SMU
SINGAPORE MANAGEMENT UNIVERSITY

603-Quantitative Analysis of Financial Markets Project Presentation

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Objective

Objective: Forecast liquidity risk for banks by predicting "Total Loans to Total Deposits" ratio to assess and manage bank's liquidity risk effectively. Our analysis was done for multiple banks both small and large, but will focus more on FRCB (First Republic Bank) which went bankrupt in May 1 (Q2) 2023.

Why Forecast this measure?

- Critical Liquidity Health Indicator
- Early Warning Signal
- Regulatory Benchmark
- Comprehensive Measure

Models for Forecasting?

- **OLS:** Baseline model to capture predictor relationships
- **ARIMA:** Models temporal trends in the liquidity indicator
- **VAR:** Captures interdependencies among predictors
- **VECM:** Accounts for long-term equilibrium relationships

Why these Models?

- **Comprehensive Analysis:** Combines regression and advanced time series methods.
- **Robust Comparison:** Assess model performance for accurate forecasting
- **Enhanced Predictive Power:** Utilizes the strengths of each model

Research Introduction

Research objectives : Forecasting the Future Risks of Major U.S. Banks.

Research subjects : Bank of America Corp/ Citizens Financial Group Inc/ FIFTH THIRD/ JPM US CHASE/ USB US Equity/ WFC US Equity

FCNCA US Equity (acquired the failed Silicon Valley Bank in Mar 2023)

FRCB US Equity (had declared bankruptcy in 2023)

Research data: Net Loans(millions)

Total Deposits(millions)

Total Loans(millions)

Total Loans to Total Deposits(%)

CPI (Consumer Price Index)

REAL GDP(Gross Domestic Product)

Reserve for Loan Losses(millions)

Provision for Loan Losses(millions)/

Non-Performing Loans(millions)/

FED FUNDS(Fed funds rate)

UN RATE(Unemployment Rate)

obtained from Bloomberg and the Federal Reserve, covering quarterly data over a nine-year period

Date Gathering

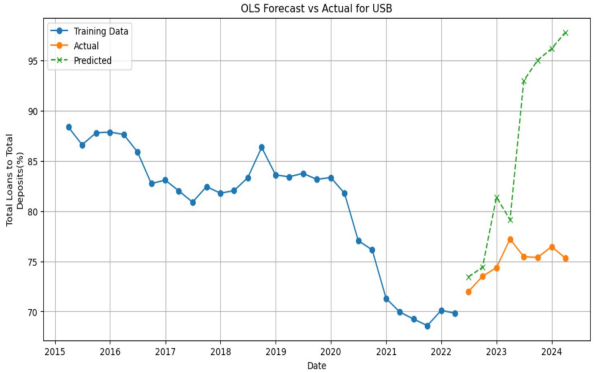
- **Bloomberg**

- **Macroeconomic Data:**
  - Unemployment Rate:
    - Increased loan defaults
    - Higher credit risk for banks
  - Federal Funds:
    - Affecting the cost of borrowing
    - Liquidity and profitability

- **Bank-Specific Variables:**
  - Non-Performing Loans
  - Loan Loss Provisions

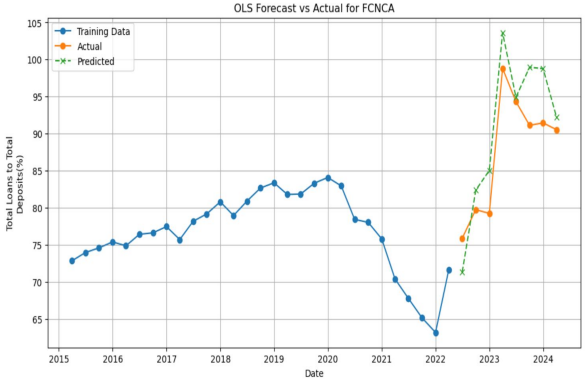
OLS Regression

USB



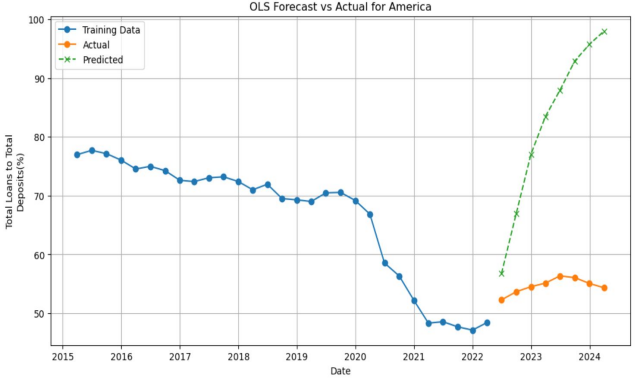

```
Processing bank: USB
Datetime index set successfully.
Data cleaning completed successfully.
Data split into 29 training and 8 testing observations.

Breusch-Pagan test p-value: 0.1332
White's test p-value: 0.4366
No heteroscedasticity detected.
Durbin-Watson statistic: 0.9565
Breusch-Godfrey test p-value: 0.0066
Serial correlation detected.

OLS Model refitted with robust standard errors (HAC).

Generated predictions for 8 testing observations.


MAPE for USB: 15.04%
```

FCNCA




```
Processing bank: FCNCA
Datetime index set successfully.
Data cleaning completed successfully.
Data split into 29 training and 8 testing observations.

Breusch-Pagan test p-value: 0.0000
White's test p-value: 0.0000
Heteroscedasticity detected. Using robust standard errors.
Durbin-Watson statistic: 1.0869
Breusch-Godfrey test p-value: 0.0010
Serial correlation detected.

OLS Model refitted with robust standard errors (HAC).

Generated predictions for 8 testing observations.


MAPE for FCNCA: 5.08%
```

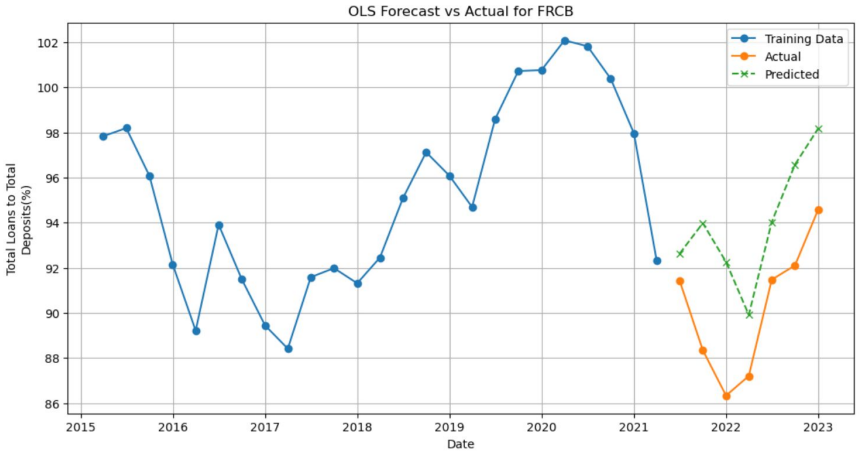
Bank of America Corp




```
Processing bank: America
Datetime index set successfully.
Data cleaning completed successfully.
Data split into 29 training and 8 testing observations.

Breusch-Pagan test p-value: 0.5052
White's test p-value: 0.0062
Heteroscedasticity detected. Using robust standard errors.
Durbin-Watson statistic: 0.9007
Breusch-Godfrey test p-value: 0.0033
Serial correlation detected.

OLS Model refitted with robust standard errors (HAC).

Generated predictions for 8 testing observations.


MAPE for America: 50.23%
```

OLS Regression

FRCB US Equity:




```
Processing bank: FRCB
Datetime index set successfully.
Data cleaning completed successfully.
Data split into 25 training and 7 testing observations.

Breusch-Pagan test p-value: 0.0854
White's test p-value: 0.7877
No heteroscedasticity detected.
Durbin-Watson statistic: 1.0576
Breusch-Godfrey test p-value: 0.0294
Serial correlation detected.

OLS Model refitted with robust standard errors (HAC).

Generated predictions for 7 testing observations.


MAPE for FRCB: 4.16%
```

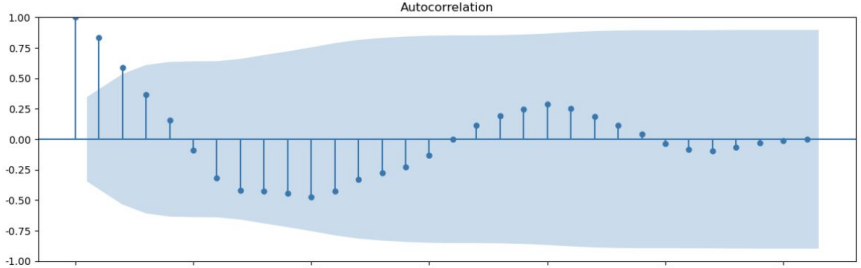
Durbin-Watson : strongly suggests the presence of positive autocorrelation, this is typical of time series data.

Condition Number: serious multicollinearity issues.

Introduction of Macroeconomic Variables: suggests that time-related factors are important in explaining changes

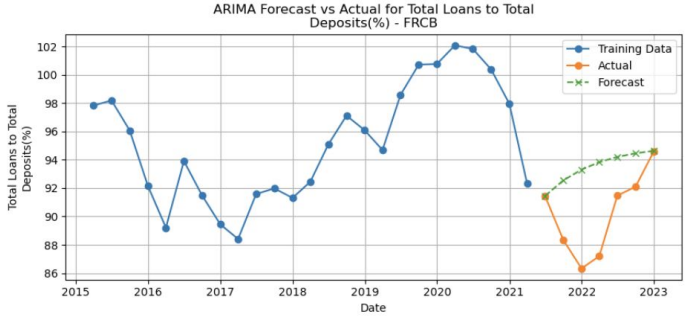
Comprehensive Analysis of ARIMA Models（FRCB）

ACF

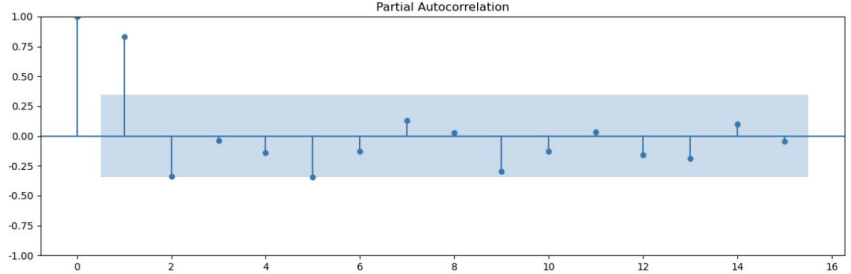


ARIMA(0,1,0)

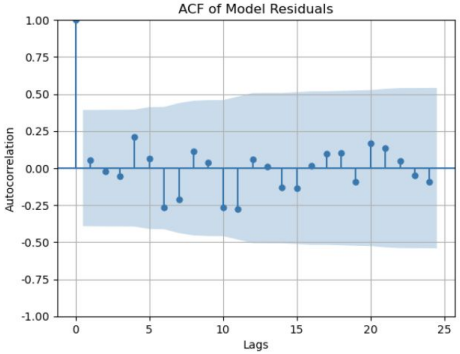
FORECAST



PACF



Ljung-Box Test



Performing Ljung-Box test on residuals.

	lb_stat	lb_pvalue
10	9.758847	0.461899
11	13.476154	0.263346
12	13.642376	0.324126
13	13.646749	0.399183
14	14.695879	0.399255
15	15.983469	0.383151
16	15.997238	0.453154
17	16.756413	0.470984
18	17.813715	0.467987
19	18.722347	0.474773
20	22.583083	0.309726

Residuals appear to be white noise.

Comprehensive Analysis of ARIMA Models（FRCB）

Interpretation of Metrics:

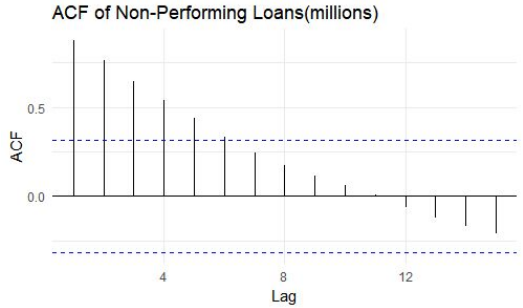
- **RMSE (4.20):** Here, an RMSE of 4.20 suggests the forecast deviates from the actual values by around 4.2 percentage points on average, which is relatively low.
- **MAPE (3.73%):** MAPE indicates the percentage error on average between the forecasted and actual values. A MAPE of 3.73% is quite low, indicating good predictive accuracy, as MAPE values below 5% are generally considered excellent in time series forecasting.

Performance Interpretation:

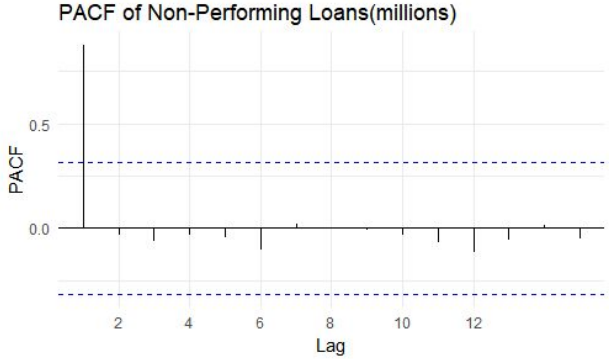
- **Trend Alignment:** The ARIMA model captures the overall trend well, initially aligning with the downward trend in the actual values. However, the model's upward trend in the forecast period is somewhat shallower than the actual recovery observed in 2022 and 2023.
- **Forecast Accuracy:** The small deviations indicate that the ARIMA model is relatively accurate, but it slightly underestimates the sharpness of the upward trend in 2022. This underestimation is visible as the actual data rises more steeply than the forecasted data.

Comprehensive Analysis of ARIMA Models（Bank of America）

ACF

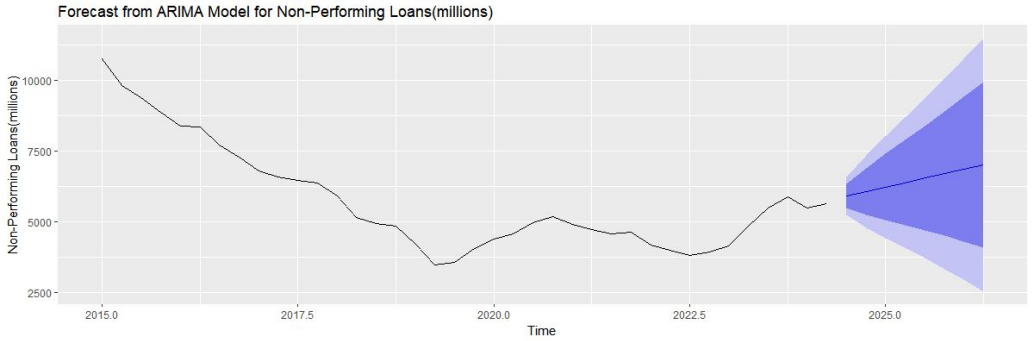


PACF

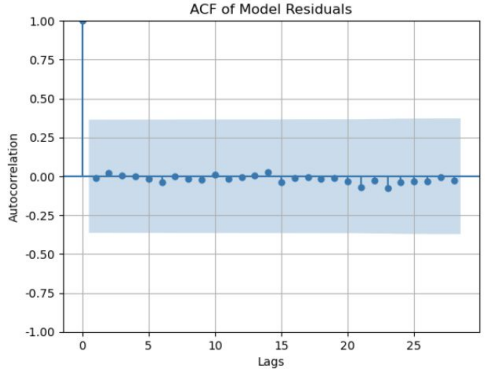


ARIMA(0,2,2)

FORECAST



Ljung-Box Test

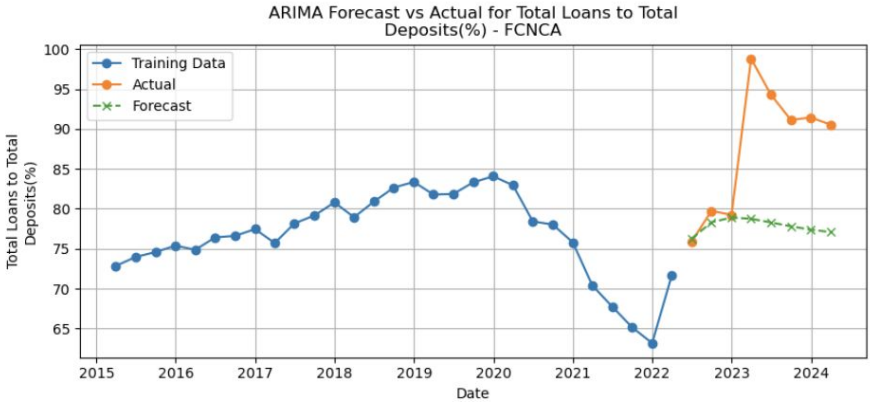



```
Performing Ljung-Box test on residuals.
     lb_stat  lb_pvalue
10  0.128861        1.0
11  0.143628        1.0
12  0.145550        1.0
13  0.146396        1.0
14  0.183270        1.0
15  0.278870        1.0
16  0.289561        1.0
17  0.291745        1.0
18  0.320649        1.0
19  0.331895        1.0
20  0.428715        1.0
Residuals appear to be white noise.
```

Compare

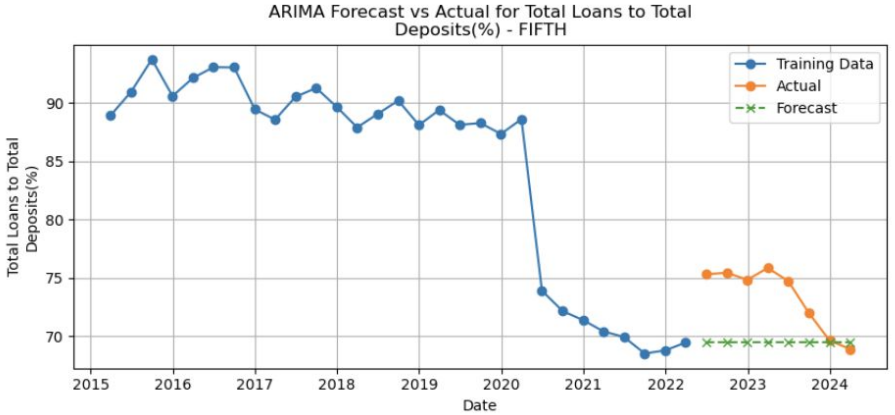
· FCNCA

forecast



· FIFTH THIRD

forecast



In conclusion, through ACF and PACF analysis, Ljung-Box test and Forecasts, ARIMA model has some shortcomings and has some room for improvement.

Next, we will show the VAR and VECM Models for predicting more accurately.

VAR（data of USB）

ADF test & use BIC

```
ADF Test Results Before Differencing:
                                  ADF Statistic   p-value Stationary
UN RATE                               -3.264314  0.016551       True
FEDFUNDS                              -1.871076  0.345788      False
Reserve for Loan\nLosses(millions)    -2.008947  0.282664      False
Provision for Loan Losses(millions)   -4.112172  0.000925       True
Non-Performing Loans(millions)        -1.783346  0.388761      False
Total Loans to Total\nDeposits(%)     -2.146293  0.226312      False
ADF Test Results After Differencing:
                                  ADF Statistic   p-value Stationary
UN RATE                               -3.224502   0.01861       True
FEDFUNDS                              -3.670341   0.00455       True
Reserve for Loan\nLosses(millions)    -4.534912   0.00017       True
Provision for Loan Losses(millions)   -4.044215  0.001196       True
Non-Performing Loans(millions)        -3.823549  0.002675       True
Total Loans to Total\nDeposits(%)     -2.872962  0.048584       True
USB Selected Optimal Lag (BIC): 4
```

1. Data Preparation and Differencing

- [80:20] Data Split : USB Bank
- Augmented Dickey-Fuller (ADF) test;
- differencing to variables until they became stable

2. Selection of Lag Order

- a good balance between fitting the data well and keeping the model simple

VAR（data of USB）

VAR model

```
  Summary of Regression Results
==================================
Model:                         VAR
Method:                        OLS
Date:           Wed, 06, Nov, 2024
Time:                     22:23:45
--------------------------------------------------------------------
No. of Equations:         6.00000    BIC:                    16.4959
Nobs:                     32.0000    HQIC:                   11.9027
Log likelihood:          -276.440    FPE:                    374413.
AIC:                      9.62527    Det(Omega_mle):         11722.0
--------------------------------------------------------------------
```

	coefficient	std. error	t-stat	prob
const	1.097340	0.679037	1.616	0.106
L1.UN RATE	0.209179	0.156394	1.338	0.181
L1.FEDFUNDS	0.399267	0.279057	1.431	0.152
L1.Reserve for Loan Losses(millions)	0.009953	0.001543	6.452	0.000
L1.Provision for Loan Losses(millions)	-0.003767	0.003592	-1.049	0.294
L1.Non-Performing Loans(millions)	-0.004809	0.001134	-4.240	0.000
L1.Total Loans to Total Deposits(%)	-0.007128	0.034805	-0.205	0.838
L2.UN RATE	0.229615	0.147483	1.557	0.119
L2.FEDFUNDS	-1.189931	0.368119	-3.232	0.001
L2.Reserve for Loan Losses(millions)	0.000954	0.001928	0.495	0.621
L2.Provision for Loan Losses(millions)	-0.000041	0.002492	-0.016	0.987
L2.Non-Performing Loans(millions)	0.000424	0.001155	0.367	0.714
L2.Total Loans to Total Deposits(%)	-0.013812	0.031827	-0.434	0.664
L3.UN RATE	0.122618	0.185865	0.660	0.509
L3.FEDFUNDS	0.665685	0.315015	2.113	0.035
L3.Reserve for Loan Losses(millions)	-0.004571	0.001197	-3.818	0.000
L3.Provision for Loan Losses(millions)	0.009552	0.001796	5.319	0.000
L3.Non-Performing Loans(millions)	0.003347	0.001137	2.943	0.003
L3.Total Loans to Total Deposits(%)	-0.079403	0.044645	-1.779	0.075
L4.UN RATE	0.270291	0.097346	2.777	0.005
L4.FEDFUNDS	-0.581862	0.196440	-2.962	0.003
L4.Reserve for Loan Losses(millions)	-0.003460	0.002257	-1.534	0.125
L4.Provision for Loan Losses(millions)	0.004221	0.002036	2.073	0.038
L4.Non-Performing Loans(millions)	-0.001341	0.000912	-1.471	0.141
L4.Total Loans to Total Deposits(%)	0.113955	0.030013	3.797	0.000

3. Model Training and Parameter Estimation

- **Reserve for Loan Losses**: When reserves go up, the LDR often goes down, meaning more reserves might reduce lending.
- **Non-Performing Loans (NPLs)**: Higher NPLs affect the LDR, showing how liquidity risk can impact loan strategy.
- **Federal Funds Rate**: Has a mixed effect on LDR—raising the rate lowers LDR after 2 and 4 periods but increases it after 3 periods, showing a delayed, back-and-forth impact.

VAR（data of USB）

Ljung-Box Test

Results for UN RATE:

	lb_stat	lb_pvalue
1	0.291493	0.589265
2	2.249515	0.324731
3	2.442868	0.485705
4	2.485809	0.647179
5	2.543852	0.769877
6	2.543902	0.863522
7	2.625414	0.917361
8	7.311895	0.503386
9	7.421634	0.593309
10	8.327578	0.596873

Results for FEDFUNDS:

	lb_stat	lb_pvalue
1	1.114470	0.291112
2	2.361294	0.307080
3	3.672696	0.299045
4	5.397635	0.248875
5	5.978407	0.308326
6	6.405091	0.379373
7	6.504769	0.482194
8	6.868639	0.550870
9	6.971044	0.640134
10	7.048374	0.720870

Losses(millions):

	lb_stat	lb_pvalue
1	0.179019	0.672218
2	1.632969	0.441983
3	1.760714	0.623521
4	1.835410	0.765998
5	2.999928	0.699997
6	4.133237	0.658651
7	5.473842	0.602341
8	5.562294	0.696129
9	6.231710	0.716522
10	6.270820	0.792020

Results for Provision for Loan Losses(millions):

	lb_stat	lb_pvalue
1	0.074903	0.784327
2	0.388221	0.823567
3	0.401984	0.939832
4	1.095566	0.894975
5	1.443744	0.919469
6	2.831810	0.829641
7	3.149896	0.870798
8	3.509356	0.898462
9	3.587422	0.936414
10	4.151634	0.940247

USB Model passed Ljung-Box Test with lag order 4.

Results for Non-Performing Loans(millions):

	lb_stat	lb_pvalue
1	0.182074	0.669597
2	0.188331	0.910132
3	0.337761	0.952777
4	0.811278	0.936930
5	0.816530	0.975967
6	1.240044	0.974861
7	1.245757	0.989835
8	1.425884	0.993871
9	2.415413	0.983072
10	2.567353	0.989857

Results for Total Loans to Total Deposits(%):

	lb_stat	lb_pvalue
1	0.142034	0.706267
2	1.523182	0.466923
3	1.524273	0.676680
4	1.539476	0.819627
5	2.519489	0.773557
6	3.786688	0.705517
7	7.883897	0.342943
8	13.073840	0.109334
9	13.132656	0.156695
10	13.482269	0.197943

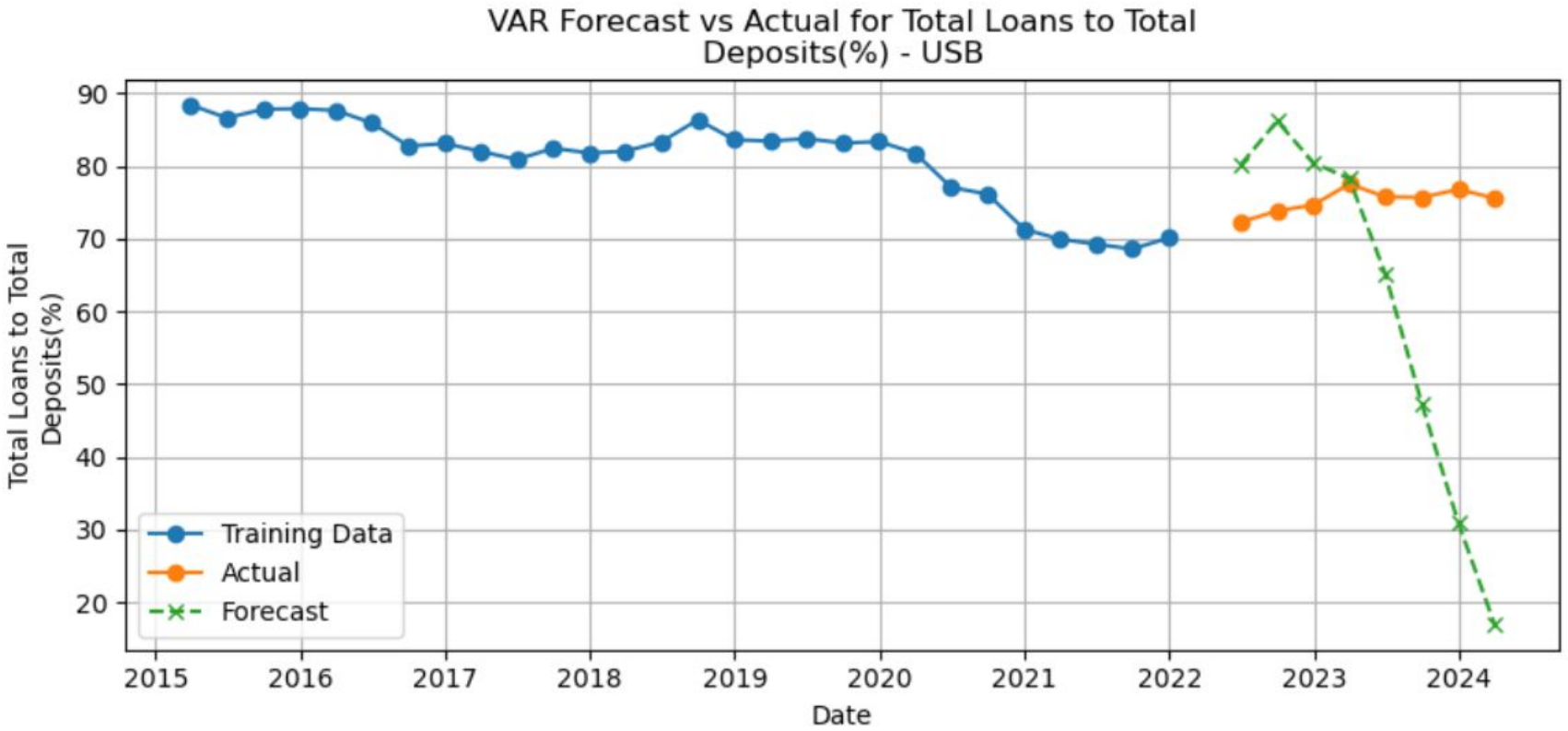
4. Independence Test of Model Residuals

- The test showed that with a lag order of 4, the model passed, meaning the errors were independent enough.

VAR（data of USB）

Forecast

5. Generating Predictions Based on the Test Set: compared the predicted results with actual values



VAR（data of USB）

Error

```
RMSE for USB:
UN RATE: 19.0253
FEDFUNDS: 15.0132
Reserve for Loan
Losses(millions): 11879.1604
Provision for Loan Losses(millions): 2074.4352
Non-Performing Loans(millions): 846.9295
Total Loans to Total
Deposits(%): 28.9267

MAPE for USB:
UN RATE: 408.77%
FEDFUNDS: 314.24%
Reserve for Loan
Losses(millions): 192.95%
Provision for Loan Losses(millions): 8835.51%
Non-Performing Loans(millions): 40.46%
Total Loans to Total
Deposits(%): 28.12%
```

6. Error Evaluation

- Low RMSE and MAPE values mean the model's predictions were close to the actual LDR values in the test data.

VAR（data of FIFTH THIRD）

ADF test & use BIC for initial order

```
ADF Test Results Before Differencing:
                                  ADF Statistic   p-value Stationary
UN RATE                               -3.264314  0.016551       True
FEDFUNDS                              -1.871076  0.345788      False
Reserve for Loan\nLosses(millions)    -1.587092  0.490074      False
Provision for Loan Losses(millions)   -3.602973  0.005704       True
Non-Performing Loans(millions)         -3.50469  0.007867       True
Total Loans to Total\nDeposits(%)     -0.572837  0.877002      False
ADF Test Results After Differencing (First Differencing):
                                  ADF Statistic   p-value Stationary
UN RATE                               -3.224502   0.01861       True
FEDFUNDS                              -3.670341   0.00455       True
Reserve for Loan\nLosses(millions)    -4.063376  0.001113       True
Provision for Loan Losses(millions)   -3.543763  0.006932       True
Non-Performing Loans(millions)        -3.080899  0.027999       True
Total Loans to Total\nDeposits(%)     -5.788185       0.0       True
ADF Test Results After Differencing (Second Differencing):
                                  ADF Statistic   p-value Stationary
UN RATE                               -3.224502   0.01861       True
FEDFUNDS                              -3.670341   0.00455       True
Reserve for Loan\nLosses(millions)    -4.063376  0.001113       True
Provision for Loan Losses(millions)   -3.543763  0.006932       True
Non-Performing Loans(millions)        -3.080899  0.027999       True
Total Loans to Total\nDeposits(%)     -5.788185       0.0       True
FIFTH Selected Optimal Lag (BIC): 4
```

The ADF test shows that all variables become stationary after the first differencing, and the optimal lag order is selected as 4 based on BIC.

VAR（data of FIFTH THIRD）

VAR

```
  Summary of Regression Results
==================================
Model:                         VAR
Method:                        OLS
Date:           Wed, 06, Nov, 2024
Time:                     20:52:34
--------------------------------------------------------------------
No. of Equations:         6.00000    BIC:                    36.0012
Nobs:                     32.0000    HQIC:                   31.4079
Log likelihood:          -588.524    FPE:                1.10757e+14
AIC:                      29.1305    Det(Omega_mle):     3.46756e+12
--------------------------------------------------------------------
Results for equation UN RATE
================================================================================================
                                        coefficient       std. error           t-stat            prob
------------------------------------------------------------------------------------------------
const                                     4.002438         2.700922            1.482           0.138
L1.UN RATE                               -1.101618         0.548688           -2.008           0.045
L1.FEDFUNDS                               2.044451         1.173812            1.742           0.082
L1.Reserve for Loan
Losses(millions)          -0.003967        0.001258           -3.152          0.002
L1.Provision for Loan Losses(millions)    0.004494         0.000813            5.530           0.000
L1.Non-Performing Loans(millions)         0.000184         0.000526            0.350           0.726
L1.Total Loans to Total
Deposits(%)           -0.175099         0.212746           -0.823           0.410
L2.UN RATE                               -0.127724         0.865928           -0.147           0.883
L2.FEDFUNDS                              -1.586716         1.490652           -1.064           0.287
L2.Reserve for Loan
Losses(millions)          -0.001278        0.001239           -1.032          0.302
L2.Provision for Loan Losses(millions)    0.002293         0.001531            1.498           0.134
L2.Non-Performing Loans(millions)        -0.000463         0.000460           -1.007           0.314
L2.Total Loans to Total
Deposits(%)           -0.051727         0.190969           -0.271           0.786
L3.UN RATE                                1.231539         0.791688            1.556           0.120
L3.FEDFUNDS                              -0.619968         1.703020           -0.364           0.716
L3.Reserve for Loan
Losses(millions)           0.000871        0.001177            0.740          0.459
L3.Provision for Loan Losses(millions)   -0.001232         0.001096           -1.124           0.261
L3.Non-Performing Loans(millions)         0.000479         0.000471            1.015           0.310
L3.Total Loans to Total
Deposits(%)           -0.314836         0.177834           -1.770           0.077
L4.UN RATE                               -0.181342         0.606635           -0.299           0.765
L4.FEDFUNDS                              -1.296232         1.627471           -0.796           0.426
L4.Reserve for Loan
Losses(millions)           0.003665        0.001341            2.733          0.006
L4.Provision for Loan Losses(millions)   -0.003606         0.001270           -2.839           0.005
L4.Non-Performing Loans(millions)         0.000642         0.000615            1.044           0.296
L4.Total Loans to Total
Deposits(%)           -0.393442         0.196848           -1.999           0.046
================================================================================================
```

The VAR results indicate that some variables, like "Provision for Loan Losses (millions)" at lag 1, have a significant impact on UN RATE.

VAR（data of FIFTH THIRD）

Ljung-Box Test

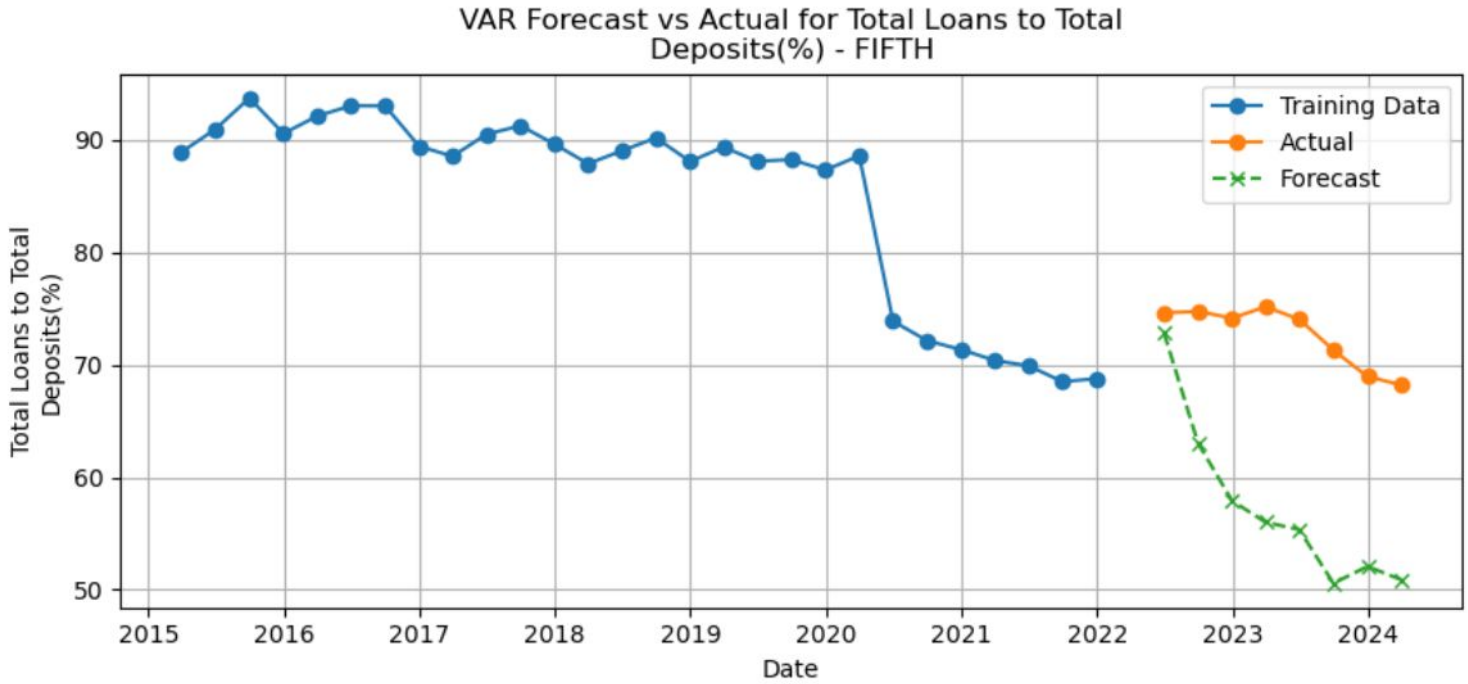
```
Performing Ljung-Box Test for FIFTH Residuals:
  UN RATE: LB Stat=14.8310, p-value=0.1383
  FEDFUNDS: LB Stat=10.8464, p-value=0.3696
  Reserve for Loan
Losses(millions): LB Stat=6.2049, p-value=0.7978
  Provision for Loan Losses(millions): LB Stat=6.8824, p-value=0.7365
  Non-Performing Loans(millions): LB Stat=13.4247, p-value=0.2009
  Total Loans to Total
Deposits(%): LB Stat=19.6904, p-value=0.0323
Some residuals exhibit autocorrelation. Consider revising the model.
Forecasted 8 steps ahead on differenced data.
Rescaled forecast and test data to original scale.
```

The Ljung-Box test for FIFTH THIRD shows a good model fit.

VAR（data of FIFTH THIRD）

Forecast

The forecast results for FIFTH THIRD show a promising trend alignment for some variables, though certain deviations suggest that refining the model could further enhance its predictive accuracy.



VAR（data of FIFTH THIRD）

Error

```
RMSE for FIFTH:
UN RATE: 5.2649
FEDFUNDS: 5.4182
Reserve for Loan
Losses(millions): 1029.1867
Provision for Loan Losses(millions): 253.0167
Non-Performing Loans(millions): 251.2524
Total Loans to Total
Deposits(%): 16.3425

MAPE for FIFTH:
UN RATE: 117.36%
FEDFUNDS: 125.92%
Reserve for Loan
Losses(millions): 44.61%
Provision for Loan Losses(millions): 1558.32%
Non-Performing Loans(millions): 41.06%
Total Loans to Total
Deposits(%): 21.20%
```

The error analysis for FIFTH THIRD shows moderate RMSE and MAPE values, indicating reasonable predictive performance

VAR（data of FRCB）

ADF test & use BIC for initial order

```
ADF Test Results Before Differencing:
                                   ADF Statistic   p-value Stationary
UN RATE                                -3.264314  0.016551       True
FEDFUNDS                               -1.871076  0.345788      False
Reserve for Loan\nLosses(millions)     -3.324773  0.013807       True
Provision for Loan Losses(millions)    -2.993829  0.035475       True
Non-Performing Loans(millions)          3.160257       1.0      False
Total Loans to Total\nDeposits(%)      -2.543771  0.105184      False
ADF Test Results After Differencing (First Differencing):
                                   ADF Statistic   p-value Stationary
UN RATE                                -3.224502   0.01861       True
FEDFUNDS                               -3.670341   0.00455       True
Reserve for Loan\nLosses(millions)     -3.254868   0.01702       True
Provision for Loan Losses(millions)    -2.925852  0.042423       True
Non-Performing Loans(millions)          3.467553       1.0      False
Total Loans to Total\nDeposits(%)      -1.345071  0.608309      False
ADF Test Results After Differencing (Second Differencing):
                                   ADF Statistic   p-value Stationary
UN RATE                                -3.170311  0.021769       True
FEDFUNDS                               -3.593217  0.005892       True
Reserve for Loan\nLosses(millions)     -3.178378  0.021271       True
Provision for Loan Losses(millions)    -2.851984  0.051223      False
Non-Performing Loans(millions)          1.138102  0.995529      False
Total Loans to Total\nDeposits(%)      -5.321528  0.000005       True
FCNCA Selected Optimal Lag (BIC): 4
```

The ADF test results show that some variables become stationary after differencing, providing a data foundation for the VAR model.

VAR（data of FRCB）

VAR model

Results for equation Total Loans to Total Deposits(%)

	coefficient	std. error	t-stat	prob
const	11.346225	2.124042	5.342	0.000
L1.UN RATE	-1.206625	0.521899	-2.312	0.021
L1.FEDFUNDS	5.013168	2.153834	2.328	0.020
L1.Reserve for Loan Losses(millions)	0.784814	0.429942	1.825	0.068
L1.Provision for Loan Losses(millions)	-0.770554	0.402571	-1.914	0.056
L1.Non-Performing Loans(millions)	0.029033	0.018148	1.600	0.110
L1.Total Loans to Total Deposits(%)	-0.695090	0.279879	-2.484	0.013
L2.UN RATE	-0.752835	0.620458	-1.213	0.225
L2.FEDFUNDS	5.088210	2.553896	1.992	0.046
L2.Reserve for Loan Losses(millions)	0.672053	0.439326	1.530	0.126
L2.Provision for Loan Losses(millions)	-0.600119	0.435280	-1.379	0.168
L2.Non-Performing Loans(millions)	0.055552	0.027608	2.012	0.044
L2.Total Loans to Total Deposits(%)	-0.358697	0.232899	-1.540	0.124
L3.UN RATE	-0.681218	0.571872	-1.191	0.234
L3.FEDFUNDS	0.185695	3.320259	0.056	0.955
L3.Reserve for Loan Losses(millions)	0.088864	0.290618	0.306	0.760
L3.Provision for Loan Losses(millions)	-0.054527	0.286058	-0.191	0.849
L3.Non-Performing Loans(millions)	0.051440	0.032857	1.566	0.117
L3.Total Loans to Total Deposits(%)	-0.426330	0.184176	-2.315	0.021

Highlighting significant coefficients and statistical relationships, suggesting heightened volatility and liquidity issues compared to other normal banks.

VAR（data of FRCB）

Ljung-Box Test

Ljung-Box tests confirmed residual independence, enhancing model reliability.

FRCB Ljung-Box Test Results:
Results for UN RATE:

	lb_stat	lb_pvalue
1	0.190912	0.662158
2	0.357800	0.836190
3	1.360286	0.714870
4	2.960254	0.564499
5	6.767311	0.238529
6	7.091119	0.312503
7	7.201370	0.408219
8	7.540789	0.479560
9	8.654637	0.469745
10	8.677424	0.562966

Results for FEDFUNDS:

	lb_stat	lb_pvalue
1	0.577601	0.447254
2	0.577833	0.749075
3	0.580956	0.900778
4	0.995833	0.910427
5	1.235693	0.941408
6	1.981020	0.921436
7	2.514819	0.925977
8	2.703318	0.951575
9	6.593922	0.679315
10	6.954750	0.729710

Results for Reserve for Loan Losses(millions):

	lb_stat	lb_pvalue
1	3.392752	0.065484
2	3.603420	0.165016
3	4.657122	0.198696
4	4.691292	0.320464
5	4.920009	0.425720
6	6.976290	0.323045
7	11.212234	0.129626
8	11.460724	0.176935
9	11.500637	0.242946
10	12.084149	0.279464

Results for Provision for Loan Losses(millions):

	lb_stat	lb_pvalue
1	0.487440	0.485072
2	0.541770	0.762704
3	0.545153	0.908865
4	0.581131	0.965137
5	1.193721	0.945478
6	1.738240	0.942131
7	4.091227	0.769212
8	4.268943	0.832080
9	4.450423	0.879350
10	4.610484	0.915635

Results for Non-Performing Loans(millions):

	lb_stat	lb_pvalue
1	2.274524	0.131516
2	2.388692	0.302902
3	3.512181	0.319186
4	12.623364	0.013271
5	17.514797	0.003620
6	17.791053	0.006776
7	18.108625	0.011489
8	19.139413	0.014132
9	21.532464	0.010485
10	21.605156	0.017247

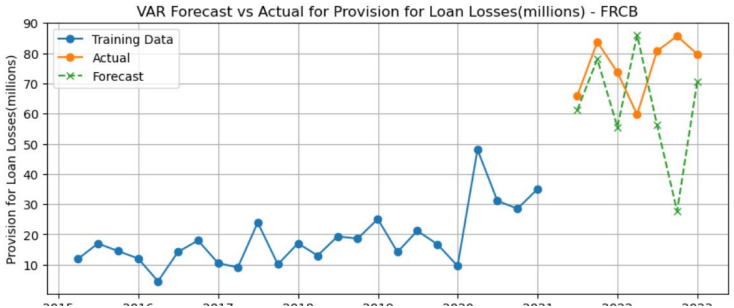
Results for Total Loans to Total Deposits(%):

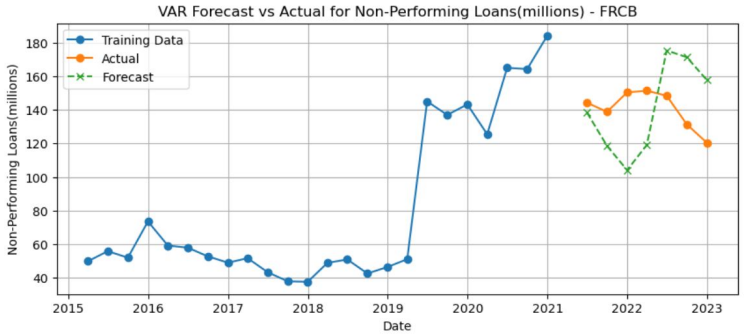
	lb_stat	lb_pvalue
1	0.278353	0.597783
2	0.284057	0.867597
3	0.474737	0.924405
4	1.747259	0.782116
5	2.992068	0.701209
6	5.439460	0.488804
7	5.439840	0.606450
8	6.720238	0.567096
9	6.722850	0.665949
10	8.323685	0.597252

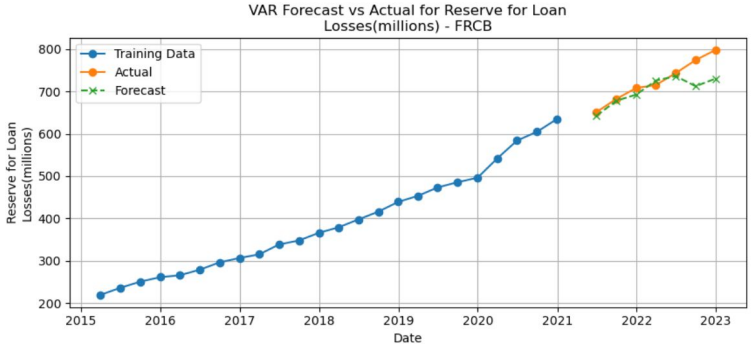
Testing with Lag Order 4...

VAR（data of FRCB）

Forecast







Forecasts revealed FRCB's severe liquidity issues, with significant increases in non-performing loans and loan loss reserves from 2022 to 2023, indicating liquidity shortfalls and high credit risk.

Changing Market Conditions: The loan-to-deposit ratio could be influenced by economic shifts, customer behavior, or bank-specific policies, which the VAR model did not account for.

VAR（data of FRCB）

Error

```
RMSE for FRCB:
UN RATE: 4.3947
FEDFUNDS: 0.8064
Reserve for Loan
Losses(millions): 35.6908
Provision for Loan Losses(millions): 27.0460
Non-Performing Loans(millions): 32.3777
Total Loans to Total
Deposits(%): 7.1882

MAPE for FRCB:
UN RATE: 77.23%
FEDFUNDS: 464.50%
Reserve for Loan
Losses(millions): 3.30%
Provision for Loan Losses(millions): 27.45%
Non-Performing Loans(millions): 21.47%
Total Loans to Total
Deposits(%): 6.67%
```

Total Loans to Total Deposits:

- An **RMSE of ~7.19%** is noteworthy. Given the historical range of this ratio (86.33% to 102.08%).

A **MAPE of 6.67%** is very good, indicating that the model's predictions for this ratio are highly accurate and reliable

Methodology

1. **Data Cleaning and Preparation:**

   - Cleaning
   - [80:20] Data Split

2. **Selection of Lag Order**

   - Use the same optimal lag as VAR

3. **Determine the Cointegration rank**

   - Use the Johansen procedure to choose the smallest number of cointegrating relationships where we fail to reject the null regardless of the number of variables

4. **Decide if VECM model can be applied:**

   1. r = 0: build VAR model on differenced data
   2. 0 < r <= N-1: build VECM
   3. r > N-1: build VAR model on data in levels

VECM (data of USB)

Model Selection based on Cointegration Rank:

```
Cointegration Rank (r) for USB: 6

Suggested Model Type for USB: VAR model on data in levels
Model type is not suitable for USB. Exiting.
```

VECM (data of FRCB)

Model Selection based on Cointegration Rank:

```
Cointegration Rank (r) for FRCB: 5

Suggested Model Type for FRCB: VECM model
```

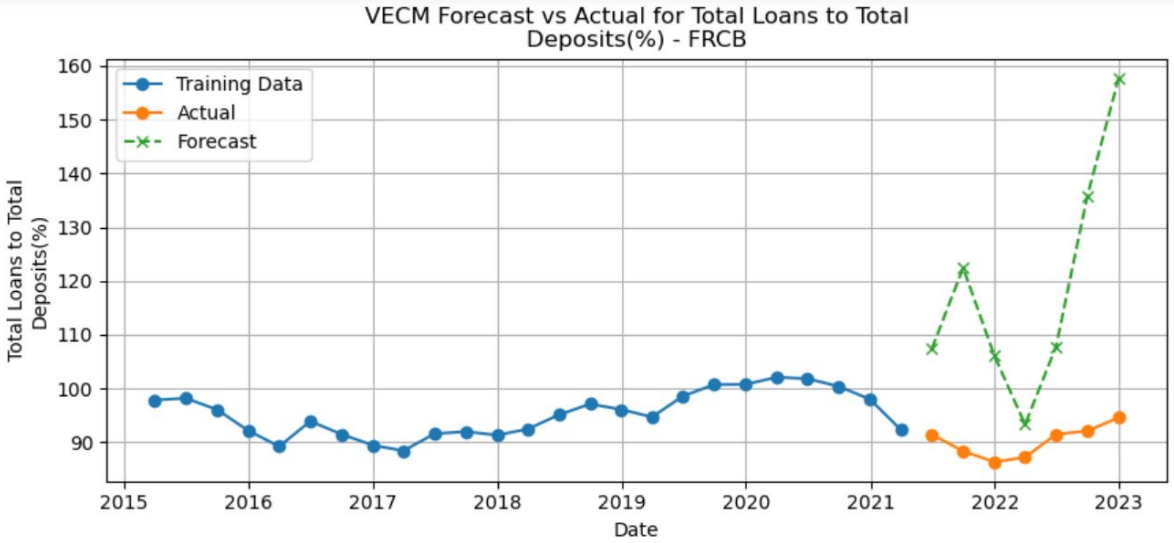
Error:

```
RMSE for FRCB:
UN RATE: 8.072772455743495
FEDFUNDS: 5.08910330130808
Reserve for Loan
Losses(millions): 93.64364489300564
Provision for Loan Losses(millions): 48.50333786976513
Non-Performing Loans(millions): 162.5723880215586
Total Loans to Total
Deposits(%): 33.83578946696481

MAPE for FRCB:
UN RATE: 173.51549033814095%
FEDFUNDS: 1590.1561738616952%
Reserve for Loan
Losses(millions): 11.699113220123218%
Provision for Loan Losses(millions): 164.31671563039794%
Non-Performing Loans(millions): 117.15817999364096%
Total Loans to Total
Deposits(%): 31.143181215913803%
```

Strengths:
Reasonable predictive accuracy for Reserve for Loan Losses and Total Loans to Total Deposits.

VECM (data of FRCB)

Forecast:



Performance Interpretation:

Overprediction: The VECM model appears to overpredict the ratio significantly for the forecast period.

Possible Explanations:

1. **Economic or Structural Changes:** The sudden divergence might reflect economic or bank-specific factors not accounted for in the training period.
2. **Potential Model Limitation:** Since VECM models are designed to capture long-term equilibrium relationships, it's possible that the model struggled with shorter-term variations or structural changes in FRCRB's loan-to-deposit dynamics.

VECM (data of Citizens)

Model Selection based on Cointegration Rank:

```
Cointegration Rank (r) for Citizens: 3

Suggested Model Type for Citizens: VECM model
```

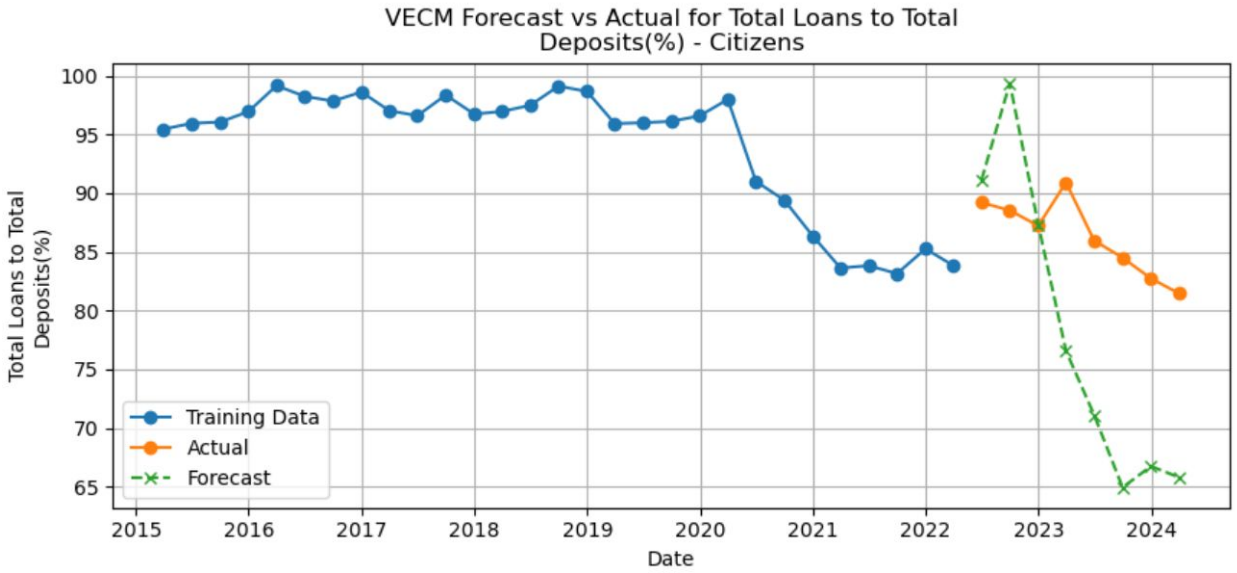
Error:

```
RMSE for Citizens:
UN RATE: 9.410835348482978
FEDFUNDS: 9.217450266875273
Reserve for Loan
Losses(millions): 1479.022358706579
Provision for Loan Losses(millions): 546.4736451179074
Non-Performing Loans(millions): 698.6200466509035
Total Loans to Total
Deposits(%): 13.373837149490804

MAPE for Citizens:
UN RATE: 223.37500300458197%
FEDFUNDS: 225.62990547682716%
Reserve for Loan
Losses(millions): 63.354574265303775%
Provision for Loan Losses(millions): 315.92004539119625%
Non-Performing Loans(millions): 57.43481145941727%
Total Loans to Total
Deposits(%): 13.654160501855827%
```

Strengths:
Acceptable accuracy for Total Loans to Total Deposits and moderate performance for Non-Performing Loans.

VECM (data of Citizens)

Forecast:



Performance Interpretation:

Underprediction: The VECM model underpredicts the "Total Loans to Total Deposits" ratio, forecasting a sharp decline that does not align with the stable historical trend..

Possible Explanations:

1. **Trend Misinterpretation:** The training data shows a gradual decline in recent years, which the VECM model might interpret as a signal for a continuous sharp decline. However, this interpretation appears inaccurate in the test period.
2. **External Economic Factors:** Similar to FRCRB, external factors like changes in customer behavior, market conditions, or interest rates may influence the bank's deposit-loan dynamics and are not reflected in the model.

Comparison of Models for FRCB

Model	RMSE	MAPE	Forecast Accuracy	Key Strengths	Key Weaknesses	Trend Capture	Suitability for Stability Analysis
OLS	4.05	4.16%	High	Simple, interpretable; captures overall trend well	May miss complex patterns or sudden shifts	Good	Suitable; stable model for gradual changes
ARIMA	4.2	3.73%	High	Effective for linear trends and seasonality	Underestimates sharp trend reversals in volatile periods	Good	Suitable; flexible but less adaptive to extreme shifts
VAR	7.19	6.67%	Moderate	Handles multiple interdependent variables well	High error; struggles with short-term fluctuations	Moderate	Less suitable; accuracy dependent on variable relationships
VECM	33.84	31.14%	Low	Suitable for cointegrated series with long-term relationships	High error, significant overestimation of trend	Poor	Unsuitable; fails in short-term forecasting for liquidity ratios

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