Heterogeneity in Net-Interest Income Exposure to Interest Rate Risk and Non-Interest Expense Adjustment*

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Abstract
In this paper I document two new facts. First, bank net-interest margins (NIM) are insensitive to the short rate on average but this masks substantial heterogeneity in the cross section. I find cross sectional variation ranging from a -30bp to +40bp change in one quarter NIM after a 100bp change in rates, which compounds over the following four quarters. I find that this cross sectional heterogeneity is driven by differences in bank business models: banks with large negative NIM sensitivity to rate changes hold more residential mortgages, and rely more on interest bearing deposits whereas banks with large positive NIM sensitivity hold more typically shorter term commercial and industrial loans and rely more on non-interest bearing deposits.

Second, bank NIM sensitivity to rate changes is muted by offsets in non-interest expenses, reducing ROA sensitivity by approximately 30% on average. The positive relationship between net-interest income and non-interest expenses is not consistent with investment sensitivity to cash-flows as a result of costly external funds, but is somewhat consistent with investment sensitivity to profitability. However I also find that banks pass through NIM declines on the upside but not the downside, and the intensity of the relationship between net-interest income and non-interest expenses substantially increases closer to fiscal year end. These adjustments are consistent with the management of expenses in order to prop up earnings to meet executive performance targets, and have the side effect of reducing earnings sensitivity to rate changes.

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1 Introduction

The sensitivity of bank profits to interest rates is important for understanding the transmission of monetary policy (Bernanke and Blinder [1988], Bernanke and Gertler [1995] and Vanden Heuvel [2007]). A recent theoretical literature has emphasized concerns about the so-called reversal rate (Brunnermeier and Koby [2019]). The idea is that cutting interest rates beyond a certain threshold can adversely impact bank profits, which tightens equity capital constraints, and subsequently constricts lending. The Federal Reserve and other regulators voiced concerns about a reversal rate in the most recent Financial Stability Report\(^1\), and industry participants have expressed similar worries.

The empirical literature has found that bank profits are surprisingly insensitive to changes in interest rates in the aggregate. Indeed absent the financial crisis, since 1984, banks’ return on assets (ROA) has consistently been around 1 percent (Figure 1), despite changes in the competitive landscape of banking and a volatile interest rate environment in which the short rate has ranged from nearly 12 percent to essentially zero over the last four decades. The most compelling explanation the existing literature has provided for this phenomena is that bank net-interest margins (NIM), and profits more broadly, are insensitive to interest rates because banks perfectly match the interest rate sensitivity of their assets and liabilities (Drechsler et al. [2018] (hereafter, DSS [2018]).

In this paper, I present two new facts. First, I reject perfect hedging and show that there is significant heterogeneity in the sensitivity of bank net-interest income to interest rate changes. While the median bank matches interest income and interest expenses well, I show that the majority of banks have large positive or negative net-interest income sensitivity to rate changes: one quarter net-interest margins decline by as much as 30bp or increase by as much as 40bp after a 100bp increase in rates\(^2\). After breaking down net-interest income into interest income and interest expenses, I find that one quarter interest expense sensitivity to rate changes is relatively similar in the cross section, hovering at around 40bp change after


\(^2\)Furthermore, this effect grows to around \(-60bp\) to \(+85bps\) before stabilizing after 4 quarters.
a 100bp change in rates. However one quarter interest income sensitivity to rate changes varies substantially ranging from around a 10bps to around 80bp change after a 100bp change in rates. I find that this heterogeneity is consistent with differences in bank business models. Banks with negative net-interest income sensitivity to rate changes tend to hold more long term residential real estate loans, less typically shorter term C&I loans and fund themselves with more interest bearing deposits. Banks with negative net-interest income sensitivity to rate changes look more like the “traditional” bank, borrowing short with more pass-through on liabilities, and lending long. Hence when rates increase, interest income resets at a much slower pace than interest expense and thus net-interest income declines. On the other hand banks with the most positive net-interest income sensitivity to rate changes hold opposite portfolios i.e. shorter term assets such as C&I loans, which are funded with substantially more liabilities that dont require interest payments. Hence when rates increase, interest income increases more than interest expense and so net-interest income increases. This heterogeneity in net-interest income sensitivity is also passed through to equity value: there is a strong positive correlation between bank NIM betas and FOMC betas, which are the sensitivity of 1 day returns to changes in the 1 year Treasury rate around scheduled FOMC announcements.

The second fact I present in this paper is that net-interest income changes are offset by changes in non-interest expense. This expense adjustment is meaningful. For banks in the most sensitive net-interest margin (NIM) decile, a 100 bp basis point drop in the federal funds rate decreases banks one quarter NIM by 40bp: at 10:1 leverage this is a large hit to ROE, even absent the additional impact on NIM over the following 4 quarters. However a substantial portion of this decline in NIM is offset by around 30% on average by a reduction in non-interest expenses. While the amount of offset varies in the cross section, banks with larger net-interest income sensitivity to rate changes, both positive and negative, also have larger non-interest expense sensitivity to rate changes. The close relationship between net-interest income and non-interest expense exists for as far back as I have data, both in levels and in sensitivity to rate changes, and is surprising, since non-interest expense is often
thought of as the “fixed costs” of bank operations.

These findings are particularly relevant in the current low interest rate environment and have implications for understanding to what extent cutting rates beyond a “reversal rate” would impact bank profits and hence monetary policy transmission in the cross section. For example, banks with negative net-interest income exposure to interest rates experience increases in profits when interest rates are cut and thus do not experience declines in net worth, which would negatively impact lending. Furthermore, banks with positive net-interest income exposure to interest rates may not experience as large declines in total profits after rate cuts if these declines are to some extent offset by changes in non-interest expenses. These non-interest expense cuts have the effect of muting the negative impact a rate cut has on net worth and subsequently lending for positive NIM exposure banks.

I explore four mechanisms that could plausibly explain the positive relationship between net-interest income and non-interest expense.

One possibility is that there is simply a mechanical relationship between net-interest income and non-interest expenses. While transactions deposits accounts offer lower interest rates than non-transactions deposits accounts they are more expensive to run: for example banks must pay costs related to core processing, maintaining access and services related to payments networks and monitoring fraud. This would predict that banks with more transactions deposits that pay zero interest, would likely have higher net-interest income, and also have higher non-interest expenses. This mechanical relationship could also be relevant as rates change and the composition of bank balance sheets changes with deposit flows induced by rate changes and changes in demand and supply of loans. In this mechanism, non-interest expenses would provide a natural hedge against rate changes by offsetting fluctuations in net-interest income.

I find that indeed banks with higher net-interest income in levels, also have higher non-interest expenses, more transactions deposits and more loans as a fraction of total assets. These results indicate there appears to be a possible mechanical relationship between net-

\footnote{See for example Kashyap and Stein [1995], Kashyap and Stein [2000], and Drechsler et al. [2017] for details on deposit flows after rate changes.}
interest income and non-interest expenses in levels. However I show that after controlling for balance sheet composition changes, that might be induced by say interest rate changes, changes in net-interest income are still positively related to changes in non-interest expenses.

A second possible mechanism is that bank net-interest income is a proxy for forward looking profitability, and bank non-interest expenses – that contain expenditures on salaries, branches and technology – are a noisy proxy for bank investment\(^4\). Hence as predicted by Tobin’s Q theory, banks scale up operations when profitability is high and invest more in human capital and the deposit franchise, and similarly scale down operations when profitability is low. If rate changes impact bank net-interest income, then Q theory would accurately predict a positive relationship between bank net-interest income and non-interest expenses after rate changes, and more generally.

I find that net-interest income is indeed positively related to Tobin’s Q, indicating that the positive relationship between net-interest income and non-interest expenses might be capturing the fact that banks respond to future profitability changes by changing investment. I also find that the market rewards banks who cut expenses after net-interest income declines relative to banks who don’t, with higher stock prices, indicating that banks who have more responsive investment to changes in profitability are considered more efficient by investors. However this high frequency – potentially quarterly– response of investment to changes in profitability seems implausible.

An third possible mechanism is that bank net-interest income is a proxy for bank cash flows, and cash flows are in fact driving investment for which non-interest expenses are a proxy. This is because banks face financing frictions and internal and external funds are imperfect substitutes. In this case, if rate changes impact bank net-interest income (cash flows) then bank investment (non-interest expenses) will adjust in the same direction – a finding well documented in the literature on investment/cash flow sensitivity starting with Fazzari et al. [1988].

I indeed find that after controlling for “cash flows” Tobin’s Q becomes an insignificant

\(^4\)Noisy because they clearly also contain expenses related to day to day operations of the bank.
predictor of bank investment, however I reject the hypothesis that bank investment is sensitive to cash flows (for which net-interest income is a proxy) as a result of imperfect access to external funds. Net-interest income is positively related to next periods investment after controlling for Tobin’s Q, however large banks/banks with high equity ratios have higher sensitivity of non-interest expense to net-interest income, and the sensitivity of investment to Tobin’s Q does not vary with measures of financial constraints.

A final mechanism that could explain the positive relationship between net-interest income and non-interest expense is that due to the nature of executive incentives such as ROE targets in compensation contracts – as documented by Pennacchi and Santos [2019] – bank managers will make “adjustments” to bank expenses in order to meet compensation targets.

I find that banks are more likely to cut expenses after net-interest income declines, and hold them low until ROA bounces back, but not hold them high after net-interest income increases. The result is that net-interest income changes are passed through on the upside but not the downside. Furthermore, I find that the intensity of the relationship between net-interest income and non-interest expenses increases the closer to fiscal year end when executive compensation is set and banks are also substantially more likely to increase leverage\(^5\) the closer to fiscal year end after a NIM decline. These findings are consistent with executive performance targets whereby banks “borrow” earnings from the future, or make other adjustments to prop up current earnings and meet targets. I leave causal identification of income targeting for future work.

These results collectively indicate that accounting for bank heterogeneity is necessary in order to understand the aggregate effects of monetary policy transmission through the net worth channel. Furthermore, adjustments to non-interest expenses seems to mute the impact of rate changes on profits, net worth and subsequently lending. The positive relationship between net-interest income and non-interest expenses seems to be a result of a combination of mechanical ties between net-interest income and non-interest expenses, and investment sensitivity to profitability. However the fact that banks are more likely to make adjustments\(^5\) which “artificially” boosts ROE
to expenses and leverage after a net-interest income decline, the closer to fiscal year end, casts
doubt that the positive relationship between net-interest income and non-interest expenses
is entirely efficient.

The rest of the paper is organized as follows. Section 2 discusses related literature,
Section 3 describes the data, Section 4 documents bank cash flow interest rate risk exposure,
Section 5 documents bank equity interest rate risk exposure, Section 6 discusses potential
mechanisms and Section 7 concludes.

2 Related Literature

This paper is related to four strands of literature. The first is the literature on the measure-
ment of interest rate risk within the banking system.

Measuring interest rate risk within the banking system is challenging - for one interest
rate risk is a high dimensional object, which arises from varying rates on rate sensitive assets
and liabilities at a large number of maturities. It is therefore hard to boil down interest rate
risk within the banking system to a single statistic.

The existing literature has typically used three different measures of bank interest rate
risk exposure that deal with this dimensionality problem differently. The first measure is
the income gap, which captures the interest rate sensitivity of cash flows within a given
maturity bucket i.e. 1 year. The income gap at a maturity of 1 year is proportional to
annual net-interest income and so is considered a cash flow measure of interest rate risk.
The second measure is duration, which captures the interest rate sensitivity of all future
cash in-and out-flows and thus has to be interpreted in terms of total bank value exposure to
rate changes. The third measure makes use of factor models, which again measures interest
rate risk in terms of total bank value yet with reduced data requirements since interest rates
have a low factor structure\(^6\).

The broad consensus resulting from studies of all three measures of interest rate risk

\(^6\)See for example a survey paper by Vuillemey for more in depth discussion of the different types of
measurement of interest rate risk
is that bank cash flows at short time horizons have a small but positive relationship with
interest rates (Landier et al. [2013]) and that bank equity value is negatively related to
interest rates (Flannery and James [1984], Aharony et al. [1986], Yourougou [1990], Akella
recently English et al. [2018]). However more recently, Drechsler et al. [2018] highlight that
given the degree of maturity transformation that occurs within the banking system, bank
duration measures imply bank value sensitivity to interest rate changes that is of an order
of magnitude larger than what is actually observed. DSS [2018] then trace this back to cash
flows and carefully document that banks perfectly match interest income to interest expenses
by exerting pricing power in deposit markets, which leaves short term cash flows completely
insensitive to interest rate changes and hence bank value also relatively insensitive.

In this paper I show that while the median bank matches interest income and interest
expenses very well, many banks do not, resulting in relatively large negative and positive
one quarter net-interest income exposure to interest rate changes in the cross section, that
compounds over the next four quarters before stabilizing. I contribute to this literature on
the measurement of interest rate risk within the banking system by documenting substantial
heterogeneity in cash flow exposure, and providing a unifying explanation for the different
conclusions that have recently been drawn on bank exposure. I show that bank cash flows are
not insensitive to interest rates, nor are they exclusively positively related to interest rates
- there is large heterogeneity in interest rate exposure which is largely offset by adjustments
in non-interest expenses.

This paper is also related to the literature on interest rate risk sharing between the
banking and the non-financial sectors. If banks write state contingent contracts (such as
variable rate loans and deposits) then they hedge themselves against interest rate fluctuations
and pass exposure to the non-financial sector. There is a large existing literature that assesses
to what extent banks hedge themselves or pass interest rate risk through via a lending and/or

The average four quarter cash flow sensitivity to rate changes is slightly positive at around 12bp -
matching well with findings in Landier et al. [2013], yet still this average masks substantial heterogeneity in
the cross section.
deposit taking channel. Ippolito et al. [2018] show that 76% of firm bank debt has a floating rate and hence interest rate risk is largely passed on to firms. Vickery [2008] finds that 54% of all bank loans have a floating rate. Kirti [2020] shows that banks lend at floating rates so as to match their floating rate liabilities, hence engaging in operational risk management. On the deposits side, Berger and Hannan [1989], Neumark and Sharpe [1992] and Drechsler et al. [2017] show that competition drives the nature and terms of deposit contracts in the cross-section making it difficult to single out the effect of banks’ active decisions to transfer risk to depositors. I contribute to this literature by providing evidence of another form of operational risk management at banks: changes in bank expenses immunize cash flow sensitivity to rate changes. My findings suggest that interest rate risk is passed to the non-financial sector through for example variation in salaries of bank employees, or variation in the provision of current and future financial services through investment in branch networks or technology.

The third strand of literature this paper is related to is that on the determinants of firm investment. In order to determine what drives the positive relationship between bank net-interest income and non-interest expenses, I notice that non-interest expenses, contain expenses related to human capital, the deposit franchise and technology\(^8\). Hence while non-interest expenses clearly contain costs related to the day-to-day operations of the bank, they also potentially capture bank investments\(^9\). I contribute to the large literature on the determinants of investment by non-financial firms (Tobin [1969], Fazzari et al. [1988], Kaplan and Zingales [1997]) by showing that for financial firms also, bank cash flows are correlated with the markets assessment of future bank profitability but that cash flows seem to matter more for bank investment.

Finally this paper is related to the extensive literature on executive compensation. Executive contracts are designed with the goal of aligning managers incentives with those

\(^8\)captured in expenses related to salaries, bank branches and premises and “other” of which approximately 75% is costs related to technology.

\(^9\)As ? notes, bank investment in capital is notoriously hard to measure – the statement of cash flows to a bank show little or no capital expenditures and correspondingly low depreciation and likely bank investment is comingled with operating costs.
of shareholders, however any incentive contract itself creates incentives to manipulate the performance measure(s) it relies upon. Pennacchi and Santos [2019] highlight that bank executive compensation is linked to ROE targets, and Edmans et al. [2017] provide an extensive survey of literature that shows non-linearities in the mapping from performance into payoffs create incentives to manipulate. This paper provides suggestive evidence that banks manage expenses to get “above the bar”. However I recognize that empirically showing that executive pay has causal effects is extremely difficult and leave causal evidence of bank manager myopia for future work.

3 Data

I obtain quarterly bank balance sheet and income statement regulatory data from FRY–9C forms and FFIEC–031 forms and run all tests on data aggregated at the holding company level (using FRY–9C data) or at the bank level (using FFIEC–031 data) if no bank holding company structure exists. The sample runs from 1986-2018. I use data at the holding company level since financing decisions and asset allocation decisions are made at the holding company level. For example the bank holding company itself can issue certain types of funding securities hence ignoring the holding company structure may cause measurement error in interest expenses. Furthermore, financial conglomerates make use of internal capital markets and allocate lending across subsidiaries\(^{10}\). Hence I argue that the holding company level (if there is one) relationship of revenues and expenses with interest rates will best reflect the interest rate risk of cash flows.

The quarterly Federal Funds rate is the daily Federal Funds rate obtained from FRED, averaged over each quarter. The quarterly yield curve slope is calculated by averaging the daily 10 year Treasury rate, also obtained from FRED and subtracting the quarterly Federal Funds rate.

Ban regulatory data is linked to CRSP data through a publicly available linking table.

\(^{10}\)see for example Campello [2002]
Bank quarterly market capitalization is calculated as the price $\times$ shares outstanding at the end of the quarter\textsuperscript{11}

4 Interest Rates & Bank Cash Flows

4.1 Net-Interest Income

I start by calculating the sensitivity of bank NIM and ROA to interest rates by running a panel regression of the change in NIM or ROA on changes in the Fed Funds rate, controlling for changes in the slope of the yield curve and including bank/year fixed effects.

$$\Delta Y_{i,t} = \alpha_i + \sum_{\tau=0}^{h} \beta_{i,\tau} \Delta FF_{t-\tau} + \sum_{\tau=0}^{h} \gamma_{i,\tau} \Delta Slope_{t-\tau} + \psi_t + \epsilon_{i,t}$$

For $\Delta Y_{i,t} \in \{\Delta NIM_{i,t}, \Delta ROA_{i,t}\}$.

I vary the number of lags of the Fed Funds rate and slope from 0 lags (h=0, contemporaneous) to up to and including 3 lags (h=3). Table 1 documents the results of these regressions and shows that, no matter the number of lags used, consistent with the existing literature, the point estimates are small. For example, up to and including 2 lags, a 100bp change in the Fed Funds rate will impact NIM by 3.2bp and ROA by around 1.8bps.

First, focusing on NIM, I next explore the heterogeneity across banks not captured by the panel regression reported in Table 1, by running the following time series regression for each bank $i$, including 3 lags of the Fed Funds rate and term structure slope.

$$\Delta NIM_{i,t} = \alpha_i + \sum_{\tau=0}^{3} \beta_{i,t-\tau} \Delta FF_{t-\tau} + \sum_{\tau=0}^{3} \gamma_{i,t-\tau} \Delta Slope_{t-\tau} + \psi_t + \epsilon_{i,t}$$

\textsuperscript{11}Note I also run tests using quarterly average market capitalization with no material differences in results
I define a bank’s NIM interest rate beta as:

\[ \beta_{i,NIM} = \sum_{\tau=0}^{3} \beta_{i,t-\tau} \]

I choose this method of calculating NIM sensitivity to be consistent with the existing literature\(^{12}\) but note that my results are not dependent on the number of lags of the Fed Funds rate or slope included in the above regression.

Figure 2 documents the average \( \beta_{i,NIM} \) for each decile and shows that while the \( \beta_{i,NIM} \) is approximately 0 for banks in the median decile, there is substantial heterogeneity across deciles – ranging from large and negative (-30bp) to large and positive (+40bp)\(^{13}\).

I next split NIM into an interest income component and an interest expense component in order to understand what is driving the heterogeneity documented in Figure 2.

I use the same method as above to calculate \( \beta_{i,Income} \) and \( \beta_{i,Expense} \) to calculate the sensitivity for each bank \( i \), of interest income scaled by total assets and interest expense scaled by total assets to rate changes respectively. In Figure 3 I plot the average of \( \beta_{i,Income} \) and \( \beta_{i,Expense} \) for each \( \beta_{NIM} \) decile.

Figure 3 shows that for banks in the smallest \( \beta_{NIM} \) decile, interest income is substantially less sensitive to rate changes than interest expense, which results in large negative NIM exposure to rate changes. On the other hand, banks in the largest \( \beta_{NIM} \) decile have substantially greater sensitivity of interest income to rate changes than interest expenses resulting in large positive exposure to rate changes. Figure 3 shows that there is much less variability in interest expense betas: across deciles, bank interest expense exposure to rate changes is steady at around a 40bp change in interest expense after a 100bp change in rates, however interest income sensitivity varies substantially\(^{14}\). Again, the banks in the median decile have

\(^{12}\)For example DSS [2018]

\(^{13}\)I find that these 1 quarter NIM sensitivities do not reverse but are compounded over subsequent quarters. Figure A.1 panel (a) documents how the beta’s evolve

\(^{14}\)I notice that this estimate is higher than has been documented in the existing literature, for example DSS [2018]. I suggest the difference might be due to the fact that I calculate interest rate sensitivity at the bank holding company level, which will include any funding instruments issued by the holding company itself. These instruments tend to be wholesale funding instruments with market rates more sensitive to rate changes than deposit rates.
perfectly matched interest income and interest expense sensitivity to rate changes.

I next reconcile the dispersion I document in Figures 2 and 3 with the existing literature (e.g. DSS [2018]) which documents a very tight relationship between interest expense betas and interest income betas. First, interest expense betas have substantially less variation in the cross section than interest income betas or net-interest income betas\textsuperscript{15}. Hence sorting on the low cross sectional variance interest expense betas masks significant cross sectional variation in interest income betas and subsequently net-interest income betas. Second while a positive relationship between interest expense betas and interest income betas is consistent with some amount of operational interest rate risk hedging, uncovering variation in net-interest income betas is a stronger test of perfect hedging\textsuperscript{16}, which Figures 2 and 3 reject.

4.1.1 Decomposing Bank Heterogeneity

In this section, I investigate what drives the observed differences across deciles documented in Figure 2 and 3 by documenting bank balance sheet characteristics for banks in each $\beta_{NIM}$ decile.

I calculate asset and liability balance sheet components as a fraction of total assets, and compare each component for each bank each year to the average value for that component in that year. I then take an average of this relative value per bank and report the averages per $\beta_{NIM}$ decile in Figure 4. This method overcomes the fact that bank balance sheet characteristics generally change through time, and hence comparing banks to the overall average within a year rather than just reporting averages over the entire life of the bank allows us to more accurately compare bank differences for banks operating at potentially different times.

A few interesting patterns emerge. First, Figure 4 illustrates that bank portfolios are not homogenous and banks seem to specialize. For example, banks with the most negative $\beta_{NIM}$ tend to hold more long term residential real estate loans and less commercial real estate

\textsuperscript{15}I find interest expense betas have a variance of 0.32, interest income betas have a variance of 1.64 and net-interest income betas have a variance of 1.29

\textsuperscript{16}Which would require identical variation in interest income and expense betas and would result in 0 variation in net-interest income betas.
loans (Panel (a) and (b)), less shorter term C&I loans\footnote{See for example den Haan et al. [2007] for a discussion of the average maturity of C&I loans.} (Panel (c)), fund themselves with more interest bearing deposits (implied from Panel (f)) and hold less equity and hence more non-deposit funding (implied from Panels (e) and (g)). Banks in these deciles look more like the “traditional bank”, borrowing short with more pass-through on liabilities, and lending long. Hence when rates increase, interest income resets at a much slower pace than interest expense and thus NIM declines. On the other hand banks with the most positive $\beta_{NIM}$ hold opposite portfolios: shorter term assets funded with substantially more liabilities that don’t require interest payments. Hence when rates increase, interest income increases more than does interest expense and NIM increases.

Second, while bank size is not perfectly correlated with $\beta_{NIM}$, I do see that the smallest banks operate with the most positive $\beta_{NIM}$. I also see that these banks hold more commercial real estate loans (implied from Panel (a) and Panel (b)), but given the NIM beta, these loans appear to be short term. This fits with findings from the existing literature: for example small banks hold more commercial real estate loans than large bank\footnote{Commercial Real Estate loans comprise 30% of small bank loan portfolio on average and only 5% of large banks portfolio - see for example Banking Trends 2019, from the Federal Reserve Bank of Philadelphia.}, and specifically hold construction and land development loans and nonfarm non-residential loans which have a relatively short maturity on average\footnote{See Banking Trends 2019, from the Federal Reserve Bank of Philadelphia.}

Finally, there is very little difference in the amount of total deposit holdings across deciles\footnote{A similar finding to Hanson et al. [2015]}, yet substantial difference in the types of deposits that banks issue across deciles.

4.2 Non-Interest Expenses

The results above document that many banks have meaningful exposure of net-interest margins to interest rate changes. In particular, around roughly 40% of banks in my sample should experience ROE changes of greater than one standard deviation of observed ROE volatility every time rates move by just 100bp\footnote{for banks in the bottom and top 2 deciles, absolute NIM betas of greater than 20bp imply ROE changes by 2%, or roughly 1 standard deviation in ROE, after a 100bp change in rates at a conservative leverage of}. Yet in practice, after large rate increases
or decreases I find that bank earnings remain relatively stable. This is best illustrated in Figure 5, which contains a bin scatter plot of bank $\beta_{i,ROA}$ for every $\beta_{i,NIM}$ bucket i.e. each bank is sorted into 100 buckets for each percentile of $\beta_{NIM}$, and the average $\beta_{ROA}$ and $\beta_{NIM}$ for each of the 100 buckets is plotted in a scatter chart\textsuperscript{22}. The blue dashed line represents the expected ROA sensitivity to interest rate changes if NIM sensitivity is entirely passed through to net income and the green solid line represents the true ROA sensitivity for each NIM bucket. Figure 5 shows that actual ROA sensitivity is substantially reduced (the fitted green line is substantially flatter than the blue dashed line) especially for larger absolute values of NIM. I next argue that this reduction comes for offsetting changes in non-interest expenses.

I calculate non-interest expense betas in a similar way to the NIM betas defined in Section 4. First I define NIE as non-interest expense divided by total assets and then for each bank in an individual time series regression I calculate:

$$\Delta NIE_{i,t} = \alpha_i + \sum_{\tau=0}^{3} \Delta FF_{t-\tau} + \sum_{\tau=0}^{3} \Delta Slope_{t-\tau} + \gamma_t + \epsilon_{i,t}$$

and define a bank's NIE beta as:

$$\beta_{i,NIE} = \sum_{\tau=0}^{3} \beta_{i,\tau}$$

Figure 6 reports another bin scatter plot: for each $\beta_{NIM}$ percentile I plot average $\beta_{i,NIE}$ against average $\beta_{i,NIM}$. Figure 6 documents a striking positive relationship between $\beta_{i,NIM}$ and $\beta_{i,NIE}$: banks with larger NIM sensitivity to interest rate changes also have larger NIE sensitivity to interest rate changes. The slope of the line in Figure 6 is approximately 0.3 indicating that on average roughly 30% of any NIM variation induced by changes in rates is offset by non-interest expense changes. The signs of $\beta_{i,NIM}$ and $\beta_{i,NIE}$ are also remarkably

\textsuperscript{10:1} I transition from decile plots to bin scatter plots with 100 buckets simply to try to capture more of the heterogeneity and potential noise in the relationship between NIM and NIE.
similar, banks with negative $\beta_{i,NIM}$ tend to have negative $\beta_{i,NIE}$ and vice versa. The roughly 30% offset from non-interest expenses can explain a large portion of the difference in slopes between the blue dashed line and the green line in Figure 5. The slope of the fitted line in Figure 5 is roughly 0.5 indicating that non-interest expenses can account for almost 60% of the reduction in variability in earnings induced by changes in net-interest income induced by rate changes.

I find no similar non-interest income offset, in fact bank net-interest income and non-interest income are if anything positively related, and hence non-interest income amplifies total earnings sensitivity to rate changes. The variability documented in NIE is surprising also because non-interest expenses are often thought of as the fixed costs of doing bank business. Yet I document that non-interest expenses don’t remain fixed and in fact they vary with interest rates in a significant way.

5 Interest Rates & Bank Value

As noted in English et al. [2018], the impact of rate changes on the market value of bank equity is complex, since even if bank cash flows respond (say) positively to interest rate increases for example, one must also consider immediate capital losses on assets, and adjustments in quantities such as outflows of deposits, or overall changes in demand for or quality of loans (which in turn will affect quantities and future profits). While English et al. [2018] do find that the impact of rate changes on NIM tend to be positive and persistent, the existing literature has documented extensively that the overall effect of rates on bank value is negative. In this section I explore whether or not heterogeneity in NIM sensitivity to rate changes is passed through to bank value sensitivity.

I start by calculating FOMC betas following the methodology of DSS [2018]. Specifically I regress the stock returns of publicly traded banks on the change in the one year Treasury rate over a one-day window around FOMC meetings. Panel A in Figure 7 plots a histogram of

\[23\text{See Appendix Figure A.2 for a bin scatter plot of net-interest income and non-interest income betas.}\]

\[24\text{See for example DeYoung and Hunter [2002]}\]
FOMC betas obtained for publicly traded banks and documents heterogeneity across banks ranging from roughly -12% to +12%.

I next assess to what extent these FOMC betas are correlated with $\beta_{NIM}$ by creating a decile plot in Panel B, which reports average FOMC betas per $\beta_{NIM}$ decile. Panel B shows that there is a strong positive (but imperfect) relationship between banks FOMC betas and $\beta_{NIM}$.

In other words, banks with positive NIM sensitivity to rate changes also have positive value sensitivity to rate changes, and vice versa. The sensitivity of value changes to rate changes can be large in the cross section, but on average is relatively small, which squares with findings in the existing literature.

6 Mechanisms: Why do Net-Interest Income and Non-Interest Expenses Move Together?

6.1 Mechanical Relationships

Transactions, or demand deposits accounts offer lower interest rates than non-transactions deposits accounts\textsuperscript{25}, but also have greater costs associated with running these accounts. See appendix Figure A.3 for an example of the differences in costs associated with checking, savings and time deposit accounts. Hence this would predict a possible positive mechanical relationship between net-interest income and non-interest expenses since banks that issue a lot of demand deposits, likely have lower interest expenses, higher net-interest income and higher non-interest expenses. This is indeed what I find in the data: Table 2 documents summary statistics for banks sorted into NIM (net-interest income scaled by lagged total assets) quintiles. Banks with high NIM tend to have higher NIE (non-interest expenses scaled by lagged total assets)\textsuperscript{26}, and issue more non-interest bearing deposits. Higher NIM

\textsuperscript{25} Up until 2011, Regulation Q prohibited the payment of interest on demand deposit accounts, and while interest payments are not prohibited on other forms of transactions deposits, the interest rates paid on these types of deposits tend to be lower than on non-transactions deposits - See Williams [2019].

\textsuperscript{26} Note, they also have higher non-interest expenses net of non-interest income also.
banks also have more loans as a fraction of total assets. These statistics indicate that there is indeed some mechanical relationship between net-interest income and non-interest expenses. Table 2 also documents the average NIM, NIE, NII (non-interest income scaled by lagged total assets) and ROA sensitivity to interest rate changes, and indicates no relationship at all between levels and sensitivity to rate changes.

We know from the existing literature that interest rate changes induce deposit inflows and outflows and changes in lending. These changes might then mechanically cause changes in non-interest expenses and net-interest income at the same time. Table 3 documents the relationship between changes in net-interest income and non-interest expenses after controlling for any changes in asset and liability composition that could be related to non-interest expense changes. Columns (3) and (4) instrument changes in net-interest income, non-interest bearing deposits and loans with changes in rates. Table 3 shows that after controlling for balance sheet composition changes that could mechanically link net-interest income and non-interest expenses, there is still a large positive relationship between the two. Hence it is unlikely that the tight relationship between net-interest income and non-interest expenses is purely mechanical.

6.2 Non-Interest Expense as a Proxy for Bank Investment

In order to further uncover what drives the relationship between net-interest income and non-interest expenses I next notice that bank non-interest expenses contain expenses related to human capital, bank branch infrastructure and technology, which look a lot like components of bank investment in capital. I turn to the existing literature to explore whether or not the observed positive relationship between NIM and NIE can be explained by standard theories of firm investment.

Banks like all firms invest in order to produce goods or services, yet defining investment in financial services firms is difficult. Unlike manufacturing firms that invest in plant, equipment

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27See Kashyap and Stein [1995], Kashyap and Stein [2000] and Drechsler et al. [2017] amongst others: a decrease in rates for example is associated with an inflow of demand deposits, an increase in rates is associated with a decrease in lending
and other fixed assets, financial services firms invest primarily in intangible assets such as brand name and human capital. Hence many bank investments are relatively invisible in nature and cannot be accurately disentangled from operating costs. For example as points out, invisible investment might be a commitment by a company to increase the resources to client coverage. Although this is an investment in the sense this move is expected to bring long term benefits, the costs might be attributed to increases in operating expenses rather than investment itself.

Not surprisingly, the statement of cash flows to a bank show little or no capital expenditures and correspondingly low depreciation. I therefore argue that bank non-interest expenses – such as expenses related to salaries, bank branches and technology costs – might instead a better proxy for bank investments. Non-interest expenses of course also contain expenses related to day to day operations of the bank, and hence is a noisy proxy for bank investment. In order to attempt to eliminate some of this noise, I define bank investment as:

\[
I_t = \frac{\text{NonInterestExpense}_t - \text{NonInterestExpense}_{t-1}}{\text{Assets}_{t-1}}.
\]

The idea is that non-interest expenses contain both day to day operating costs and investment. Taking the first difference of non-interest expense might be a better proxy for investment if it differences out ongoing costs required in the day to day operations of the bank.

I then turn to the existing literature – drawing on Q theory and investment sensitivity to cash flows in the presence of financing constraints – in order to further understand the positive co-movement between net-interest income and non-interest expenses.

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28See for example for a discussion on the difficulty in identifying net capital expenditures and working capital at financial services firms.

29For example Fifth Third’s 2010 10K states "Salaries, incentives and benefits increased $50 million, or 10%, from the prior year due primarily to additional branch personnel related to expanded branch hours of operation" and Bank of New York Mellon’s 2005 10K states "The 2005 increase in expenses primarily reflects increased staffing and clearing costs associated with new business and acquisitions" these examples are few of many that clearly show bank investment is reported in non-interest expenses.
6.2.1 Tobins Q

Studies of investment typically begin with insights from Tobins 1969 seminal paper on investment. Tobin shows that a firm will want to invest if the market value of a project exceeds its replacement value. Tobin’s theory thus implies a positive relationship between Tobin’s Q (market value relative to replacement value) and firm investment.

If net-interest margin is a proxy for the viability of bank business, and hence forward looking profitability/market value, then I would expect to see a positive relationship between bank NIM and a measure of Tobin’s Q. If this is the case, the positive and close relationship between net-interest income and non-interest expenses, which is my proxy for bank investment, could be explained by Tobin’s theory: when bank net-interest margin is high banks future profitability looks promising, and banks scale up and invest more in things like human capital, bank branches and technology. When net interest margin is low banks future profitability looks less appealing and banks scale down and invest less: hence under this hypothesis non–interest expenses would be positively related to net-interest income. Furthermore, if rate changes impact bank net–interest income, I would expect bank NIM betas to be positively related to bank NIE betas.

In order to test this hypothesis, I follow the existing literature on non-financial firms and regress bank NIM on a standard measure of Tobin’s Q in a panel regression. Specifically I run the following bank/quarter level regression:

\[ NIM_{i,t} = \alpha_i + \beta_{i,t} Q_t + \gamma_t + \epsilon_{i,t} \]

To calculate Tobin’s Q, I proxy the market value of assets by the book value of assets minus the book value of equity minus deferred taxes plus the market value of common stocks. The book value of assets is used as a proxy for the replacement value of assets.\(^\text{30}\)

Column (1) of Table 4 shows that Tobin’s Q are positively and significantly related to NIM.

\(^{30}\text{Note using this measure of Tobin’s Q I am implicitly making the assumption that average } q \text{ is a decent proxy for marginal } Q \text{ – see Summers [1981]}\)
I next instrument NIM with the Fed Funds rate, to assess whether NIM changes specifically induced by rate changes are positively related to Tobin’s Q. Specifically I run the following two stage regression:

**First Stage:**

\[
NIM_{i,t} = \alpha_i + \sum_{\tau=0}^{3} \beta_{1-\tau} FF_{t-\tau} + \sum_{\tau=0}^{3} \gamma_{t-\tau} Slope_{t-\tau} + \psi_t + \epsilon_{i,t}
\]  

(1)

In the first stage above, NIM is instrumented with the Fed Funds rate.

**Second Stage:**

\[
Q_{i,t} = \alpha_i + \beta_{t-\tau} \widehat{NIM}_{t-\tau} + \gamma_t + \epsilon_{i,t}
\]

In the second stage above predicted NIM is used as the independent variable. The results in Column (2) again show that NIM changes that result from rate changes in rates are also positively and significantly related to Tobins Q.

Results in Table 4 are consistent with the hypothesis that NIM is a proxy for future profitability and hence banks scale up or down operations and invest more or less when NIM changes.

I next investigate the markets reaction to banks that experience NIM declines relative to NIM increases. Figure 8 plots the cumulative daily returns of banks that have a NIM increase (the blue line), a NIM decline combined with a non-interest expense cut (the green line) and a NIM decline with no non-interest expense cut. The cumulative returns are plotted relative to the quarter end of the quarter during which the NIM increase or decrease occurred. Figure 8 shows that the market rewards banks that cut investment after a decrease in NIM with substantially higher stock prices than banks that do not “respond” to these declines in profitability with cuts in investment.
However, these results - at a quarterly frequency - also suggest that banks scale up and down operations as a response to high frequency changes in profitability and future outlook, which seems implausible.

6.2.2 Investment/Cash Flow Sensitivity

Net-interest income may not be a proxy for forward looking profitability, but instead a proxy for firm cash flow, which could be driving firm investment. Under this hypothesis, bank cash flow determines bank investment, which the market responds positively to.

Following the standard practice of Fazzari et al. [1988], I begin the investigation into investment sensitivity to cash flow by first assessing to what extent “cash flows” matter for investment controlling for Tobin’s Q.

I run the standard horse with non-interest expenses as the dependent variable, specifically I run the following bank/quarter level regression:

\[ I_{i,t} = \alpha_i + \beta_{i,t}NIM_t + \gamma_{i,t}Q_{t-1} + \psi_t + \epsilon_{i,t} \]

Columnw (1) to (3) of Table 5 contains results of this regression: Tobin’s Q is negatively related to investment, and cash flows is positively related to investment.\(^{31}\)

I next instrument NIM with the Fed Funds rate, to assess the relationship between NIM and Tobin’s Q induced by rate changes, and investment. Specifically I run the following two stage regression:

First Stage:

\[ NIM_{i,t} = \alpha_i + \sum_{\tau=0}^{3}\beta_{i,-\tau}FF_{t-\tau} + \sum_{\tau=0}^{3}\gamma_{i,-\tau}Slope_{t-\tau} + \psi_t + \epsilon_{i,t} \]  

\(^{31}\)Note, these results are robust to including non-interest income as part of bank cash flow.
In the first stage above, NIM is instrumented with the Fed Funds rate.

**Second Stage:**

\[
I_{i,t} = \alpha_i + \beta_i,t \hat{NIM}_{i,t} + \gamma_i,t Q_{i,t-1} + \psi_t + \epsilon_{i,t}
\]

In the second stage, predicted NIM and Tobin’s Q are used as the independent variables. Column (4) of Table 5 reports results using instrumented values of NIM and Tobin’s Q and again show similar relationships: NIM is positively related to investment controlling for Q.

The coefficients on Q in columns (1) to (4) vary in sign, however they are economically very small. These results are relatively consistent with the existing literature on non-financial firms i.e. cash flows are far more important than Q in the determination of firm investment.

The existing literature has interpreted these results for non-financial firms as evidence that cash flows matter for investment as a result of financing constraints. I next test this interpretation of results in Table 5 by splitting banks into large vs small groups and within each size group into high vs low equity ratios. The idea is that the sensitivity of investment to cash flow should be much smaller (or non-existent) for large banks who likely have no trouble accessing external funds, and should be higher for banks who have low equity and so are more likely to have difficulty raising external funds even deposits if it will raise leverage\(^\text{32}\).

I record results in Table 6. Column’s (1) and (2) in Panel A contain results for large banks with low vs high equity ratios respectively and columns (3) and (4) contain results for small banks with low vs high equity ratios respectively. These results show that if anything, the sensitivity of non-interest expenses is significantly higher for large banks, and the magnitude of the relationship is not significantly different for banks with low vs high equity ratios.

Panel B contains results following Baker Stein and Wurgler [2003], to test whether or not the relationship between Tobin’s Q and investment is a function of financing constraints. Results in Panel B also show that there seems to be no relationship between financing con-

\(^{32}\)I note that my implicit assumption here is that as pointed out in Kaplan and Zingales [1997] that the magnitude of sensitivity is increasing in the degree of financing constraints.
straints and the sensitivity of non-interest expenses to net-interest income. The relationship
between Q and investment is both economically and statistically insignificant for all banks
and unrelated to plausible measures of financing constraints.

These results indicate that the observed positive relationship between net-interest income
and non-interest expenses is unlikely to be a result of investment sensitivity to cash flows
due to imperfect substitutability between internal and external funds.

6.3 Income Targeting

Pennacchi and Santos [2019] do a thorough analysis of bank annual reports and find that
from the 1970’s onwards, ROE is the most common accounting metric for the compensation
contracts of bank managers\textsuperscript{33}. Stock market investors also appear to differentiate between
banks and non-financial firms and respond more to the metric by which managers are comp-
pensated: the market-to-book values of banks stocks react more to ROE announcements
than EPS announcements while the reverse occurs for non-financial firms\textsuperscript{34}.

Furthermore, Stein [1989] shows that if bank earnings enter the utility function of man-
gers\textsuperscript{35}, and true earnings are unobservable, then it is rational (but inefficient) to “borrow”
earnings from the future by cutting expenses or investment today to prop up earnings.

Hence given that first ROE enters the bank managers utility function, and second the real
world is one of imperfect information, it is plausible that managers borrow earnings from the
future by cutting investment today to push earnings above the target set in compensation
contracts. Income targeting might then explain the relationship between net-interest income
and non-interest expenses: for example when net-interest income declines, say after an interest
rate change, if managers are targeting a particular level of ROE, they might cut expenses
in order to increase total earnings and meet the target. If so, this could explain the positive

\textsuperscript{33}Figure A.4 contains an example of a compensation contract explicitly stating ROE targets for Regions
Financial in 2015.

\textsuperscript{34}Similarly, Begenau and Stafford [2018] find that investors reward banks with high ROE, regardless of
how it is obtained i.e. mechanically through high leverage.

\textsuperscript{35}I propose similar to the set-up in Stein [1989] that bank earnings enter the utility function of managers
through an explicit ROE target in compensation contracts - see Figure A.4 for a real world example.
relationship between net-interest income and non-interest expenses, and more specifically the positive relationship between the sensitivity of net-interest income and non-interest expense to rate changes.

I explore this mechanism by making use of the asymmetric response to changes in expenses that it predicts: if bank managers are trying to get “above the bar” then I would expect more aggressive expense cutting when net-interest income declines than spending increases when net-interest income increases

This is indeed what I find. Figure 9 shows that after a NIM decline, ROA does not decline, but after a NIM increase ROA increases: in other words, NIM changes are passed through to net-income on the upside on average. The asymmetric ROA responses to NIM changes are driven by differences in non-interest expense responses to NIM changes. After a NIM decline, non-interest expenses are immediately cut - not one-for one though, so there is an immediate small decline in ROA. However non-interest expenses are then held lower over the following quarters so that the initial drop in ROA reverses and overall there is no impact on ROA. On the other hand, when NIM increases, non-interest expenses immediately increase - not one-for one however, so that there is some pass through of the NIM increase to ROA. Non-interest expenses then decline back to their pre-NIM change levels, such that the ROA increase remains “permanent” over the next quarters. I find the exact same relationships with ROE - just scaled by a factor of 10. I report results for ROA since both NIE and ROA have the same denominator and are hence comparable.

If managers are indeed motivated to cut expenses in order to prop up earnings to meet performance targets, then expense cutting would be more likely the closer the NIM decline is to the fiscal year end when executive compensation is determined. I find that this is the case. Figure 10 plots the probability that non-interest expenses are cut following a decline

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36 Note a similar asymmetric response could be modelled with a manager utility function with a kink where the disutility of not making the earnings target (and receiving nothing) is a lot larger than the utility of beating the target by the same amount.

37 Cumulative ROA change hovers around 0 after the first quarter.

38 Cumulative ROA change hovers around 0.3 after the first quarter indicating around a 30% pass-through of NIM to ROA on the upside

39 I do not find that declines in NIM are particularly persistent - if anything I find a decrease in NIM is unlikely to be followed by a decrease in NIM in the following quarter.
in NIM for each quarter relative to the quarter in which the fiscal year end lies. Panel (a) shows that banks are more likely to cut expenses after a NIM decline the closer to fiscal year end. Panel (c) shows that similarly banks are significantly more likely to increases leverage, which has the mechanical effect of increasing ROE, the closer to fiscal year end. However Panel (b) and (d) do not document similar effects after NIM increases. If the entire positive relationship between NIM and NIE is a result of investment sensitivity to cash flows or profitability, it is suspicious that the intensity of the relationship is a function of proximity to the fiscal year end. I leave causal identification of income targeting for future work.

7 Conclusion

In this paper, I present two new facts. First, I show that there is significant heterogeneity in the sensitivity of bank net-interest income to interest rate changes. While the median bank matches interest income and interest expenses well, I show that the majority of banks have large positive or negative NIM sensitivity to rate changes. One quarter NIM declines by as much as 30bp or increase by as much as 40bp after a 100bp increase in rates, and this effect grows to around $-60bp$ to $+85bps$ before stabilizing after 4 quarters. At 10:1 leverage these sensitivities are meaningful.

Second I show that net-interest income changes are offset by non-interest expenses changes: when net-interest income declines, for example after a rate change, banks cut non-interest expenses such that overall profitability remains flat. These findings are particularly relevant in the current low interest rate environment and have implications for understanding to what extent cutting rates beyond a “reversal rate” would impact bank profits and hence monetary policy transmission through a net worth channel, in the cross section.

I explore four mechanisms that could plausibly explain the relationship between net-interest income and non-interest expense.

First, I document evidence of a mechanical relationship between net-interest income and

\footnote{Similarly the average size of the NIE decline and the average size of the leverage increase monotonically increases the closer to fiscal year end}
non-interest expense in levels: banks with more low interest bearing transactions deposit accounts that require larger non-interest expenses to run, have higher net-interest income and also higher non-interest expense. However after accounting for possible mechanical relationships I still find a positive relationship between net-interest income and non-interest expenses.

Next I show that net-interest income is positively related to Tobin’s Q and hence the positive relationship between net-interest income and non-interest expenses could be a function of the fact that banks scale up operations when profitability is high and invest more in human capital and the deposit franchise, and similarly scale down operations when profitability is low. I also find that the market rewards banks that cut non-interest expenses after net-interest income declines relative to banks that don’t indicating that investors perceive this expense adjustment to be efficient. However an adjustment of investment to high frequency changes in profitability seems implausible.

I find that after controlling for NIM, a proxy for bank cash flow, NIM dwarfs Q as a determinant of investment. However I reject that cash flow determines investment as a result of imperfect access to external funds. Large banks, who are very unlikely to have difficulty accessing outside funds, have higher sensitivity of non-interest expense to net-interest income, and the sensitivity of investment to Tobin’s Q does not vary with standard measures of financial constraints.

Finally I document that banks will reduce expenses after a net-interest income decline and hold them low until return on assets “bounces back”, but expense increases are not held high after net-interest income increases: the result is that net-interest income changes are passed through to earnings on the upside but not the downside. Furthermore, I find that the likelihood and magnitude of expense cuts or leverage increases after a net-interest income decline are increasingly higher the close to fiscal year end. These findings are consistent with managers “borrowing” earnings from the future in order to meet earnings targets today. It is particularly hard to square the leverage increases close to fiscal year end after NIM declines with bank adjustment to cash flow or profitability changes.
These results collectively indicate that accounting for bank heterogeneity is necessary in order to understand the aggregate effects of monetary policy transmission through the net worth channel. Furthermore, adjustments to non-interest expenses seems to mute the impact of rate changes on profits, net worth and subsequently lending. Finally, while bank investment sensitivity to expected profitability might explain some of the positive relationship between net-interest income and non-interest expenses, it is suspicious that the intensity of the relationship is a function of the proximity in timing of the net-interest income change and the banks fiscal year end.

My findings suggest that expense adjustments might provide a natural hedge to interest rate changes, but that also bank managers might perhaps inefficiently make adjustments to meet earnings targets, with the consequence that bank profit sensitivity to rate changes is reduced.
References


Figure 1: Aggregate ROA and the Fed Funds Rate
Figure 2: Average $\beta_{NIM}$ per $\beta_{NIM}$ decile
Figure 3: Average $\beta_{\text{IntInc}}$ and $\beta_{\text{IntExp}}$ per $\beta_{\text{NIM}}$ decile.
Figure 4: Balance sheet characteristics scaled relative to yearly average plotted by $\beta_{NIM}$ decile.
Figure 5: A bin scatter plot showing average ROA betas per $\beta_{NIM}$ percentile bucket, including fitted lines.
Figure 6: A bin scatter plot showing average $\beta_{NIE}$ per $\beta_{NIM}$ percentile bucket, including a fitted line.
Figure 7: Average $\beta_{FOMC}$ per $\beta_{NIM}$ decile.
Figure 8: Cumulative stock returns for -30 days to +30 days after NIM change, scaled to 1 at day 0
Figure 9: Cumulative $\beta^h_{i,t}$ plotted for $h \in [0, 6]$ from the following regression:

$$\Delta NIE_{i+h-1}^{t+1} = \alpha_i + \beta^h_{i,t} \Delta NIM_{i,t} + \psi_t + \epsilon_{i,t}$$
Figure 10: Likelihood of NIE cuts and leverage increases by quarter relative to fiscal year end
Table 1: Average NIM and ROA Sensitivity to the Short Rate

\[ \Delta Y_{i,t} = \alpha_i + \sum_{\tau=0}^{h} \beta_{i,\tau} \Delta FF_{t-\tau} + \sum_{\tau=0}^{h} \gamma_{i,\tau} \Delta Slope_{t-\tau} + \psi_t + \epsilon_{i,t}, \]  
\[ \Delta Y_{i,t} \in \{ \Delta NIM_{i,t}, \Delta ROA_{i,t} \}, \ h \in [0, 3] \]

This table contains results of bank/quarter regressions in first differences. The dependent variable is either the first difference of net interest margin (NIM) or return on assets (ROA). Net interest margin is defined as interest income minus interest expense divided by total assets. Return on assets is defined as net income divided by total assets. NIM and ROA are regressed on the first difference of the Federal Funds rate (FF), and various lags noted by column. The independent variables also include the same number of lags of the slope of the term structure, and bank/year fixed effects. Standard errors are clustered by year.

<table>
<thead>
<tr>
<th></th>
<th>( \Delta ) NIM</th>
<th></th>
<th>( \Delta ) ROA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 lag</td>
<td>1 lag</td>
<td>2 lags</td>
</tr>
<tr>
<td>( \Sigma \beta ) FF</td>
<td>-0.00311</td>
<td>0.0267***</td>
<td>0.0318***</td>
</tr>
<tr>
<td></td>
<td>(0.0048)</td>
<td>(0.0073)</td>
<td>(0.0113)</td>
</tr>
<tr>
<td>Observations</td>
<td>0.1628</td>
<td>0.1689</td>
<td>0.1765</td>
</tr>
<tr>
<td>R-squared</td>
<td>400.316</td>
<td>398.962</td>
<td>396.923</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
Table 2: Documenting a Mechanical Relationship Between Net-Interest Income and Non-Interest Expense

This table contains average bank characteristics for banks sorted into NIM quintiles. Banks are first sorted into NIM (levels) quintiles, and average characteristics are recorded for NII (non-interest income/total assets), NIE (non-interest expense/total assets), ROA (net-income/total assets) and ROE (net-income/book equity). NIM, NII, NIE and ROE betas as defined in section 4 are also reported. Finally, non-interest bearing deposits/total assets and total loans/total assets are reported in the final two rows.

<table>
<thead>
<tr>
<th>NIM Quintile</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIM</td>
<td>3.0%</td>
<td>3.6%</td>
<td>3.8%</td>
<td>4.1%</td>
<td>4.8%</td>
</tr>
<tr>
<td>NII</td>
<td>1.2%</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.1%</td>
<td>1.3%</td>
</tr>
<tr>
<td>NIE</td>
<td>3.0%</td>
<td>3.1%</td>
<td>3.2%</td>
<td>3.4%</td>
<td>4.0%</td>
</tr>
<tr>
<td>ROA</td>
<td>0.6%</td>
<td>0.8%</td>
<td>0.9%</td>
<td>1.0%</td>
<td>1.1%</td>
</tr>
<tr>
<td>ROE</td>
<td>7.1%</td>
<td>10.1%</td>
<td>10.9%</td>
<td>12.2%</td>
<td>12.7%</td>
</tr>
<tr>
<td>$\beta_{NIM}$</td>
<td>0.05</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>$\beta_{NII}$</td>
<td>(0.07)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>$\beta_{NIE}$</td>
<td>(0.02)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\beta_{ROA}$</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>0.00</td>
<td>(0.04)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Non-Interest Bearing Deposits/Assets</td>
<td>10.3%</td>
<td>11.6%</td>
<td>12.3%</td>
<td>14.3%</td>
<td>16.6%</td>
</tr>
<tr>
<td>Loans/Assets</td>
<td>59.2%</td>
<td>62.5%</td>
<td>63.2%</td>
<td>63.5%</td>
<td>65.6%</td>
</tr>
</tbody>
</table>
Table 3: The Relationship between Net-Interest Income and Non-Interest Expense Controlling for Balance Sheet Composition Changes

\[ \Delta NIE_{i,t} = \alpha_i + \beta_i \Delta NIM_t + \psi_i \Delta NonIntDep/Assets_t + \phi_i \Delta Loans/Assets_t + \gamma_t + \epsilon_{i,t} \]

This table contains results of bank/quarter regressions in first differences. The dependent variable is the first difference of no-interest expenses divided by lagged total assets (NIE). In column (1) NIE is regressed on the first differences of NIM, which is the net-interest margin defined as interest income minus interest expenses all divided by total assets. In Column (2) the first difference non-interest bearing deposits divided by lagged total assets, and the first difference of loans divided by lagged total assets are added as controls. Columns (3) and (4) mirror columns (1) and (2) except that in the first stage, the first difference of NIM is regressed on the first difference of the Fed Funds rate and the slope of the yield curve, up to and including three lags. In the second stage, predicted NIM is used as the independent variable. Bank/year fixed effects are included and standard errors are clustered by year.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>( \Delta NIE_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>( \Delta NIM_t )</td>
<td>0.573***</td>
</tr>
<tr>
<td></td>
<td>(0.0498)</td>
</tr>
<tr>
<td>( \Delta \text{Non-Interest Bearing Deposits} / \text{Assets}_t )</td>
<td>0.0359***</td>
</tr>
<tr>
<td></td>
<td>(0.00510)</td>
</tr>
<tr>
<td>( \Delta Loans/Assets_t )</td>
<td>-0.00978***</td>
</tr>
<tr>
<td></td>
<td>(0.00144)</td>
</tr>
</tbody>
</table>

Observations: 400,627 400,573 382,058 382,039
R-squared: 0.217 0.223 382,058 382,039
Number of id: 11,034 11,034

*** p<0.01, ** p<0.05, * p<0.1
Table 4: The Relationship Between Tobin’s Q and Net-Interest Margins

\[ Q_{i,t} = \alpha_i + \beta_{i,t}NIM_t + \gamma_t + \epsilon_{i,t} \]

This table contains results of bank/quarter regressions. The dependent variable is Tobins Q, defined as book value of assets minus the book value of equity minus deferred taxes plus the market value of common stocks all divided by the book value of assets. NIM is the net-interest margin defined as interest income minus interest expenses all divided by total assets. In column (1) Tobin’s Q is regressed on NIM. In column (2) in the first stage, NIM is regressed the Fed Funds rate and the slope of the yield curve, up to and including three lags. In the second stage, predicted NIM is used as the independent variable. Bank and year fixed effects are included and standard errors are clustered by year.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>( Q_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( NIM_t )</td>
<td>1.295***</td>
</tr>
<tr>
<td></td>
<td>(0.166)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>47,414</td>
<td>44,878</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.713</td>
<td></td>
</tr>
<tr>
<td>Number of id</td>
<td></td>
<td>1,272</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
Table 5: A Horse Race Between Tobin’s Q and Net-Interest Margin

\[ I_{i,t} = \alpha_i + \beta_{i,t}NIM_t + \gamma_{i,t}Q_{t-1} + \psi_t + \epsilon_{i,t} \]

This table contains results of bank/quarter regressions. The dependent variable, I, is defined as the first difference of non-interest expenses all divided by total assets. In columns (1)-(3) I is regressed on NIM, and lagged Tobin’s Q, with year fixed effects, bank fixed effects and bank and year fixed effects respectively. In column (4) NIM is regressed on the Fed Funds rate and the slope of the yield curve, up to and including three lags. Next predicted NIM is used as the independent variable as well as lagged Tobin’s Q. NIM is the net-interest margin defined as interest income minus interest expenses all divided by total assets. Tobin’s Q is defined as book value of assets minus the book value of equity minus deferred taxes plus the market value of common stocks all divided by the book value of assets. Bank and year fixed effects are included and standard errors are clustered by year.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>( I_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>( NIM_t )</td>
<td>0.112***</td>
</tr>
<tr>
<td></td>
<td>(0.0170)</td>
</tr>
<tr>
<td>( Q_{t-1} )</td>
<td>0.00343**</td>
</tr>
<tr>
<td></td>
<td>(0.00128)</td>
</tr>
<tr>
<td>Bank Fixed Effects</td>
<td>No</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>46,871</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.025</td>
</tr>
<tr>
<td>Number of id</td>
<td></td>
</tr>
</tbody>
</table>
This table contains results of bank/quarter regressions. In both panel A and B, the dependent variable is bank investment defined as the first difference of non-interest expenses all divided by total assets. In both panels, columns (1) and (2) contain results for large banks with high vs low equity ratios respectively, and columns (3) and (4) contain results for small banks with high vs low equity respectively. Large banks are banks with total assets are greater than the 90th percentile in any given year and small banks are banks with total assets are smaller than the 90th percentile in any given year. Within each size grouping, high equity banks are banks with an equity ratio greater than the 50th percentile in any given year and low equity banks are banks with equity ratios smaller than the 50th percentile in any given year. Panel A contains results for public and private banks, Panel B contains results for only public banks. Bank and year fixed effects are included and standard errors are clustered by year.

### Panel A

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>( I_t )</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( NIM_t )</td>
<td></td>
<td>0.392***</td>
<td>0.352***</td>
<td>0.136***</td>
<td>0.108***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0419)</td>
<td>(0.0340)</td>
<td>(0.0136)</td>
<td>(0.0101)</td>
</tr>
<tr>
<td>Bank Fixed Effects</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td>20,329</td>
<td>20,565</td>
<td>169,681</td>
<td>199,991</td>
</tr>
<tr>
<td>R-squared</td>
<td></td>
<td>0.138</td>
<td>0.128</td>
<td>0.049</td>
<td>0.047</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1

### Panel B

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>( I_t )</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Q_t )</td>
<td></td>
<td>-0.00341</td>
<td>-0.00344</td>
<td>0.00497</td>
<td>0.000698</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0159)</td>
<td>(0.00548)</td>
<td>(0.00644)</td>
<td>(0.00245)</td>
</tr>
<tr>
<td>Bank Fixed Effects</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td>2,505</td>
<td>2,508</td>
<td>22,401</td>
<td>22,278</td>
</tr>
<tr>
<td>R-squared</td>
<td></td>
<td>0.033</td>
<td>0.037</td>
<td>0.037</td>
<td>0.053</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
Figure A.1: $\beta_{NIM}$ and $\beta_{NIE}$ for the 1st, 5th and 10th NIM $\beta$ deciles, plotted for 1, 2, 3 and 4 quarters ahead - not cumulative.
Figure A.2: Average Non-Interest Income (NII) Beta ($\beta_{NII}$) per $\beta_{NIM}$ decile
<table>
<thead>
<tr>
<th></th>
<th>Low Balance, Low Activity</th>
<th>Medium Balance, High Activity</th>
<th>High Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monthly Income/Expenses</td>
<td>Monthly Income/Expenses</td>
<td>Monthly Income/Expenses</td>
</tr>
<tr>
<td>Income</td>
<td>Activity</td>
<td>Activity</td>
<td>Activity</td>
</tr>
<tr>
<td>Interest income</td>
<td>$ 600</td>
<td>$ 83</td>
<td>$ 5,689</td>
</tr>
<tr>
<td>Investment income (average monthly estimate)</td>
<td>$ 2.00</td>
<td>$ 2.80</td>
<td>$ 3.80</td>
</tr>
<tr>
<td>Service charges</td>
<td>$ 0.55</td>
<td>$ 0.55</td>
<td>$ 0.55</td>
</tr>
<tr>
<td>Other</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
</tr>
<tr>
<td>Total revenue</td>
<td>$ 6.55</td>
<td>$ 8.35</td>
<td>$ 5.689</td>
</tr>
<tr>
<td>Expenses</td>
<td>Activity</td>
<td>Activity</td>
<td>Activity</td>
</tr>
<tr>
<td>Account charges</td>
<td>$ 0.01</td>
<td>$ 0.03</td>
<td>$ 0.02</td>
</tr>
<tr>
<td>Withdrawal—electronic</td>
<td>$ 0.94</td>
<td>$ 0.94</td>
<td>$ 0.94</td>
</tr>
<tr>
<td>Withdrawal—non-electronic</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
</tr>
<tr>
<td>Total non-check related</td>
<td>$ 0.94</td>
<td>$ 0.94</td>
<td>$ 0.94</td>
</tr>
<tr>
<td>Check-related fees</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
</tr>
<tr>
<td>Total activity expense</td>
<td>$ 0.94</td>
<td>$ 0.94</td>
<td>$ 0.94</td>
</tr>
<tr>
<td>Monthly expenses</td>
<td>Activity</td>
<td>Activity</td>
<td>Activity</td>
</tr>
<tr>
<td>Account management (transaction)</td>
<td>$ 2.42</td>
<td>$ 0.91</td>
<td>$ 0.91</td>
</tr>
<tr>
<td>Interest expense</td>
<td>$ 10.54</td>
<td>$ 11.54</td>
<td>$ 11.54</td>
</tr>
<tr>
<td>Net revenue per month</td>
<td>$ 2.75</td>
<td>$ 0.71</td>
<td>$ 0.71</td>
</tr>
<tr>
<td>Average percentage cost (net of service charges and fees)</td>
<td>$ 6.52%</td>
<td>$ 2.58%</td>
<td>$ 2.58%</td>
</tr>
<tr>
<td>Average net interest margin</td>
<td>$ 2.85%</td>
<td>$ 2.85%</td>
<td>$ 2.85%</td>
</tr>
<tr>
<td>Average non-interest income</td>
<td>$ 3.16%</td>
<td>$ 3.16%</td>
<td>$ 3.16%</td>
</tr>
<tr>
<td>Average account balance</td>
<td>$ 1,200</td>
<td>$ 5,190</td>
<td>$ 11,190</td>
</tr>
<tr>
<td>Fee-related reserves</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure A.3: Examples of non-interest expenses related to deposit accounts. Source: Bank Management, 6th Edition, Koch and MacDonald
The following data outlines the performance metrics and goals as well as the results achieved by the Committee on the executive performance for FY 21 at 10 percent of target.

<table>
<thead>
<tr>
<th>Name of Performance</th>
<th>FY 21 Performance</th>
<th>FY 22 Performance</th>
<th>FY 23 Performance</th>
<th>FY 24 Performance</th>
<th>FY 25 Performance</th>
<th>FY 26 Performance</th>
<th>FY 27 Performance</th>
<th>FY 28 Performance</th>
<th>FY 29 Performance</th>
<th>FY 30 Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Metric</td>
<td>FY 21 Result (%)</td>
<td>FY 22 Result (%)</td>
<td>FY 23 Result (%)</td>
<td>FY 24 Result (%)</td>
<td>FY 25 Result (%)</td>
<td>FY 26 Result (%)</td>
<td>FY 27 Result (%)</td>
<td>FY 28 Result (%)</td>
<td>FY 29 Result (%)</td>
<td>FY 30 Result (%)</td>
</tr>
<tr>
<td>Revenue Growth</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
</tr>
<tr>
<td>Earnings Per Share</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
<td>123%</td>
</tr>
</tbody>
</table>

Figure A.4: Regions Financial 2014 executive performance target example from 2015 DEF 14A Proxy Statement