Internet Appendix for "Banking on Deposits: Maturity Transformation without Interest Rate Risk"

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This Internet Appendix serves as a companion to the paper "Banking on Deposits: Maturity Transformation without Interest Rate Risk." It contains supplementary material, tables, and figure not included in the main text in order to conserve space. text.

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A Evidence from the annual reports of the largest U.S. banks

The annual reports of the largest U.S. banks show that they calculate deposit betas similarly to our paper and that they incorporate their impact into their calculations of interest rate exposure. Consistent with our results, their estimated exposure is close to zero.

Banks are not required to disclose their deposit betas but some banks do so on occasion. For instance, in 2016, Wells Fargo stated that it has an estimated deposit beta of 0.45 to 0.55 on its interest-bearing deposits.[50] S&P reported that Bank of America also has an estimated deposit beta between 0.45 and 0.55.[51] In 2017, J.P. Morgan reported a "deposit reprice beta" of 0.4 during the 2004 rate hiking cycle but stated that it expects its beta to be higher after 2016.[52] We estimate similar betas for these banks in our data (0.51, 0.46, and 0.49, respectively). They are broadly in line with but slightly higher than the mean estimates in our data, reflecting the greater use of competitive wholesale funding by the largest banks. The importance of the deposit franchise for these betas is captured in the following statement from J.P. Morgan's 2016 annual report: *"Our firm benefits greatly when rates rise, particularly short rates, which allow us to capture the full value of our significant deposit franchise"*.[53]

The annual reports also show that banks believe they have low exposure to interest rate risk and are either hedged to, or even slightly benefit from, unexpected interest rate increases. In 2016, Wells Fargo reported that a 100 bps level shift in interest rates would increase NIM by 5 to 15 bps (NIM in 2015 was 295 bps).[54] J.P. Morgan and Wells Fargo report that a level shift in the yield curve would have a small, positive effect on net interest income.

The annual reports make clear that the deposit franchise and the low deposit beta it provides are central to banks' business model. In February 2017, at the start of the most recent hiking cycle, an S&P industry report quotes a bank analyst as saying *"We are all*

[50] See Wells Fargo Investor Day, May 24, 2016, page 10. Available at `https://www08.wellsfargomedia.com/assets/pdf/about/investor-relations/presentations/2016/corporate-treasury-presentation.pdf`. Last accessed on March 19, 2018.

[51] See Nathan Stovall, "How much deposit costs increase is anyone's guess", February 13, 2017. Available at `http://www.bankingexchange.com/images/Dev_SNL/022217-Blog-HowMuchDeposit.pdf`. Last accessed on March 19, 2018.

[52] See J.P. Morgan Chase, Investor Day, February 28, 2017, page 27. Available at `https://www.jpmorganchase.com/corporate/investor-relations/document/firm_overview_investor_day_2017.pdf`. Last accessed on March 19, 2018.

[53] See J.P. Morgan Chase Annual Report 2016, "Letter of the Chief Operating Officer", page 51. Available at `https://www.jpmorganchase.com/corporate/investor-relations/document/2016-annualreport.pdf`. Last accessed on March 19, 2018.

[54] See Wells Fargo Investor Day, May 24, 2016, page 10. Available at `https://www08.wellsfargomedia.com/assets/pdf/about/investor-relations/presentations/2016/corporate-treasury-presentation.pdf`.

trying to figure out deposit betas and the banks are too."[55] So far, it appears that deposit betas in the current cycle are not significantly different from past cycles. As The Wall Street Journal reported in October 2017, *"the so-called deposit beta ... reached 34% in third quarter of 2017."*[56] A report in Barron's from August 2017 suggests that the largest U.S. banks have raised deposit rates by even less, increasing them by only 11 bps even as the Fed raised the Fed funds rate by 100 bps.[57] These reports are consistent with the small uptick in interest expense seen at the end of the sample in Figure 3. Thus, even though it may be early to assess the full impact of the current interest rate cycle, deposit betas have so far remained stable.

B Bank equity returns and interest rate changes

Table A.1 shows results from regressions of the Fama-French banking industry portfolio and the market portfolio on the change in the one-year rate in a one-day window around FOMC meetings. The results are depicted graphically in Figure 2 in the paper. They show that bank stocks have a low exposure given their duration mismatch and that this exposure is similar to the overall market.

C Repricing maturity

To calculate the repricing maturity of bank assets and liabilities, we follow the methodology of English, Van den Heuvel, and Zakrajšek (2018). Starting in 1997, banks report their holdings of five asset categories (residential mortgage loans, all other loans, Treasuries and agency debt, MBS secured by residential mortgages, and other MBS) broken down into six bins by repricing maturity interval (0 to 3 months, 3 to 12 months, 1 to 3 years, 3 to 5 years, 5 to 15 years, and over 15 years). To calculate the overall repricing maturity of a given asset category, we assign the interval midpoint to each bin (and 20 years to the last bin) and take a weighted average using the amounts in each bin as weights. For the "other MBS" category, banks only report two bins: 0 to 3 years and over 3 years. We assign repricing maturities of 1.5 years and 5 years to these bins, respectively. We compute the repricing maturity of a bank's assets as the weighted average of the repricing maturities of all of its asset categories, using their dollar amounts as weights. In some tests we include cash and Fed funds sold in

[55] See Nathan Stovall, "How much deposit costs increase is anyone's guess.", February 13, 2017. Available at `http://www.bankingexchange.com/images/Dev_SNL/022217-Blog-HowMuchDeposit.pdf`

[56] Aaron Back in *Wall Street Journal*, "A Surprising Shake-Out Among Banks as Rates Rise", October 30, 2017.

[57] Teresa Rivas in *Barron's*, "Why Big Bank Deposit Betas Will Likely Stay Low For Now", August 15, 2017.

the calculation, assigning them a repricing maturity of zero.

We follow a similar approach to calculate the repricing maturity of liabilities. Banks report the repricing maturity of their small and large time deposits by four intervals (0 to 3 months, 3 to 9 months, 1 to 3 years, and over 3 years). We assign the midpoint to each interval and 5 years to the last one. We assign zero repricing maturity to demandable deposits such as transaction and savings deposits. We also assign zero repricing maturity to wholesale funding such as repo and Fed funds purchased. We assume a repricing maturity of 5 years for subordinated debt. We compute the repricing maturity of liabilities as the weighted average of the repricing maturities of all of these categories.

Figure A.1 plots the distribution of asset and liabilities repricing maturity across banks, showing that it exhibits substantial variation. Table A.2 provides summary statistics for repricing maturity by asset category. We note in particular that securities have a substantially higher repricing maturity (5.7 years on average, 8.4 years in the aggregate) than loans (3.2 years on average, 3.8 years in the aggregate).

D Estimated duration

This section explains our procedure for estimating the duration of bank assets. The main idea is to construct a Treasury mimicking portfolio whose interest income provides the best possible fit of banks' interest income. The duration of the Treasury mimicking portfolio gives us an estimate of the duration of bank assets. The advantage of this approach is that does not require any information on asset duration, repricing maturity, or even balance sheet composition. It is also model-free, fully flexible, and can be extended to before 1997 when repricing maturity becomes available.

As explained in the text, we construct the Treasury mimicking portfolio by regressing banks' interest income on two interest income "factors" The first factor is the Fed funds rate. The second factor is the interest income earned from a buy-and-hold portfolio of ten-year Treasury bonds. Under standard book accounting, this income is equal to the ten-year moving average of the ten-year Treasury rate.

We therefore run the following regression using FDIC data on aggregate U.S. bank interest income divided by assets:

$$IntInc_t = \alpha + \beta_{FF} FedFunds_t + \beta_{10y} IntInc10y_t + \epsilon_t, \tag{A.1}$$

where $IntInc$ is the interest income rate U.S. banks, $FedFunds$ is the Fed funds rate, and $IntInc10y$ is the interest income from buying and holding ten-year Treasury bonds. Note that any additional factors that influence interest income (e.g., credit risk) show up in the intercept α and residual ϵ. Thus, our approach is fully flexible with respect to such factors. It is also possible, however, to interpret the constant as the portfolio weight on an extremely long-term asset (in the limit, a consol bond), hence we run specifications with and without it to make sure it does not play a large role. Also note that the coefficients β_{FF} and β_{10y} should sum to one in order to be interpretable as the weights of a mimicking portfolio. We therefore also run specifications with and without imposing this restriction.

Table A.3 shows the results. Column (1) runs regression (A.1) directly, column (2) omits the constant, column (3) imposes the restriction $\beta_{FF} + \beta_{10y} = 1$, and column (4) does both. The coefficient on the short-term asset is very stable across specifications, ranging from 0.243 in column (2) to 0.267 in column (4). Thus, based on column (4) the Treasury mimicking portfolio holds 26.7% of assets in zero-duration (floating-rate) bonds.

The coefficient on the ten-year Treasury varies a bit more, from 0.593 in column (1) to 0.741 in column (3). That said, columns (2) to (4) are highly similar, ranging from 0.728 in column (2) to 0.741. Note that the sum of the coefficients in column (1) is 0.86, which is slightly less than one, hence 14% of the portfolio can be thought of as invested in a consol bond (whose interest income is captured by the constant). That said, removing the constant (column 2), or imposing the restriction $\beta_{FF} + \beta_{10y} = 1$ (column (3)), or doing both (column (4)), reassigns this portfolio weight to the 10-Year Treasury and this is why its coefficient slightly rises. We therefore use column (4) as our preferred specification although the results in the other columns are very similar.

Note that the R^2 in column (1) is very high at 95.3%. This shows that the mimicking portfolio does a very good job of capturing the dynamics of banks' interest income. Also note that the R^2 barely changes to 95.1% when we impose the restriction $\beta_{FF} + \beta_{10y} = 1$. Hence, this restriction is fully consistent with the data. This result helps to validate the procedure.

Below the coefficients in Table A.3 is a row labeled "Implied duration," which refers to the implied duration of bank assets. We compute it using the coefficient on the 10-Year Treasury, β_{10y}, and the duration of the buy-and-hold 10-year Treasury portfolio. The duration of this portfolio is less than ten because the bonds it holds have staggered remaining maturities. We use the fact that in steady state the portfolio resembles a ten-year annuity and use the formula for the duration of an annuity to calculate its duration. This duration varies over time because it depends on the discount rate (we use the five-year rate but this makes almost no difference). Its sample average is 5.059 years. We multiply it by the coefficient β_{10y}, making sure to rescale it first so that $\beta_{FF} + \beta_{10y} = 1$ (otherwise the result cannot be interpreted as a portfolio). As the table shows, the resulting duration of the Treasury mimicking portfolio and hence the implied duration in bank assets ranges from 3.528 years in column (1) to 3.794 years in column (2). It equals 3.708 years in our preferred specification in column (4). All of these estimates are highly similar and only slightly below our estimates based on repricing maturity.

E Derivatives usage

Table A.4 repeats the analysis of Table 2 in the paper for banks that make use of derivatives and banks that do not. We classify banks as using derivatives if they report a non-zero derivatives exposure. The table shows that our matching results hold similarly for derivatives users and non-users.

F Asymmetry in expense betas usage

Table A.5 looks at asymmetry in interest expense betas with respect to positive and negative Fed funds rate changes. There is little evidence for asymmetry: the betas are similar at each lag and their sum is 0.374 for positive changes versus 0.341 for negative changes.

G Bank Holding Companies

Table A.6 repeats the analysis of Table 2 in the paper for bank holding companies (as opposed to individual banks). The results are very similar, indicating that the matching of interest income and expense sensitivities holds at the bank holding company level as well.

H Interest rate sensitivity of loan non-interest items

Figure A.2 shows the interest sensitivity of non-interest items including loan loss provisions, operating costs, and fee income across the distribution of interest expense betas. Operating costs are broken down into components such as salaries, rents, and deposit fee income. The results show that these non-interest items are insensitive to interest rate changes as assumed in our model.

I Additional tests using panel estimation

Tables A.8–A.11 repeat the analysis of Tables 7–10 in the paper using the panel estimation procedure. Table A.8 confirms the results in Table 7. It shows that banks match their interest expense exposure with the interest income from within their securities portfolio. Table A.9 confirms the results in Table 8 that the matching also holds for the largest 5%

of banks. Table A.10 confirms the results in Table 9, which show that banks match the sensitivity of interest expense induced by differences in market power. Table A.11 confirms the results in Table 10, which show that banks match the sensitivity of interest expense induced by differences in their retail deposit betas.

J Derivation of the panel estimator

We can show formally that the panel and cross-sectional estimators generally yield similar results. Specifically, the panel estimator is equivalent to the cross-sectional estimators with different weighting of observations.

Let $\Delta Exp_{i,t}$ and $\Delta Inc_{i,t}$ be the $T \times 1$ vectors of quarterly changes in bank i's interest expense and interest income rates, respectively. Also let ΔFF_t be the $T \times L$ matrix of the current (column 1) and lagged (columns 2 to L) Fed funds rate changes (in the paper we use $L = 4$). Under both the panel and cross-sectional regressions, the first stage is

$$\Delta Exp_{i,t} = \Delta FF_t \beta_i^{Exp} + \epsilon_{i,t}^{Exp} \tag{A.2}$$

$$\Delta Inc_{i,t} = \Delta FF_t \beta_i^{Inc} + \epsilon_{i,t}^{Inc}, \tag{A.3}$$

where β_i^{Exp} and β_i^{Inc} are the $L \times 1$ vectors of banks' expense and income betas at each lag. The OLS estimates of these betas are

$$\widehat{\beta}_i^{Exp} = \left(\Delta FF_t' \Delta FF_t\right)^{-1} \Delta FF_t' \Delta Exp_{i,t} \tag{A.4}$$

$$\widehat{\beta}_i^{Inc} = \left(\Delta FF_t' \Delta FF_t\right)^{-1} \Delta FF_t' \Delta Inc_{i,t}. \tag{A.5}$$

To prepare for the second stage, let us stack the $L \times 1$ estimated betas of the N banks into $L \times N$ matrices:

$$\widehat{\beta}^{Exp} = \left[\begin{array}{ccc} \widehat{\beta}_1^{Exp} & \cdots & \widehat{\beta}_N^{Exp} \end{array} \right] \tag{A.6}$$

$$\widehat{\beta}^{Inc} = \left[\begin{array}{ccc} \widehat{\beta}_1^{Inc} & \cdots & \widehat{\beta}_N^{Inc} \end{array} \right]. \tag{A.7}$$

The panel regression forms the fitted values from this first stage regression as

$$\widehat{\Delta Exp} = vec\left(\Delta FF_t \widehat{\beta}^{Exp}\right) \tag{A.8}$$

$$\widehat{\Delta Inc} = vec\left(\Delta FF_t \widehat{\beta}^{Inc}\right), \tag{A.9}$$

where $vec\left(\Delta FF_t \widehat{\beta}^{Exp}\right)$ takes the $T \times N$ matrix $\Delta FF_t \widehat{\beta}^{Exp}$ and stacks it column by column into a $TN \times 1$ vector that can be regressed on the analogous vector of fitted income changes.

The panel regression is then

$$\widehat{\Delta Inc} = a^{pa} + \left(\widehat{\Delta Exp}\right) b^{pa} + u^{pa}. \quad \text{(A.10)}$$

Note that in the paper we regress income changes directly on $\widehat{\Delta Exp}$ but this is equivalent since the error term in the first stage is by construction orthogonal to $\widehat{\Delta Exp}$. Plugging in,

$$vec\left(\Delta FF_t \widehat{\beta}^{Inc}\right) = a^{pa} + vec\left(\Delta FF_t \widehat{\beta}^{Exp}\right) b^{pa} + u^{pa}. \quad \text{(A.11)}$$

The cross-sectional regression instead sums the betas for each bank and regresses them as follows:

$$vec\left(\mathbf{1}_{1\times 4} \widehat{\beta}^{Inc}\right) = a^{cx} + vec\left(\mathbf{1}_{1\times 4} \widehat{\beta}^{Exp}\right) b^{cx} + u^{cx}. \quad \text{(A.12)}$$

The resulting estimates are

$$\widehat{b}^{pa} = \left(vec\left(\Delta FF_t \widehat{\beta}^{Exp}\right)' vec\left(\Delta FF_t \widehat{\beta}^{Exp}\right)\right)^{-1} vec\left(\Delta FF_t \widehat{\beta}^{Exp}\right)' vec\left(\Delta FF_t \widehat{\beta}^{Inc}\right) \quad \text{(A.13)}$$

$$\widehat{b}^{cx} = \left(vec\left(\mathbf{1}_{1\times 4} \widehat{\beta}^{Exp}\right)' vec\left(\mathbf{1}_{1\times 4} \widehat{\beta}^{Exp}\right)\right)^{-1} vec\left(\mathbf{1}_{1\times 4} \widehat{\beta}^{Exp}\right)' vec\left(\mathbf{1}_{1\times 4} \widehat{\beta}^{Inc}\right) \quad \text{(A.14)}$$

This already shows that the difference between the two approaches is in how the betas are weighted. To see this more clearly, we simplify further in the case that the panel is balanced. To the extent it is not balanced, the approaches differ in that the panel regression places more weight on banks with more observations, whereas the cross-sectional regression treats them equally. In the case of a balanced panel, we can write

$$vec\left(\Delta FF_t \widehat{\beta}^{Exp}\right) = \left(\mathbf{I}_N \otimes \Delta FF_t\right) vec\left(\widehat{\beta}^{Exp}\right) \quad \text{(A.15)}$$

$$vec\left(\mathbf{1}_{1\times 4} \widehat{\beta}^{Exp}\right) = \left(\mathbf{I}_N \otimes \mathbf{1}_{1\times 4}\right) vec\left(\widehat{\beta}^{Exp}\right) \quad \text{(A.16)}$$

and similarly for the income betas. Plugging in and simplifying,

$$b^{pa} = \left(vec\left(\widehat{\beta}^{Exp}\right)' \left(\mathbf{I}_N \otimes FF_t' FF_t\right) vec\left(\widehat{\beta}^{Exp}\right)\right)^{-1} vec\left(\widehat{\beta}^{Exp}\right)' \left(\mathbf{I}_N \otimes FF_t' FF_t\right) vec\left(\widehat{\beta}^{Inc}\right) \quad \text{(A.17)}$$

$$b^{cx} = \left(vec\left(\widehat{\beta}^{Exp}\right)' \left(\mathbf{I}_N \otimes \mathbf{1}_{4\times 4}\right) vec\left(\widehat{\beta}^{Exp}\right)\right)^{-1} vec\left(\widehat{\beta}^{Exp}\right)' \left(\mathbf{I}_N \otimes \mathbf{1}_{4\times 4}\right) vec\left(\widehat{\beta}^{Inc}\right) \quad \text{(A.18)}$$

This shows that the two approaches are the same up to a difference in weighting. In particular, the panel regression can be implemented as a cross-sectional regression but with different weighting. When the panel is balanced, both approaches weigh equally across banks.

The difference is in how they weight the betas at different lags within each bank. The panel regression weighs them by the variance-covariance matrix of the Fed funds rate changes. This means that if Fed funds rate changes are i.i.d., then the regression is testing whether income and expense betas align lag by lag. By contrast, the cross sectional regression weights by a matrix of ones. This means that it does not test whether the betas align lag by lag but only whether they align on average.

The two approaches are therefore the same if the Fed funds rate is highly autocorrelated (in this case its variance covariance matrix is close to a matrix of ones). In that case the panel regression also does not require that the betas match lag by lag since one lag of the expense betas can match a different lag of the income betas given that the shocks at different lags are highly correlated. In practice, our results in Table 4 and Tables A.8–A.11 show that the two approaches give very similar results.

Table A.1: **Bank equity returns and interest rate changes**

This table examines the effect of interest rate shocks on bank equity values on FOMC dates using the following OLS regression:

$$R_t = \alpha_0 + \beta \Delta y_t^{1yr} + \epsilon_t,$$

where Δy_t^{1yr} is the change in one-year Treasury yield on FOMC meeting days (one-day change computed using end-of-day data). The outcome variables in Columns 1 and 2 are the one-day returns on the CRSP value-weighted banking sector index and market index, downloaded from Ken French's website. The FOMC meeting dates are from Kenneth Kuttner's website. The sample are all scheduled FOMC meeting dates from January 1994 to June 2007 (108 meetings). Standard errors are clustered by meeting day.

	(1)	(2)
Δy^{1yr}	−4.243**	−3.708**
	(2.060)	(1.546)
Constant	0.203*	0.182**
	(0.114)	(0.087)
Obs.	108	108
Industry	Banks	Market
R^2	0.035	0.046

Table A.2: **Repricing maturity by asset category**

This table reports summary statistics on repricing maturity and asset shares. Repricing maturity is computed as the weighted average by asset category. Asset shares are total amounts in each asset category as a share of total assets. The sample are all U.S. commercial banks from 1997 to 2017 and we include all assets with reported repricing maturities (95%) of total assets). Columns (1) and (2) are for the average bank. Columns (3) and (4) are for the aggregate banking system.

	Average bank		Aggregate	
	Repricing Maturity (1)	Asset Share (%) (2)	Repricing Maturity (3)	Asset Share (%) (4)
Securities	5.7	22.3	8.4	18.2
Gov't securities	5.2	15.9	5.4	8.4
RMBS	9.0	4.3	14.9	6.3
Other securities	3.2	2.2	3.8	3.6
Loans	3.2	61.6	3.8	56.2
Residential loans	4.9	13.6	9.5	11.1
Other loans	2.7	48.0	2.4	45.0
Cash (includes Fed funds sold)	0.0	11.0	0.0	11.8
Securities + Loans + Cash	3.5	94.8	4.2	86.1

Table A.3: **Implied duration of bank assets**

The table shows the results from regressions used to estimate the average duration of bank assets using a Treasury mimicking portfolio. The regressions are of the form

$$IntInc_t \quad = \quad \alpha + \beta_{FF} FedFunds_t + \beta_{10y} IntInc10y_t + \epsilon_t,$$

where $IntInc$ is the interest income rate of the aggregate U.S. banking sector, $FedFunds$ is the Fed funds rate, and $IntInc10y$ is the interest income rate earned from buying and holding ten-year Treasury bonds. This interest income is calculated as a ten-year moving average of the ten-year Treasury bond yield. Column (2) restricts the constant α to zero, column (3) imposes the restriction $\beta_{FF} + \beta_{10y} = 1$, and column (4) imposes both restrictions. Also reported is the implied duration of bank assets based on each regression specification, which is calculated as follows: First, in columns (1) and (2) the coefficients are rescaled to sum to one in order to be interpretable as the weights of a mimicking portfolio (no rescaling is needed in columns (3) and (4)). Second, the implied duration is equal to the rescaled coefficient (portfolio weight) of the Treasury buy-and-hold portfolio (β_{10y}) multiplied by the average duration of that portfolio over the sample (since the Fed funds rate has zero duration). The duration of the Treasury buy-and-hold portfolio is estimated using the formula for the duration of a ten-year annuity discounted at the five-year Treasury rate (since the portfolio has a staggered maturity structure of bonds with one to ten years maturity). The data are annual from FDIC and the Federal Reserve, 1955 to 2017.

	Unrestricted		Restricted	
	(1)	(2)	(3)	(4)
Fed funds rate	0.257***	0.243***	0.259***	0.267***
	(0.024)	(0.028)	(0.029)	(0.027)
10-Year Treasury	0.593***	0.728***	0.741***	0.733***
	(0.036)	(0.026)	(0.029)	(0.027)
Constant	0.009***		−0.001	
	(0.002)		(0.001)	
Implied duration	3.528	3.794	3.746	3.708
Obs.	55	55	55	55
R^2	0.953		0.951	

Table A.4: **Interest sensitivity matching and derivatives usage**

This table examines the role of interest rate derivatives in interest sensitivity matching. The table estimates the same regressions as in Table 2. Columns 1 and 2 provide results for all banks. Columns 3 and 4 present results for banks that have no exposure to derivatives. Columns 5 and 6 present results for banks that have nonzero exposure to derivatives (these data start in 1995). The sample includes all commercial banks with at least 60 quarterly observations from 1984 to 2017. Standard errors are block-bootstrapped by quarter with 1,000 iterations.

	All banks		No derivatives		Nonzero derivatives	
	(1)	(2)	(3)	(4)	(5)	(6)
Interest expense beta	0.810***	0.806***	0.739***	0.736***	0.979***	0.978***
	(0.039)	(0.037)	(0.040)	(0.039)	(0.041)	(0.041)
Constant	0.072***	0.071***	0.094***	0.092***	0.013	0.012
	(0.021)	(0.021)	(0.022)	(0.022)	(0.020)	(0.020)
Time FE	No	Yes	No	Yes	No	Yes
No. of banks	8,086	8,086	6,011	6,011	2,075	2,075
R^2	0.271	0.266	0.224	0.219	0.370	0.360

Table A.5: **Asymmetry in expense betas**

This table presents quarterly expense beta coefficients from a specification that allows for separate coefficients for Fed funds rate increases and decreases. The results are from the following regression:

$$\Delta IntExp_{it} = \alpha_i + \sum_{\tau=0}^{3} \beta_{i,\tau}^{Exp^+} \Delta FedFunds_{t-\tau} \times \mathbb{1}(\Delta FedFunds_{t-\tau} > 0) + \sum_{\tau=0}^{3} \beta_{i,\tau}^{Exp^-} \Delta FedFunds_{t-\tau} \times \mathbb{1}(\Delta FedFunds_{t-\tau} \leq 0) + \varepsilon_{it}$$

where $\Delta IntExp_{i,t}$ is the change in interest expense rates of bank i at time t, and $\Delta FedFunds$ is the change in the Fed funds rate. The data are quarterly and cover all U.S. commercial banks with at least 60 observations from 1984 to 2017.

	β^{Exp^+}		β^{Exp^-}	
	μ	σ	μ	σ
1st Quarter	0.021	(0.120)	0.062	(0.081)
2nd Quarter	0.127	(0.131)	0.188	(0.084)
3rd Quarter	0.155	(0.112)	0.054	(0.060)
4th Quarter	0.075	(0.105)	0.036	(0.053)
Cumulative	0.374	(0.123)	0.341	(0.091)

Table A.6: **Interest sensitivity matching for bank holding companies (BHC)**

This table provides estimates of the matching of interest income and expense sensitivities at the bank holding company level. The data are quarterly and cover all U.S. bank holding companies with at least 40 observations from 1986 to 2017. The interest expense and income beta are estimated according to (9) and winsorized at the 5% level. We estimate the following OLS regression:

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

where β_i^{Inc} and β_i^{Exp} are bank i's interest and expense beta, respectively. Top 10% are the 10% largest banks by average total assets over the sample. Top 5% is 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%	
	(1)	(2)	(3)	(4)	(5)	(6)
Interest expense beta	0.824***	0.852***	0.907***	0.948***	0.989***	1.006***
	(0.053)	(0.046)	(0.095)	(0.090)	(0.116)	(0.113)
Constant	0.067***	0.055***	0.011	−0.003	−0.032	−0.031
	(0.024)	(0.021)	(0.043)	(0.041)	(0.053)	(0.052)
Time FE	No	Yes	No	Yes	No	Yes
No. of BHCs	1,525	1,525	152	152	76	76
R^2	0.341	0.333	0.472	0.470	0.509	0.502

Table A.7: **Interest sensitivity of NIM**

This table provides estimates of the interest rate sensitivity of the net interest margin (NIM). The data are quarterly and cover all U.S. commercial banks with at least 60 observations from 1984 to 2017. The NIM beta is computed as interest expense beta minus interest income beta. The interest expense and income betas are calculated according to equation (9) and winsorized at the 5% level. We estimate the following OLS regression:

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

where β_i^{NIM} and β_i^{Exp} are bank i's NIM and expense beta, respectively. Top 10% are the largest 10% of banks by average inflation-adjusted 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)
Interest expense beta	−0.190***	−0.194***	0.065	0.074	0.051	0.054	−0.044	0.007
	(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	0.0200	0.0206	0.0026	0.0033	0.0014	0.0016	0.0007	0.0000

Table A.8: **Sensitivity matching within the securities portfolio (panel estimation)**

This table provides estimates of the matching of securities interest income and expense sensitivities to Fed funds rate changes. The results are from the following two-stage ordinary least squares regression:

$$\begin{aligned} \Delta IntExp_{i,t} &= \alpha_i + \textstyle\sum_{\tau=0}^{3} \beta_{i,\tau} \Delta FedFunds_{t-\tau} + \epsilon_{i,t} & \text{[Stage 1]} \\ \Delta SecIncRate_{i,t} &= \lambda_i + \textstyle\sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau} + \delta \Delta \widehat{IntExp}_{i,t} + \varepsilon_{i,t}, & \text{[Stage 2]} \end{aligned}$$

where $\Delta IntExp_{i,t}$ is the change in the interest expense rate of bank i at time t, $\Delta SecIncRate_{i,t}$ is the change in the interest income rate on securities, $\Delta FedFunds_t$ is the change in the Fed funds rate, and $\Delta\widehat{IntExp}_{i,t}$ is the predicted value from the first stage. Columns (2), (4), (6), and (8) include time fixed effects in place of the direct effect $\sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau}$. Columns (1) and (2) include income from all securities, columns (3) and (4) are for Treasury bonds and agency debt, columns (5) and (6) are for mortgage-backed securities, and columns (7) and (8) are for other securities. We drop observations if quarterly average securities growth is greater than 50% or less than −50%, or if the securities income rate is negative, zero, or greater than 100%. The sample covers all commercial banks from 2001 to 2017. Standard errors are block-bootstrapped by quarter with 1,000 iterations.

Δ Securities income rate

	Total securities		Treasuries & agency debt		MBS		Other securities	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\widehat{IntExp}$	0.435***	0.414***	0.493***	0.493***	0.485***	0.442***	0.543***	0.544***
	(0.076)	(0.078)	(0.129)	(0.131)	(0.118)	(0.117)	(0.133)	(0.137)
$\sum \gamma_\tau$	0.056		0.079		0.055		−0.097**	
	(0.039)		(0.049)		(0.066)		(0.049)	
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes	No	Yes
Obs.	413,547	413,547	368,147	368,147	310,544	310,544	353,386	353,386
No. of banks	8,996	8,996	8,790	8,790	7,879	7,879	8,302	8,302
R^2	0.036	0.070	0.025	0.030	0.024	0.031	0.016	0.017

Table A.9: **Sensitivity matching within the securities portfolio, top 5% banks (panel estimation)**

This table provides estimates of the matching of securities interest income and expense sensitivities to Fed funds rate changes for the largest 5% of banks. The results are from the following two-stage ordinary least squares regression:

$$\Delta IntExp_{i,t} = \alpha_i + \eta_t + \sum_{\tau=0}^{3} \beta_{i,\tau} \Delta FedFunds_{t-\tau} + \epsilon_{i,t} \qquad \text{[Stage 1]}$$

$$\Delta SecIncRate_{i,t} = \lambda_i + \sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau} + \delta \Delta \widehat{IntExp}_{i,t} + \varepsilon_{i,t}, \qquad \text{[Stage 2]}$$

where $\Delta IntExp_{i,t}$ is the change in the interest expense rate of bank i at time t, $\Delta SecIncRate_{i,t}$ is the change in the interest income rate on securities, $\Delta FedFunds_t$ is the change in the Fed funds rate, and $\Delta \widehat{IntExp}_{i,t}$ is the predicted value from the first stage. Columns (2), (4), (6), and (8) include time fixed effects in place of the direct effect $\sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau}$. Columns (1) and (2) include income from all securities, columns (3) and (4) are for Treasury bonds and agency debt, columns (5) and (6) are for mortgage-backed securities, and columns (7) and (8) are for other securities. We drop observations if quarterly average securities growth is greater than 50% or less than −50%, or if the securities income rate is negative, zero, or greater than 100%. The sample covers the largest 5% of commercial banks by average assets from 2001 to 2017. Standard errors are block-bootstrapped by quarter with 1,000 iterations.

Δ Securities income rate

	Total securities		Treasuries & agency debt		MBS		Other securities	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta \widehat{IntExp}$	0.743***	0.711***	0.807**	0.831**	0.682***	0.666***	0.884***	0.911***
	(0.181)	(0.191)	(0.327)	(0.343)	(0.217)	(0.231)	(0.317)	(0.329)
$\sum \gamma_\tau$	−0.066		−0.019		−0.050		−0.164	
	(0.077)		(0.131)		(0.090)		(0.124)	
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes	No	Yes
Obs.	17,229	17,229	15,240	15,240	16,621	16,621	16,396	16,396
No. of banks	453	453	431	431	444	444	441	441
R^2	0.064	0.101	0.039	0.045	0.019	0.036	0.023	0.028

Table A.10: **Market power and interest sensitivity matching (panel estimation)**

This table estimates the effect of market power on interest rate sensitivity matching using a panel estimation procedure. The results are from the following two-stage ordinary least squares regression:

$$\begin{aligned} \Delta IntExp_{i,t} &= \alpha_i + \eta_t + \textstyle\sum_{\tau=0}^{3} (\beta_\tau^0 + \beta_\tau HHI_i) \times \Delta FedFunds_{t-\tau} + \epsilon_{i,t} && \text{[Stage 1]} \\ \Delta IncRate_{i,t} &= \lambda_i + \textstyle\sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau} + \delta \Delta \widehat{IntExp}_{i,t} + \varepsilon_{i,t}, && \text{[Stage 2]} \end{aligned}$$

where $\Delta IntExp_{i,t}$ is the change in the interest expense rate of bank i at time t, HHI_i is bank i's deposit branch Herfindahl index, $\Delta IncRate_{i,t}$ is the change in the interest income rate, $\Delta FedFunds_t$ is the change in the Fed funds rate, and $\Delta \widehat{IntExp}_{i,t}$ is the predicted value from the first stage. Columns (2) and (4) include time fixed effects in place of the direct effect $\sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau}$. To calculate the bank-level HHI index, we construct an HHI of bank branch shares at the county level, then average them across each bank's counties, using the number of branch es as weights. The data are quarterly and cover all U.S. commercial banks from 1994 to 2017. Standard errors are block-bootstrapped by quarter with 1,000 iterations.

	First stage		Second Stage	
	(1)	(2)	(3)	(4)
$\sum \beta_\tau$	−0.061*	−0.094***		
	(0.035)	(0.021)		
$\Delta \widehat{IntExp}$			0.892***	0.906***
			(0.253)	(0.163)
$\sum \gamma_\tau$			0.066	
			(0.090)	
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes
Obs.	673,234	673,234	673,234	673,234
No. of banks	12,708	12,708	12,708	12,708
R^2	0.350	0.422	0.093	0.128

Table A.11: **Retail deposit betas and interest sensitivity matching (panel estimation)**

This table estimates the effect of retail deposit betas on interest rate sensitivity matching using a panel estimation procedure. The results are from the following two-stage ordinary least squares regression:

$$\Delta IntExp_{i,t} = \alpha_i + \eta_t + \sum_{\tau=0}^{3} \left(\beta_\tau^0 + \beta_\tau RetailBeta_i\right) \times \Delta FedFunds_{t-\tau} + \epsilon_{i,t} \quad \text{[Stage 1]}$$
$$\Delta IncRate_{i,t} = \lambda_i + \sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau} + \delta \Delta \widehat{IntExp}_{i,t} + \varepsilon_{i,t}, \quad \text{[Stage 2]}$$

where $\Delta IntExp_{i,t}$ is the change in the interest expense rate of bank i at time t, $RetailBeta_i$ is bank i's retail deposit beta, $\Delta IncRate_{i,t}$ is the change in the interest income rate, $\Delta FedFunds_t$ is the change in the Fed funds rate, and $\Delta \widehat{IntExp}_{i,t}$ is the predicted value from the first stage. Columns (2) and (4) include time fixed effects in place of the direct effect $\sum_{\tau=0}^{3} \gamma_\tau \Delta FedFunds_{t-\tau}$. Retail deposit betas are calculated at the county level using Ratewatch data for interest checking, $25k money market accounts, and $10k 12-month CDs, then averaged across branches for each bank-product (using branch deposits as weights) and finally across products for each bank. They are winsorized at the 5% level and estimated for counties with at least 60 non-missing observations between 1997 and 2008 in the RateWatch data. The data are quarterly and cover all U.S. commercial banks from 1997 to 2017. Standard errors are block-bootstrapped by quarter with 1,000 iterations.

Panel A: Across-bank

	First stage		Second Stage	
	(1)	(2)	(3)	(4)
$\sum \beta_\tau$	0.555***	0.578***		
	(0.064)	(0.059)		
$\Delta \widehat{IntExp}$			1.111***	1.088***
			(0.161)	(0.159)
$\sum \gamma_\tau$			−0.011	
			(0.048)	
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes
Obs.	509,239	509,239	509,239	509,239
No. of banks	10,033	10,033	10,033	10,033
R^2	0.363	0.443	0.092	0.126

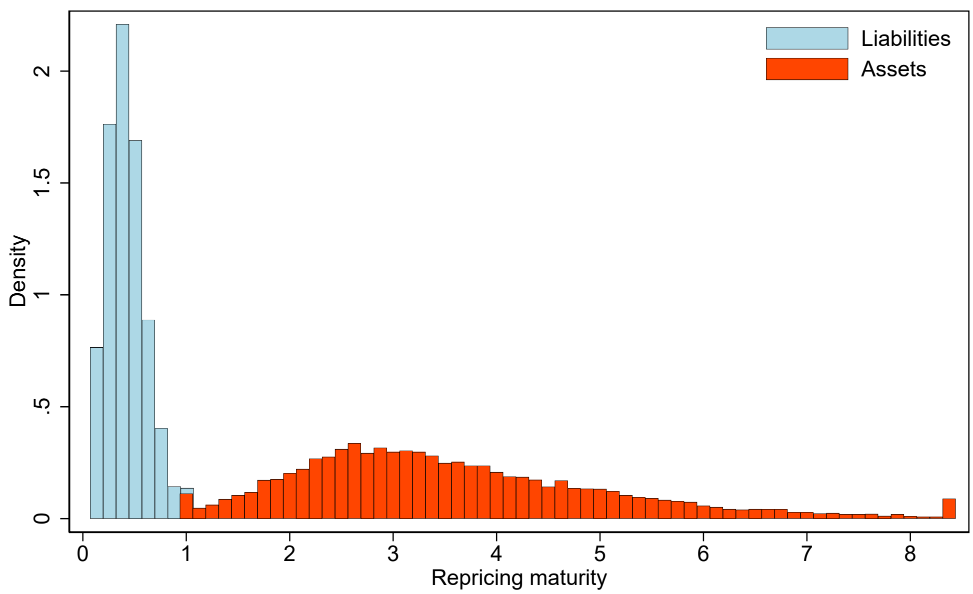
Panel B: Within-bank

	First stage		Second Stage	
	(1)	(2)	(3)	(4)
$\sum \beta_\tau$	0.180***	0.188***		
	(0.021)	(0.019)		
$\Delta \widehat{IntExp}$			0.898***	0.906***
			(0.212)	(0.207)
$\sum \gamma_\tau$			0.060	
			(0.071)	
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes
Obs.	483,297	483,297	483,297	483,297
No. of banks	9,718	9,718	9,718	9,718
R^2	0.361	0.442	0.091	0.124

Figure A.1: **Repricing maturity of bank assets and liabilities**

The figure plots the distribution of repricing maturity, a rough proxy for duration, of bank assets and liabilities. The repricing maturity of assets is estimated by calculating the repricing maturity of loans and securities using available data and assigning zero repricing maturity to cash and Fed funds sold. The repricing maturity of liabilities is calculated by assigning zero repricing maturity to transaction deposits, savings deposits, and Fed funds purchased, by assigning repricing maturity of five to subordinated debt, and by calculating the repricing maturity of time deposits using available data. All other asset and liabilities categories (e.g. trading assets, other borrowed money), for which repricing maturity is not given, are left out of the calculation. The sample is from 1997 to 2017. Only banks with at least 60 observations are kept. Repricing maturities are winsorized at the 1% level for this figure.

All banks



Top 5%

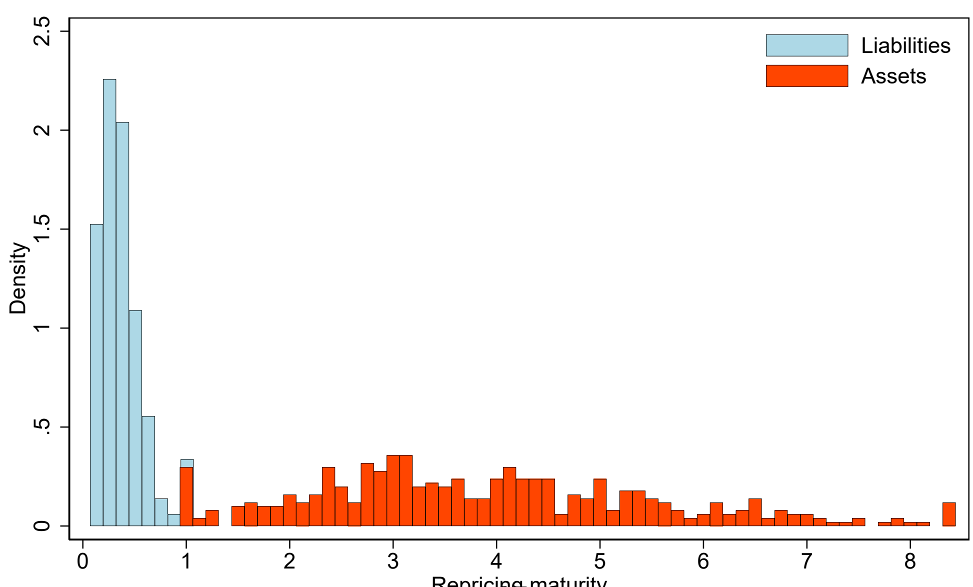


Figure A.2: **The interest rate sensitivity of non-interest items**

This figure shows bin scatter plots of bank operating costs and deposit fee income by expense betas. The betas and scatterplots are constructed the same was as in Figure 6. The sample covers all commercial banks with at least 60 quarterly observations from 1984 to 2017. The left column is for all banks and the right column for the top five percent of banks. The top panel provides information on total salaries, the middle panel on total rent, and the bottom panel on deposit fee income.

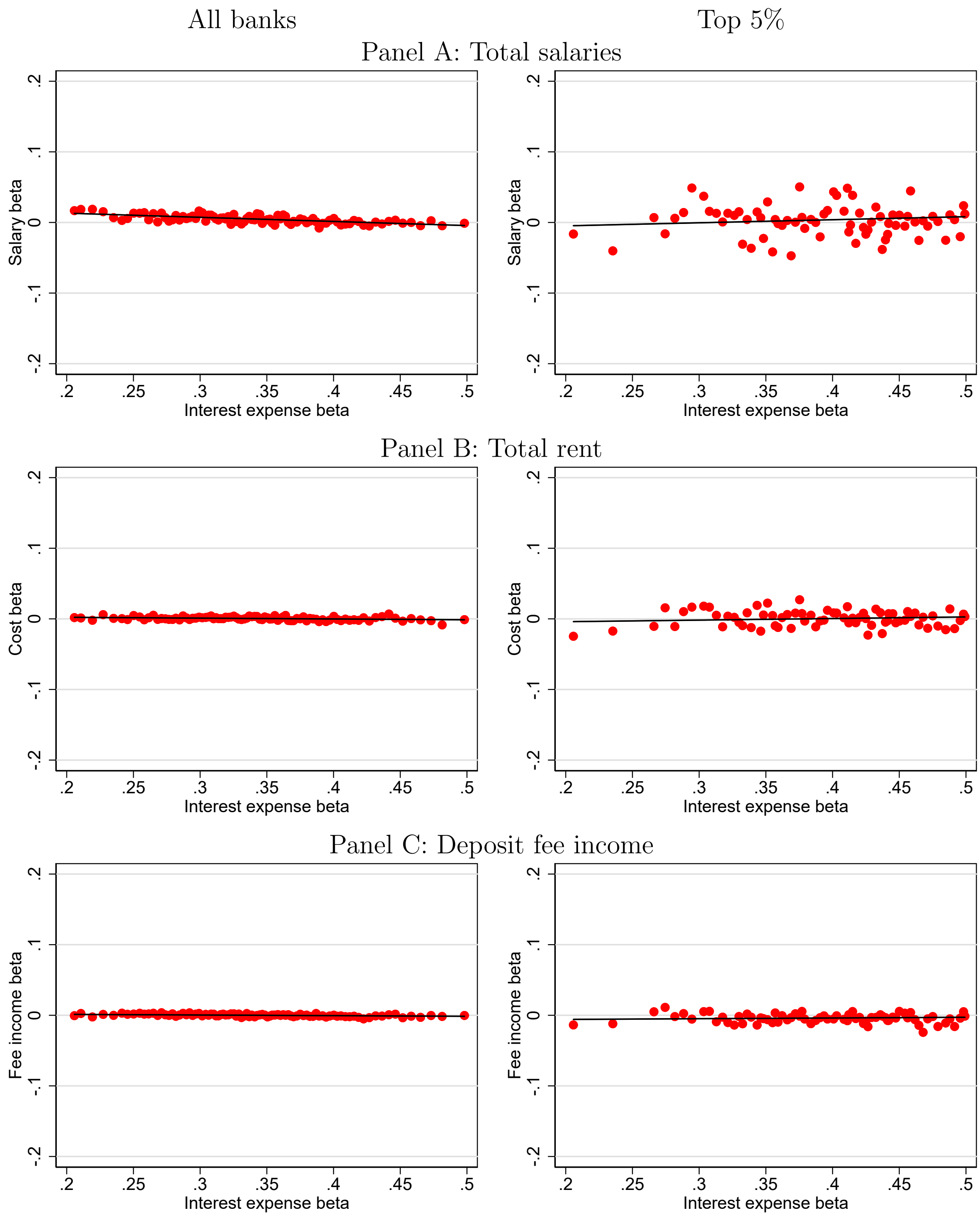
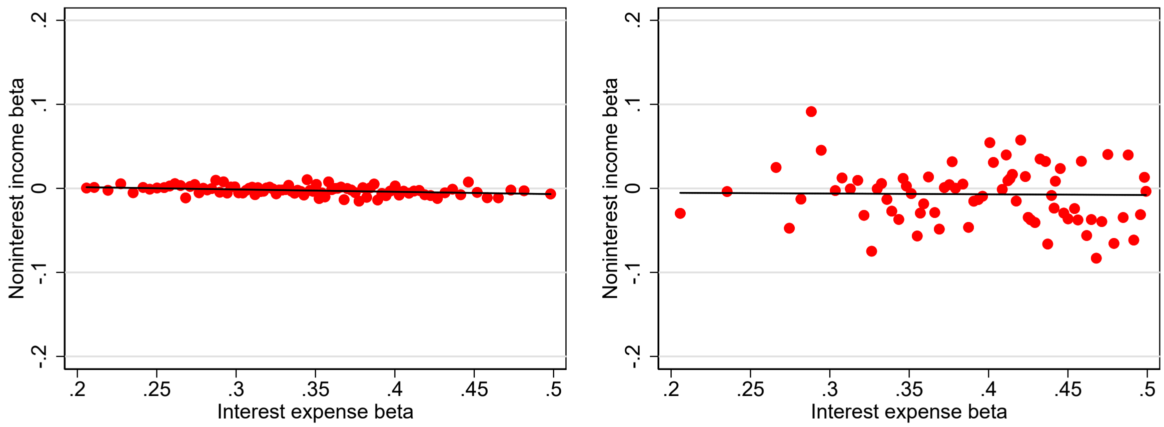


Figure A.2: **The interest rate sensitivity of operating costs and fee income (cont.)**

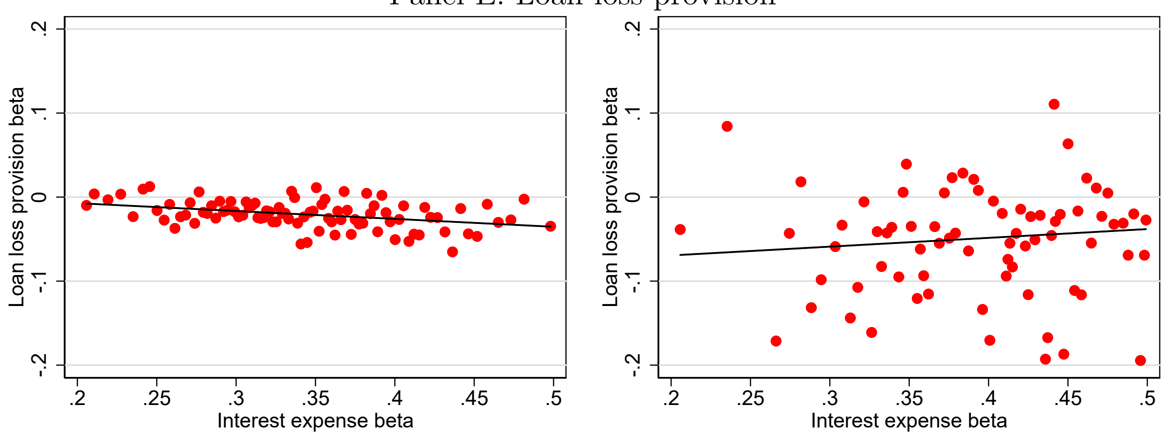
This figure shows bin scatter plots of bank operating costs and deposit fee income by expense betas. The betas and scatterplots are constructed the same was as in Figure 6. The sample covers all commercial banks with at least 60 quarterly observations from 1984 to 2017. The left column is for all banks and the right column for the top five percent of banks. The top panel provides information on noninterest income, the middle panel on loan loss provision, and the bottom panel on trading revenue.

All banks | Top 5%

Panel D: Noninterest income



Panel E: Loan loss provision



Panel F: Trading revenue

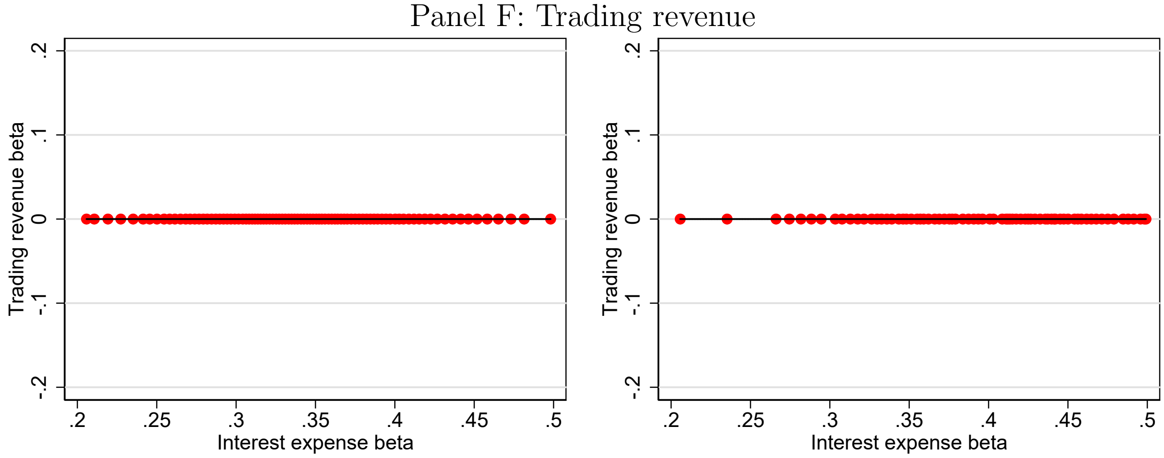


Figure A.3: **NIM betas and expense betas**

This figure shows bin scatter plots of the NIM betas and interest expense betas for all banks and the largest 5% of banks. The NIM beta is computed as interest income beta minus interest expense beta. The betas are calculated by regressing the quarterly change in each bank's interest expense rate or interest income rate on the contemporaneous and previous three changes in the Fed funds rate. Only banks with at least 60 quarterly observations are included. The betas are winsorized at the 5% level. The bin scatter plot groups banks into 100 bins by interest expense beta and plots the average NIM beta within each bin. The top 5% of banks are those whose average total assets over the sample are in the top fifth percentile. The sample is from 1984 to 2017.

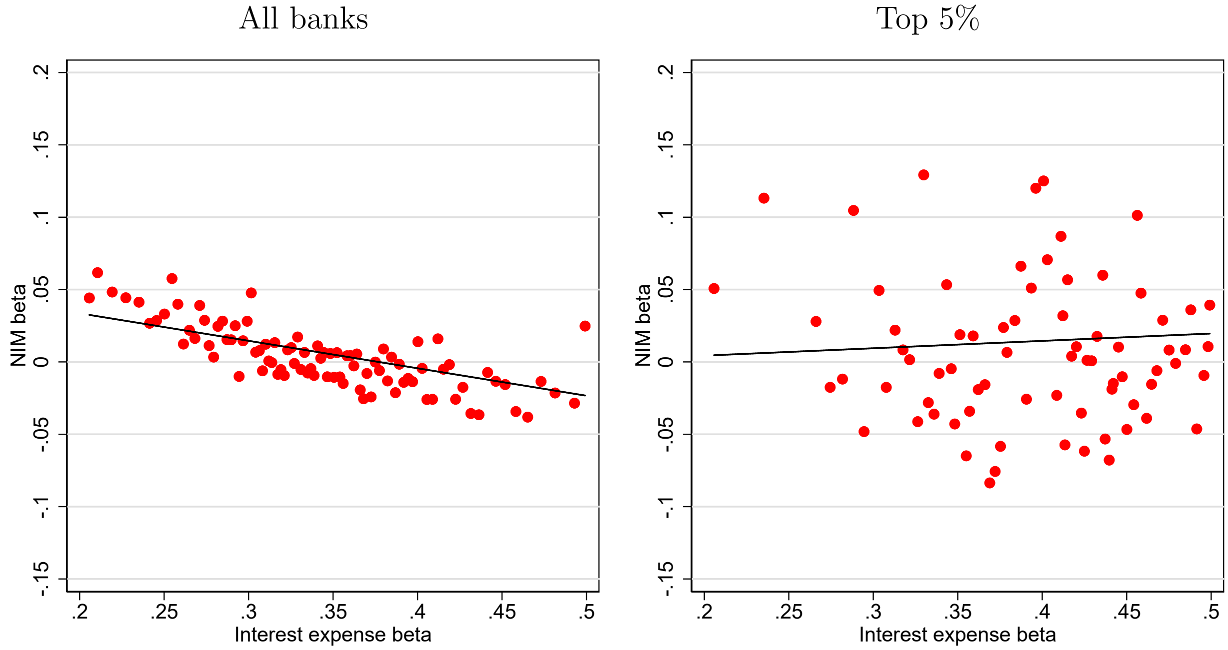


Figure A.4: **NIM betas and FOMC betas**

This figure shows a binscatter plot of the FOMC beta and the NIM beta. The analysis is at the level of the bank holding company. The FOMC beta is calculated by regressing the stock return of publicly listed banks on the change in the one-year Treasury rate over a one-day window around scheduled FOMC meetings from Feb 1994 to June 2007. The NIM beta is the interest income beta minus interest expense beta. Betas are winsorized at the 5% level.