Variable Deposit Betas and Bank Interest Rate Risk Exposure

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Whether maturity transformation exposes banks to interest rate risk depends in part on the effectiveness of bank deposits as a hedge against interest rate shocks. In this paper, we provide evidence that, despite an increase in the average maturity of bank assets, the duration of bank equity was negative for most of the post-financial crisis era. We document that an important factor contributing this was an increase in the average duration of deposits due to a positive relation between deposit betas and the level of interest rates. The dynamic nature of the duration of deposits also explains why deposits provided a poor hedge against recent rate hikes. Overall, we find that variable deposit betas contribute to the negative convexity of bank equity.

Keywords: Interest Rate Risk, Hedging, Deposit Betas

JEL Classification: G21, G38

Over the last 2 years, we felt like our deposit franchise was a coiled spring of Greens Power if we could just get the 5-year treasury back over 2%. We currently have $1.2 million deposit accounts that are diversified and granular and that should lead to a lower deposit beta. During the last rate increase cycle, our deposit beta was only 5% on the first 100 basis point increase.

SouthState Bank, Earnings Call, April 29, 2022

1. Introduction

Following the global financial crisis, banks lengthened the maturity of their assets relative to their liabilities, principally through increasing their investments in mortgage-related assets. For example, as shown in Figure 1, the median repricing maturity of bank assets increased by around 40 percent from about 4.25 years in the first quarter of 2009 to about 6 years at the end of 2022 while the reported repricing maturity of bank liabilities declined slightly.[1] Given the increase in the maturity mismatch, one would expect the interest rate risk exposure of bank stocks to have increased as well. Surprisingly, despite the increase in the maturity mismatch between bank assets and liabilities, we find, as shown in Figures 2A and 2B, a dramatic *decrease* in the rate sensitivity of bank stock prices.[2] Indeed, during the post-crisis period, we find, on average, a positive relationship between interest rate shocks and bank stock returns, indicating a negative duration of bank equity.[3]

The positive relationship between interest rate changes and bank stock returns indicates that, despite a significant balance sheet maturity mismatch, banks were expected to profit from an increase in interest rates, as the quote from the earnings call above suggests. One potential explanation for the expected gain from rate increases is that the increase in the duration of bank deposits when interest rates were low more than offset the increase in the maturity of bank assets during the post-crisis period. This explanation builds on recent research by DSS (2021) and WWWX (2022), who identify the deposit franchise as an important hedge against the interest rate risk exposure created by maturity transformation. The duration of the deposit franchise is a

[1] As shown in Figure 1, the pre- and post-crisis periods roughly correspond to high and low interest rate environments (as explained later, high and low interest rate environments are defined by whether the Federal Funds rate is above or below 2 percent).

[2] As explained in detail later, we follow Bernanke and Kuttner (2005), English, Van den Heuvel and Zakrajesek (2018) (EVZ), Drechsler, Savov and Schnabl (2021) (DSS), and Wang, Whited, Wu, and Xiao (2022) (WWWX), and measure the sensitivity of bank equity values to interest rate shocks by regressing the returns of a portfolio of bank stocks on changes in the yield of two-year Treasury bonds on Federal Open Market Committee (FOMC) meeting dates.

[3] Negative duration of equity means that the value of bank equity increases with the level of interest rates.

function of the sensitivity of deposit rates to interest rate changes. The sensitivity of deposit rates to interest rate changes is often referred to as the deposit pass-through rate or deposit beta. *Ceteris paribus,* the lower the pass-through rate or deposit beta, the greater the value gained from an increase in rates and thus the longer the duration of deposits.

The effectiveness of the deposit franchise as a hedge against the interest rate risk, however, depends on how deposit betas change with interest rates. Drawing on recent work by WWWX (2022) and Abadi, Brunnermeir and Koby (2023) (ABK) we hypothesize that, when interest rates are low, deposit yields become less sensitive to changes in interest rates (since the convenience benefits of holding deposits are high relative to the opportunity cost of deposits). As a result, when interest rates are low, an increase in interest rates improves the spread between Federal Funds rates (FFRs) and deposit yields which increases current interest income (as the quote from above suggests). However, significant rate hikes can lead to significant increases in deposit betas which, in turn, leads to a decrease in the duration of deposits which reduces the effectiveness of deposits as a hedge against interest rate changes.

In this paper, we examine the relationship between deposit betas and interest rate levels. We provide evidence that deposit betas vary significantly with interest rates and more important that variations in deposit betas are significantly related to the variations in the interest rate sensitivity of bank stock returns. We refer to this as the variable deposit franchise hypothesis. Overall, we find a positive but non-linear relationship between deposit betas and interest rates as well as a positive relationship between deposit betas and the duration of bank equity. We also find evidence that the deposit franchise provides a poor hedge against large increases in interest rates.

To motivate our analysis, we compare the interest rate sensitivity of bank stocks and the market portfolio in low and high interest rate environments. As in WWWX (2022), we define a low interest rate environment as quarters in which the effective FFR is below 2 percent and high-rate environments as quarters in which it is at or above 2 percent.[4] As shown in Figure 3, during periods of high interest rates we find a negative relationship between bank stock returns and interest rate changes, consistent with an on-balance sheet maturity mismatch between long-term

[4] As in WWWX (2022), when estimating the interest rate sensitivity of bank stocks, we exclude the financial crisis period (2007 to 2009) because during the financial crisis information other than interest rate policy was included in FOMC meeting releases. However, we find a similar reversal in rate sensitivity if we include the financial crisis years. Finally, as discussed later, we provide empirical support for this cutoff by testing for break points in the relation between bank stock returns and interest rate changes.

assets and liabilities. However, as Figure 3 shows, when interest rates are low, the duration of bank equity is negative.[5] In low interest rate environments, the implied duration of bank equity based on the sensitivity of bank stock returns to interest rate changes, appears to be inconsistent with the on-balance sheet maturity mismatch of over 5 years.

We test the variable deposit franchise hypothesis by calculating two measures of the sensitivity of deposit rates to changes in interest rates. The first measure is based on a recent method proposed by DSS (2021) in which we estimate deposit rate sensitivity by regressing, for each bank, changes in quarterly deposit expenses on the current and three-quarter lagged changes in FFRs. Our estimate of deposit rate sensitivity for bank i, β_i^D, is the sum of the coefficient estimates on changes in FFRs.

Our second measure of deposit rate sensitivity is based on work by Kang-Landsberg, Luck and Plosser (2023) (KJL), who calculate deposit betas as the ratio of quarterly changes in deposit rates to quarterly changes in FFRs. While KJL calculates quarterly deposit betas for the banking sector, we use Call Reports data to calculate quarterly deposit betas at the bank level over the period from 1997 through the first quarter of 2023. We refer to these betas as β_{it}^{DS}, where the subscript refers to bank *i* in quarter *t*.

Overall, we find the mean β_i^D and β_{it}^{DS} for our sample banks are about 0.30 and 0.40 respectively, indicating banks on average pass-through 30-40 percent of the change in FFRs to depositors in terms of higher deposit rates. This explains why the gap between FFRs and deposit yields widens as interest rates increase (and narrows when rates decrease) and is consistent with the findings of DDS (2021) that deposits financing serves to hedge against declines in the value of fixed-rate assets as rates increase.

We extend the analysis of DSS (2021) by documenting that deposit betas vary significantly with the level of interest rates. Specifically, we find a positive non linear relationship between deposit betas and FFRs, indicating that the duration of deposits decreases as interest rates rise. As a result, in contrast to constant pass-through rates, variable pass-through rates reduce the effectiveness of deposits as a hedge against interest rate changes and create convexity.[6]

[5] WWWX (2022) also document a reversal in the rate sensitivity of banks stocks when FFRs are below 2 percent. We extend their findings by providing evidence that the reversal is related to changes in deposit pass-through rates.

[6] Convexity measures the curvature of the price-yield relation. Duration is the percentage change in price for a small change in in yield (i.e., the semi-elasticity of price with respect to yield). The duration of a bond with negative convexity increases with interest rates whist the duration of a positively convex bond declines with interest rates. See Hansen (2014) for an analysis of (negative) convexity in mortgages and mortgage-backed securities.

We argue that three factors explain the positive relationship between deposit betas and interest rates. First, as ABK (2023) and WWWX (2022) explain, when FFRs are low, cash competes with deposits, pushing pass-through rates down. Second, lower FFRs result in banks paying lower spreads on liquid deposits, which leads to a substitution of liquid deposits for less liquid time deposits that in turn reduces deposit betas.[7] Finally, heterogeneity among depositors in terms of their propensity to substitute money market instruments for deposits leads to a positive relation between deposit betas and the level of interest rates in a high-rate environment. Consistent with pass-through rates varying with the level of interest rates, we find, for example, the average deposit beta when FFRs are below 2 percent is over 41 percent *lower* than when FFRs are above 2 percent. In addition, consistent with Supera (2021), we find that banks' use of time deposits is positively related to the level of interest rates and more importantly, within-bank variation in deposit betas is positively related to the proportion of time deposits to total deposits. Finally, we find that the increase in deposit betas when interest rates rise is significantly greater for banks that rely heavily on uninsured deposits. As a result, uninsured deposits are less effective as a hedge against changes in the value of fixed-rate assets.

We provide corroborative evidence concerning the impact of variation in deposit betas on bank interest rate risk exposure from bank earnings conference call transcripts. Specifically, using the regular expression (regex) package in Python, we searched for discussions concerning deposit betas in earnings call transcripts for the publicly traded banks in our sample. As shown in Figure 4 we find only limited discussion of deposit betas prior to the increase in FFRs in 2017. Moreover, interest in deposit betas among analysts and bank management varies directly with the level of interest rates.

Our analysis provides an additional reason why the hedge provided by the deposit franchise performed poorly when rates began rising in 2022. Drechsler, Savov, Schnable, and Wang (2023) (DSSW) argue that rate increases prompt large withdrawals by uninsured depositors which lead to declines in the value of the deposit frachise. Specifically, they argue that deposit runs occur in high-rate environments because that is when the deposit franchise is most valuable and thus when

[7] Supera (2021) provides evidence that banks' reliance on time deposits is positively related to the level of interest rates.

the value destroyed by a run is the greatest. As a result, when rates are high, uninsured depositors stand to lose the most from deposit withdrawals.[8]

Our analysis suggests that increases in deposit betas were a factor contributing to the poor performance of banks stocks when rates began increasing in 2022. Specifically, the mix of short- and long-term assets that hedge earnings in a low-rate, low deposit beta environment, exposes banks to interest rate risk in high-rate environments. To see why, consider a bank that adds longer-term mortgage-related assets to match the increase in the duration of deposits when rates are low. When rates increase, the duration of the bank's mortgage portfolio will increase because of a decline in prepayments, which in turn leads to negative convexity in mortgages (Hansen, 2014). In addition, if the duration of deposits decreases, this will lead to a further increase in the duration of the bank's equity. For example, if, as we find, deposit betas increase from 0.35 when FFRs are 0.5 percent to 0.55 when FFRs are 4 percent, the decrease in the duration of deposits is about 60 percent.

The decrease in deposit duration as interest rates increase requires a significant reduction in the duration of assets in order to mitigate the impact of the rise in rates on interest rate risk exposure. However, as discussed later, adjusting the duration of assets through selling long-term assets or through swap transactions potentially involves significant costs. In any event, several recent studies find limited use of hedges by banks to offset the adverse impact of recent increases in interest rates.[9]

Our research contributes to two important strands of banking literature. The first strand examines the effect of low interest rates on the profitability of banks. Recent work by WWWX (2022), ABK (2023) and Ampudia and Van Den Heuvel (2023) find that bank interest rate risk changes at very low or negative rates (in the case of Euro zone rates). These papers argue that the reversal occurs in part due to the inability of banks to pass-through market rate changes to depositors when interest rates are negative or close to zero. We provide evidence that pass-through rates vary significantly with interest rates even for rates that are well above zero. The other related strand of literature examines the interest rate risk that arises from maturity transformation. DSS (2021) find that because deposit pass-through rates are, on average, substantially less than one,

[8] This creates payoff complementarities in which uninsured depositors have an incentive to withdraw if they expect other depositors to withdraw. See Diamond and Dyvig (1983) and Chen, Goldstein, and Jiang (2008) who analyze payoff complementarities in the context of open-end mutual funds.
[9] See for example MCPhail, Schnable, and Tuckman (2023),and Jing, Matvos, Piskorski, and Seru (2023).

banks are able to hedge investment in long-term assets with deposit financing. We find that when rates are low, banks do not fully hedge by adjusting the duration of their assets to match the longer duration of their liabilities.

We also provide evidence that in low-rate environments, banks do not fully offset the decrease in the interest rate sensitivity of deposits by reducing the rate sensitivity of their assets. Consistent with our finding of a negative duration of equity in low-rate environments, we also find the sensitivity of return on assets (ROA) to interest rates varies inversely with deposit (and interest expense) betas when interest rates are low. One potential explanation for not completely hedging changes in the duration of deposits is the dynamic nature of deposit duration, much like negative convexity in mortgages, which implies that static hedges expose banks to interest rate risk when there are large changes in interest rate.

The remainder of the paper is organized into 7 sections. In the next section, we describe the data and provide evidence of a significant shift in the rate sensitivity of bank stocks in the post-crisis era. In section 3, we discuss the relationship between Federal Funds pass-through rates and the value of the deposit franchise and describe how we measure deposit pass-through rates. Section 4 provides summary statistics. In section 5 and 6, we present our empirical findings concerning the relation between pass-through rates and the level of interest rates and the interest sensitivity of bank stock prices. The last section contains a summary and conclusions.

2. Data and Motivating Evidence

2.1 Data

We obtain bank balance sheet and income statement data from bank Call Reports from 1997 through the first quarter of 2023. Our sample begins in 1997 because starting in 1997, Call Reports provide detailed information on repricing maturities of bank assets and liabilities which we use to calculate the maturity composition of bank assets and liabilities.[10]

[10] A Call Report divides assets into 6 repricing bins (ranging from 0 to 3 months to over 5 years) for 5 asset categories. Liabilities are divided in to 4 repricing bins. For each group of assets and liabilities we define their repricing maturity as the mid-point of the repricing bin. Demand deposits and other non-maturity deposits (NMDs) are assumed to have a 0-month repricing.

We supplement Call Reports data with stock return information from the Center for Research in Security Prices (CRSP).[11] We merge our Call Reports data and stock returns using the CRSP-FRB link, which is provided by the Federal Reserve Bank of New York.[12] This link facilitates the mapping of CRSP's primary company identifier (PERMCO) and the highest corporate parent in a banking organization. By using PERMCO, we map bank organizations to CRSP stock identifiers (PERMNO).[13]

We obtain information on the daily Effective Federal Funds Rates (series DFF) from the Federal Reserve Economic Data (FRED). We obtain daily Treasury yields for various maturities from the U.S. Department of the Treasury. In addition, we obtain Fama-French industry returns from Kenneth French's Data Library. Lastly, we manually gather meeting dates of the Federal Open Market Committee (FOMC) from the Federal Reserve Board's website.

Our bank dataset consists of bank-quarter data for all publicly traded banks from 1997 to the first quarter of 2023. We require that our main variables of interest have non-missing values. Consequently, our final sample consists of an unbalanced panel of 1,121 publicly listed banks. To address concerns that changes in the variables of interest may be caused by a change in the composition of the banks in our sample, for some analyses we restrict the sample to banks that have non-missing data for at least 12 quarters during low interest rate environments (defined as quarters in which the average FFR is below 2 percent) and at least 12 quarters during high-rate environments. This unbalanced panel consists of 452 banks.

In addition to examining the relationship beween changes in deposit betas and interest rates, we explore the importance of variations in deposit betas to bank earnings by examining the frequency that deposit betas are discussed in bank earnings conference calls. For this analysis we obtain transcripts of earnings conference calls through Refinitiv Workspace for publicly traded banks in our sample. Our earnings call sample comprises 9,238 transcripts spanning from January 2001 to May 2023, representing 238 banks. To identify discussions concerning "deposit beta," we

[11] Because we use CRSP annual files, the return dataset ends in December 2022. To include stock return information from the first quarter of 2023, we supplement our return data with daily return information from S&P's Capital IQ. We manually match bank stocks in our sample to those from Capital IQ.
[12] We thank Fulvia Fringuellotti for assisting with the link table.
[13] In a few cases where a PERMCO is associated with multiple PERMNOs, we manually assign the bank organization to Class A shares. For the few cases with missing values for the share class variable, we use the PERMNO with the highest market capitalization. In addition, from the Call Reports we use the information reported by the highest corporate parent. To identify the highest corporate parent in a banking organization, we use relationship data provided by the National Information Center (NIC).

search for patterns in the transcripts using the regular expression (regex) package in Python.[14] We then generate dummy variables to indicate whether "deposit beta" is mentioned in the presentation or Q&A session of a call. Additionally, we identify sentences containing the term "deposit beta" along with their prior and subsequent sentences. Using these sentences, we generate Figure 5, which is a WordCloud figure, using Python's NLTK and WordCloud packages.

2.2 Motivating evidence

As discussed in the introduction, our study is motivated by two seemingly conflicting trends that emerged in the low interest rate environment of the post-crisis period. First, as illustrated in Figure 1, the median repricing maturity of assets increased by over 40 percent from the first quarter of 2009 to the fourth quarter of 2022, while the repricing maturity of bank liabilities declined slightly. If we divide the sample into low- and high-rate environments, where low-rate environments are quarters in which the average FFR is below 2 percent, we see a somewhat smaller shift in repricing maturities. Specifically, the mean (median) repricing maturity of assets is 4.9 (4.5) years in high-rate quarters and 5.3 (5.0) years in low interest rate quarters.

Assuming the average repricing maturity of bank assets is a proxy for the duration of bank assets, then *ceteris paribus* one would expect the duration of bank equity and therefore the rate sensitivity of bank stocks to increase as well. As discussed earlier, a common measure of the rate sensitivity of bank equity is the return on bank stocks on FOMC meeting dates. The idea is that rate changes on these dates represent arguably exogenous interest rate shocks, unrelated to macro or bank sector fundamentals.

Following DSS (2021) and WWWX (2022), we estimate the sensitivity of bank stock prices to interest rate shocks by regressing the return on a bank stock portfolio on changes in two-year Treasury rates on FOMC dates.[15] For this analysis we use the return on the Fama-French bank industry portfolio as a measure of the bank industry return.[16] In addition, we also construct a value- and equally-weighted portfolio using stock returns for the banks in our sample.

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[14] Our regex pattern would catch various versions of deposit beta mentions, such as "deposit beta," "deposit betas," "sensitivity of deposit rates," in a sentence.

[15] DSS (2021) regress bank stock returns on changes in one-year rates. WWWX (2022) examine the relationship between bank stock returns and two-year Treasury rates because two-year rates are more likely to capture the effects of forward guidance in FOMC announcements (see Hanson, Stein, and Vishny (2015)). Our findings are similar if we use one-year instead of two-year Treasury rates.

[16] We obtain banking industry and market returns from Ken French's Website.

Figure 3 presents estimates of the interest rate sensitivity of the banking industry along with the Fama-French market portfolio in high- and low-rate environments. Again, following WWWX (2022), we define low interest rate environments as quarters in which the average effective FFR is below 2 percent. However, as discussed later we also examine variations in the rate sensitivity of bank stocks using continuous measures of interest rate levels. In addition, we test for structural breaks at different levels of interest rates.

As shown in Figure 3B, we find a negative and significant relation between bank stock returns and changes in the two-year rate during high interest rate quarters. This is consistent with a positive duration of equity (i.e., the duration of assets exceeds the duration of bank liabilities) and is consistent with the findings of earlier studies by Flannery and James (1984a, 1984b), EVZ (2018), and DSS (2021) using data covering the pre-crisis period. However, in sharp contrast, as shown in Figure 3A, in low interest rate quarters, we find a positive relation between bank stock returns and interest rate changes, indicating that the duration of bank equity is negative. Finally, as shown in Figure 3C, a reversal back to positive duration of equity in 2022 to first quarter of 2023 period of rapid rate hikes.

Our findings of a reversal from positive duration in high-rate quarters to negative duration in low interest rate quarters are not sensitive to the composition of the bank index or how we measure interest rate shocks. As shown in Figure 3, we find reversals in duration for the Fama-French banking index as well as for the value- and equally-weighted portfolio of publicly traded banks in our sample. We also find similar declines in rate sensitivity if we include as a control for changes in the spread between one- and 10-year Treasury rates or if, following Flannery and James (1984a), we measure unexpected interest rate shocks using the residuals from a third-order autoregressive model (AR (3)) of daily holding period returns on Treasury securities.

In our empirical analysis, we use a FFR of 2 percent for the reversal rate. The reversal rate is the interest rate at which the relation between bank capital and the FFR changes signs. WWWX (2022) estimate a structural model of the banking sector and find a reversal rate of around 2 percent. During our sample period, effective FFRs varied between 6.51 percent (September 2000) and 0.06 percent (March 2020) with a pre-crisis low of about 1 percent in December 2003 and a post-crisis high of 4.81 percent in March 2023. We investigate other potential cutoff rates at 25 basis-point intervals around 2 percent by estimating the relation between bank stock returns and changes in two-year Treasury yields on FOMC dates for low- and high-rate environments (below and above the cutoff rate). For each cutoff rate, we then plot the difference between the coefficient estimates for low- and high-rate environments. As shown in Figure 6, the differences are positive for cutoff rates between 1.75 percent and 3 percent. More important, the estimated coefficients below the cutoff are positive while the coefficients above the cutoff are negative. In short, Figure 6 indicates negative convexity in the relationship between changes in bank equity and interest rate changes. In subsequent analyses we use a FFR of 2 percent as the cutoff rate.[17]

The lower duration of bank equity when interest rates are low, despite an increase in the reported maturity mismatch, is puzzling. One explanation is that banks engaged in hedging transactions to offset the increase in the duration of their assets. However, Jing, Matvos, Piskorski, and Seru (2023) find limited use by banks of interest rate swaps (less than 6 percent of bank assets) to hedge interest rate risk.[18]

An alternative explanation is that the duration of bank deposit liabilities increases as interest rates decline. As DSS (2021) and WWWX (2022) explain, sticky deposit rates create a natural hedge against declines in the value of fixed-rate assets as interest rates increase. However, the effectiveness of deposits as a hedge depends on a stable duration of deposits (i.e., the passthrough of market interest rates to deposit yields is relatively stable). If the duration of deposits varies with interest rates, then the effectiveness of deposits as a hedge against interest rate changes will vary with the level of interest rates. We investigate this issue in the next section.

3. Pass-Through Rates and the Duration of the Bank Deposit Franchise

3.1 Pass-through rates and the value of the deposit franchise

The value of the deposit franchise is the present discounted value of the spread earned on deposits less the operating cost of the franchise. DSS (2021) and DSS (2017) provide a model of the deposit franchise based on bank market power that allows banks to pay rates on deposits which are below the Fed Funds rate. Specifically, they assume a constant pass-through rate β_t^D ($0 < \beta_t^D < 1$) so that the interest paid on deposits is simply

$$r_t^D = \beta_t^D f_t, \tag{1}$$

where f_t is the FFR. Then, the per period earnings from the deposit franchise is

[17] Our main results hold if we use cutoff rates between 1.75 and 3 percent.
[18] We also find for our sample a similar proportion of banks using derivatives.

$$[(1-\beta_t^D)f_t - c_t]D_t, \quad (2)$$

where c_t is the constant per unit cost of operating the deposit franchise and D_t is the total amount of deposits.

For simplicity assume that banks issue no long-term fixed-rate deposits and that changes in Fed Funds reflect a parallel shift in the yield curve. Given these assumptions, (2) is a measure of per period earnings from the deposit franchise and the effect of a change in the Fed Funds rate on the value of the deposit franchise is simply a multiple of the one-period change in earnings.

How the value of the deposit franchise varies with the level of interest rates and the effectiveness of the deposit franchise as a hedge depend on whether β_t^D varies with the level of interest rates. For example, DSS (2021) assume a constant pass-through rate which implies the value of the deposit franchise varies directly with the level of interest rates. However, if depositors are heterogenous and vary with respect to the pecuniary benefits they receive from holding deposits (benefits such as transactions costs and account services) then the pass-through rate is likely to be increasing in the level of interest rates.

Specifically, in determining the proportion of deposit holdings relative to other money market investments, such as money market mutual funds and short-term Treasuries, depositors will weigh the pecuniary and liquidity benefits of deposits against the opportunity cost of deposits, where the opportunity cost of deposits is the spread between the FFR and the rate paid on deposits. Given a constant pass-through rate, the opportunity cost of holding deposits will increase in the level of interest rates. Assuming the pecuniary and liquidity benefits per dollar of deposits are relatively fixed, banks will face increased competition from money market instruments for deposits as interest rates increase. The increase in competition is in turn likely to increase the pass-through rate needed to attract and retain deposits. In addition, the composition of bank deposits is also likely to vary with the level of interest rates.

We conjecture that the sensitivity of β_t^D to changes in the level of interest rates is likely to vary with the composition of bank deposits. Specifically, when rates are low customers are likely to substitute more liquid check and savings accounts for less liquid (but higher beta) time deposits. In addition, banks that are heavily reliant on large uninsured deposits may need to increase deposit rates more when rates rise since transaction costs are likely to decrease with the size of the deposit accounts and uninsured depositors are likely to require higher deposit rates for the credit risk associate with a loss in deposit franchise value in the event of large deposit withdrawals.

If β_t^D is positively related to the level of interest rates, then the duration of the deposit franchise will vary inversely with the level of interest rates. This in turn implies the effectiveness of the deposit franchise as a hedge against declines in the value of long- term fixed-rate assets will decline as interest rates increase. In other words, variable deposit betas complicate interest rate risk management in ways that are akin to negative convexity in bond pricing. Specifically, effective hedging requires estimating and accounting for the changing sensitivity of deposit rates to changes in interest rates over the interest rate cycle.

Bank regulators have recently recognized the need to account for changes in the sensitivity of deposits to interest rate changes. For example, in providing interest rate risk management (IRRBB) guidance, the Basel Committee on Bank Supervision explains "Behavioural assumptions for deposits that have no specific repricing date [NMD] can be a major determinant of IRRBB exposures… Banks should document, monitor, and regularly update key assumptions for NMD balances and behaviour used in their IMS [interest rate management system]. To determine the appropriate assumptions for its NMDs, a bank should analyse its depositor base in order to identify the proportion of core deposits (i.e., NMDs which are unlikely to reprice even under significant changes in interest rate environment)."[19]

3.2 Measuring pass-through rates

To investigate how the duration of deposits varies with interest rates, we compute two measures of the sensitivity of bank deposit yields to changes in FFRs. The first measure is based on recent work by DSS (2021) and measures the relation between changes in deposit yields and contemporaneous and lagged changes in FFRs. Specifically using quarterly bank level data, we estimate the following regression:

$$\Delta DepYield_{i,t} = \sum_{j=0}^{3} \beta_{i,j}^{D} \Delta FFR_{t-j} + \mathrm{X}_{i,t-1} + \delta_i + \tau_t + \varepsilon_{i,t} \qquad (3)$$

where $\Delta DepYield_{i,t}$ is the change in deposit yield between quarter t-1 and t for bank i. ΔFFR is the change in the Federal Funds rate in the contemporaneous and prior 3 quarters. $\mathrm{X}_{i,t-1}$ refers to controls for the natural logarithm of inflation-adjusted asset size and equity over assets, and δ_i and

[19] See Bank Committee on Banking Supervision: "SRP, Supervisory review process SRP31: Interest rate risk in the banking book". Version effective as of 15 December 2019.

τ_t are bank and year fixed effects, respectively. Our estimate of deposit rate sensitivity, β_i^D, is the sum of the coefficient estimates on changes in FFRs from equation (3). We investigate whether β_i^D varies with interest rates by estimating equation (3) in high and low-rate environments and testing whether the average β_i^D is higher when interest rates are high.

Our second measure of pass-through rates is simply the ratio of the change in a bank's deposit yield from *t*-1 to *t* divided by the change in the FFR over the same time interval. We refer to this measure as β_{it}^{DS}. The advantage of this measure is that it allows us to examine how pass-through rates vary with interest rates and bank characteristics on a more granular basis.[20] The disadvantage of β_{it}^{DS} is that it does not incorporate potential lags in the response of deposit rates to changes in FFRs and thus may understate the pass-through rate for deposits.

4. Summary Statistics

Our analyses are based on bank-quarter data for the period 1997 through the first quarter of 2023.[21] Appendix A provides definitions of the key variables in our analysis. Bank level summary statistics for the 1,121 banks in our sample are presented in Panel A of Table 1. To get a sense of how the rate sensitivity of bank income, deposit rates, and interest expense vary with the level of interest rates we divide the sample into quarters in which the average FFR is below 2 percent and quarters when the average FFR is at or above 2 percent. To address concerns that the differences we observe between high and low interest rate environments may be due to a change in the composition of banks in our sample, in Panel B of Table 1 we report summary statistics for 452 banks with at least 12 quarters of data in both high- and low-rate environments and at least eight quarters of data from before the financial crisis.[22] As shown, the mean and median assets for the 452 bank sample are substantially larger than those for our entire sample of banks.

As reported in Panel A of Table 1, the mean and median deposit betas (β_{it}^{DS}) are between 0.30 and 0.45 depending on the sample, indicating that banks on average pass-through 30 to 45

[20] We winsorize values of β_{it}^{DS} at the 5 percent level to avoid large values of β_{it}^{DS} associated with small quarterly changes in FFRs.
[21] To investigate whether our findings are sensitive to changes in the composition of banks in our sample, as a robustness check we use bank-quarter data for a well-balanced panel of 138 banks.
[22] In the Internet Appendix, we provide summary statistics for a balanced panel of 138 banks with data for all of the quarters in our sample. As discussed later, our findings are robust to using alternative samples of banks.

percent of FFR changes.[23] Comparing the average deposit betas in Panel A and Panel B suggests that deposit betas are on average higher for larger banks than for smaller banks.[24]

The significant greater mean and median deposit betas when interest rates are high suggest that pass-through rates varying with the level of interest rate. As shown, the mean and median deposit betas are between 60 to 70 percent higher when FFRs are at or above 2 percent than below 2 percent. Consistent with a positive relation between the value of the deposit franchise and the level of interest rates, the average deposit gap, defined as the difference between FFRs and average deposit yields, is -41 basis points when rates are below 2 percent compared to over 160 basis points in high interest rate quarters. Thus, using deposits to fund short-term investments in FFRs results in negative net interest margins when rates are low.

We find that reliance on interest bearing time deposits varies with the level of interest rates. As shown in Table 1, the median ratio of time to total deposits is about 24 percent higher when FFRs are at or above 2 percent. Thus, an increase in reliance on time deposits is one potential driver of the increase in deposit betas when interest rates increase.

We find that the average (median) maturity of bank assets is significantly greater when interest rates are low. As shown in Panel A of Table 1, the average maturity of bank assets is roughly 10 percent longer in low-rate environments than in high-rate environments. The increase in the maturity of bank assets in low-rate environments is driven by an increase in the proportion of assets held in mortgage-related assets. As shown, the proportion of mortgages relative to assets is on average about 19 percent greater when interest rates are low. The increase in the maturity of bank assets when rates are low is consistent with banks reaching for yield. Reaching for yield is typically defined as the propensity to buy riskier assets to boost returns and is motivated by the desire to circumvent regulatory restrictions on risk taking (see, for example, Becker and Ivashina (2015), Choi and Kronlund (2017) and Di Maggio and Kacperczyk (2017)).[25]

[23] We find very similar pass-through rates, about 0.30 to 0.40, using equation (3).

[24] In the Internet Appendix, we report bank-level summary statistics for large and small banks where large banks are defined as banks with over $100 billion in assets (in 2015 dollars) based on the Federal Reserve Board's definition of large financial institutions. See https://www.federalreserve.gov/supervisionreg/large-financial-institutions.htm.

[25] While risk-based capital requirements focus on credit risk, bank examiners evaluate banks' interest rate risk exposure as a part of scenario-based stress tests. U.S. bank holding companies (BHCs) with $100 billion or more in assets are subject to the Federal Reserve Board's supervisory stress test rules. Beginning in 2019 banks with assets between 100 and 200 billion are subject to stress tests on a two-year cycle. See "2023 Federal Reserve Stress Test Results" released by the Board of Governors of the Federal Reserve system. However, the tests typically model either no change in rates or scenarios with only modest rate shocks (less than 250 basis points in a one-year period). See "Fed's Bank Tests Overlooked Risk of Rapid Rise in Interest Rate."

While higher yields on long-term assets may have enticed banks to lengthen the maturity of ther assets, they may also have been motivated to lengthen the maturity of their assets to match the longer duration of their deposits when rates are low. As shown in Panel A of Table 1, the average repricing maturity of assets is about 10 percent longer in low interest rate quarters than in high interest rate quarters. However, the duration of deposits (as measured by β_{it}^{DS}) is between 60 and 70 percent higher, suggesting that banks did not completely match the increase in the duration of deposits with longer-term assets. In addition, we find no significant change in the stated repricing maturity of bank liabilities, suggesting that banks did not offset the increase in the duration of deposits by shortening the duration of their other liabilities.

Investing in longer-term assets appears to offset somewhat the decline in the average deposit gap when rates are low. In particular, while the difference in the average deposit gap is over 200 basis points in high- versus low-rate environments, the difference in average net interest margins is only about 34 basis points. The decline in the average interest income beta, which is the ratio of the quarterly change in interest income as a percent of assets to the change in FFRs, is consistent with an increase in long-term fixed-rate investments when rates are low. In section 6, we formally test whether banks matched changes in deposit duration with changes in the duration of assets by examining the relationship between changes in asset repricing maturities and deposit betas, and by examining the relation between changes in ROA and changes in deposit pass-through rates.

As shown in Table 1, reliance on uninsured deposits does not vary with interest rates Uninsured deposits are defined as the aggregate amount of deposit balances above the deposit insurance threshold ($100,000 before October 2008 and $250,0000 thereafter). As shown, the mean and median ratios of uninsured deposits to total assets are only about 4 percent higher in low-rate environments than when interest rates are high.

Consistent with the findings of DSS (2021), the sensitivity of bank interest income and interest expenses to changes in FFRs are *on average* well matched. As shown in Panels A and B, the average interest expense and interest income betas are both between 0.30 and 0.45 depending on the sample.[26] In addition, both interest expense and interest income betas are significantly greater in high interest rate quarters than in low interest rate quarters. However, consistent with

[26] The average income and interest expense betas are computed differently than in DSS (2021) but are similar in magnitude to those that DSS (2021) report.

banks not fully hedging their interest rate risk exposure, net interest margins and ROA are significantly lower when interest rates are below 2 percent than when rates are higher.

Finally, we find reliance on non-interest income varies with the level of interest rates. Non-interest income consists primarily of fee income and gains and losses from the sale or revaluation of loans and securities. We find the ratio of non-interest income to total income is roughly 30 percent higher when interest rates are below 2 percent than when interest rates are at or above 2 percent. This finding is consistent with the findings of Lopez, Rose and Spiegel (2018) who find that losses of interest income when nominal interest rates are low (negative) are almost exactly offset by gains in non-interest income. We examine the relation between changes in non-interest income and interest rates in more detail in section 6.

5. Do Deposit Betas Vary with Interest Rates?

The summary statistics in Table 1 suggest that deposit betas are inversely related to the level of interest rates. To further investigate the relationship between deposit betas and interest rates we conduct two additional tests. First, we estimate equation (3) separately for high and low interest rate quarters and test for differences.[27] For this analysis we include bank fixed effects to control for time-invariant bank characteristics, such as the deposit market concentration, that may affect the sensitivity of deposit rates to interest rates.

Estimates of equation (3) are reported in Table 2. The sum of the beta estimates from equation (3) indicates that banks, on average, pass-through to depositors 30 to 40 percent of changes in market rates (which is similar to the average estimate of β_{it}^{DS} reported in Table 1). Moreover, we find that on average β_i^D is greater in high-rate quarters than when rates are low. As shown, the average estimate of β_i^D is 17 percent higher when interest rates are at or above 2 percent than when rates are below 2 percent.[28]

Our second test involves examining the relation between β_{it}^{DS} and FFRs. Since pass-through rates are measured relative to FFRs, it is natural to focus on how pass-through rates vary with the level of FFRs. However, as a robustness check we also estimate the relation between β_{it}^{DS} and two-year Treasury rates. We estimate both a linear log specification as well as a non-linear

[27] We report estimates using the full sample of banks although the estimates are qualitatively similar when using the sample of 452 banks.

[28] Using a Chow test, we reject the null hypothesis that the coefficient estimates are equal at the 1% level.

(quadratic) specification. Both specifications are based on the on the idea that the sensitivity of β_{it}^{DS} to interest rate changes is likely to diminish beyond some level of interest rates as the proportion of rate-sensitive depositors declines. In all specifications, we include bank fixed effects and controls for bank size and leverage. To examine whether deposit betas are related to the composition of deposits, we also include the ratio of time deposits to total deposits.

Table 3 provides estimates of the relation between β_{it}^{DS} and the level of interest rates. As shown, we find a positive and significant relation between estimates of β_{it}^{DS} and the logarithm of interest rates (in decimals). The coefficient estimates for the specifications in columns (1) and (3) indicate that a doubling in the FFR or two-year Treasury rate is associated with more than a 11 percent increase in deposit beta relative to its mean.

In columns (2) and (4), we report the coefficient estimates for the quadradic specifications. The coefficient for the square of the interest rate variable is negative and statistically significant, indicating the relationship between β_{it}^{DS} and the level of short-term interest rates is nonlinear. Overall, our estimates reported in Table 3 indicate pass-through rates and therefore the duration of deposits vary significantly with the level of interest rates.

As discussed earlier, one potentially important driver of changes in deposit betas is changes in the composition of deposits.[29] As shown in columns (1)-(4), we find a positive and significant relation between deposit betas and the ratio of time deposits to total deposits. The economic magnitude of the within-bank impact of increases in the ratio of time deposits to total deposits on deposit betas is substantial. The coefficient estimate indicates that a one standard deviation increase in the ratio of time deposits to total deposits is associated with on average about a 68% increase in deposit betas relative to the mean.

Our review of earnings call transcripts for publicly traded banks in our sample indicates interest in the impact of changes in deposit betas is a relatively recent phenomenon and varies with the level of interest rates. Specifically, as shown in Figure 4, analyst and management discussions concerning the impact of deposit betas on bank earnings began increasing when interest rates first began to rise in 2017. As shown, the frequency of discussions concerning deposit betas decreased

[29] We also investigate the relation between the ratio of time deposits to total deposits and interest rates by regressing the ratio of time deposits on FFR (two year Treasury rates), including bank fixed effects and controls for bank size and leverage. In untabulated results, we find that a doubling in the FFR (two year Treasury rates) is associated with a 5% (9%) increase in the ratio of time deposits to total deposits.

when rates decreased in 2020 and then increased substantially when the Federal Reserve began increasing interest rates in early 2022.

When rates are increasing, not surprisingly, earnings call discussions generally focus on the impact of increases in deposit betas on net interest margins. The following quotes reflect the nature of discussions surrounding deposit betas.

"*On average, deposit costs increased 10 basis points from the fourth quarter and 31 basis points from a year ago, driven primarily by increases in wholesale and WIM deposit rates… The cumulative 1-year beta has increased to 43%, up from 38% last quarter, reflecting continued pricing competition across major deposit categories."*(Wells Fargo Confernce Call 4/12/2019)

and

"…net interest income was down 3%, primarily reflecting a lower net interest margin, which was down 13 basis points to 3.17% with the increase in asset yields more than offset by higher funding costs given the competitive environment and migration from lower-cost categories. With Fed funds increasing 500 basis points since the end of 2021, our cumulative interest-bearing deposit beta is 42% through the second quarter, which has been rising in response to the rate and competitive environment and is generally in the pack of peers. (Citizen's Financial Group earnings call 7/19/2023)

Interestingly, the frequency of discussions concerning deposit betas in earnings calls is positively related to our estimates of β_{it}^{DS}. Table 4 reports estimates of a linear regression model relating the likelihood of a discussion of deposit betas in a call to β_{it}^{DS} and whether or not interest rates are increasing. We include bank fixed effects so that identification is through within-bank variation in the frequency of mentions of deposit betas. As shown in Table 4, regardless of the specification we find a positive and significant relation between the likelihood of a discussion concerning deposit betas and β_{it}^{DS}. Higher deposit betas are associated more frequent discussions of deposit betas. Also, as reported in columns (3) and (4) of Table 4 the frequency of discussions and questions concerning a bank's deposit beta increases in quarters in which FFRs are increasing.

We also investigate whether the sensitivity of deposit betas to the level of interest rates varies with the reliance on uninsured deposits as a source of funding. This analysis is motivated by recent work by DSSW (2023) and Jiang, Matvos, Piskorski and Wang (2023) who argue that sharp increases in interest rates may give rise to value destroying runs by uninsured depositors. As interest rates increase, the value of the deposit franchise also increases (assuming a constant pass-through rate). However, whether this increase in value can offset the decline in the value of fixed-rate assets depends on the retention of deposits in the banks. The vulnerability to losses in case of withdrawals renders uninsured deposits susceptible to runs, and this risk intensifies with a greater dependence on uninsured deposits as a funding source. One way to potentially mitigate withdrawals of uninsured deposits is to increase deposit rates. Thus, we expect that the sensitivity of changes in deposit betas to interest rate changes to vary with the reliance on uninsured deposits.

We measure bank reliance on one quarter lagged ratio of uninsured deposits to total assets. We interact these measures with the logarithm of FFR or two-year Treasury yields and estimate regressions relating deposit betas and interest rates.[30] As shown in Table 5, the sensitivity of deposit betas to interest rates is significantly greater for banks that rely more heavily on uninsured deposits. Our finding that the sensitivity of pass-through rates varies with the reliance on uninsured deposits is not solely driven by the interest rate hikes in 2022 and 2023. Specifically, if we exclude this period the coefficient estimates are similar to those reported in Table 5.

Since the sensitivity of deposit betas to interest rate changes affects a bank's exposure to interest rate risk, the estimates in Table 5 suggest that banks that, *ceteris paribus*, rely heavily on uninsured deposits have much greater exposure to interest rate risk (aside from an obvious increase in exposure to liquidity risk).

6. Deposit Betas, Maturity Transformation, and the Interest Rate Sensitivity of Bank Stock Returns

6.1 How are deposit betas related to interest expense?

While deposits are an important source of bank funding, banks also rely on other sources of funding such as wholesale money market and bond financing. As shown in Table 1, on average deposits make up about 80 percent of financing and do not vary significantly with the interest rate environment. The use of non-deposit financing raises the question of whether banks adjust the duration of other funding sources in response to changes in the duration of deposits. The lack of any significant difference in the repricing maturity of liabilities between high and low interest rate environments, despite significantly lower average deposit betas when rates are low, suggests that this is not the case. However, to examine how interest expenses vary with deposit betas we

[30] We focus on the linear logarithm specification because the relationship between deposit betas and the level of interest rates is easier to interpretation using the linear specification, although our findings are qualitatively similar if we estimate a nonlinear model by interacting our measures of uninsured deposit reliance with the FFR and the FFR-squared. For the nonlinear specification, the coefficient estimates on squared interest rate interacted with the ratio of uninsured deposits to total assets are also positive and significant at the 1% level.

estimate an OLS regression relating interest expense betas to deposit betas. Since interest expense betas are simply the value weighted sum of the non-deposit liability beta and the deposit beta, if banks adjust the maturity composition of their non-deposit liabilities, we expect the estimated coefficient on deposit beta to differ significantly from the proportion of deposits to assets.

Estimates of the relationship between interest betas and deposit betas are presented in Table 6. In both specifications the coefficient estimates on deposit beta are around 0.73, slightly smaller but not significantly different than the average ratio of deposits to assets at the 5% level. Overall, the estimates in Table 6 suggest that banks do not adjust the maturity composition of their non-deposit liabilities in response to changes in the duration of deposits.

6.2 Duration of bank equity and deposit betas

The dynamic nature of the duration of deposits documented in Tables 2 and 3 suggests that banks intending to hedge their interest rate risk exposure need to adjust the maturity composition of their assets to match the changes in the duration of deposits as interest rates change. However, as we discuss later, selling long-term fixed-rate assets at a loss to match the reduction in deposit duration as rate rises are likely to be costly and may force banks to recognize mark-to-market losses for regulatory capital requirements. As a result, given the dynamic nature of pass-through rates, banks may not fully hedge changes in deposit pass-through rates.

We investigate the relation between deposit betas and bank interest rate risk exposure by examining the relations between the duration of bank equity and deposit betas. For this analysis we estimate the duration of equity based on the relation between banks stock returns and interest rate shocks. We measure interest rate shocks in two ways. The first is based on work by Flannery and James (1984a and 1984b) who measure unexpected changes in interest rates as the residuals from an AR (3) model on Treasury yields. The second measure is based on work by DSS (2021) and WWWX (2022) who measure interest rate shocks as the change in Treasury yields on FOMC meeting days. For both measures we use two-year Treasury yields although we find similar relationships using one-year Treasury yields.

We refer to equity duration measures based on the AR (3) residuals as *Yield betas* and equity duration based on changes in Treasury yields on FOMC meeting dates as *FOMC betas*. The advantage of using *Yield betas* is that they can be calculated on a quarterly basis and used to examine the relationship between equity duration and quarterly deposit betas (β_{it}^{DS}), controlling for bank fixed effects. As a result, using *Yield betas* enables us to examine within-bank variations over time in the sensitivity of bank equity associated with changes in deposit betas.

Because the FOMC typically meets only 8 times a year, we have too few observations to estimate quarterly bank-level *FOMC betas* and to control for bank fixed effects. Instead, we estimate bank-level *FOMC betas* when rates are high (quarters in which the average effective FFR is equal to or greater than 2 percent) and low (when the FFR is less than 2 percent). We then estimate the relation between bank *FOMC betas* and average bank deposit betas in high- and low-rate quarters. Using FOMC betas we are able to estimate the cross-sectional relation between the interest rate sensitivity of bank stock returns and average deposit betas. Since the duration of deposits varies inversely with deposit betas, if bank do not duration match changes in deposit betas, we expect a negative relation between *Yield betas* (*FOMC betas*) and β_{it}^{DS} (the quarterly average β_{it}^{DS}).

In Table 7, we report regression estimates relating both *Yield betas* and *FOMC betas* to deposit betas. When we estimate *Yield betas,* we include controls for one quarter lagged bank size (the natural logarithm of assets), leverage (the ratio of book equity to assets) and the average repricing maturity of bank assets. We also include bank fixed effects so that the identification is through within-bank variation in deposit betas. When we estimate *FOMC betas*, we include the natural logarithm of average bank size, average leverage, and average asset maturity calculated for each bank-interest rate environment. As shown in Table 7, regardless of the measure of interest rate shocks, we find a negative and significant relation between the rate sensitivity of bank stock returns and deposit betas. For example, the coefficient estimates in columns (1) and (2) indicate that a one standard deviation increase in deposit betas is associated with about a 13 percent decrease (relative to the mean) in the rate sensitivity of bank stock returns. The negative relation between bank rate sensitivity and deposit betas suggests that banks do not fully offset changes in deposit betas with changes in fixed-rate assets, derivatives, or changes in the maturity of their non-deposit liabilities.

While the focus of our analysis is on the dynamic nature of deposit betas and their effect on banks interest rate exposure, we also examine the relation between the interest rate sensitivity of banks stocks and interest expense betas. The analysis in the previous section shows that interest expense betas are positively related to deposit betas, which together with the findings in Table 7 suggests that during our sample period, the sensitivity of bank stock returns varies with the sensitivity of interest expenses to changes in interest rates. This is exactly what we find. Specifically, when we estimate regressions like those reported in columns (1) and (2) of Table 7 but substitute interest expense betas for deposit betas, the estimated coefficients are positive and statistically significant and range between 0.126 and 0.129.

Our findings differ from those reported by DSS (2021) who find that deposits effectively hedge banks' interest rates risk exposure. Specifically, Figure 8 in DSS (2021) shows that the relation between FOMC betas and interest expense betas is essentially flat, which they interpret as evidence that on average banks are not exposed to interest rate risk. What accounts for the difference between our findings and those of DSS (2021)? One explanation is that our sample is more heavily weighted towards periods when interest rates are low. As discussed earlier, DSS's (2021) stock return analysis is based on a sample period from 1994 to 2007, before the sustained period of low interest rates after the financial crisis. Recall, deposit betas vary inversely with interest rates and are less sensitive to interest rate changes when rates are high. Given the dynamic nature of deposit betas and the negative convexity of mortgage-related assets, during periods of sustained low interest rates, banks may be reluctant to match the long duration of deposits with long duration of assets. Consistent with this conjecture, in high interest rate quarters we find no significant relation between *Yield betas (FOMC betas*) and deposits betas or interest expense betas, which is consistent with the findings of DSS (2021).

6.3 The Relation between the duration of bank assets and deposit betas

How does the maturity composition of bank assets vary with deposit betas? To answer this questions, we use Call Reports information on the repricing maturity for bank assets to compute the quarterly, value weighted average repricing maturity of bank assets.

Estimating the relationship between the duration of assets and deposit betas is challenging for at least three reasons. First, a bank's investment portfolio is likely to evolve slowly over time, particularly for banks who classify their securities as held to maturity (HTM).[31] Second, the

[31] While the classification for accounting purposes does not have any direct economic effect on a bank's interest rate risk exposure, the classification does limit the ability of banks to sell securities before maturity. Early sale of HTM

average repricing maturity of assets is a relatively crude measure of the duration of assets because it is based on the stated repricing interval of bank assets and not the expected time to repricing or repayment. For example, most mortgages and loans have prepayment options, the value of which are likely to vary inversely relative to the level of interest rates. As a result, the duration of bank assets may decline with a decrease in interest rates even if the stated average repricing maturity increases with interest rates.[32] Importantly, the measurement error arising from using the repricing maturity of assets as a dependent variable is likely to be nonrandom and vary inversely with interest rates. The potential bias is similar to omitted variable bias since we cannot control for changes in expected prepayment rates. Finally, given dynamic deposit betas and convexity in bank assets, banks may choose not to match the duration of assets with liabilities to mitigate their exposure to large interest rate shocks.

We address these challenges by estimating the relation between the quarterly percentage change in the repricing maturity of assets and the cumulative change in deposit betas over the prior 4 quarters. We use the cumulative change in deposit betas to account for potential lags in the adjustment in maturity composition of bank assets in response to changes in the duration of bank deposits. We control for HTM securities holdings since, as discussed above, banks with large HTM securities are likely to adjust the maturity of their assets more slowly to match changes in the duration of bank assets. We also control for the proportion of mortgage holdings to assets because mortgages are one of the longest-term assets banks hold and as a result, the higher proportion of mortgage holdings, the smaller the proportion of assets maturing in any quarter and thus the smaller potential change in asset maturity.[33]

Finally, changes in the maturity composition of assets are likely to vary with the term structure of interest rates. On the one hand, a large term premium may tempt banks to reach for

securities typically requires all HTM securities to be reclassified as AFS. Moreover, reclassification increases the potential for loss in regulatory capital if rates subsequently increase. This is because if banks designate securities as held to maturity, the bank is allowed to exclude unrealized losses from equity capital. However, since 2013 most banks are required to market their AFS securities to market which impacts regulatory capital. See Granja (2023) for an analysis of the use of HTM accounting in banking.

[32] Since most commercial loans have floating rates, the prepayment option is likely most important for fixed rate mortgages and mortgage-backed securities. The callability of mortgages limits price appreciation from lower interest rates which creates negative convexity.

[33] Consistent with this argument, if instead of controlling for the proportion of mortgages to total assets we control for the proportion of assets maturing or repricing in 5 years or more (the longest maturity bucket), we find a negative and significant relation between change in asset repricing and the proportion of assets in the longest maturity bucket.

yield, suggesting a positive relation between changes in the maturity of assets and the spread between long and short term interest rates. On the other, given the convexity of deposit financing and mortgage loans, banks may be reluctant to lengthen the maturity of their assets when rates are expected to increase, leading to a negative relation between changes in maturity and the term premium. We measure the term premium as the difference between the yield on 10-year and one-year constant maturity Treasury yields.

Estimates of the regressions relating changes in the average maturity of assets to changes in deposit betas are presented in Table 8. Regardless of the controls included we find a negative and significant relation between changes in the maturity of bank assets and changes in deposit betas. However, the economic magnitude of the effect is small. Using the coefficients reported in column (1) of Table 8, a one standard deviation increase in the cumulative change in deposit betas is associated with about a 2. percentage points change in the repricing of bank assets. Given the sample average repricing maturity is about 5 years, the coefficient estimates in column (1) suggest only a 1.2-month change in the repricing maturity of bank assets.

What explains the small economic effect of changes in the duration of deposits on the maturity composition of assets? There are several potential explanations. First, constraints on early sale of HTM securities may slow the adjustment in the maturity of bank assets to match increases in the duration of bank liabilities. As shown in Table 8, we find a negative and significant relation between changes in the repricing of bank assets and the proportion of bank assets in HTM. Second, as discussed earlier, changes in the repricing maturity of bank assets are likely to measure changes in the duration of bank assets with error. For new mortgages originated when rates are low, expected prepayment rates are likely to be much lower (and the duration of mortgages much longer) than for mortgages originated when rates are high. As a result, changes in the repricing maturity of assets will understate changes in the duration of bank assets arising from new mortgage lending or investments in mortgage-backed securities. Finally, given the dynamic nature of deposit betas, banks may avoid engaging in static duration matching, since in the event of a sharp increase in rates the duration of deposits declines while the duration of assets with prepayment options increase. Consistent with this explanation we find a negative and significant relation between percentage change in the maturity of bank assets and the spread between 10-year and one-year Treasury yields.

6.4 Interest income, deposit expense and interest expense matching

To gain further insights into whether banks match changes in the duration of their deposits by changing the duration of their assets, we adopt the methodology of DSS (2021) who examine whether banks match changes in the interest sensitivity of assets with changes in the interest sensitivity of liabilities. Specifically, DSS (2021) test whether banks match interest expense sensitivity to income sensitivity by regressing ROA betas (the sensitivity of ROA to changes in FFRs) on interest expense betas. Consistent with matching, during their sample period, DSS (2021) find no significant relationship between ROA betas and interest expense betas.

During periods of low interest rates, the findings in Tables 7 and 8 suggest that banks do not match the rate sensitivity of their assets to changes in the rate sensitivity of their deposits. As a result, we expect bank ROA to vary inversely with interest rates. To test whether such matching varies with the level of interest rates we examine whether the relationship between ROA betas and deposit betas varies with the level of interest rates. If banks engage in matching, we expect no significant relation between ROA betas and deposit betas. Alternatively, if banks do not fully hedge their rate exposure, we expect a negative relation between the rate sensitivity of ROA and the rate sensitivity of deposits and interest expenses.

Table 9 presents estimates of regressions relating bank ROA betas to deposit betas and interest expense betas. Consistent with banks not completely hedging changes in the duration of deposits with changes in the duration of assets, as shown in columns (1) and (2), we find a negative and significant relation between ROA betas and deposit betas. Since as shown in Table 6, the primary determinant of the sensitivity of interest expense to interest rates is the sensitivity of deposit rates to interest rates, it is not surprising that we also find a negative and significant relation between ROA betas and interest expense betas. Specifically, as shown in columns (5) and (6), a one standard deviation increase in interest expense betas is associated with about a 26.5 percent decrease in ROA sensitivity relative to its mean.

The estimates in columns (3) -(4) and (7) -(8) suggest that banks engage in less interest rate sensitivity matching when interest rates are low. For example, in high-rate environments we find no significant relationship between ROA betas and deposit betas and a small but statistically significant relation between ROA betas and interest expense betas. In contrast when rates are low, we find a negative and significant relation between ROA betas and both interest expense betas and deposit betas.

The negative relation between ROA betas and interest rate/deposit betas is consistent with our finding of positive *Yield (FOMC) betas* in low-rate environments. Specifically, the negative relationship between ROA betas and interest rate/deposit betas indicates that banks do not fully match the sensitivity of their interest expense to interest rate changes with the sensitivity of their earnings to interest rate changes during periods of low interest rates. Decomposing changes in ROA into its interest and non-interest components we find that, similar to DSS (2021), the estimated relationship between interest income and interest expense betas is close to one for the entire sample (0.928) and in both high- and low-rate environments. However, we find that the sensitivity of non-interest components of net income (and ROA) varies inversely with deposit/interest rate betas. Non-interest income consists primarily of fee income, gains/losses on the sale of assets, and mark-to-market gains or losses on AFS securities. Non-interest expenses consist of SGA and other expenses. We compute other income betas as the ratio of the quarterly change in other net income to changes in effective FFRs.

As shown in Table 10, we find a negative and significant relation between other income betas and both interest expense and deposit betas. More important, we find a negative and significant relation between other income and deposit/interest betas only when rates are low. One explanation for this reversal, consistent with recent work by Lopez, Rose and Spiegel (2018), is that capital gains and losses on fixed-rate assets (which move inversely with interest rates) are a greater component of non -interest income when rates are low.

7. Conclusion

The post-crisis era has, until recently, been characterized by a period of sustained low interest rates. Recent research suggests that the impact of interest rate changes on the profitability and value of bank capital may be different when interest rates are close to the zero bound. As DSS (2021) and others show, one important factor affecting the interest rate risk exposure of banks is the duration of a bank's deposit franchise. In this paper, we provide evidence that the pass-through rate of market interest rates to depositors (and therefore the duration of deposits) varies with the level of interest rates and whether the deposits are insured. We also provide evidence that banks do not fully match the increase in the duration of deposits when rates are low with long-term fixed-rate assets. As a result, in low-rate environments the duration of bank equity is negative. More importantly, the dynamic nature of deposit pass-through rates implies that banks' interest rate risk exposure can increase substantially when interest rates increase sharply, even for banks that prior to the interest rate hike appeared well hedged against interest rate increases.

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Figures and Tables

Figure 1: Repricing Maturities of Bank Balance Sheet Items and the Federal Funds Rate

This figure plots quarterly median repricing maturities of assets and liabilities for publicly listed banks in the U.S. between 1997 and the first quarter of 2023. Repricing maturity is defined as the time until the interest rate resets. The left axis refers to repricing maturities of assets (blue line) and liabilities (red line). The right axis refers to the effective Federal Funds Rate (green line). Variable definitions are described in Appendix A.

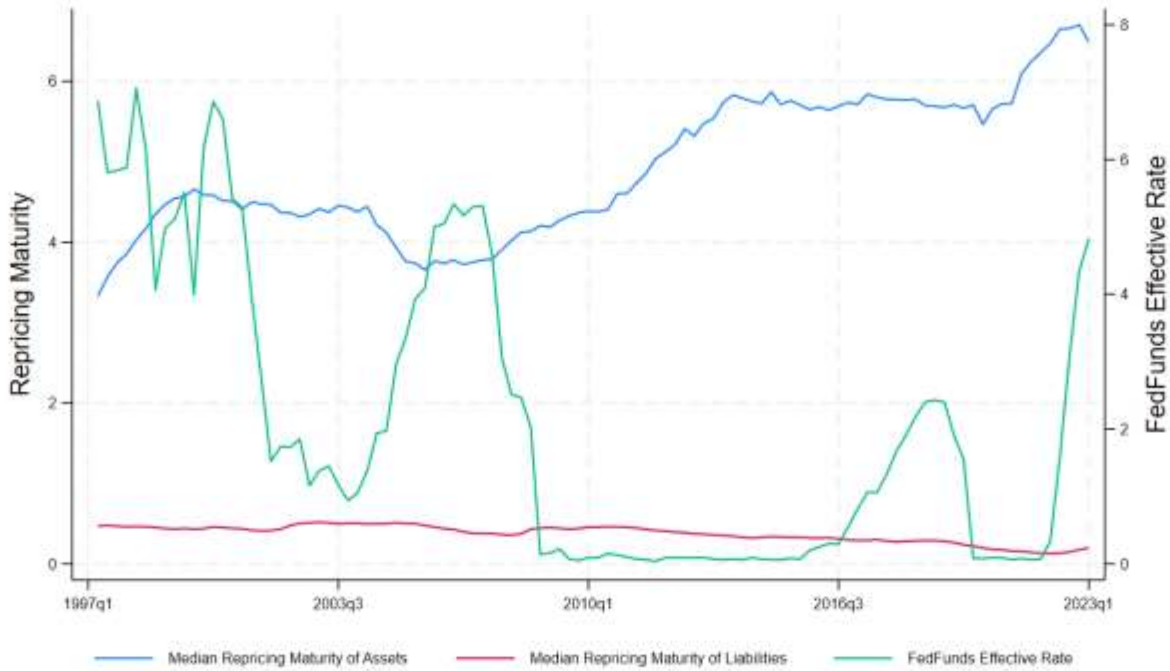

Figure 2: Industry-Level Stock Returns and Interest Rate Changes

This figure shows the sensitivity of returns of industry portfolios to rate changes following FOMC meetings. Returns of the 49 Fama-French industry portfolios and the market portfolio are obtained from Ken French's website. FOMC meeting dates are taken from the Federal Reserve Board's website. The figure plots the coefficients from regressions of these industry and market returns on the change in two-year Treasury yield over a one-day window around FOMC meetings. If an FOMC meeting lasts more than a day, we include in the sample the last day of the FOMC meeting dates. Figure 2A uses a sample period prior to the Global Financial Crisis, i.e., from January 1994 to June 2007. Figure 2B features the period after the financial crisis, i.e., from June 2009 to March 2023.

Figure 2A: Pre-Global Financial Crisis (January 1994 – June 2007)

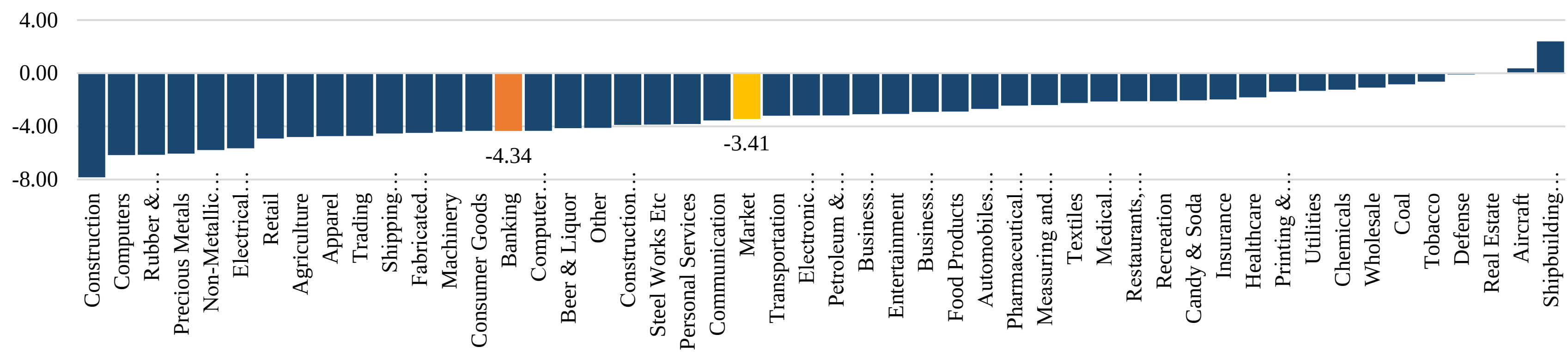

Figure 2B: Post-Global Financial Crisis (June 2009 – March 2023)

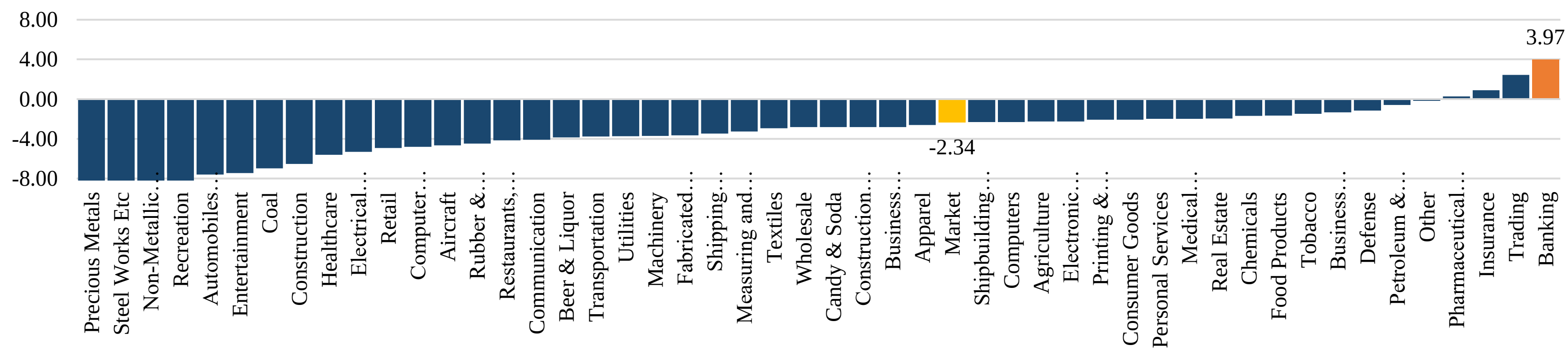

Figure 3: Interest Rate Sensitivity in High- and Low-Rate Environments

This figure presents interest rate sensitivity for portfolios of bank stocks and the Fama-French market portfolio (*Market*) in high- and low-rate environments, as well as the recent rate-hike period from January 2022 through March 2023. We implement the same methodology used in Figure 2 to generate the figure. High-rate (low-rate) environment refers to periods when the effective Federal Funds rate is 2% or above (below 2%). *Banking* refers to the Fama-French bank portfolio while *VW Bank* and *EW Bank* refer to value-weighted and equal-weighted returns of bank stocks in our sample, respectively.

Figure 3A: Low-Rate Environments

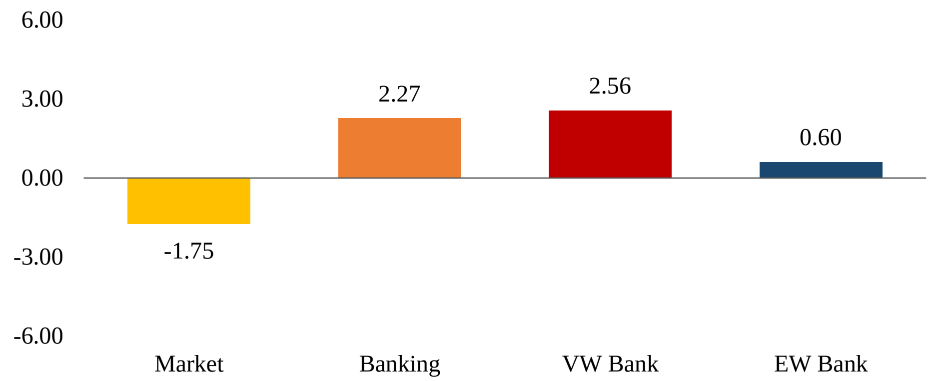

Figure 3B: High-Rate Environments

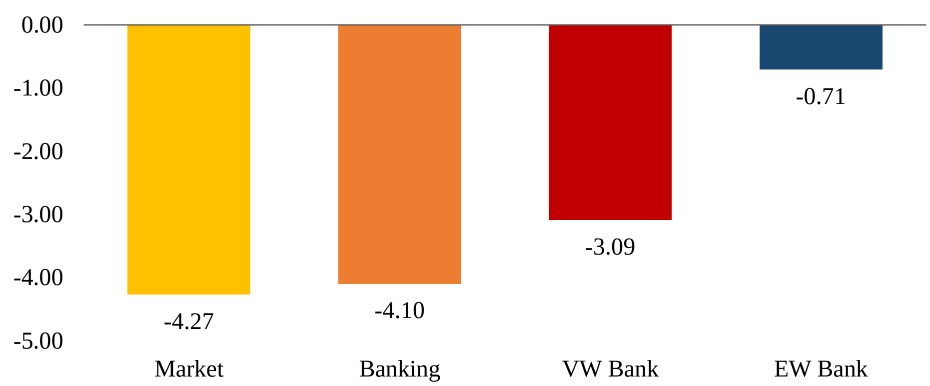

Figure 3C: Recent Rate Hikes

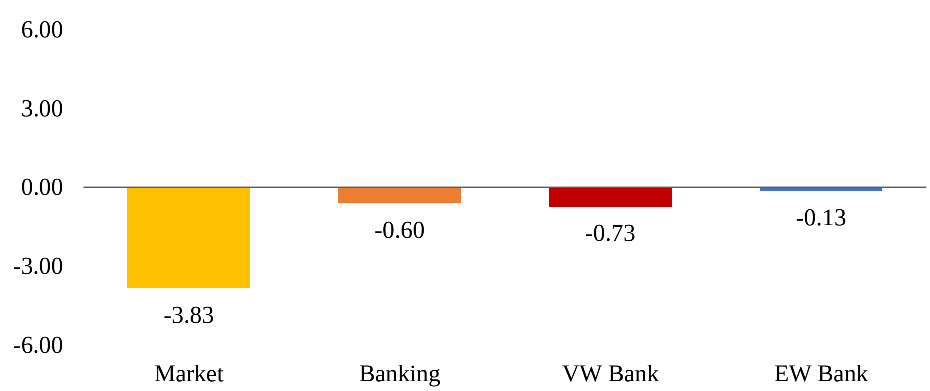

Figure 4: Deposit Beta Discussions in Bank Earnings Calls

We obtain transcripts of earnings calls for publicly listed banks from Refinitiv Workspace and identify earnings calls in which deposit beta was discussed. The left axis refers to the percentage of transcripts that include mentions of deposit beta. Gray (blue) bars represent percentages of earnings calls when the term was mentioned during company presentations (Q&A sessions with analysts). The right axis refers to the effective Federal Funds Rate (red line) at the quarterly frequency. The sample period starts in 2013 because deposit betas were rarely discussed before 2013 (less than five times).

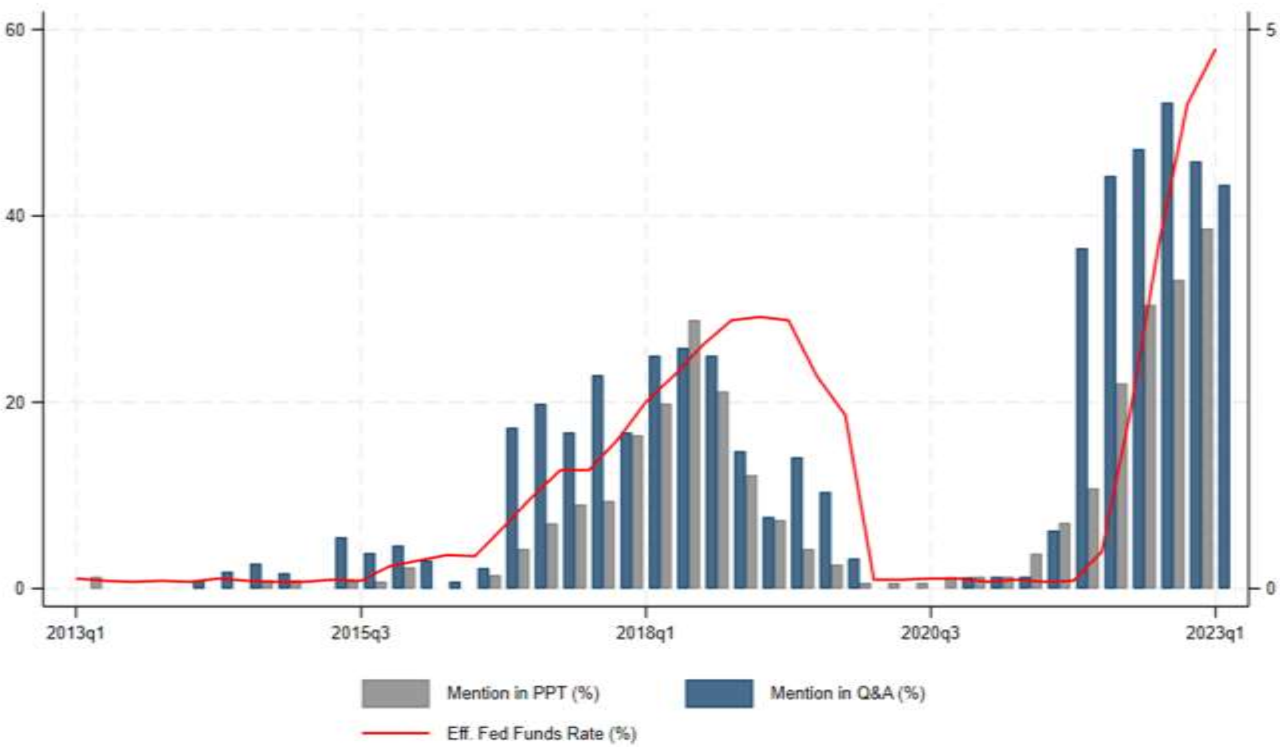

Figure 5: WordCloud Related to Deposit Beta

This figure illustrates the keywords discussed in bank earnings calls when deposit beta is the topic. We obtain transcripts of earnings calls for publicly listed banks from Refinitiv Workspace. After identifying earnings calls with deposit beta discussions through regular expressions, we store the sentences that include deposit beta mentions, along with the sentences preceding and following them. Subsequently, we remove stop words and filler words from the resulting set of words and generate a WordCloud.

Figure 6: Interest Rate Sensitivity Differences

To plot this figure, we first regress returns of the Fama-French banking portfolio on changes in two-year Treasury yields over a one-day window around FOMC meetings for low- and high-rate environments. We use various cutoff rates at 25 basis-point intervals around 2 percent to define low-rate and (high-rate) environments, which refer to periods when the effective Fed Funds rate is below (at or above) a given cutoff rate. For each cutoff rate, we then plot the difference between the coefficient estimates for low- and high-rate environments.

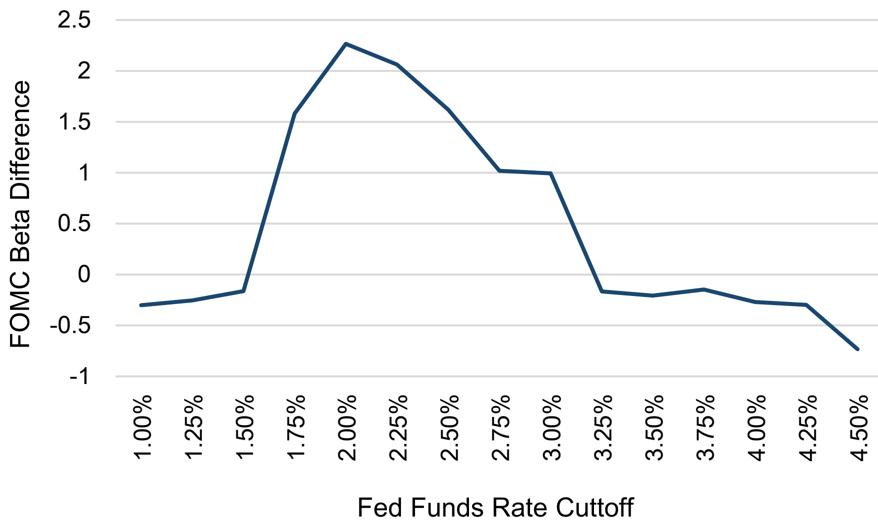

Table 1: Descriptive Statistics

This table presents summary statistics on publicly listed U.S. banks for the period from Q1 1997 through Q1 2023. Variable definitions are described in Appendix A. We partition the full sample into high- and low-rate environments based on whether the Federal Funds rate is greater than 2% or not. Column (10) reports test results of the differences in the mean values between high- (column (4)) and low-rate environments (column (7)), assuming unequal variances. Panel A features the full sample of 1,121 banks while Panel B includes 452 banks that have at least 12 quarterly observations in both high- and low-rate environments and have at least eight quarterly observations before 2008. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

Panel A: Full sample of banks	Full Sample			High-Rate Environment			Low-Rate Environment			
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean Diff.
Interest Rate Sensitivity Measures	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Federal Funds Rate (%)	2.903	2.341	1.802	4.493	4.503	1.038	0.806	0.581	0.487	3.687***
Deposit Yield (%)	2.162	2.035	1.223	2.795	2.951	1.125	1.245	1.025	0.779	1.551***
Deposit Gap (%)	0.746	0.572	1.001	1.696	1.710	0.840	-0.415	-0.305	0.603	2.110***
Deposit Beta	0.285	0.310	0.625	0.453	0.434	0.705	0.269	0.274	0.594	0.184***
Interest Expense	2.074	1.983	1.157	2.567	2.736	1.118	1.372	1.132	0.855	1.195***
Interest Expense Beta	0.331	0.309	0.491	0.430	0.390	0.508	0.264	0.216	0.517	0.167***
Interest Income	5.718	5.588	1.498	6.323	6.530	1.430	4.796	4.619	1.093	1.527***
Interest Income Beta	0.309	0.307	0.601	0.432	0.380	0.605	0.250	0.259	0.669	0.182***
ROA (%)	0.913	0.974	0.579	1.066	1.112	0.504	0.730	0.883	0.810	0.336***
ROA Beta	-0.239	-0.185	0.650	0.020	0.024	0.473	-0.466	-0.429	0.804	0.486***
Other Income Beta	-0.052	-0.040	0.684	0.054	0.045	0.542	-0.189	-0.182	0.837	0.243***
Yield Beta	1.690	1.306	3.180	0.581	0.426	2.657	2.725	2.180	3.786	-2.144***
FOMC Beta	0.654	0.841	5.632	0.053	0.000	6.412	1.396	1.124	5.232	-1.343***
Bank Characteristics										
Repricing Maturity of Assets	5.042	4.734	2.275	4.866	4.482	2.334	5.328	4.984	2.284	-0.462***
Repricing Maturity of Liabilities	0.451	0.428	0.230	0.444	0.424	0.218	0.455	0.419	0.258	-0.011
Maturity Mismatch	4.587	4.295	2.278	4.418	4.027	2.332	4.868	4.527	2.303	-0.451***
Market-to-Book Ratio	2.054	1.564	1.712	2.254	1.703	1.824	1.636	1.333	1.370	0.618***
Assets ($billion)	13.217	1.239	82.758	12.138	1.214	67.572	15.508	1.429	103.251	-3.370
Equity/Assets	0.098	0.094	0.026	0.097	0.091	0.028	0.100	0.099	0.027	-0.004***
Uninsured Deposits/Assets	0.205	0.185	0.110	0.205	0.186	0.110	0.213	0.194	0.117	-0.007
Non-Interest Income / Income (%)	14.598	12.462	9.785	12.841	11.110	8.593	16.669	14.474	10.667	-3.828***
Deposits/Assets	0.788	0.801	0.077	0.786	0.800	0.080	0.791	0.803	0.073	-0.005
HTM to Assets (%)	3.434	1.175	5.791	3.738	1.357	6.142	2.578	0.612	5.251	1.160***
(MBS + Mortgage)/Assets	0.540	0.575	0.190	0.515	0.546	0.205	0.612	0.625	0.136	-0.097***
Cash/Assets	0.049	0.041	0.031	0.042	0.035	0.028	0.054	0.044	0.036	-0.012***
Time Deposits/Total Deposits	0.385	0.389	0.162	0.411	0.421	0.161	0.353	0.339	0.169	0.058***
Observations	1,121			1,053			893			

Panel B: Alternative sample of 452 banks

	Full Sample			High-Rate Environment			Low-Rate Environment			
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean Diff.
Interest Rate Sensitivity Measures	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Federal Funds Rate (%)	2.493	2.115	0.859	4.481	4.503	0.461	0.830	0.581	0.407	3.651***
Deposit Yield (%)	1.987	1.849	0.771	2.876	2.857	0.689	1.260	1.105	0.641	1.616***
Deposit Gap (%)	0.511	0.472	0.546	1.604	1.644	0.593	-0.417	-0.347	0.466	2.021***
Deposit Beta	0.489	0.462	0.270	0.658	0.623	0.416	0.366	0.352	0.315	0.292***
Interest Expense	1.963	1.845	0.732	2.674	2.701	0.638	1.417	1.239	0.682	1.257***
Interest Expense Beta	0.450	0.428	0.270	0.595	0.552	0.363	0.316	0.306	0.334	0.279***
Interest Income	5.558	5.413	0.944	6.422	6.407	0.838	4.882	4.736	0.876	1.540***
Interest Income Beta	0.463	0.459	0.301	0.608	0.574	0.437	0.331	0.337	0.394	0.277***
ROA (%)	0.943	0.968	0.420	1.140	1.161	0.385	0.791	0.872	0.570	0.349***
ROA Beta	-0.222	-0.196	0.290	0.031	0.041	0.237	-0.409	-0.403	0.498	0.440***
Other Income Beta	-0.088	-0.075	0.311	0.091	0.104	0.275	-0.213	-0.223	0.518	0.305***
Yield Beta	1.782	1.430	2.350	0.220	0.249	1.501	2.567	2.054	3.126	-2.347***
FOMC Beta	0.124	0.573	3.754	-0.775	-0.403	5.155	0.885	0.841	4.322	-1.660***
Bank Characteristics										
Repricing Maturity of Assets	5.005	4.675	2.063	4.701	4.265	2.110	5.203	4.871	2.115	-0.502***
Repricing Maturity of Liabilities	0.443	0.428	0.207	0.445	0.433	0.203	0.450	0.426	0.231	-0.005
Maturity Mismatch	4.558	4.272	2.068	4.253	3.833	2.108	4.750	4.460	2.126	-0.497***
Market-to-Book Ratio	1.993	1.585	1.341	2.339	1.829	1.601	1.740	1.407	1.269	0.600***
Assets ($billion)	21.120	1.566	123.753	16.655	1.386	95.038	23.881	1.689	142.056	-7.226
Equity/Assets	0.097	0.095	0.017	0.095	0.091	0.019	0.098	0.096	0.019	-0.003**
Uninsured Deposits/Assets	0.209	0.198	0.094	0.209	0.196	0.097	0.210	0.197	0.100	-0.001
Non-Interest Income / Income (%)	16.242	14.272	9.396	14.091	12.572	8.363	18.394	17.102	9.876	-4.302***
Deposits/Assets	0.778	0.794	0.075	0.772	0.783	0.076	0.784	0.799	0.074	-0.012**
HTM to Assets (%)	3.232	1.331	5.882	3.684	1.461	6.425	2.788	0.886	5.711	0.896**
(MBS + Mortgage)/Assets	0.561	0.570	0.130	0.524	0.533	0.154	0.600	0.613	0.124	-0.075***
Cash/Assets	0.046	0.040	0.025	0.038	0.034	0.021	0.051	0.044	0.030	-0.013***
Time Deposits/Total Deposits	0.381	0.379	0.143	0.423	0.424	0.139	0.354	0.344	0.152	0.069***
Observations	452			452			452			

Table 2: Deposit Pass-Through Rates

This table presents results from regressions of quarterly changes in deposit yields on changes in the Federal Funds rate and three lags of Federal Funds changes. In addition to the full sample, we partition the full sample into high- and low-rate environments based on whether the Federal Funds rate is greater than 2% or not. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. Variable definitions are described in Appendix A. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: Δ Deposit yield		
	Full sample	High-rate environment	Low-rate environment
	(1)	(2)	(3)
Δ Fed funds rate$_t$	0.036***	0.042***	0.022***
	(0.004)	(0.005)	(0.008)
Δ Fed funds rate$_{t-1}$	0.151***	0.146***	0.168***
	(0.004)	(0.004)	(0.006)
Δ Fed funds rate$_{t-2}$	0.126***	0.132***	0.083***
	(0.004)	(0.005)	(0.004)
Δ Fed funds rate$_{t-3}$	0.054***	0.049***	0.042***
	(0.004)	(0.005)	(0.005)
Bank FEs	Yes	Yes	Yes
Observations	0.19	0.18	0.21
R-squared	40,943	17,142	23,774
Sum of coefficients on Δ Fed funds rate	*0.367*	*0.369*	*0.315*

Table 3: Sensitivity of Deposit Betas to Interest Rates

This table presents results from regressions that relate deposit beta, which is the sensitivity of quarterly changes in deposit yields to changes in the Federal Funds rate, to levels of interest rates. In columns (1), the key independent variable is the natural logarithm of the lagged Federal Funds rate (in decimals). In column (2), the main independent variables are the lagged Federal Funds rate and its quadratic term. In columns (3) and (4), the main independent variables are the lagged two-year Treasury yield and its quadratic term. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. Controls include the natural logarithm of bank assets and the ratio of equity to assets. Variable definitions are described in Appendix A. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: Deposit beta			
	(1)	(2)	(3)	(4)
Ln(Fed funds rate$_{t-1}$)	0.051***			
	(0.007)			
Fed funds rate$_{t-1}$		0.314***		
		(0.014)		
(Fed funds rate$_{t-1}$)^2		-0.048***		
		(0.002)		
Ln(2-year yield$_{t-1}$)			0.032***	
			(0.012)	
2-year yield$_{t-1}$				0.230***
				(0.018)
(2-year yield$_{t-1}$)^2				-0.036***
				(0.003)
Time deposits$_{t-1}$/Total deposits$_{t-1}$	1.168***	1.076***	1.288***	1.206***
	(0.124)	(0.125)	(0.121)	(0.120)
Controls	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes
Observations	37,378	37,378	37,378	37,378
R-squared	0.03	0.04	0.03	0.03

Table 4: Discussions of Deposit Beta in Bank Earnings Calls

This table presents results from linear regression models where the dependent variable equals 1 if a bank's earnings call includes a discussion of deposit beta and 0 otherwise. We identify discussions of deposit beta by applying Python's regex module on transcripts of earnings calls for publicly listed banks in our sample. Our sample period starts in Q1 2013 and ends in Q1 2023 as deposit beta was rarely discussed before 2013. The main independent variable is lagged deposit beta. We also include a dummy variable I(Rate increment$_{t\text{-}1 \text{ to } t}$), which equals 1 if the quarterly average of FFR increases more than 25 basis points from quarter *t*-1 to quarter *t*. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	Discussion of deposit beta in earnings call in quarter *t*			
	(1)	(2)	(3)	(4)
Deposit beta$_{t\text{-}1}$	0.010***	0.015***	0.006**	0.006**
	(0.003)	(0.003)	(0.002)	(0.002)
I(Rate increment$_{t\text{-}1 \text{ to } t}$)			0.294***	0.302***
			(0.018)	(0.020)
Deposit beta$_{t\text{-}1}$ × I(Rate increment$_{t\text{-}1 \text{ to } t}$)				-0.025
				(0.031)
Controls	No	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes
Observations	5,052	5,050	5,050	5,050
R-Squared	0.11	0.18	0.26	0.26

Table 5: Deposit Beta and Uninsured Deposits

This table reports results from regressions that relate deposit beta, the level of interest rates, and a bank's reliance on uninsured deposits. We use the ratio of uninsured deposits to assets to measure reliance on uninsured deposits. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. Controls include the natural logarithm of bank assets and the ratio of equity to assets. Variable definitions are described in Appendix A. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: Deposit beta	
	(1)	(2)
Ln(Fed funds rate$_{t-1}$)	0.044***	
	(0.009)	
Ln(2-year yield$_{t-1}$)		0.068***
		(0.026)
Ln(Fed funds rate$_{t-1}$) × Uninsured deposits$_{t-1}$/Assets$_{t-1}$	0.143***	
	(0.028)	
Ln(2-year yield$_{t-1}$) × Uninsured deposits$_{t-1}$/Assets$_{t-1}$		0.220***
		(0.033)
Controls	Yes	Yes
Bank FEs	Yes	Yes
Observations	37,378	37,378
R-squared	0.03	0.03

Table 6: Interest Expense Beta and Deposit Beta

This table presents results from regressions that relate quarterly interest expense beta to contemporaneous deposit beta. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. Controls include the natural logarithm of bank assets and the ratio of equity to assets. Variable definitions are described in Appendix A. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: Interest expense beta	
	(1)	(2)
Deposit beta	0.725***	0.727***
	(0.005)	(0.005)
Controls	No	Yes
Bank FEs	Yes	Yes
Observations	35,745	35,345
R-squared	0.63	0.63

Table 7: Sensitivity of Bank Returns to Interest Rate Shocks and Deposit Betas

This table presents results from linear regression models where the dependent variable is the sensitivity of bank stock returns to interest rate shocks. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. We measure interest rate shocks in two ways. The first measure is the residual from an AR (3) model relating two-year Treasury yields to lagged Treasury yields. We then regress bank stock returns on the residual, the estimated coefficient of which is yield beta. The dependent variable in columns (1) and (2) is yield beta, and the controls include the natural logarithm of bank assets, the ratio of bank equity to assets, and the lagged repricing maturity of bank assets. The second measure is the change in two-year Treasury yields on FOMC dates. The dependent variable in columns (3) and (4) is the estimated coefficient from a regression relating bank returns to changes in interest rates on FOMC dates. The control variables are the natural logarithm of average bank assets, the average of bank equity to assets ratio, and the average of repricing maturity across bank-interest rate environment. Variable definitions are described in Appendix A. Standard errors are reported in parentheses. In columns (1) and (2) standard errors are clustered by bank, and in columns (3) and (4) standard errors are heteroskedasticity robust. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	Yield beta		FOMC beta	
	(1)	(2)	(3)	(4)
Deposit beta$_{t-1}$	-0.187***	-0.195***		
	(0.021)	(0.021)		
Average deposit beta$_{t-1}$			-0.653***	-0.622***
			(0.253)	(0.255)
Controls	No	Yes	No	Yes
Bank FEs	Yes	Yes	No	No
Observations	32,711	32,711	1,893	1,893
R-squared	0.13	0.18	0.01	0.01
Unit of observation	Bank-quarter		Bank-interest rate environment	

Table 8: Asset Maturity and Deposit Betas

This table presents results from regressions of the quarterly percentage change in the repricing maturity of assets on lagged deposit beta, which is the sensitivity of quarterly changes in deposit yields to changes in the Federal Funds rate. Repricing maturity is defined as the time until the interest rate resets. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. Controls include the natural logarithm of bank assets and the ratio of equity to assets. Variable definitions are described in Appendix A. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	% Change in repricing maturity of assets				
	(1)	(2)	(3)	(4)	(6)
Δ Deposit beta$_{t\text{-}4 \text{ to } t\text{-}1}$	-0.071***	-0.073***	-0.070***	-0.069***	-0.068***
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
(MBS + Mortgage)$_{t\text{-}1}$/Assets$_{t\text{-}1}$			-5.178***	-4.629***	-4.818***
			(1.093)	(1.104)	(1.122)
10-year yield$_{t\text{-}1}$ – 1-year yield$_{t\text{-}1}$				-0.219***	-0.228***
				(0.062)	(0.062)
HTM$_{t\text{-}1}$/Assets$_{t\text{-}1}$					-0.035**
					(0.016)
Controls	No	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes
Observations	28,263	28,263	28,263	28,263	28,263
R-squared	0.04	0.04	0.04	0.04	0.04

Table 9: Interest Sensitivity Matching in Differing Rate Environments

This table presents results from regressions of quarterly ROA beta on Deposit beta and Interest expense beta. *I(Low rate env.)* equals one for periods when the Federal Funds rate is below 2 percent and zero otherwise. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. Variable definitions are described in Appendix A. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	ROA beta				ROA beta			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Deposit beta	-0.038***	-0.039***	0.013	0.014				
	(0.008)	(0.008)	(0.010)	(0.010)				
Interest expense beta					-0.129***	-0.131***	-0.054***	-0.055***
					(0.010)	(0.010)	(0.014)	(0.014)
I(Low rate env.)			-0.446***	-0.432***			-0.457***	-0.447***
			(0.020)	(0.020)			(0.020)	(0.020)
Deposit beta × I(Low rate env.)			-0.094***	-0.096***				
			(0.015)	(0.015)				
Interest expense beta × I(Low rate env.)							-0.113***	-0.113***
							(0.018)	(0.018)
Bank Controls	No	Yes	No	Yes	No	Yes	No	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35,745	35,345	35,745	35,345	35,745	35,345	35,745	35,345
R-squared	0.03	0.03	0.04	0.05	0.04	0.05	0.06	0.06

Table 10: Relationship Between Other Income Beta and Deposit (Interest Expense) Beta

This table presents results from regressions of quarterly Other income beta on Deposit beta and Interest expense beta. *I(Low rate env.)* equals one for periods when the Federal Funds rate is below 2 percent and zero otherwise. Our sample includes publicly listed U.S. banks for the period running from Q1 1997 through Q1 2023. Variable definitions are described in Appendix A. Standard errors are clustered at the bank level and reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

	Other income beta				Other income beta			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Deposit beta	-0.019*	-0.018*	0.056***	0.060***				
	(0.010)	(0.010)	(0.011)	(0.011)				
Interest expense beta					-0.078***	-0.076***	0.098***	0.104***
					(0.012)	(0.012)	(0.017)	(0.017)
I(Low rate env.)			-0.249***	-0.248***			-0.208***	-0.205***
			(0.021)	(0.021)			(0.021)	(0.021)
Deposit beta × I(Low rate env.)			-0.128***	-0.132***				
			(0.018)	(0.018)				
Interest expense beta × I(Low rate env.)							-0.248***	-0.254***
							(0.022)	(0.022)
Bank Controls	No	Yes	No	Yes	No	Yes	No	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35,745	35,345	35,745	35,345	35,745	35,345	35,745	35,345
R-squared	0.03	0.03	0.03	0.03	0.03	0.03	0. 04	0. 04

Appendix A

Variable	Definition	Source
Deposit yield	Interest expense on all deposits in quarter *t* divided by the average of total deposits (i.e., domestic and foreign deposits) in *t*-1 and *t*. We compound quarterly yields to obtain annualized yields. This variable is winsorized at the 1% level.	Call Reports
Deposit beta	Change in a bank's deposit yield from quarter *t*-1 to quarter *t* divided by the change in the Federal Funds rate from *t*-1 to *t*. This variable is winsorized at the 5% level.	Call Reports, U.S. Treasury
Deposit pass-through rate	Sum of the four coefficients from regressing quarterly changes in deposit yields on changes in the Federal Funds rate and three lags of Federal Funds changes, controlling for bank fixed effects.	Call Reports, U.S. Treasury
Deposit gap	The difference between the Federal Funds rate in quarter *t* and a bank's deposit yield in *t*. This variable is winsorized at the 1% level.	Call Reports, U.S. Treasury
Interest expense	Total interest expense in quarter *t* divided by the average of assets in in *t*-1 and *t*. Due to the seasonality of reported income statement items, we smooth this variable by taking the average over the four quarters from *t*-3 through *t* before calculating annualized rates. This variable is winsorized at the 1% level.	Call Reports
Interest expense beta	Change in a bank's interest expense from quarter *t*-1 to quarter *t* divided by the change in the Federal Funds rate from *t*-1 to *t*. This variable is winsorized at the 5% level.	Call Reports, U.S. Treasury
Interest income	Total interest income in quarter *t* divided by the average of assets in in *t*-1 and *t*. Due to the seasonality of reported income statement items, we smooth this variable by taking the average over the four quarters from *t*-3 through *t* before calculating annualized rates. This variable is winsorized at the 1% level.	Call Reports
Interest income beta	Change in a bank's interest income from quarter *t*-1 to quarter *t* divided by the change in the Federal Funds rate from *t*-1 to *t*. This variable is winsorized at the 5% level.	Call Reports, US Treasury
ROA	Net income in quarter *t* divided by the average of assets in in *t*-1 and *t*. Due to the seasonality of reported income statement items, we smooth this variable by taking the average over the four quarters from *t*-3 through *t* before calculating annualized rates. This variable is winsorized at the 1% level.	Call Reports

ROA beta	Change in a bank's ROA from quarter t-1 to quarter t divided by the change in the Federal Funds rate from t-1 to t. This variable is winsorized at the 5% level.	Call Reports, US Treasury
Other Income Beta	Change in a bank's Other Income from quarter t-1 to quarter t divided by the change in the Federal Funds rate from t-1 to t. This variable is winsorized at the 5% level. Other Income is calculated using the following equation: Net Income = Interest Income – Interest Expense + Other Income	Call Reports, US Treasury
Federal Funds rate	Federal Funds effective rate.	FRED (Federal Reserve Bank of St. Louis)
Two-year Treasury yield	The yield based on the closing market bid price in the over-the-counter market on the most recently auctioned Treasury security with a maturity of two years.	U.S. Treasury
Yield beta	For daily two-year Treasury yields, we implement an autoregressive (AR) model with 3 lags for the period running from January 1997 through March 2023. We exclude the Global Financial Crisis (GFC) period. For each day, we calculate the residual from the AR(3) model. For each bank-quarter, we run the following regression. $$r^{bank} = \alpha + \gamma * r^{market} + \beta * AR3\_Res + \varepsilon$$ where r^{bank} (r^{market}) is the daily return for bank stocks (the stock market) and $AR3\_Res$ is the residual from the AR(3) model for the two-year yield. We require a bank-quarter to have at least 50 observations to be included in the regression analysis. The estimated β, referred to as the yield beta, is winsorized at 5% levels.	CRSP, Ken French Data Library, U.S. Treasury
FOMC beta	For the period running from January 1997 through March 2023 (excluding the GFC), the sample is partitioned into low- and high-rate environments based on whether the average Federal Funds rate is less than 2% or not in a quarter. For each bank-interest rate environment pair, we run the following regression around the FOMC meeting dates. $$r^{bank} = \alpha + \beta * \Delta(2Y\ Yield) + \varepsilon$$ where r^{bank} is the daily return for bank stocks and $\Delta(2Y\ Yield)$ is the daily change in the treasury yield with a maturity of two years on an FOMC meeting date. The estimated β, referred to as the FOMC beta, is winsorized at 5% levels.	CRSP, FRED (Federal Reserve Bank of St. Louis), U.S. Treasury
Market-to-book ratio	Market capitalization in quarter t divided by the book value of equity. This variable is winsorized at the 1% level.	CRSP, Call Reports

Repricing maturity of assets	We include Treasury Securities, MBS Securities, Mortgages, Loans, Leases, Cash and Federal Funds, and Repo Assets when calculating the repricing maturity of assets, using the midpoint of each asset's maturity as weights. For example, Treasuries with maturities less than 3 months are weighted by 1.5/12 and Treasuries with maturities from 1 to 3 years are weighted by 2. We assign a maturity of 20 (5) years for cases where the maturity is over 15 (3) years. This variable is winsorized at the 1% level.	Call Reports
Repricing maturity of liabilities	We include Time and Saving deposits, Federal Funds, Repo Liabilities, and subordinated debt when calculating the repricing maturity of liabilities, using the midpoint of each liability's maturity as weights. Small (large) time deposits are defined as time deposits less than (greater or equal to) \$100,000 prior to October 2008 and less than (greater or equal to) \$250,000 from October 2008. For example, time deposits with maturities less than 3 months are weighted by 1.5/12 and time deposits with maturities from 1 to 3 years are weighted by 2. We assign a maturity of 5 years for cases where the maturity is over 3 years. We assign a maturity of 5 years to subordinated debt. This variable is winsorized at the 1% level.	Call Reports
Maturity mismatch	Repricing maturity of assets minus repricing maturity of liabilities.	Call Reports
Assets	Bank assets in billions of dollars, inflation adjusted to 2015 dollars. This variable is winsorized at the 1% level.	Call Reports
Non-Interest Income / Income (%)	Non-Interest Income / Non-Interest Income + Interest Income. Reported in percentage points.	Call Reports
Uninsured deposits/Assets	(AUD – NUD × Threshold) / Assets where AUD is aggregate amount in deposit accounts that exceed the insurance threshold, NUD is the number of deposit accounts that exceed the insurance threshold, Threshold is the insurance threshold set by the FDIC (i.e., \$100,000 prior to October 2008 and \$250,000 from October 2008), and Assets is the size of bank assets. This variable is winsorized at the 1% level.	Call Reports
Cash/Assets	Value of cash in quarter *t* divided by the value of assets in *t*. This variable is winsorized at the 1% level.	Call Reports