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US BANK FRAGILITY

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ABSTRACT

Building on the work of Jiang et al. (2023) we develop a framework to analyze the effects of credit risk on the solvency of U.S. banks in the rising interest rate environment. We focus on commercial real estate (CRE) loans that account for about quarter of assets for an average bank and about \$2.7 trillion of bank assets in the aggregate. Using loan-level data we find that after recent declines in property values following higher interest rates and adoption of hybrid working patterns about 14% of all loans and 44% of office loans appear to be in a “negative equity” where their current property values are less than the outstanding loan balances. Additionally, around one-third of all loans and the majority of office loans may encounter substantial cash flow problems and refinancing challenges. A 10% (20%) default rate on CRE loans – a range close to what one saw in the Great Recession on the lower end -- would result in about \$80 (\$160) billion of additional bank losses. If CRE loan distress would manifest itself early in 2022 when interest rates were low, not a single bank would fail, even under our most pessimistic scenario. However, after more than \$2 trillion decline in banks’ asset values following the monetary tightening of 2022, additional 231 (482) banks with aggregate assets of \$1 trillion (\$1.4 trillion) would have their marked to market value of assets below the face value of all their non-equity liabilities. To assess the risk of solvency bank runs induced by higher rates and credit losses, we expand the Uninsured Depositors Run Risk (UDRR) financial stability measure developed by Jiang et al. (2023) where we incorporate the impact of credit losses into the market-to-market asset calculation, along with the effects of higher interest rates. Our analysis, reflecting market conditions up to 2023:Q3, reveals that CRE distress can induce anywhere from dozens to over 300 mainly smaller regional banks joining the ranks of banks at risk of solvency runs. These findings carry significant implications for financial regulation, risk supervision, and the transmission of monetary policy.

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1. Introduction

In this paper we build on the work of Jiang et al. (2023) and develop a framework to analyze the effects of credit risk on the solvency of U.S. banks in the rising interest rate environment. Jiang et al. (2023) develop a conceptual framework and empirical methodology to analyze the effect of rising interest rates on the value of U.S. bank assets and bank stability. They present a model of solvency runs, which illustrates that interest rate increases can lead to self-fulfilling solvency bank runs by the uninsured depositors even when banks' assets are fully liquid. To assess such risk empirically, they develop a new measure of bank fragility, the *Uninsured Depositor Run Risk* (UDRR), that identifies the bank as insolvent if the mark-to-market value of their remaining assets after a given withdrawal by uninsured depositors would be insufficient to repay all insured deposits. Their framework identifies banks with asset losses, low capital, and critically, high uninsured leverage, the concept developed by Jiang et al. (2020), as being most fragile. Applying their methodology to the monetary tightening that started in 2022, Jiang et al. (2023) find that the higher interest rates during that period led to a reduction of approximately \$2 trillion in the market value of assets within the U.S. banking system accounting for loan portfolios held to maturity compared to what is indicated by their book value. These losses, coupled with the banks' uninsured leverage, create incentives for solvency runs among uninsured depositors for a significant subset of U.S. banks.

We expand their framework by considering the impact of credit risk on the stability of U.S. banks. We illustrate the relative importance of this factor by analyzing the exposure of US banks to distress on their commercial real estate (CRE) loans during the monetary tightening that started in 2022. We start by noting that (CRE) loans account for substantial portion of bank assets: about quarter of assets for an average bank and about \$2.7 trillion of bank assets in the aggregate. Moreover, as of 2023, there are several reasons why CRE has been considered a potential source of significant distress in the near-term. This includes the potential adverse impact of higher interest rates on the value of CRE assets and their cost of funding, risk of recession, and a lower demand for office due to the hybrid working patterns with potential negative spillovers on other asset classes such as urban retail, multifamily, and hotels.

Using the loan-level data on CRE loans we find that after recent declines in property values following higher interest rates and adoption of hybrid working patterns about 14% of all loans and 44% of office loans appear to be in a "negative equity" where their current property values are less than the outstanding loan balances. Additionally, around one-third of all loans and the majority of office loans may encounter substantial cash flow problems and refinancing challenges, reflecting in part more than doubling of cost of debt following monetary tightening and substantial increase in credit spreads. This evidence 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.

We find that a 10% (20%) default rate on CRE loans – a range close to what one saw in the Great Recession on the lower end -- would result in about \$80 (\$160) billion of additional bank losses. If such CRE loan distress would manifest itself early in 2022 when interest rates were low, not a single bank would fail, even under our most pessimistic scenario. However, we show that the large decline in banks' asset values following this monetary tightening of 2022 has significantly eroded the banks' ability to withstand adverse credit events. While the above losses due to CRE distress are an order of magnitude smaller than more than \$2 trillion decline in bank asset values associated with higher interest rates, they would increase the insolvency risk on a substantial set of US banks. We find that additional 231 (482) banks with aggregate assets of \$1 trillion (\$1.4 trillion) would have their marked to market value of assets below the face value of all their non-equity liabilities.

This calculation may appear extreme since it implicitly assumes that increasing interest rates do not decrease the value of bank liabilities, i.e., the fed funds rate instantaneously pass-through to deposit rates. However, it has been long established in the banking literature that banks in concentrated markets and with stronger deposit franchise can be slower to raise their deposit rates in response to raising interest rates, which could allow them to earn positive rents on their 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 the deposit franchise has hedging benefits that effectively allow the banks to engage in the “maturity transformation without an interest rate risk.” Jiang et al. (2023) demonstrate, both theoretically and empirically, that this argument may need to be refined due to the potential occurrence of self-fulfilling solvency runs. In essence, the decrease in bank asset values resulting from interest rate hikes, coupled with the potential credit losses we also consider here, can undermine, or entirely negate the hedging benefits of the deposit franchise. This exposure leaves banks susceptible to significant solvency risk.

To assess the risk of such solvency runs in the presence of both higher rates and credit losses, we employ the UDRR financial stability measure developed by Jiang et al. (2023) where we incorporate the impact of credit losses into the market-to-market asset calculation, along with the effects of higher interest rates. Consequently, we utilize the UDRR measure that integrates the impact of credit losses to analyze the bank's ability to withstand a given withdrawal by uninsured depositors. It is important to note that the assessments based on this measure should be interpreted through the lens of the multiple equilibria model developed by Jiang et al. (2023). They only identify whether a bank can be susceptible to a self-fulfilling solvency run by the uninsured depositors. 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, and (ii) when all uninsured depositors withdraw their funds at each bank.

Our analysis demonstrates that distress in the commercial real estate sector could lead to the inclusion of dozens to over three hundred predominantly smaller regional banks within the cohort of institutions vulnerable to insolvency arising from the uninsured depositor runs. In a scenario where half of uninsured depositors choose to withdraw their funds from each bank, the losses stemming from commercial real estate (CRE) distress could result in the insolvency of between 31 to 67 primarily smaller regional banks with aggregate assets of \$13 to 29 billion. The lower range corresponds to a 10% default rate, while the higher one aligns with a 20% CRE loan default rate. This is in addition to the 340 banks with aggregate assets of about \$400 billion that we find would already face insolvency solely due to higher interest rates by extending the analysis of Jiang et al. (2023) to 2023:Q3. If all uninsured depositors were to withdraw their funds, an additional 200 to 385 banks would fail due to CRE distress with aggregate assets of about \$250 to \$500 billion. This is in addition to the 1,799 banks with aggregate assets of \$6.3 trillion that we find would already face insolvency in such scenario solely due to higher interest rates by extending the analysis of Jiang et al. (2023) to 2023:Q3. As we discuss in Section 5, these findings hold significant implications for financial regulation, risk supervision, and the transmission of monetary policy.

Related Literature: As we discussed above our paper is most closely related to Jiang et al. (2023) who develop a conceptual framework and an empirical methodology to analyze the effect of rising interest rates on the value of U.S. bank assets and bank stability. We extend their work to analyze the effects of credit risk on the solvency of U.S. banks in the rising interest rate environment. Our paper is also related to a vast literature on bank runs that we cannot fully cover here. A large part of this literature, including the seminal contribution of Diamond and Dybvig (1983), focuses on asset illiquidity as a central factor driving the runs. However, as noted by Jiang et al. (2023), the average U.S. bank has a large share of liquid assets, which makes it difficult for runs to arise in the canonical framework in which asset illiquidity drives run behavior. Consequently, like Jiang et al. (2023) we assess the risk of bank runs in an environment where bank assets are fully liquid. In this regard, our paper is also connected to the model of runs without assets illiquidity in Egan et al. (2017) and to Jiang et al. (2020) who underscores the role of bank *uninsured leverage*, the concept developed by them.

Our paper, which centers on the interplay between the impacts of higher interest rates and credit distress on bank stability, is also situated within a broader literature that examines the transmission of monetary policy through financial markets and the banking sector. This literature includes an emerging body of work that addresses the 2023 regional banking crisis. In addition to the study by Jiang et al. (2023), Drechsler et al. (2023) and Haddad et al. (2023) also offer analyses of how solvency bank runs can interact with monetary policy. Other papers in this literature include,

among others, the contributions by Cookson et al. (2023), Jiang et al. (2023b), Flannery and Sorescu (2023), Granja (2023), and Koont et al. (2023).

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 (see Table 1).² 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. 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.³ 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 remote working patterns relative to their pre-pandemic levels may persist, eroding part of the demand for office space (see also Gupta et al. 2022).⁴ This lower demand for office can

² We consider all non-residential real estate loans as commercial loans. See also Appendix A1 for more detail on banks assets and liabilities.

³ Over the next five years, \$2.56 trillion in CRE loans will mature with \$1.4 trillion held by banks (Source: Trepp).

⁴ 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 March 2023, 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 Appendix A3).

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 2019.⁵ By the end of November 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.

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 4.58% by November 2023, with a notably swift increase in the delinquency rate on office loans—from 1.58% in December 2022 to 6.08% in November 2023 (see Appendix A4). Notably, delinquency rates on lodging and retail loans have also remained elevated, standing at 5.21% and 6.57%, 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

⁵ 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).

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.⁶ 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 by senior lenders.⁷ 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) shows the percentage of loans in a state of “negative equity,” defined as situations where the current loan

⁶ 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.

⁷ In fact, in most loan segments except multifamily it may be difficult to get a loan with LTV above 60% threshold.

balance is more than the current assessed property value, resulting in an estimated LTV exceeding 100%. As we observe 14.3% of all loans and 44.6% of office loans are 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 debt obligations. 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 (3) of Panel (b) 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. 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 (6), 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 (5), 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 (7) 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. 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 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. Methodology and Data

We use the bank call report data to assess the banks' ability to withstand the CRE distress in the rising interest rate environment. We proceed in three steps. First, we use the methodology developed by Jiang et al. (2023) to mark-to-market bank assets to reflect a decline in their values following an increase in interest rates, extending their analysis to 2023:Q3. Second, we reduce further the value of bank assets by considering several scenarios regarding the default rates on bank CRE loans that reflect various levels of CRE distress. Third, we use Jiang et al. (2023) conceptual framework and their UDRR bank stability measure to assess the risk of insolvency of banks due to uninsured depositor runs. In doing so we account for *both* the adverse impact of higher interest rates and CRE distress on 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.⁸
- 2) We use traded indexes in real estate and treasuries to impute the market value of real estate loans held on bank balance sheet.⁹ Longer duration fixed income assets were affected more by interest rate increases, so we want to adjust the market values of loans based on their maturity. Because of limited maturity information across RMBS maturities, we use one RMBS exchange traded fund, and then adjust across maturities using treasury prices. As a baseline, we use changes in the market price of the U.S. Treasury bonds and RMBS from 2022:Q1 to 2023:Q3. To adjust for maturity, we use the iShares U.S. Treasury Bond ETFs and the S&P Treasury Bond Indices across various maturities that match the maturity and repricing breakdowns in the call reports.
- 3) We compute the mark-to-market value loss as

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

where t indicates the maturity and repricing breakdowns: less than 1 year, 1-3 years, 3-5 years, 5-10 years, 10-15 years, and 15 years or more. $\Delta TreasuryPrice_t$ is the market price change of Treasury bonds with maturity t from 2022:Q1 to 2023:Q3 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:

⁸ 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.”

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

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

We then define the mark-to-market asset value in 2023:Q3 as total assets in 2022:Q1 minus the mark-to-market value loss defined above.

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. Finally, we note that Jiang et al. (2023b) shows that vast majority of banks assets are unhedged for interest rate risk with interest rate swaps.

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 loss of bank asset value due to a given level of credit distress (d) as follows:

$$\begin{aligned} \text{Asset Value Loss due to CRE Distress}(i, d) = \\ \$\text{Amount of Bank CRE Loans}(i) \times d \times (1-R) \end{aligned} \tag{1}$$

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 *R* is the loan recovery rate.

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 the banks can recover about 70% of outstanding face value of their loans (so *R*=0.7), which is in line with the historical data.¹⁰ 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.

¹⁰ 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.

3.3 Financial Stability Measures

To assess bank stability, we follow the conceptual framework of Jiang et al. (2023) and use the financial stability measures developed by them.

3.3.1 *Extreme Bank Insolvency*

We first assess whether the reduced (marked-to-market) value of bank assets following higher rates and the losses due to CRE distress defined in (1) is sufficient to cover all non-equity bank's 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 appear extreme since it assumes that is no value to banks' deposit franchise. On the other hand, it is a useful first benchmark to better understand the impact of CRE losses on the de facto capitalization of the U.S. banking sector.

3.3.2 *Bank Insolvency due to the Uninsured Depositor Runs*

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) UDRR financial stability measure to analyze the bank ability to survive a given withdrawal by the uninsured depositors.

To analyze how higher rates and CRE distress can trigger panic induced runs in banks we follow the conceptual framework of Jiang et al. (2023). They show that when bank asset values decline due to higher rates (and in addition due to CRE distress in our context), self-fulfilling bank runs are possible even if bank assets are fully liquid. Their model implies that banks with smaller initial capitalization, higher uninsured leverage, higher share of awake depositors, and more exposure to CRE distress in our context are more susceptible to such runs and insolvency.

To assess such risk empirically, we use the Jiang et al. (2023) Uninsured Depositor Run Risk (UDRR) measure of bank fragility 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:

$$\text{UDRR}(i, s, d) = \quad (2)$$

$$\frac{\text{Mark-to-Market Assets}(i) - \text{Asset Value Loss due to CRE Distress}(i, d) - s \times \text{Uninsured Deposits}(i) - \text{Insured Deposits}(i)}{\text{Insured Deposits}(i)}$$

In the above *Mark-to-Market Assets* is the measure of the current value of bank assets that reflects higher interest rates estimated by extending the analysis from Jiang et al. (2023) to 2023:Q3 (see Section 3.1 for more details). *Asset Value 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 (1). 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 the UDRR 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 all insured deposits. In this case such bank could be considered as insolvent.

The assessments based on the UDRR measure should be interpreted through the lens of multiple equilibria model developed by Jiang et al. (2023). A negative UDRR does 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 and Bank Stability

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 the more than \$2 trillion decline in the market value of bank assets identified by Jiang et al. (2023) due to higher interest rates. 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 2023:Q3 we find that after these declines almost half of US banks (2,405) accounting for \$11.6 trillion of aggregate assets have negative capitalization taking 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 3.3.1. 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 2A 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 2023:Q3. 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 70% recovery rate.

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 close to 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 -0.8% of mark-to market bank assets (including CRE losses).

Figure 2B 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).

In Figure 3, we analyze 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 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 231 banks with about \$1 trillion of assets in negative equity position (Figure 3A and 3B). At 20% CRE distress, additional 482 banks with assets worth \$1.4 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. Jiang et al. (2023) establishes that the uninsured leverage (i.e., Uninsured Debt/Assets) is the key to understanding whether these losses would lead to some banks in the U.S. becoming insolvent--unlike insured depositors, uninsured depositors stand to lose a part of their deposits if the bank fails, potentially giving them incentives to run (see also Egan et al. 2017). As we explained in Section 3.3.2, to assess such bank insolvency risk, we consider the *Uninsured Depositor Run Risk* (UDRR) bank stability measure developed by Jiang et al. (2023). 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. Following Jiang et al. (2023) 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 4A shows the distribution of the UDRR 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 4B shows the corresponding distribution of the UDRR ratio across bank asset size. As can be observed, CRE distress further lowered the UDRR ratio relative, especially for smaller and midsize banks that have a large concentration of CRE loans.

Figure 5 shows the number of insolvent banks (Figure 5A), their assets in billions of dollars (Figure 5B), and their insured deposits coverage shortfall in billions of dollars (Figure 5C) 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 UDRR 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 340 US banks (aggregate assets of about \$400 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 2023:Q3. 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 31 additional insolvent banks with aggregate assets of about \$13 billion if half of the uninsured depositors decide to withdraw their funds. At 20% CRE loan default rate, we compute this to be 67 additional insolvent banks with aggregate assets worth about \$29 billion.

Figures 6 and 7 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 200 banks insolvent with aggregate assets of about \$250 billion. At 20% CRE loan default rate there would be 385 additional banks insolvent with aggregate assets of about \$500 billion. This is in addition to 1,799 banks (with aggregate assets of about \$6.3 trillion) that face such risk solely due to higher interest rates as calculated by extending the analysis of Jiang et al. (2023) to 2023:Q3.

5. Conclusion

Building on the work of Jiang et al. (2023) we develop a framework to analyze the effects of credit risk on the solvency of U.S. banks in the rising interest rate environment. Applying this framework to 2022 monetary tightening episode we find that the commercial real-estate distress would add up to an additional \$160 billion of losses to more than \$2 trillion decline in the value of bank assets due to higher rates. While losses due to commercial real estate distress are an order of magnitude smaller than the decline in bank asset values associated with a recent rise of interest rates, they would impact a sizable set of banks. Due to these losses, up to 482 additional banks with aggregate assets of \$1.4 trillion would have their mark-to-market value of assets below the face value of all their non-equity liabilities. If half of uninsured depositors decide to withdraw, the losses due to CRE distress would result in up to 31 smaller regional banks becoming insolvent (in addition to 340 banks that face such insolvency risk just due to higher interest rates). If all uninsured depositors would withdraw their money up to 385 mainly smaller regional banks could fail due to CRE distress (in addition to 1,799 banks facing such risk just due to higher interest rates).

Our estimates could be a lower bound for potential effects of credit distress in the US banking system. First, we only focus on CRE distress, and we do not account for potential distress affecting

other types of bank loans. However, it's important to note that our methodology can be readily extended to encompass other loan categories within the bank's portfolio. Second, in all our calculations we assume that bank assets are liquid. If uninsured deposit withdrawals cause even small fire sales, substantially more banks would be at risk. Third, as the regional banking institutions play an important role in lending to local businesses, their distress could lead to a credit crunch with adverse effects on the real economy. We abstract away from such spillover effects that could amplify losses we have computed. Finally, and importantly, the news about commercial real estate default and banking losses could be a trigger for a widespread run on the banking system by uninsured depositors, unraveling a fragile equilibrium in the banking system.

Our findings have also important implications for monetary policy pass-through, bank risk supervision, financial stability. Our analysis suggests that given the current composition of bank assets the rising interest rates is significantly larger risk factor for banks than their exposure to a potential commercial real estate distress. In that regard, a significant decline in interest rates would also largely eliminate the consequences of CRE distress on bank stability. This fragility of the US banking system to higher rates can significantly constrain the conduct of monetary policy, adversely affecting its 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 together with other policy responses to the recent banking vulnerabilities may put a pause on the crisis and reduce the risk of acute deposit runs across the banking system. However, these are temporary measures that do not really address the fundamental insolvency risk identified by Jiang et al. (2023), which as we show the CRE distress would only make worse for a non-trivial set of banks.

A near-term solution could consider a market-based recapitalization of the U.S. banking system (see DeMarzo et al. 2023). In the longer-term, one regulatory response to the crisis could involve an increased oversight of US banking system. The regulators could adopt our methodology including the UDRR financial stability measure to stress test the banking system for the joint scenario of higher interest rates and credit distress considering both the composition of bank assets as well as their liabilities and assessing the insolvency risk due to runs by the uninsured depositors. Longer-term, banks could face stricter capital requirements, which would bring their capital ratios closer to less regulated non-bank lenders that retain more than twice as much capital buffers as banks (see Jiang et al. 2020). Increased capital buffers could make the U.S. banking system more resilient to adverse shocks to their asset values both due to higher rates and credit distress. Importantly, such analysis should consider the industrial organization of the financial intermediation market and its impact on overall credit market equilibrium that goes well beyond the traditional bank balance sheet model of intermediation (Buchak et al. 2018, 2022, 2023; Jiang et al. 2020; Xiao 2020; Jiang 2023).

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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) shows these statistics for banks with assets below \$1.384 billion, the Community Reinvestment Act asset size thresholds for large banks. Column (3) shows these statistics for banks with assets above \$1.384 billion but below \$250 billion. Column (4) shows these statistics for banks with assets above \$250 billion, the threshold for the Global Systemically Important Banks (GSIBs) according to bank regulators' definition as of 2022. We also assign GSIB status to US chartered banks affiliated with holding companies that are classified as GSIB. *Data Sources:* Bank Call Reports.

	(1)	(2)	(3)	(4)
	All Banks	Assets <1.384B	Assets [1.384B,250B]	Assets >250B
Aggregate Assets	24T	1.4T	9.0T	13.5T
Aggregate Commercial Real Estate Loans	2.7T	419.5B	1.7T	589.5B
Commercial Real Estate Loans/Asset (%)				
Mean	25.7	24.9	30.6	4.7
Standard Deviation	14.3	13.9	14.9	3.4
P5	2.6	2.9	0.7	0.0
P25	15.3	14.8	21.6	1.6
P50	25.1	23.9	31.7	3.7
P75	35.3	34.2	40.1	7.7
P95	49.9	48.8	53.8	10.2
Number of banks	4,844	4,096	735	13

Table 2: Assessing Distress Risk of Commercial Real Estate Loans*Panel A: Current LTV and Percentage of Loans in “Negative Equity”*

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%.

	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]*Panel B: Current Debt Service Coverage Ratio (DSCR) and Hypothetical DSCR after Refinance at the Current Benchmark Rate*

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 (b), 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) 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. Column (3) 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 (4) shows the average current DSCR of these loans as reported in the data. Column (5) 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 (6) 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 (7) indicates the percentage of loans that would have a hypothetical DSCR less than 1 if loans were to be refinanced at the benchmark rate. 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.

	Average “Legacy” Mortgage Rate	Average “Benchmark” Mortgage Rate	Average Initial DSCR	Average Current DSCR	Average DSCR at “Benchmark” Rate	% with Current DSCR<1	% with DSCR<1 at Benchmark Rate	% with LTV>100% & DSCR<1 at Benchmark Rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All Loans	3.97%	6.71%	2.3	1.7	1.2	6.4%	17.2%	4.5%
Office Loans	3.96%	7.42%	2.7	2.0	1.2	6.6%	24.3%	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.

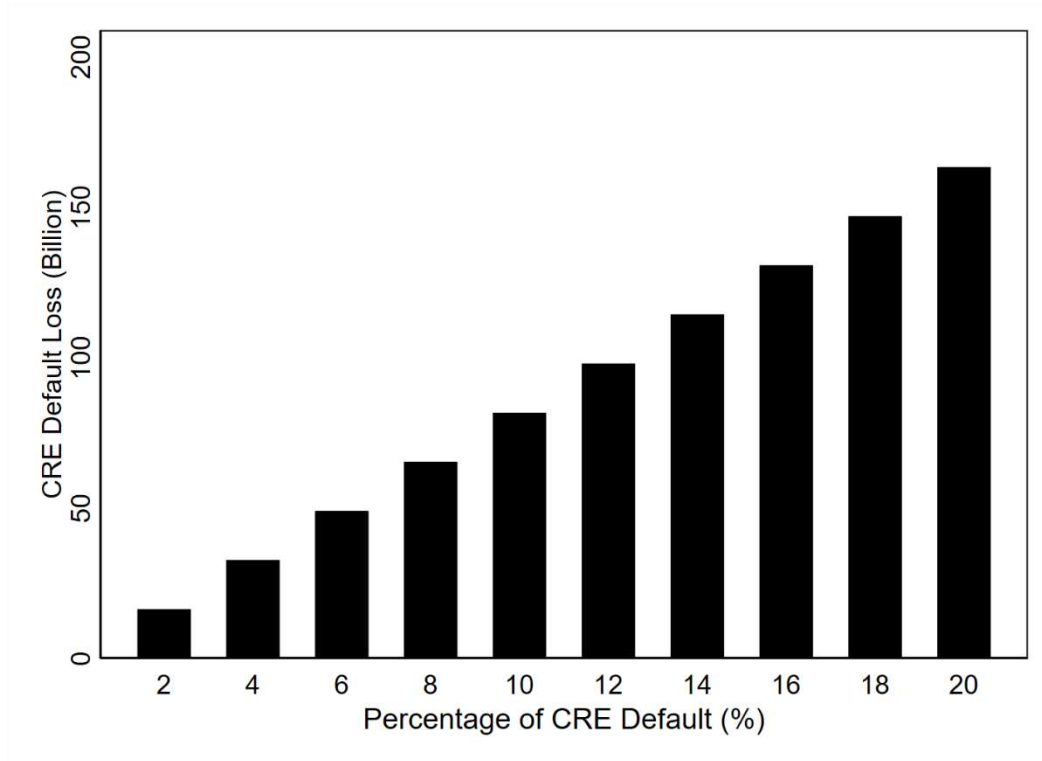
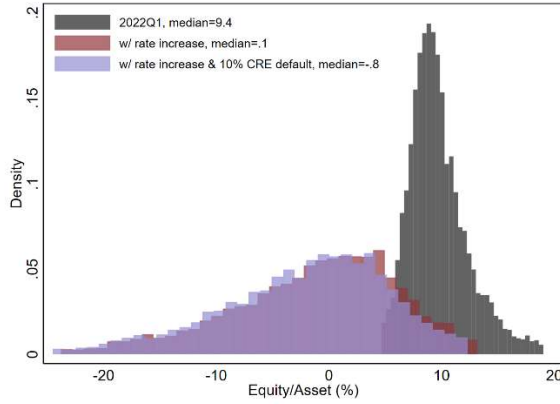
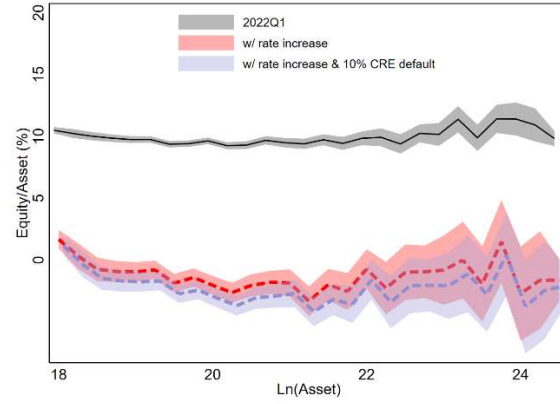


Figure 2: Distribution of Change in Equity Value with 10% CRE Distress

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 2023:Q3 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 70% recovery rate. 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.



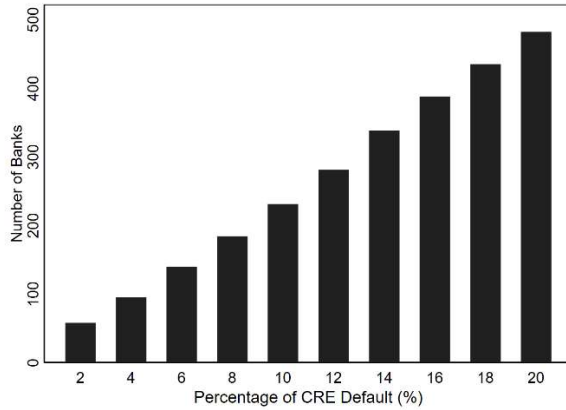
(a) Histogram



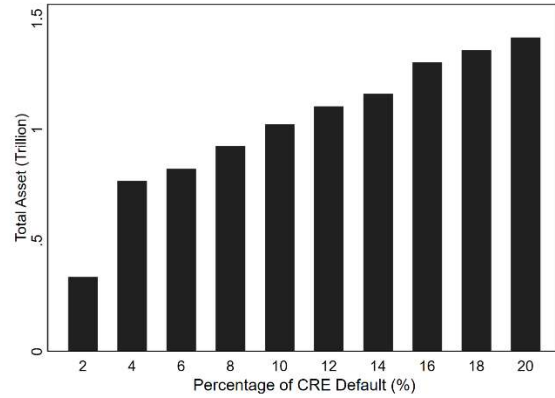
(b) Size

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

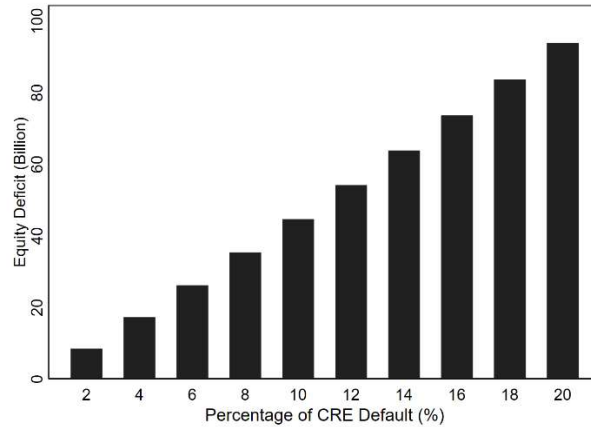
This figure shows how many US banks would end up in the negative equity position due to a given scenario for the CRE distress. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. The bank is in “negative equity” position if its mark-to-market value 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 2,405 US banks with about \$11.6 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 Q3:2023. 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”



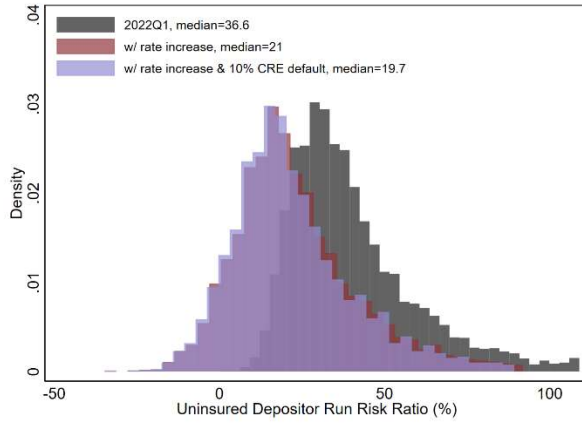
(b) Assets of Banks with Negative Equity



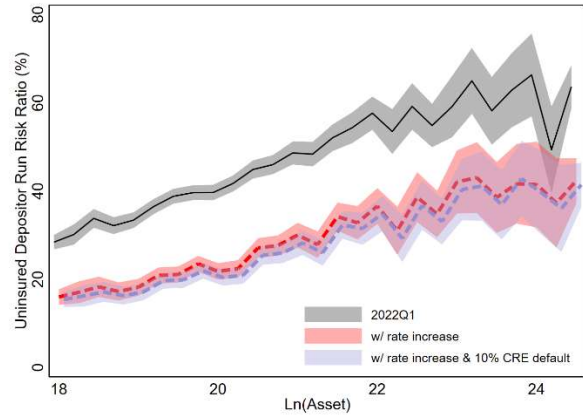
(c) Equity Deficit

Figure 4: Distribution of the Uninsured Depositor Run Risk Ratio (50% Uninsured Depositors Run & 10% CRE Loan Default Rate)

Panel (a) of this figure plots the histograms (density) of the *Uninsured Depositor Run Risk* (UDRR) 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 UDRR ratio across bank asset size. We consider three cases. First, we show the UDRR ratio given the bank equity position as of 2022:Q1. Second, we present the UDRR ratio as of 2023:Q3, 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 2023:Q3. Finally, we show the UDRR 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 70% recovery rate. We remove outliers by trimming the sample at the 95th percentile. *Data Sources*: Bank Call Reports.



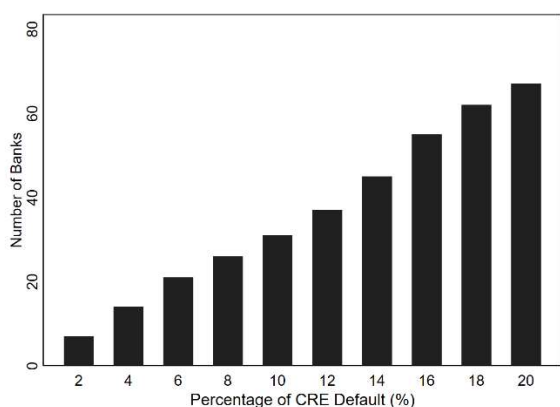
(a) Histogram



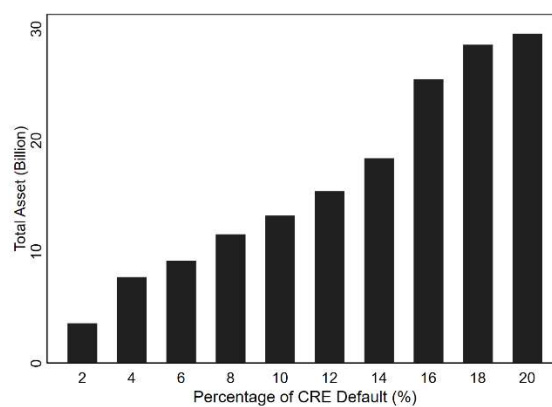
(b) Size

**Figure 5: Impact of CRE Distress on Number of Insolvent Banks
(50% Uninsured Depositors Run)**

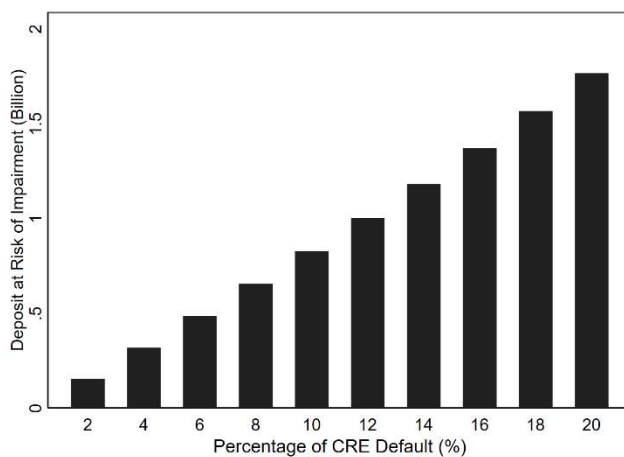
This figure shows how many US banks would end up insolvent due to a given scenario for the CRE distress if half of uninsured depositors withdrew their money at each bank. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. A bank is considered insolvent if its UDRR 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 figure are in addition to 340 US banks with about \$400 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 2023:Q3. 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 insured deposits coverage shortfall at these banks (in billions of dollars). *Data Sources:* Bank Call Reports.



(a) Number of Banks



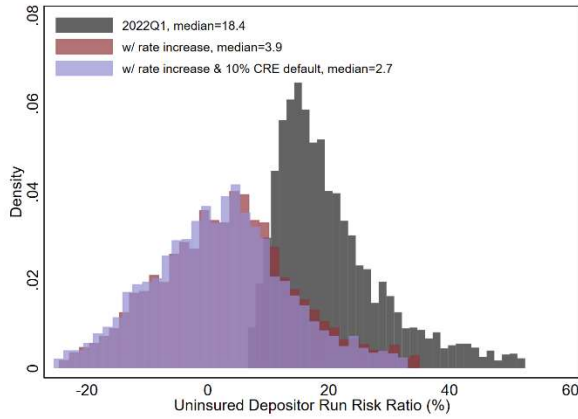
(b) Assets



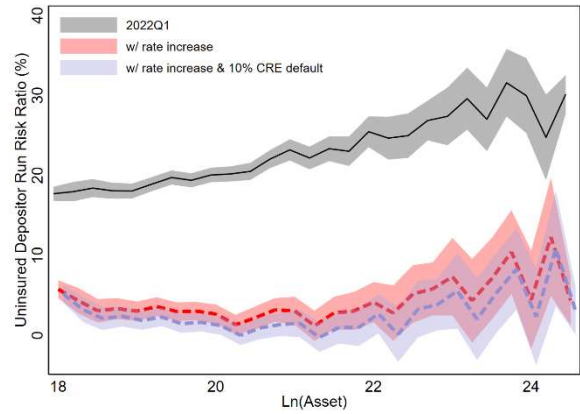
(c) Insured Deposits Coverage Shortfall

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

Panel (a) of this figure plots the histograms (density) of the *Uninsured Depositor Run Risk Ratio* (UDRR) calculated based on 2022:Q1 balance sheets and mark-to-market values assets assuming 100% of uninsured depositors withdraw their money at each bank. Panel (b) shows the corresponding distribution of the UDRR ratio across bank asset size. We consider three cases. First, we show the UDRR ratio given the bank equity position as of 2022:Q1. Second, we present the UDRR ratio as of 2023:Q3, 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 2023:Q3. Finally, we show the UDRR 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 70% recovery rate. We remove outliers by trimming the sample at the 1st and 95th percentiles. *Data Sources*: Bank Call Reports.



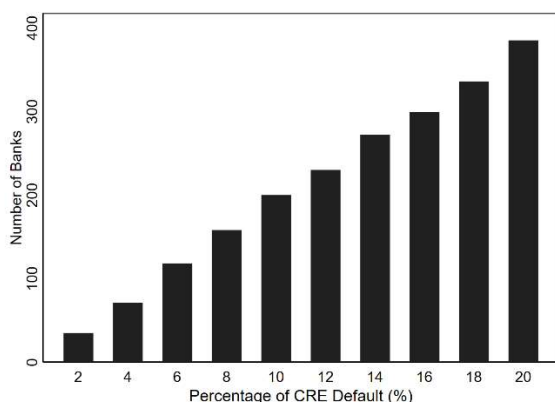
(a) Histogram



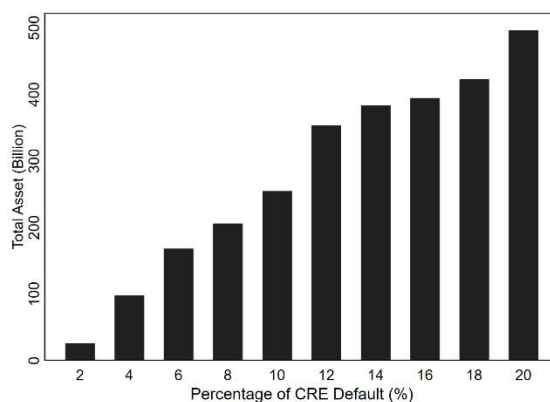
(b) Size

**Figure 7: Impact of CRE Distress on Number of Insolvent Banks
(100% Uninsured Depositors Run)**

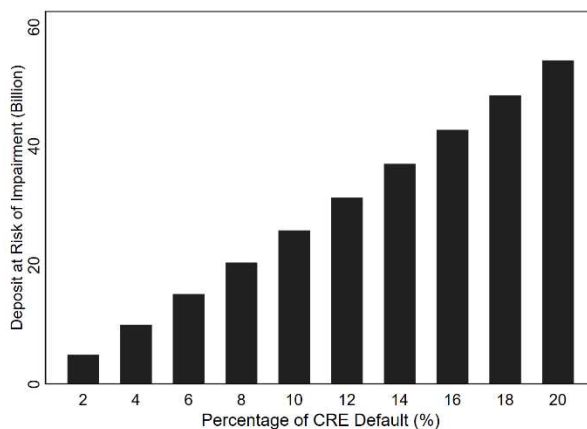
This figure shows how many US banks would end up insolvent due to a given scenario for the CRE distress if all uninsured depositors withdrew their funds. We consider a range of default scenarios starting from 2% default rate to 20% default rate on CRE loans. A bank is considered insolvent if its UDRR 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 1,799 US banks with about \$6.3 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 2023:Q3. 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 insured deposits coverage shortfall at these banks (in billions of dollars). *Data Sources:* Bank Call Reports.



(a) Number of Banks



(b) Assets



(c) Insured Deposits Coverage Shortfall

Appendix A1: Bank Balance Sheets

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

Panel A: Bank Asset Composition – 2022:Q1

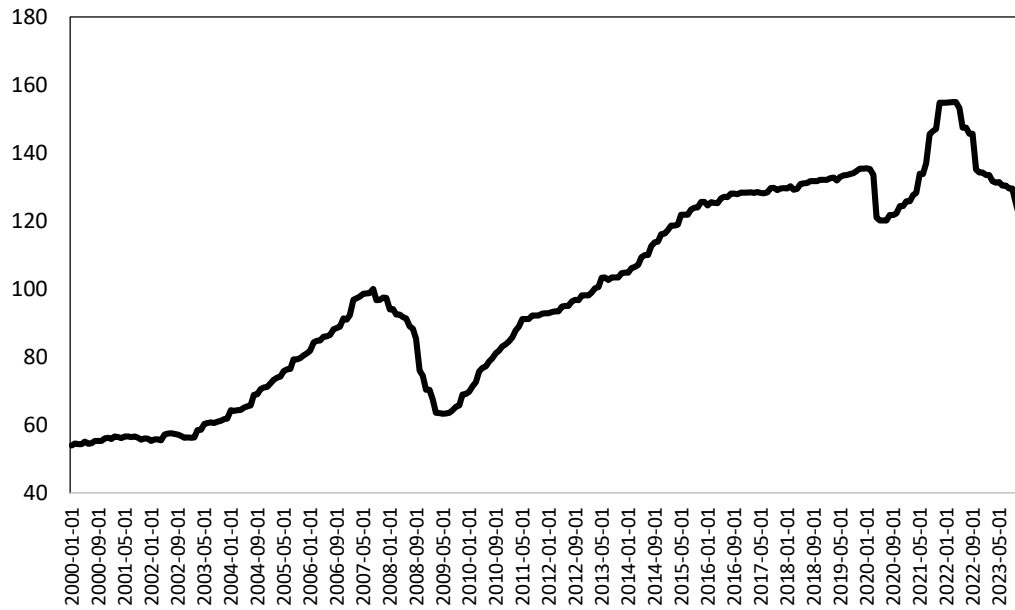
	(1) Aggregate	(2) Full Sample	(3) Small (0,1.384B)	(4) Large (non GSIB) [1.384B,)	(5) GSIB
Total Asset \$	24T	5.0B (74.7B)	0.3B (0.3B)	19.7B (137.1B)	273.1B (618.3B)
Number of Banks	4844	4844	4072	743	29
(Percentage of Asset)					
Cash	14.1	13.1 (9.8)	13.6 (10.0)	10.0 (7.9)	24.3 (12.4)
Security	25.2	23.9 (15.7)	24.4 (16.1)	21.5 (13.0)	18.1 (18.1)
Treasury	6.1	2.6 (4.1)	2.7 (4.2)	2.1 (3.3)	4.7 (5.5)
RMBS	12.1	3.1 (4.6)	2.5 (4.1)	6.6 (5.6)	5.5 (7.1)
CMBS	2.3	0.9 (1.6)	0.7 (1.5)	1.6 (1.9)	0.8 (1.5)
ABS	2.7	0.8 (1.6)	0.7 (1.5)	1.3 (1.8)	1.1 (2.0)
Other Security	2.1	14.9 (12.7)	16.2 (13.0)	7.8 (8.3)	3.0 (7.8)
Total Loan	46.6	55.7 (15.6)	54.7 (15.6)	61.9 (13.9)	39.5 (16.3)
Real Estate Loan	21.9	41.9 (16.7)	41.4 (16.6)	45.2 (16.5)	19.4 (14.8)
Residential Mortgage	10.6	15.5 (11.7)	15.9 (11.8)	13.9 (10.7)	10.3 (14.0)
Other Real Estate Loan	11.3	25.4 (13.2)	24.7 (13.0)	30.2 (13.3)	5.4 (6.0)
Agricultural Loan	0.3	2.6 (4.1)	2.9 (4.4)	0.7 (1.8)	0.1 (0.4)
Commercial & Industrial Loan	9	6.9 (5.2)	6.6 (5.0)	9.1 (6.0)	4.2 (5.6)
Consumer Loan	7.7	2.2 (2.5)	2.2 (2.3)	2.3 (3.1)	2.8 (3.8)
Loan to Non-Depository	2.8	0.1 (0.2)	0.0 (0.1)	0.2 (0.3)	0.3 (0.4)
Fed Funds Sold	0.1	1.4 (3.1)	1.6 (3.3)	0.2 (1.0)	0.0 (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 – 2022:Q1

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

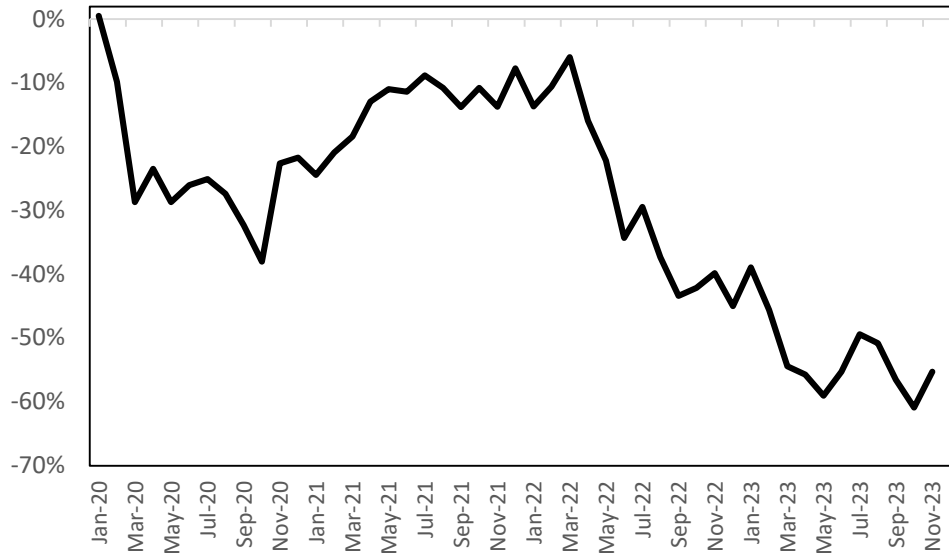
Appendix A2: Commercial Property Price Index

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

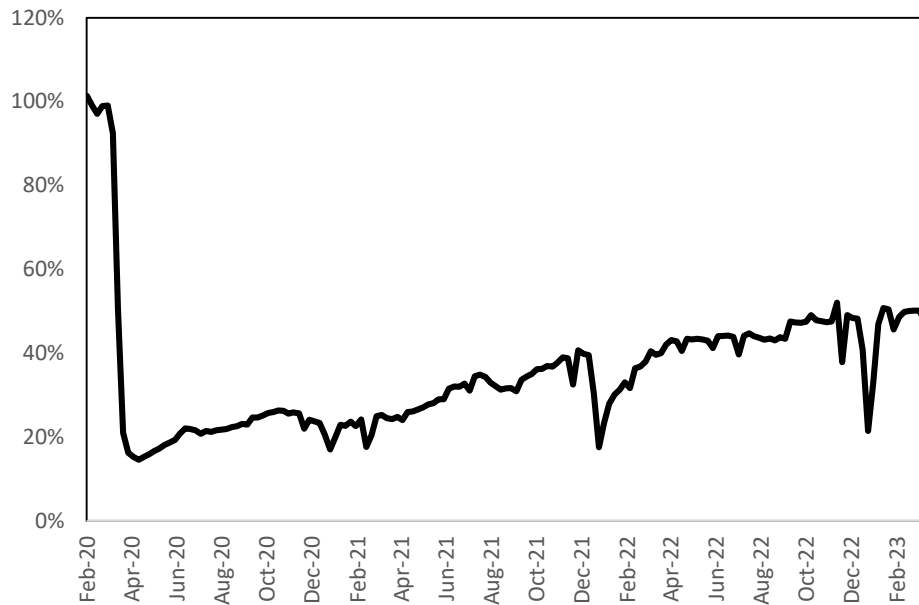


Appendix A3: Office Distress Indicators

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 buildings 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.



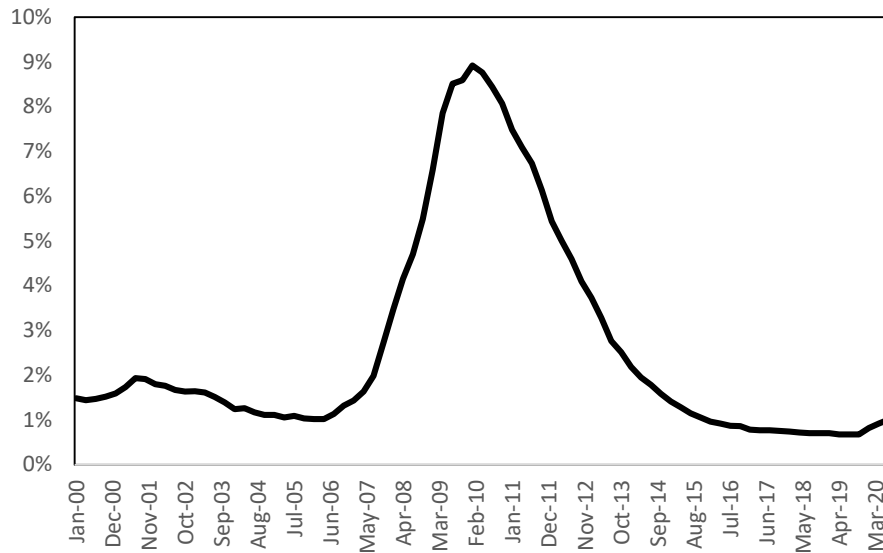
(a) Office Index Price Cumulative Change in % (REIT Equity)



(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.



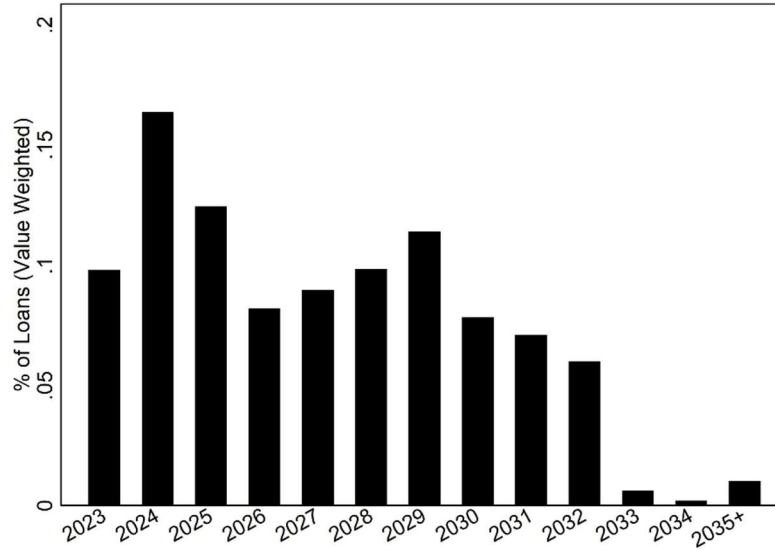
(a) Historical Delinquency Rate on Banks' Commercial Real Estate Loans

	November 2023	June 2023	March 23	December 22
Overall	4.58	3.90	3.09	3.04
Office	6.08	4.50	2.61	1.58
Lodging	5.21	5.35	4.41	4.40
Multifamily	4.46	1.59	1.91	2.17
Retail	6.57	6.48	6.23	6.97
Industrial	0.38	0.42	0.37	0.42

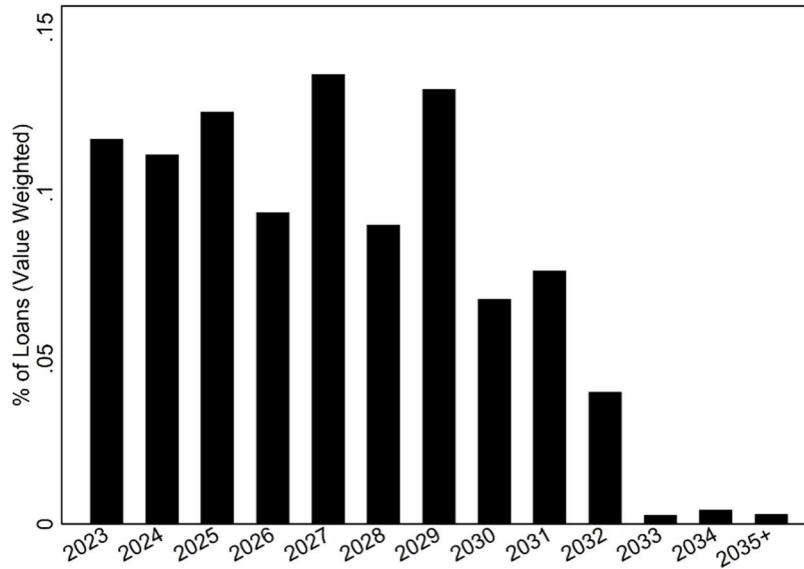
(b) Recent Commercial Real Estate Loans Delinquency Trends (based on the CMBS data)

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