. banking system assets became $2.2 trillion lower than suggested by their book value which is on the order of aggregate bank capital (Figure A1).

A case study of SVB confirms that banks' asset losses and bank capitalization alone are insufficient to understand how monetary policy tightening affects bank stability. Liabilities composition plays a central role. About 500 banks (10 percent) had larger unrecognized losses than SVB. Similarly, 10 percent of banks had lower capital prior to monetary tightening, as well as post tightening, accounting for mark-to-market losses. On the other hand, SVB had a disproportional share of uninsured funding: only 1 percent of banks had higher uninsured leverage, defined as uninsured debt over assets in Jiang et al (2020). Intuitively, a bank in the 5th percentile of uninsured leverage bank uses 6 percent of uninsured debt. For this bank, 94% of funding is not run prone comprising equity and deposits. For SVB, 78 percent of its assets was funded by uninsured deposits. This fact suggests that uninsured deposits played a critical role in the failure of SVB. Even if 78% of SVB liabilities were run prone, 62% were liquid cash and securities. Therefore, SVB should not have been subject to a canonical panic run in the spirit of Diamond and Dybvig (1983) or Goldstein and Pauzner (2005). In these models, runs occur because bank assets are illiquid, like the mortgage loans of S&Ls in the 1980s and 1990s.

To analyze how monetary policy can trigger panic induced runs in banks with liquid assets, we next develop a model. The model builds on the idea of solvency runs of Egan et al. (2017) but extends to model to study the role of maturity transformation: banks invest in long and short maturity assets, exposing banks to asset declines due to monetary policy and fund with demandable deposits. Intuitively, banks have market power in the deposit market, which allows them to pay below the risk-free rate on insured and uninsured deposits. Unlike insured depositors, uninsured depositors stand to lose a part of their deposits if the bank fails, giving them incentives to withdraw their funds if they believe that the bank is not sound. When interest rate are relatively low bank asset values are high enough that they can survive the withdrawal of all uninsured deposits. Then

[3] For assessments of U.S. banks' exposure to credit and interest rate risk in periods preceding the 2022-2023 monetary tightening episode see, among others, Begenau et al. (2015), Kelly et al. (2016), Drechsler et al. (2017, 2021), Egan et al. (2017), Atkeson et al. (2018), Begenau and Stafford (2019), and Xiao (2020).

it is not rational for any individual depositor to withdraw, and the bank is immune to solvency runs. When interest rates rise sufficiently, and thus asset values decline, self-fulfilling runs are possible. In fact, we illustrate that bank equity values can increase as interest rates rise if uninsured depositors believe that banks are stable; but also expose banks to self-fulfilling runs by the same uninsured depositors. Banks with smaller initial capitalization, higher uninsured leverage, and higher share of awake depositors are more susceptible to such runs and insolvency.

Using the intuition from the model, we compute new empirical measures of bank fragility for the sample of all U.S. banks across a broad range of scenarios. We identify which banks were at risk of uninsured depositor solvency runs under different scenarios in March 2023. For example, without regulatory intervention, even if only half of uninsured depositors had decided to withdraw, almost 190 banks with assets of $300 billion are at a potential risk of insolvency, meaning that the mark-to-market value of their remaining assets after these withdrawals would be insufficient to repay all insured deposits. These measures hold up well even ex post. We released our study on March 13, 2023. As we discuss in the paper, the events and work that followed us releasing our paper validate our approach and findings. For example, the subsequent bank failures of First Republic closure of Signature Bank have similar characteristics to the banks at risk we identify: significant decline in the value of their assets and high share of funding coming from the uninsured depositors. The collapse of all these banks was also preceded by significant withdrawals of funds by uninsured depositors. We see these as providing validity to our approach and findings.

We conclude by discussing several extensions of our work. First, we illustrate that banks were not likely to have hedged vast majority of the decline of their assets due to raise in interest rates. Second, we compute the extent to which decline in banks' asset values quantified above eroded their ability to withstand adverse credit events – focusing on commercial real estate loans. Next, we show that the risk in the banking sector due to monetary tightening is not spread uniformly across space, with higher exposure in regions with more minorities and lower income households.

## 2. Banks' Hidden Losses: "Marking to Market" Bank Assets

To understand the impact of interest rate increases on banks' asset values, we begin by examining bank balance sheets, following Jiang et al. (2020). Since a substantial portion of bank portfolios, specifically loans held to maturity, are not marked to market, we rely on exchange-traded funds (ETFs) across various asset classes to conduct our analysis. We focus on assets comprising more than two-thirds of bank assets (72% of $24 trillion dollars). Among these, for the average bank, real estate loans account for approximately 42% of their assets (Table A1). Moreover, securities linked to real estate (such as mortgage-backed securities (MBS), commercial mortgage-backed securities (CMBS), treasuries, and other asset-backed securities (ABS) constitute approximately 24% of the average bank's assets. We note that since we do not mark all the banks' assets, we may be underestimating the effect of interest rates on the remaining portion of the bank balance sheet, which we leave unchanged.

### 2.1 Methodology and Data

We mark bank assets to market in three steps.

1) We obtain the asset maturity and repricing data for all FDIC-insured banks in their regulatory filings (Call Report Form 031 and 051) in 2022:Q1. Banks are required to report

the values of residential MBS and non-residential MBS securities (Schedule RC-B). They are also required to report the values of loans that are secured by first liens on 1- 4 family residential properties and all loans and leases excluding loans that are secured by first liens on 1-4 family residential properties (Schedule RC-C) by maturity and repricing breakdowns.[4]

2) We use traded indexes in real estate and treasuries to impute the market value of real estate loans held on bank balance sheet.[5] Longer duration fixed income assets were affected more by interest rate increases, so we want to adjust the market values of loans based on their maturity. Because of limited maturity information across RMBS maturities, we use one RMBS exchange traded fund, and then adjust across maturities using treasury prices. As a baseline, we use changes in the market price of the U.S. Treasury bonds and RMBS from 2022:Q1 to 2023:Q1. To adjust for maturity, we use the iShares U.S. Treasury Bond ETFs and the S&P Treasury Bond Indices across various maturities that match the maturity and repricing breakdowns in the call reports. For each of these ETFs and indices, we calculate the price declines since 2022:Q1, plotted in Figure 1.

3) We compute the mark-to-market value loss as

$$Loss = \sum_t RMBS\ multiplier \times (RMBS_t + Mortgage_t) \times \Delta TreasuryPrice_t + Treasury\ and\ Other\ Securities\ and\ Loans_t \times \Delta TreasuryPrice_t,$$

where t indicates the maturity and repricing breakdowns: less than 1 year, 1-3 years, 3-5 years, 5-10 years, 10-15 years, and 15 years or more. $\Delta TreasuryPrice_t$ is the market price change of Treasury bonds with maturity t from 2022:Q1 to 2023:Q1 that we obtained in the second step. RMBS and residential mortgages have additional risk due to prepayment risk. We account for this by constructing an $RMBS\ multiplier$ that uses average market price changes of RMBS and Treasury bonds across various maturities over this period:

$$RMBS\ multiplier = \frac{\Delta iShare\ MBS\ ETF}{\Delta \text{S\&P}\ Treasury\ Bond\ Index}.$$

We then define the mark-to-market asset value in 2023:Q1 as total assets in 2022:Q1 minus the mark-to-market value loss defined above. In some ways, our estimates are conservative, since we only marked down the value of real estate loans and other assets and securities and loans discussed above, rather than all assets on the bank balance sheets. On the other hand, in our main analysis we do not account for possible interest rate hedges that banks could have entered, potentially offsetting decline in value due to interest rate change. In extension of our main analysis (Section 5.1), we show that use of hedging and other interest rate derivatives was not large enough to offset a vast majority of the loss in the value of U.S. banks' assets that we quantify.

[4] The breakdowns are "less than three months," "three months to one year," "one to three years," "three to five years," "five to fifteen years," and "more than fifteen years."
[5] Variable rate notes are recorded as maturity at the repricing date in bank call reports.

Our computation relies on contractual maturities of loans and securities. These may differ from effective maturities, which can be shorter due to prepayment. Accounting for effective maturities would lower the impact of rising rates on bank assets. On the other hand, rising interest rates lower prepayment incentives, and the effective maturity may lengthen closer to the contractual one as monetary policy tightens.

### 2.2 Declines in the Value of Banks' Assets

Marking the value of real estate loans, government bonds, and other securities results in significant declines in bank assets. Table 1 shows the aggregate losses in the US banking system and their distribution among small, large, and GSIB banks. In total the U.S. banking system's market value of assets is $2.2 trillion lower than suggested by their book value of assets as of 2023:Q1.[6] This estimate is similar to the back of the envelope $2.16 trillion aggregate loss in Jiang et al. (2023a), computed from the reported duration of public bank assets.[7]

We present the distribution of asset declines due to unrealized losses in Figure 2A. The median value of banks' unrealized losses is around 9% after marking to market. The 5% of banks with worst unrealized losses experience asset declines of about 20%. We note that these losses amount to a stunning 96% of the pre-tightening aggregate bank capitalization.

The unacknowledged losses do differ slightly across the size distribution. They are smallest for GSIBs (Global Systemically Important Banks) at 4.6% and largest for large non-GSIB banks at 10%. Note that there are also differences in the uses of interest rate hedges across the size distribution of banks (esp. GSIBs) as we discuss in Section 5.1. There are substantial differences in the types of loans from which the losses arise. For GSIBs, RMBS is the largest part of the losses, and for small banks, it is other loans.

Perhaps somewhat puzzling at first, the recently failed SVB does not stand out as much in the distribution of marked to market losses. About 11 percent of banks suffered worse marked to market losses on their portfolio (Figure 2). In other words, if SVB failed because of losses alone, more than 500 other banks should also have failed.

## 3. The Role of Uninsured Leverage

### 3.1 Banking Sector and the Case of SVB

We next turn to assessing banks' funding structure before the monetary tightening. We show that SVB was not especially thinly capitalized relative to other banks. Instead, we show that it stood out on the dimension of uninsured leverage, making it much more run prone than other banks. Table A1 presents the funding structure of the U.S. banking industry prior to the monetary tightening. The average bank funds 10% of their assets with equity, 63% with insured deposits,

[6] Liquid RMBS indices are based on loan pools with shorter contractual maturities than the stated maturity of real estate related loans and securities, and thus experience lower losses. As a robustness check, we also verified that even if we effectively assign much shorter maturity to long-term residential real estate loans and RMBS we would still find aggregate asset declines in the US banking system well in the excess of $1 trillion.

[7] The reported duration of 4.6 years implies a 9% decline in bank asset values because of a two-percentage point increase in the 10-year Treasury yield.

and 27% with uninsured debt comprising 23% uninsured deposits and 4% other debt funding.[8] There was very little difference in the capitalization across banks prior to monetary policy tightening. The 10th percentile best capitalized bank had a ratio of equity to assets (E/A) of 14%, while the 10th percentile worst capitalized bank had 8% percent capital. Again, SVB is not an outlier—it is at the 10th percentile of capitalization of U.S. banks.

SVB did stand out from other banks in its distribution of uninsured leverage, the ratio of uninsured debt to assets (see Jiang et al. 2020 for a more comprehensive analysis of uninsured leverage of U.S. banking and shadow banking sector). Banks differ significantly in the share of funding they obtain from uninsured sources. The 5th percentile bank uses 6 percent of uninsured debt. For this bank, 94% of funding is not run prone comprising equity and deposits.

On the other hand, the 95th percentile bank uses 52 percent of uninsured debt. For this bank, even if only half of uninsured depositors panic, this leads to a withdrawal of one quarter of total marked to market value of the bank. If any fire sale discounts result from these withdrawals, this can impose substantial losses on the remaining creditors, increasing their incentives to run. SVB was in the 1st percentile of distribution in insured leverage. Over 78 percent of its assets was funded by uninsured deposits. This fact suggests that uninsured deposits played a critical role in the failure of SVB. We formalize this insight in a simple framework and then illustrate its implications through several numerical scenarios.

### 3.2 Self-fulfilling Solvency Runs, Sleepy Depositors, and Monetary Policy

In this section, we present a model, which illustrates that banks can become exposed to self-fulfilling solvency runs when monetary policy tightens. In the current banking environment, liquid assets represent a significant part of bank balance sheets. This makes it difficult for runs to arise in a framework of Diamond and Dybvig (1983) or Goldstein and Pauzner (2005) in which asset illiquidity is paramount. Instead, we model the existence of solvency runs, which arise even if banks' assets are fully liquid. This differentiates the model from liquidity run models. The model builds on the idea of solvency runs of Egan et al. (2017) but extends to model to study the role of maturity transformation: banks invest in long and short maturity assets, exposing banks to asset declines due to monetary policy and fund with demandable deposits.

The basic mechanism of self-fulfilling solvency runs is the following. Banks have market power in the deposit market, which allows them to pay depositors below the risk-free rate. In return for banking services, uninsured depositors are willing to earn low deposit rates if they believe that the bank is sound. If they believe that the bank is not sound, on the other hand, they withdraw their deposits. When risk-free interest rate is low, bank asset values are high enough that they can survive uninsured depositor withdrawals. Then it is not rational for any individual depositor to withdraw, and the bank is immune to self-fulfilling solvency runs. When interest rates rise sufficiently, and thus asset values decline, self-fulfilling runs are possible. In fact, we illustrate that bank equity values can increase as interest rates rise if uninsured depositors believe that banks are stable; but also expose banks to self-fulfilling runs by the same uninsured depositors. We use the

[8] As shown in Table A1 Panel B, only less than 1% of the uninsured deposits are time deposits with time to maturity and repricing in more than a year.

model to highlight the central role of uninsured leverage in exposing banks to insolvency runs in the data, and then use this insight to study insolvency run potential empirically in Section 4.

We present a simple and stylized model, which takes assets, liabilities, and markups of banks as exogenous to illustrate the basic mechanism of solvency runs and their interaction with uninsured leverage.[9] This allows us to generate predictions that can be taken to data.

*Setting:*

A monopolist bank has long-dated assets and liabilities (deposits) in place. We study how the withdrawal behavior of uninsured depositors interacts with monetary policy and the consequences for bank stability.

*Bank Assets*

A bank holds two assets normalized to book value of 1: $c$ share of bank assets is interest insensitive cash paying a yield of 0; $(1-c)$ share of its assets are risk-free liquid perpetuities (e.g., T-bonds with infinite maturity), paying an annual coupon $r_0$. Because cash has duration of 0, $(1-c)$ effectively captures the duration of bank's assets and their sensitivity to interest rate risk. The perpetuities are completely liquid: the bank can always sell them at their present value of coupons discounted at the risk-free rate. At the risk-free rate $r_f$, the market value of bank assets is given by $c+(1-c)\frac{r_0}{r_f}$.

*Deposits:*

Bank's existing liabilities comprise insured and uninsured deposits with face value $l_i$ and $l_u$. We refer to the share of funding from uninsured debt, $l_u$, as *uninsured* book leverage. The bank therefore has (book) capital $e_b = 1-(l_i+l_u)$. Existing depositors can keep their deposits with the bank or withdraw them to invest in the outside good such as a money market fund or deposits at other banks, which earn $\mu(r_f) < r_f$. The external rate increases in the risk-free rate $1 > \mu'(r_f) > 0$. On the other hand, if the bank fails, *uninsured* depositors realize a flow cost of failure $\nu_f > r_f$; in other words, prevailing rates do not compensate uninsured depositors if they think the bank will fail for sure. There is no utility loss of default for insured depositors. This payoff structure captures the idea that depositors are willing to pay to obtain deposit services and want to use these services if the bank is sound, but uninsured depositors prefer to withdraw their funds to keeping them in the bank, if the bank will fail. In this setting banks have market power in the deposit market, which may give rise to franchise value.[10]

To further map the model to the data, we assume that $s$ share of uninsured depositors is potentially "awake" while $(1-s)$ share of the uninsured depositors are "sleepy" and keep the money in the bank irrespective of the bank's condition. This captures the idea that perhaps a part of the reason why investors hold deposits is so that they (rationally or not) do not have to pay attention to banks' health. Either way, depositors being sleepy makes it more difficult to sustain a self-fulfilling run.

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[9] Egan et al. (2017) endogenize bank size, financing choices, and markups; Jiang et al. (2020) study the role of uninsured leverage in a model of banks and shadow banks.

[10] See, among others, Hannan and Berger (1991), Neumark and Sharpe (1992), Drechsler et al. (2017) and Egan et al. (2017) for evidence of bank market power in the deposit market.

We also assume that all insured depositors are "sleepy". In practice, some of them may also be awake and consider withdrawing their money following an interest rate increase. It is easy to incorporate such deposit outflows in our framework and these would only increase the range of model parameters when a "bad" run equilibrium can occur.

*Bank Failure:*

In the baseline model, we assume that a bank fails when the bank is insolvent, i.e., when the market value of equity is negative in present value terms. Because bank default is initiated by regulators, we also consider alternative default rules when mapping the model to the data.

*Equilibria:*

We consider pure strategy symmetric equilibria of the game between the depositors and the bank. Given the setup, the profit maximizing pricing strategy of the bank is straightforward: it sets deposit rates at the outside option $\mu(r_f)$, expropriating the full depositor surplus. Insured depositors and sleepy uninsured depositors are passive and collect their deposit rates. The focus of the analysis is on the decision of awake uninsured depositors. There are two equilibria: a "no run" equilibrium in which awake uninsured depositors do not withdraw, and a "run" equilibrium, at which awake uninsured depositors withdraw.

The good equilibrium arises if bank fundamentals can support the uninsured depositors' belief that the bank is solvent. In other words, market value of equity (franchise value) if depositors do not run, $e_{no\ run}$, has to be positive.

$$e_{no\ run}(r_f) = \underbrace{c + (1-c)\frac{r_0}{r_f}}_{PV\ Assets} - \underbrace{(l_i + l_u)\frac{\mu(r_f)}{r_f}}_{PV\ Deposit} > 0 \tag{1}$$

To simplify notation, define the per dollar net gain (or loss) on assets due to differences in interest rates as $\Delta a(r_f) = \frac{r_0 - r_f}{r_f}$, and the per dollar value of deposit franchise as $\Delta f(r_f) = \frac{r_f - \mu(r_f)}{r_f}$. Then the market value of a bank in the no run equilibrium comprises its book capital, as well as the net value of its assets and the deposit franchise of all deposits:

$$e_{no\ run}(r_f) = e_b + \underbrace{(1-c)\Delta a(r_f)}_{Assets\ Gain/Loss} + \underbrace{(l_i + l_u)\Delta f(r_f)}_{Deposit\ Franchise\ of\ Total\ Deposits} > 0 \tag{2}$$

The bank can survive if the deposit franchise of all depositors and capital exceeds losses due to interest rates. In other words, better capitalized banks, with more deposit franchise are less prone to bank failure.

A run equilibrium occurs if it is rational for an individual uninsured depositor who is awake to withdraw their funds conditional on believing other awake uninsured depositors are withdrawing also. This occurs when the banks' equity value is negative if all awake depositors withdraw, i.e., if:

$$e_{run}(r_f) = e_b + \underbrace{(1-c)\Delta a(r_f)}_{Assets\ Gain/Loss} + \underbrace{(l_i + (1-s)l_u)\Delta f(r_f)}_{Deposit\ Franchise\ of\ Sleepy\ Deposits} < 0$$

With a little algebra, we can write the run condition as:

$$\underbrace{e_b + \underbrace{(1-c)\Delta a(r_f)}_{Assets\ Gain/Loss} + \underbrace{(l_i + l_u)\Delta f(r_f)}_{Deposit\ Franchise\ of\ Total\ Deposits}}_{e_{no\ run}} < \underbrace{s l_u \Delta f(r_f)}_{Deposit\ Franchise\ of\ Awake\ Deposits} \tag{3}$$

In other words, a run equilibrium can be supported if the value of the bank under the no run condition is lower than the deposit franchise of runnable deposits.

*Proposition 1:* Combining the above expressions, the equilibrium structure is the following:

1) Unique no-run equilibrium: $e_b + (1-c)\Delta a(r_f) + (l_i + l_u)\Delta f(r_f) > s l_u \Delta f(r_f)$
2) Multiple equilibria: when $0 < e_b + (1-c)\Delta a(r_f) + (l_i + l_u)\Delta f(r_f) < s l_u \Delta f(r_f)$
3) Unique equilibrium with bank insolvency: $0 > e_b + (1-c)\Delta a(r_f) + (l_i + l_u)\Delta f(r_f)$

The structure of equilibria shows, unsurprisingly, that no run equilibria are more easily supported in better capitalized banks with higher asset valuations, and a higher overall deposit franchise value. The run equilibrium, on the other hand, critically depends on the types of deposits used to fund the bank. The higher the uninsured leverage, $l_u$, and more awake the depositors $s$, the more runnable the bank is, especially if it derives a large share of its value from the deposit franchise $f(r_f)$. Intuitively, banks with large uninsured deposit base can at the same time support large bank valuation, and still be susceptible to bank runs.

More formally, there is a threshold:

$$s^* = \frac{e_b + (1-c)\Delta a(r_f) + (l_i + l_u)\Delta f(r_f)}{l_u \Delta f(r_f)} \tag{4}$$

such that if the share of awake depositors $s$ is less or equal than that, $s \leq s^*$, we are in no run equilibrium, assuming that $e_b + (1-c)\Delta a(r_f) + (l_i + l_u)\Delta f(r_f) > 0$. If $s > s^*$ a “bad” run equilibrium becomes a possibility. Thus, we can think about $(1 - s^*)$ as a measure of bank insolvency risk due to uninsured depositor runs. All else equal, this index of bank instability will be weakly higher for banks with higher uninsured leverage.

*Monetary Policy, Franchise Value and Bank Instability*

Here we show that when interest rates rise sufficiently, and thus asset values decline, self-fulfilling runs are possible for banks, especially those with high uninsured leverage and a large share of awake depositors. We further illustrate the conditions under which bank equity values can increase as interest rates rise if uninsured depositors believe that banks are stable; but also expose banks to self-fulfilling runs by the same uninsured depositors.

Increased interest rates make it easier to support a run equilibrium if interest rates increase asset losses at a faster rate than the franchise value of sleepy depositors, i.e., if [11]

$$-(1-c)\Delta a'(r_f) \ > (l_i + (1-s)l_u)\Delta f'(r_f) \tag{5}$$

In other words, banks, which are most susceptible to a monetary policy induced run are those with more long maturing assets (low $c$), those with high uninsured leverage, $l_u$ (holding overall leverage $l_i + l_u$ fixed), and more awake depositors (high $s$).

While rising interest rates make it easier to support a run equilibrium, they can also lead to increased bank valuations if depositors believe that no run will take place. This situation occurs in banks when:

$$(l_i + l_u)\Delta f'(r_f) > (1-c)\Delta a'(r_f) \ > (l_i + (1-s)l_u)\Delta f'(r_f) \tag{6}$$

Consider banks, whose per deposit franchise value increases in interest rates $f'(r_f)$ but their deposit base comprises runnable deposits, with high $sl_u$. Their valuations increase if depositors believe the bank is stable, but also become most susceptible to a deposit run if those beliefs change.

*Example 1: Insolvency bank runs with constant deposit markups*

To better understand the role that deposit mark-ups play in determining bank stability and equity valuations, consider the example of banks, which earn a constant markup on their deposits, so $\mu(r_f) = (1-m)r_f$. Then $f(r_f) = m$ and the value of the deposit franchise is isolated from interest rates as $f'(r_f) = 0$. First, from the condition (5), it is clear that rising interest rates in this case increase the support of bank runs if $\Delta a'(r_f) < 0$. They also lead to lower equity valuations when a run is absent. This is intuitive, since interest rates only operate through the asset valuations, which decline in interest rates.[12] In this case as interest rates rise, asset values decline, decreasing bank valuations in the good equilibrium as well as the bad. When interest rates are sufficiently low so that the condition

$$e_b + (1-c)\frac{(r_0 - r_f)}{r_f} + (l_i + (1-s)l_u)(1-m) > 0$$

is satisfied only the good equilibrium exists. When rates rise beyond the threshold $r_f$ that turns the above inequality into equality, the run equilibrium emerges, and both equilibria co-exist. Finally, if rates are sufficiently high so that.

$$e_b + (1-c)\frac{(r_0 - r_f)}{r_f} + (l_i + l_u)m < 0,$$

the bank is fundamentally insolvent and cannot support the good equilibrium anymore.

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[11] More formally, consider a bank who is arbitrarily close to a possible to a run equilibrium $\lim\Big(e_b + (1-c)\Delta a(r_f) + (l_i + l_u)\Delta f(r_f) - sl_u\Delta f(r_f)\Big) \to 0$. Then the unique no run equilibrium will switch to multiple equilibria as the risk-free rate increases.

[12] This also implies that to obtain increasing equity valuations and increase in banking instability, banks pass-through a declining share of risk-free rates as interest rates rise, i.e., $\mu''(r_f) < 0$

*Example 2: Insolvency bank runs when the deposit franchise "hedges" the asset interest rate exposure*

We next illustrate that insolvency bank runs can also happen even if the deposit franchise perfectly "hedges" the bank's asset interest rate exposure in the absence of the deposit withdrawals. The intuition behind this insight reflects our above discussion: a bank run by the uninsured depositors destroys a part of the deposit franchise value along with its hedging benefits, which can render a bank insolvent.

To illustrate it in a simple example, consider a "pass-through" bank where $\mu(r_f) = r_0$ and so $\Delta f(r_f) = -\Delta a(r_f)$. We further assume that $l^i + l^u = (1-c)$. Then the equity value in the case of no-run is independent of interest rates and equal to:

$$e_{no\ run}(r_f) = \underbrace{c + (1-c)\frac{r_0}{r_f}}_{PV\ Assets} - \underbrace{(l_i + l_u)\frac{\mu(r_f)}{r_f}}_{PV\ Deposit} = \underbrace{c + (1-c)\frac{r_0}{r_f}}_{PV\ Assets} - \underbrace{(1-c)\frac{r_0}{r_f}}_{PV\ Deposit} = c$$

In this case the changes in the value of bank's deposit liability perfectly hedge the changes in the value of bank assets due to changes in interest rates. Consequently, in this case the bank is always solvent absent the deposit withdrawals, and the unique insolvency equilibrium is not possible. However, we can still have a case of multiple equilibria with the insolvency bank run being one of them if interest rates increase sufficiently. Let $\gamma = \frac{r_0}{r_f}$, where lower $\gamma$ corresponds to higher rates. Then using the condition (4) and simplifying we find that the "awake" depositors run threshold equals to:

$$s^* = \frac{e_b + (1-c)\Delta a(r_f) + (l_i + l_u)\Delta f(r_f)}{l_u \Delta f(r_f)} = \frac{e_b}{l_u \Delta f(r_f)} = \frac{c r_f}{l_u(r_f - r_0)} = \frac{c}{(1-\gamma) l_u}. \quad (7)$$

We have several possibilities depending on the value of $s^*$. First, if $s^* \geq 1$, the bank can survive any run by the uninsured depositors. This corresponds to the case of a unique no run equilibrium. Second, if $s^* < 1$ there will be two possibilities. One, if uninsured depositors believe that share $s \leq s^*$ of uninsured depositors is awake, we have a unique "good" equilibrium. Alternatively, any belief by the uninsured depositors that a share $s > s^*$ of the uninsured depositors is awake leads to multiple equilibria, with a "bad" run equilibrium leading to the bank insolvency becoming a possibility. Banks with smaller initial capitalization (lower $c$) and higher uninsured leverage (higher $l_u$) have a smaller range of awake depositors supporting a "good" no run equilibrium, increasing their fragility to uninsured depositor runs.[13]

[13] We illustrate this point further in a simple numerical example. Consider a bank with initial value of assets equal to \$100 billion. The bank's long duration assets are risk free perpetuities (T-bonds with infinite maturity), paying an annual coupon of 3% before monetary tightening, and short duration asset is cash paying 0. Specifically, the bank holds \$10 billion in cash and \$90 billion in treasuries so that $c$ = 0.1. The bank has \$90 billion of deposits, so that $(l^i + l^u) = 0.9$, at the "sticky" deposit cost of 3% The current risk-free rate is 3%. In other words, for simplicity, the market value and face value of bank liabilities are the same. Then, the market value of equity is $c$ share of its initial value of assets and equals \$10 billion. Now suppose that the risk-free rate increases by 100 basis points to 4% (i.e., $\gamma = 0.75$). Note that this does not change the value of equity in the case of no run because the decline in the value of bank assets is perfectly hedged by the decline in the value of bank liabilities. As we discussed above if the insured depositors

## 4. Marked to Market Losses, Solvency, and Run Risk

Motivated by our analysis above, we next more systematically consider whether marking banks' asset to market renders a share of U.S. banks insolvent or exposes them to run risk. There are several challenges that arise when assessing whether banks are insolvent and run prone, even after marking assets to market. First, it is difficult to evaluate the market value of deposit liabilities. On the one hand deposits are on demand, and thus could be evaluated at their face value at prevailing market rates. On the other hand, there may be a spread between deposit rates to fed funds rates due to banks' market power, allowing banks to earn rents (Egan et al. 2017, Dreschler et al. 2021). Under this scenario one may want to consider on demand liabilities more akin to long duration assets, which also lose value when rates rise (Dreschler et al. 2021). Second, it is unclear how run prone uninsured deposits are. Egan et al. (2017) estimate that uninsured deposits are somewhat elastic to default, but this elasticity can result in multiple equilibria. Such complex counterfactuals are beyond the empirical assessments in this paper. Instead, we follow our framework in Section 3.2 and consider several alternative scenarios with a range of uninsured depositors' withdrawal behavior. We also go beyond our simple framework to consider the role of regulators, which play a central role in bank failures (Granja et al. 2017).

### 4.1 Are Assets of U.S. Banks Sufficient to Cover Uninsured Deposits?

The first benchmarking exercise considers the run incentives of uninsured depositors from the perspective of assets after marking assets to market. Specifically, we consider whether the assets in the U.S. banking system are large enough to cover all uninsured deposits. Intuitively, this situation would arise if all uninsured deposits were to run, and the FDIC *did not close the bank prior to the run ending*.

Figure 3A plots the histogram of uninsured deposit to asset ratio and marked-to-market asset ratio. Figure 3B plots uninsured deposit to asset ratio against bank size. As we observe, while the decline in asset values increased the ratio of uninsured deposits to assets, virtually all banks (barring two) have enough assets to cover their uninsured deposit obligations. In other words, if the FDIC does not step in to protect the deposit insurance fund, or if the liquidation of the assets does not cause large enough fire sales, there may be no reason for uninsured depositors to run.[14]

Notably, SVB, is one of the worst banks in this regard. Its marked-to-market assets are barely enough to cover its uninsured deposits. Even a small fire sale discount would result in uninsured depositors in losing money in a run, making a run rational. This fact can help explain why the uninsured depositors run may have occurred for this bank.

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are sticky, the bank's solvency will crucially depend on the behavior of uninsured depositors. Suppose that the uninsured leverage equals to $l_u = 0.8$. We can now compute the highest share of the awake uninsured depositors that is sustainable in a unique equilibrium without bank runs. According to (7) we have that $s^* = \frac{c}{(1-\gamma)l_u} = \frac{0.1}{0.25\times 0.8} = 0.5$. Hence any belief that up to a half of uninsured depositors is awake can be sustained in a unique "good" equilibrium without a bank run and insolvency. The belief that more than half of uninsured depositors is awake will lead to multiple equilibria with an insolvency bank run being one of the equilibria.

[14] We note that the uninsured depositors could start running due to risk of further asset losses even if currently banks have enough assets to cover their uninsured deposit obligations.

### 4.2 Uninsured Deposits and Scenarios on Running

We next assess the bank solvency across various beliefs regarding the share of uninsured depositors withdrawing (i.e., *s* in the model) using bank balance sheet data and their marked-to-market asset declines. Like in the SVB case, the FDIC steps in to protect insured depositors when a bank is put into receivership (Granja, et al. 2017). Thus, we consider a simple *empirical solvency condition* that reflects the idea that insured depositors being impaired is the lower bar for the FDIC intervention. Specifically, instead of considering whether the marked-to-market value of bank assets after such withdrawal is enough to cover the marked-to-market value of bank liabilities (i.e., solvency condition (10) from Section 3.2), we study whether insured depositors would be impaired under these scenarios. For that purpose, Figure 4 plots the distribution of insured deposit coverage ratio. We defined it as:

$$\text{Insured Deposit Coverage ratio} = \frac{\text{Mark-to-Market Assets} - s \times \text{Uninsured Deposits} - \text{Insured Deposits}}{\text{Insured Deposits}}$$

A negative value of insured deposit coverage ratio means that the remaining mark-to-market asset value – i.e., after paying uninsured depositors who withdraw their deposits -- is not sufficient to repay all insured deposits. We simulate two cases. In case 1 (Figure 4a and 4b), we assume all uninsured depositors run (i.e., s=1). In case 2 (Figure 4c and 4d), we assume half of all uninsured depositors run (i.e., s=0.5). We compare these cases pre and post FED monetary tightening.

Prior to FED interest rate increases, U.S. banks were solvent under both scenarios, and uninsured depositors had no incentives to run. In other words, even if all uninsured deposits would have been withdrawn, the remaining assets would have been sufficient to cover insured deposits. Of course, this assumes that deposit withdrawals do not result in fire sales, which would further depress assets. But absent fire sales, the U.S. banks would have been able to withstand all deposit withdrawals.

As we discuss above, the recent FED tightening has been associated with substantial losses in the value of banks' long duration assets. Our calculations imply that banks are much more fragile to uninsured depositors runs after the tightening. Suppose that all uninsured depositors were to withdraw funds from U.S. banks. Table 2 shows that 1,619 U.S. banks would have negative insured deposit coverage, suggesting insured deposits would be impaired. While the median bank is small, with assets of $0.3 billion, the aggregate assets of these banks are $4.9 trillion and failure of these banks would involve $2.6 trillion of aggregate insured deposits, and a shortfall for the deposit insurance fund of $300 billion. This would provide the FDIC with strong incentives to intervene during a run, such as in the case of SVB, and thus in fact provide incentives for uninsured depositors to run.

The case under which all uninsured depositors run is likely too extreme, although not impossible once the news of a run spreads as illustrated in our stylized framework in Section 3.2. Therefore, in case 2 we consider whether banks can withstand half of their uninsured depositors withdrawing funds. Again, this scenario assumes that banks can liquidate their assets at market prices, rather than facing a fire sale discount. Even under this scenario, we find that there are 186 banks with assets of about $300 billion that have a negative insured deposit coverage ratio (Table 2). In other words, for these banks comprising about $250 billion of insured deposits, even insured deposits would be impaired absent regulatory intervention (e.g., by the FDIC). The losses to the deposit insurance fund would total approximately $10 billion. If the FDIC shut these banks following a run, there would be no funds left for the remaining uninsured depositors. In other words, the decision to run would have been a rational one. So, our calculations suggest these banks are certainly at a potential risk of a run, absent other government intervention or recapitalization.

Interestingly, while SVB is very close to the boundary of a negative insured deposit coverage ratio, our calculations suggest it should have been able to survive a run without impairing insured depositors. However, even a 0.4% fire sale discount would have resulted in impaired insured deposits if all uninsured depositors ran.

To further assess the vulnerability of the US banking system to uninsured depositors run, we plot the 10 largest banks at the risk of a run, which we define as a negative insured deposit coverage ratio if all uninsured depositors run (see Figure 5). Figure A2 in the Appendix shows the same plot for the universe of all banks that become insolvent if all uninsured depositors run. Because of the caveats in our analysis as well as the potential of exacerbating their situation, we anonymize their names, but we also plot SVB as comparison. We plot their mark-to-market asset losses (Y axis) against their uninsured deposits as a share of marked to market assets. Some of these banks have low uninsured deposits, but large losses, but the majority of these banks have over 50% of their assets funding with uninsured deposits. SVB stands out towards the top right corner, with both large losses, as well as large uninsured deposits funding. As Figure 5 shows, the risk of run does not only apply to smaller banks. Out of the 10 largest insolvent banks, 1 has assets above $1 Trillion, 3 have assets between $200 billion and $1 trillion, 3 have assets between $100 billion and $200 billion and the remaining 3 have assets between $50 billion and $100 billion.

We conclude by plotting the sensitivity of the US banking system to the uninsured depositor runs for a broader range of "run" cases. This exercise assesses the solvency of US banks for a range of beliefs about the share of uninsured depositors that are expected to withdraw their funds, as we did in Section 3.2, given our *empirical solvency condition*. Figure 6 presents the number of insolvent banks (Figure 6A) and their aggregate assets (Figure 6B) associated with a given uninsured deposits withdrawal case. We consider ten cases ranging from 10% to 100% of uninsured deposits being withdrawn at each bank. The bank is considered insolvent if its mark-to-market value of assets – after paying a given share of the uninsured depositors –is insufficient to repay all insured deposits. Figure 6 shows that even if only 10% of uninsured depositors decided to withdraw their money, we would have 66 banks failing with about $210 billion of assets. If 30% of uninsured depositors ran instead, which is close to the share of withdrawals just preceding the shutdown of the SVB, we would have 106 banks failing accounting for $250 billion of assets.

### 4.3 Extreme Insolvency: No Deposit Franchise

Finally, we also consider an extreme case under which we compute the solvency of banks by assessing whether the marked to market value of assets is sufficient to cover all non-equity liabilities. This is equivalent to empirically assessing the solvency condition (6) from Section 3.2 for the universe of US banks. In other words, if all depositors and debtholders withdrew their funding today, could banks repay their debts. As noted in Section 3.2, this is akin to assuming that there is no value to banks' deposit franchise. We assume that when assets are liquidated, there is no additional discount due to liquidation, so assets can be sold at their current market value. This scenario is extreme, because insured depositors have no incentives to withdraw funds as a function of default risk. On the other hand, it is a useful benchmark to better understand the de facto capitalization of the U.S. banking sector. Implicitly, this calculation assumes that increasing interest rates do not decrease the value of bank liabilities, i.e., the fed funds rate instantaneously pass-through to deposit rates.

We present these results in Appendix A that plots the histograms (density) of the equity to asset ratio as of 2022:Q1 and the mark-to-market equity to asset ratio as of 2023:Q1 (Panel A, Figure A3) and these values by bank size (Panel B, Figure A3). The reference lines in Panel A indicates Silicon Valley Bank's equity to asset ratio as of 2022:Q1 and its mark-to-market equity to asset ratio. As we observe, prior to the recent asset declines all US banks had positive bank capitalization. However, after the recent decrease in value of bank assets, 2,315 banks accounting for $11 trillion of aggregate assets have negative capitalization relative to the face value of all their non-equity liabilities (see Column 1 of Table 2). We further find that regions with lower household incomes and large share of minorities are much more exposed to the bank risk (see Section 5.3).

## 5. Extensions: Hedging, Credit Risk and Regional Variation

We consider several extensions of our analysis in Section 4. First, we discuss whether banks may have hedged some of the declines of their assets due to raise in interest rates. Second, we consider the extent to which banks can withstand adverse credit events, focusing on the case of commercial real estate. Finally, we consider where the risk in banking sector resides spatially in the US.

### 5.1 Limited Hedging by U.S. Banks During the 2022 Monetary Tightening

Up to this point, we have not formally considered the possibility that banks may have hedged their interest rate exposure. However, this does not imply that the aggregate $2.2 trillion losses in the banking system are any less relevant for financial stability. Suppose that most banks had hedges covering their interest risk exposure. In that case, an important question arises as to who provided these hedges as a counterparty. If the hedges were provided by other banks, this would not alter the aggregate losses but merely reallocate them across banks. Given that all banks were thinly capitalized prior to the rate increase, with an average Equity to Asset ratio of about 10%, the overall impact and the big picture remain largely unchanged.[15] Alternatively, if the counterparty entities were non-bank institutions that insured the US banking system's aggregate interest rate risk, we would likely witness severe stress in such institutions at this point, as seen with AIG's systemic risk exposure in 2007.

Nevertheless, to address this issue formally, in a companion note (Jiang et al. 2023a) we analyze the extent to which U.S. banks hedged their asset exposure as the monetary policy tightened in 2022. We use call reports data for interest rate swaps covering close to 95% of all bank assets and supplement it with hand-collected data on broader hedging activity from 10K and 10Q filings for all publicly traded banks (68% of all bank assets).

We find that interest rate swap use is concentrated among larger banks who hedge a small amount of their assets. Overall, only 6% of aggregate assets in the U.S. banking system are hedged by interest rate swaps. This analysis implies that the use of hedging and other interest rate derivatives was not large enough to offset a vast majority of the $2.2 trillion loss in the value of U.S. banks'

[15] As shown in Table A1, the aggregate equity in the banking system was about $2.3 trillion in 2022:Q1.

assets. Moreover, we also find that banks with the most fragile funding like the SVB – i.e., those with highest uninsured leverage – if anything sold or reduced their hedges during the monetary tightening.[16] This allowed them to record accounting profits but exposed them to further rate increases. These actions are reminiscent of asset substitution: if interest rates had decreased, equity would have reaped the profits, but if rates increased, then debtors and the FDIC would absorb most of the bank losses.

### 5.2 Impact of Potential Credit Losses on the Fragility of the US Banking System

We abstracted away from a potential impact of credit losses on bank stability. In a companion note (Jiang et al. 2023b) we analyze the extent to which the losses established in Section 4 eroded banks' ability to withstand adverse credit events. We focus on potential distress on bank's commercial real estate (CRE) loan portfolios.

We focus on commercial real estate for a couple of reasons. First, the commercial real estate loans constitute a substantial share of assets for a typical bank accounting for about quarter of assets for an average bank and $2.7 trillion of bank assets in the aggregate.[17] Second, commercial real estate is also seen as a potential source of adverse credit events in the near term, especially the office sector (e.g., see Gupta et al. 2022).

We find that 10% (20%) default rate on CRE loans – a range close to what one saw in the Great Recession on the lower end – would result in about $80 billion ($160 billion) of additional bank losses. While these losses are an order of magnitude smaller than the decline in bank asset values associated with a recent rise of interest rates, they can have important implications. An additional 285 (578) banks with aggregate assets of $700 billion ($1.2 trillion) would have their marked-to-market value of assets insufficient to cover the face value of all their non-equity liabilities. Even if half of uninsured depositors decide to withdraw, the losses due to CRE distress would result in additional 21 (58) smaller regional banks at a potential risk of impairment to insured depositors (over what we discussed in Section 4). Thus, the unrealized losses due to monetary tightening have made banks less resilient to adverse credit events, further contributing to the fragility of the banking system.

### 5.3. Regional Exposure to Bank Risk

We conclude our analysis by assessing where the risk in the banking sector – established in Section 4 – resides spatially in the US. We proceed in three steps. We first find banks' deposit impairment ratio by assuming that equity and non-deposit debt are in the first position to absorb mark-to-market losses in the extreme insolvency case discussed above:

$$Deposit\ Impairment\ Ratio_j = \frac{Asset_j - Mark\text{-}to\text{-}Market\ Loss_j}{Total\ Deposit_j}.$$

We then obtain information about bank branch networks and the regional distribution of deposit taking from the FDIC Summary of Deposit (SOD) in 2022. We assign bank risk to regions where

[16] SVB hedged about 12% of all securities at the end of 2021. By the end of 2022, they hedged only 0.4%.
[17] We consider all non-residential real estate loans as commercial loans. See Appendix A1 for more detail on banks assets and liabilities.

they have branches. Lastly, we find a county's exposure to bank risk by calculating the percentage of its total deposits at the risk of impairment:

$$Share\ of\ Deposit\ at\ Risk_c = \frac{\sum_{j \in c} \max\{Deposit\ Impairement\ Ratio_j, 0\} \times Deposit_{jc}}{\sum_{j \in c} Deposit_{jc}}.$$

Figure 7 presents the map of local exposure to bank risk. Figure 7A plots the share of deposits at risk. The most exposed counties have up to 13% deposits at the risk of impairment. These counties are clustered in several states, such as New Hampshire, Massachusetts, Wyoming, and New York. Some counties do not have much exposure to the risk, such as Delaware, Nebraska, Arkansas, and Maryland. Figure 7B plots the dollar amount of deposits at risk. The most exposed counties in terms of share of deposit at risk do not necessarily have the largest dollar amount of deposits at risk. As we will discuss below, this is because the most exposed regions are more likely to have lower median income and thus lower total deposit amount.

Figure 8 plots the county-level share of impaired deposits against local demographics. Counties with more minority population, especially those with more than 80% Black and Hispanic population, tend to be more exposed to the bank risk (Figure 8A). For instance, on average, counties with more than 90% Black and Hispanic population have about 4% of total deposits at the risk of impairment. Counties with low median-income are more likely to be exposed to bank risk (Figure 8B). Regions with median annual income below $35,000 are mostly exposed to the risk, with about 4% of deposit at the risk of impairment. Lastly, counties with a larger population without a college degree are more exposed to the risk (Figure 8C). In particular, regions with nearly the entire population with a college degree have no exposure to the risk, while regions with more than 90% population without a college degree have about 2% of deposits at risk of impairment. Thus, the risk in the banking sector due to monetary tightening is not spread uniformly across space, with higher exposure in regions with more minorities and lower income households.

## 6. External Validity and Replicability: Events after Release of our paper on March 13, 2023

Empirical work typically faces two key challenges: (i) whether the findings are replicable and (ii) whether the findings have external validity. In the context of our study, we can provide substantial evidence in the affirmative on both fronts. We released our study on March 13, 2023. As we discuss below, the events and work that followed us releasing our paper validate our approach and findings. We summarize these briefly in this section.

On May 1, 2023, the FDIC announced that First Republic had been closed and sold to JPMorgan Chase becoming the third bank that failed during 2023 following the Silicon Valley Bank collapse and closure of Signature Bank on March 12, 2023. All three banks have similar characteristics to the banks at risk we identify: significant decline in the value of their assets and high share of funding coming from the uninsured depositors.[18] The collapse of all these banks was also preceded by significant withdrawals of funds by uninsured depositors (e.g., First Republic Bank saw almost half of their uninsured depositors withdraw). In addition, several other banks like the Pacific West suffered large declines in their share prices putting them at the brink of bankruptcy with SPDR S&P regional banking ETF declining by more than 40% between March 2023 and May 2023. In

[18] As of 2022:Q4, SVB had 93% uninsured leverage, Signature Bank had 88% uninsured leverage, and First Republic had 71% uninsured leverage.

line with our analysis, these events indicate that financial stability risk we focus on is not an isolated phenomenon to the Silicon Valley Bank and affects a significant set of other banks.

Notably, our analysis does not consider the impact of various stabilization measures that were implemented following the advent of run on Silicon Valley Bank. Notably, on March 12, Federal Reserve created the Bank Term Funding Program (BTFP), an emergency lending program providing loans of up to one year in length to banks, which effectively allowed the banks to borrow more than the current value of their assets. This and other interventions may have short-circuited a broader bank run that as our analysis indicates could involve hundreds of banks. The signs of continued pressure on regional banks that we discussed above are consistent with our findings since recent interventions have provided the banks with temporary liquidity support without directly addressing the fundamental insolvency risk we identify and quantify in our paper.

The growing literature on recent banking crisis that followed the release our paper is consistent with our approach and findings. Like our framework, Drechsler et al. (2023) and Haddad et al. (2023) also underscore the fragility of banks to runs by depositors following an increase in interest rates. Drechsler et al. (2023), in particular, find “mark to market” losses in the banking system that are in the close proximity of our findings. Both studies also highlight the economic effect of uninsured deposits on bank runs in presence of franchise value from sleepy depositors. Cookson et al. (2023) provide evidence that social media could have increased the speed of deposits withdrawals during the SVB run while Koont et al. (2023) finds that when the Fed funds rate increases deposits flow out faster and the cost of deposits increases more in banks with a digital platform. Like our work, these two papers underscore the fragility of bank deposit funding following an increase in interest rates. Granja et al. (2023) finds that banks with lower capital ratios, higher share of run-prone uninsured depositors, and whose portfolios were more exposed to interest rate risk were more likely to reclassify securities into hold-to-maturity during 2021 and 2022. This is consistent with our findings that banks did not recognize their losses and that banks with most fragile funding may have engaged in gambling for resurrection type of strategies (see also Jiang et al. 2023a). Finally, consistent with our findings (see also Jiang et al. 2023a) that banks did not hedge their asset interest rate exposure with derivatives, McPhail et al. (2023) provide evidence that interest rate swap positions are not economically significant in hedging the interest rate risk of bank assets.

## 7. Conclusion

We provide an empirical methodology and conceptual framework to analyze all U.S. banks’ exposure to raising interest rates and uninsured depositors runs with implications for financial stability. By focusing on monetary tightening that started in 2022:Q1, we show that by March 2023 the U.S. banking system’s market value of assets declined by about $2.2 trillion relative to what is suggested by the book value of assets. We show that these losses, combined with a large share of uninsured deposits at some U.S. banks can impair their stability. Even if only half of uninsured depositors decide to withdraw, almost 190 banks are at a potential risk of impairment to even insured depositors, with potentially more than $250 billion of insured deposits at risk absent regulatory intervention. If uninsured deposit withdrawals cause even small fire sales, substantially more banks are at risk. Overall, our analysis suggests that recent declines in bank asset values significantly increased the fragility of the US banking system to uninsured depositors runs (summarized in Table 2 and Figure 6). As we discussed above, the events and subsequent literature following the release of our paper have been broadly consistent with our main insights.

Our findings have also important implications for financial stability, regulation, and monetary policy pass-through. First, our analysis suggests that US banks have significant asset exposure to higher interest rates that can lead to insolvency bank runs by the uninsured depositors. Second, this fragility of the US banking system to higher rates can significantly constrain the conduct of monetary policy, adversely affecting its price stability objectives. Third, our findings have implications for several short-run and longer-term regulatory responses one could consider addressing the financial fragility risk we focus on.

In the near term, the creation of the Bank Term Funding Program in March 2023 together with other policy responses to the recent banking vulnerabilities may have put a pause on the crisis and reduced the risk of acute deposit runs across the banking system. However, these polices do not address the fundamental insolvency risk, which our analysis indicates could involve hundreds of banks. Hence a near term response to the crisis could involve a recapitalization of the US banking system (see DeMarzo et al. 2023).

In the longer-term, one regulatory response to the crisis could involve an increased oversight of US banking system. In this regard, the regulators could adopt our methodology to stress test the banking system for the scenario of higher interest rates taking into account both the composition of bank assets as well as their liabilities and assessing the insolvency risk due to runs by the uninsured depositors. The regulators could also consider expanding even more complex banking regulation on how banks account for mark to market losses. However, such rules and regulation, implemented by myriad of regulators with overlapping jurisdictions might not address the core issue at hand consistently (Agarwal et al. 2014).[19] Alternatively, banks could face stricter capital requirement, which would bring their capital ratios closer to less regulated lenders that retain more than twice as much capital buffers, as documented in Jiang et al. (2020). Discussions of this nature remind us of the heated debate that occurred after the 2007 financial crisis, which many might argue did not result in sufficient progress on bank capital requirements (see Admati et al. 2013, 2014 and 2018). They also resonate well with historical studies on the impact of deposit insurance on banks' risk-taking behavior (see Calomiris and Jaremski 2019).

[19] In addition, such regulations might have implications for non-bank institutions (shadow banks) that provide several services like banks and have gained market share that reflects in part the regulatory actions on banks (see Buchak et al. 2022). These institutions are predominantly financed with short-term uninsured debt, but they are also significantly better capitalized than banks on average (Jiang et al. 2020). See also Greenwood et al. (2017), Corbae and D'Erasmo (2021), and Begenau and Landgvoit (2022) for recent studies of impact of regulatory policies on banks.

## References:


Admati, A, P. DeMarzo, M. Hellwig, and P. Pfleiderer, 2013, "Fallacies, Irrelevant Facts, and Myths in the Discussion of Capital Regulation: Why Bank Equity Is Not Socially Expensive," Working Paper.

Admati, A. and M. Hellwig, 2014, "Bankers New Clothes: What's wrong with Banking and what to do about it?", Princeton University Press.

Admati, A, P. DeMarzo, M. Hellwig, and P. Pfleiderer, 2018, "The Leverage Rachet Effect," *Journal of Finance* 73, 145-198.

Agarwal, S., Lucca, D., Seru, A., and Trebbi, F., 2014, "Inconsistent Regulators: Evidence from Banking," *Quarterly Journal of Economics* 129, 889-938.

Atkeson, A. G. A. d'Avernas, A. L. Eisfeldt, and P.-O. Weill, 2018, "Government Guarantees and the Valuation of American Banks," *NBER Macroeconomics Annual*.

Begenau, J., M. Piazessi, and M. Schneider, 2015, "Banks' Risk Exposures," working paper.

Begenau, J., and E. Stafford, 2019, "Do Banks Have an Edge," working paper.

Begenau, J, and T. Landgvoit, 2022, "Financial Regulation in a Quantitative Model of the Modern Banking System," *Review of Economic Studies* 89, 1748–1784.

Buchak, G., G. Matvos. T. Piskorski, and A. Seru, 2022, "Beyond the Balance Sheet Model of Banking: Implications for Bank Regulation and Monetary Policy," forthcoming in the *Journal of Political Economy*.

Calomiris, C.W., and M. Jaremski, 2019. Stealing Deposits: Deposit Insurance, Risk-Taking, and the Removal of Market Discipline in Early 20th-Century Banks, *Journal of Finance* 74, 711-754.

Chen, Q., I. Goldstein, Z. Huang, R. Vashishtha, 2022, "Liquidity Transformation and the Fragility in the US Banking System," working paper.

Corbae, D., and P. D'Erasmo, 2021, "Capital Buffers in a Quantitative Model of Banking Industry Dynamics," *Econometrica* 89, 2975–3023.

Cookson, J. A., C. Fox, J. Gil-Bazo, J. F. Imbet, C. M. Schiller, 2023, "Social Media as a Bank Run Catalyst," working paper.

DeMarzo, P., E. Jiang, A. Krishnamurthy, G. Matvos, T. Piskorski, and A. Seru, "Resolving the Banking Crisis," policy proposal.

Diamond, D.W. and Dybvig, P.H., 1983, "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy*, 91, 401-419.

Drechsler, I., A. Savov, and P. Schnabl, 2017, "The Deposits Channel of Monetary Policy," *Quarterly Journal of Economics* 132, 1819-1876.

Drechsler, I., A. Savov, and P. Schnabl, 2021, "Banking on Deposits: Maturity Transformation without Interest Rate Risk," *Journal of Finance* 76, 1091-1143.

Drechsler, I., A. Savov, P. Schnabl, O. Wang, 2023, “Banking on Uninsured Deposits,” working paper.

Egan, M., G. Matvos, and A. Hortacsu, 2017, “Deposit Competition and Financial Fragility: Evidence from the US Banking Sector,” *American Economic Review* 107, 169-216

Granja, J., G. Matvos, and A. Seru. 2017, “Selling Failed Banks,” *Journal of Finance*, 72, 1723-1784.

Granja, J., 2023, “Bank Fragility and Reclassification of Securities into HTM, working paper.

Gupta, A., V. Mittal, and S. Van Nieuwerburgh, 2022, “Work from Home and the Office Real Estate Apocalypse,” NBER working paper.

Greenwood, R., J. C. Stein, S. G. Hanson, and A. Sunderam, 2017, “Strengthening and Streamlining Bank Capital Regulation,” *Brookings Papers on Economic Activity*, 479–565.

Hannan, T. H., and A. N. Berger, 1991, “The Rigidity of Prices: Evidence from the Banking Industry”, *American Economic Review* 81, 938–945.

Haddad, V., B. Hartman-Glaser, and T. Muir, 2023, Bank Fragility When Depositors Are the Asset, working paper.

Jiang, E., G. Matvos, T. Piskorski, and A. Seru, 2020, “Banking without Deposits: Evidence from Shadow Bank Call Reports,” NBER working paper.

Jiang, E., G. Matvos, T. Piskorski, and A. Seru, 2023a, “Limited Hedging and Gambling for Resurrection by U.S. Banks During the 2022 Monetary Tightening?,” working paper.

Jiang, E., G. Matvos, T. Piskorski, and A. Seru, 2023b, “U.S. Bank Fragility to Credit Risk in 2023: Monetary Tightening and Commercial Real Estate Distress,” working paper.

Kelly, B., H. Lustig, and S. Van Nieuwerburgh, 2016, “Too-Systemic-to-Fail: What Option Markets Imply about Sector-Wide Government Guarantees,” *American Economic Review*, 106, 1278-1319.

Koont, N., T. Santos, and L. Zingales, 2023, “Destabilizing Digital 'Bank Walks',” working paper.

McPhail, L., P. Schnabl, and B. Tuckman, 2023, “Do Banks Hedge Using Interest Rate Swaps,” working paper.

Neumark, D., and S. A. Sharpe, 1992, Market Structure and the Nature of Price Rigidity: Evidence from the Market for Consumer Deposits, *Quarterly Journal of Economics*, 107, 657–680.

Xiao, K., 2020, “Monetary Transmission through Shadow Banks,” *The Review of Financial Studies* 33, 2379-2420.

**Table 1: Mark-to-Market Statistics by Bank Size**

This table presents the descriptive statistics of our key metrics after marking-to-market the asset values for each FDIC-insured depository institutions in the U.S. Column (1) shows these statistics of all the banks, Column (2) for small banks, Column (3) for large and non-systemically important banks (non GISB), and Column (4) for systemically important banks (GSIB banks). Bank size is based on the reported bank asset value as of 2022:Q1. Small banks have assets less than $1.384 Billion, the Community Reinvestment Act asset size thresholds for large banks. Large (non GISB) banks have asset greater than equal to 1.384 Billion. GSIB banks are classified according to bank regulators' definition as of 2022:Q1. We also assign GSIB status to US chartered banks affiliated with holding companies that are classified as GSIB. The first row shows the aggregate loss which is defined as the sum of the dollar loss at each bank based on marking-to-market their 2022:Q1 balance sheets. Other rows in the table report bank level statistics. Bank level statistics are based on the sample median values. Numbers in parentheses are the standard deviations. Loss for each bank is computed based on marking-to-market all its securities and loans (see text) according to the market price growth from 2022:Q1 to 2023:Q1. We also decompose these dollar losses into those from RMBS, Treasury and other securities, loans secured by residential 1 to 4 family properties (residential mortgage), and other loans. We then report them in terms of the percentage of total losses. Loss/Asset at the bank level is the loss as a percentage of the book value of assets as of 2022:Q1. Uninsured Deposit/MM Asset is the uninsured deposit amount of 2022:Q1 divided by the mark-to-market asset value (MM Asset) as of 2023:Q1. Insured Deposit Coverage ratio is defined as (mark-to-market asset value - uninsured deposit -insured deposit)/insured deposit. Note that our analyses are done at bank charter level instead of bank holding company level. *Sources*: Bank Call Reports in 2022:Q1 and various ETF and indices price data as described in the main text.

| | (1)<br>All<br>Banks | (2)<br>Small<br>(0, 1.384B) | (3)<br>Large (non GSIB)<br>[1.384B, ) | (4)<br>GSIB |
|---|---|---|---|---|
| Aggregate Loss | 2.2T | 144B | 1.3T | 0.73T |
| Bank Level Loss | 28.6M | 22.3M | 308.0M | 837.0M |
| | (6.7B) | (38.2M) | (8.9B) | (69.7B) |
| Share RMBS | 13.2 | 11.4 | 22.6 | 17.4 |
| | (19.2) | (18.5) | (20.6) | (32.8) |
| Share Treasury and Other | 15.5 | 17.0 | 10.4 | 8.1 |
| | (35.1) | (37.5) | (14.8) | (33.0) |
| Share Residential Mortgage | 19.9 | 19.8 | 20.4 | 20.5 |
| | (33.4) | (35.4) | (19.5) | (35.9) |
| Share Other Loan | 32.8 | 32.7 | 33.8 | 1.0 |
| | (32.7) | (34.3) | (21.6) | (38.9) |
| Loss/Asset | 9.2 | 9.1 | 10.0 | 4.6 |
| | (4.7) | (4.8) | (4.4) | (6.1) |
| Uninsured Deposit/MM Asset | 24.2 | 22.7 | 35.7 | 19.0 |
| | (14.1) | (12.6) | (15.8) | (26.6) |
| Insured Deposit Coverage Ratio | 4.2 | 3.9 | 5.9 | 15.4 |
| | (32.7) | (30.4) | (36.4) | (115.7) |
| Number of Banks | 4844 | 4072 | 743 | 29 |

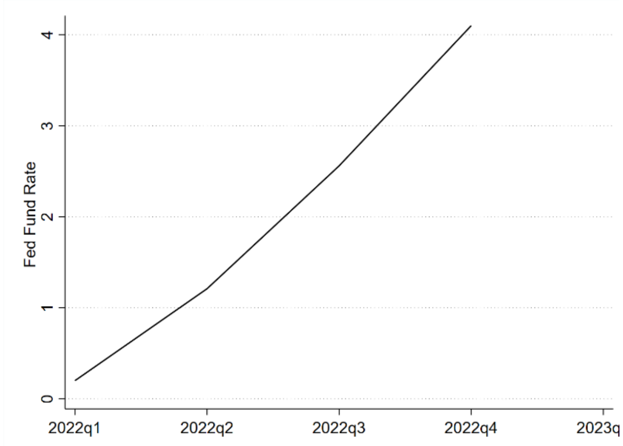
**Table 2: Insolvent Banks Under Different Cases**

The top panel of the table shows aggregate statistics of insolvent banks as of 2022:Q1. The bottom panel of the table presents the statistics using median values of all the banks in each category as defined below as of 2022:Q1. Numbers in parentheses in the bottom panel are standard deviations. Insolvency is defined based on mark-to-market asset values under four different cases as of 2023:Q1. In column (1), we assume all assets are liquidated at their mark-to-market value. The bank is considered insolvent if the mark-to-market value of assets is insufficient to cover all non-equity liabilities. In column (2) we assume all uninsured depositors run. The bank under this case is considered insolvent if the mark-to-market value of assets – after paying all uninsured depositors -- is insufficient to repay all insured deposits. In column (3) we assume half of the uninsured depositors run. The bank under this case is considered insolvent if the mark-to-market value of assets – after paying half of the uninsured depositors – is insufficient to repay all insured deposits. In column (4) we assume all uninsured depositors run and there is a fire sale discount of 0.4%. The bank under this case is considered insolvent if the mark-to-market value of assets net of fire sales – after paying all uninsured depositors -- is insufficient to repay all insured deposits. The fire sale discount of 0.4% is obtained by considering the case of Silicon Valley Bank (SVB). At this value of fire sale discount, the mark-to-market value of assets net of fire sales – after paying all uninsured depositors -- is just sufficient to repay all insured deposits. Note that SVB is not classified as insolvent in column (2). Aggregate asset shows the sum of total assets of banks in each category as of 2022:Q1. Aggregate equity shows the sum of equity of banks in each category as of 2022:Q1. Aggregate insured deposit is the sum of total insured deposits of banks in each category as of 2022:Q1. Total shortfall is the sum of total uncovered insured deposits as of 2022:Q1. Systemically important banks (GSIB banks) are classified according to bank regulators' definition as of 2022:Q1. We also assign GSIB status to US chartered banks affiliated with holding companies that are classified as GSIB. *Data Sources:* Bank Call Reports in 2022:Q1 and ETF and indices price data.

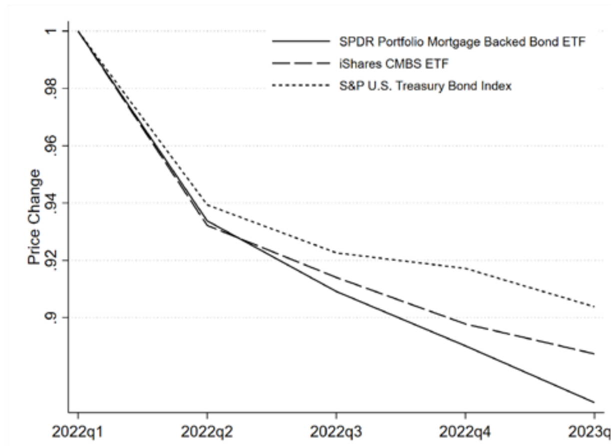
| | (1)<br>All Assets Liquidate | (2)<br>100% Uninsured Depositor Run | (3)<br>50% Uninsured Depositor Run | (4)<br>0.4% Fire Sale Discount |
|---|---|---|---|---|
| Aggregate Asset | 11T | 4.9T | 0.3T | 5.3T |
| Aggregate Equity | 1.0T | 0.4T | 0.02T | 0.4T |
| Aggregate Insured Deposit | 5.2T | 2.6T | 0.25T | 2.7T |
| GSIB Banks | 2.2T | 1.1T | 20B | 1.1T |
| Total Shortfall | 1.5T | 0.3T | 0.01T | 0.3T |
| GSIB Banks | 0.6T | 0.11T | 0.8B | 0.1T |
| Total Asset | 0.4B | 0.3B | 0.2B | 0.3B |
| | (68B) | (46B) | (9B) | (45B) |
| Liability/Asset | 91.7 | 91.9 | 92.0 | 91.9 |
| | (2.3) | (2.3) | (3.0) | (2.3) |
| Domestic Deposit/Asset | 89.6 | 90.7 | 90.8 | 90.7 |
| | (4.9) | (3.1) | (3.7) | (3.0) |
| Insured Deposit/Asset | 66.4 | 67.8 | 79.7 | 67.6 |
| | (11.6) | (11.4) | (5.8) | (11.6) |
| Uninsured Deposit/Asset | 22.1 | 22.4 | 10.2 | 22.5 |
| | (11.7) | (11.8) | (7.2) | (12.0) |
| Equity/Asset | 8.3 | 8.1 | 8.0 | 8.1 |
| | (2.3) | (2.3) | (3.0) | (2.3) |
| Number of Banks | 2315 | 1619 | 186 | 1724 |

**Figure 1: Fed Tightening and Asset Prices**

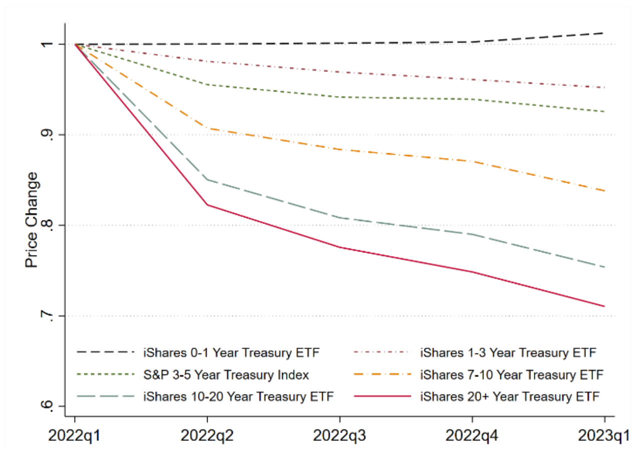
Panel (a) plots the time series of the fed funds rates (in %). Panel (b) plots the market price of the portfolio of residential mortgage-backed securities (RMBS), the commercial mortgage-backed securities (CMBS), and the US Treasuries relative to their values in 2022:Q1 (normalized to one). Panel (c) plots the corresponding market prices of US Treasuries with different maturities, relative to their value in 2022:Q1. The maturity structure is chosen to match the asset maturity breakdowns in the call reports. We plot the prices from 2022:Q1 till 2023:Q1. *Data Sources:* Fed Funds Rate is from the Federal Reserve System data, RMBS market price is from the SPDR Portfolio Mortgage-Backed Bond ETF (SPMB), CMBS market price is from the iShares CMBS ETF (CMBS), and the US Treasury market price indexes are from the S&P U.S. Treasury Bond Index and the iShares Treasury ETF.




(a) Fed Funds Rate (in %)



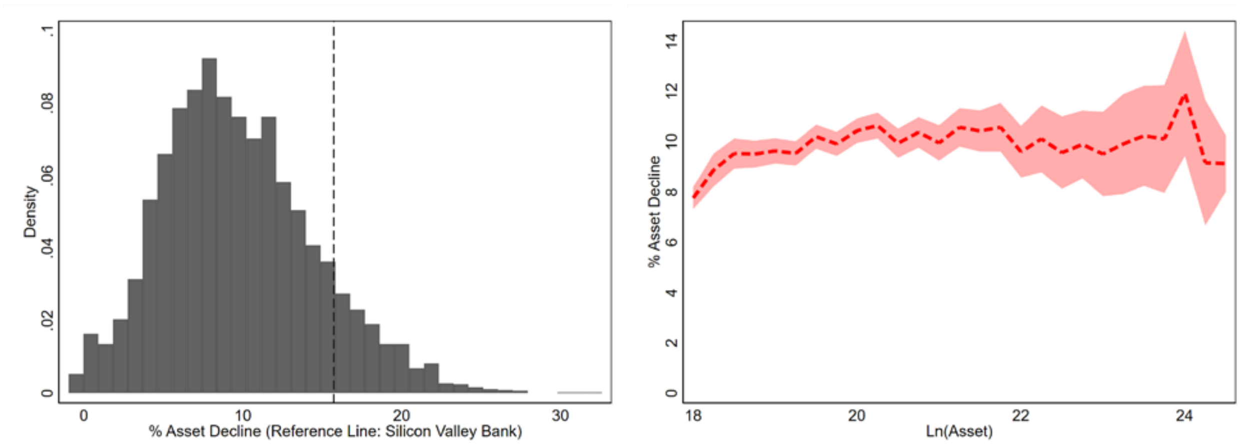

(b) RMBS, CMBS, Treasury




(c) Treasury by Maturity

**Figure 2: Distribution of Change in Asset Value ("Marking to Market")**

This figure plots the histograms (density) of the percentage of bank's asset value decline when assets are mark-to-market according to market price growth from 2022:Q1 to 2023:Q1 (Panel a) and bank asset value decline by bank size (Panel b). We describe the steps to calculate the mark-to-market asset values in the main text. The reference line in Panel (a) indicates Silicon Valley Bank's asset value decline. Silicon Valley Bank's asset value declines by 15.7%, or $34 billion, after their assets are marked to market. The reference line is at 89th percentile. The 5th, 25th, median, 75th, and 95th percentiles in Panel (a) are 4%, 6%, 9%, 13%, and 19%, respectively. In Panel (b), the x-axis is asset value in log terms. The size distribution of the U.S. banking industry has a fat left-tail, meaning that there are many extremely small banks. The largest 50 banks' asset sizes range from $58.9 billion to $3.5 trillion, while the bottom 10 percentiles have asset values less than $68 million. Log assets of 18, 20, 22, and 24 are about $66 million, $485 million, $3.6 billion, and $26 billion. The decline at the right-end starts around log asset value of 24, which is about $26B. *Data Sources*: Bank Call reports in 2022:Q1 and various ETF and indices price data as described in the main text.

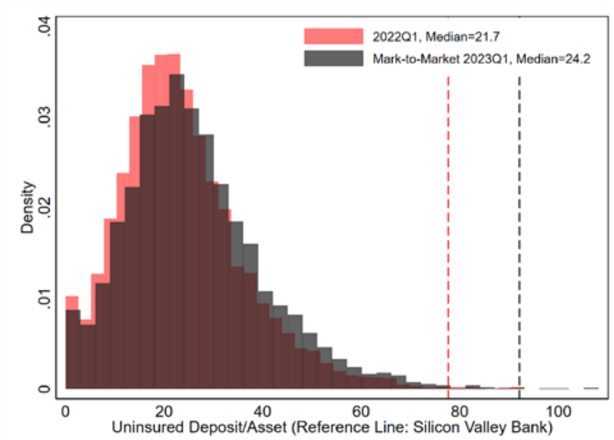



(a) Histogram

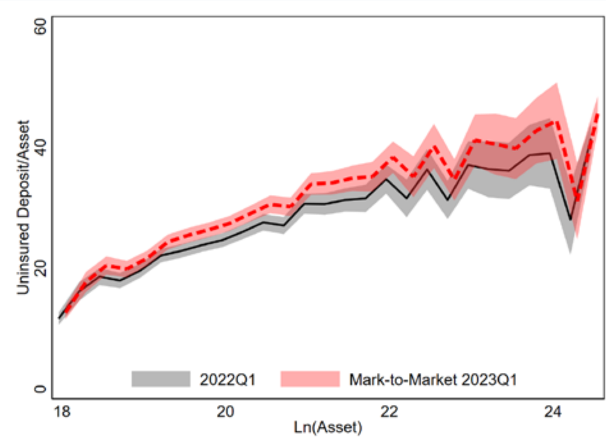
(b) Asset Decline by Size

**Figure 3: Distribution of Uninsured Deposit to Asset Ratio (With & Without "Marking to Market")**

This figure plots the histograms (density) of uninsured deposit to asset ratios calculated based on 2022:Q1 balance sheets and mark-to-market values using various ETFs and indices according to the method described in the main text (Panel a) and uninsured deposit ratio against bank size (Panel b). The reference lines in Panel (a) indicate Silicon Valley Bank's (SBV) values. SVB's uninsured deposit ratio is 78% based on its 2022Q1 balance sheet, which is about \$169 billion. Its uninsured deposit to mark-to-market asset ratio is 92%. Both reference lines are at the 100$^{th}$ percentile. The 5$^{th}$, 25$^{th}$, median, 75$^{th}$, and 95$^{th}$ percentiles of the mark-to-market distribution in Panel (a) are 6%, 17%, 24%, 33%, and 52%, respectively. In Panel (b), the decline at the right-end starts around log asset value of 24, which is about \$26B. *Data Sources*: Bank call reports in 2022:Q1 and various ETF and indices price data as described in the main text.




(a) Histogram



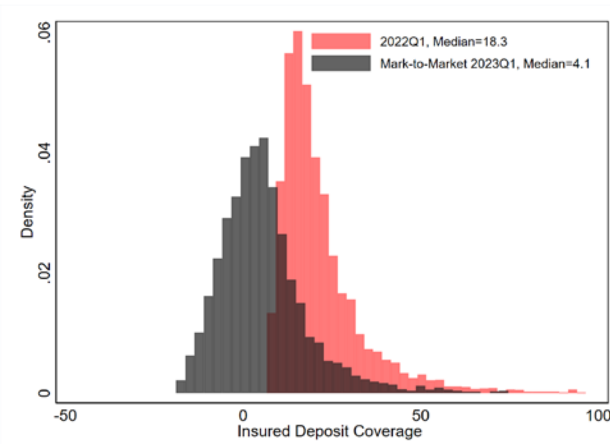

(b) Uninsured Deposit/Asset by Size

**Figure 4: Distribution of Insured Deposit Coverage Ratio under Different "Run" Cases**

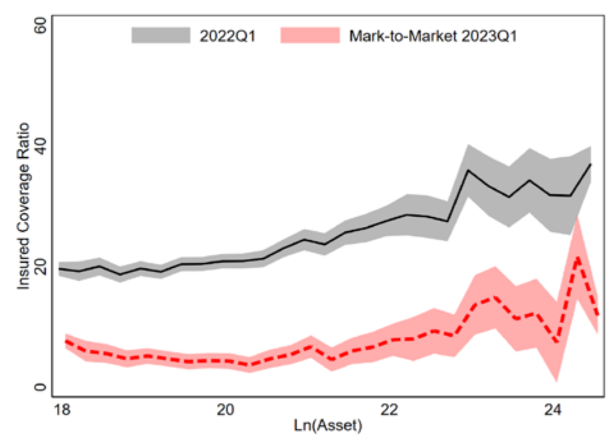
This figure plots the histograms (density) of insured deposit coverage ratio calculated based on 2022:Q1 balance sheets and mark-to-market values as described in the main text (Panel a and c) and insured deposit coverage ratio against bank size (Panel b and d). Insured deposit coverage ratio is defined as

$$\text{Insured Deposit Coverage ratio} = \frac{\text{Mark-to-Market Assets} - s\times\text{Uninsured Deposits} - \text{Insured Deposits}}{\text{Insured Deposits}}.$$

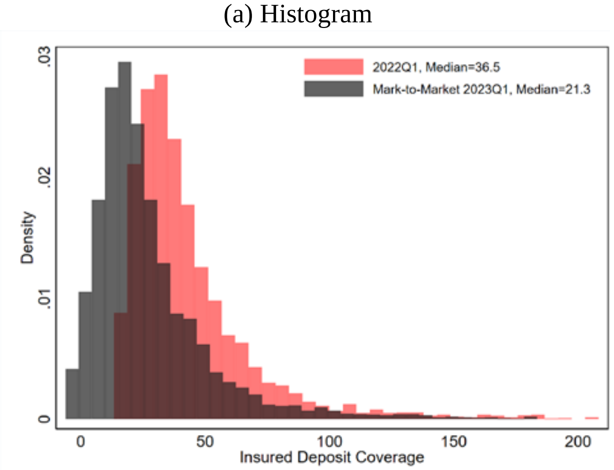
We simulate two cases. In the first case (panel a and b), we assume all uninsured depositors run and withdraw their uninsured deposits from banks (i.e., s=1). In the second case (panel c and d), we assume half of uninsured depositors withdraw their uninsured deposits from banks (i.e., s=0.5). We remove the outliers by truncating the sample at 98$^{th}$ and 1$^{st}$ percentiles. The 5$^{th}$, 25$^{th}$, median, 75$^{th}$, and 95$^{th}$ percentiles of the mark-to-market distribution in Panel (a) are -12%, -2.5%, 4%, 11%, and 34%, respectively and in Panel (b) are 1.3%, 12.5%, 21%, 36%, and 59%, respectively. A negative value of insured deposit coverage ratio means that the remaining mark-to-market asset value after paying uninsured depositors who withdraw their deposits is not enough to repay all insured deposits. For example, -12% means that 12% of total insured deposits will not be repaid without deposit insurance fund. Silicon Valley Bank (SVB) has a positive insured deposit coverage ratio of 5.6%, though notably its liabilities have a very small proportion of insured deposits. Because of this even a tiny additional asset fire sale discount (0.4%) will make the insured coverage ratio of the SVB to fall below zero after the uninsured deposits have withdrawn. *Data Sources*: Bank Call reports and various ETF and indices price data as described in the main text.



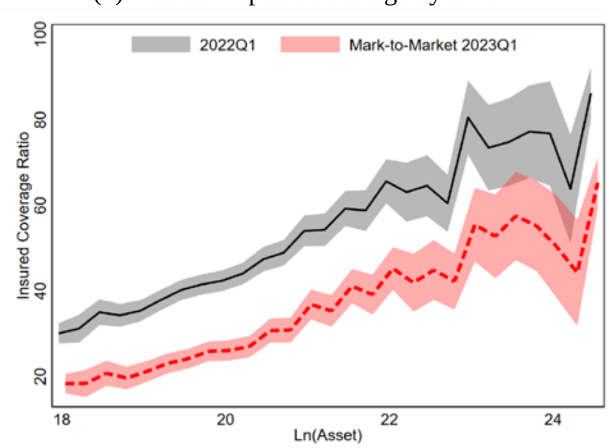

(a) Histogram




(b) Insured Deposit Coverage by Size




(c) Histogram




(d) Insured Deposit Coverage by Size

**Figure 5: Largest Insolvent Banks if All Uninsured Depositors Run**

This figure plots the 10 largest "insolvent" banks. A bank is considered insolvent if the mark-to-market value of its assets – after paying all uninsured depositors -- is insufficient to repay all insured deposits. On the y-axis we plot mark-to-market losses as a percentage of initial bank asset value. On the x-axis we plot uninsured deposits as a percentage of mark-to-market bank's asset value. Out of the 10 largest insolvent banks, 1 has assets above $1 Trillion, 3 have assets above $200 Billion (but less than $1 Trillion), 3 have assets above $100 Billion (but less than $200 Billion) and the remaining 3 have assets greater than $50 Billion (but less than $100 Billion). We also show Silicon Valley Bank (assets of $218 Billion in the plot). The assets are based on bank call reports as of 2022:Q1. Banks in the top right corner, where Silicon Valley Bank is, have the most severe asset losses and the largest runnable uninsured deposits to mark-to-market assets. The bubble size indicates the size of bank asset in 2022:Q1. *Data Sources*: Bank Call reports and various ETF and indices price data as described in the main text.

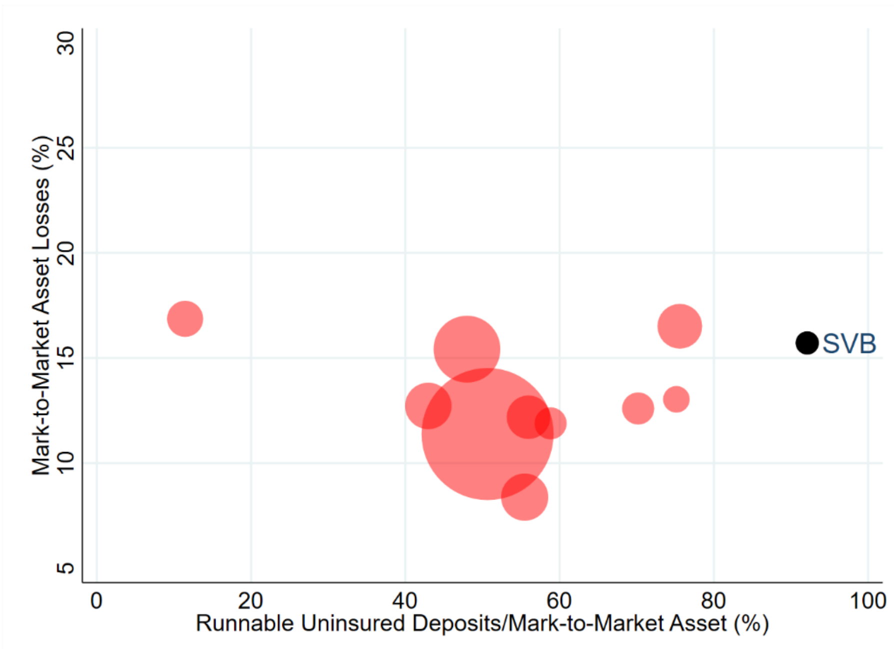
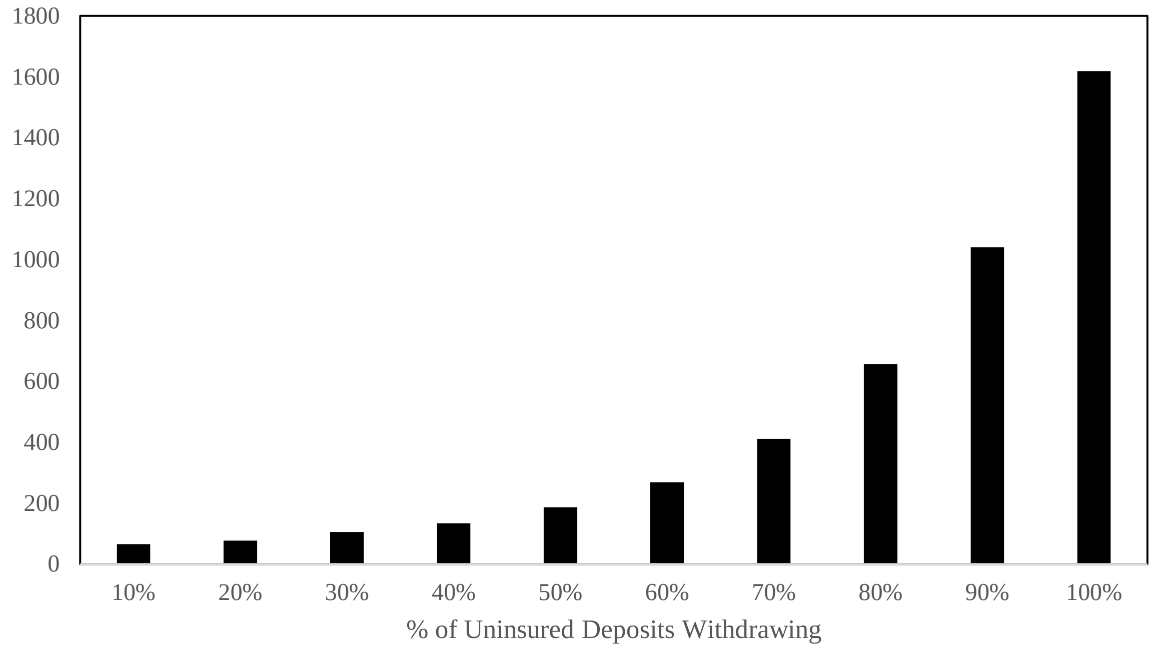
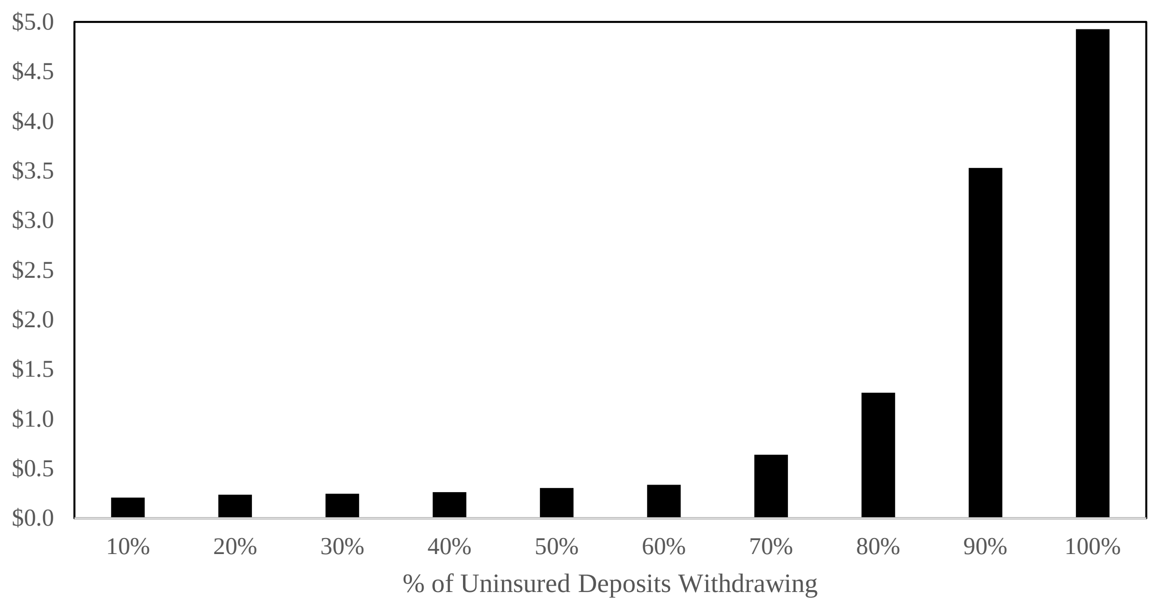


**Figure 6: Insolvent Banks under Different Uninsured Deposits Runs Cases**

This figure presents the number of insolvent banks (panel a) and their aggregate assets (panel b) associated with a given uninsured deposits withdrawal case. We consider ten cases ranging from 10% to 100% of uninsured deposits being withdrawn at each bank. The bank is considered insolvent if its mark-to-market value of assets – after paying a given share of the uninsured depositors -- is insufficient to repay all insured deposits. *Sources*: Bank Call reports and various ETF and indices price data as described in the main text.



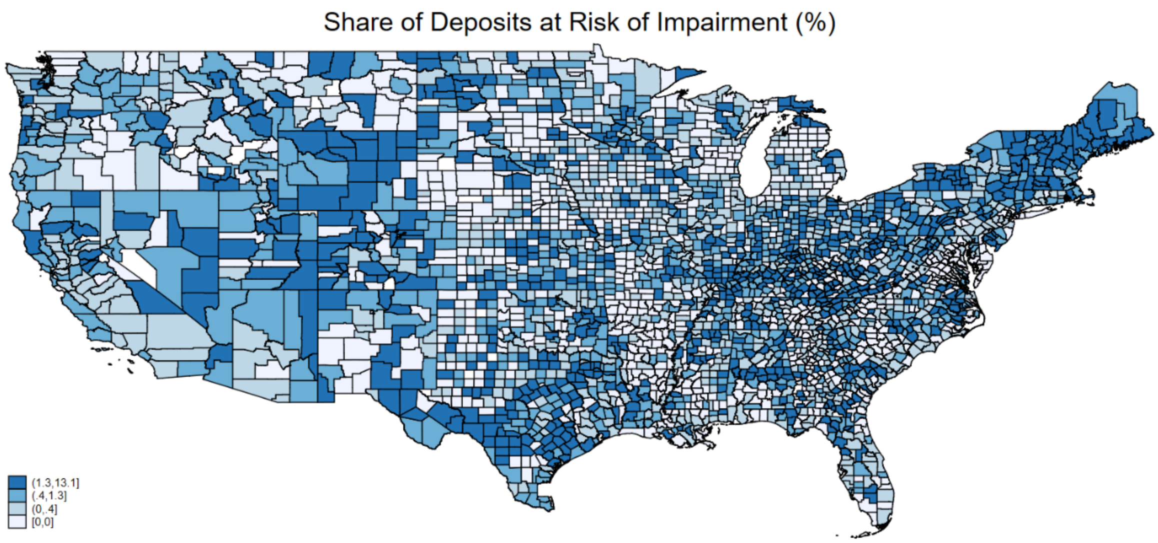

(a) Number of Insolvent Banks



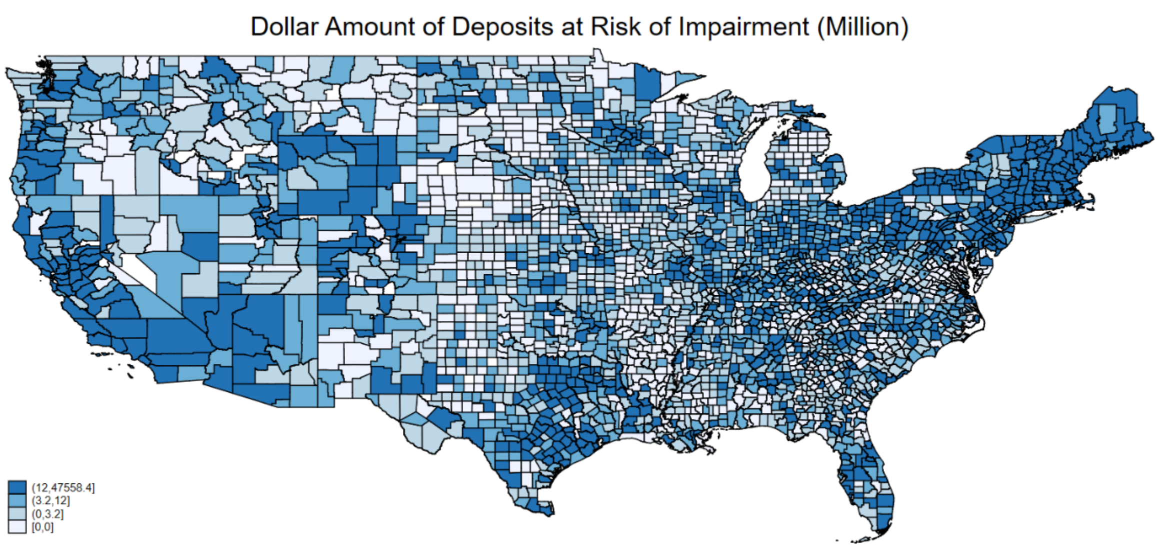

(b) Aggregate Assets of Insolvent Banks (in $ Trillions)

**Figure 7: Regional Exposure to Bank Risk**

This figure plots the regional exposure to bank risk, measured by the aggregate deposits in 2022 that are at the risk of impairment in each county. To find the deposit at the risk of impairment, we obtain bank branch network information from the FDIC Summary of Deposit in 2022 and assign banks' deposit impairment ratio, defined in the main text, to each county where it has branches. The detailed steps are introduced in the main text. Panel (a) plots the share of deposits at risk of impairment. Panel (b) plots total dollar amount of deposits at risk of impairment. In both panels, counties are divided into four groups based on their at-risk deposits. The darkest blue indicates the top quartile in terms of at-risk deposits. *Data sources*: bank call reports and the FDIC Summary of Deposits.



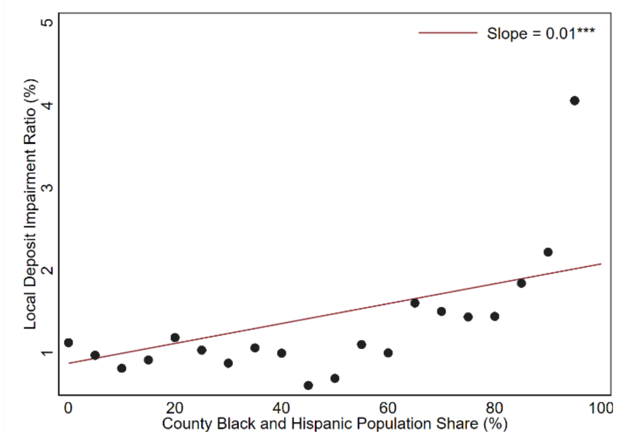

(a) Share



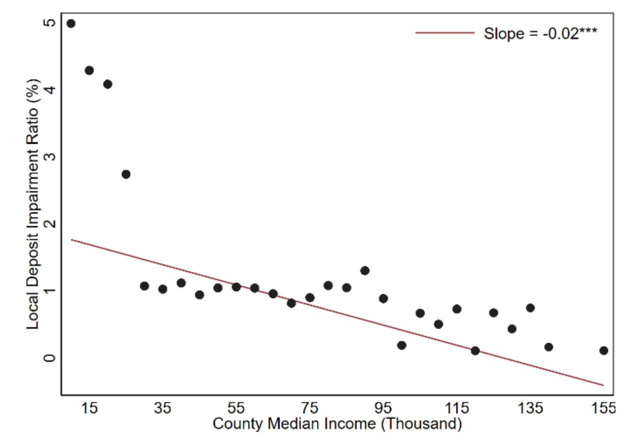

(b) Dollar Amount

**Figure 8: Local Bank Exposure Risk Exposure and Local Demographics**

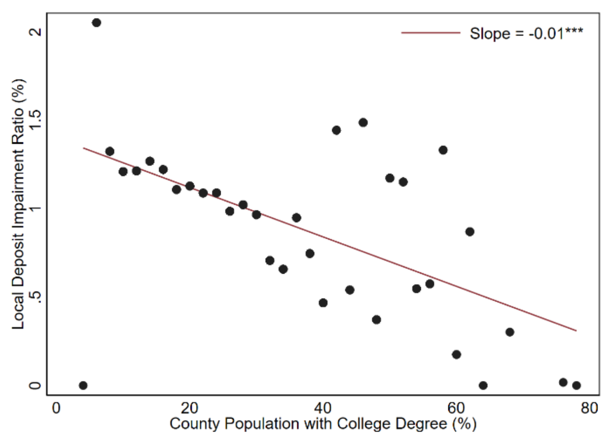
This figure plots the county-level share of impaired deposits against local demographics. In all panels, the y-axis is the share of deposits at the risk of impairment. We divide all counties into various numbers of bins based on its Black and Hispanic population share in Panel (a), median income in Panel (b), and the share of county population that received a college degree in Panel (c). We then plot the average y-value in each bin against the x-value. In Panel (a), each bin covers an incremental value of 2 percentage-points in the Black and Hispanic population share. In other words, the difference between the largest and the smallest Black and Hispanic population share in each bin is 2%. In Panel (b), each bin covers an incremental value of $20,000. In panel (c), each bin covers an incremental value of 2 percentage points. The lines in each panel are the best fit lines based on weighted least squares. The slope and statistical significance are reported in each panel (with ***, ** and * implying significance at 1%, 5% and 10% levels respectively). *Data sources*: bank call reports, the FDIC Summary of Deposit, American Community Survey.




(a) Race




(b) Income




(c) Education

## APPENDIX

### Table A1: Bank Balance Sheets

This table reports the bank asset composition (Panel A) and liability and equity composition (Panel B) as of 2022:Q1. In all panels, column (1) reports the aggregate statistics. Column (2) reports the average statistics at the bank level in the full sample of banks. Column (3) reports the bank-level statistics in the subsample of small banks, where small banks are defined as having the total asset size below $1.384 billion (the Community Reinvestment Act asset size thresholds for large banks). Column (4) reports the statistics in the subsample of large, non-systematically important banks, where large banks are defined as having the asset size above $1.384 billion. Column (5) reports the statistics of the subsample of systemically important banks (GSIB banks). GSIB banks are classified according to bank regulators' definition as of 2022:Q1. We also assign GSIB status to US chartered banks affiliated with holding companies that are classified as GSIB. All numbers in columns (2)-(5) are based on sample average, after winsorizing at 5$^{th}$ and 95$^{th}$ percentiles. Numbers in parentheses are standard deviations. *Data Sources: Bank Call Reports.*

**Panel A: Bank Asset Composition – 2022Q1**

| | (1) Aggregate | (2) Full Sample | (3) Small (0,1.384B) | (4) Large (non GSIB) [1.384B, ) | (5) GSIB |
|---|---|---|---|---|---|
| Total Asset $ | 24T | 5.0B | 0.3B | 19.7B | 273.1B |
| | | (74.7B) | (0.3B) | (137.1B) | (618.3B) |
| Number of Banks | 4844 | 4844 | 4072 | 743 | 29 |
| (Percentage of Asset) | | | | | |
| Cash | 14.1 | 13.1 | 13.6 | 10.0 | 24.3 |
| | | (9.8) | (10.0) | (7.9) | (12.4) |
| Security | 25.2 | 23.9 | 24.4 | 21.5 | 18.1 |
| | | (15.7) | (16.1) | (13.0) | (18.1) |
| Treasury | 6.1 | 2.6 | 2.7 | 2.1 | 4.7 |
| | | (4.1) | (4.2) | (3.3) | (5.5) |
| RMBS | 12.1 | 3.1 | 2.5 | 6.6 | 5.5 |
| | | (4.6) | (4.1) | (5.6) | (7.1) |
| CMBS | 2.3 | 0.9 | 0.7 | 1.6 | 0.8 |
| | | (1.6) | (1.5) | (1.9) | (1.5) |
| ABS | 2.7 | 0.8 | 0.7 | 1.3 | 1.1 |
| | | (1.6) | (1.5) | (1.8) | (2.0) |
| Other Security | 2.1 | 14.9 | 16.2 | 7.8 | 3.0 |
| | | (12.7) | (13.0) | (8.3) | (7.8) |
| Total Loan | 46.6 | 55.7 | 54.7 | 61.9 | 39.5 |
| | | (15.6) | (15.6) | (13.9) | (16.3) |
| Real Estate Loan | 21.9 | 41.9 | 41.4 | 45.2 | 19.4 |
| | | (16.7) | (16.6) | (16.5) | (14.8) |
| Residential Mortgage | 10.6 | 15.5 | 15.9 | 13.9 | 10.3 |
| | | (11.7) | (11.8) | (10.7) | (14.0) |
| Commercial Mortgage | 2.2 | 2.1 | 1.8 | 3.6 | 0.9 |
| | | (2.5) | (2.4) | (2.9) | (1.8) |
| Other Real Estate Loan | 9.1 | 23.0 | 22.6 | 25.7 | 4.4 |
| | | (11.9) | (11.8) | (11.9) | (4.9) |
| Agricultural Loan | 0.3 | 2.6 | 2.9 | 0.7 | 0.1 |
| | | (4.1) | (4.4) | (1.8) | (0.4) |
| Commercial & Industrial Loan | 9 | 6.9 | 6.6 | 9.1 | 4.2 |
| | | (5.2) | (5.0) | (6.0) | (5.6) |
| Consumer Loan | 7.7 | 2.2 | 2.2 | 2.3 | 2.8 |
| | | (2.5) | (2.3) | (3.1) | (3.8) |
| Loan to Non-Depository | 2.8 | 0.1 | 0.0 | 0.2 | 0.3 |
| | | (0.2) | (0.1) | (0.3) | (0.4) |
| Fed Funds Sold | 0.1 | 1.4 | 1.6 | 0.2 | 0.0 |
| | | (3.1) | (3.3) | (1.0) | (0.1) |
| Reverse Repo | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | (0.0) | (0.0) | (0.0) | (0.0) |

**Panel B: Bank Liability Composition – 2022Q1**

| | (1) Aggregate | (2) Full Sample | (2) Small (0, 1.384B) | (3) Large (non GSIB) [1.384B, ) | (4) GSIB |
|---|---|---|---|---|---|
| Total Liability | 90.5 | 89.8 | 89.8 | 89.9 | 86.9 |
| | | (3.2) | (3.3) | (2.7) | (4.9) |
| Domestic Deposit | 76.6 | 86.8 | 87.1 | 85.7 | 79.9 |
| | | (5.3) | (5.2) | (5.1) | (7.7) |
| Insured Deposit | 41.1 | 62.7 | 64.6 | 53.0 | 44.9 |
| | | (12.3) | (11.4) | (11.9) | (16.8) |
| Uninsured Deposit | 37.4 | 23.3 | 21.7 | 32.0 | 24.4 |
| | | (11.3) | (10.4) | (11.4) | (18.5) |
| Uninsured Time Deposits | 1.8 | 3.6 | 3.8 | 3.0 | 0.8 |
| | | (3.0) | (3.0) | (2.7) | (1.6) |
| Uninsured Long-Term Time Deposits | 0.4 | 0.8 | 0.9 | 0.6 | 0.1 |
| | | (1.0) | (1.0) | (0.7) | (0.3) |
| Uninsured Short-Term Time Deposits | 1.3 | 2.6 | 2.7 | 2.3 | 0.7 |
| | | (2.4) | (2.4) | (2.1) | (1.5) |
| Foreign Deposit | 6.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | (0.0) | (0.0) | (0.0) | (0.0) |
| Fed Fund Purchase | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | (0.0) | (0.0) | (0.0) | (0.0) |
| Repo | 0.6 | 0.3 | 0.2 | 0.5 | 0.3 |
| | | (0.7) | (0.7) | (0.9) | (0.6) |
| Other Liability | 2.3 | 2.3 | 2.1 | 3.0 | 4.3 |
| | | (2.8) | (2.7) | (2.8) | (3.4) |
| Total Equity | 9.5 | 10.2 | 10.2 | 10.1 | 13.1 |
| | | (3.2) | (3.3) | (2.7) | (4.9) |
| Common Stock | 0.2 | 0.4 | 0.4 | 0.2 | 0.9 |
| | | (0.6) | (0.6) | (0.5) | (1.1) |
| Preferred Stock | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | (0.0) | (0.0) | (0.0) | (0.0) |
| Retained Earning | 4 | 6.8 | 7.0 | 5.7 | 7.6 |
| | | (4.0) | (4.1) | (3.2) | (5.4) |

**Figure A1: Aggregate Asset and Liabilities of US Banks**

This figure plots the composition of aggregate total assets and liabilities of US banks as of 2022:Q1 in trillions of dollars (see also Table A1). On the asset side bank had about $24 trillion of assets as of 2022:Q1. Of these *Cash* constitutes about 14% of the aggregate bank assets. *Security* that includes bank investments in US Treasuries, RMBS, CMBS, ABS, and other securities accounts for about 25% of the aggregate bank assets. *Real Estate Loan* are the residential and commercial loans and other real estate loans that account for about 22% of the aggregate bank assets. *Other Loan* are commercial and industrial loans, consumer loans, loans to non-depository institutions, and agricultural loans that account for about 20% of aggregate bank assets. *Other Assets* account for the reminder of bank assets. On the liability side, *Insured Deposits* account for about 41% of total bank funding. *Uninsured Deposits* account for about 37% of total bunk funding and amount to about $9 trillion. *Other* includes other loans and liabilities. *Equity* accounts for about 9.5% of total bank liabilities. *Data Sources*: Bank Call reports.

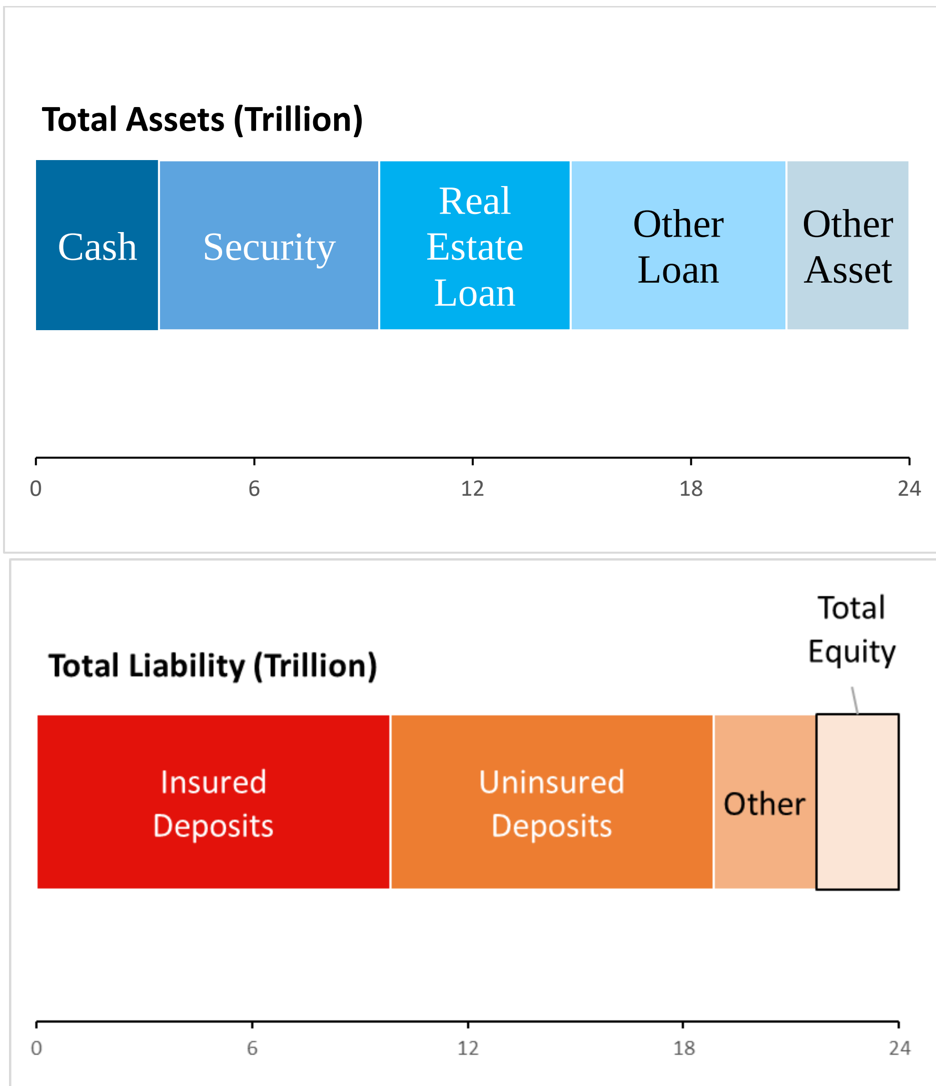


**Figure A2: Full Set of Insolvent Banks if All Uninsured Depositors Run**

This figure plots the full set of “insolvent” banks. A bank is considered insolvent if the mark-to-market value of its assets – after paying all uninsured depositors -- is insufficient to repay all insured deposits. On the y-axis we plot mark-to-market losses as a percentage of initial bank asset value. On the x-axis we plot uninsured deposits as a percentage of mark-to-market bank’s asset value. The assets are based on bank call reports as of 2022:Q1, and banks with larger asset size are marked with bigger dots. Banks in the top right corner, where Silicon Valley Bank is, have the most severe asset losses and the largest runnable uninsured deposits to mark-to-market assets. The red dots correspond to the 10 largest insolvent banks plotted in Figure 5. *Data Sources*: Bank Call reports and various ETF and indices price data as described in the main text.

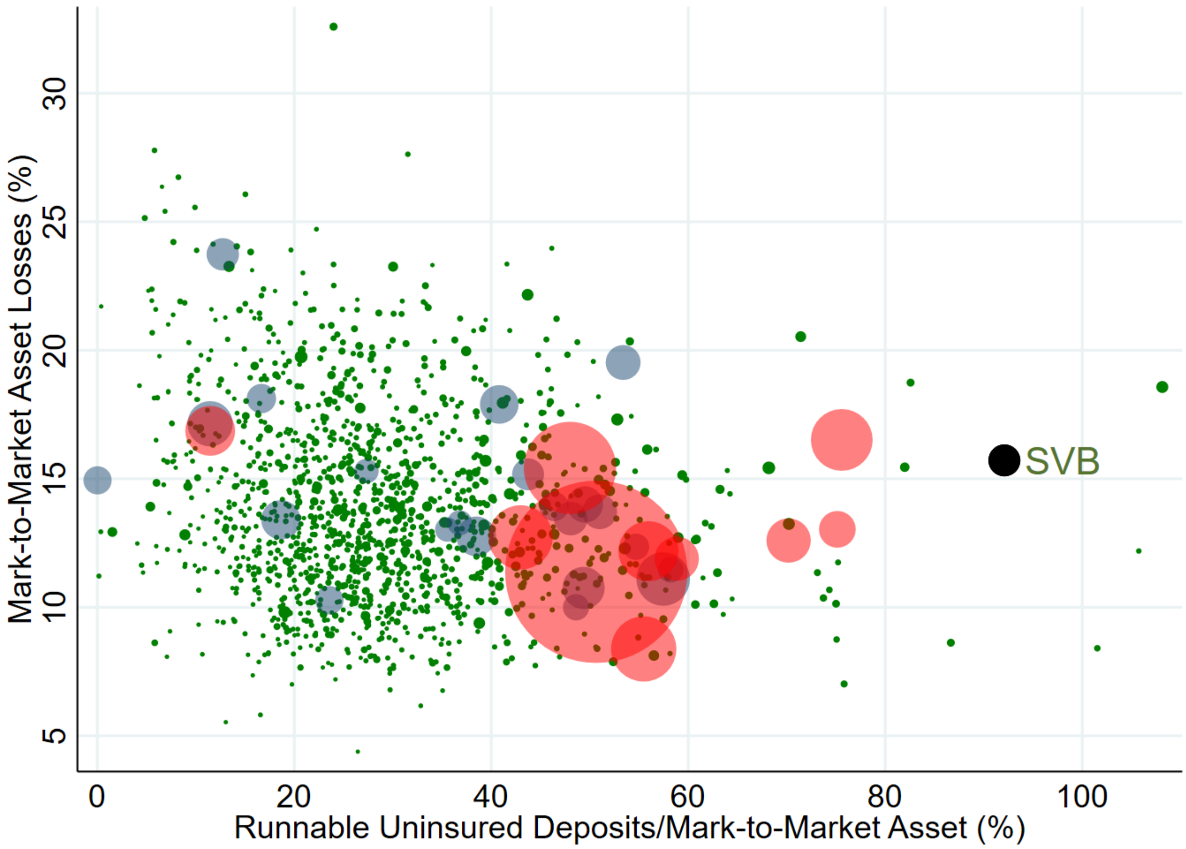
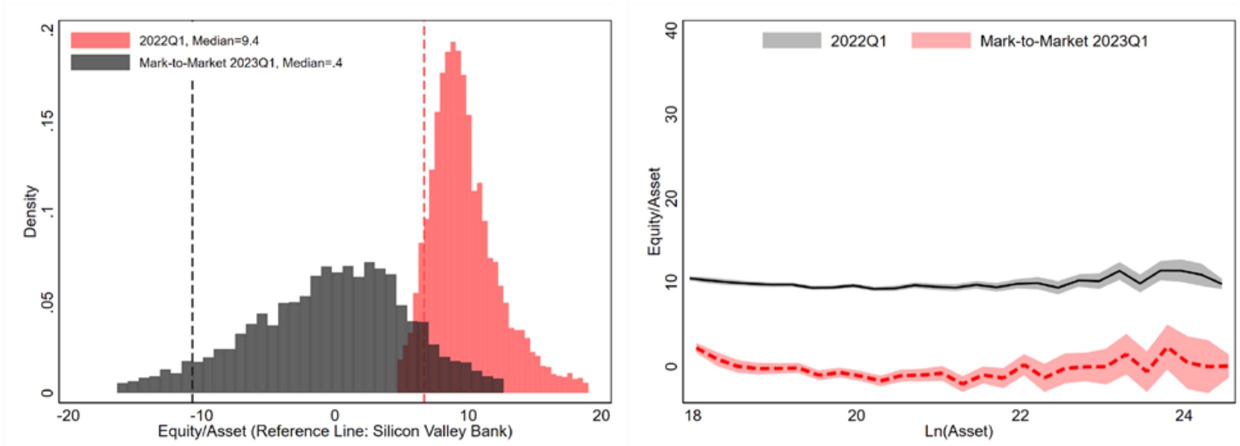


**Figure A3: Distribution of Bank Equity to Asset Ratio (With & Without "Marking to Market")**

This figure plots the histograms (density) of equity to asset ratios calculated based on 2022:Q1 balance sheets and mark-to-market values using various ETFs and indices according to the method described in the main text (Panel a) and equity to asset ratio against bank size (Panel b). The reference lines in Panel (a) indicate Silicon Valley Bank's (SBV) values. Silicon Valley Bank's equity to asset ratio 6.7% based on its 2022Q1 balance sheet. Its equity to mark-to-market asset ratio is -10.7%. The red and the gray lines are at the $10^{th}$ and $7^{th}$ percentiles, respectively. In Panel (b), the decline at the right-end starts around log asset value of 24, which is about $26B. *Data Sources*: Bank Call reports and various ETF and indices price data as described in the main text.




(a) Histogram

(b) Equity to Asset by Size