Deposit Betas, Asset Betas and Bank Interest Rate Risk Exposure

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ABSTRACT

Two papers by Drechsler, Savov, and Schnabl (DSS 2017, 2021) have introduced the idea that bank monopoly power generates quasi-rents that increase with the level of market rates. These rents can be valued as an asset with negative duration, making it possible for a bank to finance long-term assets without being exposed to substantial interest rate risk. They estimate deposit and income "betas" that summarize how interest revenue and interest expenses change with levels of market rates over a one-year period. The deposit beta, they argue, is substantially less than unity on account of monopoly power in the typical bank's market area. Their estimated asset betas are also substantially less than unity, although this seems inconsistent with the need for bank assets to eventually be re-priced (roughly) point-for-point with market rate changes. DSS show that banks' mean asset and liability betas are roughly equal and conclude that banks are therefore insulated from interest rate risk.

This paper replicates DSS estimates for sub-periods of the overall 1986-2023 period and finds that the most recent decade's "zero interest rate risk" conclusion has much less support than the prior three decades. We also expand on the DSS regression specifications by including measures of the bank's initial balance sheet position – specifically, its endowment with short- vs. long-term liabilities and assets. We use our estimates to replicate the DSS tests of bank market interest rate risk exposure and find two things. First, there is general agreement that the full-sample period estimates imply limited interest rate risk exposure. Second, the most recent decade is quite different from the preceding data.

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I. Introduction

Bank Call Report information clearly indicates that the stated times to maturity or repricing for assets far exceed those for liabilities. For example, at yearend 2023, ChatGPT estimates the U. S. banking system's average asset maturity (or time to re-pricing) at 3.67 years while its liabilities matured or repriced in an average of 0.38 years. If these reported times to repricing are accurate, banks' net interest margins (the difference between interest earned on assets and interest paid on liabilities) should be very sensitive to changes in market interest rates. A rapid increase (decrease) in market rates should be reflected in a sharp decline (increase) in banks' net interest margins. Because some observers take these stated maturities at face value, they have expressed considerable nervousness about the implications of sharp monetary contractions for systemic stability.

This would be a systematic risk, to which many or most banks might be exposed at the same time. Arguably, if liability and asset maturities mean what they say, a sharp increase in market rates should cause substantial losses on many banks at the same time.

Despite the U.S. banking system's apparent maturity mismatch, the typical bank's net interest margin (NIM) has been remarkably stable. (NIM = (Interest income – interest expenses) / (Total assets)). Figure 1 illustrates that the Federal Funds rated varied between 11.23% and approximately zero. In this environment, the banking system's net interest margin is strikingly smooth even in the presence of large and rapid interest rate changes such as occurred in 1984-1986, 1986-89, 1989-1992, etc. The banking system's average NIM was confined to the range of 57 to 95 bps. Figure 2 presents data back to 1955 and adds information about the banking system's "bottom line" return on assets (ROA), which adjust NIM for realized capital gains/losses and other non-recurring amounts. This Figure clearly indicates the insensitivity of ROA to market rate changes, as well as NIM. ROA is only slightly more variable than the NIM.[1] These

[1] Accountants define NIM as the simple difference between interest earned and interest expenditures, as a proportion of some balance sheet item like "earning assets". The academic literature has used slightly different denominators. After computing NIM, a bank has other income and expenses (some of it non-recurring, like realized losses on a particular product or program). Most of the items here should not be particularly interest sensitive, unless a bank is choosing to recognize costs (income) at times when their NIM is high (low).

empirical insensitivities are dramatically inconsistent with the stereotypical notion that banks "borrow short and lend long".

NIM

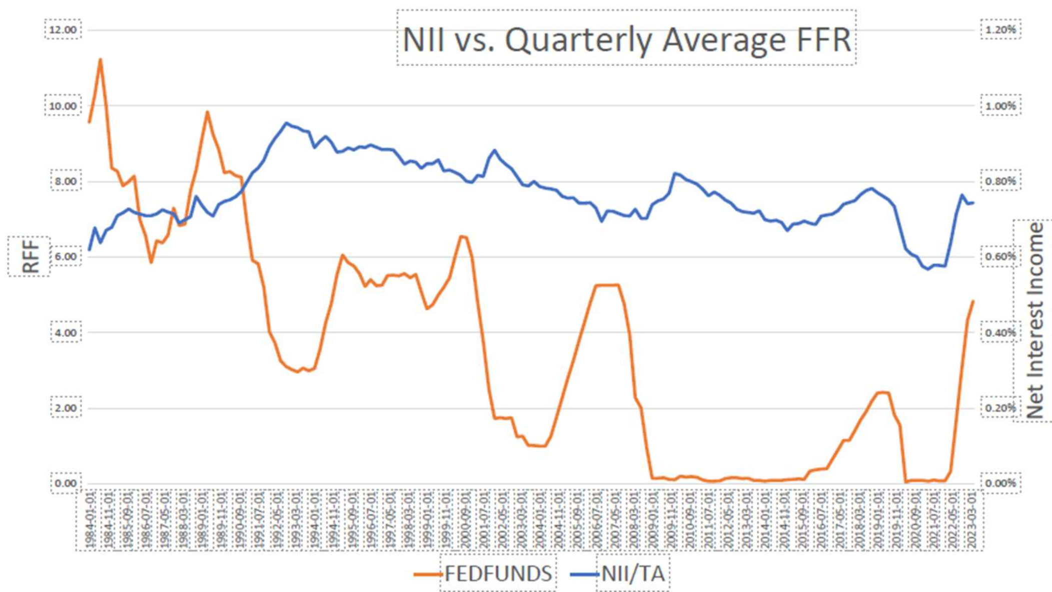

Figure 1

The figure plots the aggregate time series of the net interest margin for the U.S. banking system. The figure is reproduced from Drechsler, Savov, and Schnabl (2021).

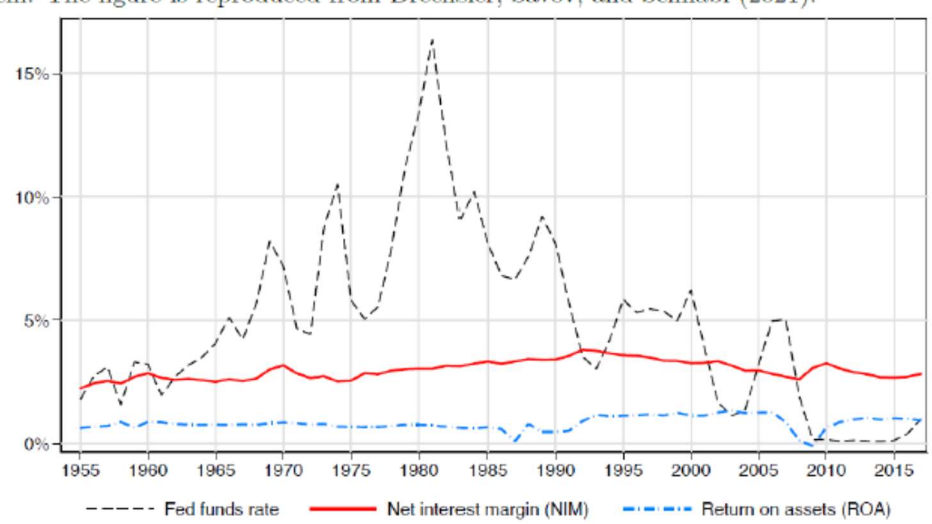

Figure 2

The relatively stable NIM and ROA strongly suggest that the effective maturity of some assets or liabilities differs, perhaps substantially, from their contractual maturity. DSS (2017, 2021) assert that market power protects the typical bank from needing to match changes in market interest rates. This ability to borrow cheaply constitutes a valuable asset, which offsets much of the interest rate risk associated with holding long-term, fixed rate loans and securities. This conclusion follows from an elegantly simple regression specification estimating a "beta coefficient" for each bank's interest income and interest expense. Specifically, DSS (2021, page 1,112) estimate the quarterly change in a bank's total interest paid on all its liabilities,[2] as a function of the contemporaneous and three lags of the change in the federal funds rate:

$$\Delta IntExp_{i,t} = \alpha_i + \eta_t + \sum_{\tau=0}^{\tau=3} \beta_{i,\tau}^{Exp} \Delta FedFunds_{t-\tau} + \varepsilon_{i,t} \qquad (1)$$

where $\Delta IntExp_{i,t}$ = the change in quarterly interest expense of bank i during quarter t

$\Delta FedFunds_{t-\tau}$ = the quarterly change in the federal funds rate during quarter t-τ

A similar specification applies to bank interest income:

$$\Delta IntInc_{i,t} = \delta_i + \theta_t + \sum_{\tau=0}^{\tau=3} \gamma_{i,\tau}^{Exp} \Delta FedFunds_{t-\tau} + \varepsilon_{i,t} \qquad (2)$$

where $\Delta IntInc_{i,t}$= the change in quarterly interest income of bank i during quarter t.

Although the presentation of equations (1) and (2) imply panel estimations that include bank and time fixed effects, DSS also run a separate regression for each bank with a sufficiently large number of reported quarterly data points. We follow this procedure, which they report yields comparable results. A bank's "deposit beta" is given by the sum of the four beta coefficients in (1), multiplied by four to convert the

[2] Although DSS (2017) emphasize their empirical deposit betas, they also present (in a separate Excel workbook: (https://pages.stern.nyu.edu/~pschnabl/data/data_deposit_beta.htm)) liability betas that explain the interest-rate sensitivity of a bank's total liability costs. Their deposit and liability betas are highly correlated (ρ = 0.86). Furthermore, the sample bank's size rank is positively correlated with both the deposit betas (ρ = 0.21) and the liability betas (ρ = 0.26).

quarterly dependent variable into an annual change. By framing the regression model in first differences, DSS omit cross-sectional measures of the bank's balance sheet from their specification.[3]

DSS estimate an identical specification for a bank's interest income (equation (2) below) and investigate the comparability of banks' income and expense betas. The first column in DSS' (2021) Table I reports "The average expense beta is 0.345 and the average income beta is 0.351" (page 1,113) and the authors conclude that, on average, the banking system is well protected against market rate fluctuations. To assess the correspondence between income and expense betas at the individual bank level, DSS regress the banks' estimated income betas on the expense betas (after winsorizing the estimated coefficients). Their Table II reports estimation results: slopes of about 0.81 when estimating across their full sample period, which they conclude is economically similar to unity. With similar one-year interest sensitivities, DSS conclude that "[a]s, a consequence of this matching, banks' profitability is largely insulated from interest rate changes." (page 23).

Our paper evaluates the appropriateness of the specifications (1) and (2) for measuring a representative bank's income and expense betas, motivated particularly by the relatively low estimated income betas. Drechsler et al. (2017) attribute the incomplete adjustment of liability costs to banks' market power in local markets. (Begenau and Stafford (2022) challenge this conclusion.) The incomplete adjustment of asset returns is more difficult to reconcile with bank portfolios composed largely of marketable securities and loans that are (can be) priced via securitization vehicles.[4] Eventually, asset returns must adjust approximately fully to market rate changes, implying that the one-year adjustment of 35.1% reflects only part of the long-run revenue adjustment. The measured deposit betas less than unity may reasonably reflect banks' pricing market power, as DSS emphasize, although the pattern could also reflect banks with large proportions of fixed-rate, long-term liabilities. By contrast, theory requires that bank asset

[3] We use DSS' specification of asset and liability betas, as have many other researchers. Some have approximated the betas using the slope from a regression of the quarterly change in income or expense on the quarterly change in the contemporaneous federal funds rate (e.g. Emin et al. (2023)).

[4] Market power might raise loan rates for the same reason it lowers deposit rates, but expansion of securitization has left a diminishing proportion of bank loan portfolios priced at the bank level.

yields move approximately point-for-point with market rates in the long run, which would produce expense betas in the area of 1.0.[5] An asset beta less than unity would reflect a portfolio that includes substantial asset holdings with repricing intervals exceeding one year, which implies that the observed one-year asset and liability betas may not indicate complete hedging. [6]

In order to control for the impact of balance sheet magnitudes on estimated interest income and interest expense responses to market rate changes, we add asset and liability quantities with various stated maturities to (1). When Begenau and Stafford (2022, page 23) do this in a limited way (differentiating between transaction accounts and time deposit accounts), they conclude that "that time deposits are different from the non-time deposits and should be analyzed separately" when estimating deposit betas. Analogously, a bank's initial position in short vs. long-term assets may affect the speed and extent to which its interest income varies with changes in FFR.

The paper is organized as follows. Section II briefly reviews the recent literature. Section III derives income and expense betas for bank holding companies using the basic DSS specification (1). We then explore the extent to which these two measures offset one another, both on average across the sample and for individual banks. Like DSS (2021), we find that a regression of the income beta on the expense beta has a slope near unity, implying an absence of substantial interest rate risk, but only until 2013. The most recent decade's estimated betas imply more interest rate risk exposure than the preceding 30 years. Section IV motivates our revised specification of (1), reports estimation results, and compares the implications of these estimated coefficients to those based on the DSS specification. Our results again confirm DSS' conclusions in most regards, but the 2014-2023 sample period again appears to be inconsistent with results from the earlier times. Section V concludes and summarizes the policy implications of our findings.

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[5] A long run change different from the market rate change could reflect changes in a bank's effective monopoly power in the loan market. During the adjustment toward long run rates, Wang, Whited, Wu, and Xiao's (2022) find that banks with more market power are slower to raise loan rates when market rates rise.

[6] Begenau and Stafford (2022) argue that a one-year hedge is not at all the same thing as insulating a bank's equity value from market rate changes.

II. Literature Review

One reason for the great influence of DSS (2021) (as indicated by 506 Google Scholar citations as of December 2024) may be that the topic had previously received relatively little attention. Flannery (1981) examined the adjustment of revenue and costs to market rate changes and concluded that "Market rate levels emerge as a prominent influence on intermediary costs and revenues, but the effects of market rate changes effectively cancel one another for most large banks." Flannery and James (1984a, 1984b) concluded that liabilities with short stated maturities behave like longer-maturity liabilities in determining a bank's equity sensitivity to interest rate changes. Hutchinson and Pennacchi (1996) evaluate how market imperfections generate the observed relationship between stated and actual retail deposit maturities.

The literature has recently re-engaged with this general question. For example, English et al. (2018) study the impact of market rate changes on bank equity value and conclude that this impact varies across banks and is significantly affected by bank balance sheet positions. (See their Table 5.) Begenau and Stafford (2022) likewise include balance sheet information into their estimates of deposit betas and find that they are both statistically and economically significant. Hoffman et al. (2019) study the impact of market rate changes on 104 banks from 18 euro area countries during the period 2003-2015 and find that the aggregate banking system has little sensitivity while individual banks vary in their responses to market rate changes. Whited et al. (2021) and Ampudia and Van den Heuvel (2022) find that the effect of market rate changes on banks' interest sensitivity varies with the level of market rates. Ampudia and Van den Heuvel (2022) find that market rate increases generally reduce bank equity values, but "during the recent period with low and negative interest rates … a 25 basis point surprise cut <u>decreas[ed]</u> bank stock prices by 2.0%." (page 50, emphasis added).[7] Whited et al.'s model predicts that a rate increase leads banks to <u>increase</u> their aggregate loan supply except at unusually low market rates. Emin et al. (2023) provide further evidence on this phenomenon.

[7] The authors point out that this finding is consistent with the notion of a "reversal rate" for monetary policy (Brunnermeier and Koby (2018)).

DSS (2017) argue that a bank's ability to attract deposit balances while paying a rate below short-term market rates is a valuable asset. This asset can be measured using a "deposit beta" relating bank deposit rates to open market rates. The deposit franchise's value derives from a bank's ability to earn a stream of rents from paying low deposit rates. Viewed as an asset, these rents have a negative duration that offsets the effect of long-maturity assets on overall interest sensitivity.[8] DSS' (2021) main result is that banks can (and do) avoid interest rate risk exposure without matching explicit asset and liability maturities (repricing intervals) because many liabilities' effective maturities are longer than their stated/nominal maturities. Begenau and Stafford (2022) question whether cross-sectional differences in deposit betas truly reflect market power differences. Estimating (1) and (2) for commercial banks during 1984 to 2017, DSS find an "average expense beta" for all for 8,086 banks commercial banks of 0.345 and an "average income beta" of 0.351.[9] They conclude that "These numbers show that banks are on average well matched with income and expense betas that are almost identical." (page 1,113).

III. DSS specification and results

DSS estimate deposit betas for individual banks using Call Report data, which provide a relatively detailed specification of liability and assets times to "maturity or repricing". In contrast, our estimates are derived from BHC data. Although these reports provide less detail about the stated maturity of holding company assets and liabilities, they do all of the traded firm's asset and liability cash flows, perhaps

[8] They explain their reasoning in footnote 33: "The low average expense beta suggests that banks see a large increase in revenues from their liabilities when interest rates go up. The average size of the banking sector from 1984 to 2017 is $7.768 trillion, which implies an increase in annual revenues of (l % - 0.345%) x $7,768 $51 billion per year from a 100 hp increase in the Fed funds rate. The revenue increase is large compared to the banking sector's average annual net income of $70.2 billion over this period." (Drechsler et al. (2021))

[9] Some researchers have estimated the change in <u>deposit</u> interest expense rather than the total interest paid on all liabilities. Logically, the interest on liabilities provides a more complete measure of bank costs' response. Two things happen when the market rate rises. First, banks will raise their deposit rates by the profit-maximizing amount. But unless the deposit rate change equals some deposits are likely to leave the bank,[9] forcing it to rely on higher-yielding non-deposit liabilities like interbank loans, large denomination CDs, repo'ed securities or FHLB advances. A deposit beta omits these additional effects and therefore tends to under-estimate the effect of market rate changes on financing costs. As a practical matter, though, this difference may be minimal.

permitting a more precise estimate of the traded entity's interest sensitivity.[10] Our measure of the federal funds rate is a quarterly average.

We follow DSS by estimating (1) and (2) separately, via OLS, for the full (1986-2023) sample period for BHCs with at least 50 observations and for each sub-period in which the BHC has at least 20 observations.[11]

A. Estimated Betas and Gammas

When DSS estimate (1) and (2) using Call Reports data, they find an average expense beta of 0.345 and an average income beta of 0.351 when estimated over their full sample period (page 1,113). DSS report in their Internet Appendix that their bank-level results are similar to results from bank holding companies and we see no reason to disagree. We estimated the same regressions using a sample of bank holding companies' Y-9c data and report results for the average coefficient values estimated over our entire sample period (1986-2023) and for four approximately equal sub-periods in Table 1. The full-sample estimates (.359 and .398 from Panels A and B respectively) are close enough to be consistent with DSS' conclusion that the average bank is relatively unaffected by market rate changes. However, as summarized in Panel C, the sub-periods' paired estimates indicate some variation over time. The other time periods' estimates imply that a 100 bp change in FFR will change the industry's mean NIM in the same direction by (+4) to (-8) basis points. The implied ΔNIM should be compared to the mean NIM across all sample BHCs, which has fluctuated between 60 and 80 bps since 1984. Applying the (-8) bp estimate from 2014-2023 to calendar 2022 would have <u>reduced</u> NIM by 40 bp, reflecting an apparent change in the historical

[10] In their Internet Appendix Table IA.VI, DSS replicate their bank-level estimate from Table II using maturity data for the aggregate of all the holding company's bank subsidiaries. They find similar results to their Table II and conclude that their "matching results are independent of whether we use commercial bank data or bank holding company data." (page 1128).

[11] Neither the bank-level nor the BHC-level data are ideal. The Call Reports' maturity/repricing data are more granular than the analogous reports on the FR-Y9C. However, the bank data exclude assets and liabilities held in a BHC's nonbank subsidiaries, such as broker-dealers.

relationship that we discuss further below. To summarize, our BHC results are broadly consistent with those of DSS, although the evidence for banks being interest rate hedged is slightly weaker. The latest sub-period also differs substantially from the overall period's estimates, indicating some potential for inter-temporal changes.[12]

B. Cross-sectional matching

DSS evaluate how well banks are hedged by regressing their (winsorized) estimated expense betas on their (winsorized) income betas. A slope of unity would be consistent with the typical bank being well hedged against interest rate risk. Their Table II (reproduced here) reports the results of these regressions:

Table II
Interest Sensitivity Matching

This table provides estimates of the matching of interest income and expense sensitivities. The data are quarterly and cover all U.S. commercial banks with at least 60 observations from 1984 to 2017. The interest expense beta and income beta are calculated according to equation (9) in the main text and winsorized at the 5% level. We estimate the OLS regression

$$\beta_i^{Inc} \quad = \alpha + \gamma \beta_i^{Exp} + \epsilon_i,$$

where β_i^{Inc} and β_i^{Exp} are bank i's income and expense beta, respectively. Top 10% are the largest 10% of banks by average inflationadjusted assets over the sample. Top 5% and top 1% are defined analogously. Time FE denotes whether time fixed effects are included in the estimation of income and expense betas. Standard errors are block-bootstrapped by quarter with 1,000 iterations.

	All banks		Top 10%		Top 5%		Top 1%	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Int. exp. beta	0.810***	0.806***	1.065***	1.074***	1.051***	1.054***	0.956***	1.007***
	(0.039)	(0.037)	(0.057)	(0.057)	(0.076)	(0.077)	(0.176)	(0.186)
Constant	0.072***	0.071***	−0.012	−0.015	−0.006	−0.007	0.021	−0.003
	(0.021)	(0.021)	(0.028)	(0.027)	(0.037)	(0.037)	(0.082)	(0.084)
Time FE	No	Yes	No	Yes	No	Yes	No	Yes
No. of banks	8,086	8,086	808	808	404	404	80	80
R^2	0.271	0.266	0.416	0.416	0.377	0.372	0.251	0.254

[12] It is tempting to apply the full-sample estimates from (1) and (2) to present-day policy discussions, under the implicit assumption that the relationship is stable across time. However, communications costs and technical changes (e.g. SVB) have occurred. In addition, Whited et al and Van den Heubel demonstrate different bank responses to rate changes when the level of rates is low, and the latest sub-sample had the lowest mean fed funds rate – 1.28% with a standard deviation of 1.55, compared to compared to a full-sample average of 3.14 with a standard deviation of 2.67.

The largest banks have slopes close to unity, and even the "All banks" slopes (about 0.81) are sufficiently close to unity that the authors conclude "The direct effect of Fed funds rate changes is small and insignificant" (page 22). Of course, as emphasized by Hoffman et al. (2019) and English et al. (2018) an industry that is hedged on average will still include some banks exposed to market rate changes.

We replicate DSS' cross-sectional regressions broken down by bank asset size Table 2, where the details of our results differ somewhat from DSS' Table II. Our "Largest 5%" sample is quite close to theirs, but our "Largest 10%" sample coefficient is smaller than for the full sample and (inexplicably), the "Largest 1%" sample coefficient is very large.

Table 3 reports our results from regressing the interest income beta on the interest expense beta.[13] In their Table II, DSS report a slope of 0.810 (without time fixed effects) or 0.806 (with time fixed effects), both highly significant, which they conclude indicates a high level of income hedging at the typical bank.[14] Our estimated slope for our full sample period (0.79) is slightly lower than DSS', although it is still broadly consistent with the conclusion that sample bank holding companies are roughly hedged. The first three sub-periods have similar slopes (0.74, 0.72, 0.73), but the most recent sub-period (in column (5)) exhibits a much lower slope (0.50), indicating less complete hedging. The r-squared statistic for the most recent sub-period is also notably lower than for the other periods. We conclude that the banks' full-sample regression estimates imply hedged bank income but the most recent period's results are quite different from the other periods'. The same phenomena are shown graphically in the Appendix.

One possible reason why the recent period's estimated betas fit one another less well may be related to the level of market interest rates. Both Ampudia and Van den Heuvel (2022) and Wang et al. (2022) find that banks' interest sensitivity switches signs at low interest rates, and the most recent sub-period's mean

[13] Following DSS, we winsorize the estimated betas and gammas (.05, .95) before running these cross-sectional regressions.

[14] They also state that the banks that do suffer income effects of rate changes can collectively borrow from the hedged banks. This addresses the question whether interest rate risk is a systemic risk but fails to consider imperfections and transaction costs that might interfere with challenged banks borrowing enough to cover their losses.

fed funds rate was the lowest in our sample: 1.28% vs. a full-period mean of 3.14%. Regardless of the reason why estimated betas vary over time, we conclude that they do.

IV. Revised Empirical Specification

As we have noted above, the DSS specification does not permit a bank's balance-sheet composition to affect its estimated adjustment to Fed funds rate changes. However, there are both theoretical and empirical reasons to think that adjustments to market rate changes will reflect a bank's balance sheet proportions.

1. Asset and liability maturities

All assets and liabilities "reprice" at maturity and some assets (such as floating rate loans) also reprice periodically according to a formula tied to an index rate. Because the maturity distribution of assets and liabilities affects the extent of these "automatic" repricing opportunities, the initial balance sheet composition will affect the adjustment of interest income and interest expense to market rate changes. In addition to "automatic" repricing, some customers will withdraw (prepay) deposit (loan) balances before maturity under appropriate market conditions. We might categorize these repricings as "spontaneous". For example, a sharp rate increase is more likely to lead time depositors to pay the penalties associated with early withdrawal. If spontaneous repricings are less frequent than automatic repricings, the initial maturity distribution of a bank's assets and liabilities will affect its rate sensitivities to market rate changes.

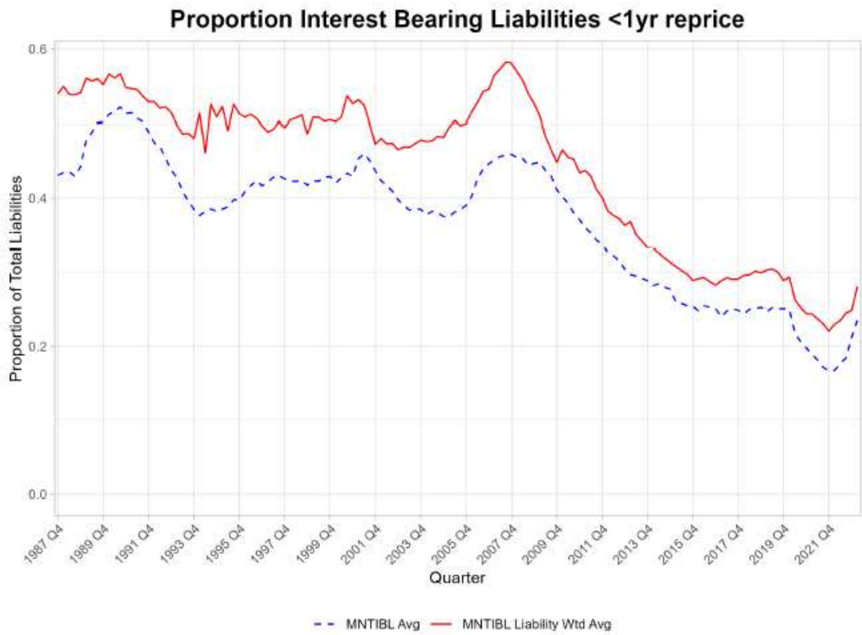
The situation is somewhat different for noninterest bearing deposits, which represent a surprisingly large proportion of total deposits: 16.1% over the entire period and 22.5% of all deposits over the past ten years. Although the interest rate paid on non-interest bearing liabilities should always be zero, changes in market rates (the opportunity cost of holding those deposits) will affect their equilibrium quantity, which may force a change in the bank's equilibrium need for short or long-term time deposits or other liabilities. Accordingly, a bank's optimal liability rate response to changes in the FF rate will depend on its liability composition, which is not included in the basic DSS specification.[15] A bank with more near-term liabilities seems likely to have a larger deposit beta, other things the same; likewise, a bank with more near-term repricing or maturing assets should have a larger income beta.

Liability maturity changes

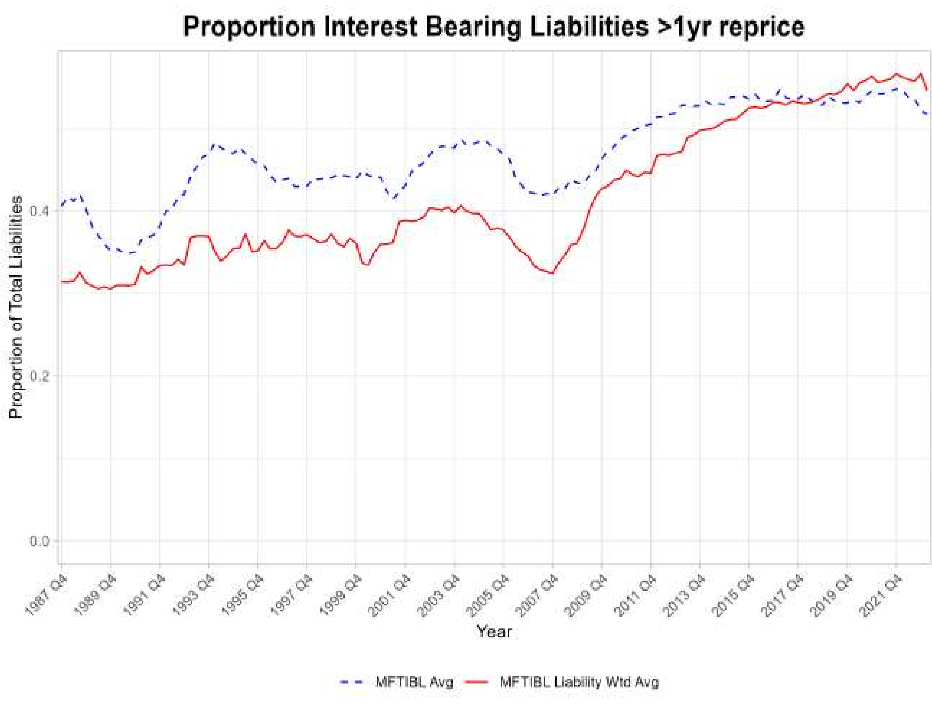
These considerations are particularly relevant because the proportion of short vs. long liabilities and assets has changed quite a lot in recent years. Panels A and B Figure 3 show the average proportion of interest-bearing BHC liabilities that are repriced or mature beyond (within) one year. The dotted line shows a simple mean across reporting BHCs, the solid line shows a BHC-asset-weighted average. Panels A and B indicate that short-term liabilities have fallen sharply, particularly following the GFC, while longer-term liabilities rose but not so sharply. The effect of these changes are not theoretically clear. For example, longer-term time deposits might be more or less likely to prepay while shorter-term deposits automatically get repriced more rapidly. It is an empirical question that cannot be addressed with the standard DSS specification. Panel C shows that the proportion of non-interest-bearing liabilities also Increased after the GFC, perhaps further affecting the typical bank's deposit beta.

[15] Begenau and Stafford (2022) include liability maturity variables in their "deposit beta" regressions.

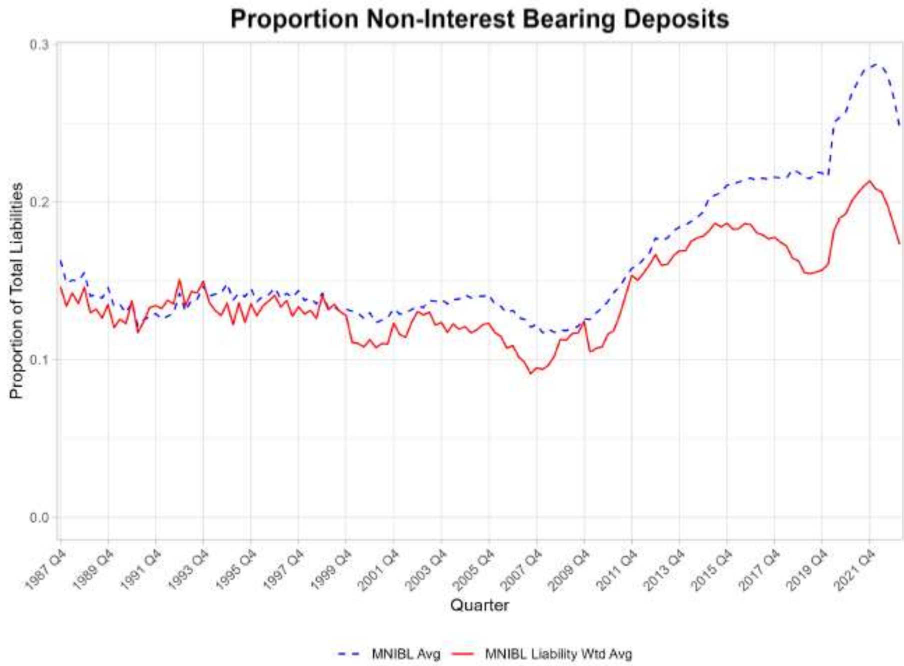
2 Figure 3, Panel B



1 Figure 3, Panel A



3 Figure 3, Panel C



<u>Asset maturity changes</u>

Figure 4 plots the dollar value of BHC assets repricing in less than one year, as a proportion of total liabilities. Panel A illustrates a broad decline in short-term assets over the period, from about 50% in 1986 to 35% in 2023. All bank sizes exhibit a reduced proportion of short-term assets until the GFC. Subsequently, the simple average proportion continues to fall while the weighted average partly reverses the decline. After the GFC, therefore, larger banks increased their short-term assets relatively more than the smaller banks, perhaps tending to raise their typical asset beta.

Panel B of Figure 4 breaks down the mean proportion of “near term” assets by bank size. BHCs with total assets exceeding $100 bn (the highest dashed line) maintained a relatively constant proportion of short-term assets. The smallest BHCS (total assets below $5 bn, represented by the lowest broken line) continuously reduced their short-term asset holdings throughout the period. These changes in the proportion of short-term assets could plausibly affect asset betas over time and across BHCs.

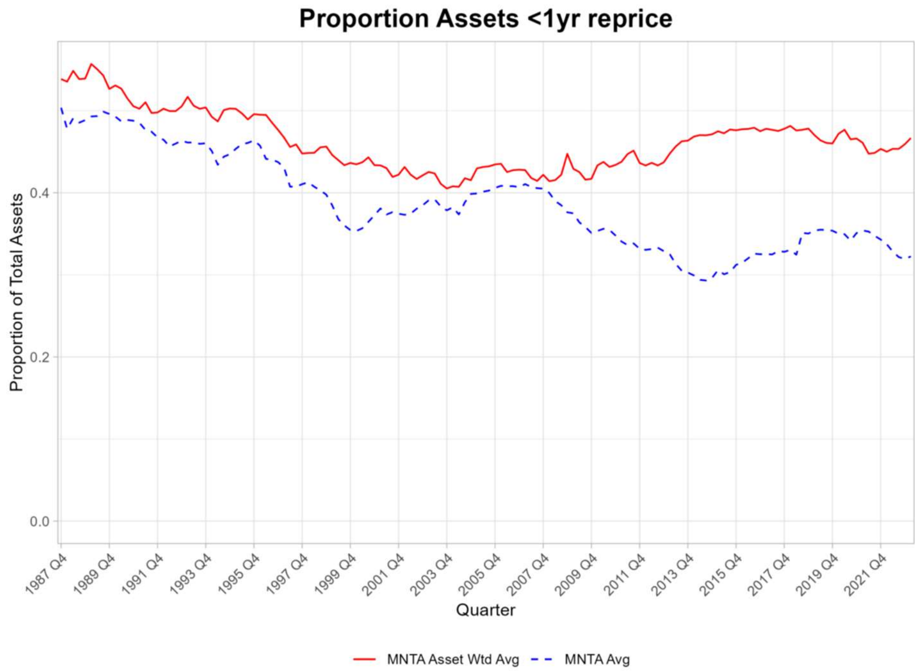
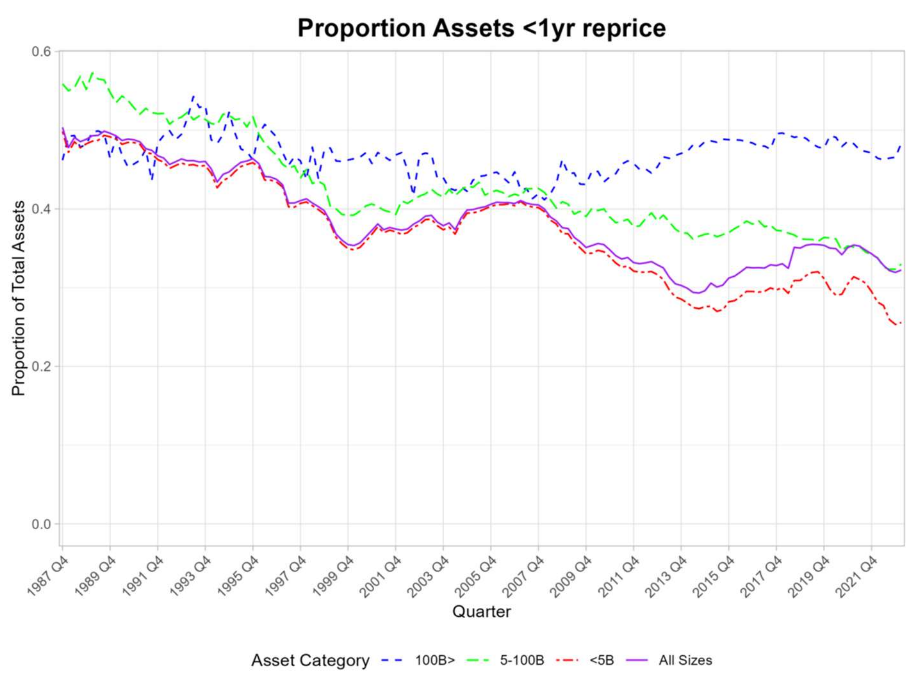


Figure 4, Panel A:



Figures 4, Panel B

2. An Augmented Empirical Specification

Begenau and Stafford (2022) test whether a bank's adjustment to market rate changes reflects the maturity of its liabilities at the start of that period. (The same logic applies to asset maturities.) They find that adding measures of deposit maturity composition to the independent variables in (1) substantially affects the estimated liability beta and the regression's r-squared. Their Table 5 (partially reproduced here) reports alternative specifications for explaining a bank's deposit beta. Their first specification ("1") has a very low r-squared statistic (.006), indicating that market competitiveness has little explanatory power. Incorporating asset size (in their specification "2") raises the regression's explanatory power to 0.197, and adding information about liability composition (in their specification "5") raises the r-squared even further (to .312). Begenau and Stafford observe that the significantly positive coefficients on the four liability maturity variables suggest "that there is a strong relation between measured partial adjustment coefficients for time deposits and the maturity of these deposits." (page 23) [16]

Table 5 from Begenau and Stafford (2022)

Selected results from Table 5 of Begenau and Stafford (2022), reporting regressions that explain changes in bank deposit costs.

Deposits	Constant	HHI	log Assets	log Empl.	3m-1y	1y-3y	3y+	TrShr	avgR2
1	0.615	0.06							0.006
	(203.48)	(4.88)							4056
2	0.763		-0.021	-0.003				0.274	0.197
	(57.25)		(-17.58)	(-3.92)				(25.59)	4056
5	0.576	0.058	-0.025	0.000	0.012	0.520	0.756	0.466	0.312
	(15.21)	(4.50)	(-21.83)	(0.42)	(0.23)	(10.95)	(10.13)	(12.66)	4056

We have revised the basic DSS specifications (1) and (2) to combine the effect of FF rate changes and balance sheet composition in estimating the impact of market rates on individual banks.[17] Specifically, we apply the same treatment of lagged FFR changes to a more nuanced measure of outstanding liabilities:

[16] The four "liability maturity variables" are the proportion of transaction deposits in total deposits (TrShr), and the proportion of total deposits composed of time deposits maturing withing three ranges: 3 months-to 1 year, one-three years, and more than 3 years.

[17] DSS (2021) recognize a role for balance sheet characteristics in their examination of how a bank's asset repricing maturity varies with estimated liability beta. They estimate the regression

$$\Delta IntExp_{\,i,-3,0} = [\,\textstyle\sum_{\tau=0}^{3} \beta_{t-\tau}\, \Delta FFR_{t-\tau}\,]\,[c_1 MNTIBL_{t-4} + c_2 MFTIBL_{t-4} + c_3 MNIBL_{t-4}] + \varepsilon_{i,t} \quad (3)$$

Where the four $\beta_{t-\tau}$ and three c_k are parameters to be estimated.

This specification re-defines the dependent variable to be the accumulated *ΔIntExp* over <u>four</u> quarters (t = -3, 0), which is affected by the market rate's evolution and the bank's initial (end of quarter t = -4) liability composition. The first bracketed term in (3) is identical to the one in DSS' basic specification. Within the second bracketed term, we measure (as a proportion of total liabilities)

$MNTIBL_{t-4}$ = interest-bearing liabilities maturing or repricing in the "near term" (within one year), as a proportion of total liabilities

$MFTIBL_{t-4}$ = the dollar volume of interest-bearing liabilities maturing or repricing in the "far term" (beyond one year), as a proportion of total liabilities

$MNIBL_{t-4}$ = the dollar volume of non-interest-bearing liabilities as a proportion of total liabilities.

The revised regression specification for *ΔIntInc* is similar:

$$\Delta IntInc_{\,i,-3,0} = [\,\textstyle\sum_{\tau=0}^{3} \gamma_{t-\tau}\, \Delta FFR_{t-\tau}\,]\,[a_1 MNTA_{t-4} + a_2(1 - MNTA_{t-4})] + \varepsilon_{i,t} \quad (4)$$

where $MNTA_{t-4}$ is the proportion of total assets maturing or repricing in one year or less at the end of quarter t-4, and where a_1 and a_2 are parameters to be estimated. The two asset categories sum to unity and measuring them at the end of period t-4 permits the subsequent 4 (t = -3,0) quarters' change in interest income to reflect the bank's initial asset structure.[18]

We estimate our modified specifications ((3) and (4)) as seemingly unrelated regressions on a bank-by-bank basis.[19] We again omit any bank with fewer than 50 observations in the full period or 20 observations in a sub-period. Because each specification is estimated for a very large number of BHCs, we

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$$RepricingMaturity_i = \alpha + \delta\beta_i^{\mathrm{Exp}} + \gamma X_i + \epsilon_i$$

in their Table V. The dependent variable is the average repricing maturity of the bank's loans and securities and the "control variables" *X* include the bank's "wholesale funding ratio" (defined as large time deposits plus Fed funds purchased and repo as a proportion of total assets), which carries a significantly positive coefficient.

[18] The multi-period measure of *ΔIntInc* requires a statistical adjustment for serial correlation, which we plan to implement in future work. The annual period for *ΔIntInc* also makes it unnecessary to multiple the estimated beta and gamma coefficients by four.

[19] Note that adding the balance sheet proportions to the independent variable set introduces some efficiency gains from SUR estimation, which are not attainable with the DSS specification.

report summary statistics for the estimated coefficients within each specified time period, in Tables 4 and 5. The extent to which asset and liability betas match no longer implies anything specific about banks' sensitivity to market rate changes. Nevertheless, Panel A of Table 4 indicates that these estimated coefficients are non-zero for a large proportion of the sample banks. Panel B indicates only a minority of estimated coefficients differ significantly from zero. Panel C compares the estimated values of coefficients on various liability maturities. Perhaps the most interesting comparison is between the "near term" and "far term" liabilities' effects on Δ*IntExp*, which differ significantly more than 45% of the time. Panel B indicates that the near-term liabilities have a larger coefficient than the far-term liabilities in the overall period and in the first two sub-periods. In the last two sub-periods, the order reverses, with the mean c1 (.192 or .143) being smaller than the coefficient on far-term liabilities. A similar pattern occurs when we compare the far-term coefficient to the coefficient on non-interest-bearing liabilities.

Table 5 reports a similar regression, which explains Δ*IntInc* the combination of short-term and long-term assets. Panel B indicates that only a minority of estimated coefficients on MNTA and (1-MNTA) differs significantly from zero. The coefficient on near-term assets (a1) bears no constant relation to the one on far-term assets (a2), although between one-third and one-half of the banks have significantly different values for these two coefficients. It thus appears that dividing a bank's asset portfolio according to its maturity (or repricing interval) may affect the other estimated coefficients in the regression.

A cross-sectional regression to assess individual banks' exposure to interest rate changes should compare the <u>fitted values</u> from regressions (3) and (4) and test for equality across the full sample period and for our four sub-periods.[20] Table 6 reports cross-sectional results from regressing fitted income changes on fitted expense changes, for the full sample period and for the four sub-periods. We again find that the most recent sub-period differs markedly from the results for 1986-2013, where there is less evidence of interest rate hedging and the r-squared statistic is noticeably smaller.

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[20] In the simpler DSS specification, equality in the estimated betas is equivalent to our test.

V. Summary and conclusions

Our main goal has been to assess the DSS specification for assessing the impact of market rate changes on bank condition. We have replicated the specifications used in DSS (2017, 2021) using BHC data on interest income and interest expense and find results similar to theirs for the overall sample period (1986-2023). When we examine the regression's stability across sub-periods, however, we find evidence that things have changed. The 1986-1993 and 1994-2003 sub-periods have relatively high income betas and the most recent sub-period (2014-2023) has an unusually high asset beta. The cross-sectional regressions of income on expense betas also differ distinctly for the most recent period, with a lower slope and r-squared. Others have speculated whether deposit betas (in particular) are impervious to institutional changes in the banking industry over the past 40 years. Our results imply that change in the most recent decade – whatever their cause – have reduced the extent to which deposit and asset betas insulate banks from interest rate changes.

But we have reservations about the initial DSS specification because it seems likely that a bank's initial balance sheet composition will influence estimated responses to market rate changes. We therefore modify the DSS specification to permit assets and liabilities of different maturities (or repricing intervals) to affect estimated bank responses to market rate changes. We have replicated DSS' basic tests using both their original specification and our revised one, using data on bank holding companies in place of their bank-level data from the Call Reports. To a considerable extent, this substitution makes little difference. However, we find noteworthy divergences from DSS in our sub-period estimations: using either the original DSS specification or our revised specification, the most recent decade's estimates diverge from estimates for the period from 1986 through 2013. The reasons for this divergence, and its implications, seem like a fruitful area for further research.

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Appendix: further evidence of intertemporal changes

In earlier research, we estimated the two DSS specifications and computed mean "beta" values for interest expense, interest income, NIM, and ROA over slightly different sub-periods from the ones used in this paper. The results are presented in Figure A-1, in which each estimation period is represented by four bars: the "delta" (summed coefficients times 4) of interest expense, interest income, NIM, and ROA. The leftmost group was estimated from the full sample period (1986-2023) and indicates a high degree of average hedging against interest rate risk: the income and expenses are equally responsive to market rate changes, leaving NII and NCOI basically isolated from rate changes. Similar patterns characterize the first four sub-periods. The situation changes in the 2008-12 period, when the income and expense betas drop sharply and the two income ratios increase in market sensitivity. Interest expense beta remains below the interest income beta in the final two subperiods, making NII and NCOI respond to market rate changes.

In short, the time-related changes in Tables 3 and 7 in this paper are consistent with similar estimates from a different set of sub-periods.

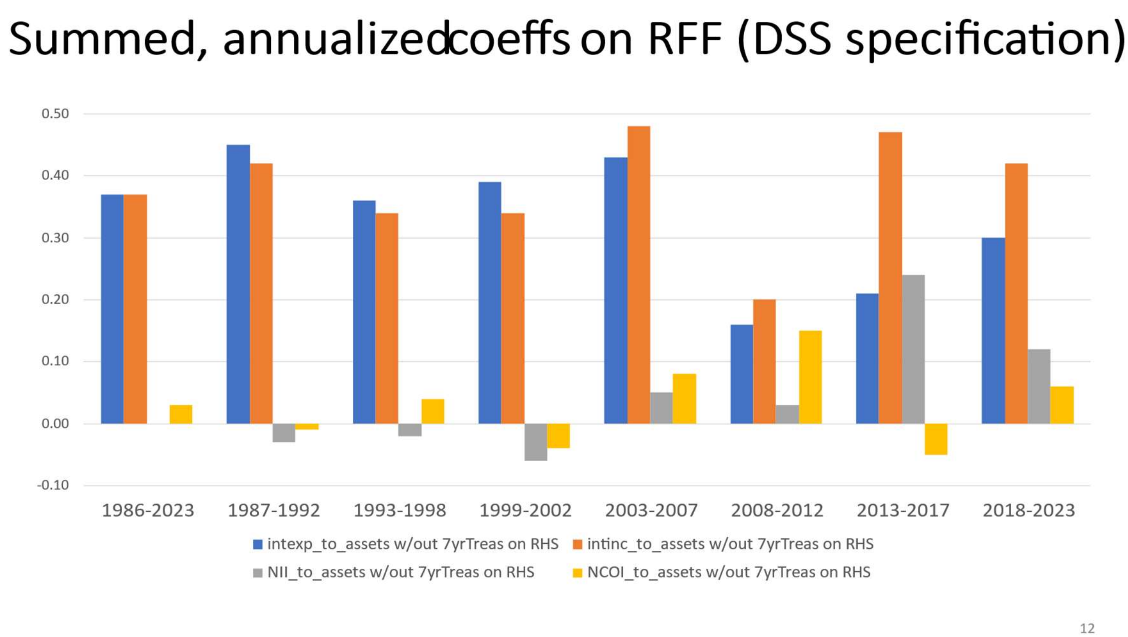

Figure A-1

Table 1: Estimation Results for Interest Expense and Income, DSS Specification

Panel A: Beta Coefficients (Expenses)

$$\Delta IntExp_{i,t} = \alpha_i + \eta_t + \sum_{\tau=0}^{\tau=3} \beta_{i,\tau}^{Exp} \, \Delta FedFunds_{t-\tau} + \varepsilon_{i,t} \qquad (1)$$

Years	Count	Mean	Median	SD	Sum betas= 0, % sig
1987-2023	1093	0.359	0.354	0.108	80.4%
1987-1993	472	0.374	0.368	0.137	40.7%
1994-2003	904	0.356	0.349	0.153	57.6%
2004-2013	802	0.346	0.335	0.122	81.7%
2014-2023	294	0.414	0.402	0.144	75.9%

Panel B: Gamma Coefficients (Income)

$$\Delta IntInc_{i,t} = \delta_i + \theta_t + \sum_{\tau=0}^{\tau=3} \gamma_{i,\tau}^{Exp} \, \Delta FedFunds_{t-\tau} \varepsilon_{i,t} \qquad (2)$$

Years	Count	Mean	Median	SD	Sum gammas= 0, % sig
1987-2023	1093	0.398	0.394	0.076	93.5%
1987-1993	472	0.441	0.424	0.110	78.0%
1994-2003	904	0.425	0.424	0.105	84.2%
2004-2013	802	0.349	0.345	0.076	96.4%
2014-2023	294	0.334	0.333	0.120	93.9%

Panel C: Mean Deposit and Asset Betas for BHCs, DSS specification

	Nobs	Mean Sum of betas (IntExp)	Mean Sum of gammas (IntInc)	Implied mean ΔNIM (in bp) for 100 bp increase in FFR
1986-2023	1093	0.359	0.398	3.9
1986-1993	472	0.374	0.441	6.7
1994-2003	904	0.356	0.425	6.9
2004-2013	802	0.346	0.349	0.3
2014-2023	294	0.414	0.334	-8.0

Panel D: Test of equality: (Sum of Betas) – (Sum of Gammas)

Years	Count	Mean	Median	SD	% sig
1986-2023	1093	-0.0102	-0.011	0.0204	3.93%
1986-1993	472	-0.0171	-0.016	0.0241	0.00%
1994-2003	904	-0.0178	-0.018	0.0286	1.88%
2004-2013	802	-0.0015	-0.005	0.0255	2.49%
2014-2023	294	0.0191	0.0200	0.0381	14.63%

Table 2: Regression of (DSS) income on expense betas, by asset size (full time period)
BHC data

	Sum of Betas			
	All Banks	Largest 10%	Largest 5%	Largest 1%
Sum of Gammas	0.843***	0.799***	1.011***	2.086***
	(0.034)	(0.114)	(0.196)	(0.296)
Constant	0.006*	0.011	−0.019	−0.151***
	(0.003)	(0.013)	(0.024)	(0.038)
Observations	1,093	110	55	11
R^2	0.358	0.312	0.334	0.846
Adjusted R^2	0.358	0.306	0.321	0.829
Residual Std. Error	0.022	0.026	0.028	0.013
F Statistic	609.063***	49.067***	26.538***	49.585***

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3: Regressions of Income on Expense Betas, DSS Specification

OLS results from regressing the sum of estimated beta coefficients (summed, multiplied by 4) from equation (1) on estimated gamma coefficients (summed, multiplied by 4) from equation (2). Because each specification is estimated for numerous BHCs, we report summary statistics for the estimated coefficients within each specified time period. All estimated coefficients winsorized at the 5, 95% level before running this regression. coefficients. IID residuals (no bootstrapping), t-statistics in parentheses below estimated coefficient.

	Intercept		Slope		NOBS	R2
1986-2023	0.0001%	***	0.786	***	92,598	0.782
	(1.96)		(479.5)			
1986-1993	-0.0079%	***	0.736	***	11,017	0.762
	(-32.87)		(175.1)			
1994-2003	0.0009%	***	0.717	***	31,671	0.728
	(7.76)		(238.0)			
2004-2013	0.0001%	***	0.733	***	29,608	0.731
	(0.62)		(214.30)			
2014-2023	0.0038%	***	0.503	***	10,245	0.649
	(34.36)		(97.5)			

Table 4: Estimation Results for Interest Expense, Revised Specification

$$\Delta IntExp_{i,-3,0} = [\sum_{\tau=0}^{3} \beta_{t-\tau}\, \Delta FFR_{t-\tau}]\, [c_1 MNTIBL_{t-4} + c_2 MFTIBL_{t-4} + c_3 MNIBL_{t-4}] + \varepsilon_{i,t} \quad (3)$$

Panel A: Beta Coefficients (Expense)

					Sum betas=0	All betas=0
Years	Count	Mean	Median	SD	% sig	% sig
1987-2023	1071	1.225	1.007	0.832	72.4%	46.9%
1987-1993	453	2.775	2.399	1.908	66.0%	36.0%
1994-2003	893	1.552	1.048	1.366	47.7%	31.6%
2004-2013	795	1.818	1.561	1.259	51.1%	31.9%
2014-2023	287	1.486	1.19	1.097	62.7%	47.4%

Panel B: Coefficients on Liability Proportions

		Estimated c1		Estimated c2		Estimated c3	
Years	Count	Mean	% sig	Mean	% sig	Mean	% sig
1987-2023	1071	0.578	40.4%	-0.136	11.5%	0.441	41.7%
1987-1993	453	0.413	45.0%	-1.106	14.6%	0.505	49.7%
1994-2003	893	0.672	19.7%	0.377	4.4%	0.398	20.6%
2004-2013	795	0.192	17.9%	0.842	9.1%	0.295	22.6%
2014-2023	287	0.143	22.0%	0.273	16.0%	0.324	30.3%

Panel C: Tests of equal liability coefficients

		MNTIBL= MFTIBL? c1 = c2	MFTIBL = MNIBL? c2 = c3	MNTIBL = MNIBL? c1 = c3
Years	Count	% sig	% sig	% sig
1987-2023	1071	55.9%	55.2%	26.9%
1987-1993	453	64.7%	65.8%	20.8%
1994-2003	893	45.1%	47.5%	18.5%
2004-2013	795	55.3%	52.5%	18.9%
2014-2023	287	45.6%	42.9%	39.4%

Table 5: Estimation Results for Interest Income, Revised Specification

$$\Delta IntInc_{i,-3,0} = [\sum_{\tau=0}^{3} \gamma_{t-\tau} \Delta FFR_{t-\tau}] [a_1 MNTA_{t-4} + a_2(1 - MNTA_{t-4})] + \varepsilon_{i,t} \qquad (4)$$

Panel A: Gamma Coefficients (Income)

Years	Count	Mean	Median	SD	Sum gammas= 0 % sig	All gammas=0 % sig
1987-2023	1071	0.895	0.838	0.425	82.1%	42.3%
1987-1993	453	1.079	0.930	0.661	52.3%	32.9%
1994-2003	893	0.995	0.843	0.664	58.1%	30.9%
2004-2013	795	1.094	0.951	0.639	55.1%	30.3%
2014-2023	287	1.440	1.344	0.694	65.2%	46.3%

Panel B: Coefficients and Tests on Asset Proportions

		Estimated a1		Estimated a2		a1 = a2
Years	Count	Mean	% sig	Mean	% sig	% sig
1987-2023	1071	0.521	17.4%	0.348	20.0%	41.6%
1987-1993	453	0.325	14.3%	0.448	16.1%	38.6%
1994-2003	893	0.483	16.7%	0.400	13.4%	39.0%
2004-2013	795	0.338	18.6%	0.358	10.1%	38.1%
2014-2023	287	0.506	22.0%	0.256	19.9%	50.2%

Table 6: Bootstrapped Cross-Sectional Regressions, Revised Specification

$$\text{Fitted (IntExp)}_{i,t} = a + b^*(\text{Fitted (IntInc)}_{i,t}) + \varepsilon_{i,t}$$

Time Period	Estimated Intercept	Estimated slope	Nobs	R2
1987-2023	-2.94E-05 (23.7***)	0.910 (639***)	92,407	0.882
1987-1993	-2.00E-04 (30.0***)	0.895 (206***)	10889	0.799
1994-2003	-1.99E-05 (6.9***)	0.887 (277***)	31652	0.815
2004-2013	4.01E-05 (17.4***)	0.850 (295***)	29,536	0.850
2014-2023	2.67E-06 (1.2)	0.506 (137***)	10,131	0.774