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ABSTRACT

We analyze the impact of credit risk and higher interest rates on U.S. bank solvency, expanding on the work of Jiang et al. (2023). Our variation of their bank-run model demonstrates how credit losses and asset declines from higher interest rates can trigger self-fulfilling solvency runs, even when banks hold fully liquid assets. Banks with high credit losses, greater exposure to interest rate increases, low capital, and high uninsured leverage are particularly vulnerable. Focusing on 2022's monetary tightening, we assess banks' exposure to commercial real estate (CRE) loans, which represent about 25% of average bank assets, totaling $2.7 trillion. Loan-level data shows that, after property value declines from rising rates and the shift to hybrid work, 14% of all CRE loans and 44% of office loans are in negative equity (i.e., property values are below outstanding debt). Additionally, 43% of all CRE loans and 64% of office loans may face cash flow and refinancing issues. A 10% (20%) default rate on CRE loans could lead to $80 billion ($160 billion) in additional bank losses. Had CRE distress occurred in early 2022, when the 10-year Treasury yield was around 2%, no banks would have faced failure, even in pessimistic scenarios. However, by 2024, after substantial asset declines, CRE distress could put dozens to over 300 smaller regional banks at risk of solvency runs. We also find evidence that banks, particularly those facing higher solvency risks and lenient state oversight, have concealed credit losses through "extend-and-pretend" practices. Overall, given the composition of bank balance sheets in Q1 2022, higher interest rates pose a greater threat to U.S. banks than credit risk, potentially constraining monetary policy.

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1. Introduction

This paper examines the relative impact of credit risk and higher interest rates on U.S. bank solvency, building on the work of Jiang et al. (2023). Their framework and methodology assess how rising rates affect bank asset values and stability, demonstrating that interest rate increases can trigger self-fulfilling solvency runs by uninsured depositors, even when bank assets are fully liquid.[2] We expand their framework by incorporating the impact of credit risk on U.S. bank stability, focusing on banks' exposure to distress in commercial real estate (CRE) loans during the monetary tightening that began in 2022. CRE loans constitute a significant portion of bank assets, representing about a quarter of total assets at the average bank, totaling approximately $2.7 trillion at the start of the 2022 monetary tightening. As of 2024, CRE is considered a potential source of significant near-term distress due to several factors, including the adverse effects of higher interest rates on CRE asset values and funding costs, recession risks, and reduced demand for office space due to hybrid work patterns. These factors could also have negative spillover effects on other asset classes, such as urban retail, multifamily housing, and hotels.

Using loan-level data on CRE loans, we find that following recent property value declines due to higher interest rates and the adoption of hybrid work patterns, about 14% of all CRE loans and 44% of office loans are in "negative equity," where current property values are lower than the outstanding loan balances. Additionally, around 43% of all loans and 63% of office loans may face significant cash flow problems and refinancing challenges, partly due to the more than doubling of debt costs following monetary tightening and rising credit spreads. This evidence suggests that if interest rates remain elevated and property values do not recover, default rates could potentially reach or exceed levels seen during the Great Recession. Therefore, our assessment of bank stability includes scenarios with CRE loan default rates ranging from 10% to 20%.

We find that a 10% (20%) default rate on CRE loans—similar to the lower end of defaults seen during the Great Recession—would result in approximately $80 billion ($160 billion) in additional bank losses. Had this CRE loan distress occurred in early 2022, when interest rates were low, no bank would have failed, even under the most pessimistic scenario. However, the significant decline

[2] The model highlights banks with high asset losses, low capital, and significant uninsured leverage—a stability metric introduced by Jiang et al. (2020)—as particularly vulnerable. Applying their approach to the 2022 monetary tightening, they estimate that higher interest rates reduced the market value of U.S. bank assets by approximately $2 trillion, creating conditions that heighten the risk of solvency runs among uninsured depositors at a significant subset of U.S. banks.

in banks' asset values due to the 2022 monetary tightening has substantially weakened their ability to absorb adverse credit events. While the estimated CRE losses are much smaller than the $2 trillion decline in bank asset values caused by rising interest rates, they would significantly increase the insolvency risk for a large number of U.S. banks. We estimate that, by 2024, an additional 217 (441) banks, with total assets of $300 billion ($0.9 trillion), would have their mark-to-market asset values fall below the face value of their non-equity liabilities.

This calculation may seem extreme, as it assumes that rising interest rates do not reduce the value of bank liabilities—i.e., that the federal funds rate instantly passes through to deposit rates. However, longstanding banking literature shows that banks in concentrated markets with strong deposit franchises can delay raising deposit rates in response to interest rate hikes, allowing them to earn positive rents on deposits (e.g., Hannan and Berger 1991; Neumark and Sharpe 1992; Drechsler, Savov, and Schnabl 2017; Egan, Matvos, and Hortacsu 2017). More recently, Drechsler, Savov, and Schnabl (2021) argue that deposit franchises provide hedging benefits, enabling banks to engage in "maturity transformation without interest rate risk." However, Jiang et al. (2023) refine this argument by showing, both theoretically and empirically, that self-fulfilling solvency runs can arise, particularly when interest rate-driven asset declines combine with potential credit losses. These factors can undermine, or even negate, the hedging benefits of the deposit franchise, leaving banks vulnerable to significant solvency risks.

To assess the risk of solvency runs amid both rising interest rates and credit losses, we extend Jiang et al. (2023)'s bank-run model to show how a combination of credit losses and asset value declines from higher rates can trigger self-fulfilling solvency runs, even when a bank's assets are fully liquid. Banks with high credit losses, significant exposure to interest rate increases, low capital, and high uninsured leverage are especially vulnerable.

We assess this risk empirically by applying the financial stability measures developed by Jiang et al. (2023), incorporating the impact of credit losses into the mark-to-market asset calculations alongside the effects of rising interest rates. These measures identify whether a bank is vulnerable to a self-fulfilling solvency run by uninsured depositors but do not predict the likelihood of such runs, as there is no established theory on the distribution of run triggers ("sunspots"). To evaluate the potential for insolvency at each bank, we consider two scenarios: (i) when half of uninsured depositors withdraw their funds, and (ii) when all uninsured depositors do so.

Our analysis shows that distress in the commercial real estate sector could place dozens to over 300 predominantly smaller regional banks at risk of insolvency due to uninsured depositor runs. We also find evidence that banks have concealed their credit losses by engaging in "extend-and-pretend" practices, particularly those facing higher solvency run risks and being overseen by more lenient state regulators.

Overall, our empirical analysis of monetary policy constraints due to bank instability shows that higher interest rates pose a significantly greater risk to U.S. banks than credit risk. With the composition of bank balance sheets as of Q1 2022, a 10-year yield exceeding 3%, and particularly 4%, poses significant risks to the U.S. banking system, potentially constraining monetary policy and threatening price stability objectives.

As we discuss in Section 5, these findings carry important implications for financial regulation, risk supervision, and the transmission of monetary policy. Moreover, as regional banks play an important role in lending to local businesses, their distress could result in a credit crunch with broader economic repercussions.

Related Literature: As discussed earlier, our paper is most closely related to Jiang et al. (2023), who developed a conceptual framework and empirical methodology to assess the impact of rising interest rates on U.S. bank asset values and stability. We extend their work by analyzing the effects of credit risk on U.S. bank solvency in the context of rising interest rates. Our research also contributes to the broader literature on bank runs, though we cannot fully cover that extensive body of work here. Much of this literature, including the seminal work of Diamond and Dybvig (1983), centers on asset illiquidity as a key factor driving runs. However, as noted by Jiang et al. (2023), most U.S. banks hold a large share of liquid assets, making it difficult for runs to occur in the traditional framework where asset illiquidity triggers run behavior. Like Jiang et al. (2023), we assess the risk of bank runs in a setting where bank assets are fully liquid. In this context, our paper also connects to Egan et al. (2017), who model runs without asset illiquidity, and to Jiang et al. (2020), who highlight the role of uninsured bank leverage, a concept they developed.

Our paper, which focuses on the interplay between rising interest rates and credit distress on bank stability, is also positioned within the broader literature examining the transmission of monetary policy through financial markets and the banking sector. This includes emerging work addressing the 2023 regional banking crisis. In addition to Jiang et al. (2023), Drechsler et al. (2023) and

Haddad et al. (2023) analyze how solvency bank runs interact with monetary policy. Amador and Bianchi (2023) present a tractable dynamic general equilibrium model of self-fulfilling bank runs, and analyze how the vulnerability of an individual bank depends on its leverage position and the economy wide asset prices, while Amador and Bianchi (2024) explore banking regulation in a macroeconomic model of bank runs. Other relevant contributions in this literature include studies by Cookson et al. (2023), Flannery and Sorescu (2023), Koont et al. (2023), Acharya et al. (2024), Granja et al. (2024).

More broadly, our work also connects to models that examine the pass-through of macroprudential, monetary, and fiscal policies, as well as other shocks, through financial intermediaries (He and Krishnamurthy 2013; Brunnermeier and Sannikov 2014; Corbae and D'Erasmo 2021; Bianchi and Bigio 2022; Davila and Walther 2022; Buchak et al. 2024a).

2. Bank CRE Loan Exposure and CRE Distress Risk

2.1 Bank Asset Exposure to CRE Loans

We illustrate the impact of credit risk on bank stability by analyzing their exposure to CRE loans. We focus on commercial real estate for two main 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 as of Q1:2022 (see Table 1).[3] Most of these loans are held by smaller and mid-size banks. Second, as we discuss in the next section, commercial real estate has also been seen as a potential source of adverse credit events in the near term (as of December 2023).

2.2 CRE Distress Potential

There are several reasons why CRE has been viewed as having an elevated distress risk. First, long duration assets can experience significant value declines following the monetary tightening. In response to high inflation, the Federal Reserve Bank severely tightened monetary policy. From March 2022 to August 2023, the federal funds rate rose sharply from 0.08% to 5.33%. As a result, long-dated assets such as US Treasuries experienced significant value declines (see Jiang et al.

[3] See also Appendix A1 for more detail on banks assets and liabilities. We consider all non-residential real estate loans as commercial loans. We do not account for the banks' commercial real estate exposure through their credit lines to real estate businesses, leading to an understatement of the largest banks' CRE exposure. However, even with this exposure included, the largest banks still face significantly lower CRE exposure than regional banks (see Acharya et al. 2024).

2023). Such declines can also manifest itself among commercial real estate properties, especially among those with limited rent growth, which could increase default risk on CRE loans.

Second, increased interest rates put pressure on commercial real estate operators who financed their acquisitions with debt at historically high commercial property values. Most of these loans mature in the next few years and may have to be refinanced at significantly higher rates (typically more than double relative to original loan) resulting in increased risk of maturity default.[4] Third, a potential incoming recession may lead to a significant decline in the demand for commercial properties adversely affecting their valuation.

Finally, the office properties that constitute a significant share of all commercial real estate are under significant pressure due to remote and hybrid work patterns. Barrero et al. (2021) note that the elevated emote working patterns relative to their pre-pandemic levels may persist, eroding part of the demand for office space (see also Gupta et al. 2022).[5] This lower demand for office can also have potential negative spillovers on other asset classes such as urban retail, multifamily, and hotels.

Signs of distress in the commercial real estate sector are becoming increasingly apparent. Throughout 2022-2023, there has been a noteworthy decrease in commercial property prices, as highlighted in Appendix A2. Behind this average decline, there is notable variation among property types, with the office sector facing particularly adverse conditions. By the close of 2022, the office vacancy rate had spiked to over 18%, reaching levels reminiscent of the Great Recession. This marks a significant escalation from approximately 13% at the close of 2019.[6] By the end of 2023, the equity value of real estate holding companies (REITs) specializing in the office sector had plummeted by nearly 55% since the onset of the pandemic (see Appendix A3). A straightforward calculation suggests that these declines imply a 33% reduction in the value of office buildings held by these companies, given the average debt-to-asset ratio for office REITs stood at about 40% as of Q4 2019.

[4] Over the next five years, $2.56 trillion in CRE loans will mature with $1.4 trillion held by banks (Source: Trepp).
[5] The COVID-19 pandemic resulted in very large increase in remote working with close to 60% of the US labor force working remotely at the peak of pandemic (see Barrero, Bloom and Davies 2021). The recovery in the office attendance has been slow. For example, as of mid-2024, only about half of US workers were working in the office on a given day in ten large US cities relative to the pre-pandemic attendance levels (see also Appendix A3).
[6] Based on the vacancy levels from Cushman & Wakefield. About 2/3 of office leases need to be renewed in the next few years that can contribute further to an increase in the vacancy rate if these leases are not renewed at existing space levels (based on the Compstak data).

This simple calculation is in the ballpark of other studies and assessments by commercial data providers and academics. Given that office REITs generally held higher-quality buildings on average, the decline in the value of all office buildings could potentially be even more significant. The commercial property price indices from Green Street Advisors reveal that, across metropolitan areas, the value of office buildings may have, on average, decreased by approximately half from their pre-2020 values. Consistent with such indices, Gupta et al. (2022) project decline in the office values in the order of 39% to 45% relative to their pre-2020 values.

Importantly, the delinquency rate on commercial mortgages has been on the rise, surpassing 4.5% by December 2023, with a notably swift increase in the delinquency rate on office loans—from 1.58% in December 2022 to 6.58% in March 2024 (see Appendix A4). Notably, delinquency rates on lodging and retail loans have also remained elevated, standing at 5.45% and 5.56%, respectively. These trends underscore the increasing distress in the commercial real estate (CRE) loan segment. To evaluate the potential extent of this distress, we now turn our attention to the loan-level data.

2.3 Evaluating Potential Distress in CRE Loans through Loan-Level Data

To shed light on the extent of potential defaults among CRE loans we turn our attention to the loan-level data. Given that we do not have access to loan-level data on banks' balance sheet CRE loans, we redirect our attention to commercial mortgages that have been securitized in the Commercial Mortgage-Backed Securities (CMBS) market. For that purpose, we focus on a sample of 35,253 loans totaling $825 billion in aggregate principal balance from the CMBS market. These loans, drawn from the outstanding CMBS loans as of December 2023, were obtained from the DBRS Morningstar database. This comprehensive database encompasses historical loan performance data for the entire CMBS market, spanning back to 1998 and including both DBRS-rated and non-DBRS-rated transactions. It is worth noting that both bank-held and CMBS loans have generally exhibited broadly similar trends in historical data, including comparable default rate levels (including during the Great Recession).

2.3.1 Loans in "Negative Equity"

We start our analysis with an evaluation of the borrowers' equity in their properties, considering the recent decline in the value of certain commercial properties. This calculation incorporates factors such as the loan origination date, the amount of original debt repaid up to December 2023 due to loan amortization, and the evolution of property prices since loan origination, accounting for property location (MSA) and property type. The current assessed value of the property is computed by indexing the initial property value to the regional property price index from its acquisition/refinancing date until December 2023. We use the regional quarterly Commercial Property Price Index from Green Street Advisors, which factors in the property location (MSA) and property type (e.g., office, multifamily, etc.). Consequently, we can determine the estimated current Loan-to-Value (LTV) of a loan by comparing the current outstanding loan balance to the presently assessed property value. Properties with an estimated current LTV exceeding 100% are in "negative equity" territory, indicating that the property's value is less than the face value of the debt.[7] It has been long established in the empirical literature that such loans can face considerable default risk (see Piskorski and Seru 2018).

Table 2, Panel (a), presents statistics on the current LTV of loans and the percentage of loans in negative equity. On average, a loan starts with an initial (origination) LTV of approximately 61% (Column 3). However, by December 2023, the LTV has risen to 66.2% due to the recent decline in property values (Column 4). Notably, this increase is much more significant for office loans, which constitute about 19.2% of all loans in our sample. Their LTV experiences a pronounced surge from 54.4% to around 86%, attributed to substantial recent declines in the value of office buildings. Column (5) highlights the percentage of loans with an estimated average current LTV exceeding 80%, a common maximum threshold for loan origination including refinances by senior lenders.[8] As we observe 29% of all loans and 56% of office loans have current LTV about this threshold highlighting significant refinancing challenges facing these loans.

Finally, Column (6) indicates the percentage of loans in a state of "negative equity," defined as cases where the current loan balance exceeds the assessed property value, resulting in an estimated LTV over 100%. We observe that 14.3% of all loans and 44.6% of office loans are in negative equity. This means these borrowers cannot repay the face value of their debt by selling their properties. Importantly, the total amount of loans in negative equity does not solely reflect the risks

[7] We acknowledge that in order to calculate the marked-to-market LTV ratio, one may want to also compute the current market value of debt, which might be lower than the face value of debt due to the option of default. Consequently, our calculation may potentially overstate the proportion of loans in "negative equity" territory.
[8] In fact, in most loan segments except multifamily it may be difficult to get a loan with LTV above 60% threshold.

associated with office loans; for instance, among loans financing apartment buildings, 12% are also in negative equity.

2.3.2 Loans with Low Debt Service Coverage Ratio and Potential CRE Refinancing Crisis

We now shift our focus to assess the capacity of CRE borrowers to meet their debt obligations by examining the *Debt Service Coverage Ratio* (DSCR) of their loans. The DSCR is calculated as the annual property net cash flow divided by its annual debt service. A DSCR less than 1 signifies a "negative income" situation, where the net proceeds from the property are inadequate to cover annual debt payments. This scenario significantly raises the risk of borrower default.

Column (1) of Panel (b) in Table 2 displays the average current ("legacy") interest rate of loans in our sample. As we observe the average loan carries a "legacy" interest rate of 3.97% with an office loan having an interest rate of 3.96%. Column (2) displays the prevailing market interest rates for new 10-year maturity fixed-rate commercial real estate loans, sourced from the Cushman & Wakefield Capital Markets Survey, assuming borrower qualification for such loans.

It is crucial to highlight the substantial disparity between legacy rates and current rates on new loans. For an average loan in our sample, the legacy rate is 3.97%, whereas the current rate for a new loan would be 6.71%. Similarly, for office loans, the legacy rate is 3.96%, contrasting sharply with the current rate of 7.42%. This notable surge in interest rates primarily results from an escalation in risk-free rates (10-Year US Treasury) subsequent to the monetary tightening of 2022, coupled with an increase in credit spreads. It underscores the formidable challenges faced by loans approaching maturity and in need of refinancing. In this regard, we note that 39% of all loans and 35% of office loans come to maturity in 2023-2025 period (see Appendix A5) and hence need to be repaid or refinance by then.

Column (1) of Panel (c) in Table 2 shows the average initial DSCR of these loans as reported in the data. Notably, both all loans and office loans were underwritten with an average DSCR exceeding 2 (2.3 for all loans and 2.7 for office loans). However, by December 2023, the DSCR for these loans had significantly deteriorated, reaching 1.7 for all loans and 2.0 for office loans (Column 2). This decline can be attributed mainly to a decrease in property cash flow, as reported in the data, and an increase in interest rates on certain loans with adjustable rates. Moving to Column (3), the data reveals that currently, 6.4% of all loans and 6.6% of office loans have a DSCR less than 1, indicating that the net property cash flow is insufficient to cover loan debt service.

To underscore the refinancing challenges confronting CRE loans, we assess the hypothetical DSCR if they were to refinance at the average rates displayed in Column (2) of Table 2, Panel (b). This calculation adjusts for property type, the loan's current balance, and the current reported property net cash flow, assuming a new loan with a 10-year maturity and 25-year amortization term. As shown in Column (4), after such refinancing, the DSCR ratio for all loans and office loans would fall to 1.2. It's important to note that this exercise may likely overstate the DSCR, given that the benchmark rates are for loans with lower Loan-to-Value (LTV) ratios (averaging between 50% to 60%) than our sample averages. Consequently, in many instances, borrowers might face higher rates than our benchmark or might not qualify for a loan.

Column (5) of Table 2, panel (c) indicates the percentage of loans that would have a hypothetical DSCR less than 1 if loans were to be refinanced at the benchmark rate. Notably, 17.2% of all loans and 24.3% of office loans would have a DSCR less than 1 under these conditions. Column (6) shows the percentage of loans that would have a hypothetical DSCR below 1.2—a common minimum threshold for standard refinancing—if the loans were refinanced at the benchmark rate. As we observe 30.7% of all loans and 40.6% of office loans have DSCR less than 1.2. Column (7) displays the percentage of loans that either have a current LTV ratio greater than 80%, as calculated in panel (a), or a DSCR below 1.2 after hypothetical refinancing at the benchmark rate. Loans with a DSCR below 1.2 and a current LTV above 80% would typically be excluded from the regular refinance market. These statistics indicate that 42.8 of all loans and 64.8% of office loans would not be able to access a regular refinancing market.

Finally, Column (8) showcases the percentage of loans with both a current LTV greater than 100%, as computed in Panel (a), and a hypothetical DSCR after refinance at the benchmark rate less than 1. As we observe 4.5% of all loans and 14.4% of office loans are in such a "negative equity" and "negative income" situation.

2.3.3 Implications for Potential Default Rate in the CRE Loan Market

Collectively, the aforementioned evidence highlights a significant potential for distress in the CRE loan market. Approximately 14.3% of all loans appear to be in a negative equity situation and about 44% of all office loans. Additionally, around one-third of all loans and the majority of office loans may encounter substantial cash flow problems and refinancing challenges due to the combination of their high current LTV (above 80%) and low DSCR at refinance.

In our subsequent calculations, we explore various default scenarios, ranging from a 2% to a 20% default rate on CRE loans. It is noteworthy that, although the Great Recession was primarily associated with defaults on residential real estate loans (see Piskorski and Seru 2018), it also witnessed a substantial increase in foreclosures and delinquencies on CRE loans. Delinquencies on bank-held commercial real estate loans reached nearly 10% during the Great Recession (refer to Appendix A4). The evidence presented above suggests that if interest rates remain elevated and property values do not recover, default rates could potentially reach levels comparable to or even surpassing those seen during the Great Recession. Hence, our assessments of bank stability will encompass a range of 10% to 20% default rates on CRE loans.

3. Methodology and Data

We use bank call report data to evaluate banks' capacity to withstand CRE distress amid rising interest rates, focusing on the 2022 monetary tightening. Our analysis proceeds in three steps. First, using the composition of bank assets as of Q1 2022, we apply the methodology from Jiang et al. (2023) to mark-to-market bank assets, reflecting value declines due to higher interest rates, and extend this analysis to Q1 2024. Notably, the 10-year U.S. Treasury yield averaged 4.15% in Q1 2024, a sharp rise from 1.95% in Q1 2022. Additionally, we will examine the impact of higher rates on bank asset values over the full path of interest rate changes from Q1 2022 to Q2 2024. This analysis will quantify potential monetary policy constraints arising from bank instability. Second, we further reduce the value of bank assets by modeling various scenarios of CRE loan default rates, capturing different levels of distress in the commercial real estate sector. Third, we apply the conceptual framework and bank stability measures from Jiang et al. (2023) to assess the risk of bank insolvency due to uninsured depositor runs. This final step incorporates both the adverse effects of rising interest rates and CRE distress on overall bank stability.

3.1 Marking-to-Market Bank Asset Values due to Higher Interest Rates

We start by using the methodology developed by Jiang et al. (2023) to mark-to-market bank assets to reflect the decline in their values following higher interest rates. We exactly follow the three steps of their methodology:

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.[9]

2) We use traded indexes in real estate and treasuries to impute the market value of real estate loans held on bank balance sheet.[10] 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 prices of U.S. Treasury bonds and RMBS from Q1 2022 to Q1 2024. We also assess the impact of rising interest rates on the value of bank assets across the entire interest rate path observed from Q1 2022 to Q2 2024. To adjust for maturity, we use the iShares U.S. Treasury Bond ETFs and the S&P Treasury Bond Indices across various maturities, matching the maturity and repricing breakdowns in the call reports.

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

$$
\begin{aligned}
Loss = \sum_t & RMBS\ multiplier \times (RMBS_t + Mortgage_t) \times \Delta TreasuryPrice_t \\
& + Treasury\ and\ Other\ Securities\ and\ Loans_t \times \Delta TreasuryPrice_t,
\end{aligned}
$$

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 2024: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:

[9] 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.”
[10] Variable rate notes are recorded as maturity at the repricing date in bank call reports.

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

We then define the mark-to-market asset value in 2024:Q1 as total assets in 2022:Q1 minus the mark-to-market value loss defined above.

As discussed in greater length by Jiang et al. (2023) this methodology relies on number of assumptions. First, we mark to market about 75% of bank assets, effectively treating the rest as having a duration of 0. For assets with insufficient information in call reports to apply our method, we take a conservative approach in assigning duration of 0. Assigning even a short duration to those remaining (non-cash) assets will generate larger bank losses than the ones we report.

Second, these computations rely 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.

Nevertheless, following Jiang et al. (2023), in Section 4.3 we will reassess our results using a conservative loss estimation method. In this method, we employ an alternative approach where we obtain pool-level MBS trading prices from TRACE and link them to loan maturity structures. Our analysis reveals that price changes across longer maturity structures do not decline as much as treasuries' price changes across long maturity structures. One possible reason for this phenomenon is that prepayment risk counters the effect of interest rate changes. However, these results should be interpreted with caution due to the infrequent trading of individual MBS securities and the limited availability of recent transaction price data. Nonetheless, using this method, which adopts more conservative price declines by effectively assigning shorter-than-contractual maturities to real estate loans, we still observe a substantial aggregate loss in banks' asset value due to higher rates and a significant number of banks at risk of insolvency (see Section 4.3).

We also do not consider potential interest rate hedging by banks with derivative contracts. However as shown by Granja et al. (2024) this assumption is immaterial as the vast majority of banks assets are unhedged for interest rate risk with interest rate swaps.

Lastly, we assume the assets are liquid and do not account for any "fire-sale" discounts or liquidation costs. Incorporating these discounts would lead to a lower "liquidation" market value of assets, thereby increasing the number of banks at risk of insolvency, as assessed by our financial stability measures discussed below.

3.2 Quantifying the Decline in Bank Asset Values due to CRE Distress

We quantify the banks' balance sheet exposure to the CRE loan distress by using the face value of CRE loans at each bank from the call report data. More specifically, for bank *i* we define a credit loss of bank asset value due to a given level of credit distress (d) as follows:

$$\text{Credit Loss}(\mathrm{i}, \mathrm{d}) = \$\text{Amount of Bank CRE Loans}(\mathrm{i}) \times d \times (LGD) \tag{1}$$

where *$Amount of Bank CRE Loans* is the outstanding dollar amount of CRE loans on the bank's balance sheet based on the call report data, *d* is the loan default rate, and *LGD* is the loss given default expressed as a percentage of loan balance.

To assess the banks' ability to withstand the CRE credit distress, we consider a range of CRE loan default scenarios (*d*) starting from 2% default rate to 20% default rate at each bank. We assume that in the case of default, banks experience a loss of value amounting to approximately 30% of the outstanding principal balance. This is broadly consistent with historical data on loan recovery rates, which show that banks, on average, recover about 70% of loan balances in default.[11] Notably, while the Great Recession was largely associated with defaults on the residential real estate loans (see Piskorski and Seru 2018), it also led to a substantial increase in foreclosures and delinquencies on CRE loans. Indeed, delinquencies on bank-held commercial real estate loans reached nearly 10% during the Great Recession (see Appendix A4). The evidence from Section 2 suggests that if interest rates remain elevated and property values do not increase, default rates could potentially reach levels comparable to or even surpassing those seen during the Great Recession. Hence, our assessments of bank stability will encompass a range of 10% to 20% default rates on CRE loans.

3.3 Simple Modelling Framework

To assess bank stability, we follow the conceptual framework developed by Jiang et al. (2023) that in addition incorporates the impact of credit losses. We present a simple and stylized model that takes assets, liabilities, and markups of banks as exogenous to illustrate the basic mechanism of

[11] According to Trepp's data, the average recovery rate on commercial real estate loans that defaulted between 2010 and 2020 was 69.2%. The recovery rates can substantially vary depending on the specific circumstances of each loan, as well as the type and quality of the underlying property, the strength of the local real estate market, and other factors.

solvency runs and their interaction with interest rate level, credit losses, and uninsured leverage.[12] 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 a book value of 1: c shares of bank assets is interest-insensitive cash with a duration of 0, and $(1-c)$ shares of its assets are risk-free liquid perpetuities (e.g., T-bonds with infinite maturity), paying an annual coupon r_0. Because cash has a duration of 0, $(1-c)$ effectively captures the duration of the 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, which is an absorbing state, the market value of bank assets is given by $c+(1-c)\frac{r_0}{r_f}$. In addition the bank can suffer an expected credit loss due to loan defaults in PV terms of $CL(r_f)$, that makes the value of its assets equal to $c+(1-c)\frac{r_0}{r_f}-CL(r_f)$.

Deposits

The bank's existing liabilities comprise insured and uninsured deposits with face value l_i and l_u, respectively. 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 outside goods 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 $\nu_f > 0$; 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

[12] Egan, Matvos, and Hortacsu (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.

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 can have market power in the deposit market, which may give rise to franchise value as in Egan, Matvos, and Hortacsu (2017) and Drechsler, Savov, and Schnabl (2017 and 2021).

To further map the model to the data, we assume that s shares of uninsured depositors are potentially "awake," while $(1-s)$ shares 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. 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 in 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, the market value of equity if depositors do not run, $e_{no\ run}$, has to be positive:

$$e_{no\ run}(r_f) = \underbrace{c + (1-c)\frac{r_0}{r_f} - CL(r_f)}_{PV\ Assets} - \underbrace{(l_i + l_u)\frac{\mu(r_f)}{r_f}}_{PV\ Deposit} \geq 0 \tag{2}$$

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, the net value of its assets net of credit losses, and the deposit franchise of all deposits:

$$e_{no\ run}(r_f) = e_b + \underbrace{(1-c)\Delta a(r_f) - CL(r_f)}_{Assets\ Gain/Loss} + \underbrace{(l_i + l_u)\Delta f(r_f)}_{Deposit\ Franchise\ of\ Total\ Deposits} \geq 0 \tag{3}$$

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 also withdrawing. This occurs when the bank's equity value is negative if all awake depositors withdraw—i.e., if:

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

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

$$\underbrace{e_b + \underbrace{(1-c)\Delta a(r_f) - CL(r_f)}_{Assets\ Gain/Loss} + \underbrace{(l_i + l_u)\Delta f(r_f)}_{Deposit\ Franchise\ of\ Total\ Deposits}}_{e_{no\ run}} < \underbrace{s l_u \Delta f(r_f)}_{Deposit\ Franchise\ of\ Awake\ Deposits} \tag{4}$$

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:

$$e_b + (1-c)\Delta a(r_f) - CL(r_f) + (l_i + l_u)\Delta f(r_f) \geq s l_u \Delta f(r_f)$$

2) Multiple equilibria, when

$$0 \leq e_b + (1-c)\Delta a(r_f) - CL(r_f) + (l_i + l_u)\Delta f(r_f) < s l_u \Delta f(r_f)$$

3) Unique equilibrium with bank insolvency:

$$e_b + (1-c)\Delta a(r_f) - CL(r_f) + (l_i + l_u)\Delta f(r_f) < 0$$

The structure of equilibria shows, unsurprisingly, that no-run equilibria are more easily supported in better capitalized banks with higher asset valuations, lower credit losses, 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 a large uninsured deposit base can simultaneously support a large bank valuation and still be susceptible to bank runs.

3.4 Financial Stability Measures

Motivated by our analysis above, we next more systematically consider whether marking banks' assets 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 positive spread between the Fed funds rates and deposit rates due to banks' market power, allowing banks to earn rents (Hannan and Berger 1991; Neumark and Sharpe 1992; Drechsler, Savov, and Schnabl 2017; Egan, Matvos, and Hortacsu 2017). Under this scenario, one may want to consider on-demand liabilities more akin to long-duration assets, which also lose value when rates rise. Thus, not properly accounting for the market value of deposit liabilities could overestimate the degree of a bank's insolvency risk. In our model the bank run threshold is defined as negative market value of equity in present value terms, which yields the following model-guided condition:

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

According to Proposition 1, if $e_{run}(r_f)$ is negative, a run equilibrium can be supported. If one does not account for deposit franchise, i.e., $\Delta f(r_f) = 0$, it will overestimate the range of parameters at which bank run can be supported. All else equal, this over-estimation will be larger for banks with higher deposit franchise value.

We note that empirically implementing the above condition would require assessing the market value of deposit liabilities, which is challenging. One approach to estimating franchise value is by using "deposit betas" (Drechsler, Savov, and Schnabl 2021). However, "deposit betas" defined in a stable equilibrium would not be appropriate in our context, as they could shift significantly when a distressed equilibrium is imminent. It is also unclear how susceptible different depositors are to runs. For instance, Egan, Matvos, and Hortacsu (2017) estimate that uninsured deposits are somewhat elastic to default, but this elasticity can lead to multiple equilibria. In other words, we would be evaluating the franchise value of the remaining deposits after a potential "partial" run by depositors—an inherently difficult empirical task. Such complex counterfactuals fall outside the scope of the empirical assessments we are focused on in this paper.

Our approach is instead simpler. Motivated by our framework in Section 3.3, we use several empirical measures of bank stability developed by Jiang et al. (2023), amended to incorporate the impact of credit losses, and evaluate them across different scenarios of uninsured depositor withdrawal behaviors.

First, we evaluate whether the marked-to-market value of assets is adequate to cover all non-equity liabilities (*Extreme Insolvency*). Second, we consider the *Insured Deposit Coverage Ratio*, which determines whether the remaining value of bank assets after a hypothetical withdrawal by uninsured depositors is sufficient to cover the face value of insured deposits. Third, we assess the impact of withdrawals by uninsured depositors on the reported bank *Capital Ratio*, recognizing that such withdrawals may necessitate the liquidation of a portion of bank assets at their market values, effectively leading to a decline in the equity value.

As we discuss below the assessments based on these measures implicitly incorporate the role of regulators, who play a central role in bank failures (Granja, Matvos, and Seru 2017).

3.4.1 Extreme Insolvency

We first assess whether the reduced (marked-to-market) value of bank assets, following higher rates defined in Section 3.1 and the losses due to CRE distress defined in Section 3.2, is sufficient to cover all non-equity bank liabilities. In other words, if all depositors and debtholders withdrew their funding today, could banks repay their debts? As noted by Jiang et al. (2023), this calculation may be considered extreme since it assumes no value in the banks' deposit franchise. However, it serves as a useful first benchmark for understanding the impact of higher interest rates and potential credit losses on the de facto capitalization of the U.S. banking sector.

3.4.2 Insured Deposit Coverage Ratio

The above bank stability measure may significantly overstate bank insolvency risk as banks primarily fund themselves with deposits so they could survive a given level of asset value declines if they can pay low rates on their deposits and their depositors do not flee. Moreover, insured depositors may have no incentives to run.

However, unlike insured depositors, uninsured depositors who account for about half ($9 trillion) of all bank deposits stand to lose a part of their deposits if the bank fails, potentially giving them incentives to run. Consequently, to assess this risk, we use the Jiang et al. (2023) *Insured Deposit Coverage Ratio* to analyze the bank ability to survive a given withdrawal by the uninsured depositors that also incorporates the bank asset losses due to commercial real estate distress in addition to the effect of higher rates. Specifically, for each bank *i*, we calculate its insured deposit coverage ratio as follows:

$$\text{Insured Deposit Coverage Ratio}(\mathrm{i}, \mathrm{s}, \mathrm{d}) =$$

$$\frac{\text{Mark-to-Market Assets}(\mathrm{i}) - \text{Credit Loss}(\mathrm{i}, \mathrm{d}) - \mathrm{s} \times \text{Uninsured Deposits}(\mathrm{i}) - \text{Insured Deposits}(\mathrm{i})}{\text{Insured Deposits}(\mathrm{i})}$$

In the above *Mark-to-Mark Assets* is the measure of the current value of bank assets (as of Q1 2024) that reflects higher interest rates (see Section 3.1 for more details). *Credit Loss due to CRE Distress* is the bank-level asset value loss due to a given CRE loan default rate (*d*) scenario as defined in Section 3.2. The *Insured Deposits* and *Uninsured Deposits* is the outstanding volume of bank insured and uninsured deposits, while *s* is a given rate of withdrawal of uninsured deposits.

As explained by Jiang et al. (2023), the above measure reflects the idea that insured depositors being impaired is the lower bar for the FDIC intervention. A negative value of this measure means that the remaining mark-to-market asset value accounting for higher interest rates and CRE distress – i.e., after paying uninsured depositors who withdraw their deposits – is not sufficient to repay the face value of all insured deposits. In this case such bank could be considered as insolvent.

3.4.3 Capital Ratio

Finally, we enhance the empirical solvency condition from Jiang et al. (2023), which focuses on reported equity capital, by incorporating credit losses. We assume that banks recognize their credit losses but consistent with findings in Granja et al. (2024) have leniency on whether to recognize the decline in the market value of their longer-duration assets due to higher interest rates. The capital ratio condition defined below reflects the perspective that reaching a negative value of book equity serves as the minimum threshold for regulatory intervention, although it is probable that regulators would intervene well before this scenario occurs. In this context withdrawals by uninsured depositors force banks to sell a portion of their assets at their market values, potentially leading to a decline in the reported equity value.

We construct this measure as follows:

$$\text{Capital Ratio}\ (s) =$$

$$\frac{\text{Book Equity} - \text{Credit Loss}(\text{i}, \text{d}) - \ \text{s} \times \text{Uninsured Deposits} \times \left(\frac{\text{Book Asset}}{\text{MTM Asset}} - 1\right)}{\text{Book Asset}}$$

where MTM Asset is the market value of assets. When the book value of assets equals their market value, $\frac{\text{Book Asset}}{\text{MTM Asset}} = 1$, uninsured deposit withdrawals do not affect the book value of equity. But when $\frac{\text{Book Asset}}{\text{MTM Asset}} > 1$, uninsured deposit withdrawals will reduce the reported book value of equity, as satisfying each dollar of withdrawal requires liquidating more than one dollar of the bank's book assets.[13] A negative value of the capital after a given withdrawal "s" indicates that the remaining book value of bank assets is less than the remaining face value of its non-equity liabilities. In this scenario, and in the absence of other policy interventions, the bank will fail.

[13] We assume that banks liquidate their assets in equal proportion to meet deposit withdrawals. A more refined version of this financial stability measure could consider the pecking order of liquidations.

The assessments based on our financial stability measures should be interpreted though the lens of our multiple equilibria model developed in Section 3.3. A negative value of our measures do not imply a bank fails, it only diagnoses that a bank can be susceptible to a run self-fulfilling solvency run equilibrium if uninsured depositors' panic. Because we do not have a good theory of the distribution of run sunspots, we cannot say with what probability such runs would occur at each bank. To assess the possibility of such insolvency at each bank we follow Jiang et al. (2023) and focus on two cases: (i) when half of uninsured depositors withdraw their funds at each bank (i.e., $s = 0.5$), and (ii) when all uninsured depositors withdraw their funds at each bank (i.e., $s = 1$).

4. CRE Distress, Higher Interest Rates, and US Bank Stability

In this section, we apply our methodology to evaluate the relative impact of commercial real estate (CRE) distress and rising interest rates on U.S. bank stability during the monetary tightening that began in Q1 2022. Using the composition of bank assets as of Q1 2022, we first assess bank stability as of Q1 2024, when the 10-year U.S. Treasury yield averaged 4.15%, a sharp increase from 1.95% in Q1 2022.

Next, we analyze the roles of CRE distress and higher interest rates in bank stability across the full range of interest rates observed during the tightening period (Q1 2022 to Q2 2024). This analysis quantifies potential monetary policy constraints stemming from bank instability.

It's important to note that our analysis does not account for policy interventions by regulators to stabilize the banking system, nor does it consider banks' strategic responses to rising interest rates and potential credit distress. Nevertheless, our framework provides market participants and policymakers with a tool to assess financial stability risks tied to banks' asset and liability distributions across various interest rate paths and adverse credit events. This insight could inform both private and public sector responses, including the conduct of monetary policy.

4.1 Magnitude of Bank Losses due to CRE Distress

We start our analysis by computing the asset value loss due to a given level of CRE distress at each bank. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans.

In Figure 1, we illustrate the aggregate bank losses in billions of dollars resulting from various degrees of CRE distress on banks' loan portfolios. At a 10% default rate, the direct losses on banks'

CRE loans relative to their book value amount to approximately $80 billion. If the default rate increases to 20%, these losses would double, reaching about $160 billion. It is noteworthy that these losses are an order of magnitude smaller than more than $2 trillion decline in the market value of bank assets just due to higher interest rates we obtain by extending Jiang et al. (2023) analysis to Q1:2024. The rationale behind this difference is straightforward: an increase in interest rates impacts all longer-duration assets on bank balance sheets (including U.S. Treasury holdings), irrespective of their credit risk. In contrast, the credit losses we consider only affect a portion of banks' CRE loans.

4.2 Impact on Bank Insolvency Risk

While the declines in bank asset values due to CRE distress may appear relatively manageable for the banking sector at first, there are at least couple of reasons why they could have sizable implications. First, recent increase in interest rates have significantly eroded bank's capital buffer. Extending the analysis of Jiang et al. (2023) to 2024:Q1 we find that after these declines more than half of US banks (2,610) accounting for $14 trillion of aggregate assets have negative capitalization assessing all bank non-equity liabilities at their face value. The additional losses due to CRE distress could thus further erode the remaining bank capital buffers, increasing the risk of runs by the uninsured depositors. Second, as Table 1 shows, smaller and mid-size regional banks have much higher exposure to the CRE loans. Hence additional decline in their asset values could put such banks in precarious position.

We start by quantifying the impact of CRE distress on banks' equity position by assessing whether the marked to market value of assets is sufficient to cover the face value of all non-equity liabilities as described in Section 3.4.1. In other words, if all depositors and debtholders were to withdraw their funding today, could banks repay their debts. This is akin to assuming that there is no value to banks' deposit franchise. This scenario is extreme, because insured depositors have no incentives to withdraw funds due to the risk of default. On the other hand, it is a useful benchmark to better understand the de facto capitalization of the U.S. banking sector.

Figure 2, panel (a), plots the distribution of the equity to asset ratio following this procedure for three cases. First, we show the density of equity to asset ratio given the bank equity as of 2022:Q1. Second, we show the mark-to-market equity to asset ratio that incorporates the value of asset declines following recent increase in interest rates by extending the analysis in Jiang et al. (2023)

to 2024:Q1. Finally, we show the equity to asset ratio that also incorporates losses from the CRE distress scenario assuming a 10% default rate on CRE loans and a 30% loss given default.

Prior to the interest rate increases, all the banks have sufficient capital buffer to withstand the CRE distress. Once we incorporate more than $2 trillion dollars decline in asset values following monetary tightening, the median US bank's capitalization becomes essentially zero (-0.1% of assets). The addition of losses due to CRE distress further shifts the distribution of equity to asset ratio towards lower values, and now median US bank has negative capitalization equal to -1.9% of mark-to market bank assets (including CRE losses).

Figure 2, panel (b), shows the corresponding distribution of equity to asset ratio across bank size for the three cases. The addition of losses due to CRE distress moves the distribution of equity to asset ratio further into negative territory with the most pronounced effect for mid-size banks. This is consistent with Table 1 that showed that such banks have the highest concentration of CRE loans (more than 30% of their assets).

These calculations suggest that, due to higher interest rates, a significant share of banks may be at a tipping point. Consequently, losses from commercial real estate (CRE) distress—though comprising a relatively small portion of bank assets and their pre-tightening book equity—could still cause a non-trivial number of banks to fall into a "negative equity" position.

To explore this further, Figure 3 analyzes how many U.S. banks would end up in a negative equity position under the given CRE distress scenario. We consider a range of default scenarios starting from 2% default rate to 20% default rate on the CRE loans. A bank has "negative equity" if its mark-to-market value of assets including losses due to CRE distress is below the face value of its non-equity liabilities. As the CRE loans default rate increases, a significant number of additional banks join the "negative equity". At 10% CRE loan default rate we have additional 217 banks with about $0.3 trillion of assets in negative equity position (Figure 3A and 3B). At 20% CRE distress, additional 441 banks with assets worth $0.9 trillion have negative equity relative to the no CRE distress baseline. Figure 3C shows the associated equity shortfall for these CRE distress scenarios.

As noted, these calculations of mark-to-market equity value are somewhat extreme because insured depositors may have no incentives to withdraw funds as a function of bank losses. Moreover, not all uninsured depositors may be prone to bank runs. As explained in Section 3.3.2, to consider such factors, we first use the *Insured Deposit Coverage Ratio*, a bank stability measure developed by Jiang et al. (2023), and expand it to include credit losses. We recall that this measure assesses whether the remaining mark-to-market value of assets of a given bank -- including both the effect of higher interest rates and losses due to CRE distress -- is large enough to cover the face value of its insured deposits after a given share of uninsured depositors withdraw their funds. The negative value of this ratio means that the bank would not be able to survive such withdrawal scenario. We focus on two cases: (i) when half of uninsured depositors withdraw their funds at each bank, and (ii) when all uninsured depositors withdraw their funds at each bank.

Figure 4, panel (a), shows the distribution of the ratio based on 2022:Q1 balance sheets and mark-to-market values assets, assuming 50% of uninsured depositors withdraw their money at each bank. Figure 4, panel (b) shows the corresponding distribution of the insured deposit coverage ratio across bank asset size. As can be observed, CRE distress further lowered the ratio relative, especially for smaller and midsize banks that have a large concentration of CRE loans.

Figure 5 shows the number of insolvent banks (panel a) and their assets in billions of dollars (panel b) due to a given CRE distress scenario. A bank is considered insolvent if the mark-to-market value of its assets – after paying half of all uninsured depositors -- is insufficient to repay all insured deposits. In other words, the bank is insolvent if its coverage ratio after 50% withdrawal of uninsured deposits is negative. Again, we consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans and quantify how many additional banks could fail due to CRE distress. These numbers are in addition to 545 US banks (aggregate assets of about $670 billion) that face insolvency risk solely due to their decline in marked-to-market asset values following a recent rise in interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1.

Not surprisingly, additional losses due to the CRE distress increase the number of banks at risk of insolvency. Where these insolvent banks reside in the size distribution is useful to consider. At 10% CRE loan default rate we compute there would be 52 additional insolvent banks with aggregate assets of about $30 billion if half of the uninsured depositors decide to withdraw their funds. At 20% CRE loan default rate, we compute this to be 116 additional insolvent banks with aggregate assets worth about $58 billion.

Panels (c) and (d) of Figures 4 and 5 show the corresponding analysis for the case when all uninsured depositors withdraw their funds at each bank. Again, not surprisingly, under this more extreme scenario, the additional losses due to the CRE distress significantly increase the number of insolvent banks. For instance, at 10% CRE loan default rate we compute there would be an additional 179 banks facing such insolvency risk with aggregate assets of about $305 billion. At 20% CRE loan default rate there would be 370 additional banks insolvent with aggregate assets of about $591 billion. This is in addition to 2,051 (with aggregate assets of about $10.2 trillion) that face such risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1.

Finally, we consider the capital ratio solvency condition defined in Section 3.3.3, which focuses on the bank's reported equity capital. This condition reflects the perspective that a negative book equity value represents the minimum threshold for regulatory intervention, although regulators are likely to act before this scenario occurs. Following Jiang et al. (2023), this measure emphasizes that uninsured leverage (i.e., Uninsured Debt/Assets), a metric developed by Jiang et al. (2020), is key to understanding whether declines in asset values due to higher rates could lead to insolvency for some banks in the U.S. Unlike insured depositors, uninsured depositors risk losing part of their deposits if the bank fails, which could incentivize them to withdraw their funds (see also Egan et al., 2017). In this context, the measure captures the idea that withdrawals by uninsured depositors force banks to sell a portion of their assets at market values, leading the bank to recognize some of its losses and resulting in a decline in reported equity value.

Figure 6, panel (a), shows the distribution of the capital ratio based on 2022:Q1 balance sheets and mark-to-market values assets, assuming 50% of uninsured depositors withdraw their money at each bank. Figure 6, panel (b), shows the corresponding distribution of the capital ratio across bank asset size. As can be observed, CRE distress further lowered the ratio relative, especially for smaller and midsize banks that have a large concentration of CRE loans.

Figure 7 shows the number of banks at risk of insolvency (panel a) and their assets in billions of dollars (panel b) due to a given CRE distress scenario. A bank is considered at risk of insolvency if its capital ratio– after paying half of all uninsured depositors -- is negative. Again, we consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans and quantify how many additional banks could fail due to CRE distress. These numbers are in addition to 38 U.S. banks, with aggregate assets of about $1 trillion, that face insolvency risk based on a negative capital ratio measure solely due to a decline in marked-to-market asset values following a recent rise in interest rates, as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1.

Again, observe that additional losses due to the CRE distress increase the number of banks at risk of insolvency. At 10% CRE loan default rate we compute there would be 9 additional insolvent banks with aggregate assets of about $5.4 billion if half of the uninsured depositors decide to withdraw their funds. At 20% CRE loan default rate, we compute this to be 31 additional insolvent banks with aggregate assets worth about $136 billion.

Panels (c) and (d) of Figures 6 and 7 show the corresponding analysis for the case when all uninsured depositors withdraw their funds at each bank. Again, under this more extreme scenario, the additional losses due to the CRE distress significantly increase the number of insolvent banks. For instance, at 10% CRE loan default rate we compute there would be an additional 71 banks facing such insolvency risk with aggregate assets of about $2 trillion. At 20% CRE loan default rate there would be 173 additional banks insolvent with aggregate assets of about $2.3 trillion. This is in addition to 303 US banks with about $5 trillion of assets that face such risk (have negative capital ratio measure) solely due to higher interest rates.

4.3 Robustness to Alternative Loss Estimation Method

As discussed in Section 3.1, our assessments of bank losses due to higher interest rates rely on the contractual maturities of loans and securities, which may differ from effective maturities that can be shorter due to prepayments. In this section, following Jiang et al. (2023), we reassess our results using a more conservative loss estimation method. This approach incorporates more conservative price declines by effectively assigning shorter-than-contractual maturities to real estate loans (see Section 4.3 for more details). Using this conservative loss estimate we find aggregate decline in bank asset values due to higher rates in the order of $1.2 trillion.

Although the conservative loss estimation method reduces the number of banks with a "negative equity" position, we still find 1,162 U.S. banks with approximately $2.2 trillion in assets facing this issue solely due to the recent rise in interest rates. Importantly, as Appendix A6 shows, even with this conservative loss estimate, CRE distress can result in an additional 292 banks with aggregate assets of 0.5 trillion (at a 10% default rate) to 622 banks with aggregate assets of 0.9 trillion (at a 20% default rate) joining the group of banks with negative equity.

Appendices A7 and A8 assess the potential for bank insolvency risk with a conservative loss estimate, based on the insured deposit coverage ratio and capital ratio financial stability measures, assuming a 100% withdrawal of uninsured deposits. Appendix A7 shows that CRE distress can lead to an additional 181 banks with aggregate assets of 250 billion (at a 10% default rate) to 375 banks with aggregate assets of 434 billion (at a 20% default rate) joining the group of banks with a negative insured deposit coverage ratio. These figures are in addition to the 693 U.S. banks with about $1.5 trillion in assets that already face such insolvency risk solely due to higher interest rates, as calculated by extending Jiang et al.'s (2023) analysis to Q1 2024 using the conservative loss estimate. Appendix A8 presents the corresponding results based on the capital ratio financial stability measure, indicating that CRE distress can result in an additional 13 small regional banks (at a 10% default rate) to 38 banks with aggregate assets of 0.3 trillion (at a 20% default rate) joining the group of banks with a negative capital ratio.

Overall, using this more conservative method, we still observe that commercial real estate distress can put a significant number of primarily smaller regional banks at risk of insolvency.

4.4 Monetary Policy Constraints due to Bank Instability

We conclude by examining the roles of CRE distress and rising interest rates in bank stability over the entire range of interest rates during the tightening period (Q1 2022 to Q2 2024). This analysis helps assess potential monetary policy constraints arising from bank instability.

Panel (a) of Figure 8 shows the relationship between the 10-year U.S. Treasury yield and the number of U.S. banks projected to be in a "negative equity" position based on the extreme insolvency metric (i.e., when the market value of bank assets is less than their non-equity liabilities). Panel (b) displays the aggregate assets of these banks in trillions of dollars. These figures are based on the composition of bank assets as of Q1 2022, using the mark-to-market methodology from Jiang et al. (2023) across the monetary tightening cycle from Q2:2022 to Q2:2024. Each point on the curve corresponds to a specific realization of the 10-year yield, considering long-term bond prices across maturities. The "No CRE Distress" scenario isolates the impact of higher rates on bank insolvency risk, assuming no CRE loan defaults. The "CRE 10% Distress" and "CRE 20% Distress" scenarios incorporate 10% and 20% CRE loan default rates, respectively, with a 30% loss given default. The first dot marks the average 10-year yield during the decade preceding the 2022 tightening, while the second marks the average yield on March 10, 2023, the day Silicon Valley Bank failed.

As we observed, when the 10-year yield was around 2%, there was minimal risk to bank stability, even under our extreme insolvency measure. Nearly all banks had assets valued higher than their non-equity liabilities, including both insured and uninsured deposits. Importantly, this held true even in a severe 20% CRE distress scenario, suggesting that when rates were low, banks were sufficiently capitalized to withstand significant credit stress. This likely explains the limited number of bank failures during the 2012-2022 period, when the 10-year yield averaged 2%.

However, as interest rates rose and surpassed 2.5%, we observed an increasing number of banks at risk based on our extreme insolvency measure. Consistent with our earlier findings, once rates exceed this threshold—particularly above 3%—CRE distress begins to significantly impact the number of banks at risk of failure. Appendix A9 shows similar calculations using a conservative loss estimation method, where bank risks start to materialize once the 10-year yield crosses approximately 3%. At higher interest rates, CRE distress has a pronounced effect on bank stability. For example, at a 4% interest rate, nearly 1,000 banks with $1.5 trillion in assets are at risk of failure under our conservative method. Adding a 20% CRE distress scenario puts an additional 500 banks, with about $1 trillion in assets, at risk.

As we discussed, these calculations may overstate the actual risk to banks, as insured depositors and some uninsured depositors may have little incentive to withdraw. To account for this, Figures 9 and 10 provide the same analysis using our insured deposit coverage ratio and capital ratio measures, assuming a 50% withdrawal by uninsured depositors. From both figures, we observe that significant bank risks emerge once the 10-year yield crosses around 3%, and especially as it approaches 4%. This likely explains the timing of the SVB run in March 2023, when interest rates reached that level. Consistent with our previous analysis, we find that CRE distress meaningfully increases the number of banks at risk only when interest rates reach sufficiently high levels.

5. Discussion and Conclusion

In this section, we conclude our analysis and discuss several key implications. First, we explore additional potential effects of CRE distress. Second, we analyze how banks report credit risk, providing suggestive evidence that some may have concealed losses through "extend-and-pretend" strategies. Finally, we consider the implications of our findings for monetary policy, financial regulation, and risk supervision.

Broader Effects of CRE Distress

Our analysis suggests that CRE distress could put dozens to over 300 smaller regional banks at risk of solvency runs. Notably, our estimates may represent a lower bound for the potential impact of credit distress in the U.S. banking system. First, we focus solely on CRE distress, without considering potential issues in other loan categories, though our methodology can easily be extended to include them. Second, our calculations assume bank assets remain liquid; even small fire sales triggered by uninsured deposit withdrawals would significantly increase the number of banks at risk. Third, regional banks play a vital role in lending to local businesses, and their distress could lead to a credit crunch, with spillover effects on the real economy that we do not account for here. Finally, and perhaps most critically, news of CRE defaults and banking losses could trigger widespread runs by uninsured depositors, unraveling the already fragile equilibrium in the banking system.

Bank Reporting of Credit Risk and Extend and Pretend

Despite elevated risk in the commercial real estate (CRE) sector, the bank-reported share of non-performing CRE loans has not shown a corresponding upward trend as of Q2 2024 (Appendix A10). Historically, defaults on both bank loans and CMBS loans have closely tracked each other, peaking at around 10% during the Great Recession (Trepp data and Appendix A4). However, during the current period, there is a significant discrepancy between these rates, with bank loans showing only a modest increase in delinquencies—around 1.4% in Q2 2024—compared to 5.4% for CMBS loans (Appendix A4). This raises the question: Why haven't significant CRE losses materialized for banks?

One possibility is that bank loans today are of significantly better quality than CMBS loans. However, analyzing this is difficult due to the lack of comprehensive performance data on bank loans. Some studies with limited data suggest that bank loans may have slightly better observable risk characteristics (Glancy et al., 2022). Second, banks may have stronger incentives to restructure loans at risk of foreclosure compared to securitized loans, as seen with residential loans during the Great Recession (Piskorski, Seru, Vig, 2010). Third, banks may be concealing losses through "extend and pretend" strategies.

In the analysis below, we find evidence suggesting that banks, particularly those with higher solvency run risks (Jiang et al., 2024) and those under more lenient state regulators (Agarwal et al., 2014), are engaging in "extend-and-pretend" practices. [14] The fact that this analysis focuses on the bank sample, with the effects being more pronounced among weaker, leniently supervised banks, suggests that differences in renegotiation or restructuring efforts alone are unlikely to fully explain these findings.

We first empirically examine whether banks' incentives for extend-and-pretend increased following the rise in interest rates in Q1 2022. Given the highly regulated nature of the banking sector, we would expect more instances of extend-and-pretend when supervision is less strict. In the U.S., banks are supervised by different regulatory agencies based on their charter type. Federally chartered banks are always overseen by federal regulators, while state-chartered banks are supervised alternately by state and federal regulators. For state-chartered non-member banks (NMBs), supervision rotates between state regulators and the FDIC, while state member banks (SMBs) of the Federal Reserve System are supervised by both state regulators and the Federal Reserve. [15] As shown by Agarwal et al. (2014), federal regulators tend to be tougher than state regulators. Our empirical analysis leverages this variation by using banks supervised by federal regulators as a control group, comparing their reported share of non-performing CRE loans over time with those regulated by state authorities.

We estimate the following dynamic difference-in-differences (DiD) regression using bank-quarter observations from 2021Q1 to 2024Q2:

$$NonPerforming\%_{i,t} = \sum_k \beta_k I(t=k) StateCharter_i + X_{i,t}\Gamma + \mu_i + \nu_t + \epsilon_{i,t}$$

$NonPerforming\%_{i,t}$ is the non-performing share of outstanding CRE loans held by bank i in quarter t. $I(t=k)$ is a date indicator. $StateCharter_i$ indicates whether bank i is a state- or federal-chartered bank. $X_{i,t}$ controls for the dynamic asset size effect: we calculate the average log asset

[14] Extend-and-pretend, also known as zombie lending, occurs when banks continue lending to economically distressed borrowers to avoid recognizing losses. This often involves extending the loan's maturity, which can be value-enhancing if it gives borrowers time for market conditions to improve. However, banks may have distorted incentives to engage in this practice, as recognizing losses would erode their equity capital, potentially triggering regulatory constraints or solvency runs (Jiang et al. 2023). This incentive is likely to be stronger in a high-interest rate environment, especially for banks more vulnerable to solvency risks.

[15] For a detailed discussion on the alternating examination policy for state-chartered banks, see Agarwal et al. (2014).

values for each bank during our sample period and interact it with date indicators. μ_i and ν_t are bank fixed effects and time fixed effects, respectively. We estimate this specification separately for banks with above-median MTM capital ratios ("more capitalized banks") and those with below-median MTM capital ratios ("less capitalized banks"), based on their classification as of Q1 2022. In our main analysis, we calculate the MTM ratios assuming that all uninsured depositors run. For robustness, we explore an alternative scenario in the Appendix.

As shown in Figure 11, less capitalized state-chartered banks reported significantly lower non-performing shares of outstanding CRE loans compared to less capitalized federally chartered banks following the rise in interest rates in Q1 2022. This gap widened in 2023, reaching over 0.3 percentage points by Q2 2024. In contrast, there was no significant difference in the time-series trend of reported non-performing CRE loan shares between more capitalized state- and federally chartered banks. These findings support the hypothesis that less capitalized banks under more lenient supervision are more likely to engage in extend-and-pretend practices to avoid recognizing losses.

In Figure 12, we separately examine the practices of SMBs and NMBs relative to that of federal-chartered banks. Panel (a) and (b) of Figure 12 show that as of Q2 2024, the non-performing share of CRE loans reported by less capitalized NMBs is 0.34 percentage-points lower than that reported by less capitalized federal-chartered banks, while the non-performing share reported by less capitalized SMBs is only 0.16 percentage-points lower than that reported by less capitalized federal-chartered banks. Again, there is no significant difference in the time-series evolvement of the reported non-performing CRE loan shares among more capitalized banks. This suggests that banks supervised in rotation by state regulators and the Federal Reserve may be facing more stringent oversight compared to those rotating between state regulators and the FDIC (see also Agarwal et al., 2014).

Overall, this analysis suggests that riskier banks operating under more lenient regulatory regimes may be concealing the deterioration of their commercial real estate (CRE) loan portfolios. These findings are consistent with Granja et al. (2024), who showed that banks at higher risk of solvency runs were also more likely to hide long-duration asset losses due to rising interest rates by reclassifying those assets as hold-to-maturity.

Implications for Monetary Policy, Financial Regulation, and Risk Supervision

Our findings have important implications for monetary policy pass-through, bank risk supervision, and financial stability. Our analysis suggests that, given the current composition of bank assets, rising interest rates pose a significantly greater risk to banks than potential distress in the commercial real estate sector. In this context, a substantial decline in interest rates could largely mitigate the impact of CRE distress on bank stability. This fragility of the U.S. banking system to higher interest rates could constrain the implementation of monetary policy, potentially hindering its ability to achieve price stability objectives.

Our analysis also suggests that as long as interest rates remain elevated, the U.S. banking system will face a prolonged period of significant insolvency risk. In the near term, the creation of the Bank Term Funding Program in March 2023, along with other policy responses to recent banking vulnerabilities, may temporarily pause the crisis and reduce the risk of acute deposit runs. However, these are short-term measures that do not address the fundamental insolvency risk identified by Jiang et al. (2023), which, as we demonstrate, would be exacerbated by CRE distress for a substantial number of banks. As Granja et al. (2024) demonstrate, bank equity holders may be reluctant to eliminate run risk by recapitalizing or insuring against interest rate risk, even if the bank's equity value remains positive in a favorable equilibrium (e.g., due to a high deposit franchise value). Therefore, a near-term solution to reduce bank insolvency risk could involve a mandated, market-based recapitalization of the U.S. banking system, as suggested by DeMarzo et al. (2023).

In the long term, a regulatory response to the crisis could involve heightened oversight of the U.S. banking system. Regulators could adopt our methodology, including the financial stability measure, to stress test the system under a combined scenario of rising interest rates and credit distress, factoring in the composition of both bank assets and liabilities. This approach would help assess insolvency risks related to potential uninsured depositor runs. Additionally, more granular regulatory data, including stricter disclosure standards on banks' interest rate exposure and their true credit risk—particularly where banks may attempt to conceal losses—would be beneficial.

It is important to note that our analysis does not account for potential policy interventions by regulators to stabilize the banking system, nor does it consider banks' strategic responses to rising interest rates and credit distress. However, our analysis offers market participants and policymakers a framework for assessing financial stability risks based on the distribution of assets and liabilities across banks, along with potential interest rate trajectories and adverse credit events.

This insight could serve as a valuable tool for both private and public sector responses, including the formulation of monetary policy. [16]

Finally, banks may face stricter capital requirements, aligning their capital ratios more closely with those of less regulated non-bank lenders, which hold over twice the capital buffers of banks (see Jiang et al. 2020). Larger capital buffers could improve the banking system's resilience to shocks from both interest rate increases and credit distress. Importantly, any such analysis should consider the industrial organization of the financial intermediation market and its broader effects on credit market equilibrium, moving beyond the traditional bank balance sheet model (Buchak et al. 2018, 2023, 2024a, 2024b; Jiang et al. 2020; Xiao 2020; Hachem and Song 2021; Jiang 2023).

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[16] Such response could also consider reallocation of capital in the banking system (e.g., Anderson, Hachem, Zhang 2021). In this regard our analysis could help identify weaker banks in need of capital injections.

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Table 1: Commercial Real Estate (CRE) Loans as a Share of Bank Assets

The top panel of the table shows aggregate statistics of FDIC-insured banks in the United States as of the beginning of 2022 for their total assets and total book value of their commercial real estate loans, all in trillions of dollars. The bottom panel of the table presents the statistics about banks' commercial real estate loans as a share of total assets. Column (1) shows these statistics for all the banks, Column (2) for small banks, Column (3) for large and non-systemically important banks (non-GSIB), and Column (4) for systemically important banks (GSIB banks). Bank size is based on the reported bank asset value as of Q1 2022. Small banks have assets less than \$1.384 billion, the Community Reinvestment Act asset size thresholds for large banks. Large (non-GSIB) banks have assets greater than or equal to \$1.384 billion. GSIB banks are classified according to bank regulators' definition as of Q1 2022. We also assign GSIB status to U.S. chartered banks affiliated with holding companies that are classified as GSIB. *Data Sources:* Bank Call Reports.

	(1)	(2)	(3)	(4)
	All Banks	Small <1.384B	Large (non-GSIB) [1.384B,]	GSIB
Aggregate Assets	24T	1.4T	6.2T	16.4T
Aggregate Commercial Real Estate Loans	2.7T	419.3B	1.5T	774.9B
Commercial Real Estate Loans/Asset (%)				
Mean	25.7	24.9	31.5	5.0
Standard Deviation	14.3	13.9	14.3	7.2
P5	2.6	2.9	3.4	0.0
P25	15.3	14.8	22.8	0.0
P50	25.1	23.9	32.2	2.8
P75	35.3	34.2	40.4	8.0
P95	49.9	48.8	54.1	17.0
Number of banks	4,844	4,090	710	44

Table 2: Assessing Distress Risk of Commercial Real Estate Loans

In this analysis, we evaluate the distress risk associated with commercial real estate loans, focusing on a sample of 35,253 loans totaling $825 billion in aggregate principal balance from the CMBS market. These loans, drawn from the outstanding CMBS loans as of December 2023, were obtained from the DBRS Morningstar CMBS database. This comprehensive database encompasses historical loan performance data for the entire CMBS market, spanning back to 1998 and including both DBRS-rated and non-DBRS-rated transactions. The statistics provided cover all loans in the sample, with a specific focus on office loans, constituting 19.2% of the outstanding loans. In Panel (a), we present the estimated current Loan-to-Value (LTV) of these loans and the percentage of loans in a state of "negative equity." Column (2) of Panel A displays the average loan balance, as reported in the data, while Column (3) showcases the average initial LTV of these loans. Column (4) presents our calculated average current LTV, derived from the current balance reported in the data divided by the current assessed property value. This current LTV is computed by indexing the initial property value to the regional property price from its origination date until December 2023, utilizing the Green Street Advisors' index, which factors in the property location (MSA) and property type (e.g., office, multifamily, etc.). In instances where such an index is unavailable for a given loan at a given location, we utilized the average property price evolution. Column (5) highlights the percentage of loans with an estimated average current LTV exceeding 80%, a common maximum threshold for loan origination by senior loan lenders. Furthermore, Column (6) indicates the percentage of loans in a state of "negative equity," defined as situations where the current loan balance is more than the current assessed property value, resulting in an estimated LTV exceeding 100%.

Panel A: Current LTV and Percentage of Loans in "Negative Equity"

	Sample Share	Average Loan Balance	Average Initial LTV	Average Current LTV	% with Current LTV>80%	% with Current LTV>100%
	(1)	(2)	(3)	(4)	(5)	(6)
All Loans	100%	$24.1M	61.0%	66.2%	29.0%	14.3%
Office Loans	19.2%	$40.6M	54.4%	86.0%	56.0%	44.6%

Table 2: Assessing Distress Risk of Commercial Real Estate Loans [continued]

Column (1) of Panel (b) displays the average current (“legacy”) interest rate of these loans. Column (2) shows the current market interest rates for new 10-year maturity fixed-rate commercial real estate loans, obtained from the Cushman & Wakefield Capital Markets Survey, assuming borrower qualification for such loans. Notably, current rates are significantly higher due to a recent substantial increase in the 10-Year Treasury benchmark rate following 2022 monetary tightening and an uptick in credit spreads. In Panel (c), our attention shifts to the current Debt Service Coverage Ratio (DSCR) of these loans and the hypothetical DSCR after potential refinancing at the current benchmark rate. Column (1) reveals the average initial DSCR of these loans, as reported in the data, defined as annual property net cash flow divided by its annual debt service. Column (2) shows the average current DSCR of these loans as reported in the data. Column (3) presents our estimated hypothetical average DSCR of these loans if they were to refinance to the current benchmark interest rates, as reported in Column (2) of Panel (b). In this calculation we adjust for property type, the loan’s current balance, and the current reported property net cash flow, assuming a new loan with 10-year maturity and 25-year amortization term. Column (4) highlights the percentage of loans with a current DSCR less than 1, indicating a situation where the property net cash flow is insufficient to cover the property debt payments. Column (5) indicates the percentage of loans that would have a hypothetical DSCR less than 1 if loans were to be refinanced at the benchmark rate. Column (6) shows the percentage of loans that would have a hypothetical Debt Service Coverage Ratio (DSCR) below 1.2—a common minimum threshold for standard refinancing—if the loans were refinanced at the benchmark rate. Column (7) displays the percentage of loans that either have a current LTV ratio greater than 80%, as calculated in panel (a), or a DSCR below 1.2 after hypothetical refinancing at the benchmark rate. Loans with a DSCR below 1.2 and an LTV above 80% would typically be excluded from the regular refinance market. Lastly, Column (8) showcases the percentage of loans with both a current LTV greater than 100%, as computed in Panel A, and a hypothetical DSCR after refinance at the benchmark rate less than 1.

Panel B: Current CRE Mortgage Rates after Hypothetical Refinance at Benchmark Rate

	Average “Legacy” Mortgage Rate	Average “Benchmark” Refinance Mortgage Rate
	(1)	(2)
All Loans	3.97%	6.71%
Office Loans	3.96%	7.42%

Panel C: Current Debt Service Coverage Ratio (DSCR) and Hypothetical DSCR after Refinance

	Average Initial DSCR	Average Current DSCR	Average DSCR at “Benchmark” Rate	% with Current DSCR<1	% with DSCR<1 at Benchmark Rate	% with DSCR<1.2 at Benchmark Rate	% with LTV>80% & DSCR<1.2 at Benchmark Rate	% with LTV>100% & DSCR<1 at Benchmark Rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All Loans	2.3	1.7	1.2	6.4%	17.2%	30.7%	42.8%	4.5%
Office Loans	2.7	2.0	1.2	6.6%	24.3%	40.6%	64.4%	14.4%

Figure 1: Aggregate Bank Losses across CRE Distress Scenarios

This figure shows the aggregate bank losses in billions of dollars resulting from a given level of CRE distress on banks' loan portfolios. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. We assume that in the case of default the banks can recover about 70% of outstanding face value of their loans, which is in line with the historical data. We note that at 10% default rate the direct losses on banks' CRE loans relative to their book value amount to about \$80 billion. At a higher 20% default rate, these losses would double and reach about \$160 billion. *Data Sources:* Bank Call Reports.

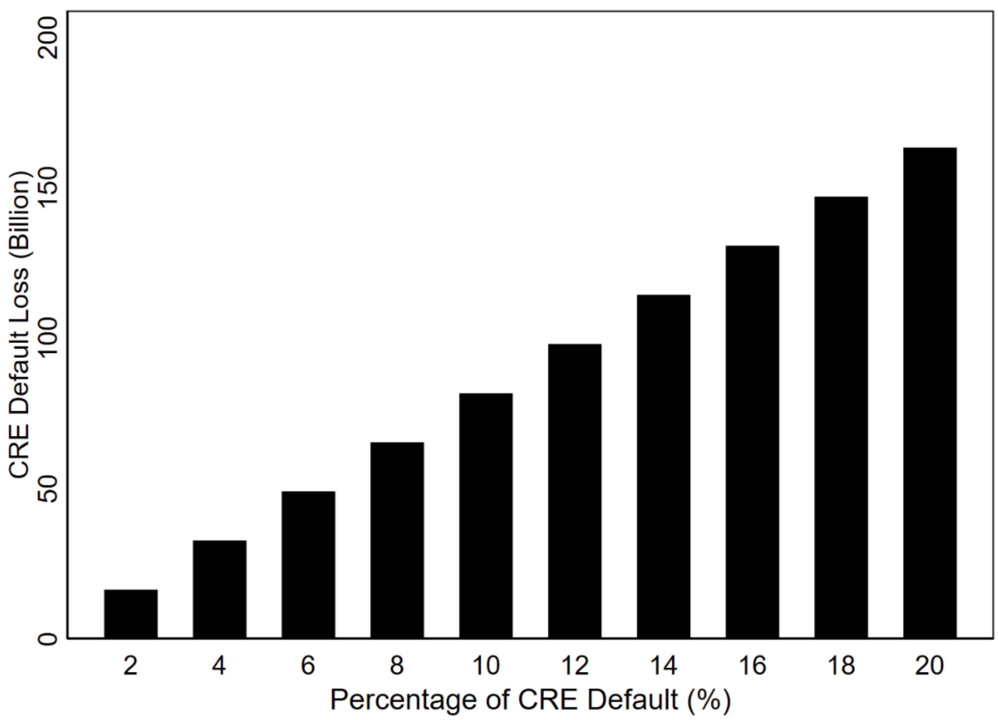
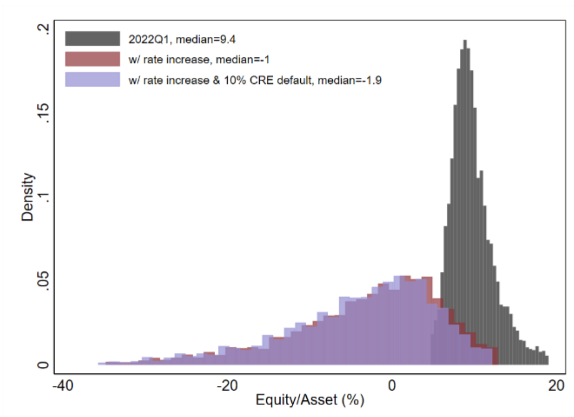
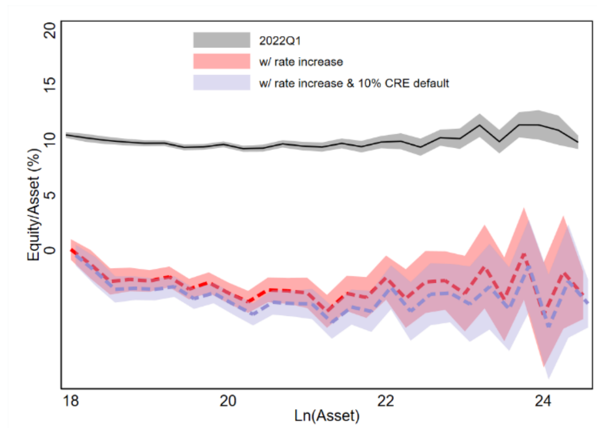


Figure 2: Distribution of Change in Equity Value with 10% CRE Distress

Panel (a) of this figure plots the histograms (density) of the equity to asset ratio, valuing all non-equity bank liabilities at its face value. The equity to asset ratio is plotted for three cases. First, we show the density of equity to asset ratio given the bank equity position as of 2022:Q1. Second, we show the mark-to-market equity to asset ratio as of 2024:Q1 that incorporates the value of asset declines following recent increase in interest rates by extending the calculation in Jiang et al. (2023). Finally, we show the equity to asset ratio that in addition to these asset declines also incorporates losses from the CRE distress scenario assuming 10% default rate on commercial loans at each bank and a 30% loss given default expressed as the percentage of outstanding loan balance. Panel (b) shows the corresponding distribution of equity to asset ratio across bank size for the three cases. We remove outliers by trimming the sample at the 1st and 95th percentiles. *Data Sources*: Bank Call Reports.



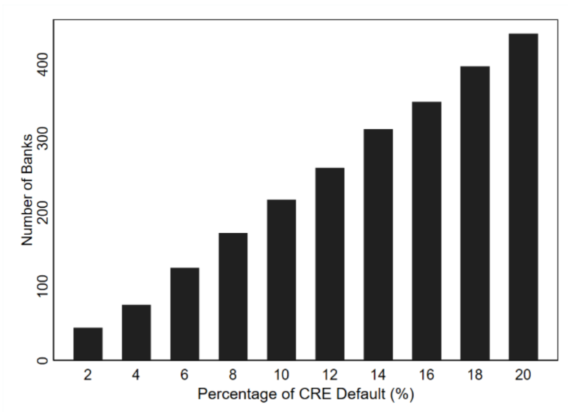
(a) Histogram



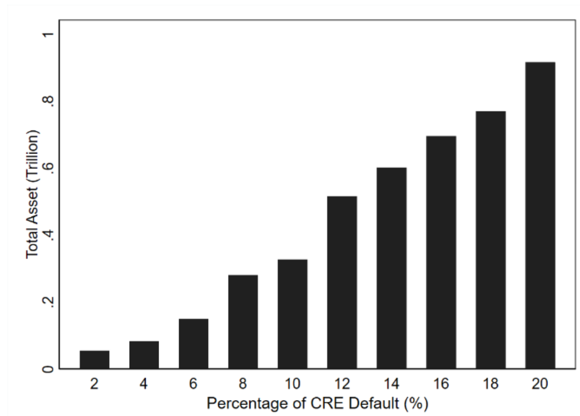
(b) Size

Figure 3: Impact of CRE Distress on Number of Banks with "Negative Equity"

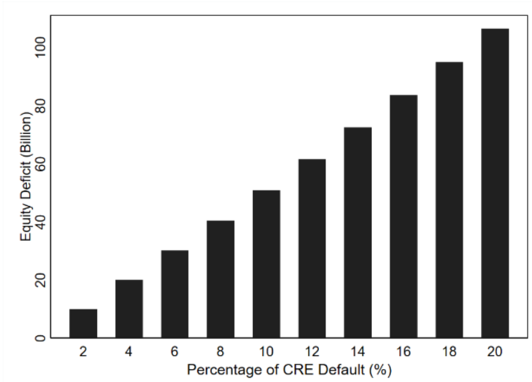
This figure shows how many US banks would end up in the negative equity position due to a given scenario for the CRE distress. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. The bank is in "negative equity" position if its mark-to-market value of assets including losses due to defaults on CRE loans is below the face value of its non-equity liabilities. We note that the numbers shown in this figure are in addition to 2,610 US banks with about $14 trillion of assets that have entered the negative equity position due to their decline in marked-to-market asset values following a recent rise in interest rates by extending the calculation in Jiang et al. (2023) to Q1:2024. Panel (a) shows the additional number of banks that enter this "negative equity" group for each of the CRE loans default scenario as compared to the baseline scenario of no CRE distress. Panel (b) shows the aggregate assets of these banks. Panel (c) shows the equity shortfall of these banks. *Data Sources*: Bank Call Reports.



(a) Number of Banks with "Negative Equity"



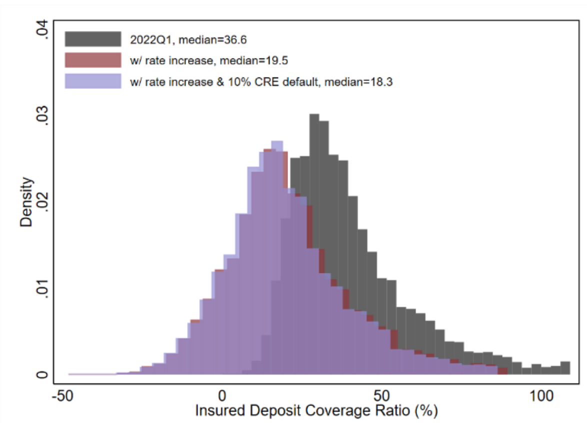
(b) Assets of Banks with Negative Equity



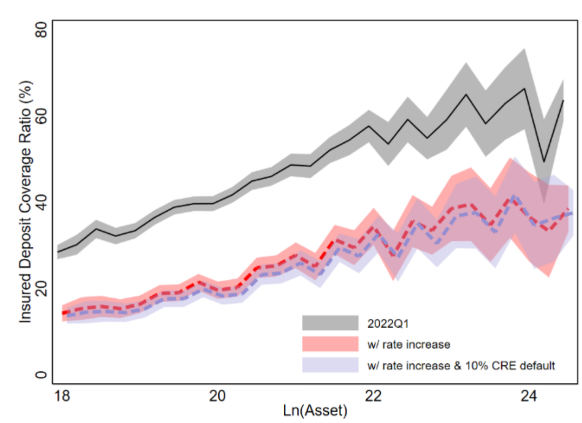
(c) Equity Deficit

Figure 4: Distribution of the Insured Deposit Coverage Ratio
(50% and 100% Uninsured Depositors Run & 10% CRE Loan Default Rate)

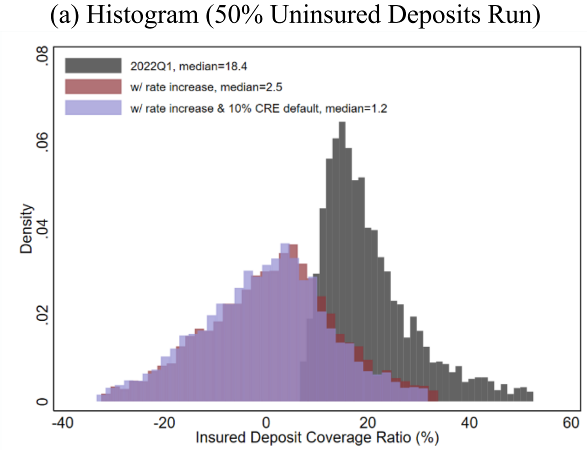
Panel (a) of this figure plots the histograms (density) of the *Insured Deposit Coverage Ratio* calculated based on 2022:Q1 balance sheets and mark-to-market values assets assuming 50% of uninsured depositors withdraw their money at each bank. Panel (b) shows the corresponding distribution of the ratio across bank asset size. We consider three cases. First, we show the ratio given the bank equity position as of 2022:Q1. Second, we present the ratio as of 2024:Q1, taking into account the reductions in the value of banks' assets resulting from the recent rise in interest rates. This calculation extends the analysis in Jiang et al. (2023) to 2024:Q1. Finally, we show the ratio that in addition to these asset declines also incorporates losses from the CRE distress scenario assuming 10% default rate on CRE loans at each bank and a 30% loss given default. We remove outliers by trimming the sample at the 95th percentile. Panel (c) and (d) show the corresponding results assuming 100% of uninsured depositors withdraw their money at each bank. *Data Sources*: Bank Call Reports.



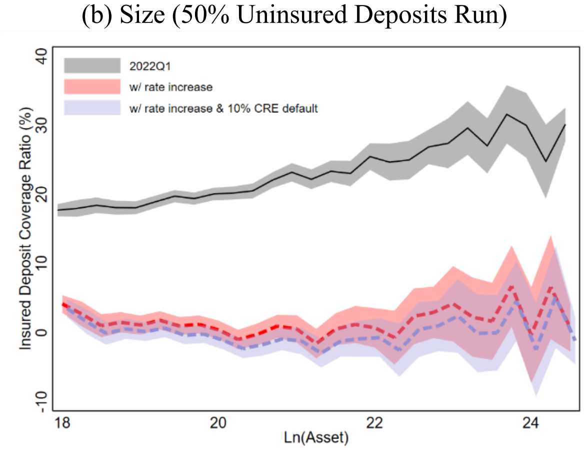
(a) Histogram (50% Uninsured Deposits Run)



(b) Size (50% Uninsured Deposits Run)



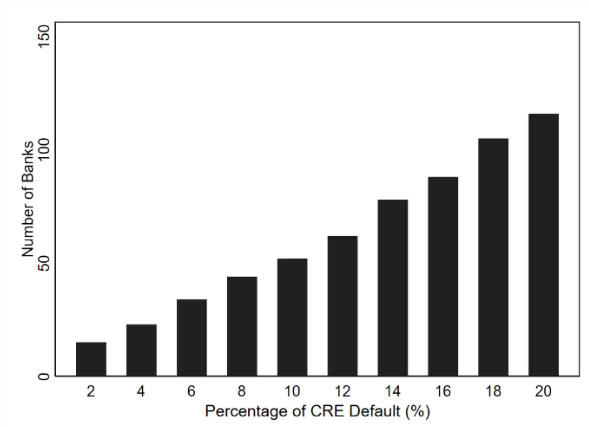
(c) Histogram (100% Uninsured Run)



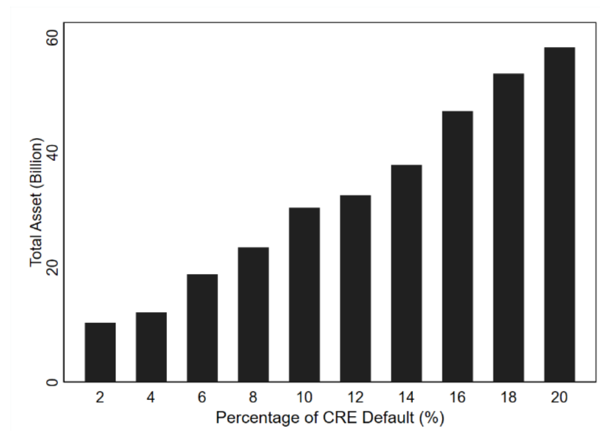
(d) Size (100% Uninsured Run)

Figure 5: Impact of CRE Distress on Number of Insolvent Banks based on the Insured Deposit Coverage Ratio (50% and 100% Uninsured Depositors Run)

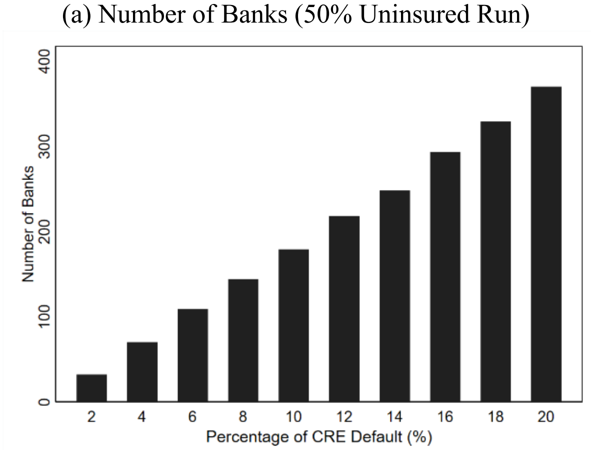
Panel (a) of this figure shows how many US banks would end up insolvent due to a given scenario for the CRE distress if half of uninsured depositors withdrew their money at each bank. Panel (b) shows the aggregate assets of these insolvent banks in each CRE distress scenario (in billions of dollars). We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. A bank is considered insolvent if its insured deposit coverage ratio is negative meaning that the mark-to-market value of its assets including losses due to CRE distress – after paying half of all uninsured depositors -- is insufficient to repay all insured deposits. We note that the numbers shown in this panel are in addition to 545 US banks with about $674 billion of assets that face such insolvency risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1. Panel (c) and (d) show the corresponding results assuming 100% of uninsured depositors withdraw their money at each bank. The numbers shown in these panels are in addition to 2,051 US banks with about $10.2 trillion of assets that face such insolvency risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1. *Data Sources*: Bank Call Reports.



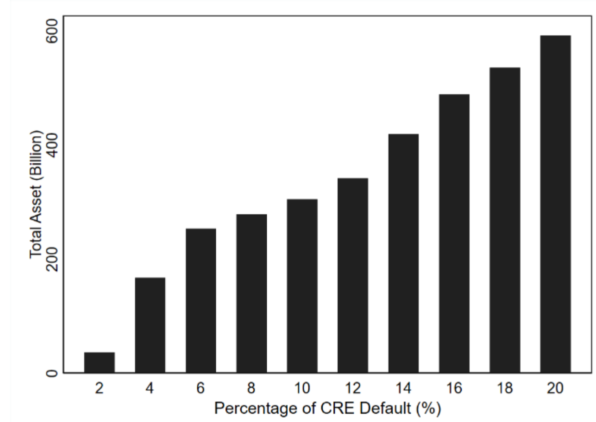
(a) Number of Banks (50% Uninsured Run)



(b) Assets (50% Uninsured Run)



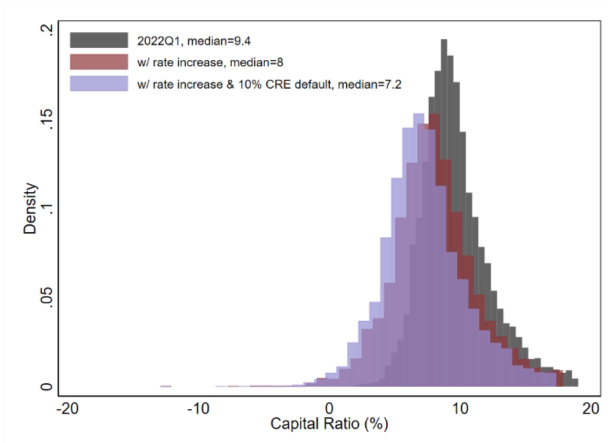
(c) Number of Banks (100% Uninsured Run)



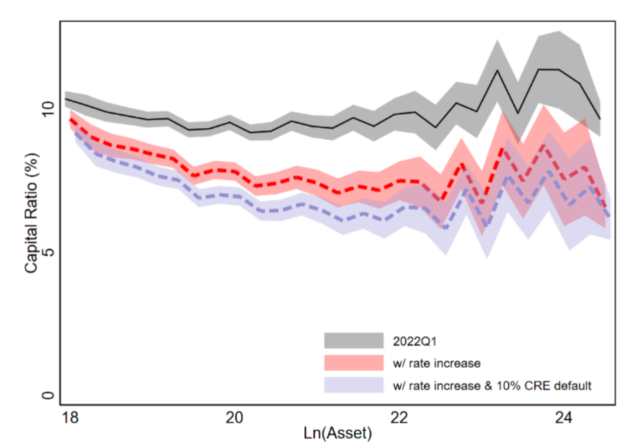
(d) Assets (100% Uninsured Run)

Figure 6: Distribution of the Capital Ratio
(50% and 100% Uninsured Depositors Run & 10% CRE Loan Default Rate)

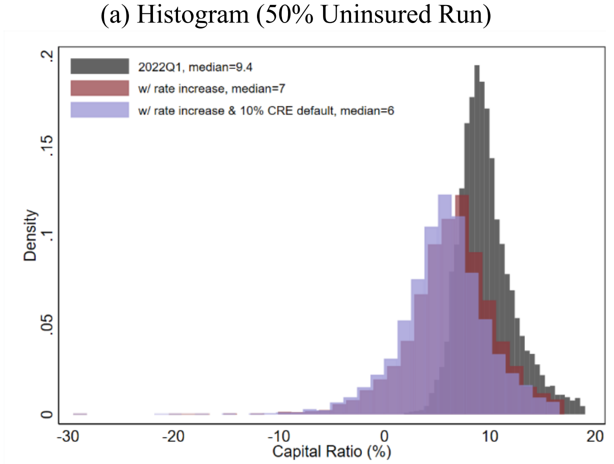
Panel (a) of this figure plots the histograms (density) of the *Capital Ratio* calculated based on 2022:Q1 balance sheets and mark-to-market values assets assuming 50% of uninsured depositors withdraw their money at each bank. Panel (b) shows the corresponding distribution of the ratio across bank asset size. We consider three cases. First, we show the ratio given the bank equity position as of 2022:Q1. Second, we present the ratio as of 2024:Q1, taking into account the reductions in the value of banks' assets resulting from the recent rise in interest rates. This calculation extends the analysis in Jiang et al. (2023) to 2024:Q1. Finally, we show the ratio that in addition to these asset declines also incorporates losses from the CRE distress scenario assuming 10% default rate on CRE loans at each bank and a 30% loss given default. We remove outliers by trimming the sample at the 95th percentile. Panel (c) and (d) show the corresponding results assuming 100% of uninsured depositors withdraw their money at each bank. *Data Sources*: Bank Call Reports.



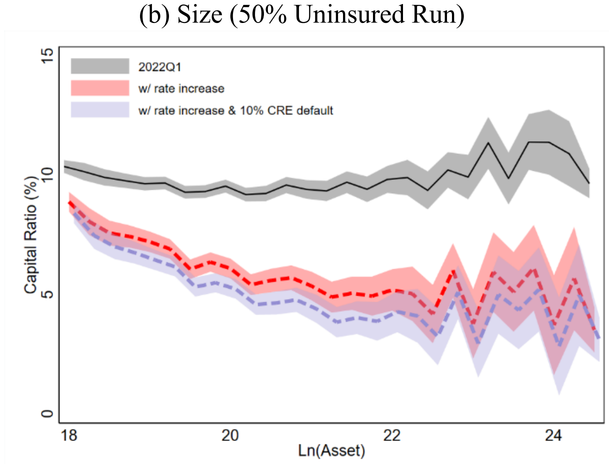
(a) Histogram (50% Uninsured Run)



(b) Size (50% Uninsured Run)



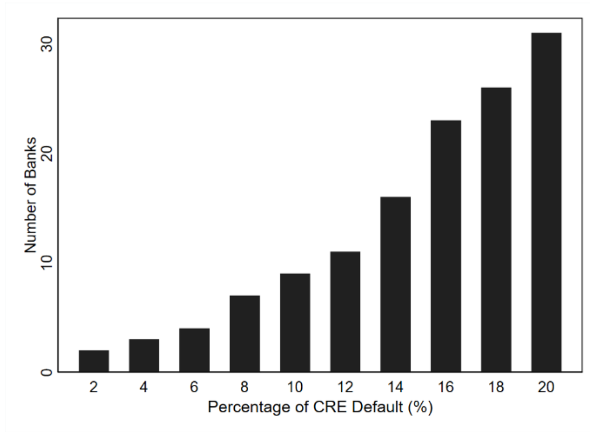
(c) Histogram (100% Uninsured Run)



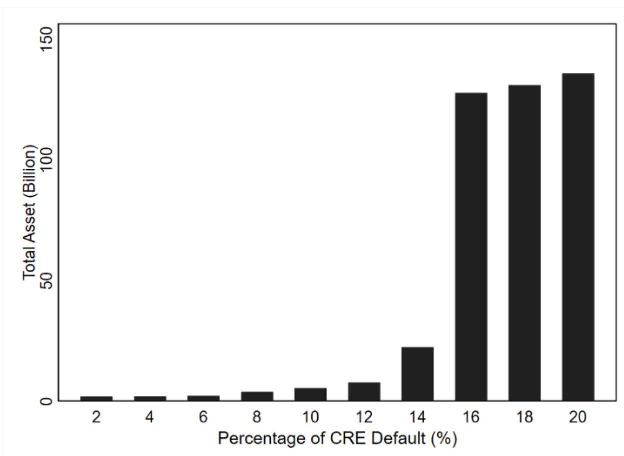
(d) Size (100% Uninsured Run)

Figure 7: Impact of CRE Distress on Number of Insolvent Banks based on the Capital Ratio (50% and 100% Uninsured Depositors Run)

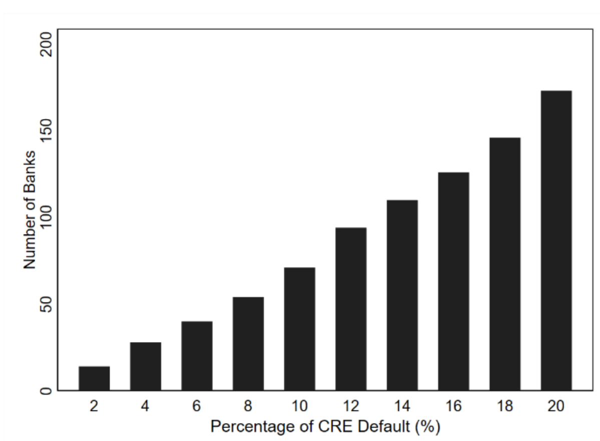
Panel (a) of this figure shows how many US banks would end up insolvent due to a given scenario for the CRE distress if half of uninsured depositors withdrew their money at each bank. Panel (b) shows the aggregate assets of these insolvent banks in each CRE distress scenario (in billions of dollars). We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. A bank is considered insolvent if its capital ratio metric is negative, after given withdrawal by uninsured depositors. We note that the numbers shown in this figure are in addition to 38 US banks with about $991 billion of assets that face such insolvency risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1. Panel (c) and (d) show the corresponding results assuming 100% of uninsured depositors withdraw their money at each bank. The numbers shown in these panels are in addition to 303 US banks with about $5 trillion of assets that face such insolvency risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1. *Data Sources*: Bank Call Reports.



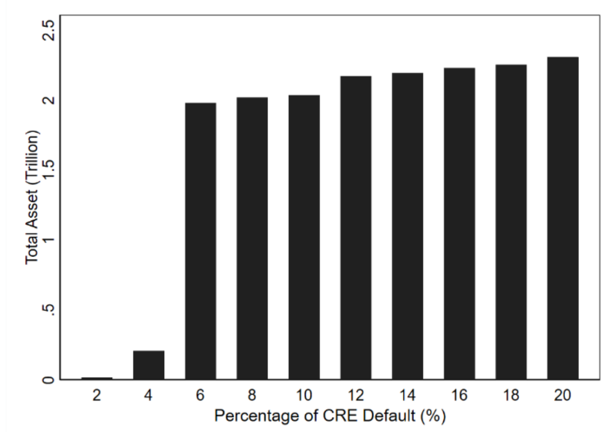
(a) Number of Banks (50% Uninsured Run)



(b) Assets (50% Uninsured Run)



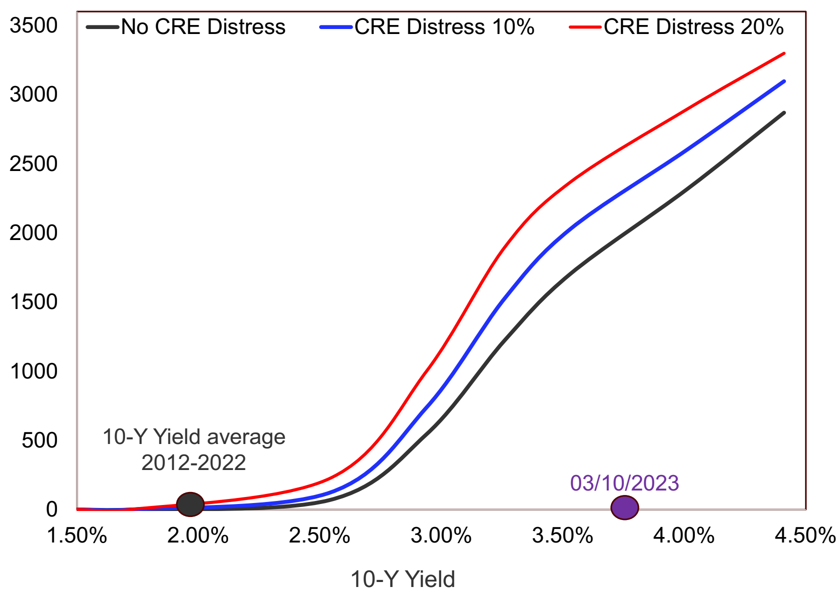
(c) Number of Banks (100% Uninsured Run)



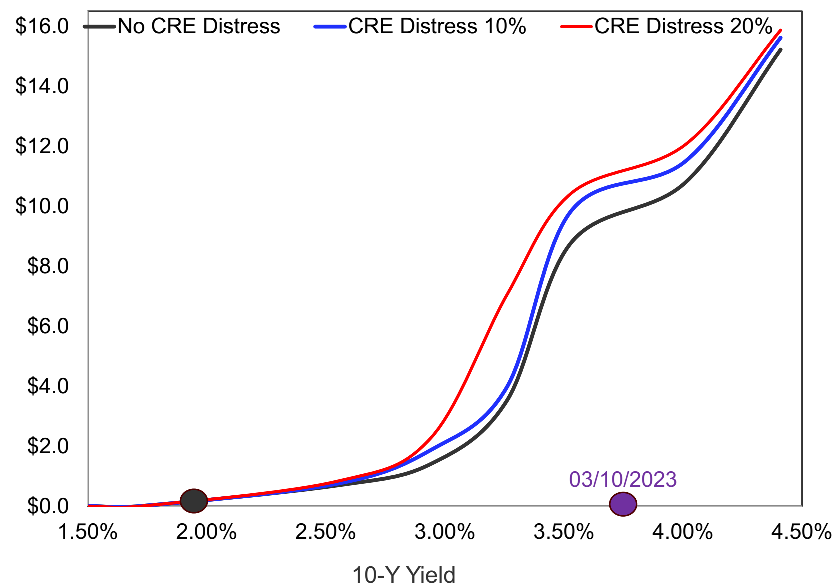
(d) Assets (100% Uninsured Run)

Figure 8: Monetary Policy Constraint due to Bank Financial Instability based on Extreme Insolvency Metric

Panel (a) of this figure shows the relationship between the 10-Year US Treasury Yield and the number of US banks projected to be in a "negative equity" position based on the extreme insolvency financial stability metric (i.e., when the market value of bank assets is less than the face value of their non-equity liabilities). Panel (b) displays the aggregate assets of these banks in trillions of dollars. These figures are generated by taking the composition of bank assets as of Q1 2022 and applying the marked-to-marked calculations in Jiang et al. (2023) throughout the monetary policy tightening cycle from Q2:2022 to Q2:2024. Each value plotted on the curve corresponds to a specific realization of the 10-Year yield during this period, considering the associated prices of long-term bonds across various maturities. The "No CRE Distress" scenario illustrates the impact of higher interest rates on the number of banks at risk of insolvency, assuming no defaults on bank CRE loans. The "CRE 10% Distress" scenario adds losses based on a 10% default rate on CRE loans at each bank, with a 30% loss given default. Similarly, the "CRE 20% Distress" scenario incorporates a 20% default rate on CRE loans at each bank, also with a 30% loss given default. The first dot marks the average 10-Year yield during the decade preceding the monetary tightening of 2022, while the second dot indicates the average 10-Year yield on March 10, 2023—the day the Silicon Valley Bank failed due to a bank run. *Data Sources*: Bank Call Reports.



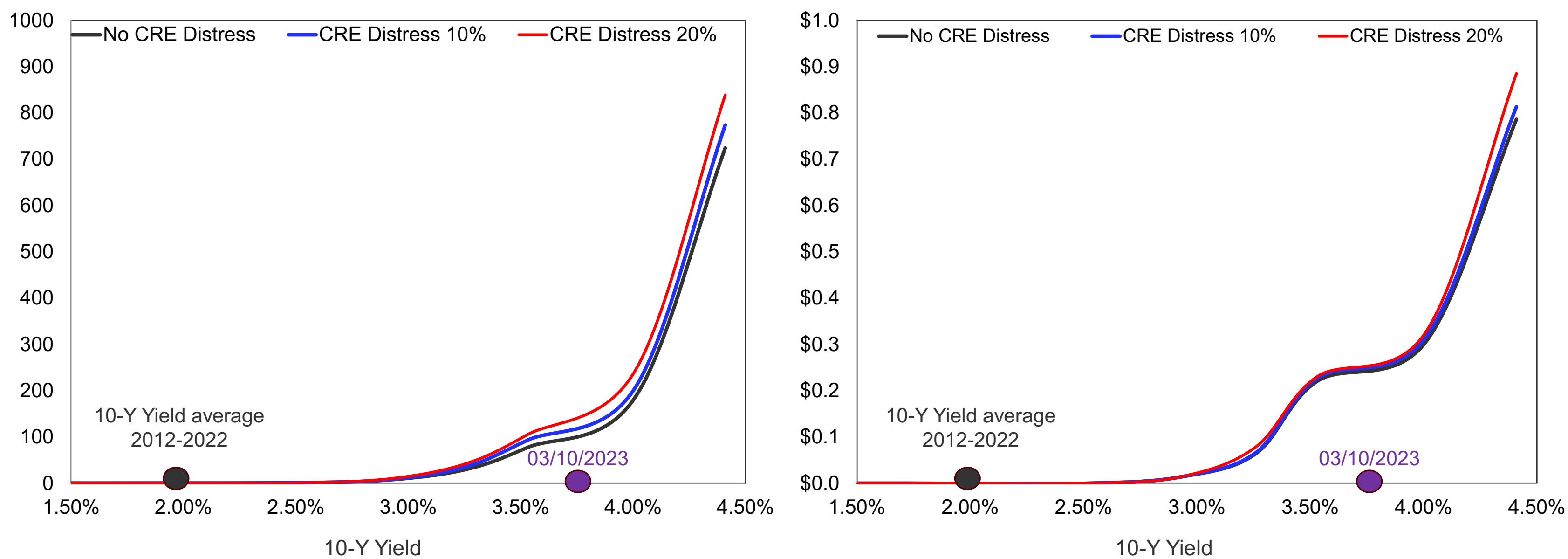
(a) Number of Banks at Insolvency Risk



(b) Assets of Banks at Insolvency Risk (in $Tn)

Figure 9: Monetary Policy Constraint due to Bank Financial Instability based on the Insured Deposit Coverage Ratio Metric (50% Uninsured Depositors Run)

Panel (a) of this figure shows the relationship between the 10-Year US Treasury Yield and the number of US banks that would become insolvent based on the insured deposit coverage ratio metric, assuming a 50% withdrawal of uninsured deposits at each bank. A bank is considered insolvent if its insured deposit coverage ratio is negative, meaning that the mark-to-market value of its assets, including losses due to CRE distress—after paying half of all uninsured depositors—is insufficient to repay all insured deposits. Panel (b) displays the aggregate assets of these banks in trillions of dollars. These figures are generated by taking the composition of bank assets as of Q1 2022 and applying the marked-to-marked calculations in Jiang et al. (2023) throughout the monetary policy tightening cycle from Q2:2022 to Q2:2024. Each value plotted on the curve corresponds to a specific realization of the 10-Year yield during this period, considering the associated prices of long-term bonds across various maturities. The “No CRE Distress” scenario illustrates the impact of higher interest rates on the number of banks at risk of insolvency, assuming no defaults on bank CRE loans. The “CRE 10% Distress” scenario adds losses based on a 10% default rate on CRE loans at each bank, with a 30% loss given default. Similarly, the “CRE 20% Distress” scenario incorporates a 20% default rate on CRE loans at each bank, also with a 30% loss given default. The first dot marks the average 10-Year yield during the decade preceding the monetary tightening of 2022, while the second dot indicates the average 10-Year yield on March 10, 2023—the day the Silicon Valley Bank failed due to a bank run. *Data Sources*: Bank Call Reports.

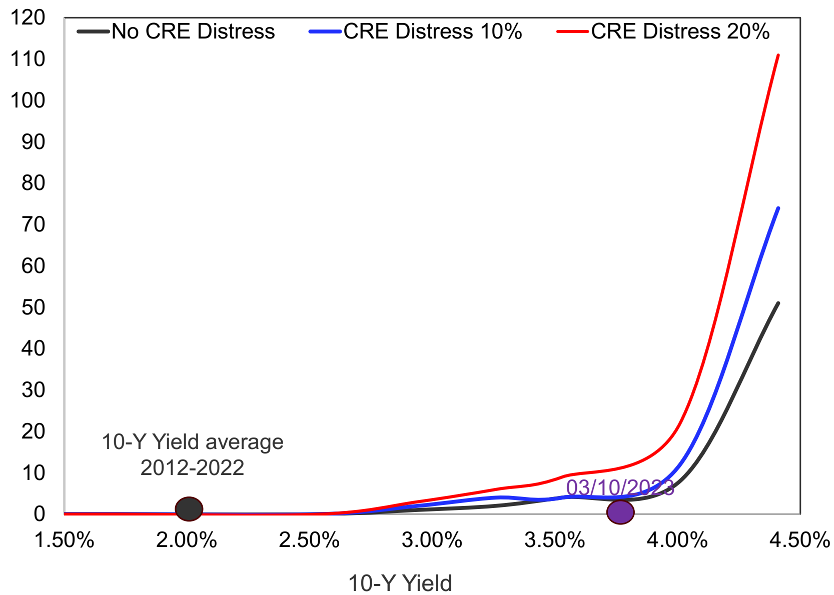


(a) Number of Banks at Insolvency Risk

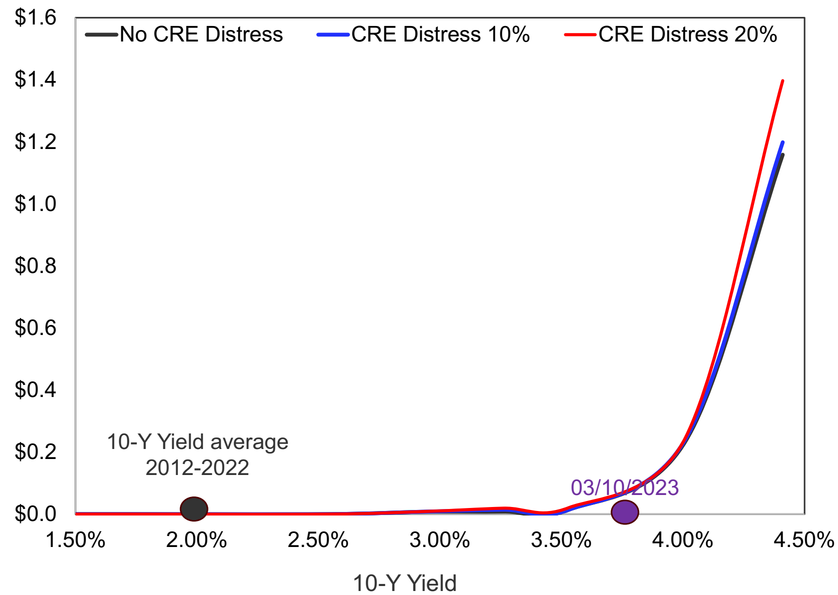
(b) Assets of Banks at Insolvency Risk (in $Tn)

Figure 10: Monetary Policy Constraint due to Bank Financial Instability based on the Capital Ratio Metric (50% Uninsured Depositors Run)

Panel (a) of this figure shows the relationship between the 10-Year US Treasury Yield and the number of US banks that would become insolvent based on the capital ratio metric, assuming a 50% withdrawal of uninsured deposits at each bank. A bank is considered insolvent if its capital ratio metric is negative, after paying half of all uninsured depositors. Panel (b) displays the aggregate assets of these banks in trillions of dollars. These figures are generated by taking the composition of bank assets as of Q1 2022 and applying the marked-to-marked calculations in Jiang et al. (2023) throughout the monetary policy tightening cycle from Q2:2022 to Q2:2024. Each value plotted on the curve corresponds to a specific realization of the 10-Year yield during this period, considering the associated prices of long-term bonds across various maturities. The "No CRE Distress" scenario illustrates the impact of higher interest rates on the number of banks at risk of insolvency, assuming no defaults on bank CRE loans. The "CRE 10% Distress" scenario adds losses based on a 10% default rate on CRE loans at each bank, with a 30% loss given default. Similarly, the "CRE 20% Distress" scenario incorporates a 20% default rate on CRE loans at each bank, also with a 30% loss given default. The first dot marks the average 10-Year yield during the decade preceding the monetary tightening of 2022, while the second dot indicates the average 10-Year yield on March 10, 2023—the day the Silicon Valley Bank failed due to a bank run. *Data Sources*: Bank Call Reports.



(a) Number of Banks at Insolvency Risk



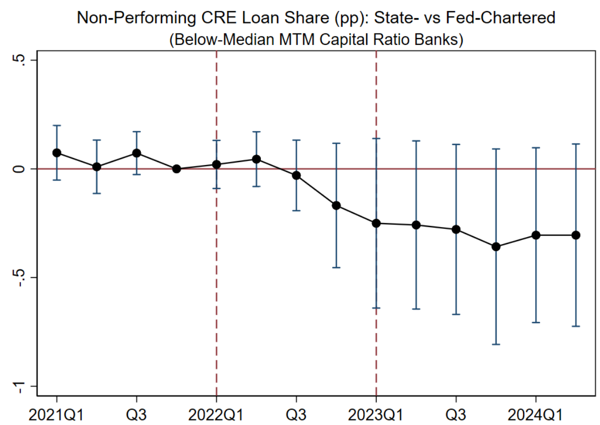
(b) Assets of Banks at Insolvency Risk (in $Tn)

Figure 11: Reported Non-Performing CRE Loans: State- vs Federal-Chartered

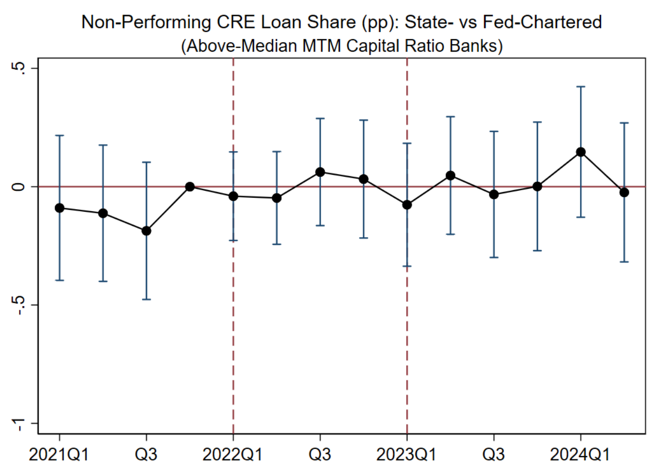
This figure reports the estimated β_k coefficients in the following dynamic difference-in-differences regression:

$$NonPerforming\%_{i,t} = \sum_k \beta_k I(t=k) StateCharter_i + X_{i,t}\Gamma + \mu_i + \nu_t + \epsilon_{i,t}$$

The outcome variable is the non-performing CRE loan ratio, calculated as total non-performing CRE loans reported by bank i divided by its total CRE loans. $I(t=k)$ is a date indicator. $StateCharter_i$ indicates whether bank i is a state- or federal-chartered bank. $X_{i,t}$ controls for the dynamic asset size effect: we calculate the average log asset values for each bank during our sample period and interact it with $Post_t$. μ_i and ν_t are bank fixed effects and time fixed effects, respectively. We divide the full sample of banks into two subsamples based on their MTM capital ratios under 100% uninsured depositor run. Panel (a) uses the subsample of banks with the ratios below the sample median (*Low* Capital Ratio banks). Panel B uses the subsample of banks with the ratios above the sample median (*High* Capital Ratio banks). Standard errors are clustered at the bank level. Vertical bars indicate 95% confidence intervals. The two dashed vertical lines indicate the onset of the recent monetary tightening (2022Q1) and the quarter of SVB failure (2023Q1).



(a) Low Capital Ratio Banks



(c) High Capital Ratio Banks

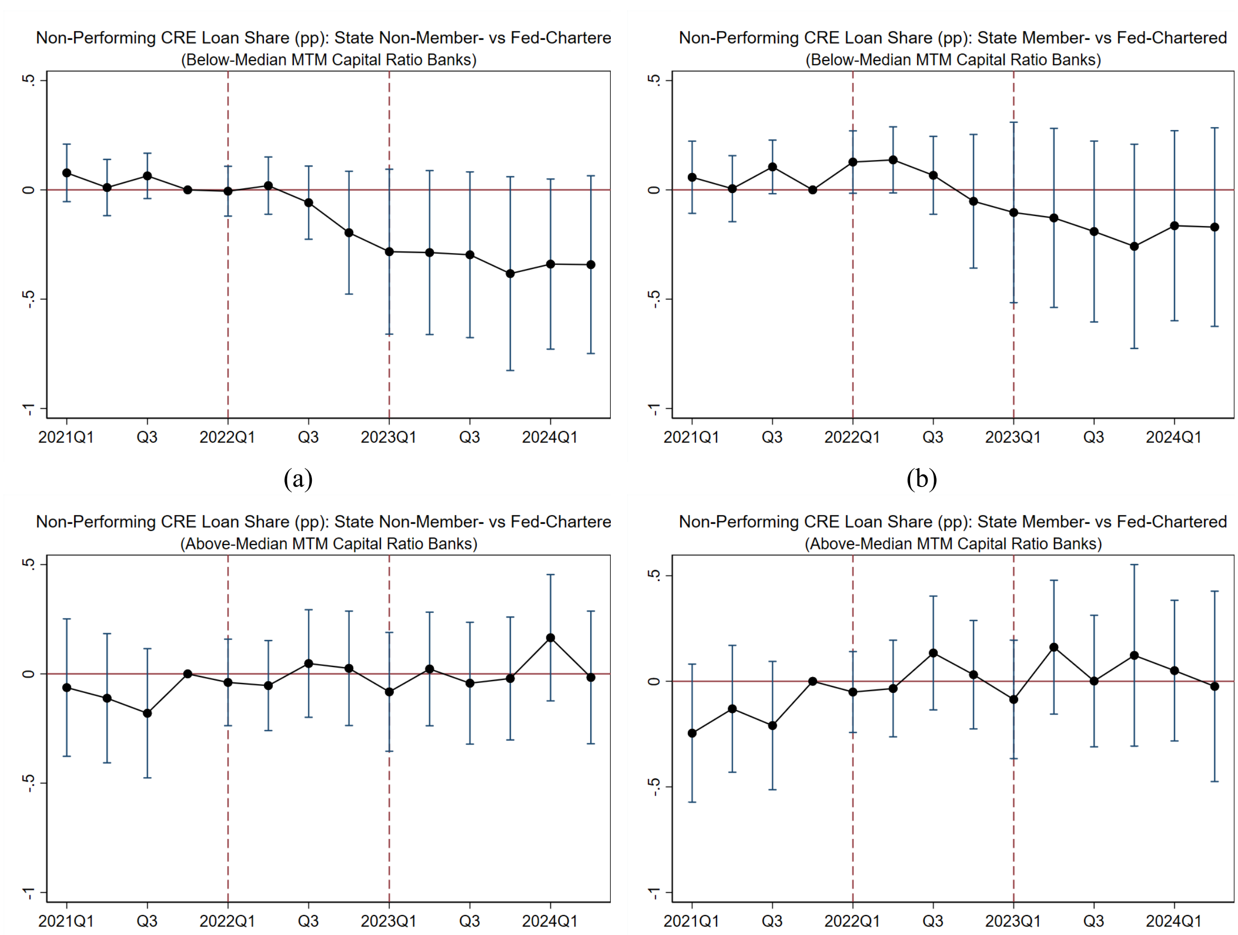
Figure 12: Reported Non-Performing CRE Loans: State-Chartered Non-Member vs Member Bank

This figure reports the estimated β_k coefficients in the following dynamic difference-in-differences regression:

$$NonPerforming\%_{i,t} = \sum_k \beta_k I(t=k) NMB_i + X_{i,t}\Gamma + \mu_i + \nu_t + \epsilon_{i,t} \text{ (Panel (a) and (c))}$$

$$NonPerforming\%_{i,t} = \sum_k \beta_k I(t=k) SMB_i + X_{i,t}\Gamma + \mu_i + \nu_t + \epsilon_{i,t} \text{ (Panel (b) and (d))}$$

The outcome variable is the non-performing CRE loan ratio, calculated as total non-performing CRE loans reported by bank i divided by its total CRE loans. $I(t=k)$ is a date indicator. NMB_i indicates whether bank i is a state-chartered non-member bank (NMB) or a federal-chartered bank. SMB_i indicates whether bank i is a state-chartered member bank (SMB) or a federal-chartered bank. $X_{i,t}$ controls for the dynamic asset size effect: we calculate the average log asset values for each bank during our sample period and interact it with $Post_t$. μ_i and ν_t are bank fixed effects and time fixed effects, respectively. We divide the full sample of banks into two subsamples based on their MTM capital ratios under 100% uninsured depositor run. Panel (a) and (c) use the subsample of NMB- or federal-chartered banks with the ratios below the sample median (*Low* Capital Ratio banks). Panel (b) and (d) use the subsample of SMB- or federal-chartered banks with the ratios above the sample median (*High* Capital Ratio banks). Standard errors are clustered at the bank level. Vertical bars indicate 95% confidence intervals. The two dashed vertical lines indicate the onset of the recent monetary tightening (2022Q1) and the quarter of SVB failure (2023Q1).



(a) (b) (c) (d)

Appendix A1: Bank Balance Sheets

This table reports the bank asset composition (Panel A) and liability and equity composition (Panel B) as of Q1 2022. 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 a 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 an 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 Q1 2022. We also assign GSIB status to U.S. 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 5th and 95th percentiles. Numbers in parentheses are standard deviations. *Data sources:* Bank call reports.

Panel A: Bank Asset Composition, Q1 2022

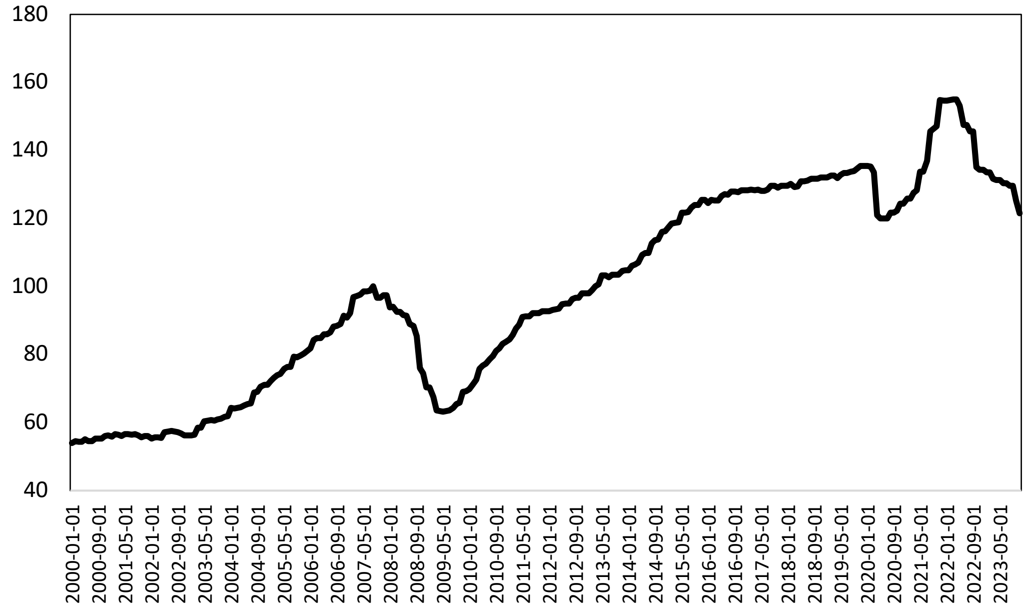
	(1) Aggregate	(2) Full Sample	(3) Small (0,1.384B)	(4) Large (non-GSIB) [1.384B,)	(5) GSIB
Total Asset $	24T	5.0B	0.3B	8.7B	370B
		(74.7B)	(0.3B)	(18.8B)	(690B)
Number of Banks	4,844	4,844	4090	710	44
(Percentage of Asset)					
Cash	14.1	13.1	13.6	10.0	19.4
		(9.8)	(10.0)	(7.9)	(11.8)
Security	25.2	23.9	24.3	21.5	19.3
		(15.7)	(16.1)	(13.0)	(15.8)
Treasury	6.1	2.6	2.7	2.1	4.0
		(4.1)	(4.2)	(3.3)	(4.3)
RMBS	12.1	3.1	2.5	6.5	7.9
		(4.6)	(4.1)	(5.6)	(6.8)
CMBS	2.3	0.9	0.7	1.6	1.9
		(1.6)	(1.5)	(1.9)	(2.2)
ABS	2.7	0.8	0.8	1.3	1.4
		(1.6)	(1.5)	(1.7)	(2.1)
Other Security	2.1	14.9	16.2	8.0	0.7
		(12.7)	(13.0)	(8.4)	(2.2)
Total Loan	46.6	55.7	54.7	62.0	46.5
		(15.6)	(15.6)	(13.6)	(18.3)
Real Estate Loan	21.9	41.9	41.4	45.8	19.2
		(16.7)	(16.7)	(15.8)	(13.5)
Residential Mortgage	10.6	15.5	15.9	13.8	10.5
		(11.7)	(11.8)	(10.5)	(11.1)
Commercial Mortgage	2.2	2.1	1.8	3.7	0.9
		(2.5)	(2.4)	(2.8)	(1.4)
Other Real Estate Loan	9.1	23.0	22.6	26.3	5.1
		(11.9)	(11.8)	(11.6)	(5.8)
Agricultural Loan	0.3	2.6	2.9	0.7	0.1
		(4.1)	(4.3)	(1.8)	(0.3)
Commercial & Industrial Loan	9.0	6.9	6.6	9.1	7.1
		(5.2)	(5.0)	(6.0)	(7.3)
Consumer Loan	7.7	2.2	2.2	2.1	5.1
		(2.5)	(2.3)	(2.9)	(4.1)
Loan to Non-Depository	2.8	0.1	0.0	0.2	0.4
		(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, Q1 2022

	(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	89.1
		(3.2)	(3.3)	(2.7)	(4.0)
Domestic Deposit	76.6	86.8	87.1	85.9	81.4
		(5.3)	(5.2)	(5.0)	(7.4)
Insured Deposit	41.1	62.7	64.5	52.9	49.3
		(12.3)	(11.5)	(11.9)	(15.5)
Uninsured Deposit	37.4	23.3	21.6	32.1	30.0
		(11.3)	(10.4)	(11.4)	(15.4)
Uninsured Time Deposits	1.8	3.6	3.8	3.0	1.6
		(3.0)	(3.0)	(2.6)	(3.1)
Uninsured Long-Term Time Deposits	0.4	0.8	0.9	0.6	0.3
		(1.0)	(1.0)	(0.7)	(0.8)
Uninsured Short-Term Time Deposits	1.3	2.6	2.7	2.3	1.1
		(2.4)	(2.4)	(2.1)	(2.0)
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	0.2
		(0.7)	(0.7)	(0.9)	(0.5)
Other Liability	2.3	2.3	2.1	2.9	4.6
		(2.8)	(2.7)	(2.7)	(3.4)
Total Equity	9.5	10.2	10.2	10.1	10.9
		(3.2)	(3.3)	(2.7)	(4.0)
Common Stock	0.2	0.4	0.4	0.3	0.2
		(0.6)	(0.6)	(0.6)	(0.6)
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	4.8
		(4.0)	(4.1)	(3.1)	(3.4)

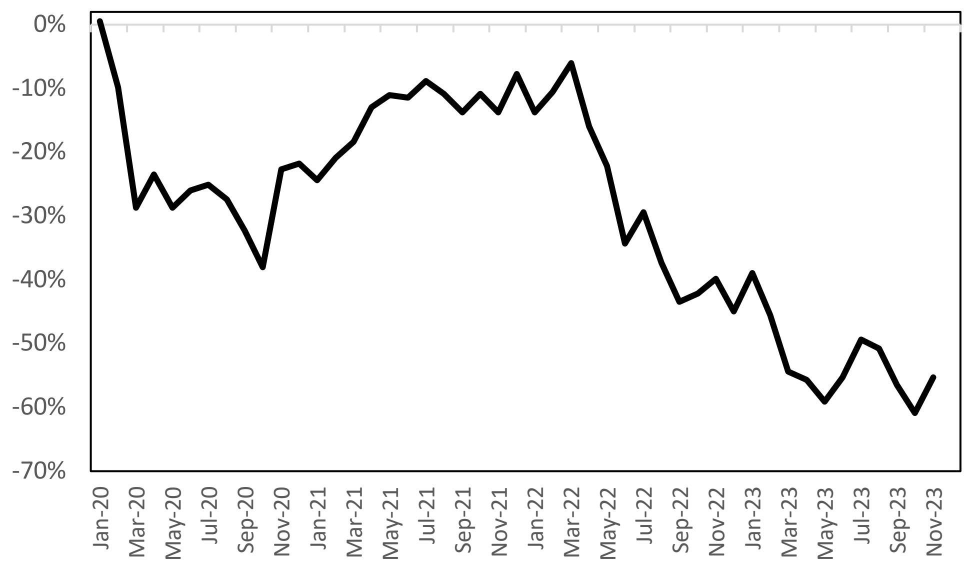
Appendix A2: Commercial Property Price Index

This plot shows the evolution of national Commercial Property Price Index from the Green Street Advisors.

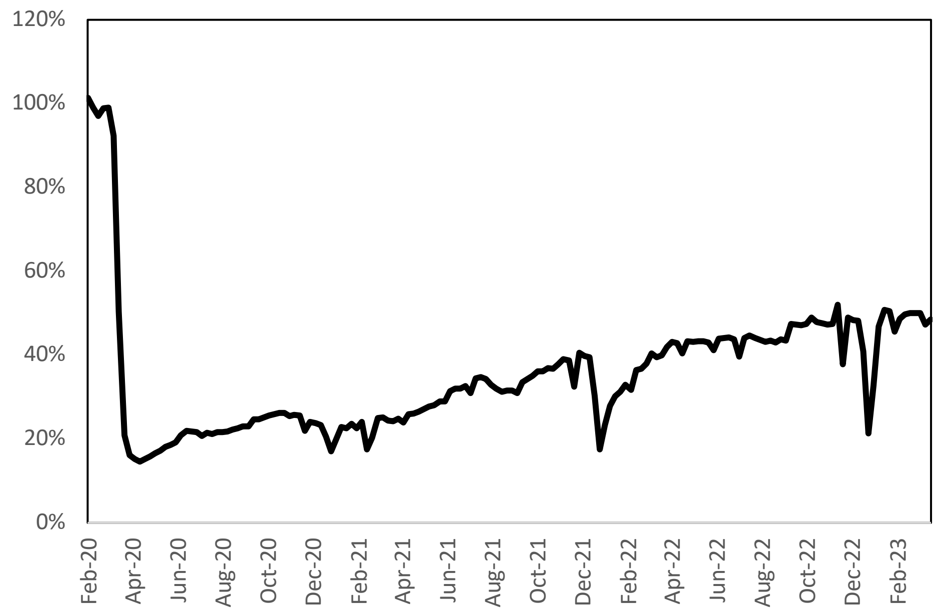


Appendix A3: Office Distress Indicators

Panel (a) of this figure shows the cumulative decline in the equity value of real estate holding companies (REITs) focused on the office sector based on the NAREIT equity office index. As we observe by November 2023, this index declined by close to 55% since January 2020. A simple calculation implies that these declines imply close to a 33% decline in the value of office budlings held by these companies, given that the average debt-to-asset ratio for office REITs as of Q4 2019 was about 40%. Panel (b) shows the partial recovery in the office attendance across top US cities relative to the pre-pandemic attendance levels based on the Kastle Systems data. *Data Sources*: NAREIT and Kastle Systems.



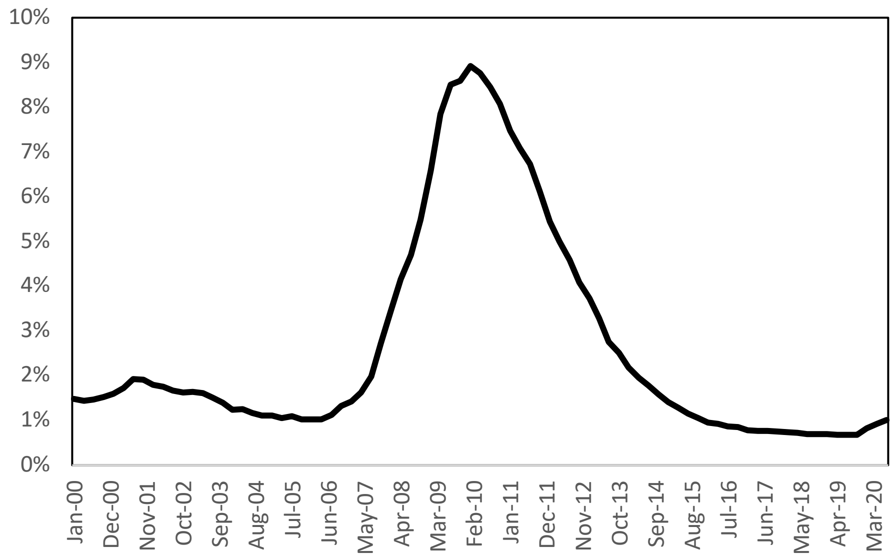
(a) Office Index Price Cumulative Change in % (REIT Equity)



(b) Physical Office Attendance Relative to the Pre-Pandemic Level

Appendix A4: Historical and Recent Delinquency Trends among CRE Loans

Panel (a) of this figure shows the average historical quarterly delinquency rate on commercial real estate loans booked in domestic offices for all commercial banks retrieved from FRED, Federal Reserve Bank of St. Louis data. Panel (b) shows the recent delinquency rate in percentage terms on commercial mortgages in the CMBS trusts based on the Trepp data. *Data Sources*: Federal Reserve System and Trepp.



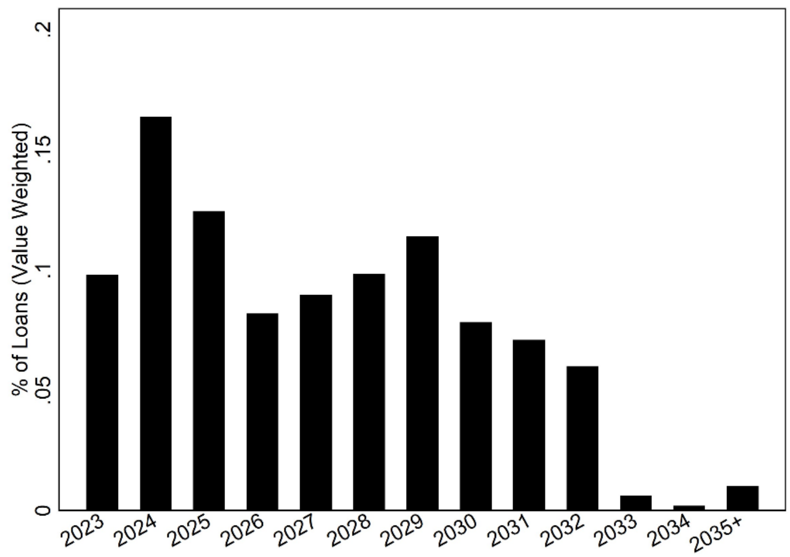
(a) Historical Delinquency Rate on Banks' Commercial Real Estate Loans

	June 2024	March 2024	December 2023	June 2023	March 23	December 22
Overall	5.43	4.67	4.51	3.90	3.09	3.04
Office	8.09	6.58	5.82	4.50	2.61	1.58
Lodging	6.17	5.45	5.40	5.35	4.41	4.40
Multifamily	2.63	1.84	2.62	1.59	1.91	2.17
Retail	6.14	5.56	6.47	6.48	6.23	6.97
Industrial	0.64	0.47	0.57	0.42	0.37	0.42

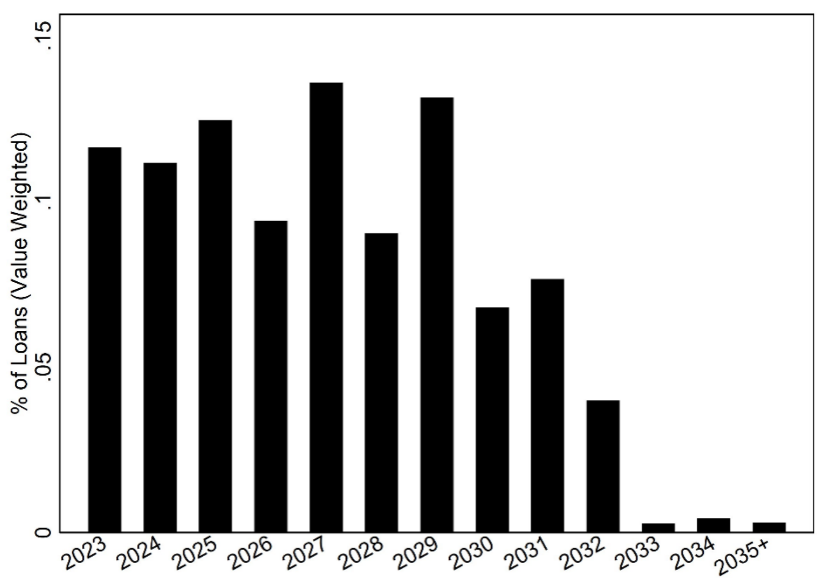
(b) Recent Commercial Real Estate Loans Delinquency Trends (based on the CMBS data)

Appendix A5: Maturity Structure of Outstanding CRE Loans

This figure illustrates the proportion of loans maturing in each respective year as a percentage of the outstanding loan volume as of 2023. These loans, drawn from the outstanding CMBS loans as of December 2023, were obtained from the DBRS Morningstar CMBS database. This comprehensive database encompasses historical loan performance data for the entire CMBS market, spanning back to 1998 and including both DBRS-rated and non-DBRS-rated transactions. Panel (a) shows these statistics for all loans and panel (b) for office loans.



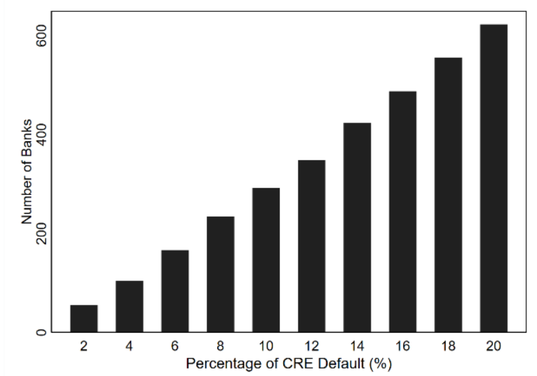
(a) All Loans



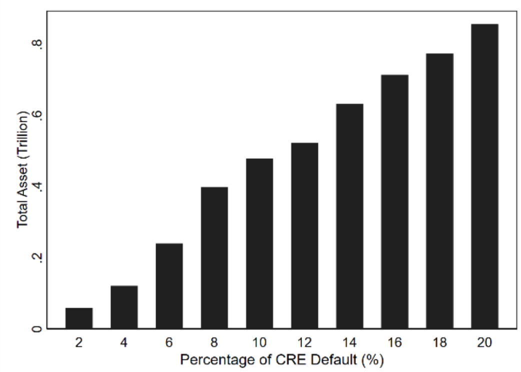
(b) Office Loans

Appendix A6: Impact of CRE Distress on Number of Banks with "Negative Equity" (Conservative Mark-to-Market Losses)

This figure shows how many US banks would end up in the negative equity position due to a given scenario for the CRE distress. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. The bank is in "negative equity" position if its mark-to-market value of assets including losses due to defaults on CRE loans is below the face value of its non-equity liabilities. We note that the numbers shown in this figure are in addition to 1,162 US banks with about $2.2 trillion of assets that have entered the negative equity position due to their decline in marked-to-market asset values following a recent rise in interest rates by extending the calculation in Jiang et al. (2023) to Q1:2024 and using the conservative loss estimate. Panel (a) shows the additional number of banks that enter this "negative equity" group for each of the CRE loans default scenario as compared to the baseline scenario of no CRE distress. Panel (b) shows the aggregate assets of these banks. *Data Sources*: Bank Call Reports.



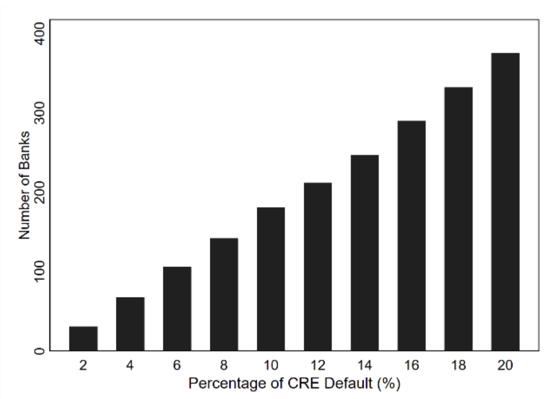
(a) Number of Banks with "Negative Equity"



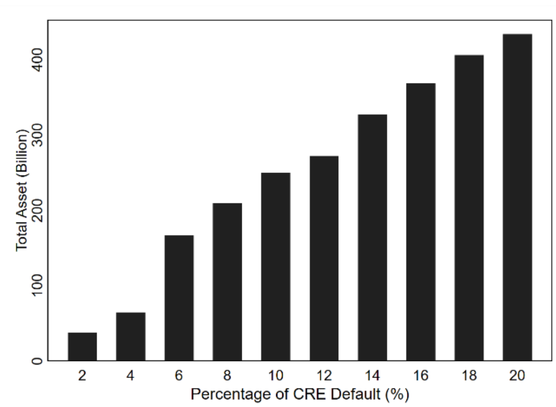
(b) Assets of Banks with Negative Equity

Appendix A7: Impact of CRE Distress on Number of Insolvent Banks based on the Insured Deposit Coverage Ratio Metric (100% Uninsured Depositors Run, Conservative Mark-to-Market Losses)

This figure shows how many US banks would end up insolvent due to a given scenario for the CRE distress if all uninsured depositors withdrew their funds. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. A bank is considered insolvent if its insured deposit coverage ratio is negative meaning that the mark-to-market value of its assets including losses due to CRE distress – after paying all of its uninsured depositors -- is insufficient to repay all insured deposits. We note that the numbers shown in this figure are in addition to 693 US banks with about $1.5 trillion of assets that face such insolvency risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1 and using the conservative loss estimate. Panel (a) shows the additional number of insolvent banks in each CRE distress scenario as compared to the baseline scenario of no CRE distress. Panel (b) shows the aggregate assets of these insolvent banks in each CRE distress scenario (in billions of dollars). *Data Sources*: Bank Call Reports.



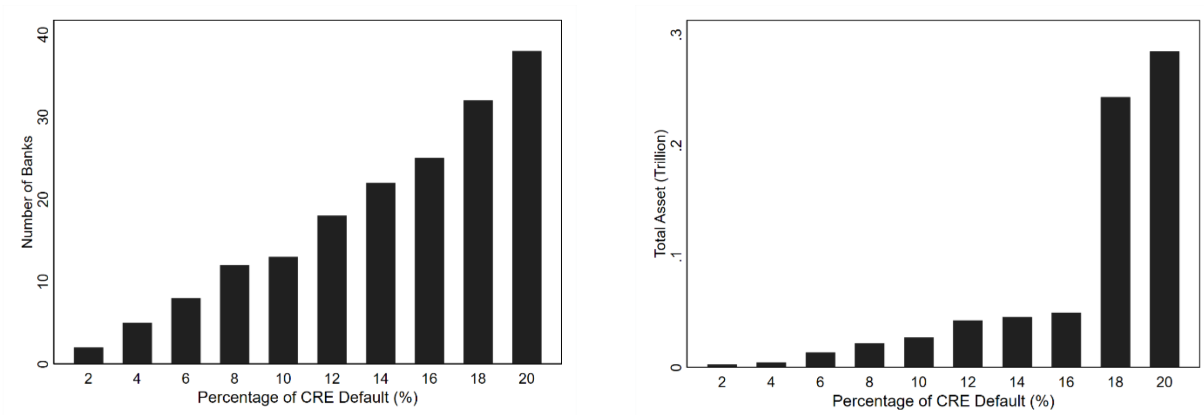
(a) Number of Banks



(b) Assets

Appendix A8: Impact of CRE Distress on Number of Insolvent Banks based on the Capital Ratio Metric (100% Uninsured Depositors Run, Conservative Mark-to-Market Losses)

This figure shows how many US banks would end up insolvent due to a given scenario for the CRE distress if all uninsured depositors withdrew their funds. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. A bank is considered insolvent if its capital ratio is negative, meaning that the initial equity is not sufficient to cover the losses from CRE distress and from selling assets at market prices to cover deposit withdrawals. We note that the numbers shown in this figure are in addition to 22 US banks with about $38 billion of assets that face such insolvency risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2024:Q1. Panel (a) shows the additional number of insolvent banks in each CRE distress scenario as compared to the baseline scenario of no CRE distress. Panel (b) shows the aggregate assets of these insolvent banks in each CRE distress scenario (in billions of dollars). Panel (c) shows the aggregate equity deficit at these banks (in billions of dollars). *Data Sources*: Bank Call Reports.

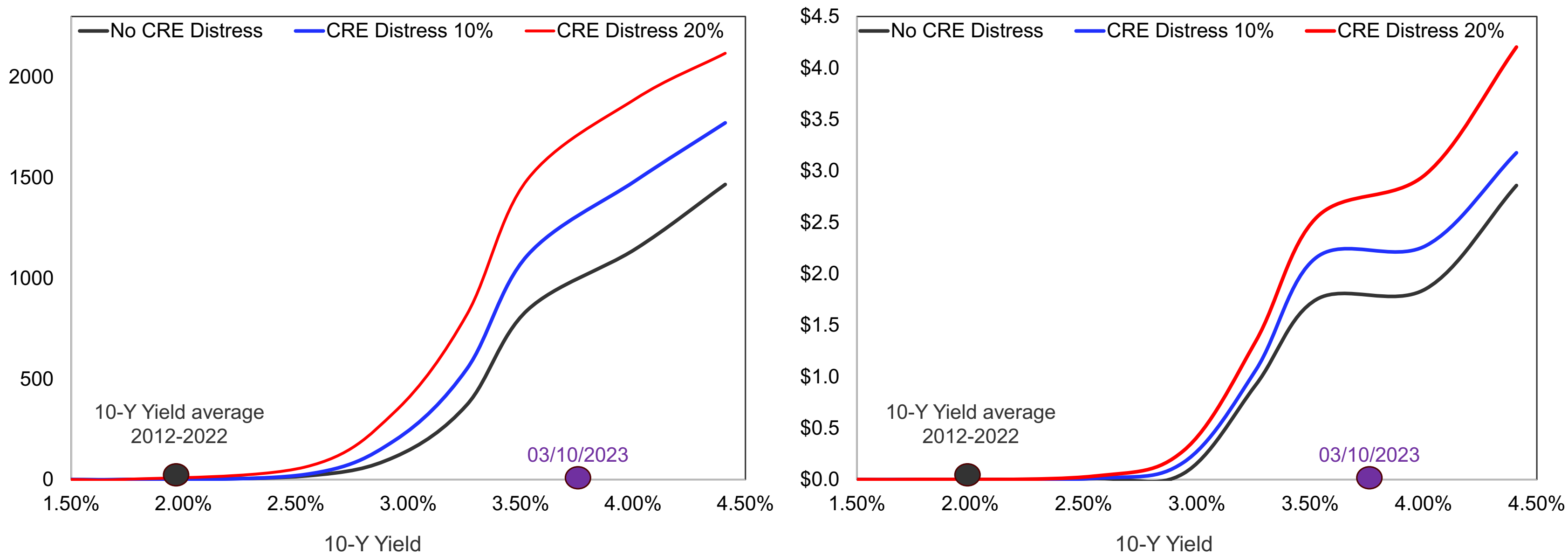


(a) Number of Banks

(b) Assets

Appendix A9: Monetary Policy Constraint due to Bank Financial Instability based on Extreme Insolvency Metric (Conservative Mark-to-Market Losses)

Panel (a) of this figure shows the relationship between the 10-Year US Treasury Yield and the number of US banks projected to be in a "negative equity" position based on the extreme insolvency financial stability metric (i.e., when the market value of bank assets is less than the face value of their non-equity liabilities). Panel (b) displays the aggregate assets of these banks in trillions of dollars. These figures are generated by taking the composition of bank assets as of Q1 2022 and applying the marked-to-marked calculations in Jiang et al. (2023) using the conservative loss estimation method throughout the monetary policy tightening cycle from Q2:2022 to Q2:2024. Each value plotted on the curve corresponds to a specific realization of the 10-Year yield during this period, considering the associated prices of long-term bonds across various maturities. The "No CRE Distress" scenario illustrates the impact of higher interest rates on the number of banks at risk of insolvency, assuming no defaults on bank CRE loans. The "CRE 10% Distress" scenario adds losses based on a 10% default rate on CRE loans at each bank, with a 30% loss given default. Similarly, the "CRE 20% Distress" scenario incorporates a 20% default rate on CRE loans at each bank, also with a 30% loss given default. The first dot marks the average 10-Year yield during the decade preceding the monetary tightening of 2022, while the second dot indicates the average 10-Year yield on March 10, 2023—the day the Silicon Valley Bank failed due to a bank run. *Data Sources*: Bank Call Reports.



(a) Number of Banks at Insolvency Risk

(b) Assets of Banks at Insolvency Risk (in $Tn)

Appendix A10: Time Series of Reported Non-Performing CRE Loans

This figure plots the time series of aggregate non-performing CRE loan ratio, calculated as the aggregate dollar volume of non-performing CRE loans divided by the aggregate stock of CRE loans held by banks. The two dashed vertical lines indicate the onset of the recent monetary tightening (2022Q1) and the quarter of SVB failure (2023Q1).