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WILLIAM & MARY

Analyzing the Impact of Rapidly Rising Interest Rates on Banks' Metrics and Strategies

CSBS 2023 Annual Data Analytics Competition Final Report

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I. Executive Summary:

The 2023 Conference of State Bank Supervisors' (CSBS) Annual Data Analytics competition has tasked teams to analyze the potential impact of the recently rising interest rate environment on banks. While many may think rising interest rates simply mean a healthy economy and therefore a happy bank, the relationship between interest rates and bank health is much more complicated. To understand this relationship, we utilized artificial intelligence in the form of neural networks to devise a model for predicting bank performance based on other bank metrics, macroeconomic factors, and the Federal Funds rate. We expect that the rising interest rates will result in higher earnings for banks, with varying results dependent on external factors such as bank size and location.

II. Background Research:

A. *Economic Background*

In March 2022 the Federal Open Market Committee (FOMC) raised rates by 25 basis points to raise the Federal Funds rate from 0.00-0.25% to 0.25-0.50%. One year later in March 2023 the FOMC raised rates to 4.75-5.00%. The 2022-2023 rate hiking cycle is the fastest in decades, and may not be over yet. The Federal Reserve has increased the Federal Funds rate in an attempt to reduce decades-high inflation. The Federal Funds rate has major effects on the economy because it is used as a standard for other interest rates as well. Mortgage, car, and credit card rates have spiked along with the Federal Funds rate. The objective of tightening monetary policy is to slow an overheating economy. The Federal Reserve achieves this by increasing rates which results in less borrowing, less spending, and more saving, allowing inflation to come down to the target of 2%. While inflation is still well north of the Federal Reserve"s flexible average inflation target (FAIT) of 2%, there have been substantial improvements in the reduction of inflation. FAIT is the inflation-targeting framework the Federal began to follow in August of 2020,

attempting to hit 2% asymmetrically. The Federal Open Market Committee (FOMC) allows inflation to run slightly above the target without using monetary tools, but does not want inflation to run under the target (an issue when the Federal was stuck at the zero-lower bound).[1] This resulted in the Federal Reserve waiting too long to raise rates, mistakenly believing inflation to be transitory, which forced their hand to raise rates very swiftly. While the Federal Reserve attempts to cool off the economy, banks are affected in a major way. The rates banks lend at for various types of loans are influenced by the Federal Funds rate. Banks can earn a lot more interest income on loans, but face losses on bond portfolios they own. As rates rise, bond prices fall. Additionally, the impact of raising rates has both long and variable lags on the economy that cannot be precisely predicted.[2] The near economic future is very uncertain.

Although the Federal Funds rate is not perfect to use as a measure for all interest rates, it is the best option available. Despite deep and unusual yield curve inversions recently,[3] the Federal Funds rate is the best way to measure the cost of borrowing due to its impact on consumer loans, including mortgages and auto loans. The Federal Funds rate is the best measure of monetary tightening in the economy. Interest rate risk is just one risk banks may face. Other risks are impacted by interest rates and the overall economic cycle, like the increase in credit risk as interest rates increase and tighten financial conditions.[4] However, we will focus on the overall impact of higher interest rates on banks earnings.

While interest rates have been low for most of the past two decades banks and regulators alike have been less concerned with interest rate risk. In recent years, the annual stress tests implemented after Dodd-Frank have not included any scenarios with drastic rate increases.[5] This is a misstep likely to be addressed in the

[1] Horan and Beckworth (2022)
[2] Friedman (1961)
[3] U.S. Department of the Treasury (2023)
[4] Carling, Jacobson, Linde, Roszbach (2007)
[5] Honohan (2023)

investigations of the Silicon Valley Bank (SVB) failure by regulators. SVB's Treasury portfolios had billions of unrealized losses, and resulted in an FDIC takeover and complete insurance of all deposits. Capital requirements, which only apply to the largest banks, have increased over the past several years due to Basel III, as well as domestic institutions like the Federal Reserve and federal banking agencies. As a result, the larger banks have been better prepared for drastic rate increases and have seen influxes of deposits in the first quarter of 2023 due to the failures of SVB and Signature Bank, and the struggles of other smaller, regional banks. First Republic received a $30 billion deposit package from JP Morgan et al.[6] Consumers and businesses, distressed by the risk of holding their money at smaller banks, started a bank run at SVB, and frightened other smaller banks, reallocating their cash to the largest banks. The speed of the bank run of SVB was unprecedented, and largely due to social media.

B. *Literature Overview*

The conventional view is that as interest rates rise, banks' profitability increases. This is due to higher Net Interest Margin (NIM), the difference between the rate banks borrow from depositors and lend to consumers.[7] However, there is also evidence that banks are able to maintain profitability in low rate periods by increasing fees on advisory services, trading, or lowering loan provisions.[8] Loan provisions, also known as loan loss reserves, are funds set aside by banks to cover potential losses, and are reported as expenses thus decreasing net income. At low interest rates, there is a zero-lower-bound, banks cannot make depositors pay to keep their money, and the Federal Reserve has refused to reduce rates below zero unlike the European Union, so when rates are at zero, NIM and profits are squeezed. The contrarian argument is that although in the short run higher interest rates result in higher NIM and earnings, higher interest rates reduce economic

[6] Copeland, Hirsch, Rappeport, and Farrell (2023)
[7] Demirguc-Kunt and Huizinga (1999)
[8] Bikker (2018).

output and employment, slowing the economy. This may balance out with the higher NIM and earnings during the higher rates and in the long run not increase banks profitability.[9]

There is no consensus on the impact of bank size on profitability. Some argue bigger banks are more inefficient, but in 2023 the biggest banks have proven to be the safest. While some find evidence that larger banks are more profitable,[10] others argue bank size negatively impacts profitability because larger banks are more complex.[11] Others find that size has an insignificant effect on profitability.[12]

The conventional thinking is that higher interest rates result in higher credit risk and thus lower asset quality for banks.[13] Higher interest rates result in higher default and delinquency rates. There is some evidence that low-rate environments may result in banks lowering lending standards and taking on more risk because they are earning less on their loans. This incentive problem when rates are low is referred to as a "reach for yield".[14] Although rising rates result in more credit risk, this may be somewhat offset by less risk-taking and more prudent due diligence on borrowers when rates increase.[15]

Liquidity crises are one of the largest issues facing banks today. Bank liquidity is the ability of a bank to meet its short-term commitments. In the case of SVB, a bank run depleted SVB's deposits. This would have forced SVB to sell their underwater Treasury bonds and turn unrealized losses to realized losses if the FDIC did not step in. The liquidity of financial markets is the ability of a market to trade smoothly without large and sudden price movements. Although bank liquidity and market liquidity are separate, the financial system is so interconnected that when one bank has a liquidity crunch market, contagion is likely. The Federal Reserve has

[9] Defusco and Paciorek (2014).
[10] Borio, Gambacorta, and Hofmann (2015)
[11] ECB (2015)
[12] Athanasoglou, Brissimis, and Delis (2008)
[13] Financial Express (2011)
[14] Williamson (2018)
[15] Maddaloni and peydro (2011)

numerous liquidity facilities, the first being the discount window. The discount window is a facility that offers overnight repos (loans) to banks that are unable to borrow from other banks in the Federal Funds markets.[16] During liquidity crunches, the Federal Reserve, as the lender of last resort, has had to step in to save money market funds and banks because of a lack of cash in the system and lack of repo counterparties. While money market funds can be considered shadow banks they are a fundamental part of the financial system that the Federal Reserve cannot let fail. The cheapest way to borrow is interbank, but when there are no options, the Federal Reserve steps in to save the market. The Federal Reserve has continued to come up with more innovative and advanced liquidity facilities. In 2019 the Federal Reserve expanded its repo facility to banks and money market funds. In March of 2020 the Federal Reserve implemented the Money Market Mutual Fund Liquidity Facility (MMLF) which lent to banks against collateral they purchased from prime MMFs.[17] In July of 2021 the Federal Reserve implemented a standing repo facility (SRF). This liquidity facility acts as a backstop in money markets. The Federal Reserve offers overnight repos every day, at the upper limit of the Federal Funds rate. This allows banks to conduct repos with other banks cheaply, but allows a safety net for banks that need to find repo counterparties within the Federal Funds rate.[18] After the SVB fallout, the Federal Reserve rolled out the Bank Term Funding Program (BTFP), which is essentially an extension from the discount window. Banks can value Treasuries and Agency MBS at par value instead of fair market value, and have no haircut when borrowing against these securities.[19] While market value is considered irrelevant if banks hold to maturity, this is not true if a bank has to use market based funding: BTFP, discount window, standing repo facility.

[16] Flannery (1996)
[17] Milstein and Wessel (2022)
[18] Tizzi (2023)
[19] Kelly (2023)

The prevailing thought that has been supported during recent crises is that banks are not willing to expand their lending during financial crises due to asymmetric information and a high uncertainty.[20]

When interest rates increase, bond prices decrease, hurting banks' portfolios. Losses on investments, even if not realized, can hurt a bank's capital position. When banks borrow against investments with realized losses they suffer. Additionally, held to maturity losses result in lower tangible common equity, which may make it harder for banks to find funding.[21]

III. Data Sources:

A. *FDIC Call Reports*

To gather important bank statistics to compare over time with Federal Funds rates, we gathered Call Reports from the Federal Deposit Insurance Corporation. These Call Reports (Consolidated Reports of Income) are quarterly reports that banks are required to submit to the FDIC. This data gave us insight not only into how interest rates affected bank metrics, but also how banks responded to different interest rate environments. The dataset had an abundance of information for each bank, leading us to narrow our efforts to a select few variables. We also used the Federal Reserve's Micro Data Reference Manual as a data dictionary for the variable codes in this dataset. This was by far our biggest dataset and was a challenge to clean and analyze due to its sheer size. The FDIC Call Reports were necessary in developing the crucial components of our analysis.

B. *FDIC Annual Historical Bank Data*

The FDIC's annual historical bank data proved to be beneficial in showing how the creation of new banks correlates with the Federal Funds rate. The dataset provides the number of banks, bank branches, and new charters by year, allowing us to compare these numbers to the Federal Funds rate over time. This information

[20] Berger, Bouwman, Kick, and Schaeck (2016)
[21] White (2023)

on the creation of banks is essential for understanding the landscape of small banks.

C. *Macroeconomic Data*

Macroeconomic data was gathered to account for major changes in the U.S. economy when predicting bank metrics. Gross Domestic Product and consumer price index data were gathered from the Federal Reserve Bank of St. Louis. We used Dow Jones' historical price data from Investing.com. Finally, our inflation rate data came from the U.S. Bureau of Labor Statistics.

D. *FDIC Bank Failures*

We used bank failure data collected by the FDIC in conjunction with the FDIC's Call Reports to gain a better understanding of what strategies or conditions may lead to the failure of a bank. This dataset also provided insight into the losses from bank failures and which types of banks were responsible for those losses.

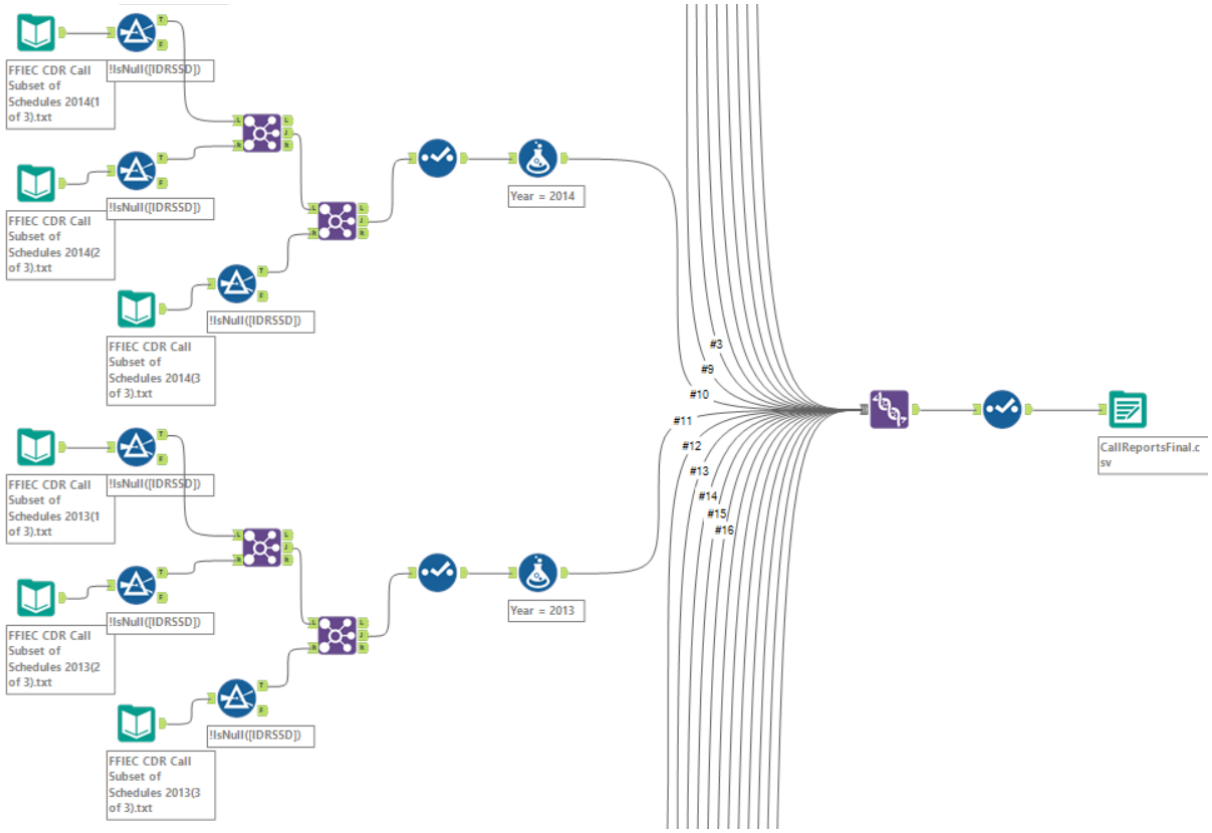
IV. Data Collection and Management:

Before being used for our analysis, each data source required cleaning in order to derive valuable insights.

A. *Alteryx Workflow*

We used Alteryx to efficiently process the FDIC Call Reports. The main problem with extracting the Call Report data from the FDIC website was that there is no way to download all of the Call Report data available for all banks for all years. At most, the FDIC allows users to download Call Report data one year at a time. We combined all of these datasets into one using Alteryx. Each year of data had several files that were combined using joins. All years of data were then combined into one file using a union. A year column was also added to track the year each row of data was from.

Figure #1: Alteryx Workflow



* File 1

Each cluster of operations on the left side of this workflow is one year of data. This figure is a small portion of the total workflow because there were over 20 years of data. However, each cluster of operations is identical for each year. Additional data cleaning was done in R for miscellaneous tasks such as combining Call Reports with bank failure data, removing columns with too much missing data, adding features, and imputing data.

B. *Variable Selection*

After creating this massive dataset of over 600,000 rows and more than 600 columns, we knew we had to narrow down our variables to efficiently create a model. We found that many columns were missing significant amounts of data, so we removed all columns missing more than 20% data. This brought our variable

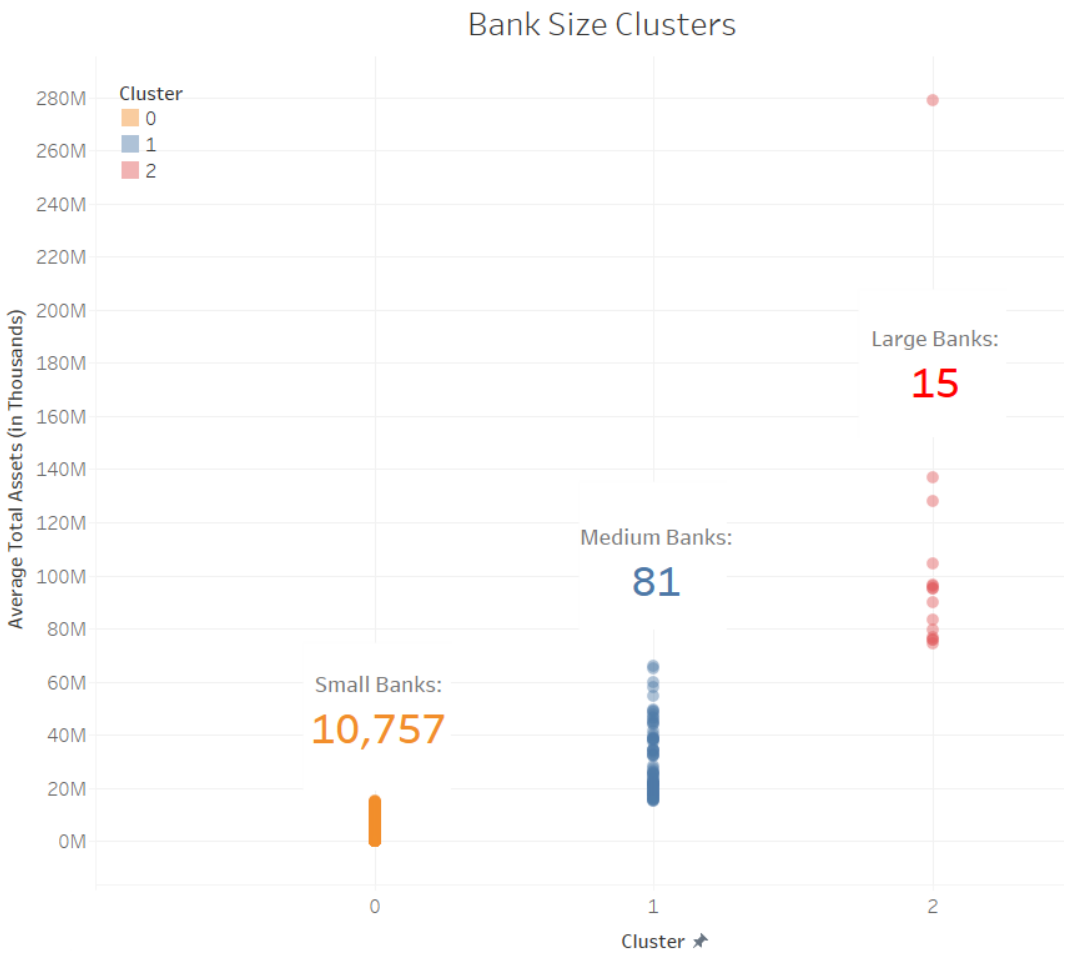
count down to nearly 100. From there, we hand selected those that we felt would be best for predicting our target metrics, while also enabling us to feature engineer more variables if needed.

C. *Feature Engineering*

Before creating our model, we knew we wanted to add features in addition to those available in the FFIEC's Call Reports. First, we wrangled data we thought would be beneficial in describing the relationship between bank metrics and macroeconomic conditions. This data included Gross Domestic Product, consumer price index, inflation rate, and the Dow Jones price. Additional changes were made such as converting the GDP to a year-over-year percentage change in GDP to better represent the rate of change of U.S. economic activity. Furthermore, we added columns to represent liquidity and asset quality to see how they affected earnings as well. The liquidity is represented by the Loans to Deposits ratio as it indicates the extent to which banks have funds available to meet its obligations so a higher ratio would indicate more liquidity. The asset quality is represented by the Allowance for Loan and Lease Losses to Total Loans ratio as it reflects the quality of banks' loan portfolio and ability to absorb losses.

Another factor we wanted to incorporate into our model was the size of the bank. Because each bank will have a different strategy depending on their size, it's no surprise that each size bank will be impacted differently by periods of rapidly rising interest rates. For this reason, we created a feature representing each size bank. This was done by producing a k-means model that clustered each bank based on its average total assets from 2002 to 2023.

Figure #2: Banks Clustered by Size



* File 4 (Derived from File 3)

The mass majority of banks are considered small banks. Once a bank's total assets reach around $20 million it is considered a medium sized bank. Banks are considered large when they reach around $75 million in total assets. This cluster feature will be used in our model to account for the different strategies implemented by banks depending on their size.

V. Data Dictionary:

Variable	Description
Date	Date on which bank submitted Call Report
IDRSSD	Unique identifier for each bank assigned by Federal Reserve System
Name	Name of bank
Address	Street address of bank
City	City the bank is located in
State	State the bank is located in
Zip	Zip Code the bank is located in
RCON2170	Total assets (in thousands)
RCON2200	Total deposits (in thousands)
RCON2948	Total liabilities and minority interest (in thousands)
RCON3230	Common stock (in thousands)
RCON3545	Trading assets, total (in thousands)
RCON3548	Trading liabilities, total (in thousands)
RIAD4340	Net income (loss) (in thousands)
LoanToDeposit	Total loans to total deposit ratio
AllowanceToTotalLoans	Allowance for loan and lease losses to total loan ratio
GDP	Average Gross Domestic Product during that quarter
GDP_Pct_Change	Percentage change in Gross Domestic Product from the previous quarter
Inflation_Rate	Average inflation rate during that quarter
CPI	Average Consumer Price Index during that quarter
DJ_Price	Average Dow Jones price during that quarter
FEDFUNDS	Federal Funds rate

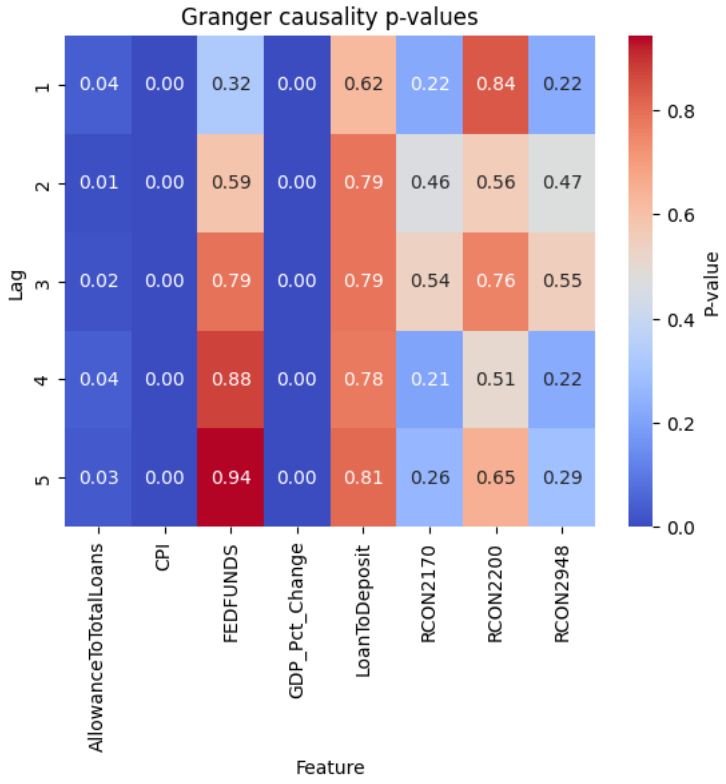
* File 5

VI. Exploratory Data Analysis:

A. *Granger Causality*

Before using the Federal Funds rate to make predictions on significant bank metrics, we want to ensure there is a causal relationship between them by conducting a Granger Causality test.

Figure #3: Granger Causality



* Derived from File 6

On the surface level, the result gives a quite counterintuitive outlook to our dataset. The test suggests that GDP percentage change, Consumer Price Index, and asset quality have a causal relationship with bank earnings over five lagged periods, while indicators such as interest rate, liquidity, total liabilities do not.

It is essential to understand the limitations and assumptions of a Granger Causality test. It checks specifically for whether the past values of one variable can help predict the future value of another variable. A non-significant value of interest rate simply indicates that the past values of the variable do not help in predicting the future values of earnings.

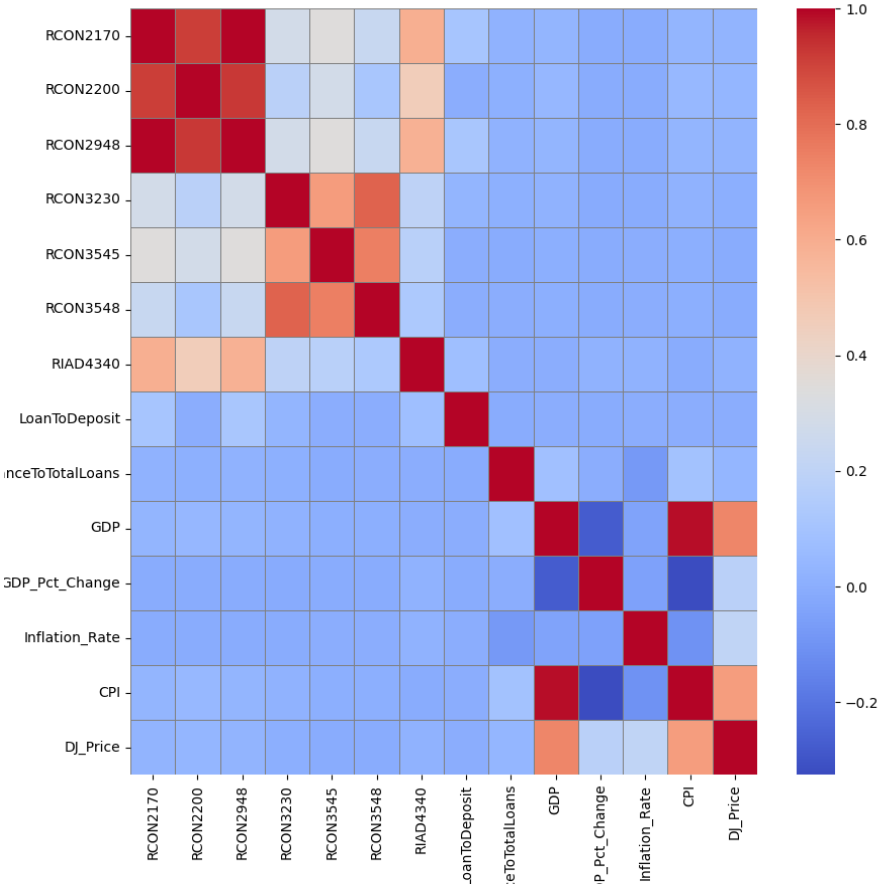
There could be several reasons why the Granger causality test misses capturing the relationship between interest rate and net income. First, the test is only able to detect linear-relationship between variables. If the relationship

between these variables is non-linear, then the test loses its predictive power. This reasoning is another motivation for us to use a RNN model that captures the nuances of non-linear relationships later in our model-building process. Furthermore, if the effect of interest rate is mediated or confounded by other variables that are not present in the model, the causality test may also fail to detect the true relationship.

B. *Correlation Heatmap*

After deciding on which variables to use for our models, we investigated how they interacted with each other by constructing a heatmap of their correlation values.

Figure #4: Variable Correlation Heatmap



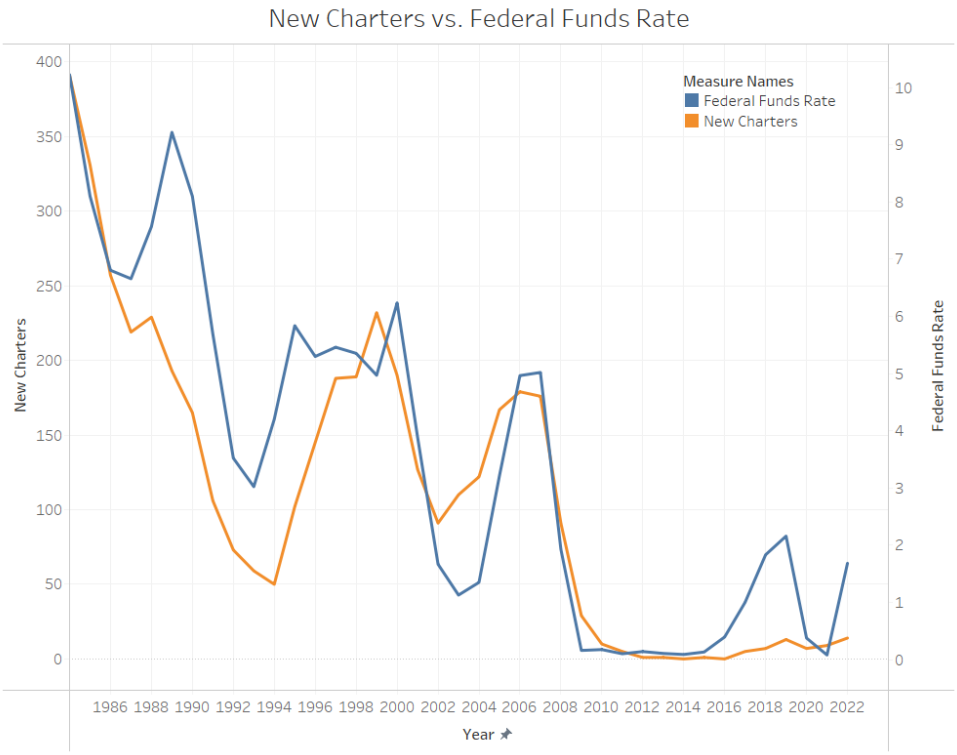
* Derived from File 7

According to the heatmap, total assets, total deposits, and total liabilities are all highly correlated. This correlation follows common logic. We expect that a bank will have more assets if they have more deposits. Additionally, a bank's liabilities increase as their deposits increase because deposits are one of several components included in liabilities. Furthermore, the consumer price index, Dow Jones price, and GDP are all highly correlated. To avoid redundancy, we will choose just one of these three variables for our model. RNN models do not require the features to be independent of one another. However, it is important to note these correlations if these variables are assigned high weights after producing the models.

C. *De Novo Banks*

De novo banks are newly established banks that have no assets or liabilities and must undergo a regulatory approval process to perform banking services. These typically small banks tend to appear in places with a need for additional banking services and are essential in encouraging innovation and competition in the banking industry. Rising interest rates tend to attract the creation of de novo banks for a number of reasons, one of which being the potential for an increased Net Interest Margin. Furthermore, low or falling interest rates are unattractive for de novo bank prospects as they may decrease the Net Interest Margin and could cause lower returns on their investments. For these reasons, it's no surprise that the number of new charters is highly correlated with the Federal Funds rate.

Figure #5: New Charters vs. Federal Funds Rate



* File 8

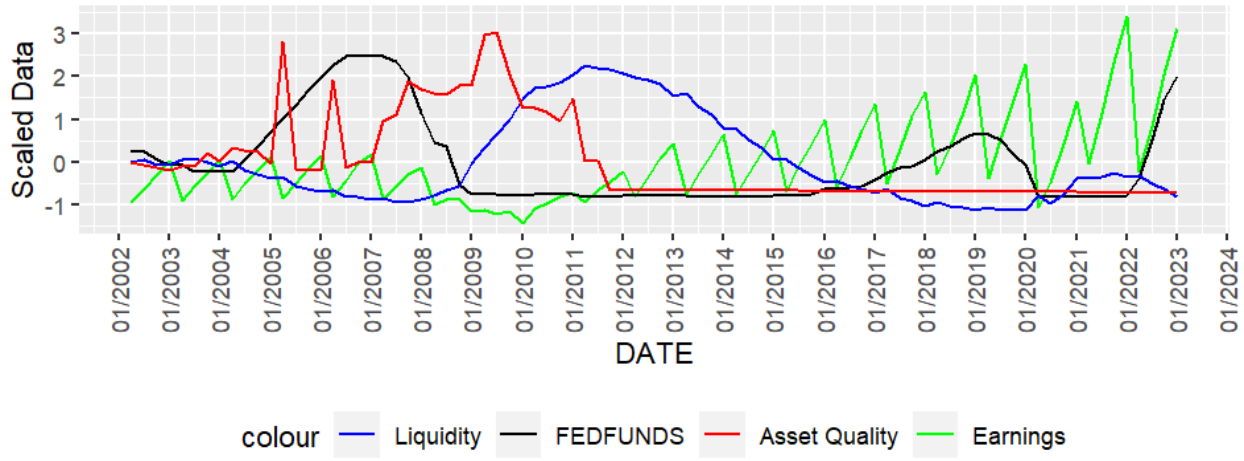
Based on this exploratory analysis, we would expect to see an increase in the number of de novo banks during periods of rising interest rates. Few de novo banks have been established since 2008, in part due to increased regulations and cost requirements. The creation of smaller banks in underserved areas is essential to providing people with opportunities for banking services nationally. A period of rising interest rates, while just one of many factors, is likely to incentivize the formation of these new charters.

D. Interest Rates and Bank Metrics

After determining the causality between our desired variables, we can visualize the general trend of rising interest rates on these variables scales by plotting the scaled data of the Federal Funds rate, earnings, liquidity, and asset quality. Visualizing the trend as interest rates go through periods of rising and

falling can further help us understand the nature of the relationship before running full analyses. We can also view any possible seasonal patterns, cyclical patterns, or trends that may affect our analysis or interpretation of the relationships.

Figure #6: Bank Metrics vs. Federal Funds Rate



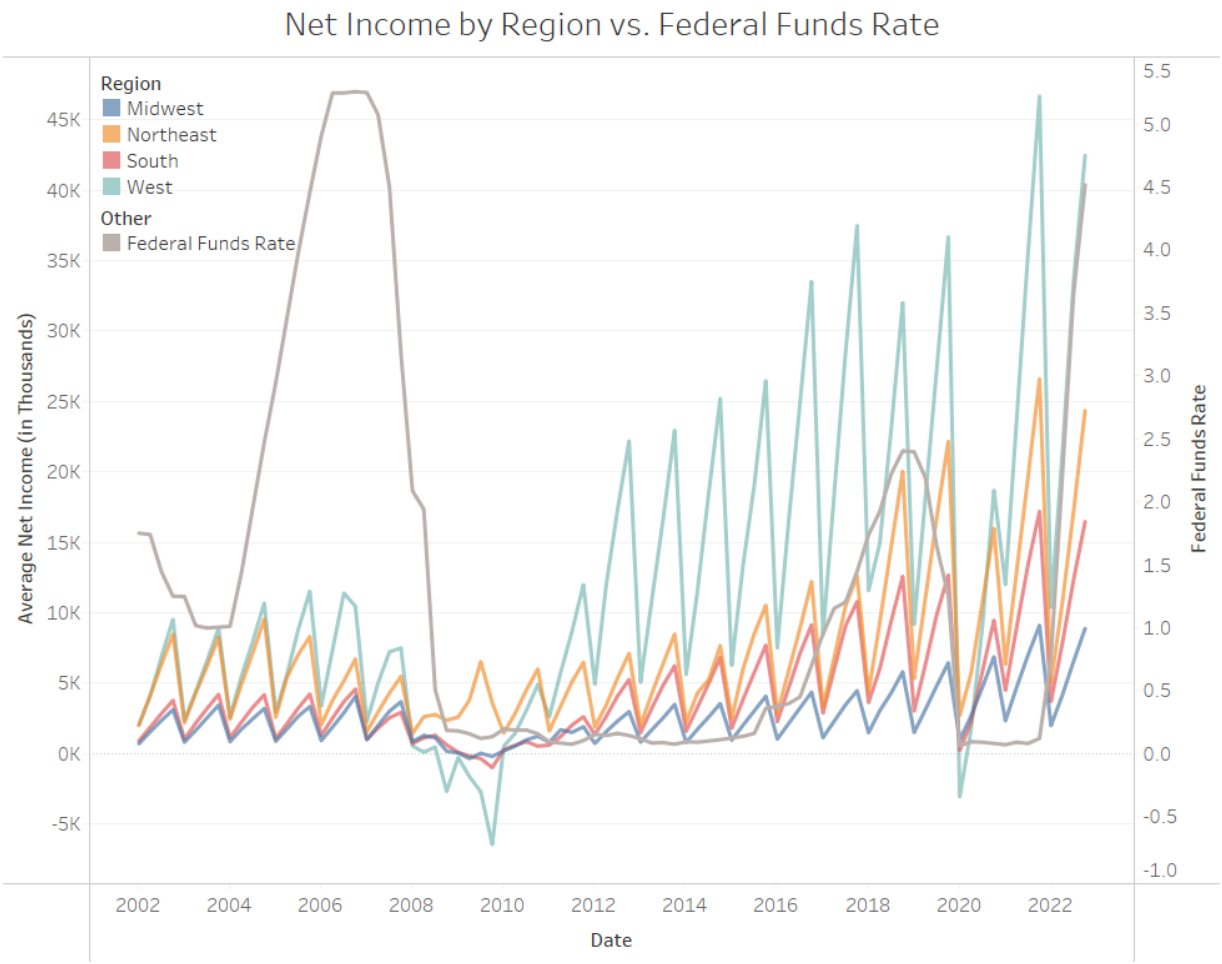
* File 9

We can see that earnings show a seasonal pattern while asset quality may show more notable fluctuations in the earlier years. Furthermore, liquidity shows a temporary rise for the time period after 2008 which may be in response to the financial crisis.

E. Bank Location

The location of a bank can change the impact of rapidly rising interest rates on its metrics. To better understand the dynamic between bank locations and Federal Funds rate, we created a time series of bank earnings by region alongside FFR.

Figure #7: Net Income by Region vs. Federal Funds Rate



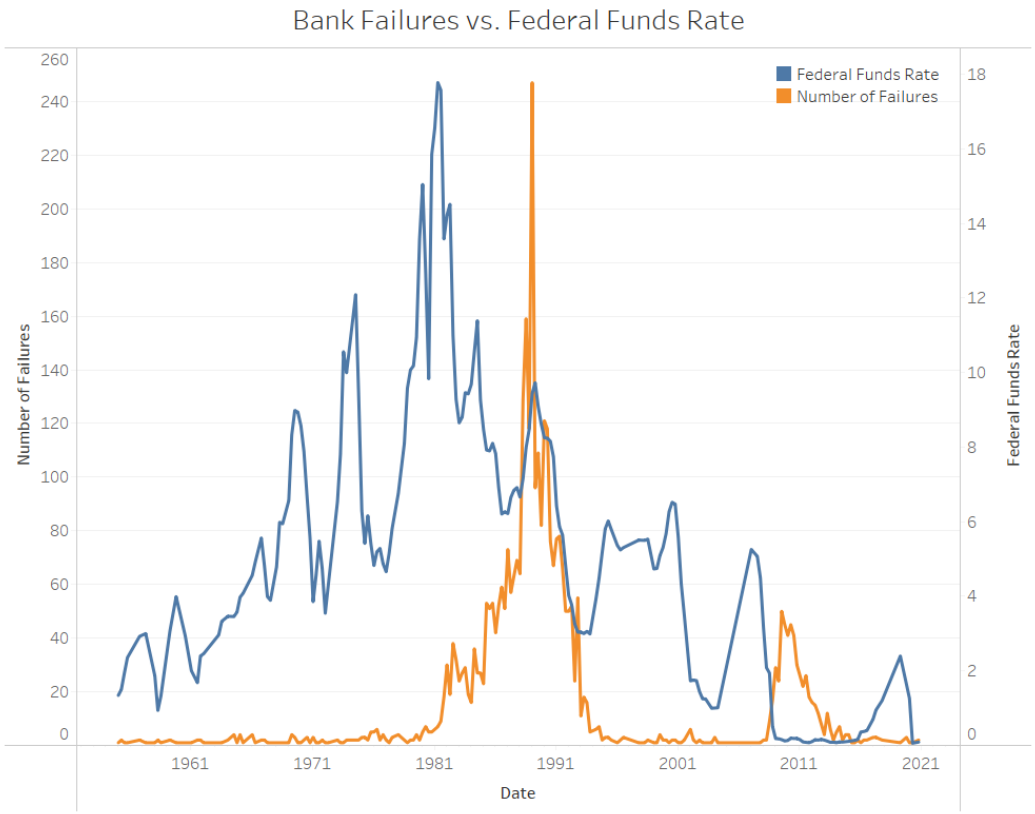
* File 10

The net income for each region has a seasonal pattern and seems to remain steady during periods of rising interest rates. During periods of flat or rising interest rates, net income seems to slowly and steadily increase until interest rates fall. The West region in particular appears especially volatile, reaching much higher average net incomes than other regions, however, experiencing negative average net incomes during periods of falling interest rates. This pattern indicates that banks in the West may have high interest rate risk exposure, allowing them to cash in when rates are steady or increasing, but leaving them especially susceptible to experiencing losses when the FFR falls.

F. Bank Failures

Whether rising or falling, periods of rapidly changing interest rates can have devastating effects on banks if they are not properly prepared. This lack of preparation can sometimes lead to the worst case scenario: bank failure. To see the relationship between bank failures and the Federal Funds rate, we plotted the two together.

Figure #8: Bank Failures vs. Federal Funds Rate



* File 11

Before taking insights from this figure, it's important to understand that many macroeconomic factors can lead to bank failures. For example, the spike in the late 1980s was caused largely by a real estate bubble and a savings and loan crisis. A real estate bubble also contributed to many of the failures from 2008 to

2012. With that said, a large number of bank failures come after periods of rapidly falling interest rates, typically up to five years after the drop. However, these falling rates are also associated with those same macroeconomic conditions. For that reason, it's uncertain whether we can say that bank failures are caused by the drastic change in the FFR.

VII. Model:

A. *Model Methodology*

We used a Recurrent Neural Network (RNN) model to analyze the historical relationships between the Federal Funds rate with banks' earnings and predict the impact of earnings during periods of rapidly rising interest rates. The RNN model is a suitable choice for time series data because it can capture the temporal dependencies between sequential data points. In this case, the time series data includes the quarterly financial data for the banks, where each data point represents the financial status of a bank at a specific point in time. Another advantage of the RNN model is that it can capture the dynamic and non-linear relationships when working in a complex financial environment.

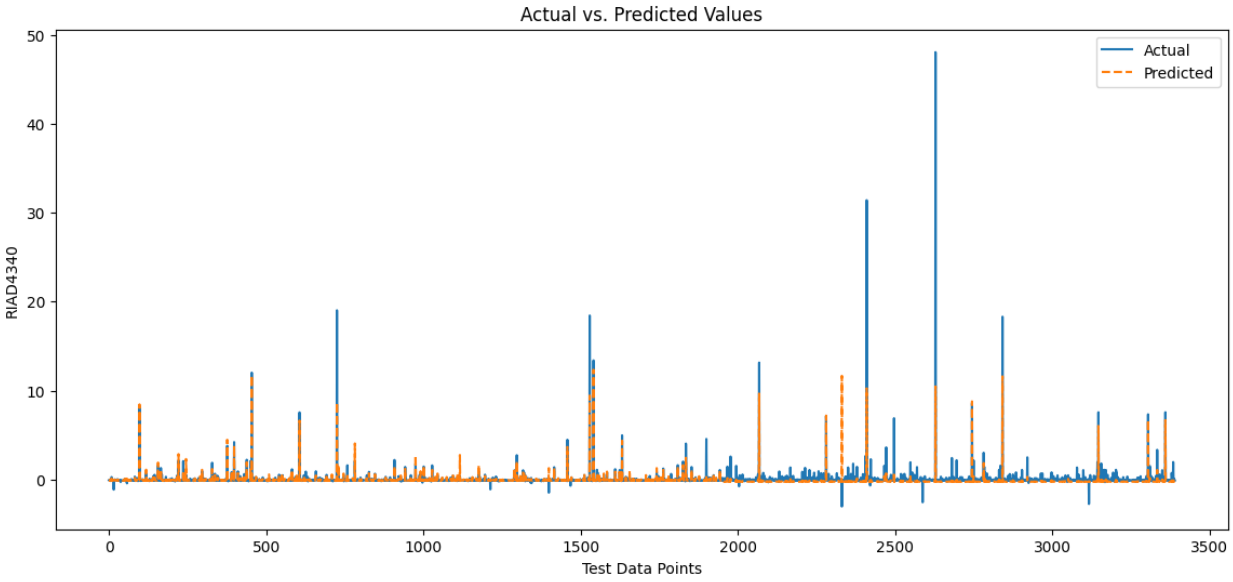
In our sequential model, we specified a Long Short-Term Memory (LSTM) layer to capture the impact of Federal Funds rate over multiple time steps rather than just the immediate effect, especially because it may have a delayed effect on borrowing and lending behaviors. By adding the LSTM layer to the RNN, we improve the model's ability to handle long-term dependencies in sequential data and prevent the gradient from vanishing. We then included a dense layer in our RNN model to extract features from the input data and transform the output to make suitable predictions. We also added two dropout layers in between the input layers to improve model performance. After hyper-parameter tuning, we decided on an epoch of 50 runs and batch size of 156 samples to train the model.

B. *Model Results for All Banks*

a. Prediction Accuracy on Test Set

Using the RNN model trained on 80% of our data, we made predictions on net income on the remaining 20% of the data. We plotted those predictions with the actual net income values.

Figure #9: Net Income Predictions Vs. Actual



* Derived from File 12

The resulting plot shows our predictions are generally correct, managing to anticipate when net income spikes. Some of these spikes, however, are much higher than our model anticipated. We expect that these spikes are medium to large sized banks that experience sudden sharp increases in net income, potentially due to changes in their strategy. When predicting on this test data, our RNN model had an R-squared score of 0.54, meaning that 54% of the variance in net income can be explained by our independent variables. Balancing between the amount of variance and model's parsimony, we concluded that a R-squared of over 50% is fairfor using eight variables to predict a bank's net income. The model has a mean absolute error (MAE) of 0.17, which means on average, the model's predictions are off by 0.17 units

from the actual values. Our MAE values are so low when considering earnings because we scaled most of our variables prior to fitting the model.

b. Feature Weights - Permutation Importance

Permutation importance measures the decrease in model performance when the values of a specific feature are randomly shuffled. The idea behind is fairly straightforward, if a feature is important for the model, shuffling its values should lead to a significant drop in model performance. After compiling and fitting our RNN model, we looked at how each feature impacted bank earnings using the permutation techniques.

Figure #10: Feature Weights

Weight	Feature
0.2376 ± 0.0327	RCON2170
0.1895 ± 0.0333	RCON2948
0.1391 ± 0.0414	RCON2200
0.0571 ± 0.0180	CPI
0.0212 ± 0.0612	GDP_Pct_Change
0.0177 ± 0.0060	AllowanceToTotalLoans
0.0137 ± 0.0005	LoanToDeposit
0.0050 ± 0.0536	FEDFUNDS

* Derived from File 12

It appears that all variables have a positive impact on earnings, with total assets, total liabilities, and total deposits having the strongest effect. The Federal Funds rate did have a positive effect on net income. However, it was by far the least important variable. Our other macroeconomic features such as the consumer price index had much stronger weights.

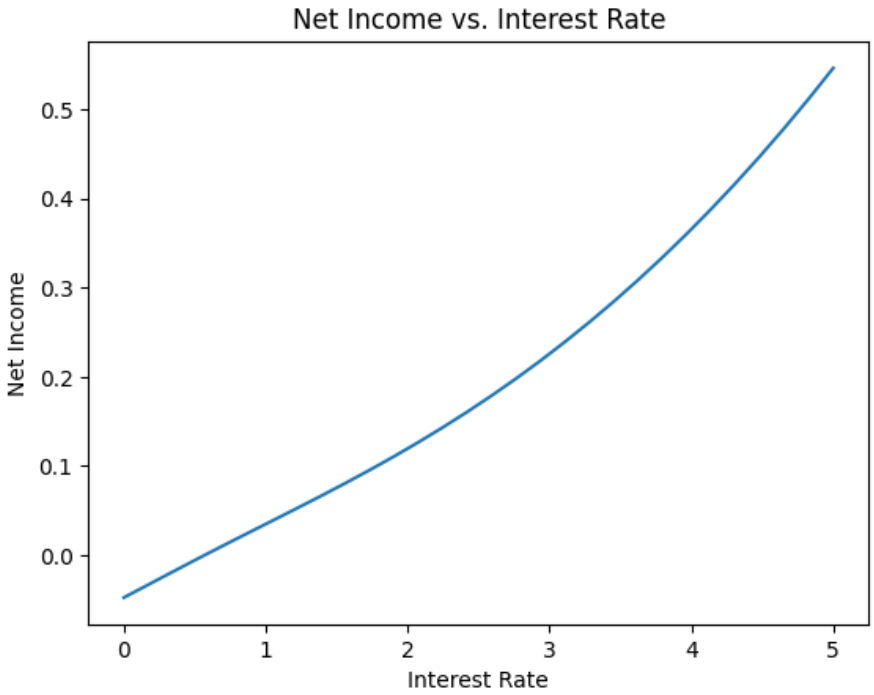
There could be a number of factors why interest rate is not considered to be the strongest indicator for this model. The importance of Federal Funds rate could be masked by other features that capture similar information which the model is

relying more heavily upon. It is also important to keep in mind that, similar to granger causality test, permutation importance assumes a linear relationship. Therefore, any non-linear or complex relationship between interest rate and net income may not be accurately represented from the permuted assignment of weights.

c. *Effect of Rising Interest Rates*

We plotted net income and interest rate together to show their relationship within the RNN.

Figure #11: Net Income vs. Interest Rate



* Derived from File 12

To isolate the effect of interest rate on bank's earnings, we varied the interest rate from 0 to 5 and ran it through the RNN model we built while keeping other variables constant. The increasing line in the plot suggests that, on average, the net income is positively correlated with the federal interest rate under 5% which

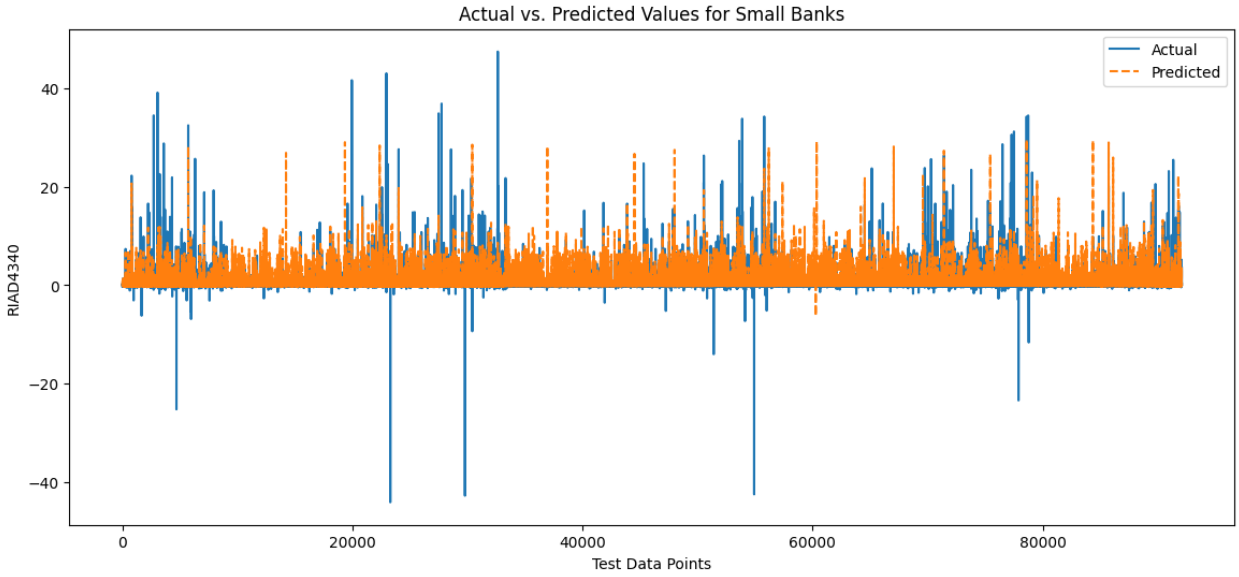
mimics the current interest rate. In accordance with our literature review and empirical evidence, higher interest rates could result in better profitability for banks due to improved net interest margins or other factors.

C. Model Results for Small Banks

a. Prediction Accuracy on Test Set

Since our K-means clustering model suggested most of our data are considered small banks, we wanted to run our full time series RNN model on the small bank cluster specifically. In the interest of comparability, we kept our model structure and train-and-test ratio the same.

Figure #12: Net Income Predictions vs. Actual (Small Banks)



* Derived from File 13

The R-squared and MAE did not deviate too significantly from when we ran the model on all banks' data which was expected. The model gave an R-squared of 44% and a 0.17 MAE. One distinction for predictions on small banks is how the model is lacking in predicting downward spikes in net losses. This issue is less apparent when we run the model on every single bank in the dataset. The issue

could be when we are only concentrating on small banks, the data we trained on may not have sufficient examples with net income losses for the model to learn from.

b. Feature Importance

Figure #13: Feature Weights (Small Banks)

Weight	Feature
3.4193 ± 0.1044	RCON2170
3.1419 ± 0.0264	RCON2200
1.1632 ± 0.0200	RCON2948
0.0165 ± 0.0065	GDP_Pct_Change
0.0100 ± 0.0098	AllowanceToTotalLoans
0.0057 ± 0.0097	CPI
0.0043 ± 0.0123	FEDFUNDS
0.0022 ± 0.0001	LoanToDeposit

* Derived from File 13

Similar to the feature importance on the full dataset, all variables have a positive impact on earnings, with total assets, liabilities, deposits exerting the strongest effect on earnings. Interestingly, we see a decline of importance in macroeconomic factors such as the consumer price index.

It is still important here to recognize the intricacies in interpreting permutation importance results. The channel of influence for interest rate and macroeconomic factor on a bank's earnings could be more complex and nonlinear, which could possibly result in lower feature weights.

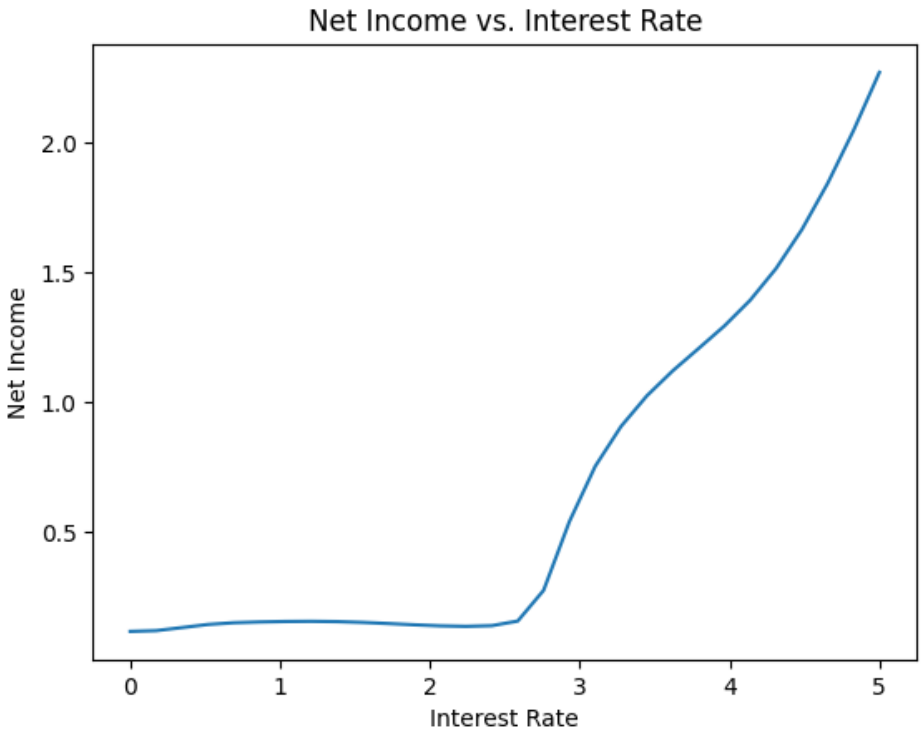
c. Effect of Rising Interest Rate

The observed pattern for focusing solely on interest rate and its effect on small banks' earnings gives a different outlook from all banks. The net income of small banks is relatively insensitive to changes in interest rates when interest rates

are lower than 3%. Once it passes the threshold, small bank's earnings seem to increase significantly.

There could be a number of factors accounting for the drastic response to higher interest rates. Interest rate spread from lending activities could contribute to higher earnings for small banks. They could also have a lower cost of funds compared to larger banks, making them more resilient to rising interest rates. It could also be an indication that small banks' incomes are more sensitive to market conditions.

Figure #14: Net Income vs. Interest Rate (Small Banks)



* Derived from File 13

VIII. Further Recommendations:

We could improve our analysis by taking a larger scope and gathering more data. Having a dataset from the early 1970s would be helpful because that would

include several more rate hiking cycles and a lot more exposure to higher interest rate environments. It should be noted that US demographics are much different than they were during the 1970s and even the early 21st century. Monetary policy and interest rate impacts may be different as we are in a structurally different economic environment. More data is likely to give us more insights. To address demographic changes perhaps we could use data on the size, growth rate, and productivity of the workforce. We also would like to collect more data relevant to liquidity. Liquidity is a large issue facing the financial sector and the Federal Reserve has had to rescue numerous banks and financial institutions. Having the proper liquidity facilities in place before crises occur is extremely important. Finally, the speed of the bank run at SVB was largely due to the rapid transmission of information through Twitter and other social media websites. More research into the use of social media on financial news could provide insight into how to mitigate liquidity risk.

IX. Conclusion:

As we determined how periods of rising Federal Funds rates affect banks, we took into account several factors that may contribute to net income. Our hypothesis that the rising rates will result in higher earnings was consistent with our findings. Through further inspection, our data was skewed with the incorporation of both large and small size banks so we used our clustering to create a more detailed analysis of all banks' and small banks' individual behaviors. While traditional models assume observations are independent of each other, our RNN model captures the dependencies that exist in sequential data which gives us further insight into the economic factors. Our findings that total assets, total liabilities, and total deposits having the largest positive weights of earnings coincides with the increases of the Federal Funds rates, which may include further correlations. The RNN model best represents this relationship with our R-squared

values showing that 54% of variability in our predicted net income of the banks can be explained by our chosen independent features.

X. Appendix:

- File 0: 2023 CSBS Data Analytics Competition Proposal - CSBS_WilliamAndMary_Team_Proposal_2023.pdf (Original Proposal)
- File 1: Alteryx Workflow - AlteryxCallReports.yxmd
- File 2: Cleaned Dataset - CR_04_22_2023.csv
- File 3: K-Means Clustering - k_means.ipynb
- File 4: Bank Clusters Visualization - BankClusters.twbx
- File 5: Data Dictionary - DataDictionary.pdf
- File 6: Granger Causality - Granger_Causality.ipynb
- File 7: Variable Correlation Heatmap - Heatmap.ipynb
- File 8: New Charts vs. Federal Funds Rate - NewCharters.twbx
- File 9: Bank Metrics vs. Federal Funds Rate - MetricsVsFFR.R
- File 10: Net Income by Region vs. Federal Funds Rate - BanksByRegion.twbx
- File 11: Bank Failures vs. Federal Funds Rate - BankFailures.twbx
- File 12: RNN Model - RNN_Final_AllBanks.ipynb
- File 13: RNN Model for Small Banks - RNN_Final_SmallBanks.ipynb
- File 14: Final Dataset - FinalDataset.csv

XI. Bibliography:

Athanasoglou, P., Brissimis, S. N., & Delis, M. D. (2008). Bank-specific, industry-specific and macroeconomic determinants of bank profitability. Journal of International Financial Markets, Institutions and Money, 18(2), 121–136.

Berger, A.N., Bouwman, C.H., Kick, T., Schaeck, K. (2016). Bank risk taking and liquidity creation following regulatory interventions and capital support. J. Financial Intermed 26, 115–141.

Bikker JA, Vervliet TM. (2017). Bank profitability and risk-taking under low interest rates. Int J Fin Econ. 2018;23:3–18.

Board of Governors of the Federal Reserve System (US). Federal Funds Effective Rate [FEDFUNDS] .(April, 2023). Retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/FEDFUNDS.

Borio, C., Gambacorta, L., & Hofmann, B. (2015). The influence of monetary policy on bank profitability. BIS Working Paper.

Carling, K, T Jacobson, J Linde, K Roszbach. (2007). Corporate Credit Risk Modeling and the Macroeconomy. Journal of Banking and Finance vol 31 issue 3, 845-868.

Copeland, R., Hirsch, L., Rappeport, A., & Farrell, M. (2023, March 16). Wall street's biggest Banks Rescue Teetering First Republic. The New York Times. Retrieved from https://www.nytimes.com/2023/03/16/business/first-republic-bank-sale.html.

Daily Treasury Par Yield Curve Rates. U.S. Department of the Treasury. (2023).

DeFusco, A. A., & Paciorek, A. (2014). The interest rate elasticity of mortgage demand: Evidence from bunching at the conforming loan limit. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2391941.

Dow Jones - DJIA - 100 Year historical chart. (April 2023). MacroTrends. Retrieved

from https://www.macrotrends.net/1319/dow-jones-100-year-historical-chart

Demirgüç-Kunt, Asli and Huizinga. (1999).Harry, Determinants of Commercial Bank Interest Margins and Profitability: Some International Evidence.

ECB (2015). Bank profitability features in Euro area banks: The role of cyclical and structural features. Financial Stability Review, 134–145.

FDIC. (2023). Bank Failures and Assistance Data. BankFind Suite. Retrieved from https://banks.data.fdic.gov/explore/failures?aggReport=detail&displayFields=NAME%2CCERT%2CFIN%2CCITYST%2CFAILDATE%2CSAVR%2CRESTYPE%2CCOST%2CRESTYPE1%2CCHCLASS1%2CQBFDEP%2CQBFASSET&endFailYear=2023&sortField=FAILDATE&sortOrder=desc&startFailYear=1934&utm_source=substack&utm_medium=email

FDIC. (2023). Find Annual Historical Bank Data. BankFind Suite. Retrieved from https://banks.data.fdic.gov/explore/historical?displayFields=STNAME%2CTOTAL%2CBRANCHES%2CNew_Char&selectedEndDate=2022&selectedReport=CBS&selectedStartDate=1934&selectedStates=0&sortField=YEAR&sortOrder=desc

Flannery, M. J. (1996). Financial Crises, Payment System Problems, and Discount Window Lending. Journal of Money, Credit and Banking, 28(4), 804–824. https://doi.org/10.2307/2077922.

Friedman, M. (1961). The Lag in Effect of Monetary Policy. Journal of Political Economy, 69(5), 447–466. http://www.jstor.org/stable/1828534.

“High Interest Rates to Impact Banks’ Asset Quality: Crisil.” Financial Express (2011): n. pag. Print.

Horan, P., & Beckworth, D. (2022, November 21). The Fate of FAIT and the Future of the Fed's Monetary Framework [audio blog].

Honohan, Patrick. (2023, March 27). The Fed's recent bank stress tests used scenarios with little variation. none examined higher interest rates. Peterson

Institution for International Economics.

Kelly, S. (2023, April 12). What's so special about the Fed's bank term funding program? What's So Special About the Fed's Bank Term Funding Program? Retrieved from https://www.withoutwarningresearch.com/p/whats-so-special-about-the-feds-bank?utm_source=post-email-title&publication_id=700349&post_id=114144502&isFreemail=true&utm_medium=email.

Maddaloni, A., & Peydró, J. L. (2011). Bank risk-taking, securitization, supervision, and low interest rates: Evidence from the Euro-area and the United State lending standards. Review of Financial Studies, 24(6), 2121–2165.

Milstein, E., & Wessel, D. (2022, March 9). What did the Fed do in response to the COVID-19 crisis? Brookings. Retrieved from https://www.brookings.edu/research/fed-response-to-covid19/.

Tizzi. (2023, January 18). The Fed's latest tool: A standing repo facility. Liberty Street Economics. Retrieved from https://libertystreeteconomics.newyorkfed.org/2022/01/the-feds-latest-tool-a-standing-repo-facility/.

U.S. Bureau of Economic Analysis, Gross Domestic Product [GDP]. (April, 2023). Retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDP, April 23, 2023.

U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL]. (April, 2023). Retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCSL, April 23, 2023.

Williamson, Stephen D. (2018). Low Real Interest Rates, Collateral Misrepresentation, and Monetary Policy. American Economic Journal: Macroeconomics, 10(4), 202-233.

White, C. (2023, February 8). Rising interest rates complicate banks' investment

portfolios. Saint Louis Fed Eagle. Retrieved from https://www.stlouisfed.org/on-the-economy/2023/feb/rising-rates-complicate-banks-investment-portfolios.