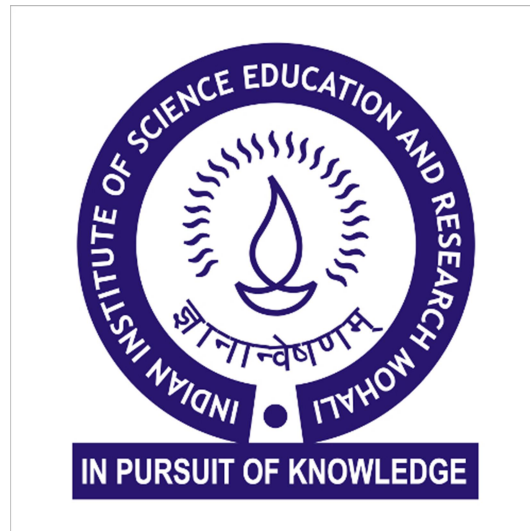


MS Thesis Report:

Financial Systems

Thesis Guide- Dr. Sudeshna Sinha



Indian Institute of Science Education and Research, Mohali

Ishita Katyal

MS13046

April 2018

CERTIFICATE

This is to certify that the dissertation titled 'Financial Systems' submitted by Ishita Katyal (Reg. No. MS13046) for the partial fulfillment of BS MS dual degree program of IISER has been examined by the thesis committee duly appointed by the institute. The committee finds the work done by the candidate satisfactory and recommends that the report be accepted.

Dr. Rajiv Kapri

Dr. Abhishek Chaudhary

Dr. Sudeshna Sinha

(Supervisor)

Date:

DECLARATION

This is to certify that I, Ishita Katyal, final year MS Student at IISER-Indian Institute of Science Education and Research, Mohali has taken up a project titled 'Financial Systems' as a part of my MS thesis. In addition, my project guide is Professor Sudeshna Sinha under whose able guidance I have spent an year doing this project from August 2017 to April 2018.

This work has not been submitted in part or in full for a degree, a diploma or fellowship for any other institute or university. Whenever contributions of others are involved, every effort is made to indicate that clearly with due acknowledgement of collaborative research and discussions This thesis is a bonafide record of the original work done and all sources listed have been detailed in bibliography.

Candidate's Signature

Date:

In my capacity as a supervisor of the candidate's project work, I certify that the above statements are true to the best of my knowledge.

Signature of the Guide

Place: Mohali

Date:

ACKNOWLEDGEMENT

I would like to thank the institute IISER Mohali for giving me an opportunity to work on this topic as my thesis project. I would also like to present my gratitude to Prof. Sudeshna Sinha for her able guidance on this subject.

I am also very thankful to Pranay Deep Rungta and Chandrakala Meena for encouraging me throughout the project. I would also like to thank my family for moral support and strength.

PREFACE

The thesis work is divided into two parts according to the odd and even semester.

1. ODD Semester- Finding patterns in Financial Data

This semester includes work on the time series analysis of the stock market prices of the banking industry in chapter 01. In chapter 02, there is fast Fourier analysis and log-log plot analysis of the data. Chapter 03 includes cross correlation graphs of the banking industry to obtain a cross correlation between the several variables of the data set.

2. EVEN Semester- Chaos model of liquidity

This semester includes reading and understanding of a research paper titled 'Chaos model of liquidity' by You Chen, Zhang Xinmin and Song Xuefeng in chapter 04. It also includes writing codes in C++ and/or python for facilitating the understanding of the equations in chapter 05.

In addition, chapter-06 has some of the variables plotted in a 3d plot scheme to replicate the phase spaces as mentioned in the paper.

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PART-01 ODD SEMESTER

It includes statistical analysis of the stock market prices of the banking industry. This includes analyzing the stock market prices of open, close, highest and lowest stock market prices for a day. The data set chosen are eight national banks, seven private and six foreign banks with branches in India.

Sample Data Set-

The dataset includes the opening, closing, highest and lowest stock market prices for a day for

a) National banks- Allahabad Bank, Bank of India, Canara Bank, Central Bank, Corporation Bank, Indian Bank, State Bank of India and Syndicate Bank;

b) Private Banks- Axis Bank, Federal bank, Housing Development Finance Corporation Bank (HDFC), Jammu and Kashmir Bank, Kotak Bank, South Bank and Yes Bank; and

c) Foreign Banks with branches in India- BAC Florida Bank, Bank of Nova Scotia, Commonwealth Bank of Australia, Deutsche Bank, Doha Bank, HongKong and Shanghai Banking Corporation Limited.

The data has been collected in two regular intervals of daily and monthly doses. The data starts from January 2000 to May 2017.

Chapter: 01

TIME SERIES ANALYSIS-

Time series analysis emphasizes the presence of an internal structure in the data points taken over time. Plotting time series highlights any trend, autocorrelation or seasonal variation present in the data points. It arises often when monitoring industrial processes or tracking corporate business metrics.

The opening, closing, highest and lowest stock market prices of these banks have been plotted against time since 2002 to February 2018 to look out for any trend that existed. Series analysis can be divided into two classes- frequency domain and time domain. Frequency analysis includes power spectral density analysis whereas the latter include auto-correlation and cross-correlation.

ANNEXURE-A: TIME SERIES ANALYSIS

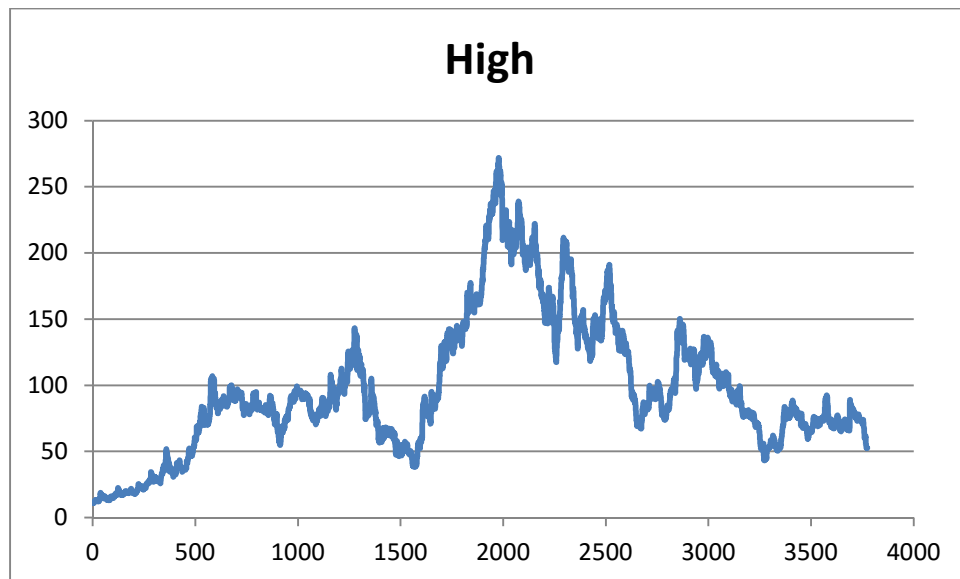
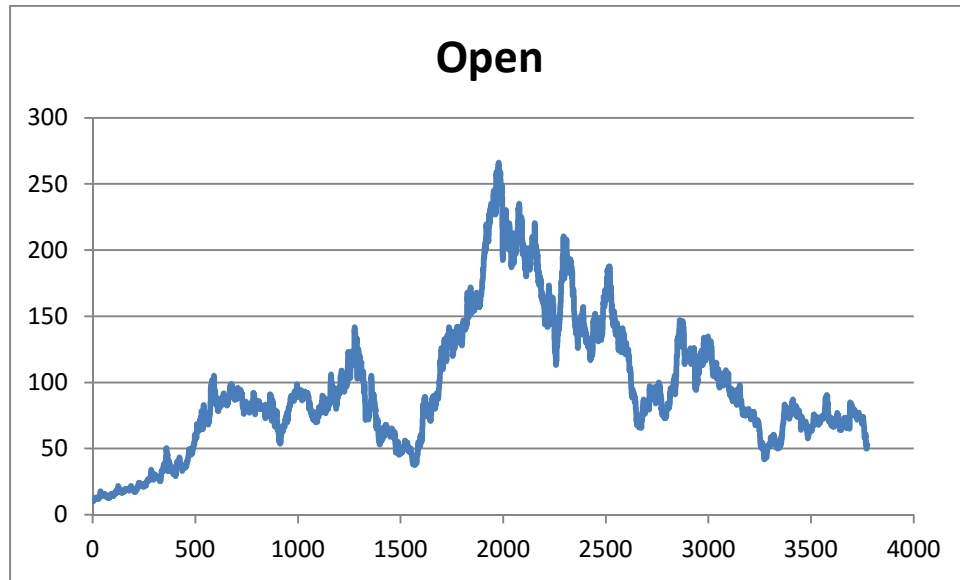
Time series analysis is a statistical technique that deals with time series data or trend analysis. The data set is spread over time which is distributed in regular intervals (daily; till 26/02/2018).

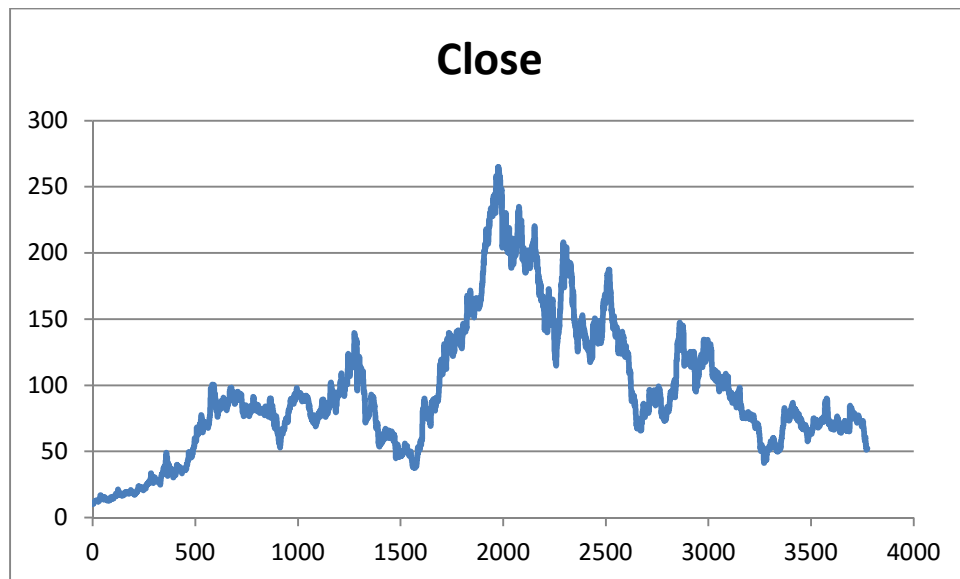
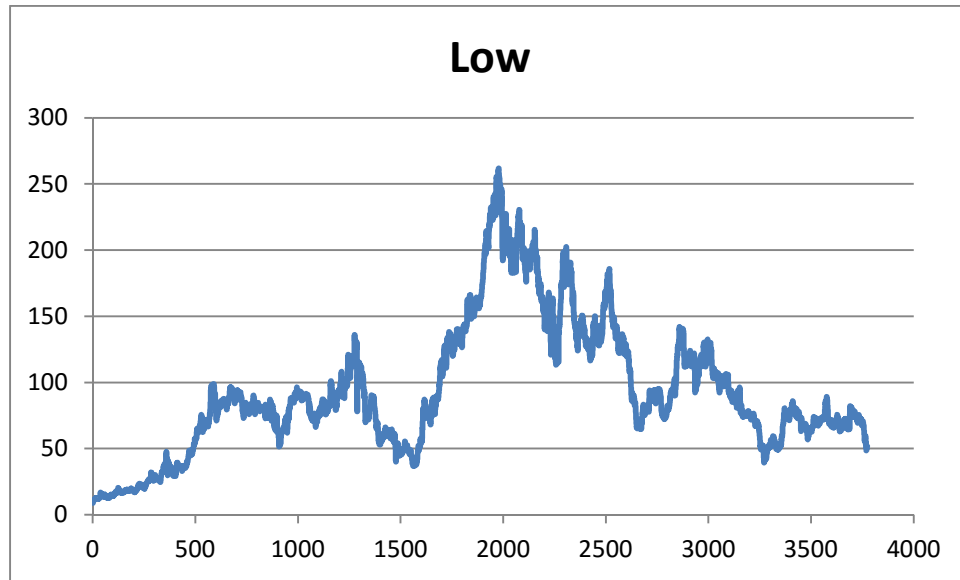
Name of Bank	Data from	Number of points
Allahabad Bank	29/11/2002	3774
Bank of India	01/07/2002	3871
Canara Bank	23/12/2002	3753
Central Bank	21/8/2007	2591
Corporation Bank	01/07/2002	3871
Indian Bank	01/03/2002	2709
State Bank Of India	01/01/2001	4227
Syndicate Bank	01/07/2002	3871
Axis Bank	01/01/2001	4235
Federal Bank	02/07/2001	4137
HDFC Bank	01/01/2001	4245
J&K bank	12/08/2002	3170
Kotak Bank	02/07/2001	4133
South Bank	01/01/2001	4241
Yes Bank	12/07/2005	3111
BAC Florida Bank	02/01/2001	4314
Bank of Nova Scotia	02/01/2001	4314
Commonwealth Bank of Australia	01/01/2001	4340
Deutsche Bank	02/01/2001	4314
Doha Bank	22/02/2010	1980
HongKong & Shanghai Banking corporation Limited	27/10/2006	2601

x-axis: Number of points as per the date (schedule)

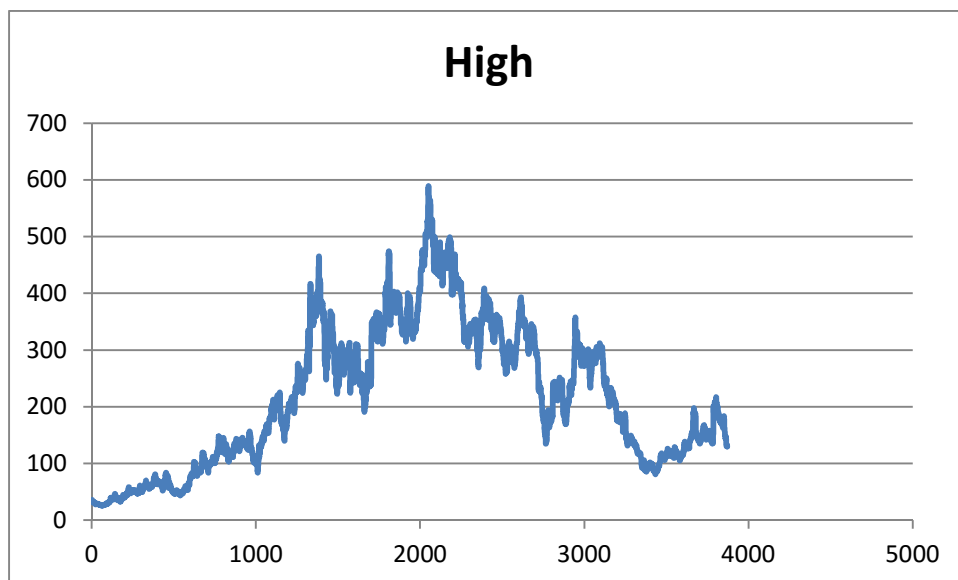
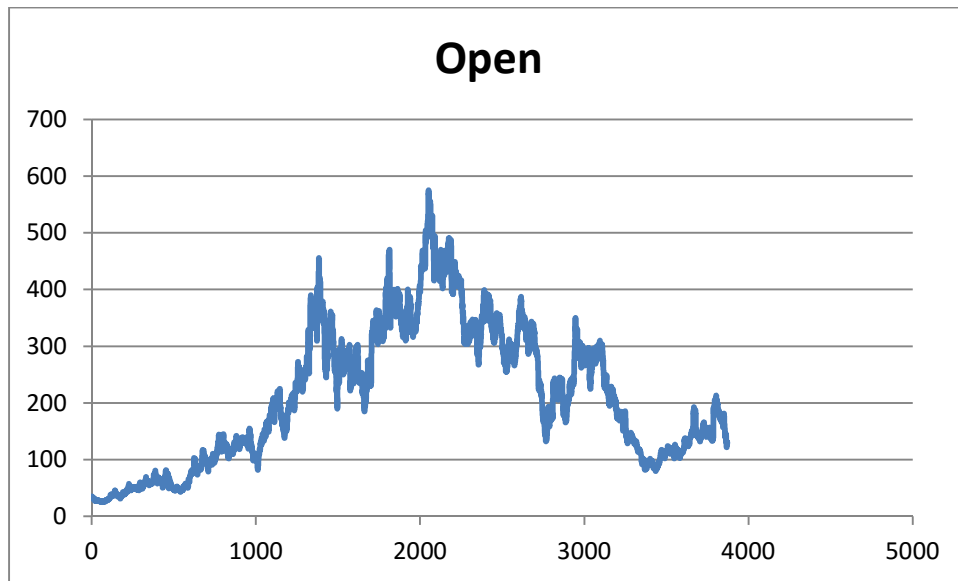
y-axis: Stock Market price(in dividend proportion)

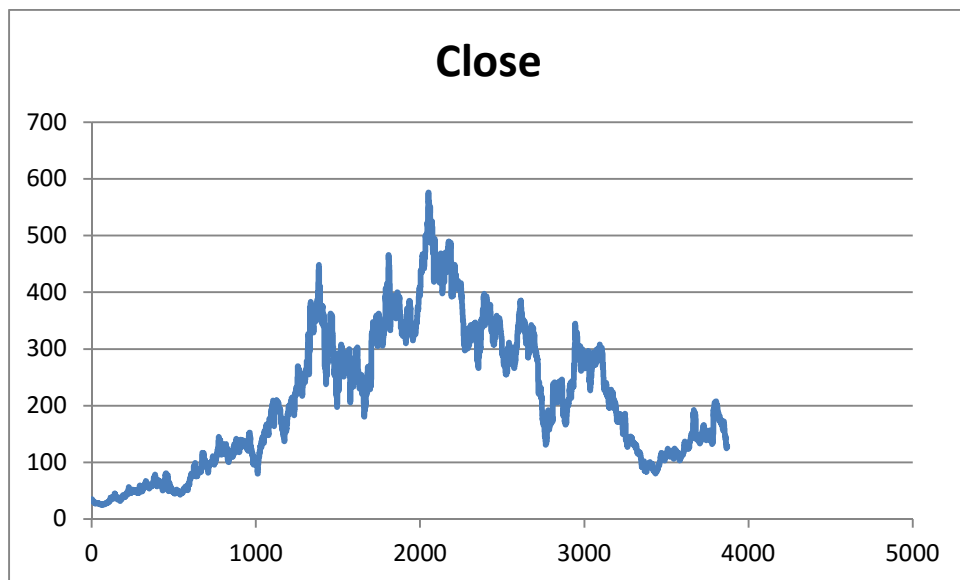
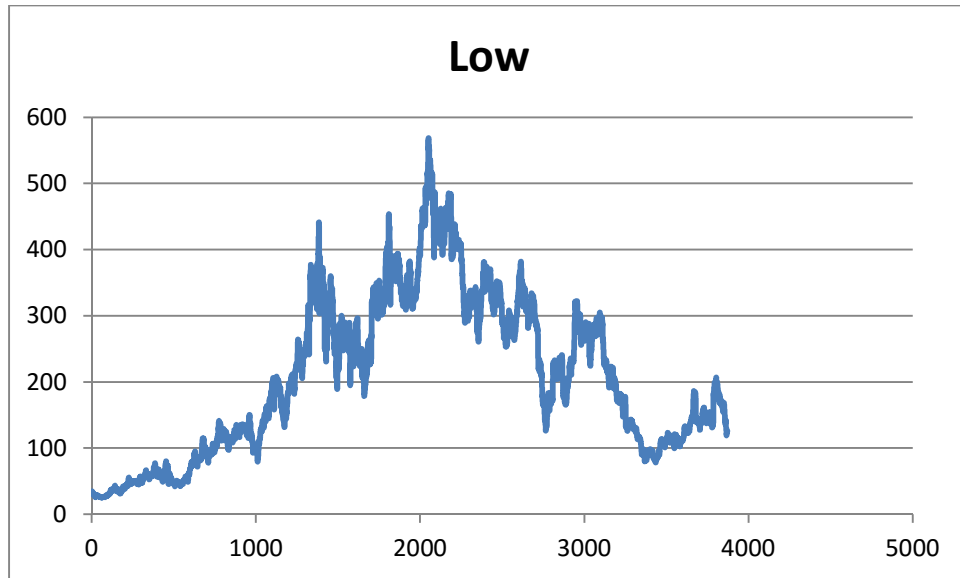
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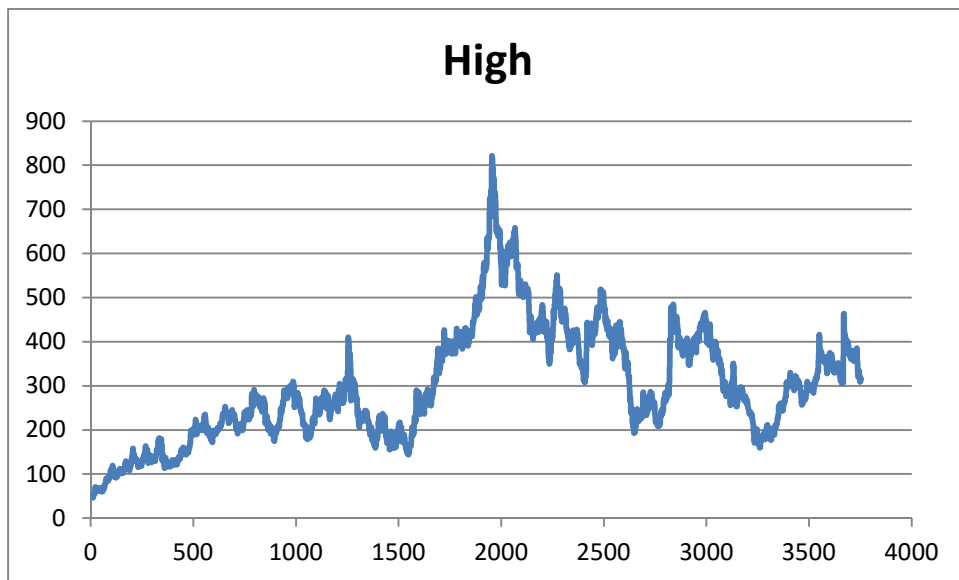
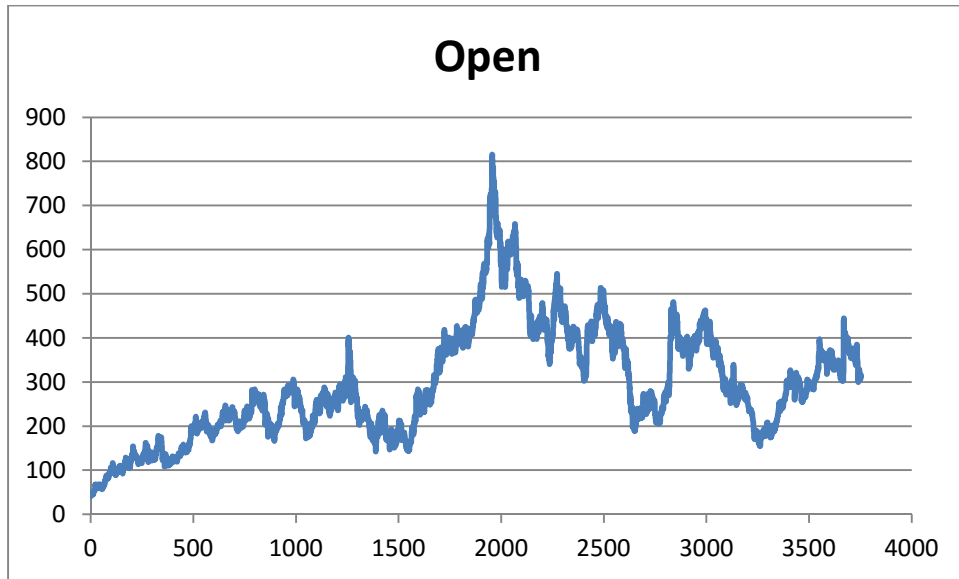


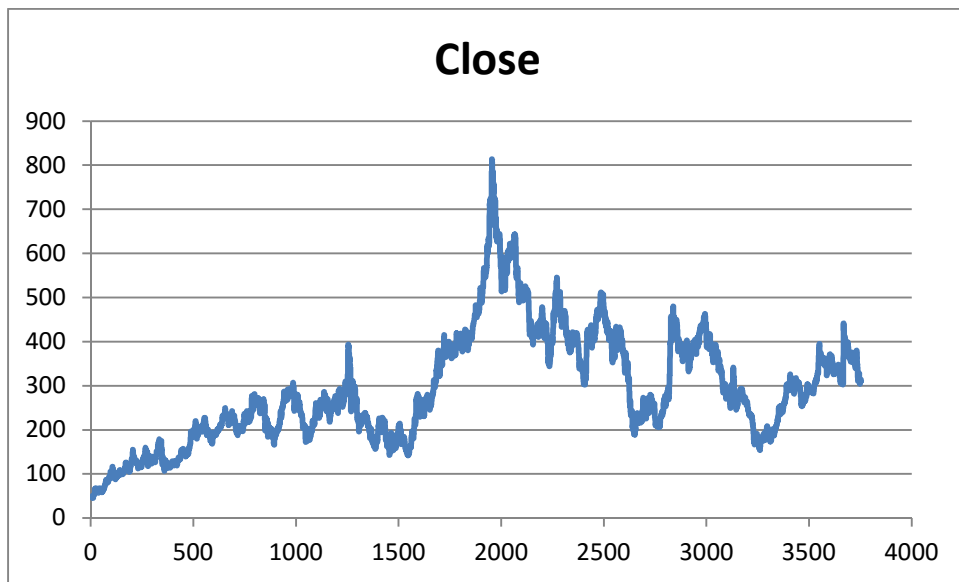
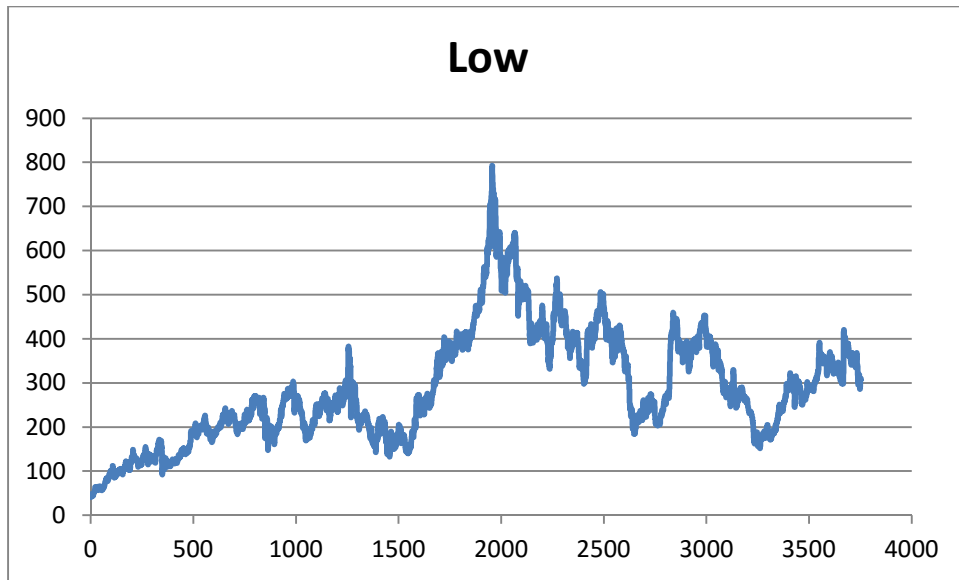
2. Bank Of India



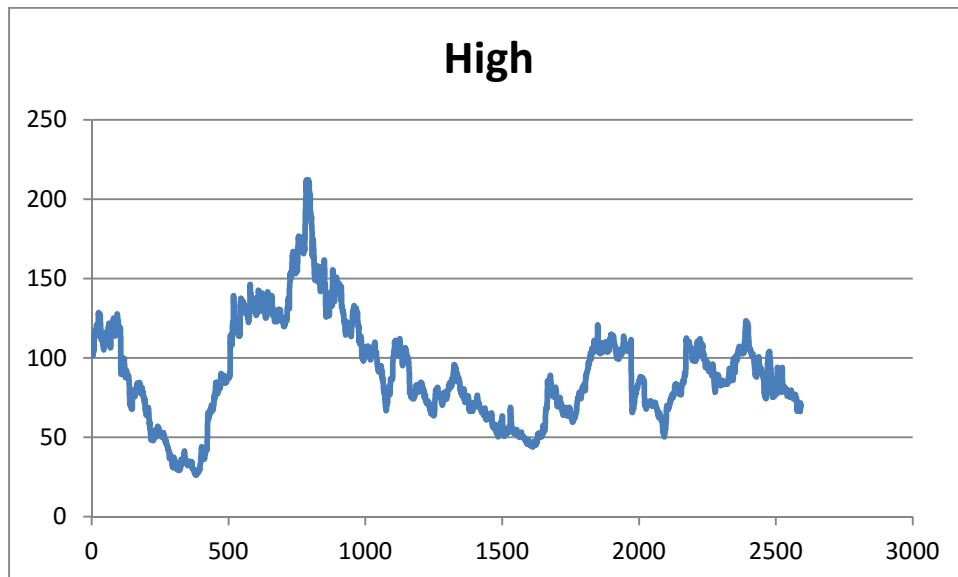
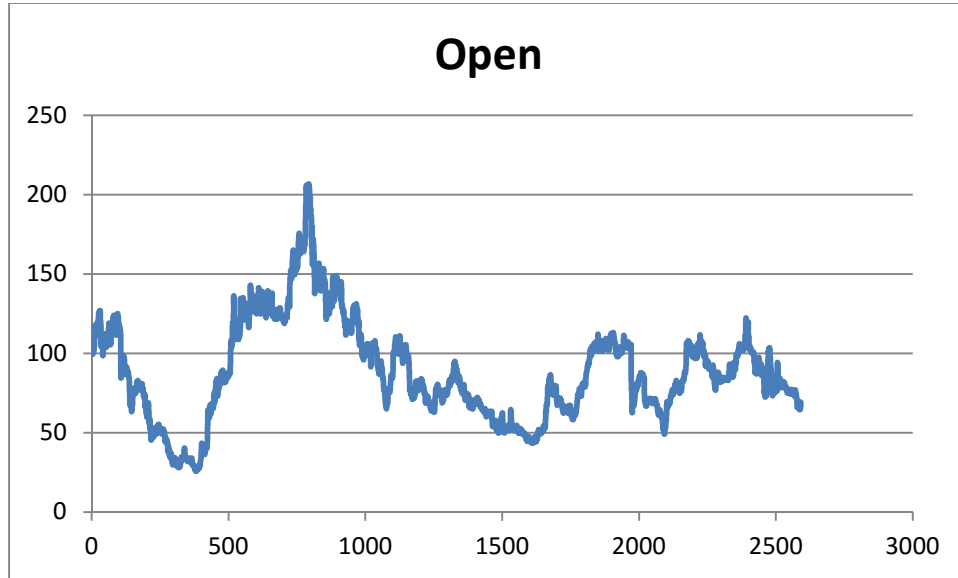


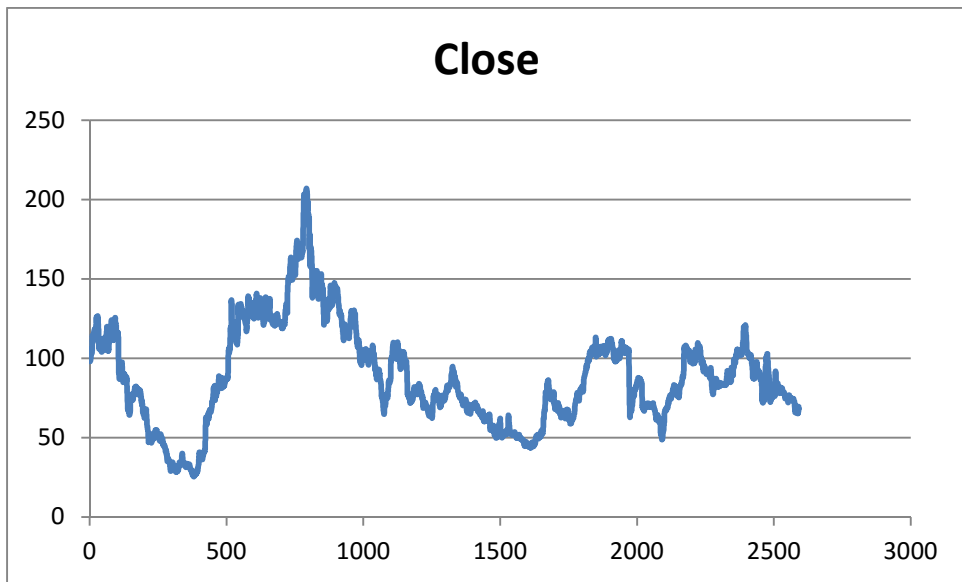
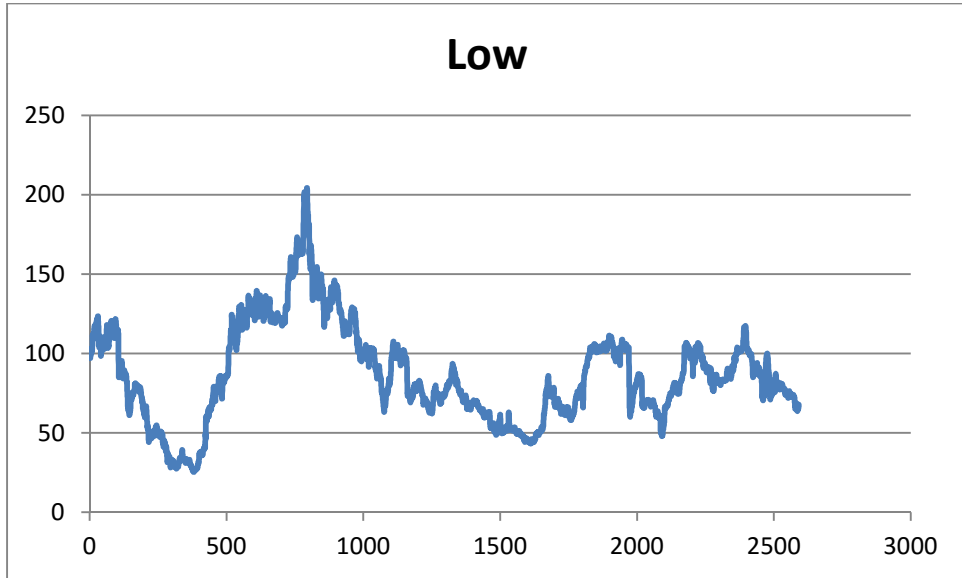
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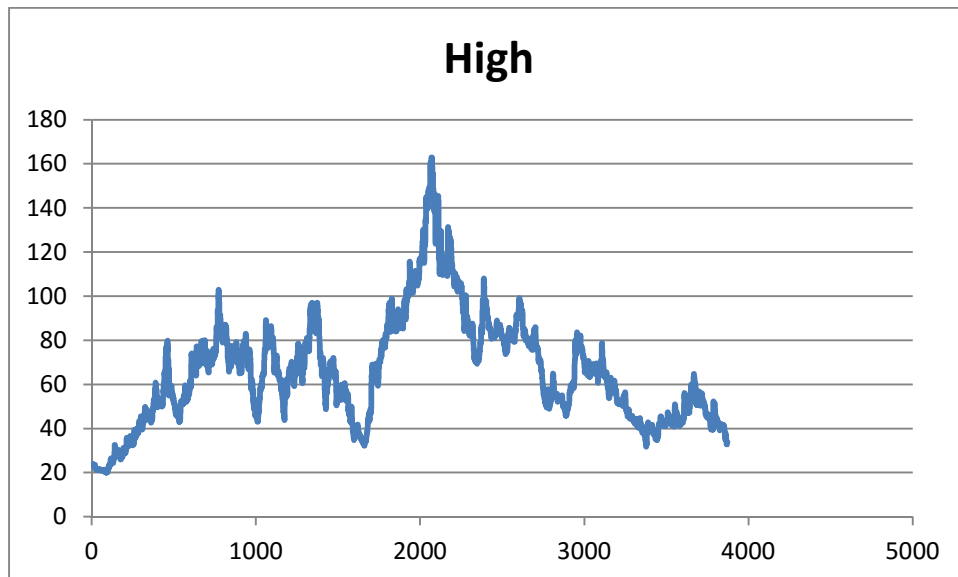
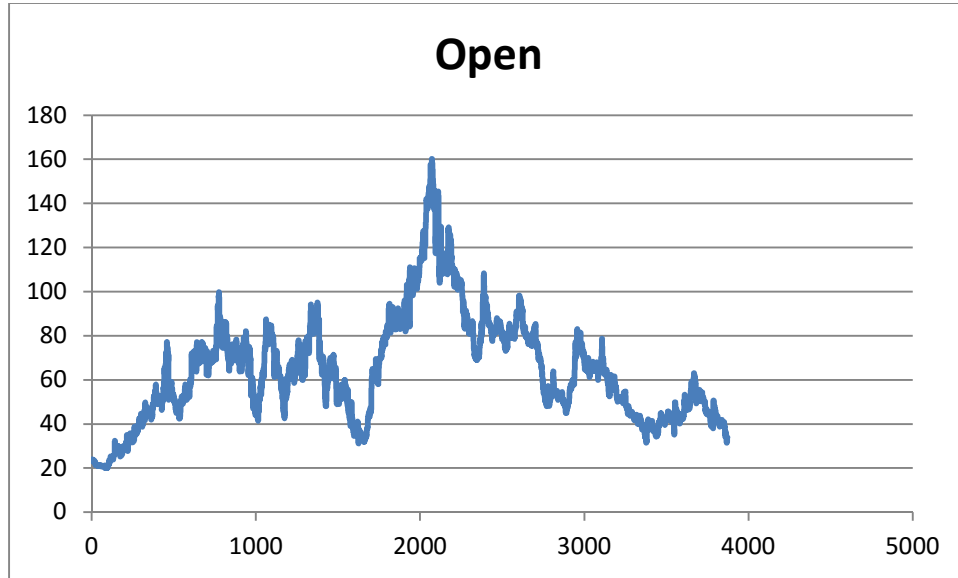


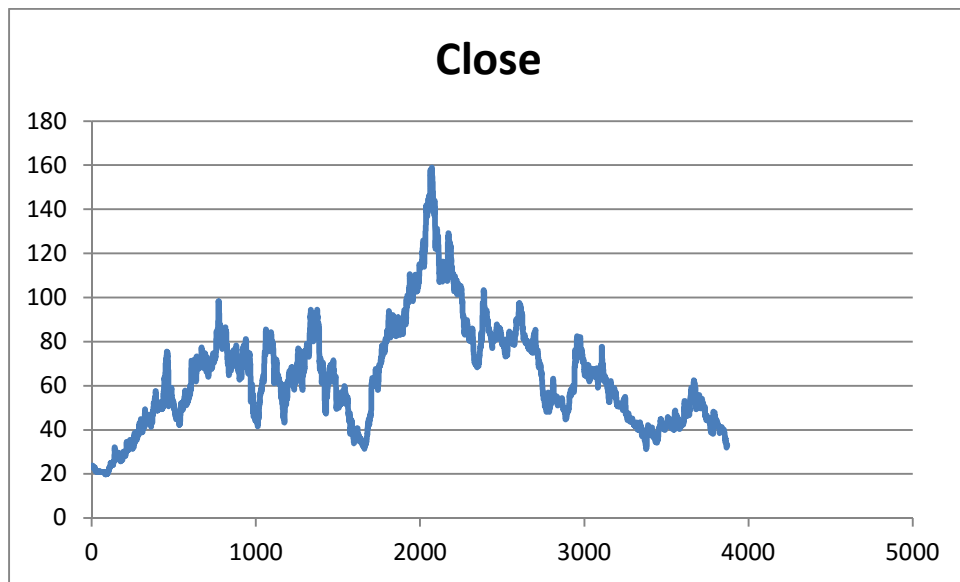
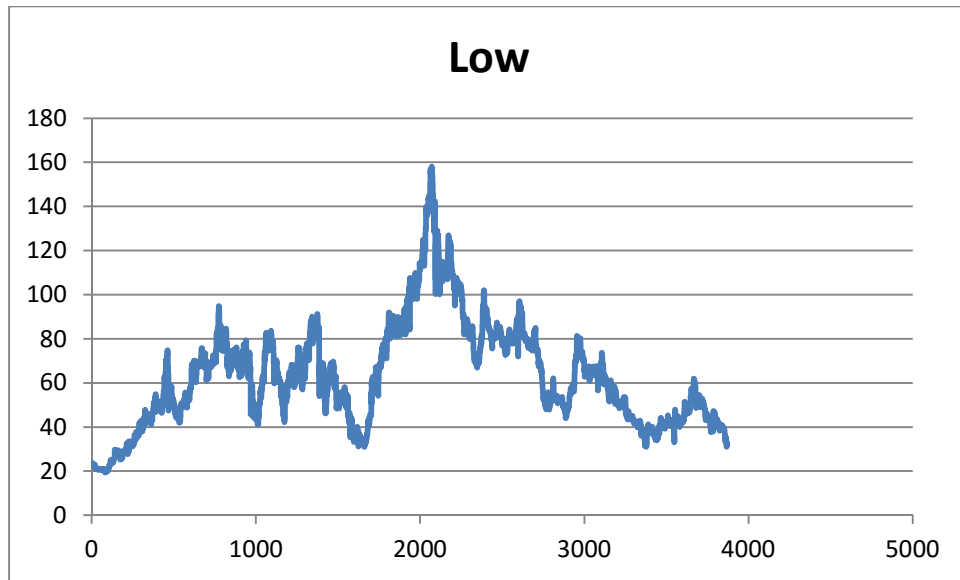
4. Central Bank



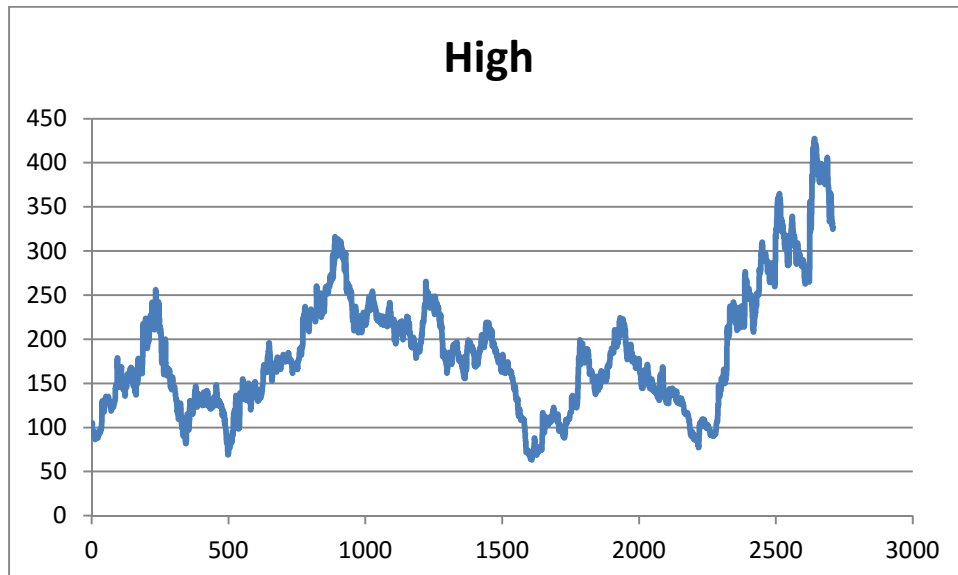
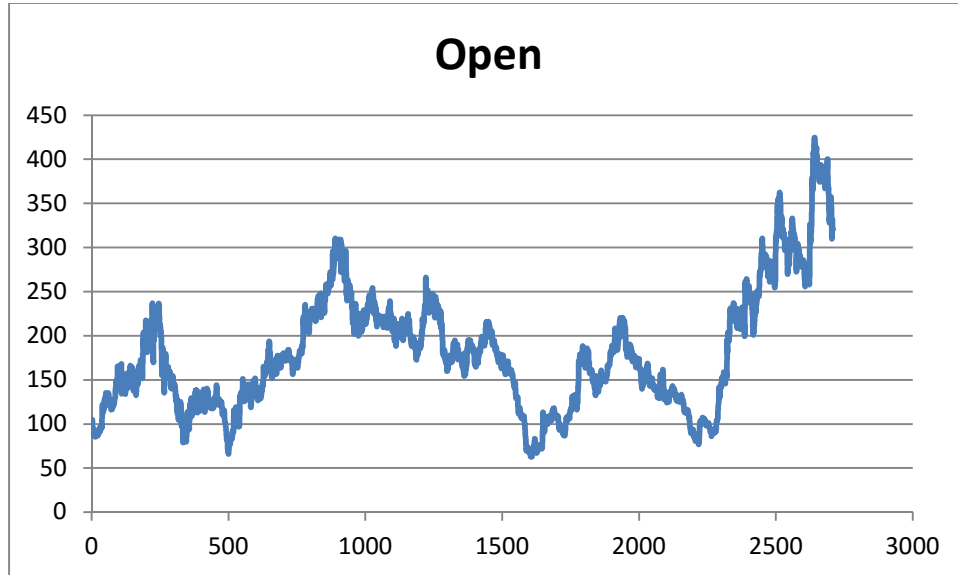


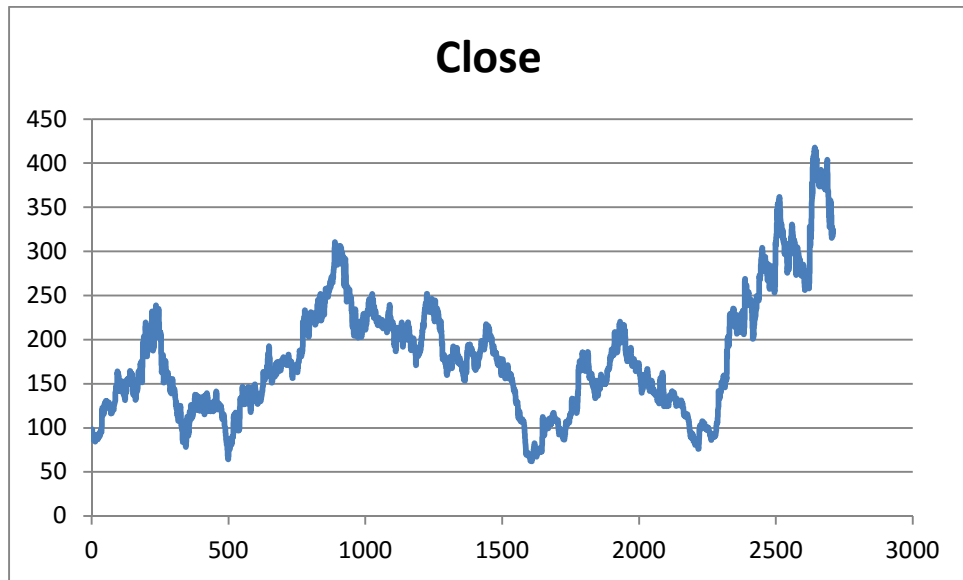
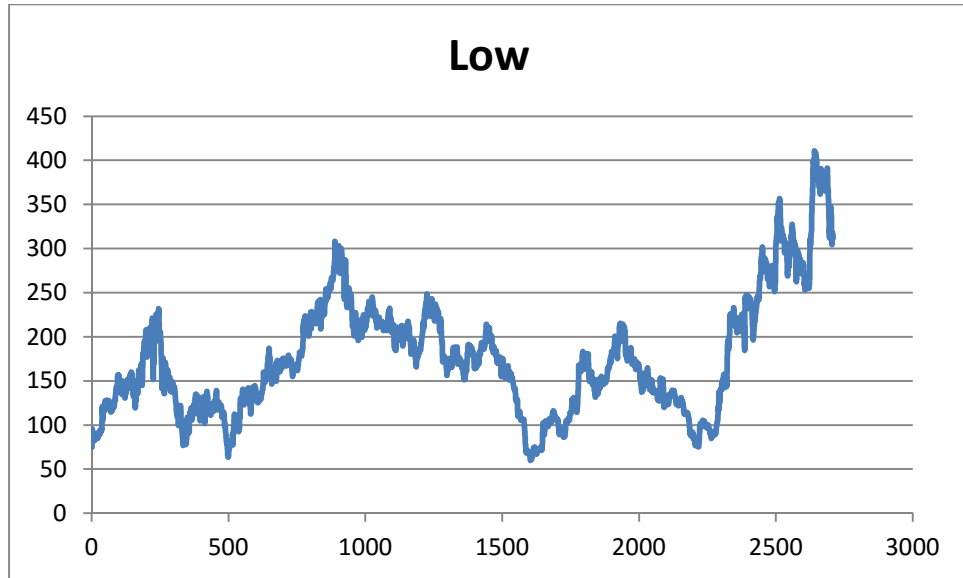
5. Corporation Bank



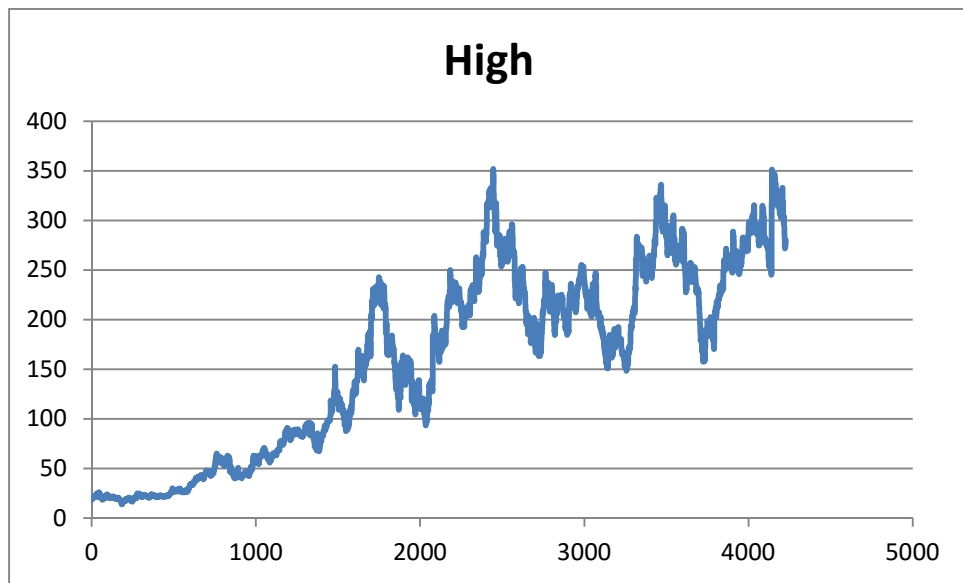
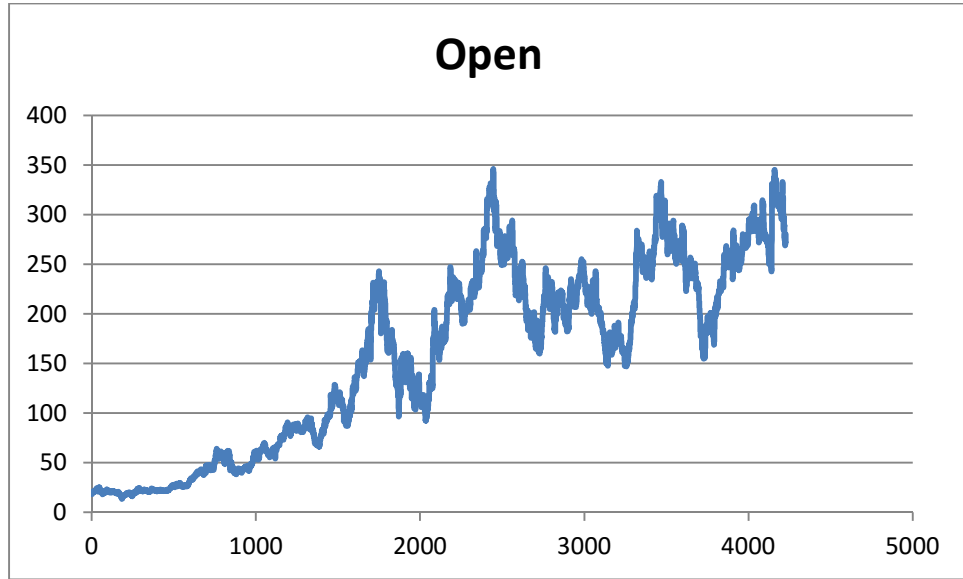


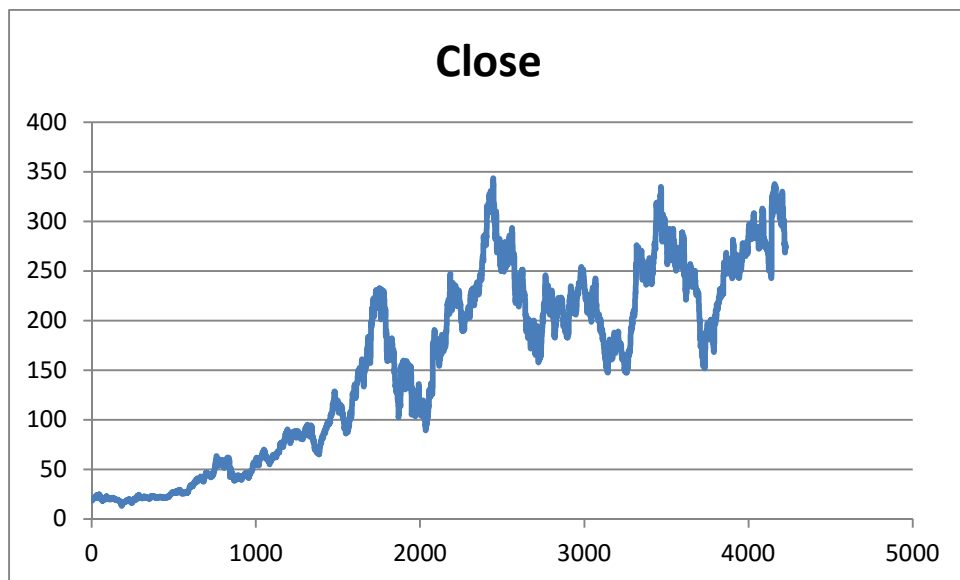
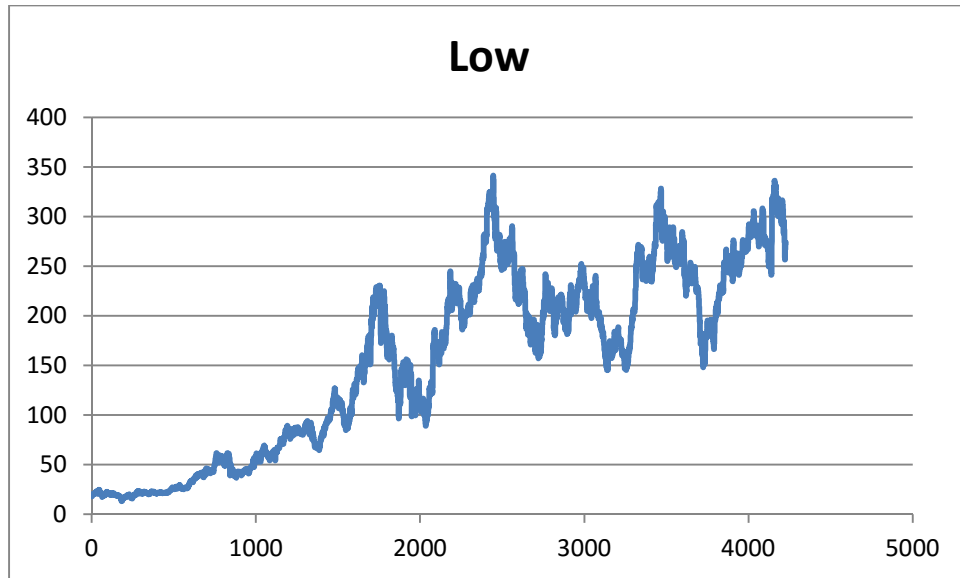
6. Indian Bank



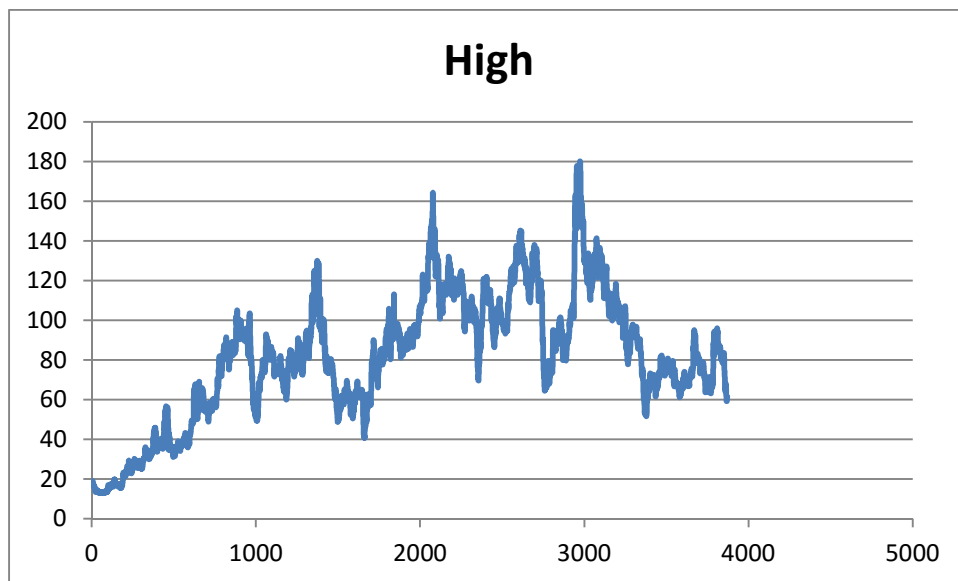
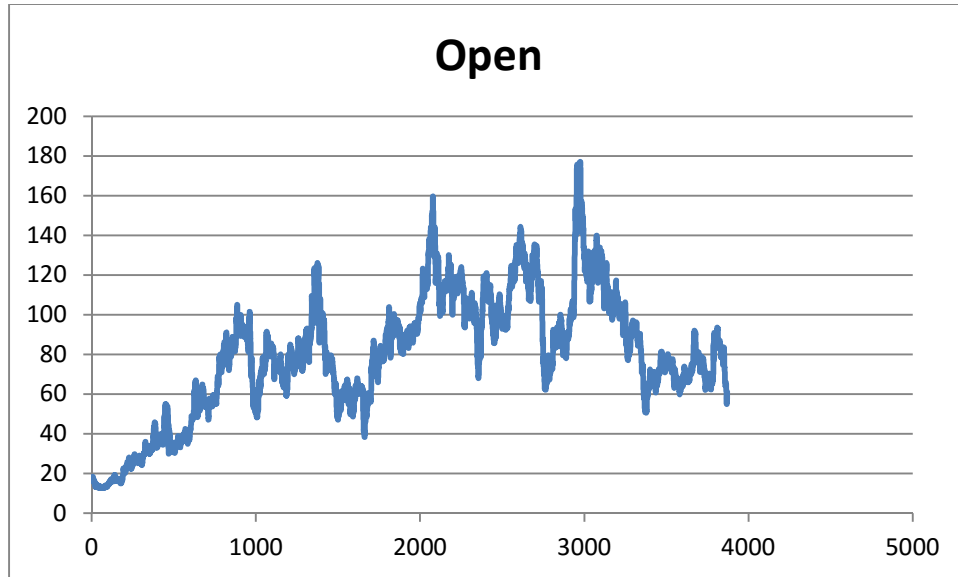


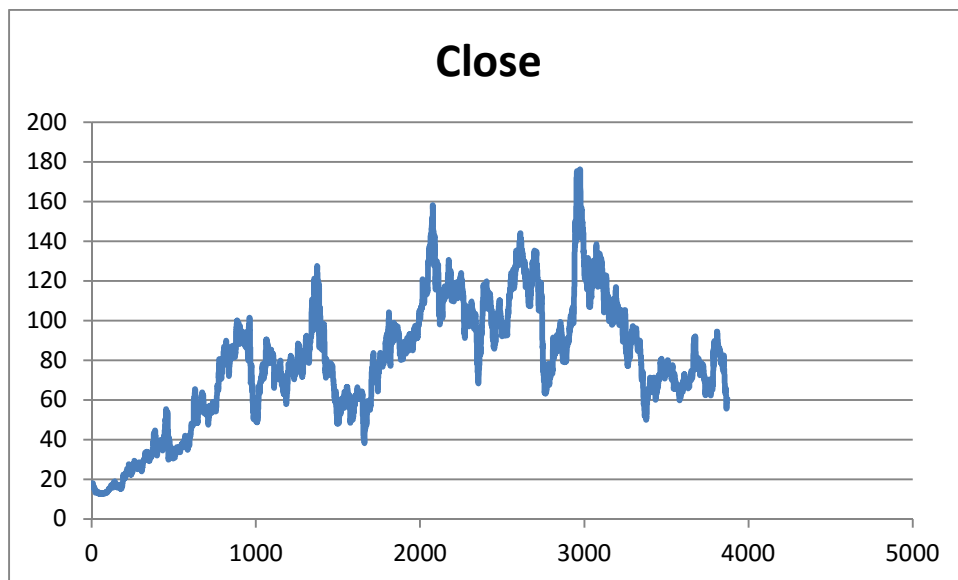
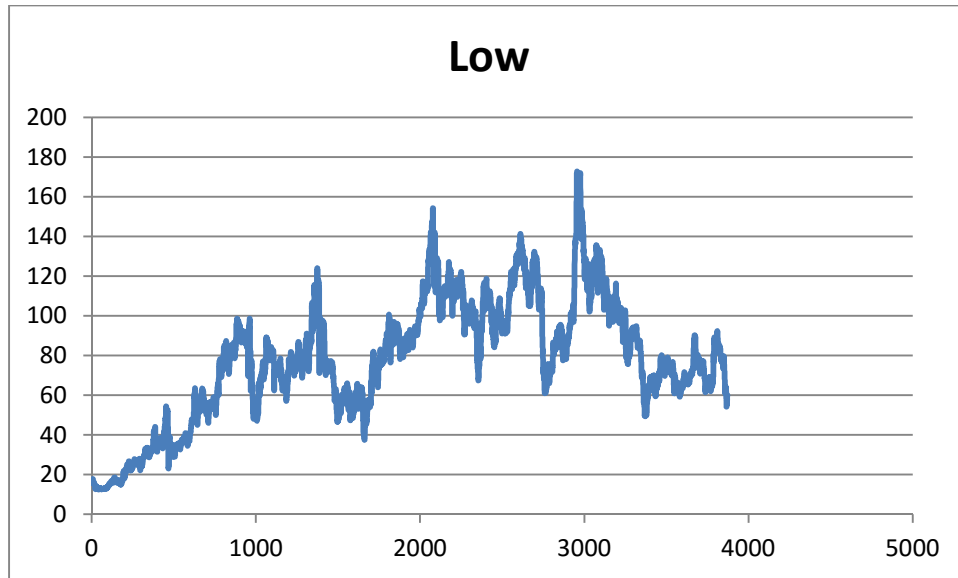
7. State Bank of India



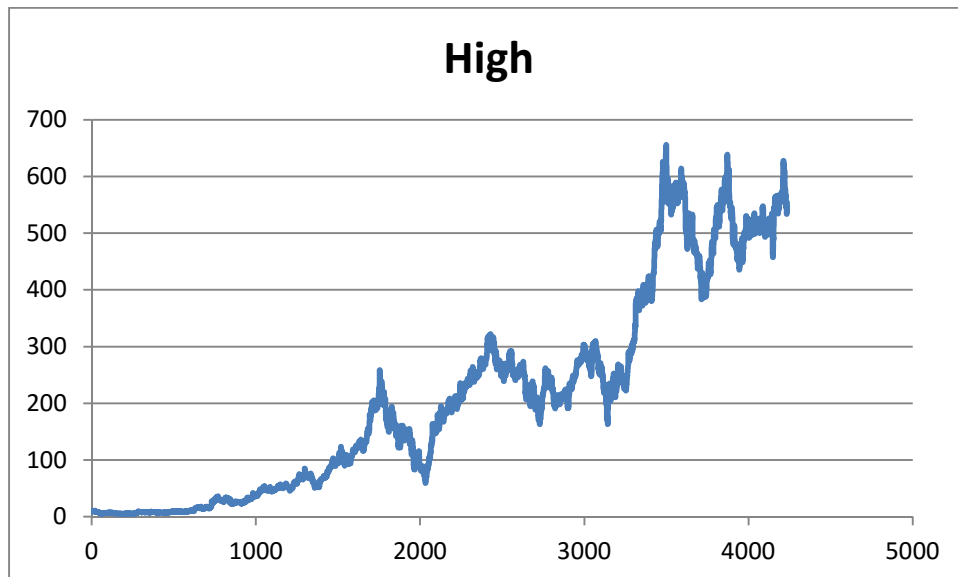
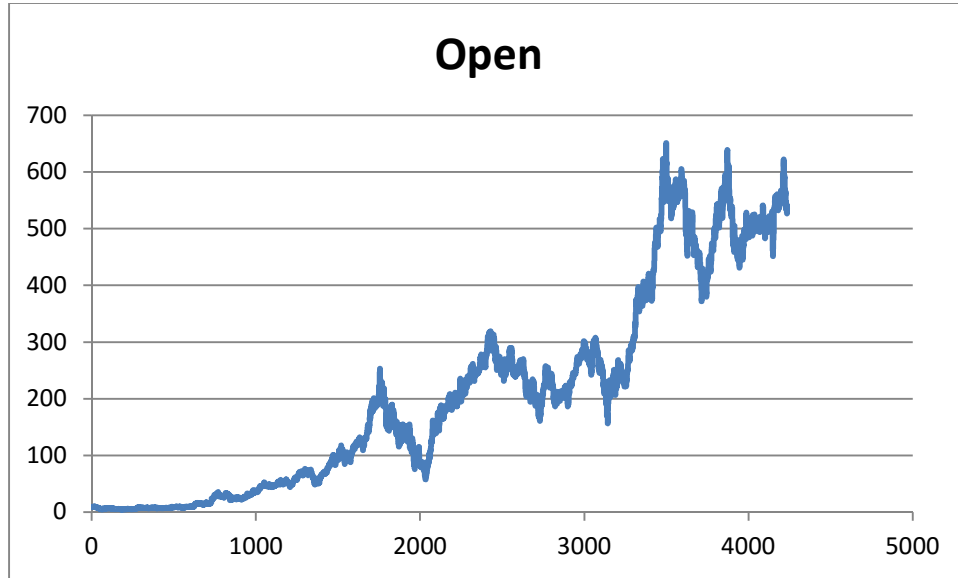


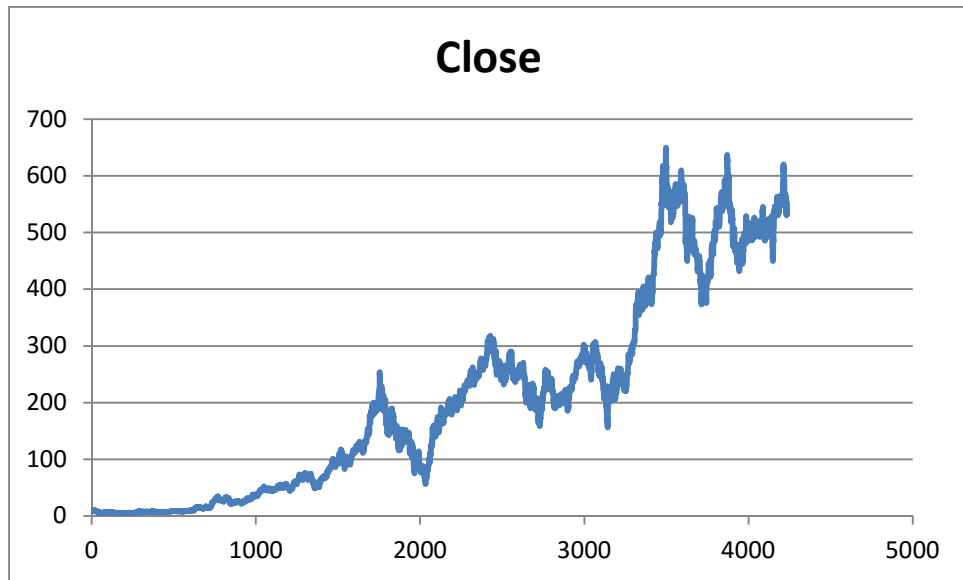
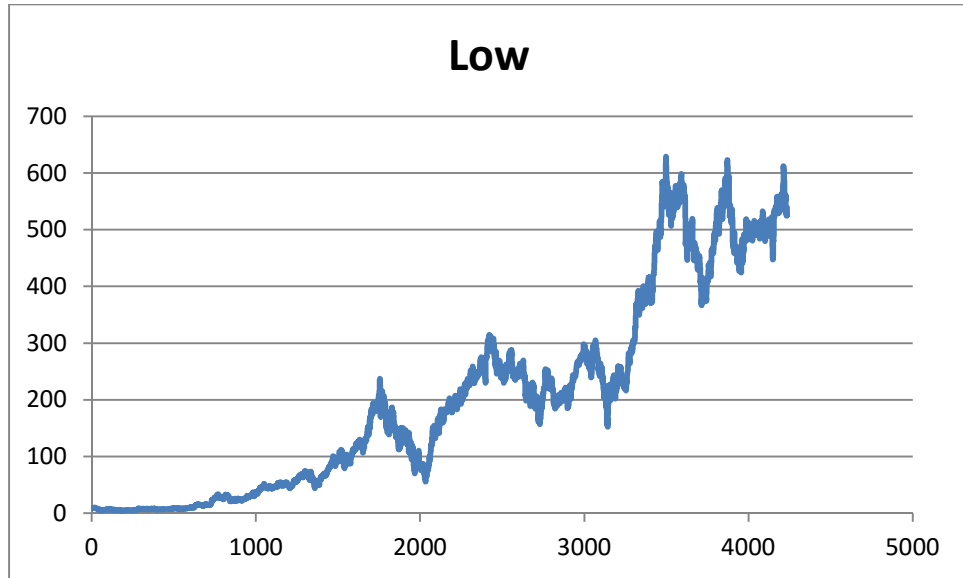
8. Syndicate Bank



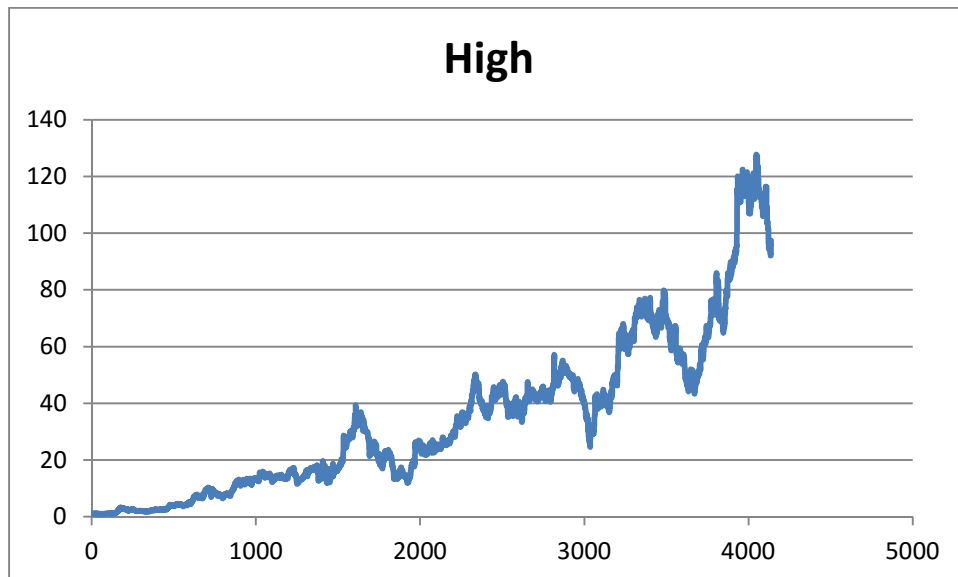
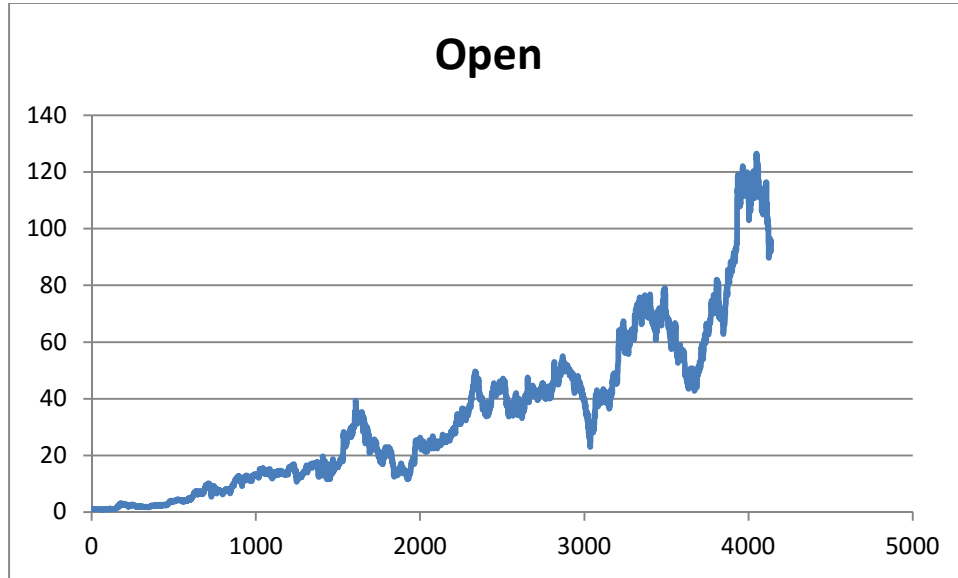


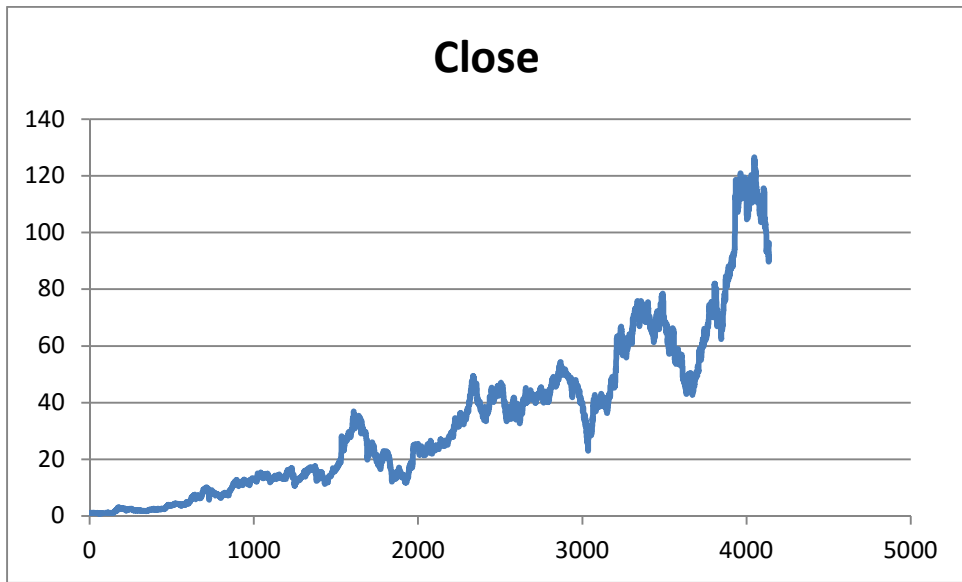
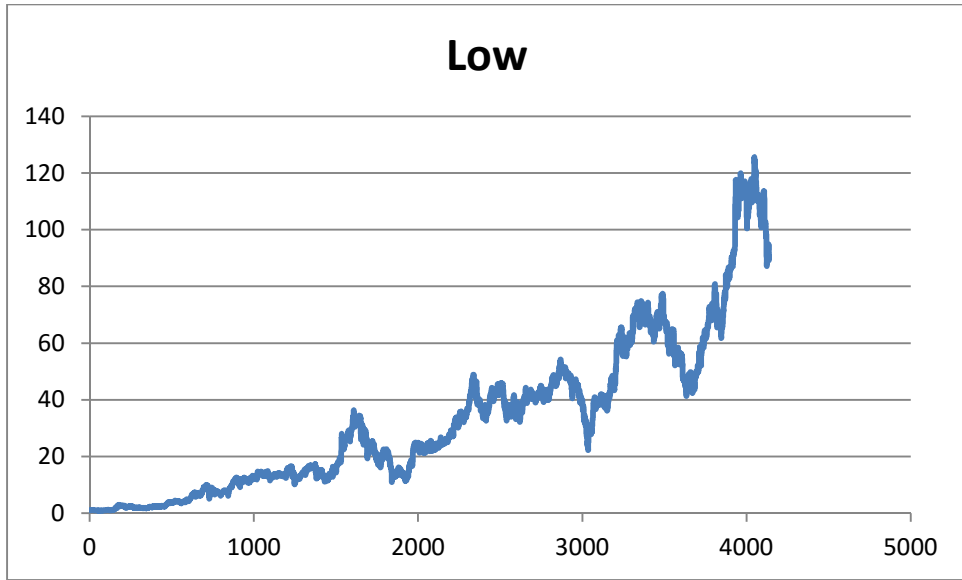
9. Axis Bank



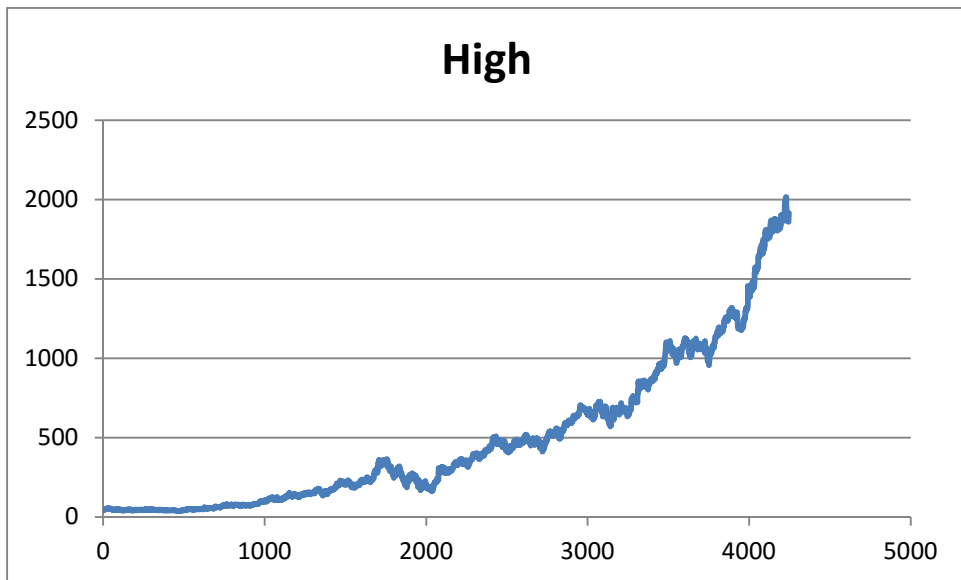
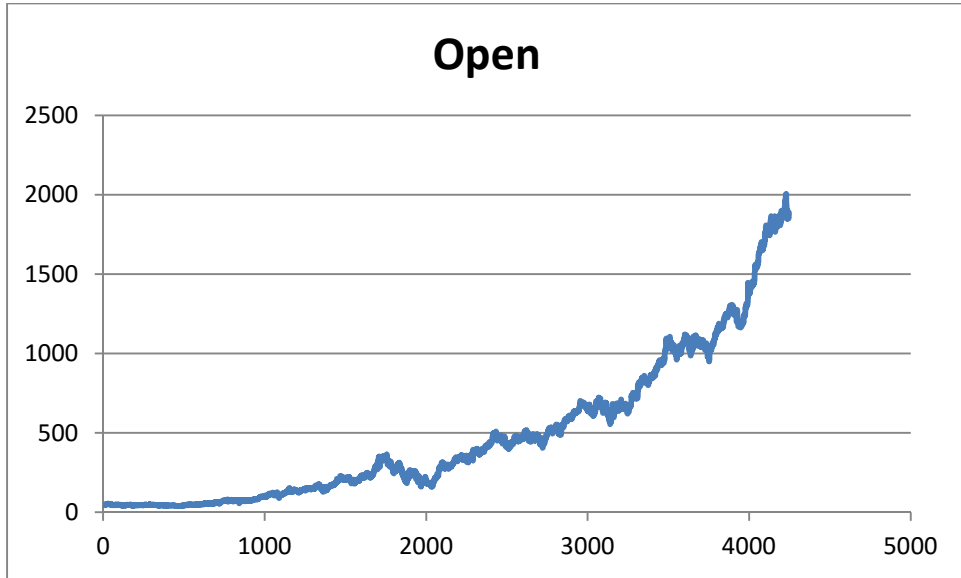


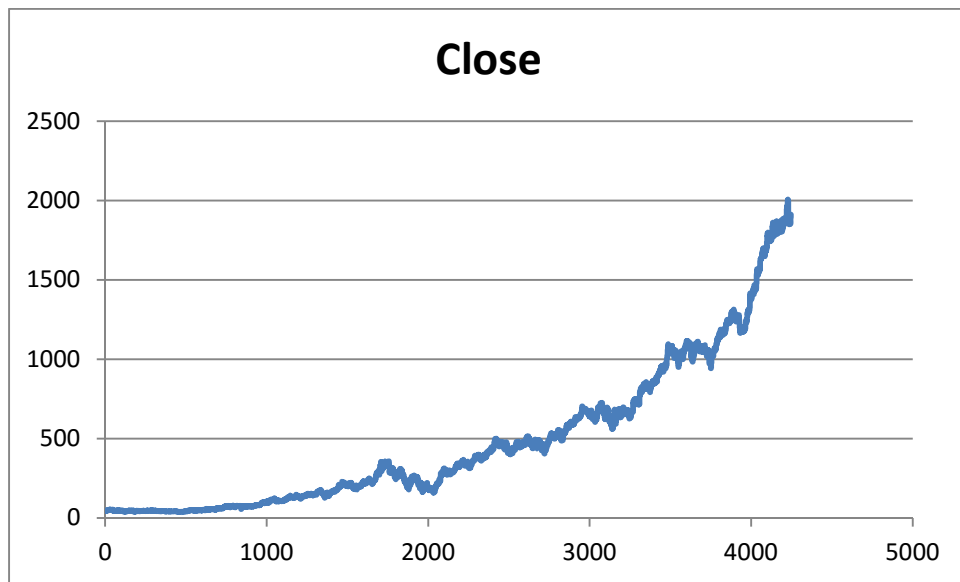
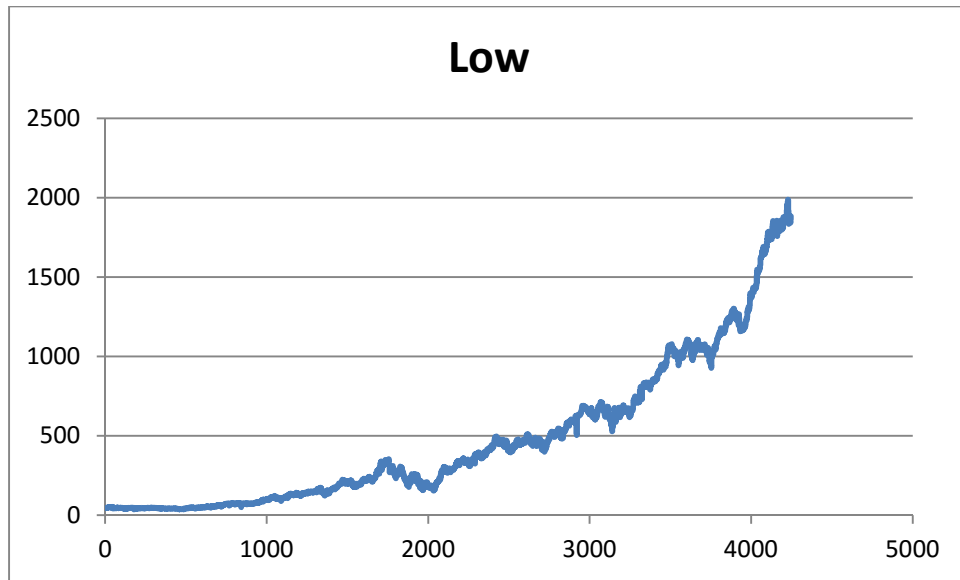
10. Federal Bank



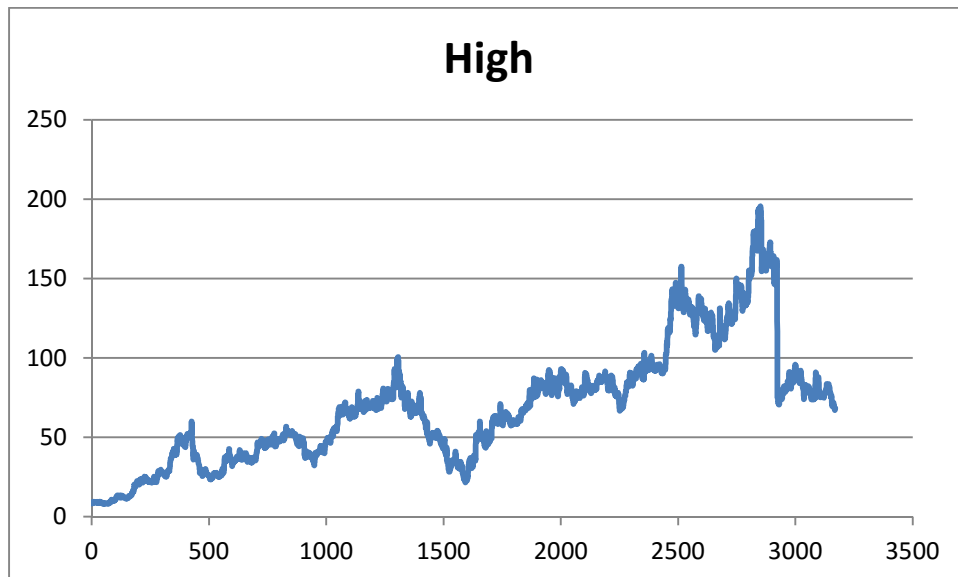
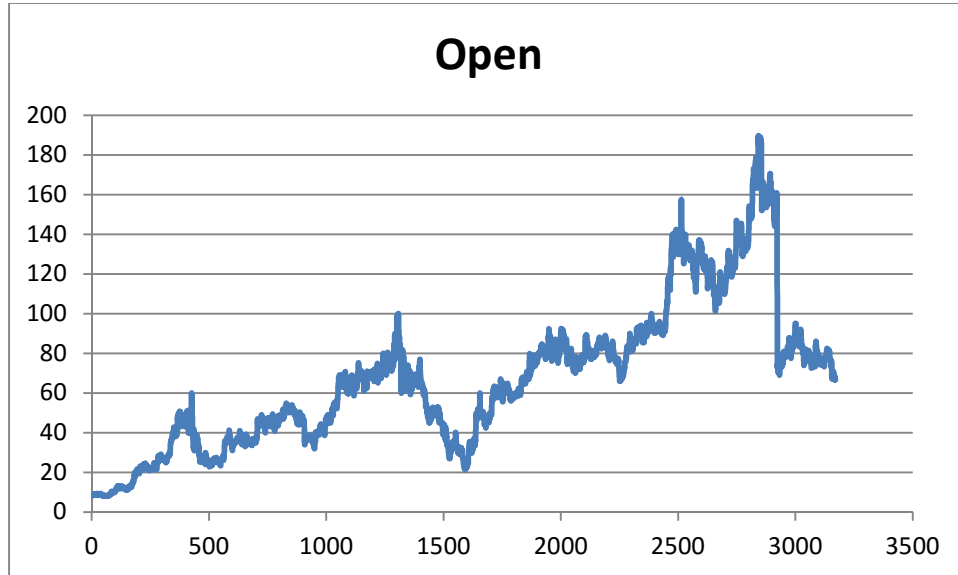


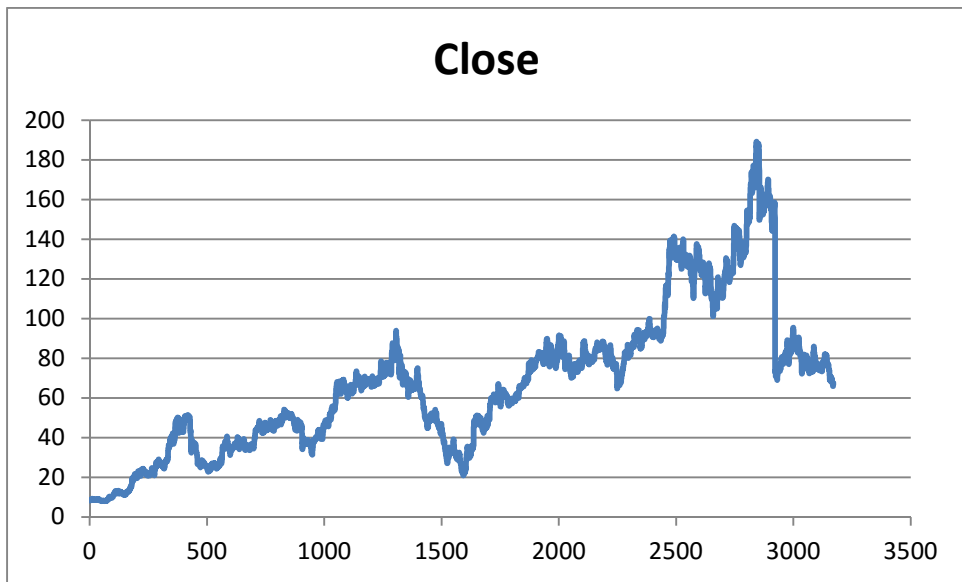
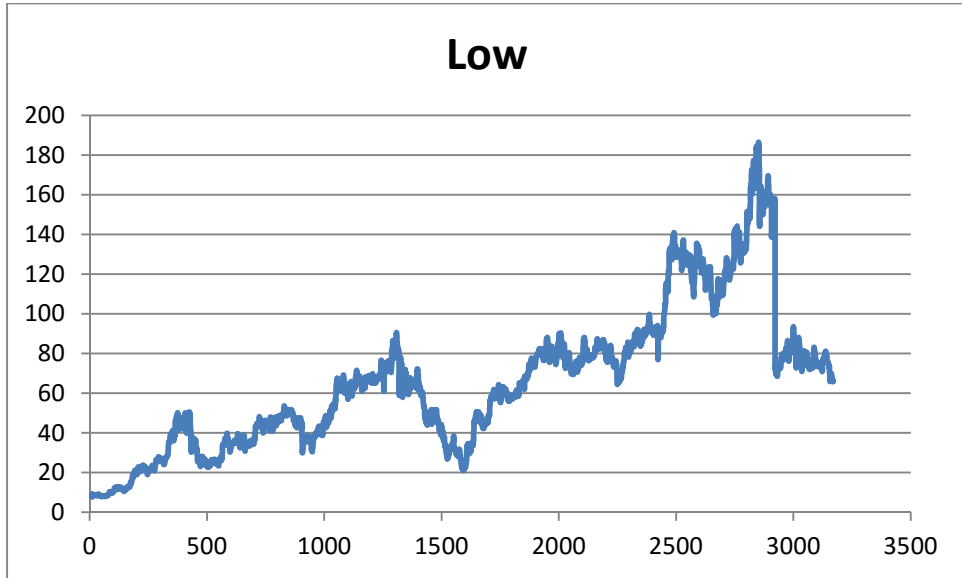
11. HDFC Bank



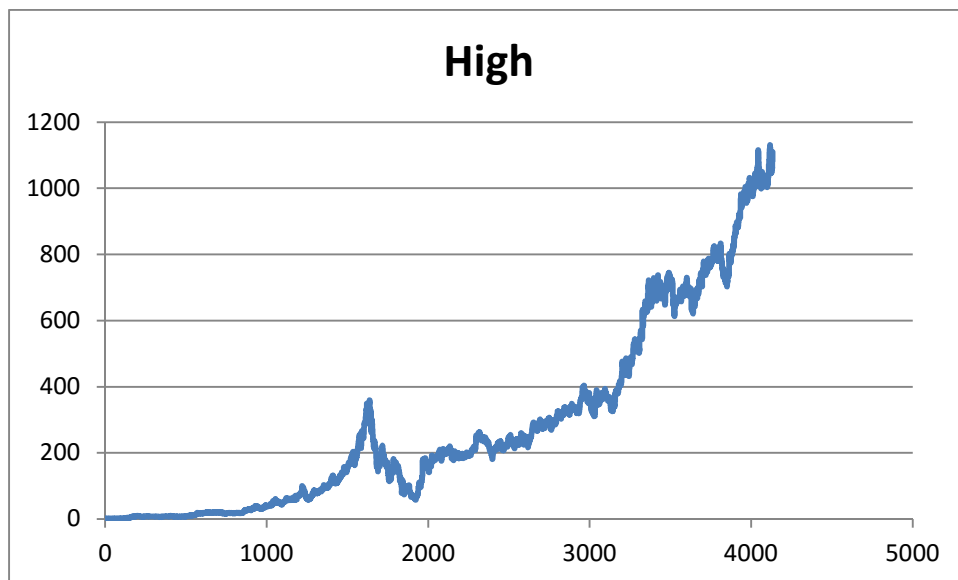
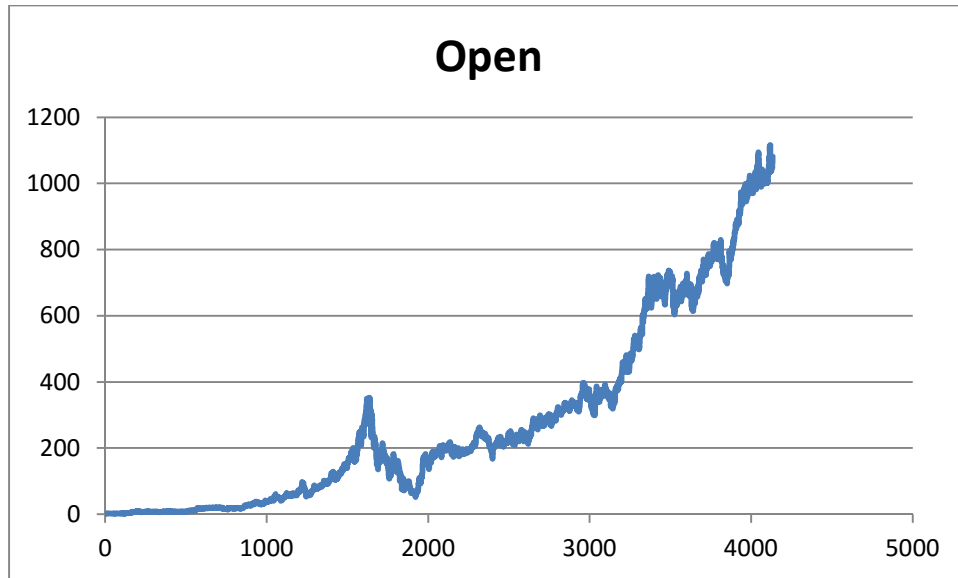


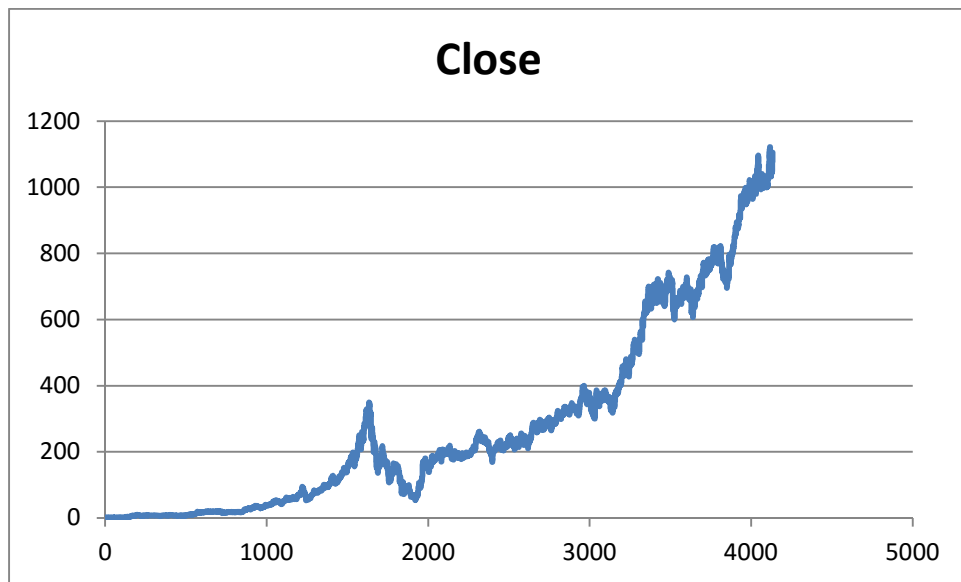
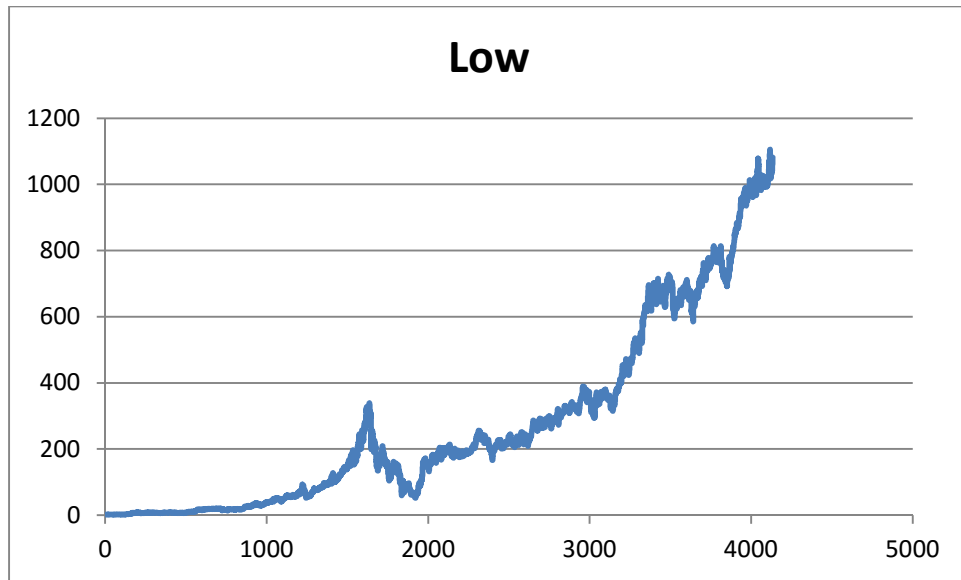
12. J&K bank



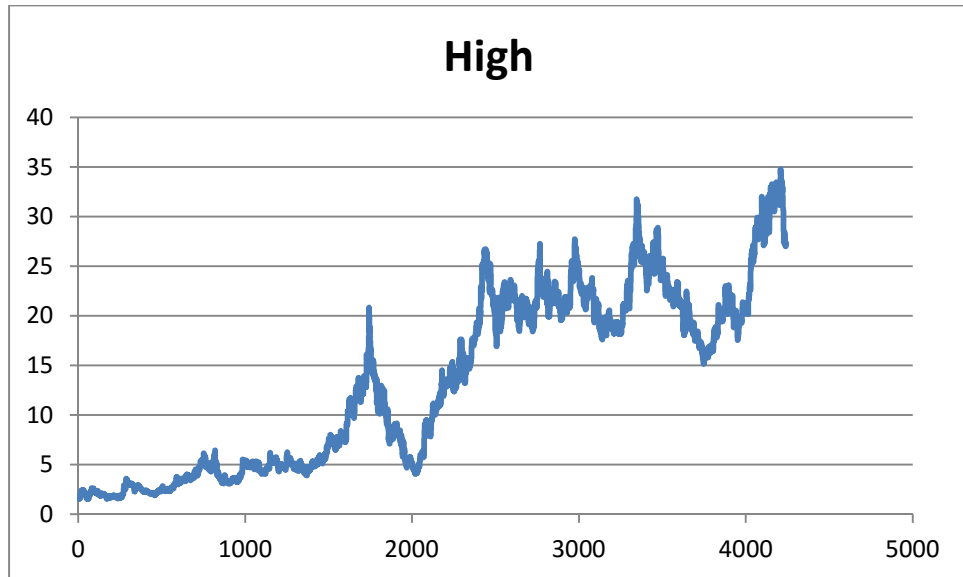
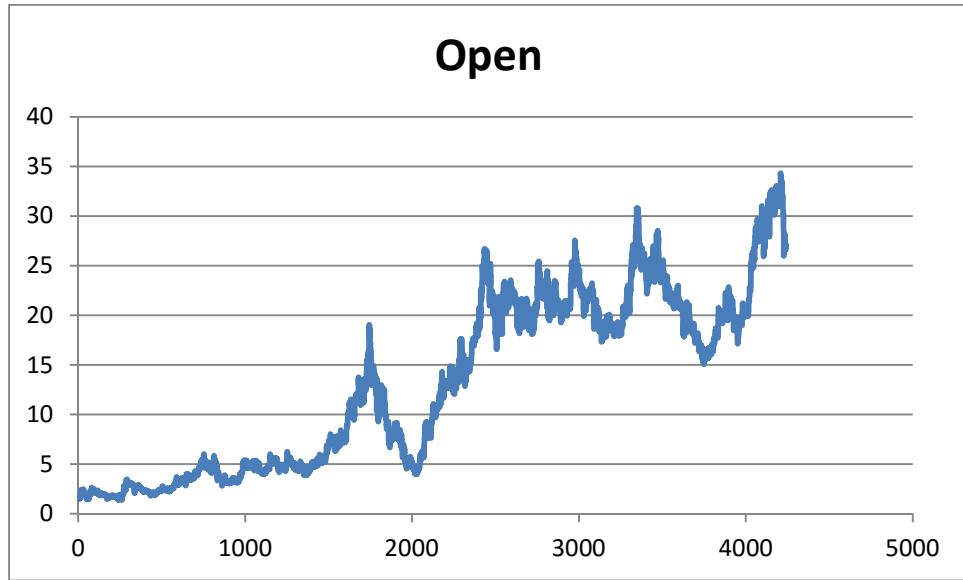


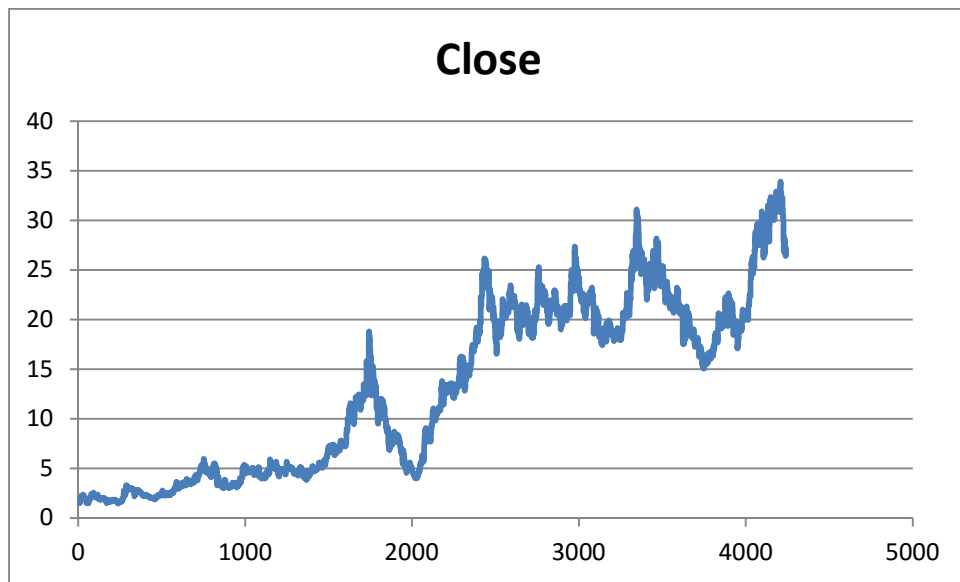
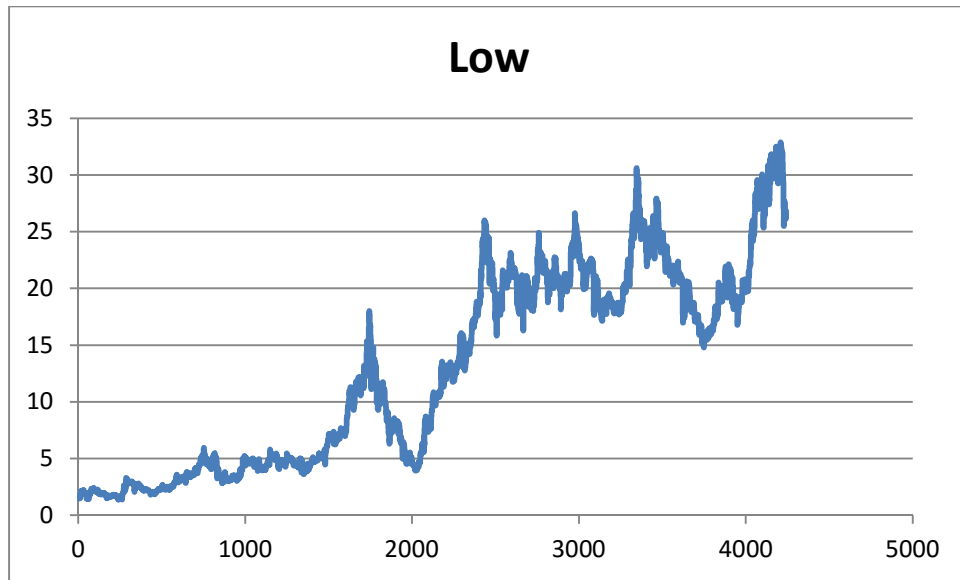
13. Kotak Bank



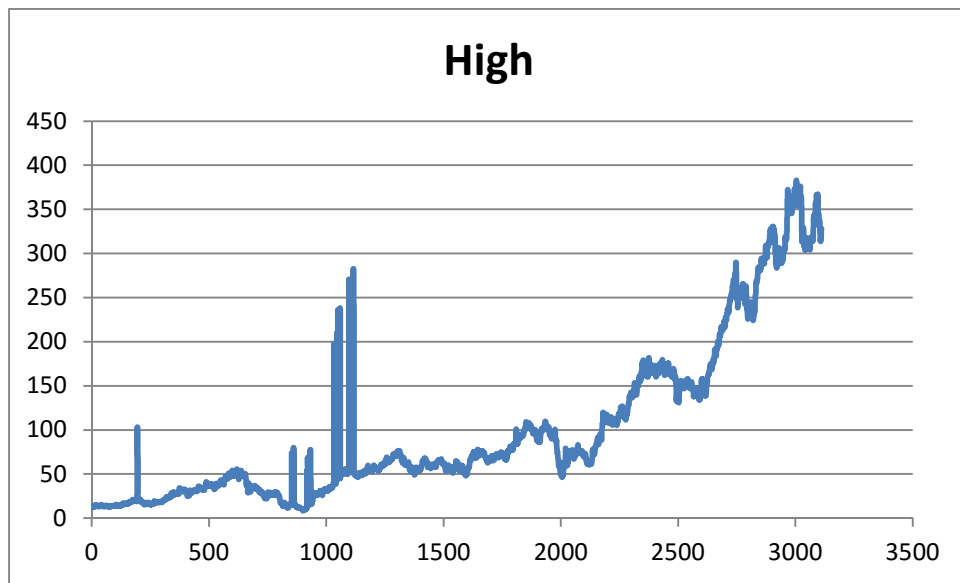
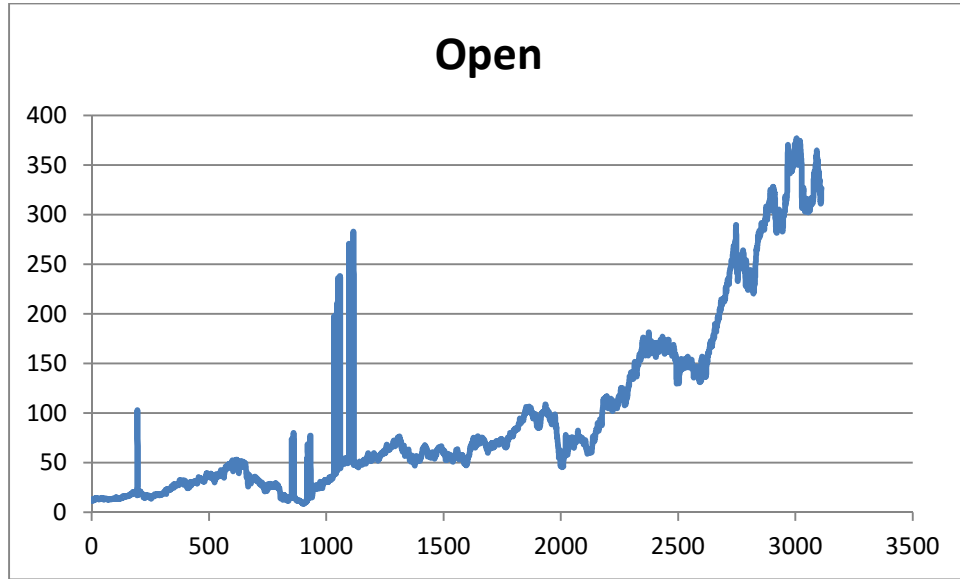


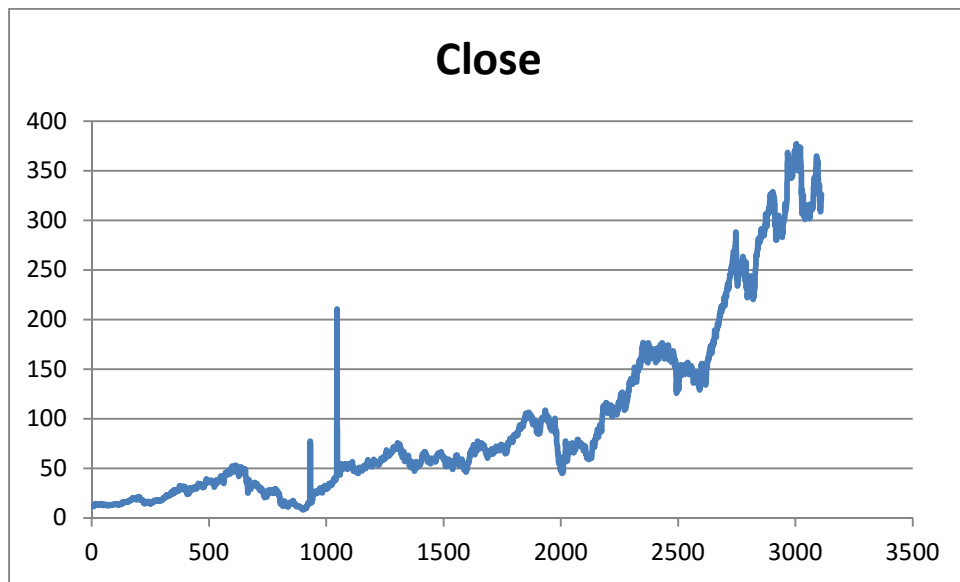
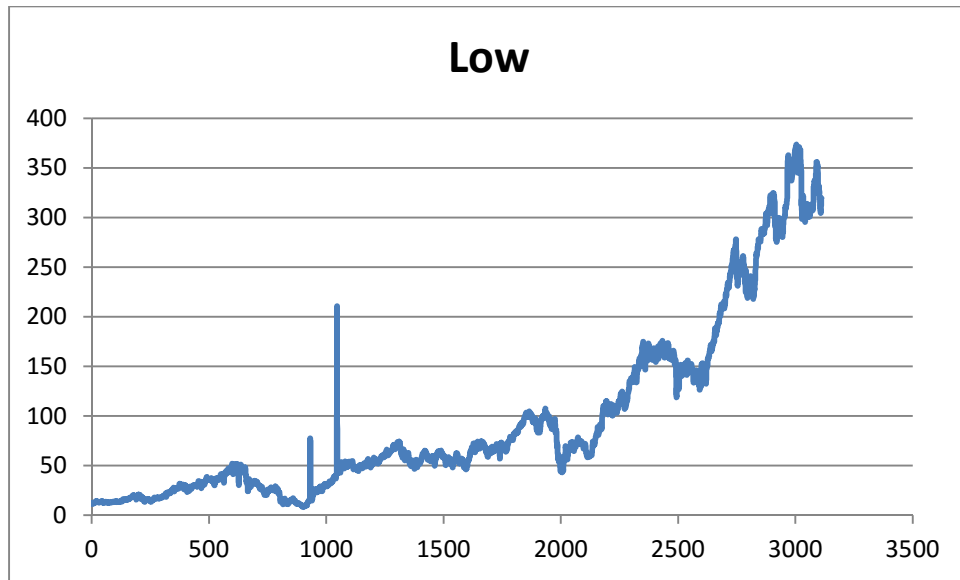
14. South bank



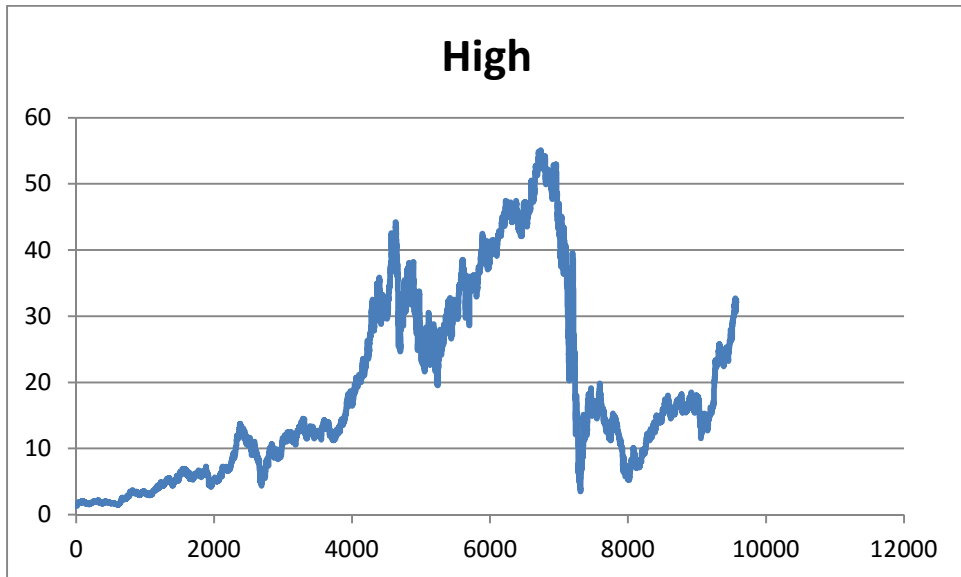
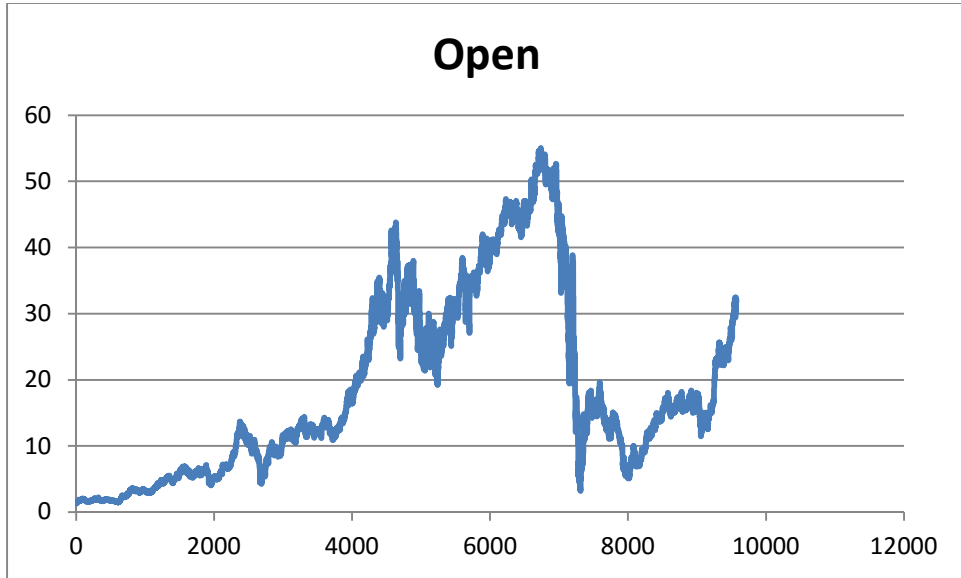


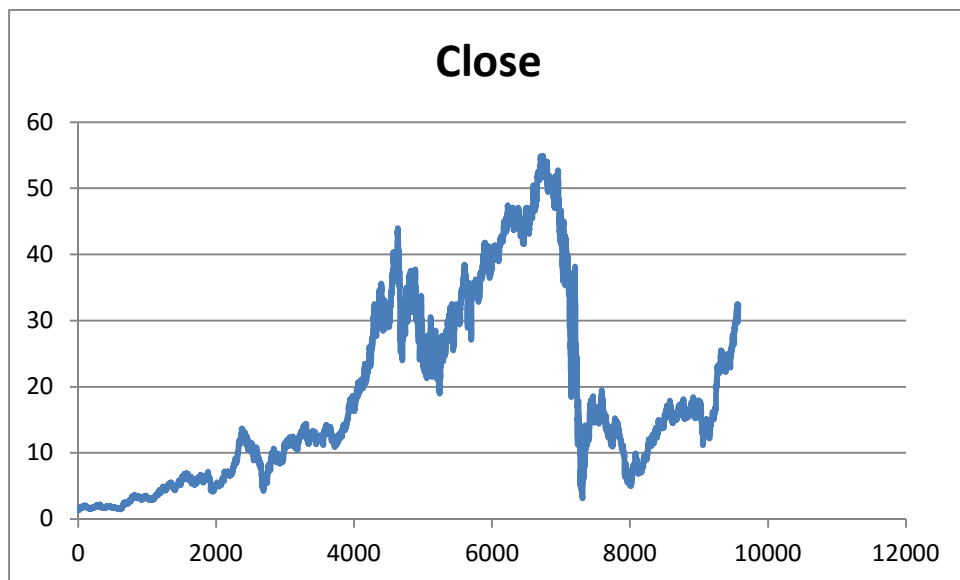
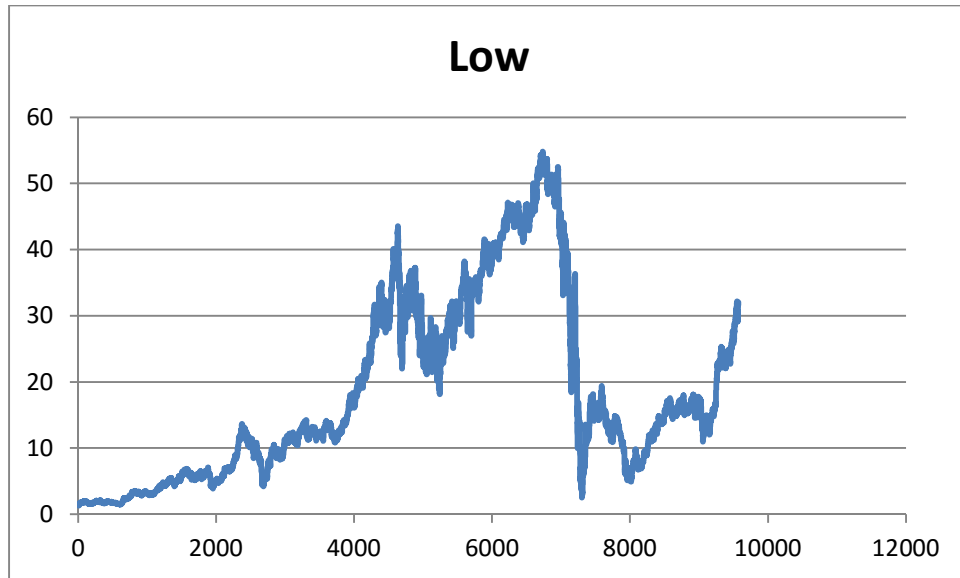
15. Yes Bank



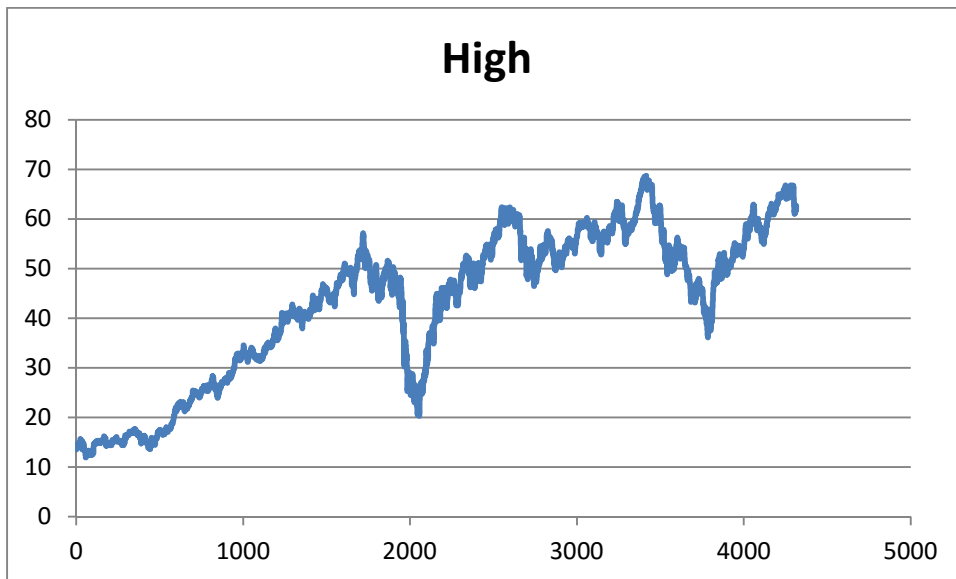
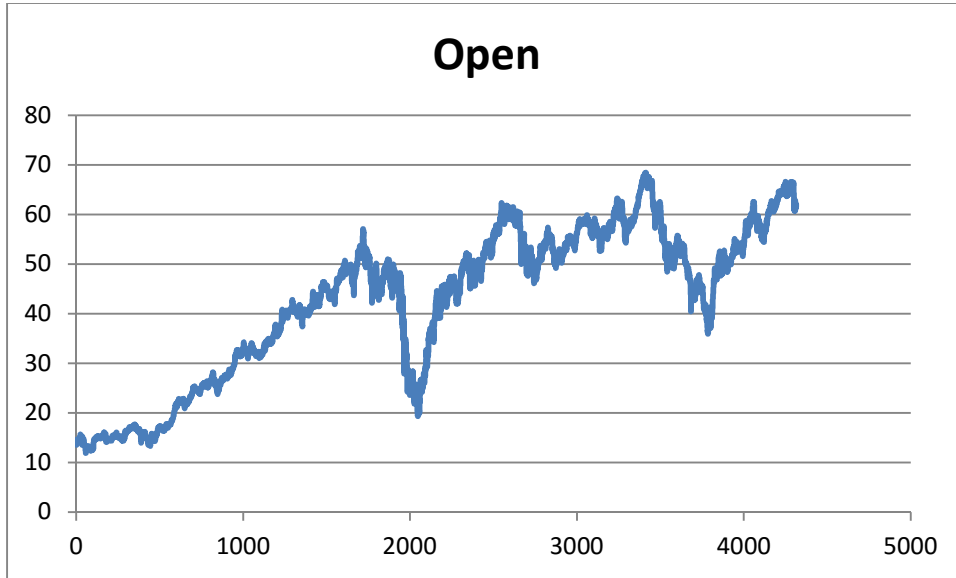


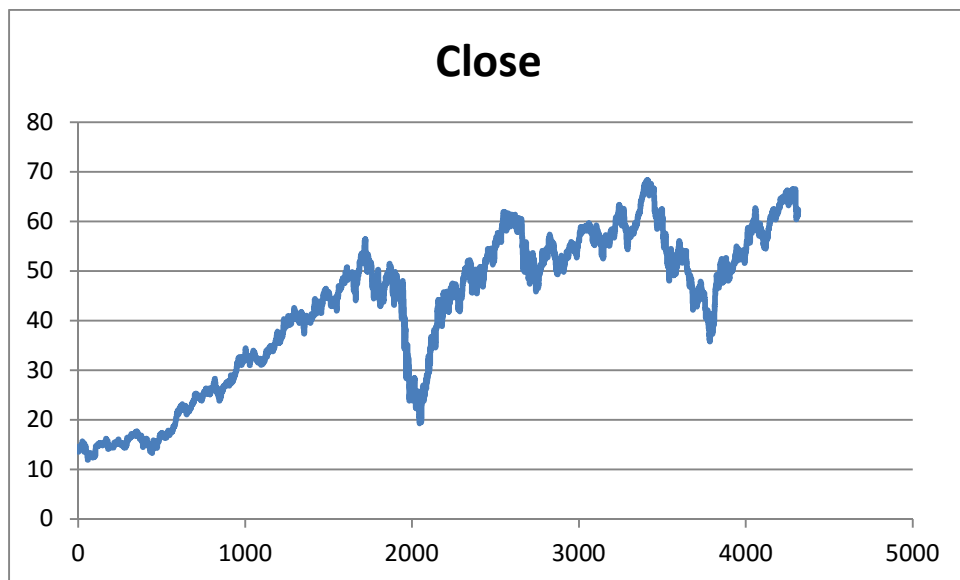
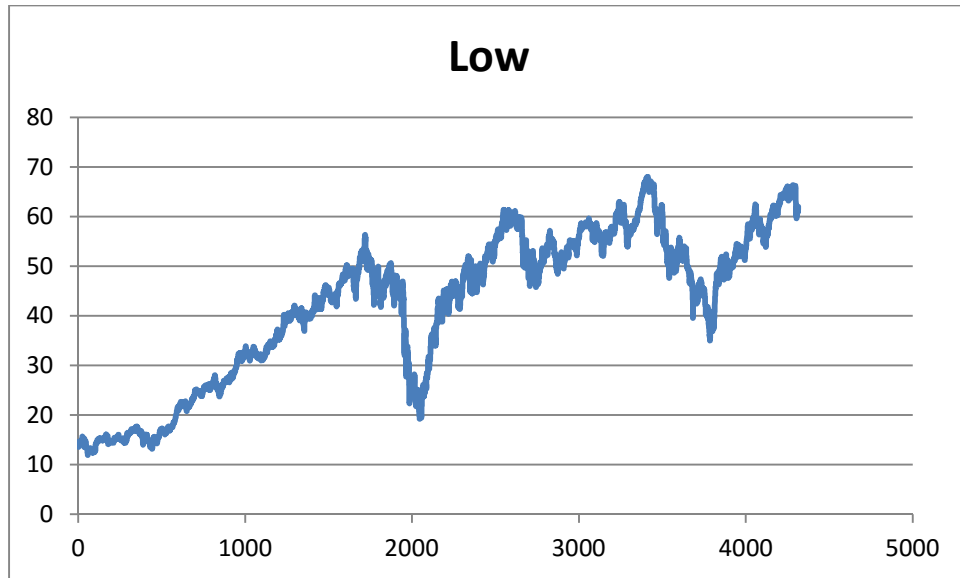
16. BAC Florida Bank



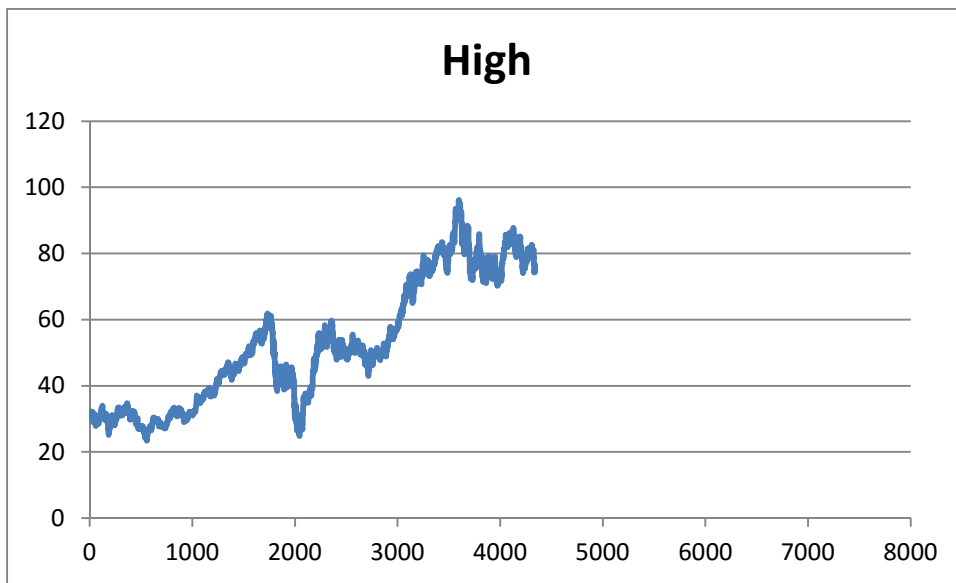
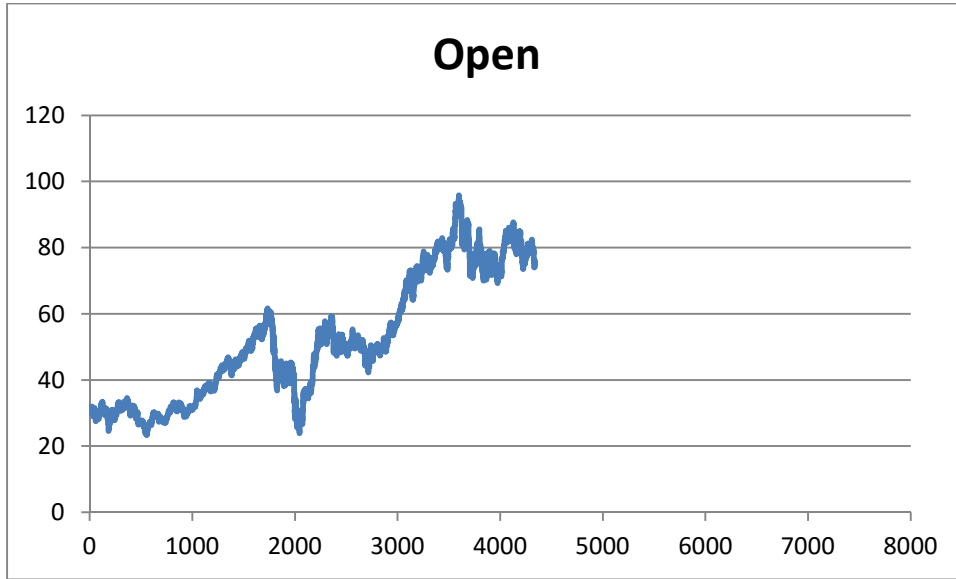


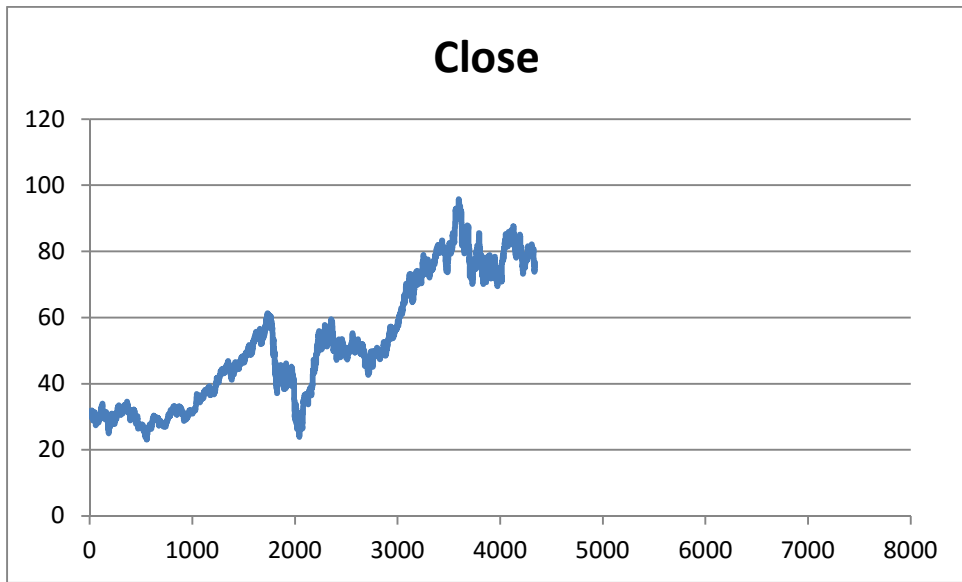
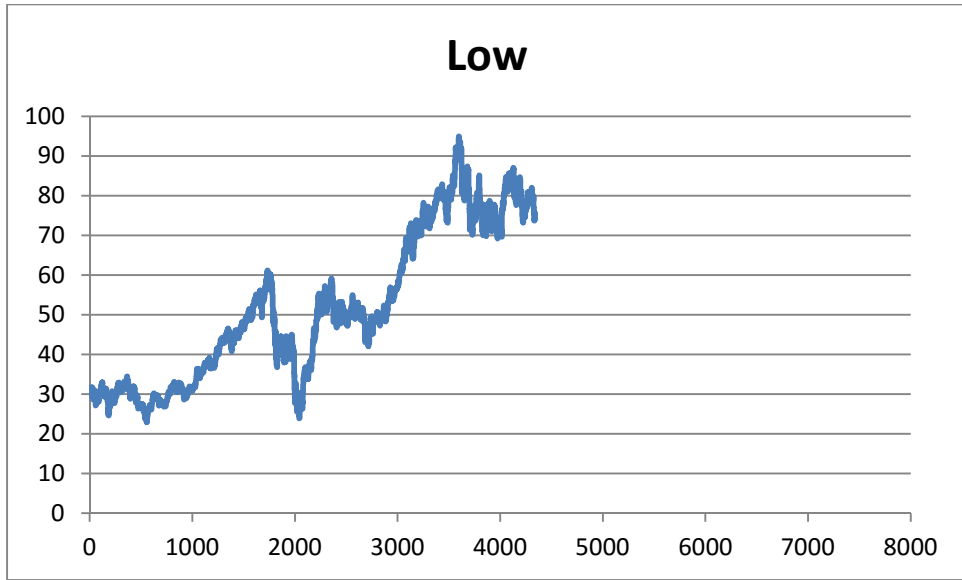
17. Bank Of Nova Scotia



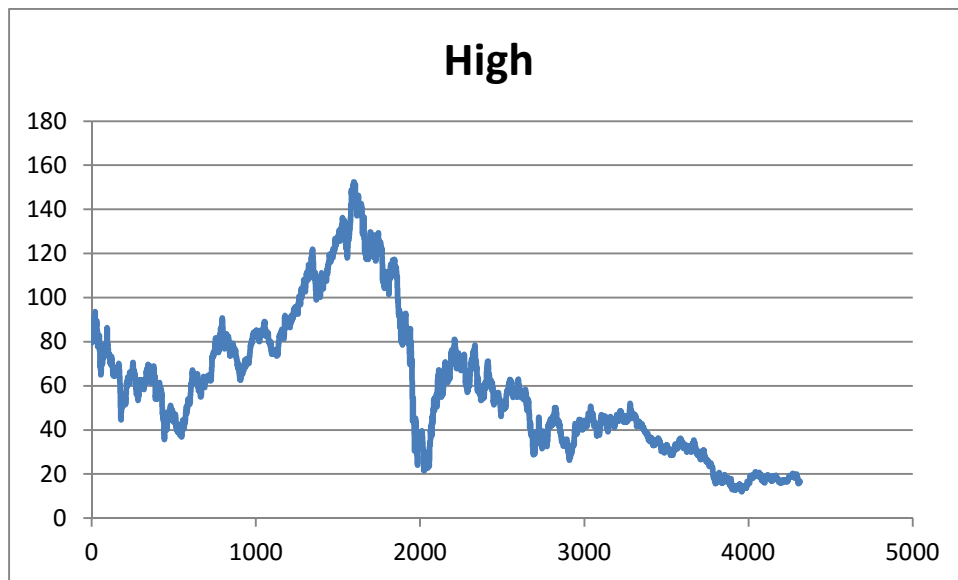
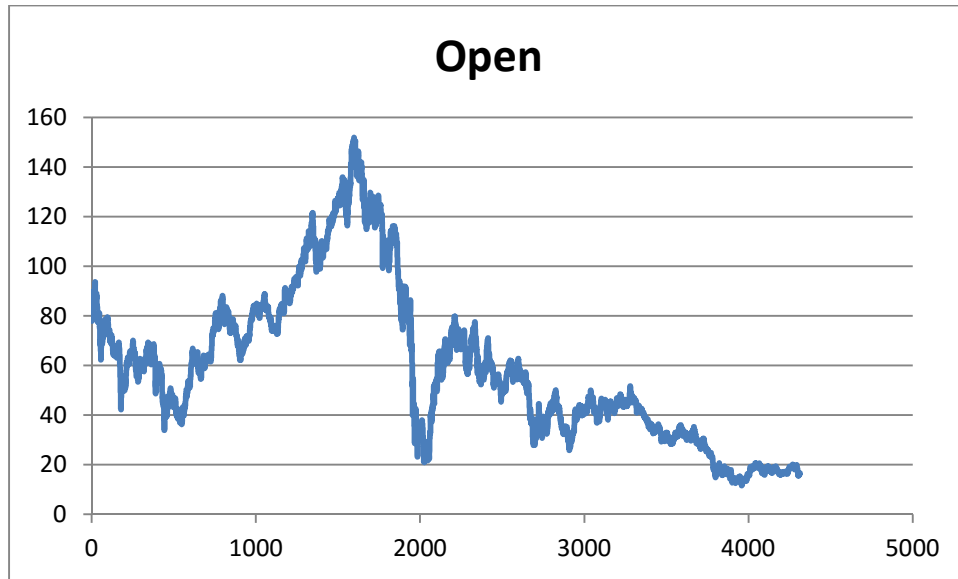


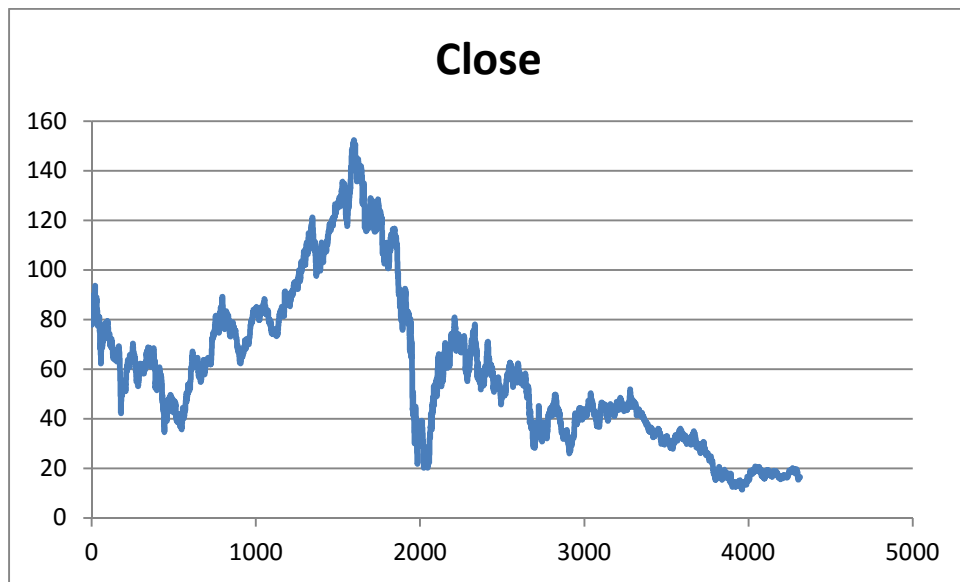
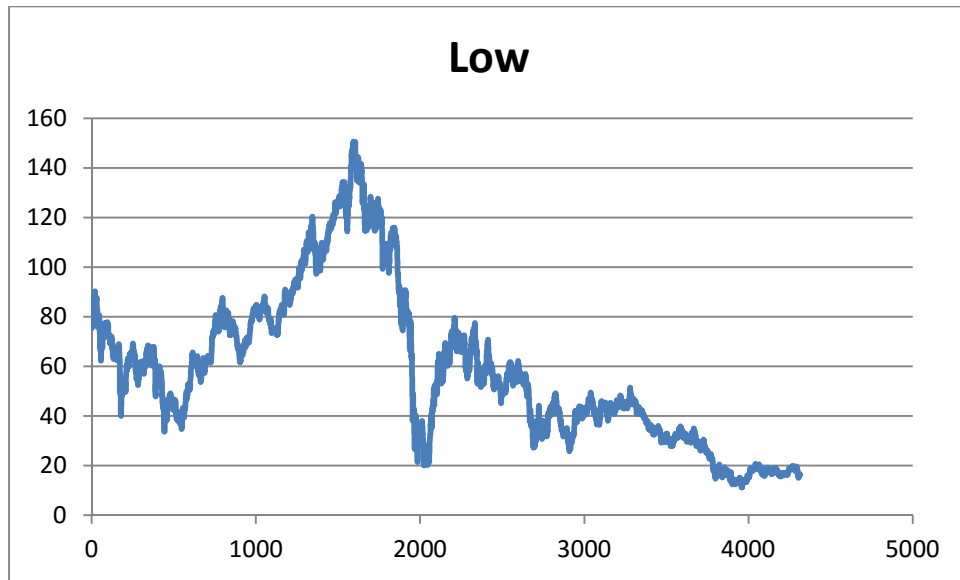
18. Commonwealth Bank of Australia



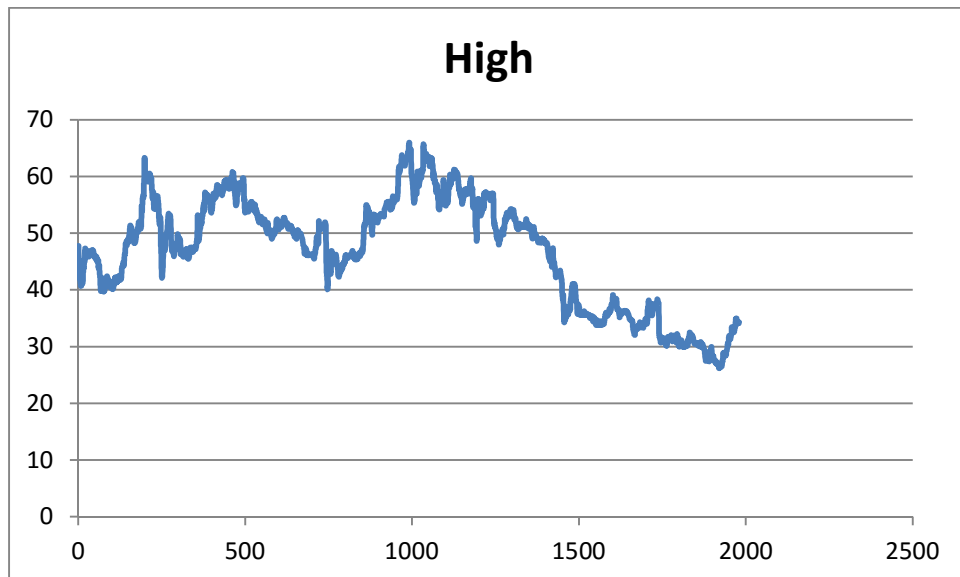
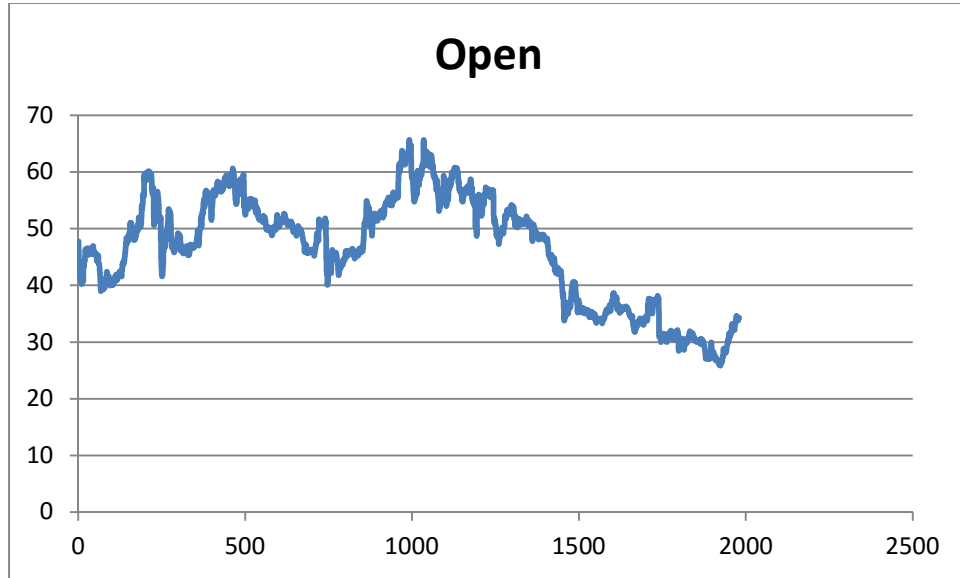


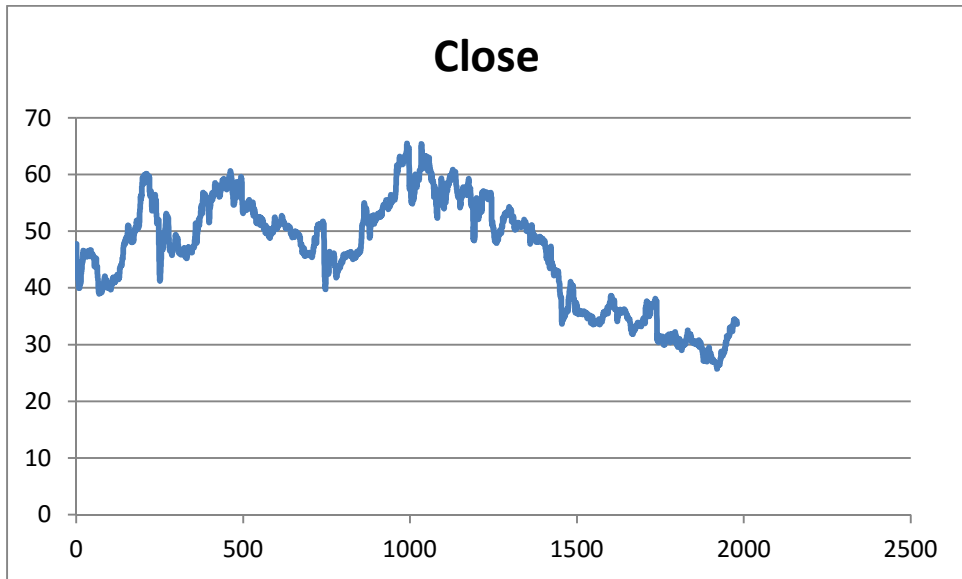
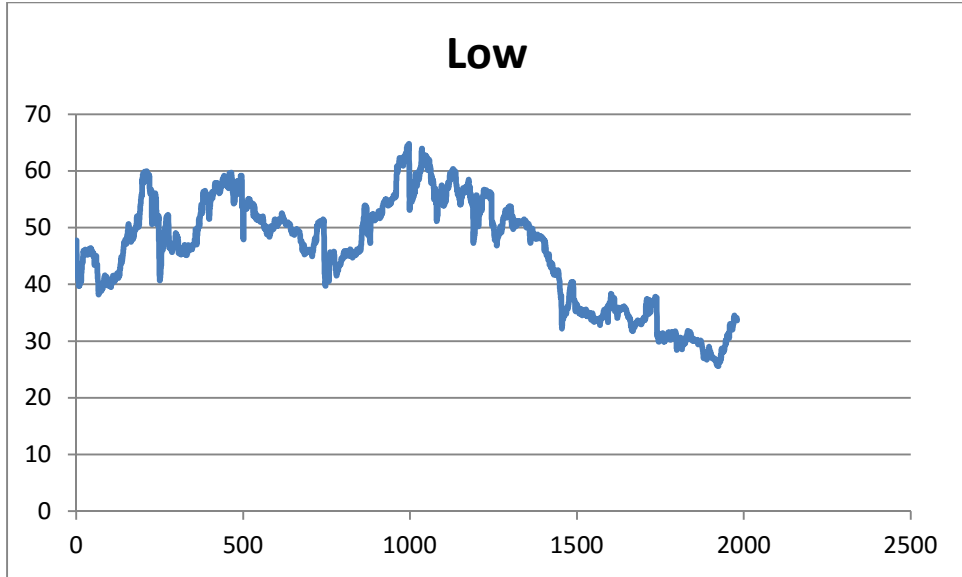
19. Deutsche Bank



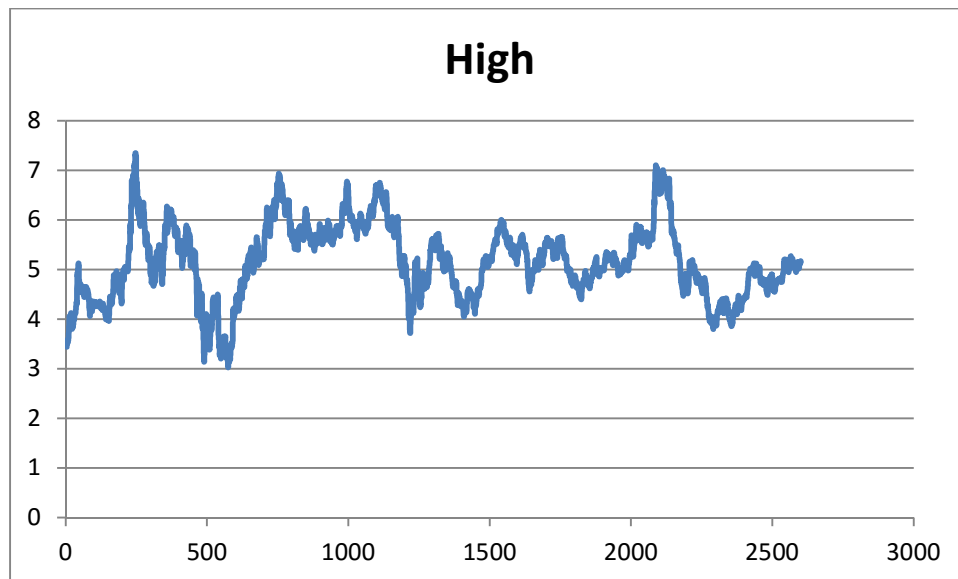
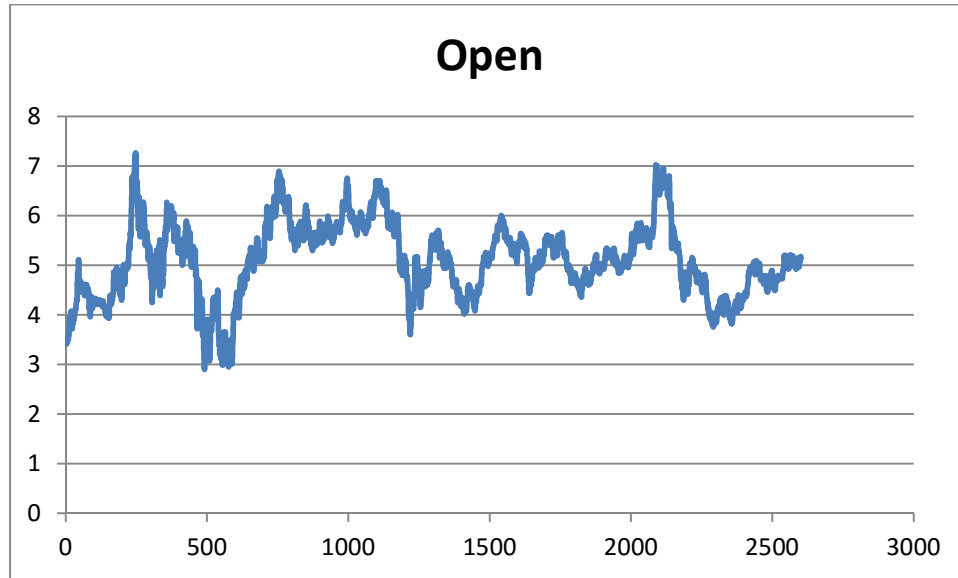


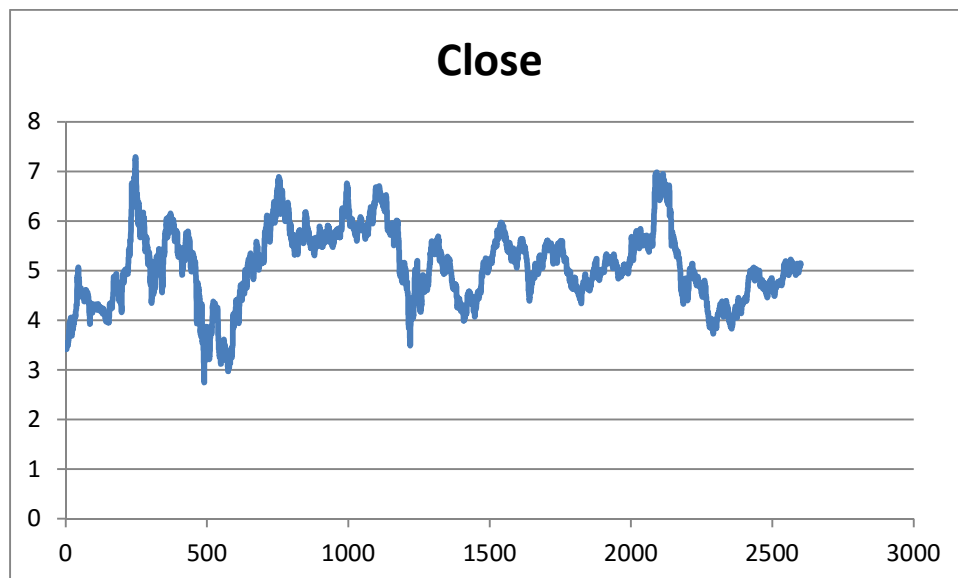
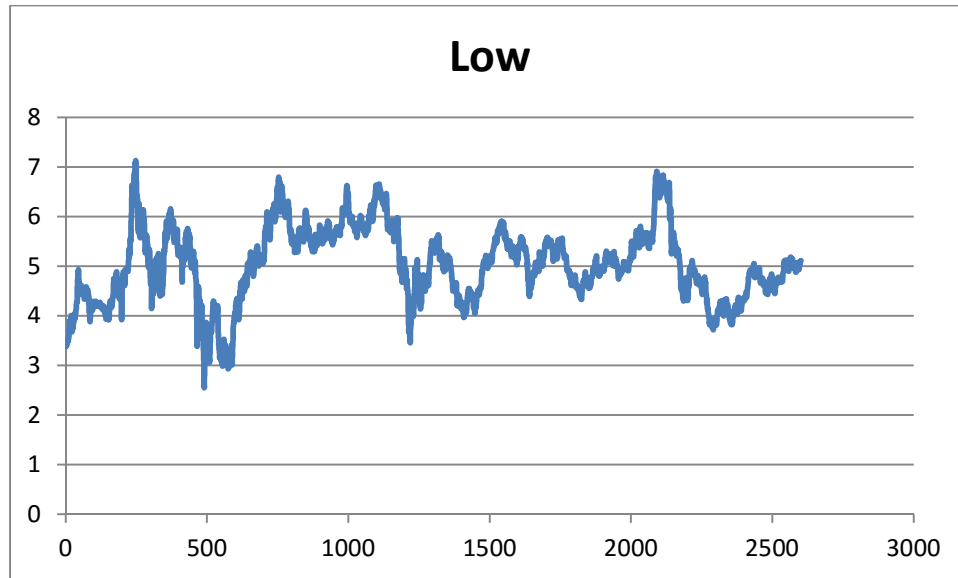
20. Doha Bank





21. HSBC Bank





Chapter: 02

POWER SPECTRAL DENSITY-

The power spectrum of time series is a description of the distribution of power into frequency components composing that signal. Fourier analysis highlights that any physical signal can be decomposed into a number of discrete frequencies.

Spectrum is the statistical average of a signal analyzed for its frequency content. After doing a Fourier analysis, some graphs exhibited periodicity while others exhibited $1/f$ noise. $1/f$ noise or pink noise is inversely proportional to frequency of signal. Here,

$$S(f) \propto \left(\frac{1}{f}\right)^\alpha$$

Where

f is frequency and $0 < \alpha < 2$ with exponent α usually close to 1.

$1/f$ noise in economic data is usually studied as long range dependence or long memory. The autocorrelation functions do not decay exponentially as expected. It reaches a non-zero asymptote and stays there for a long period indicating that distant past events influence current prices of production.

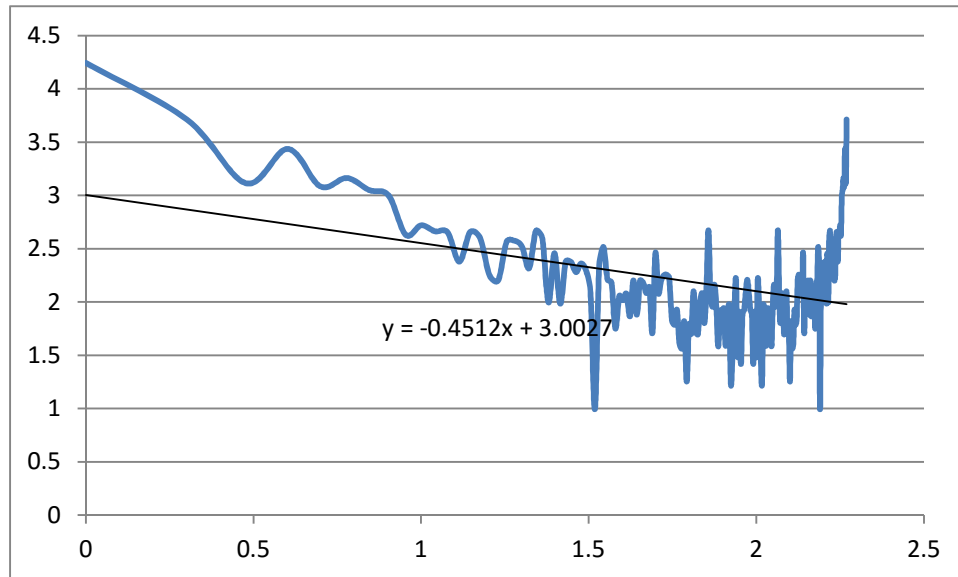
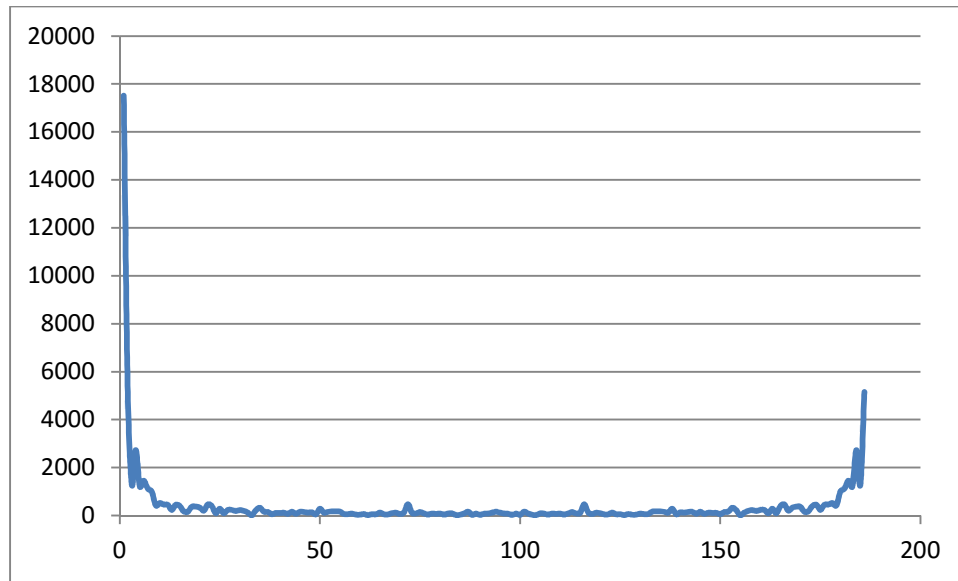
ANNEXURE-B: FAST FOURIER TRANSFORM ANALYSIS

Fast Fourier transform gives information on the periodicity of the data points to reveal the effect of information from a distant past on the current event.

There are 21 banks in this annexure for which some Fast Fourier Transform reveals a periodic frequency like Bank of India whereas others do not give a conclusive review. The log-log plot gives a review of the log of amplitude of frequency with log of the serial number which denotes the number of days (/dates) included. The small variations in the low frequency region reveal the effect of data entering the system from past events.

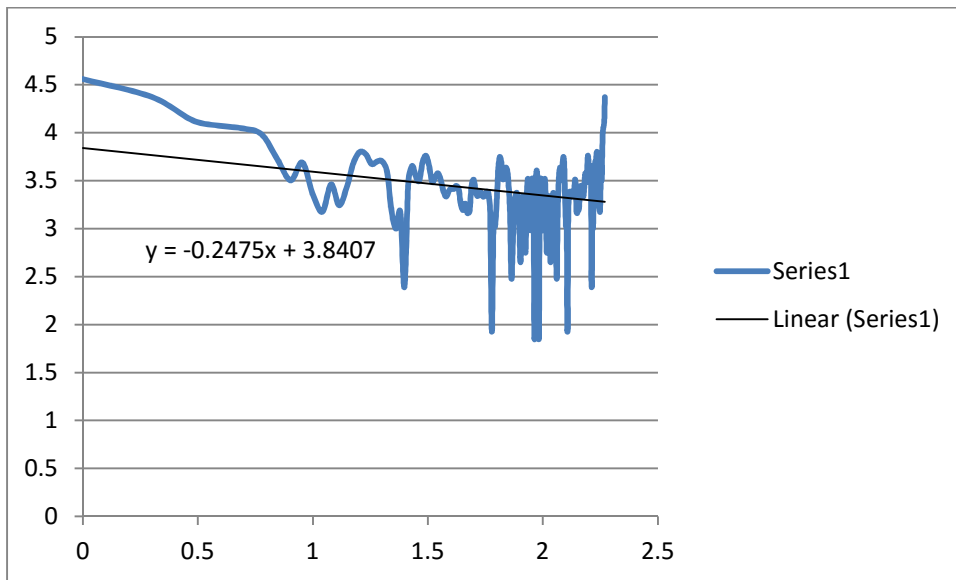
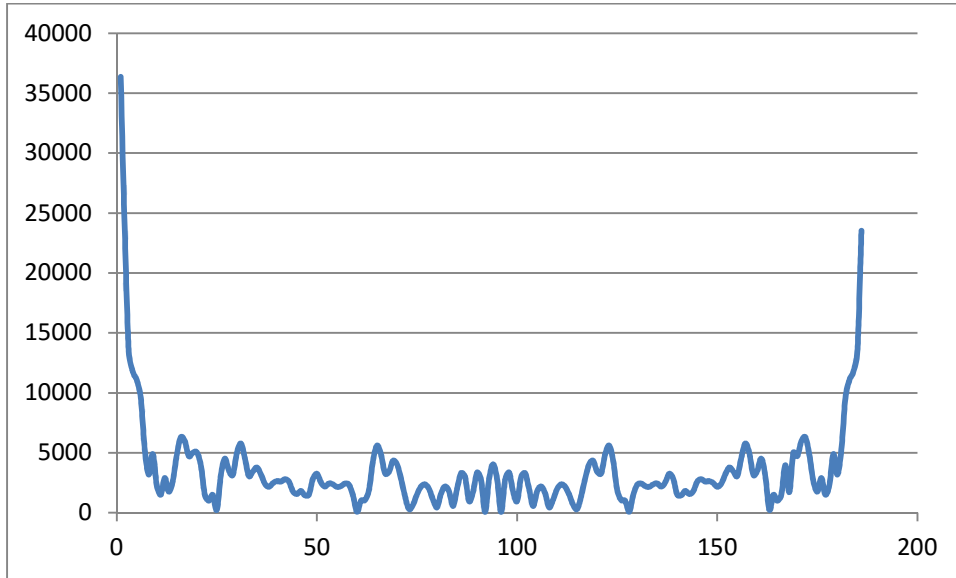
The majority of α range from 0.4 to 0.5 for this data.

1. Allahabad Bank



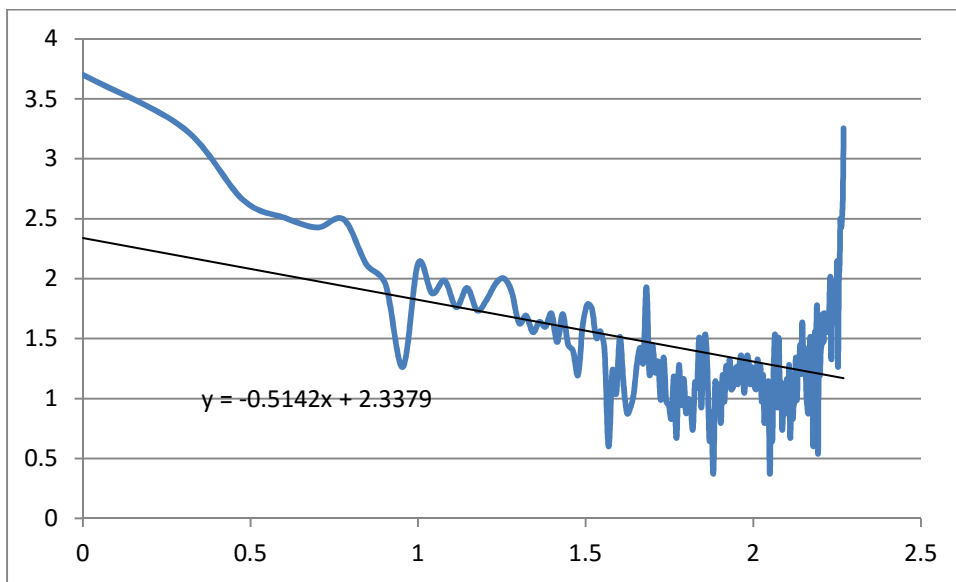
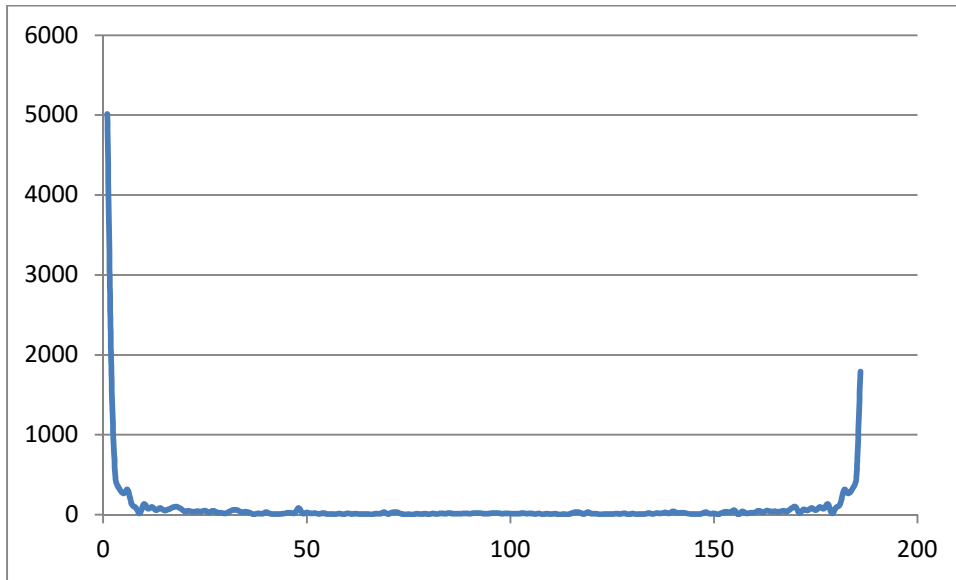
$\alpha = 0.4512$

2. Axis Bank



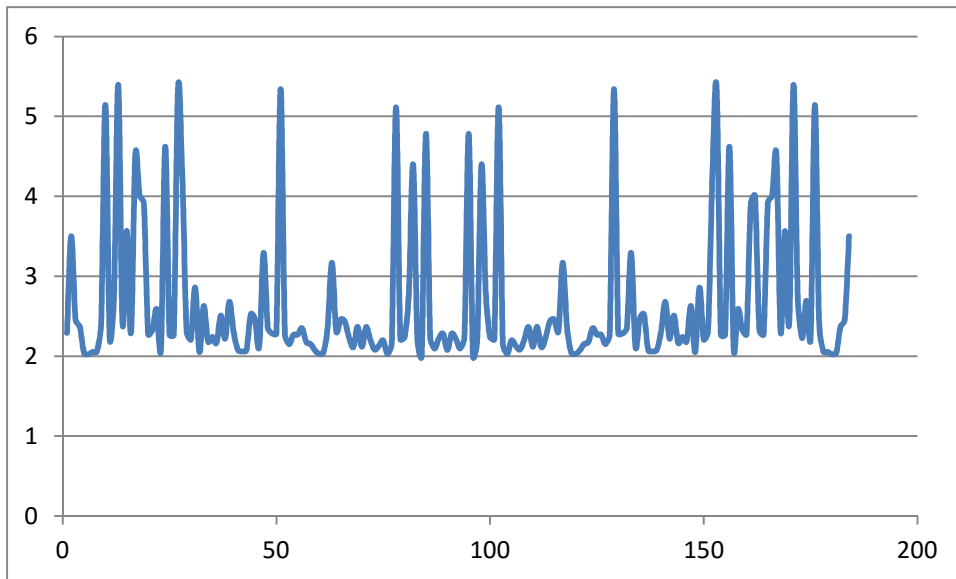
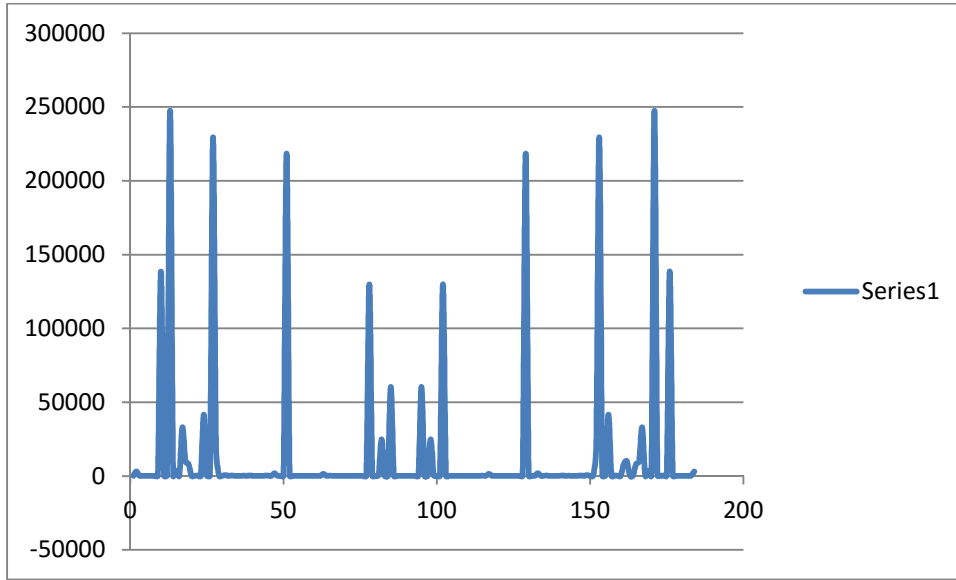
$\alpha = 0.2475$

3. Bank of America Cooperation, Florida

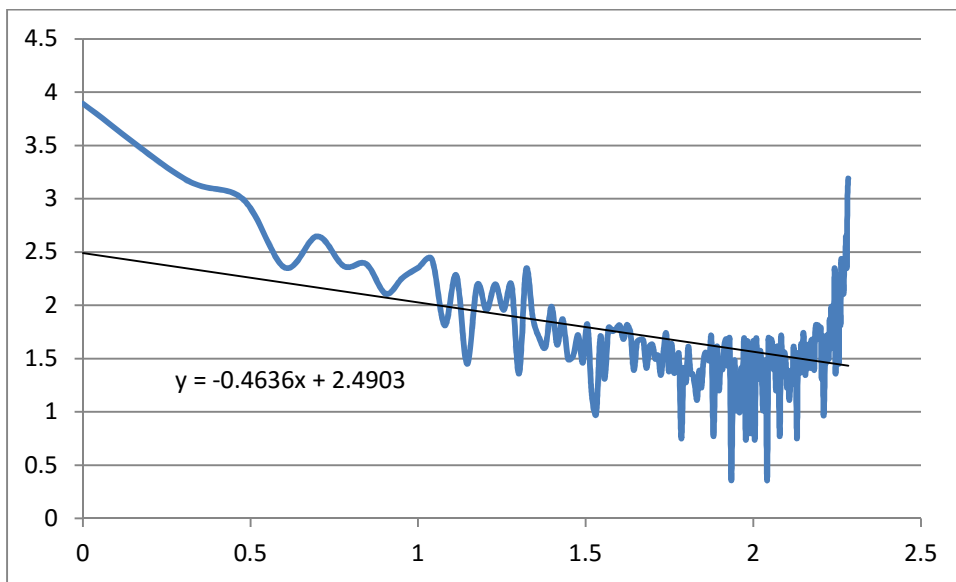
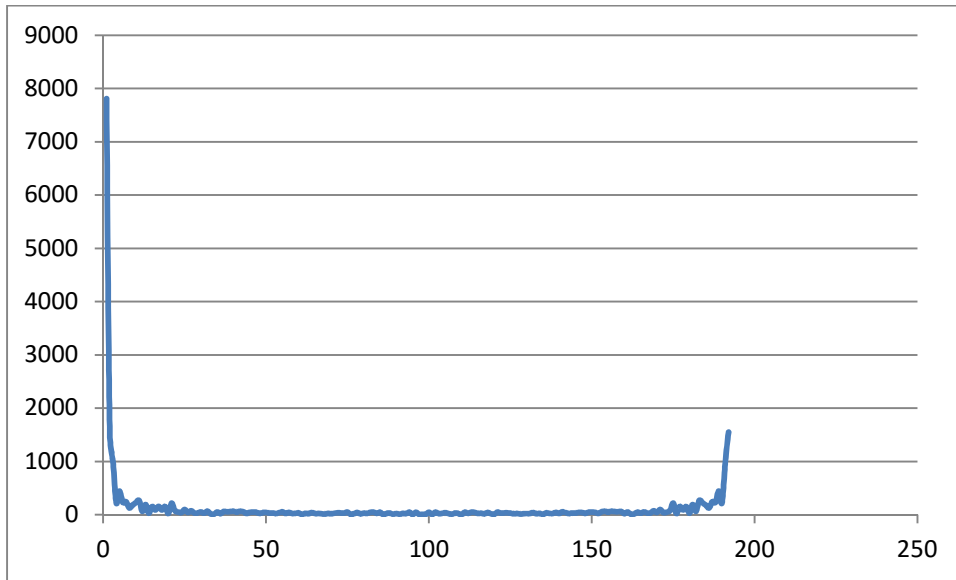


$$\alpha = 0.5142$$

4. Bank of India

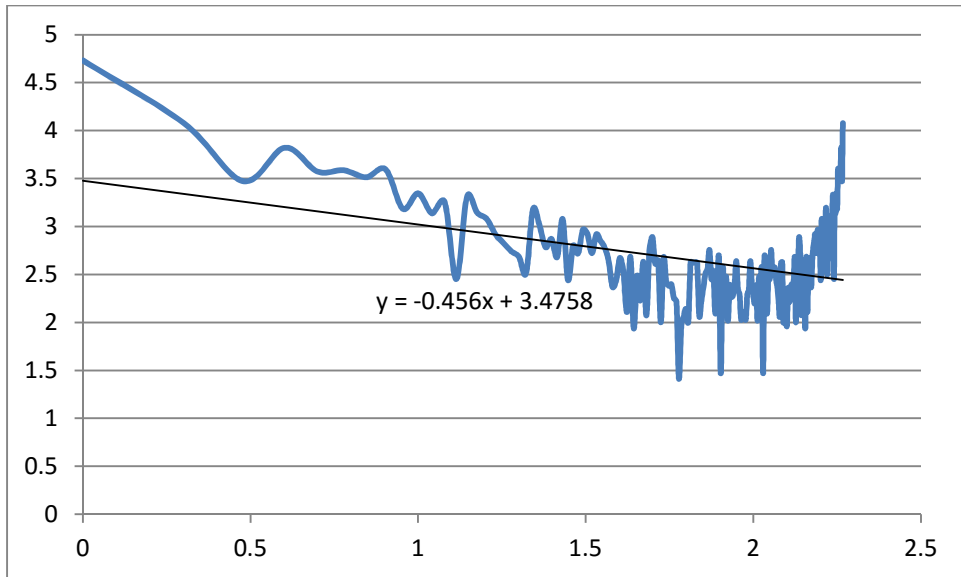
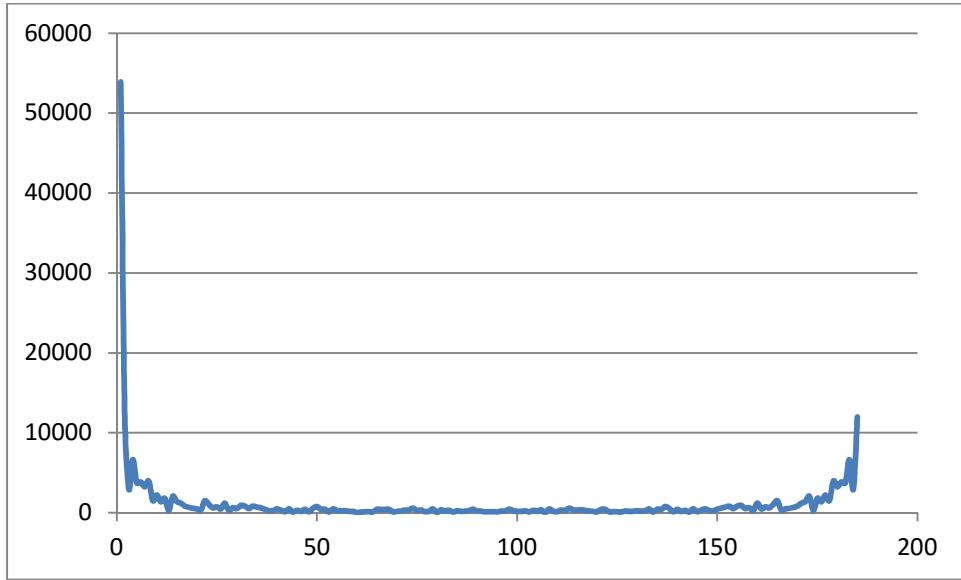


5. Bank of Nova Scotia



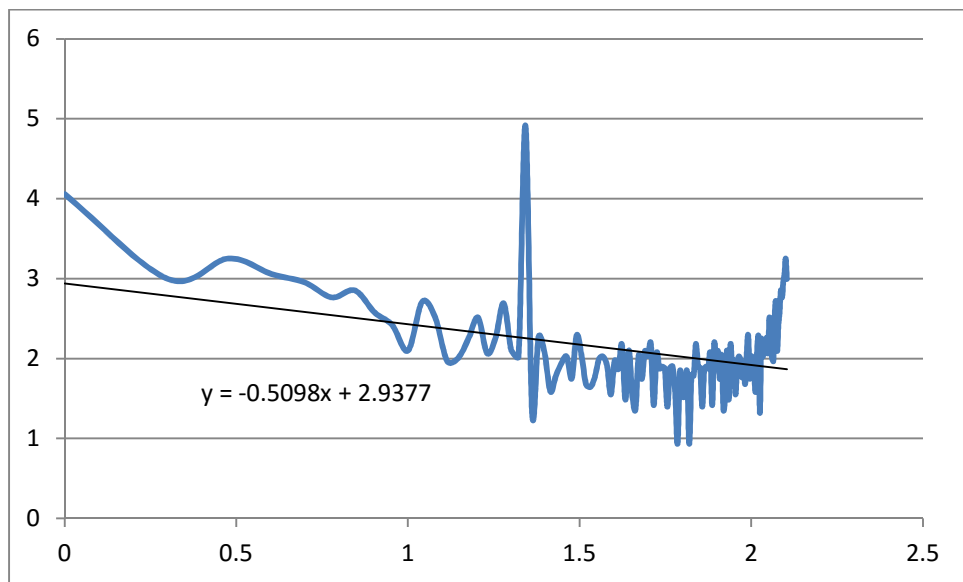
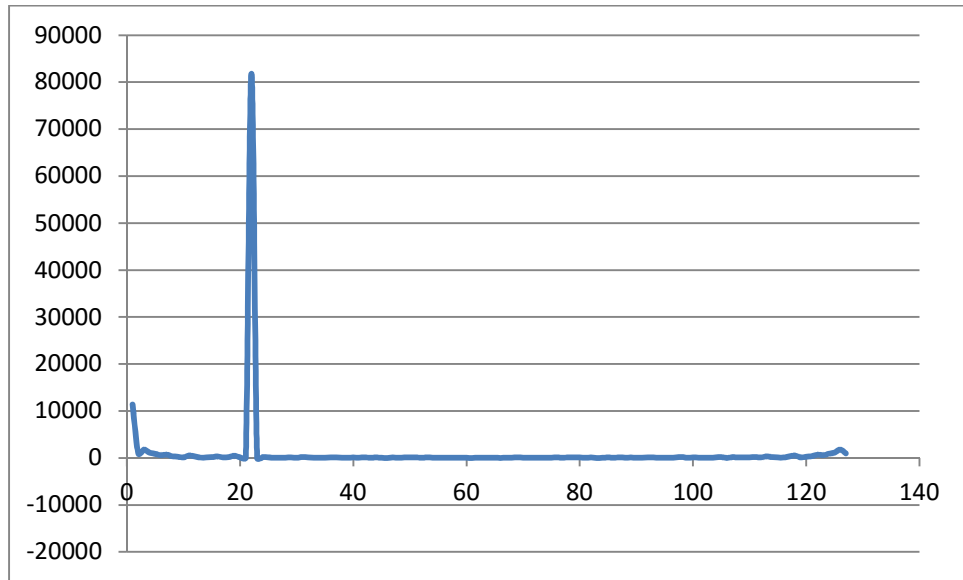
$\alpha = 0.4636$

6. Canara Bank



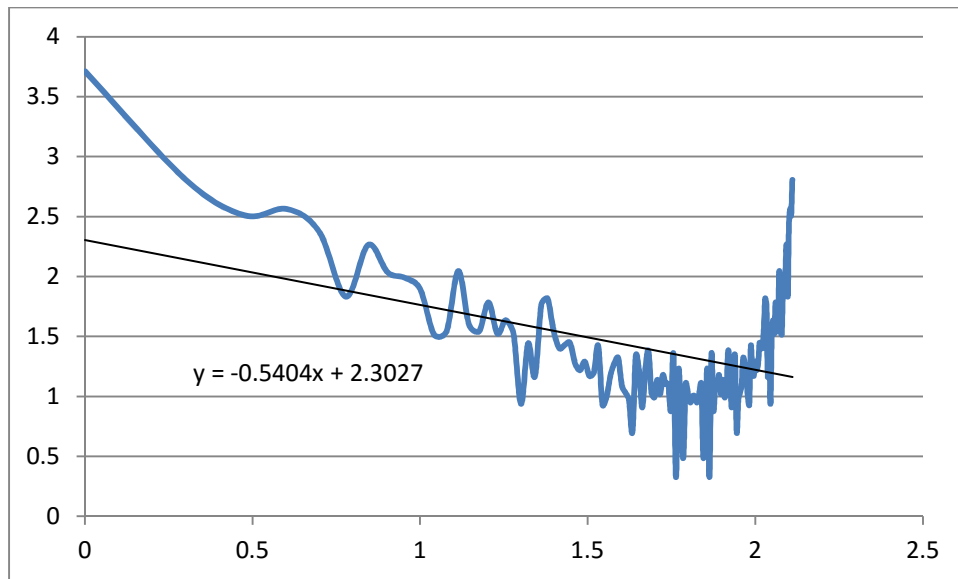
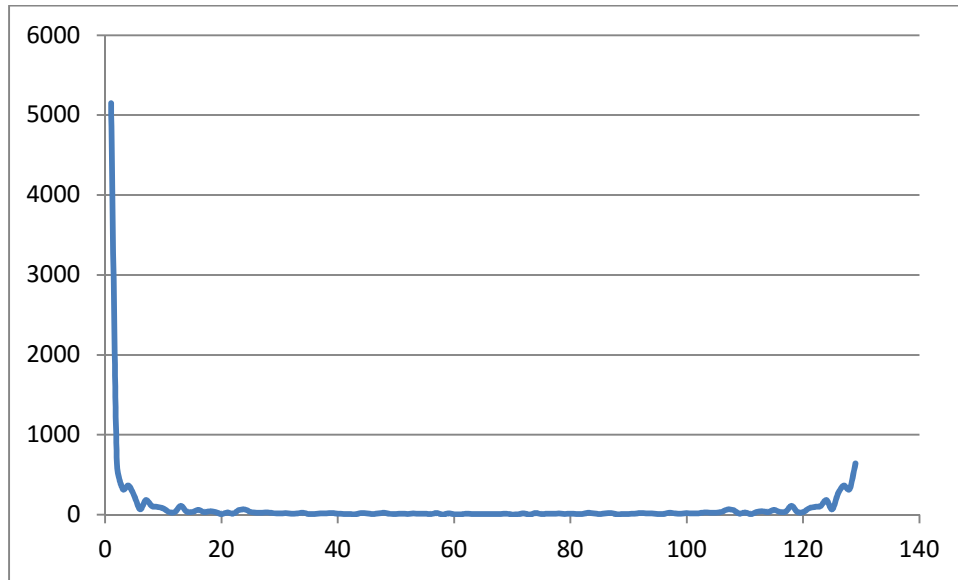
$$\alpha = 0.456$$

7. Central Bank



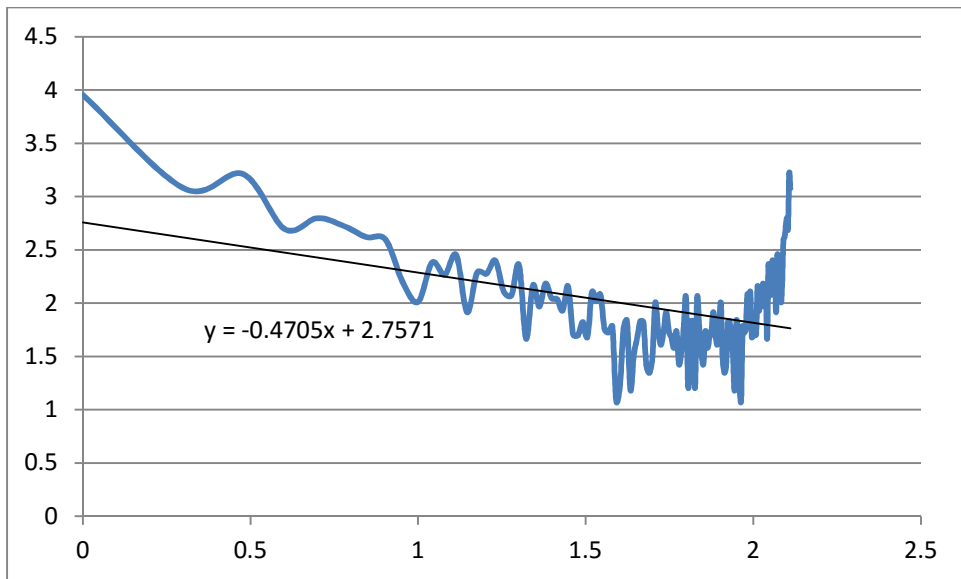
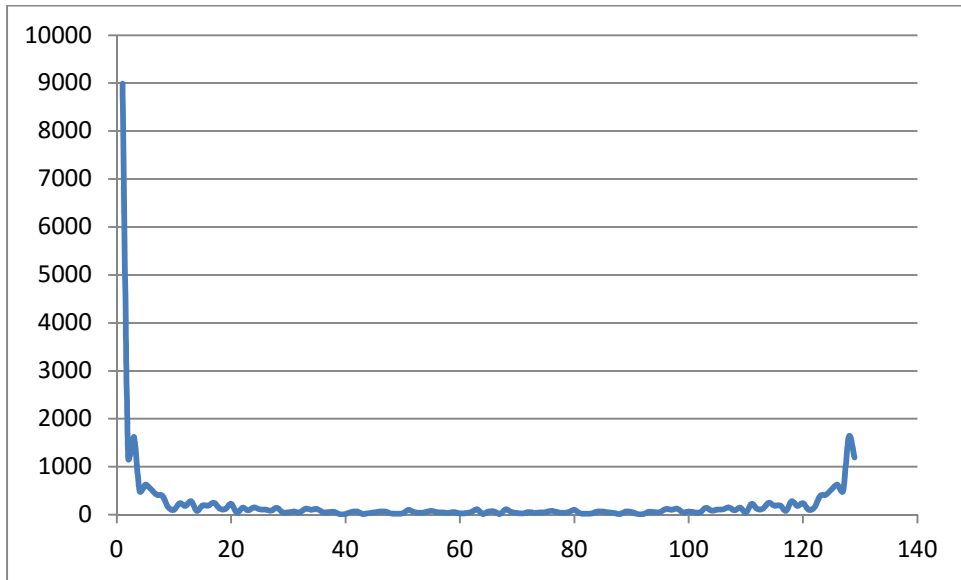
$$\alpha = 0.5098$$

8. Commonwealth Bank of Australia



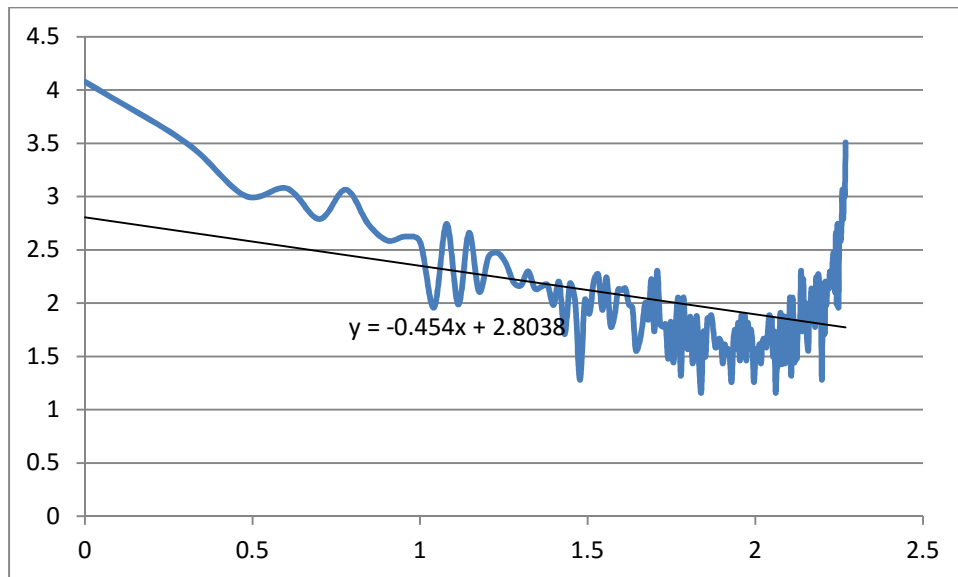
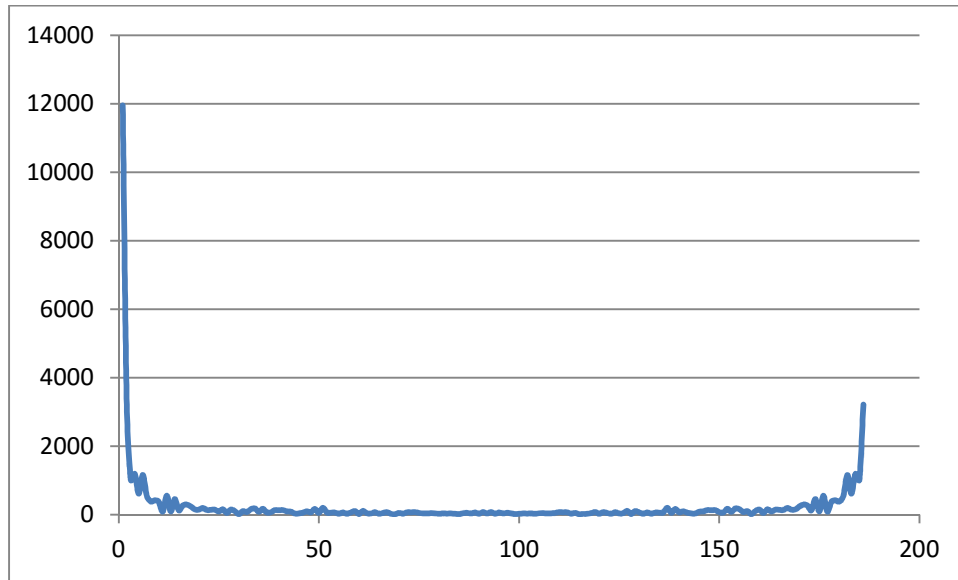
$$\alpha = 0.5404$$

9. Corporation Bank



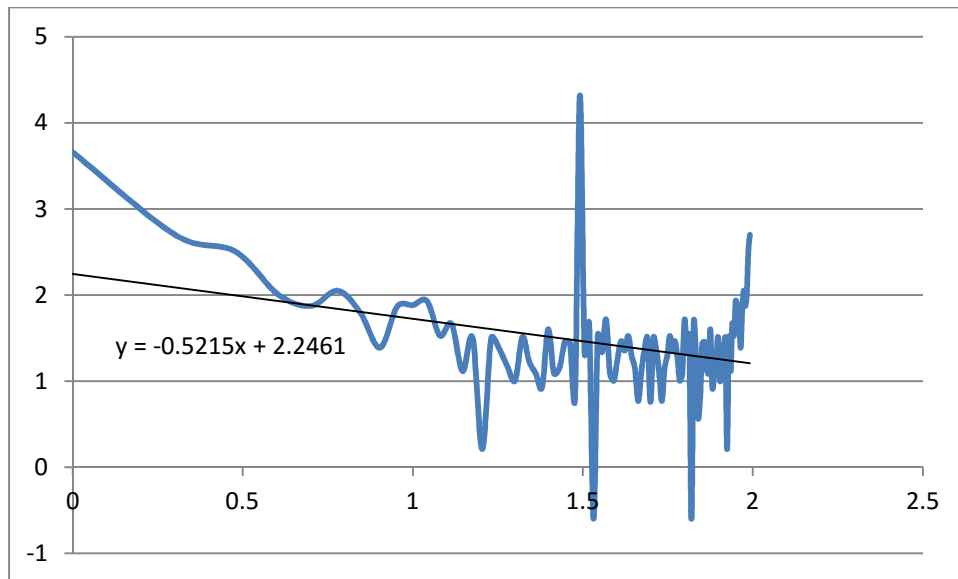
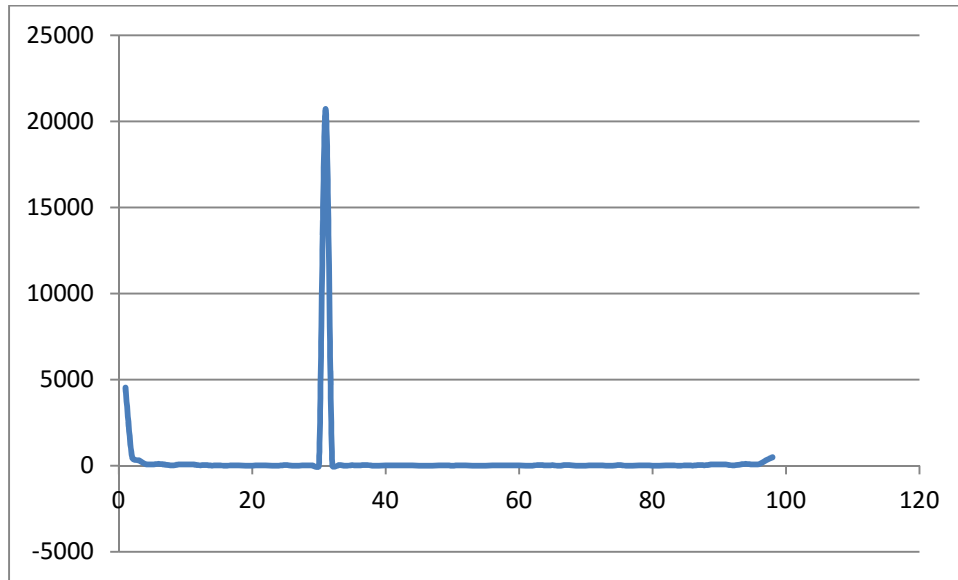
$\alpha = 0.4705$

10. Deutsche Bank



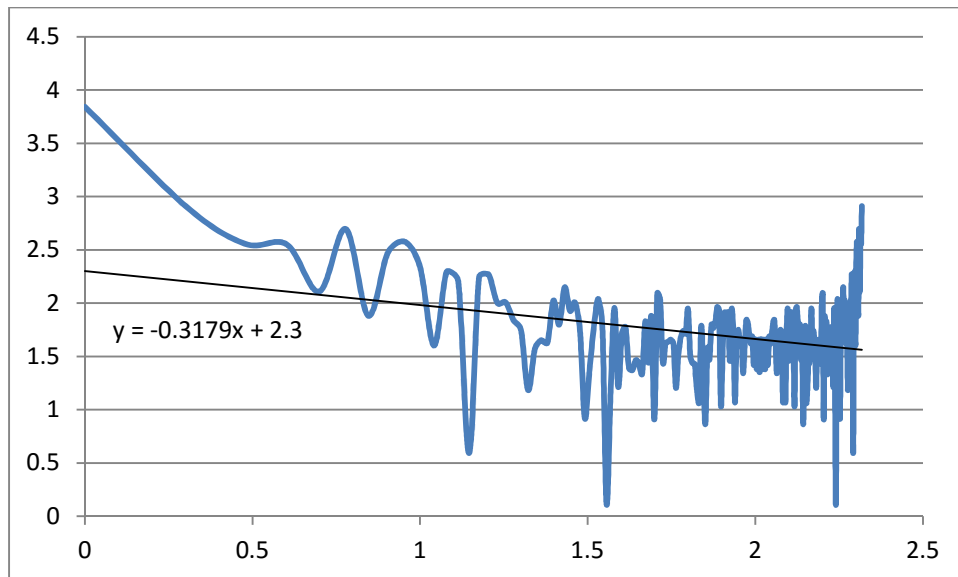
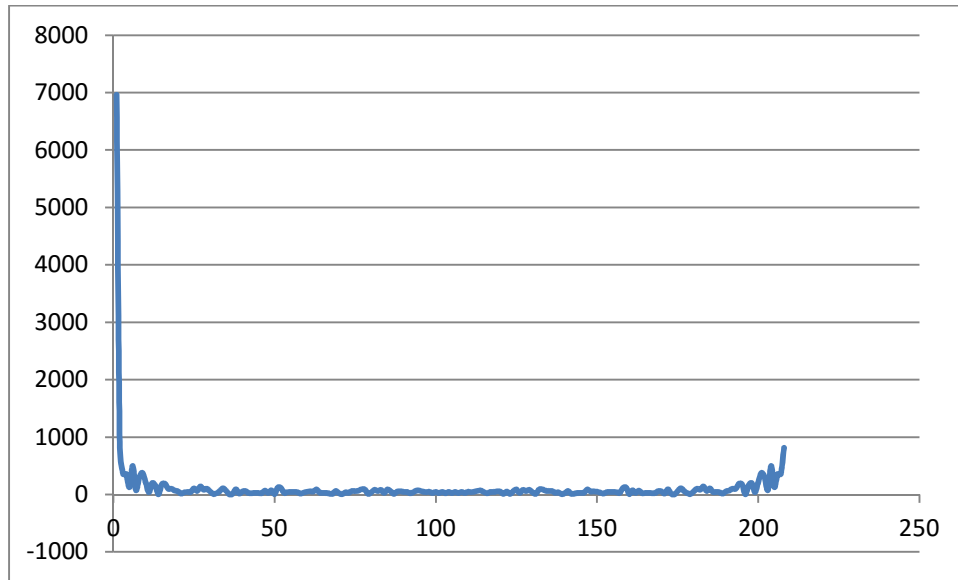
$\alpha = 0.454$

11. DHBK



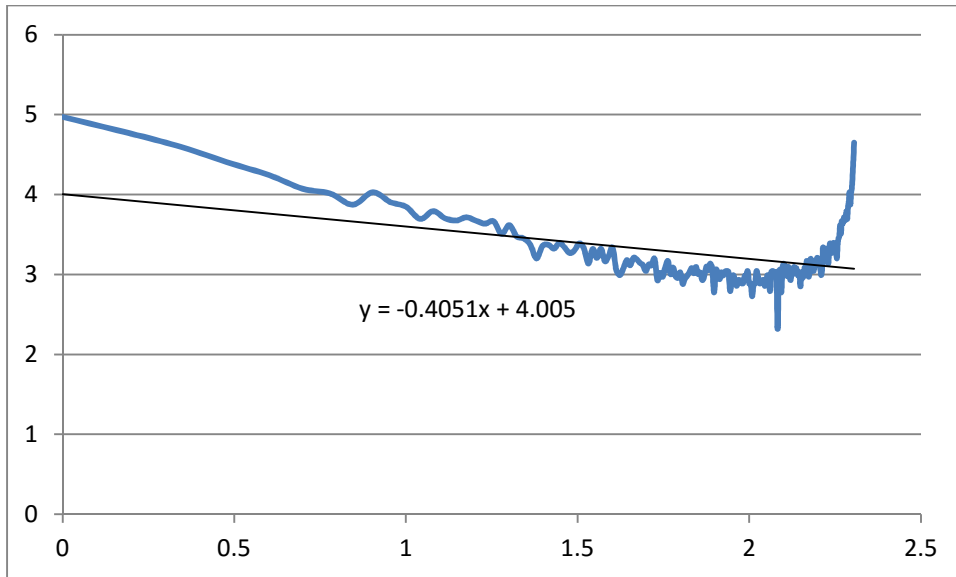
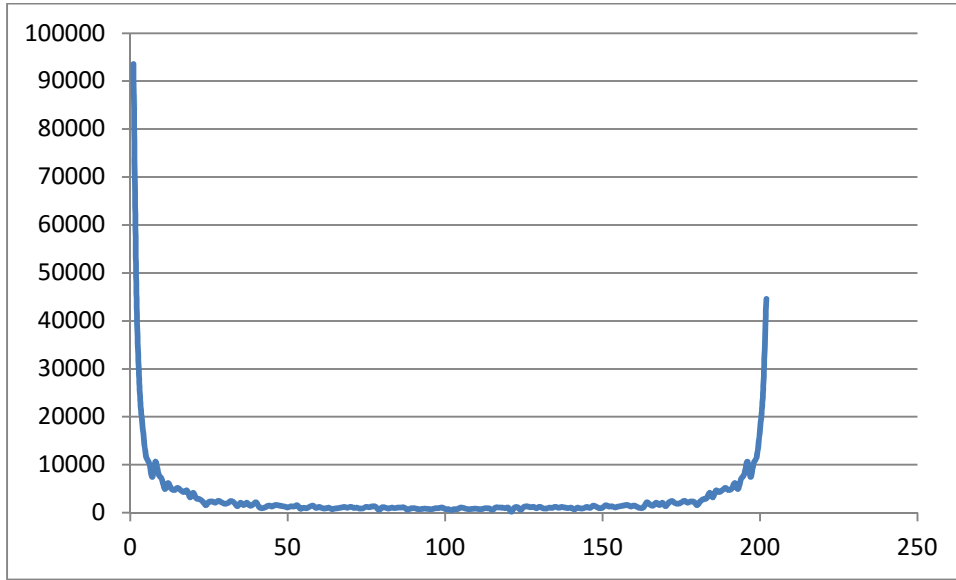
$\alpha = 0.5215$

12. Federal Bank



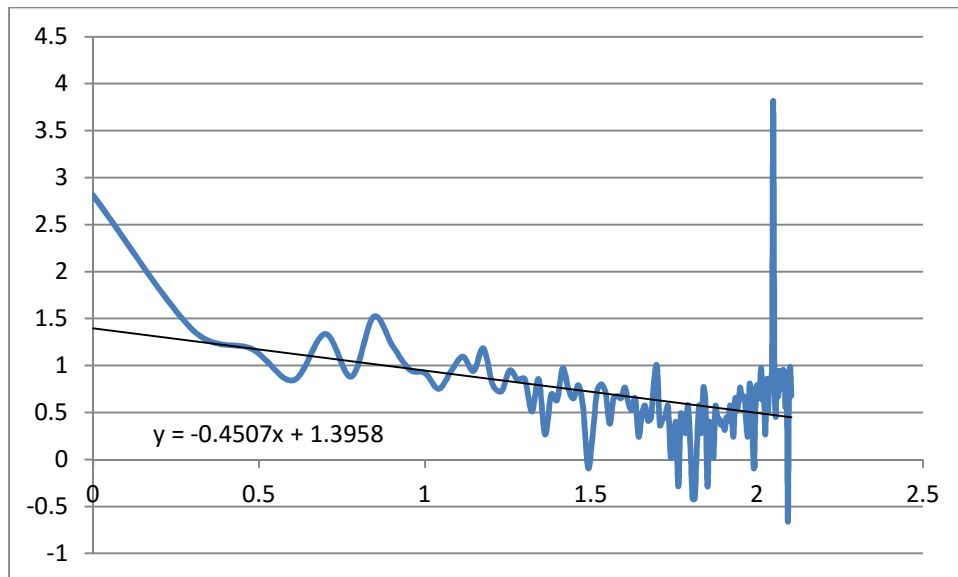
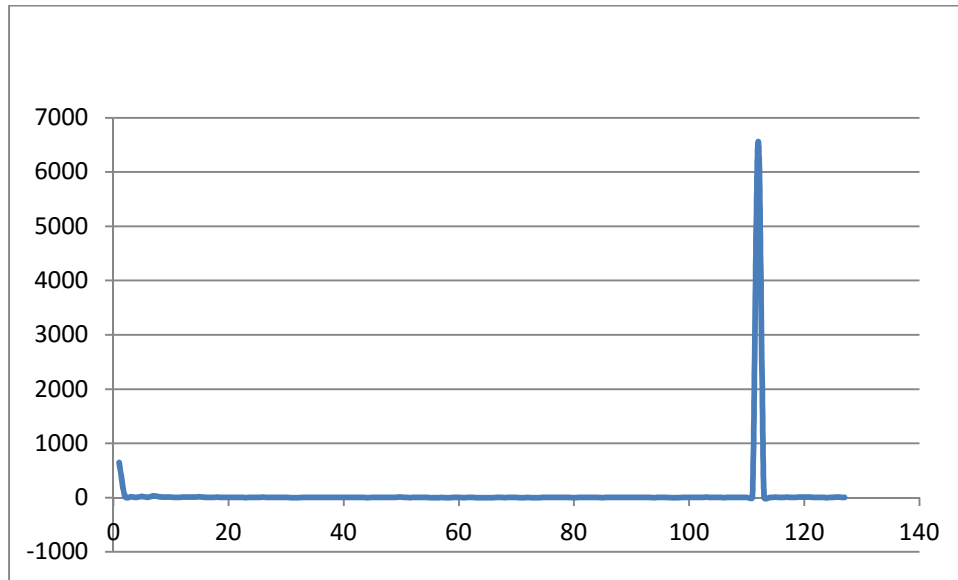
$$\alpha = 0.3179$$

13. HDFC



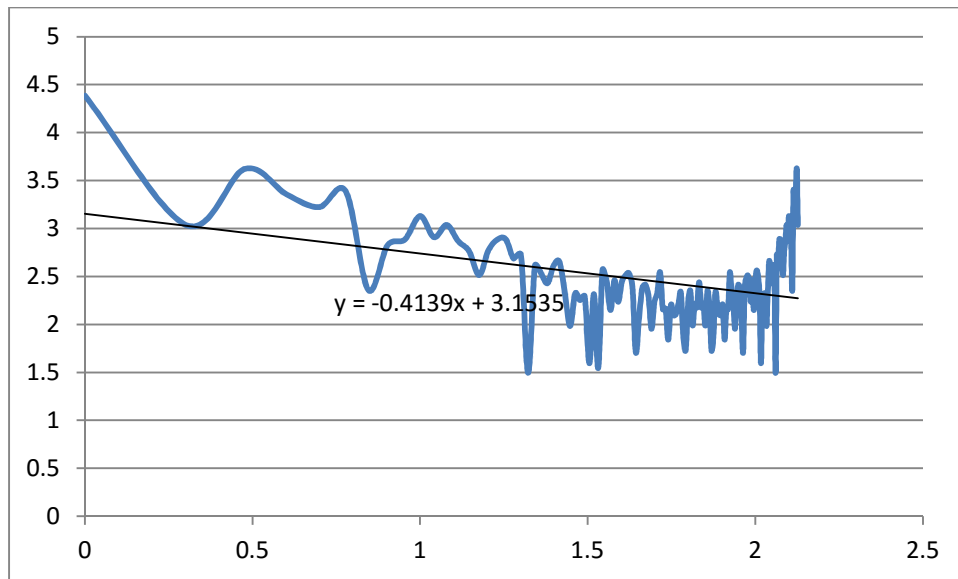
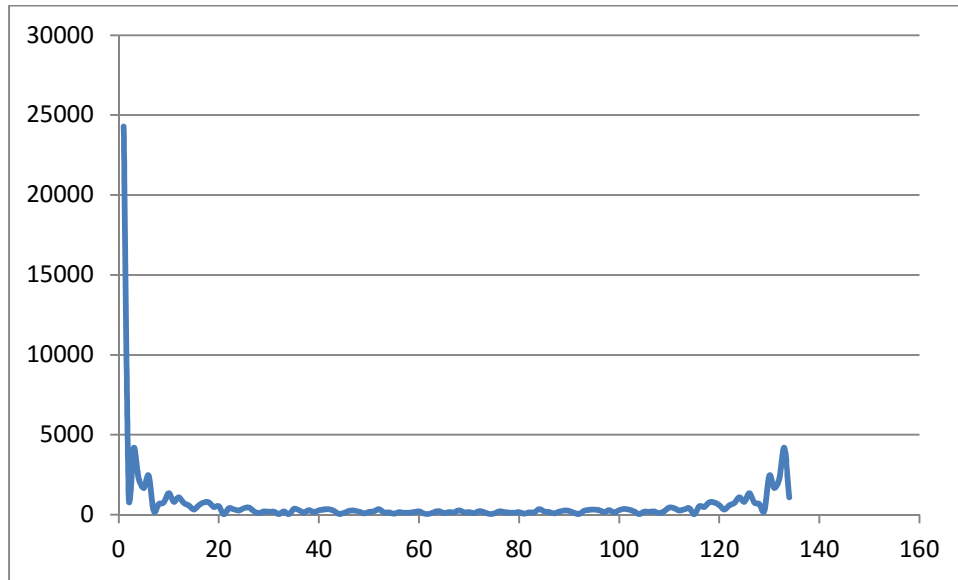
$\alpha = 0.4051$

14. HSBC



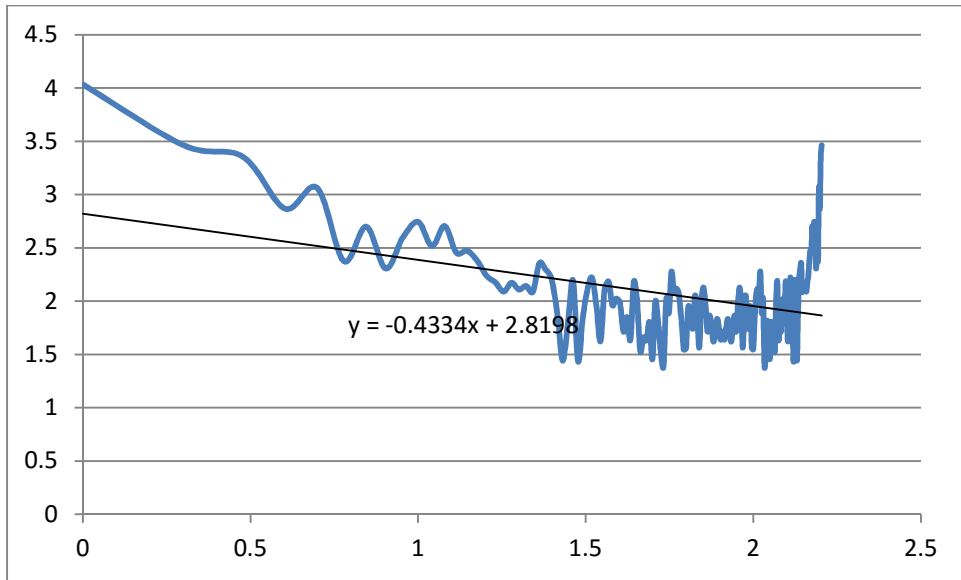
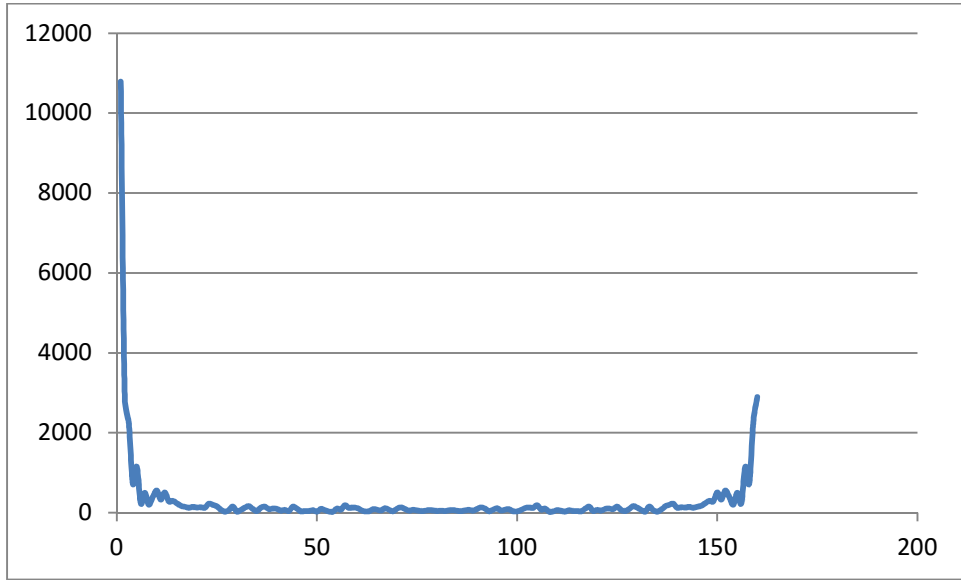
$\alpha = 0.4507$

15. Indian Bank



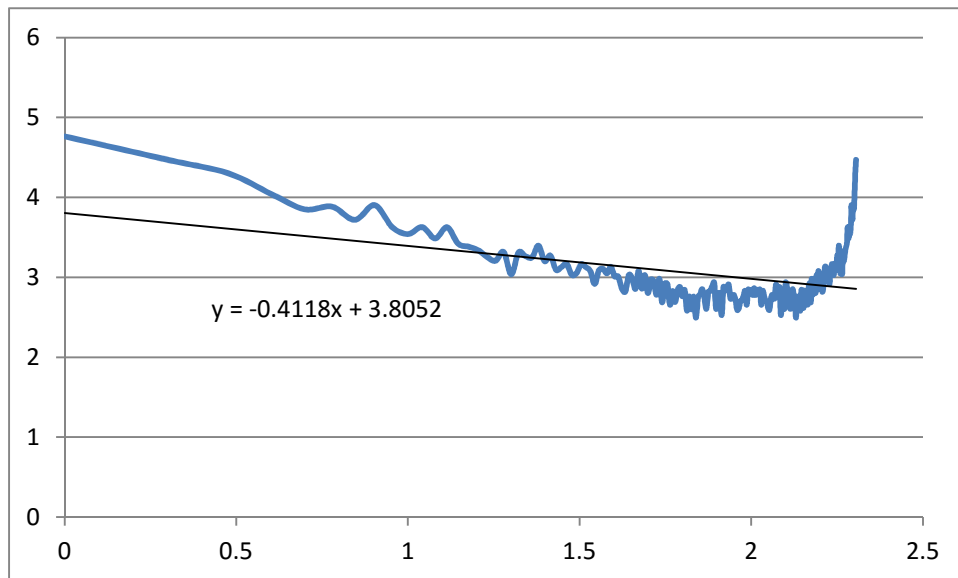
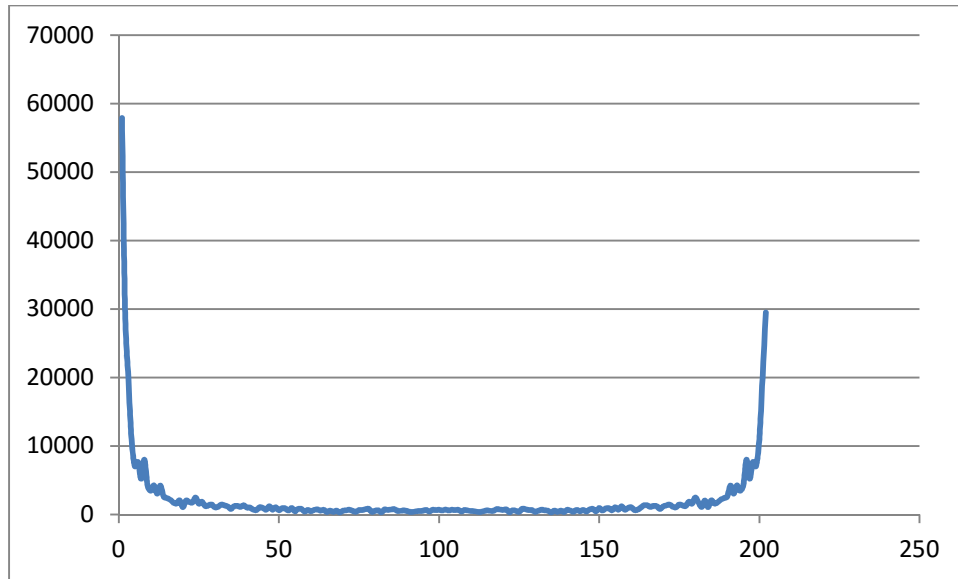
$$\alpha = 0.4139$$

16. J&K Bank



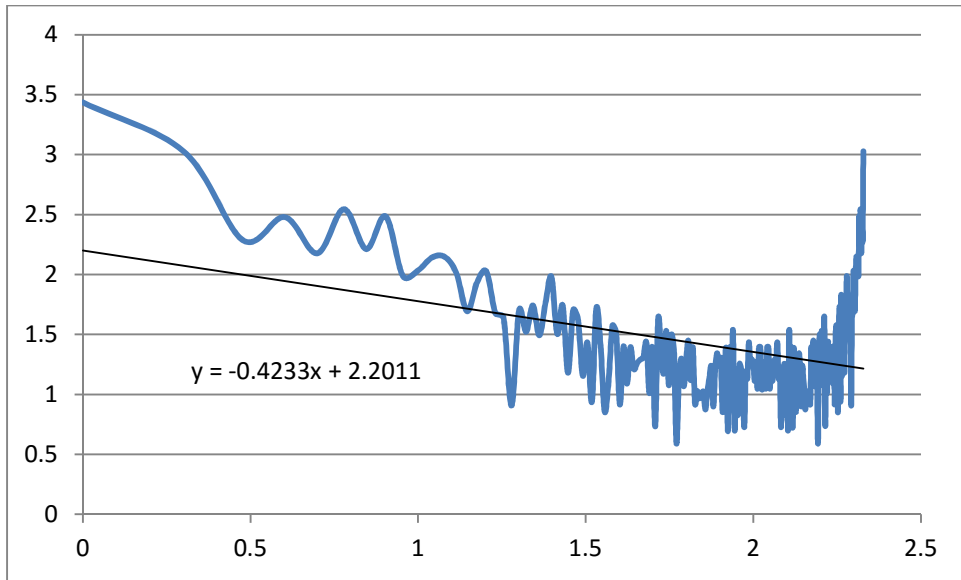
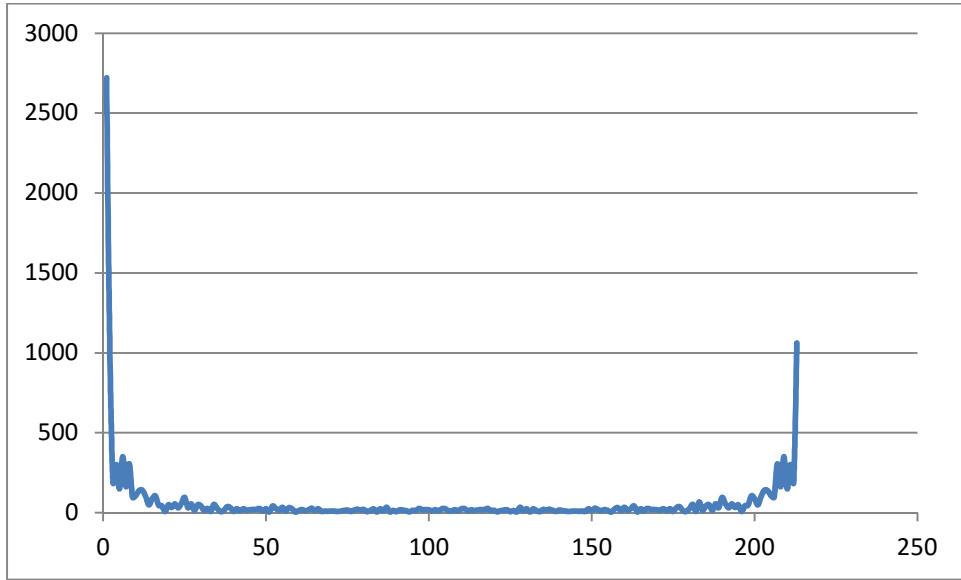
$$\alpha = 0.4334$$

17. Kotak Bank



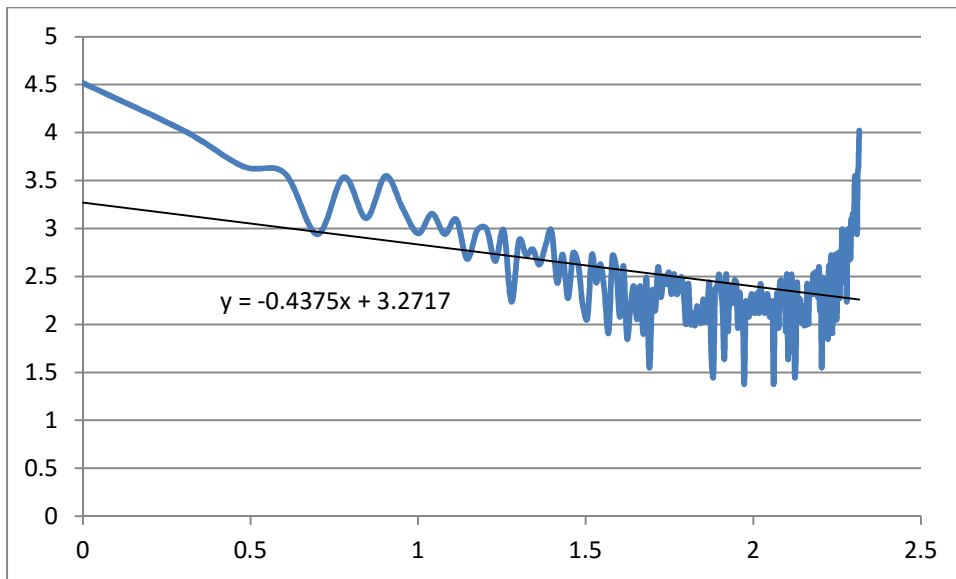
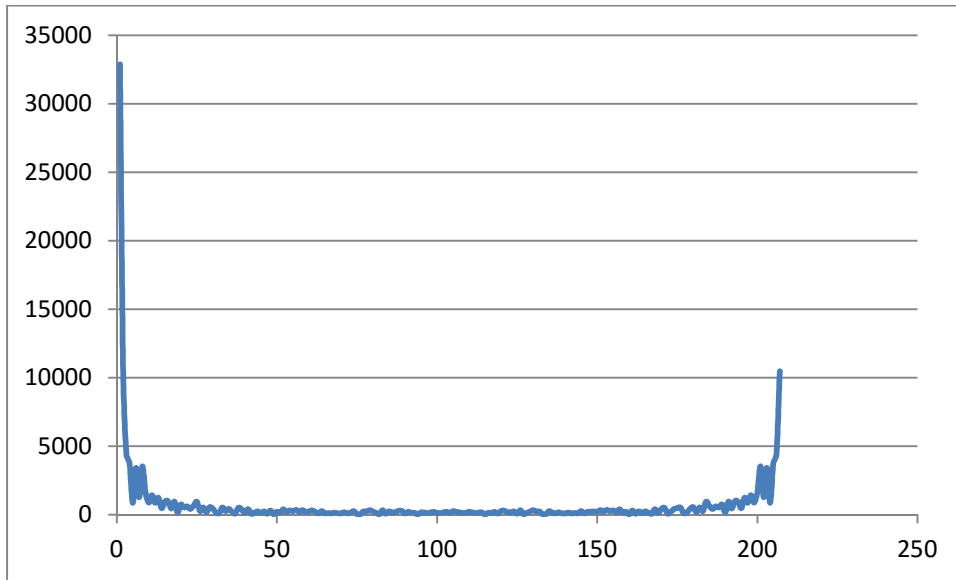
$$\alpha = 0.4118$$

18. South Bank



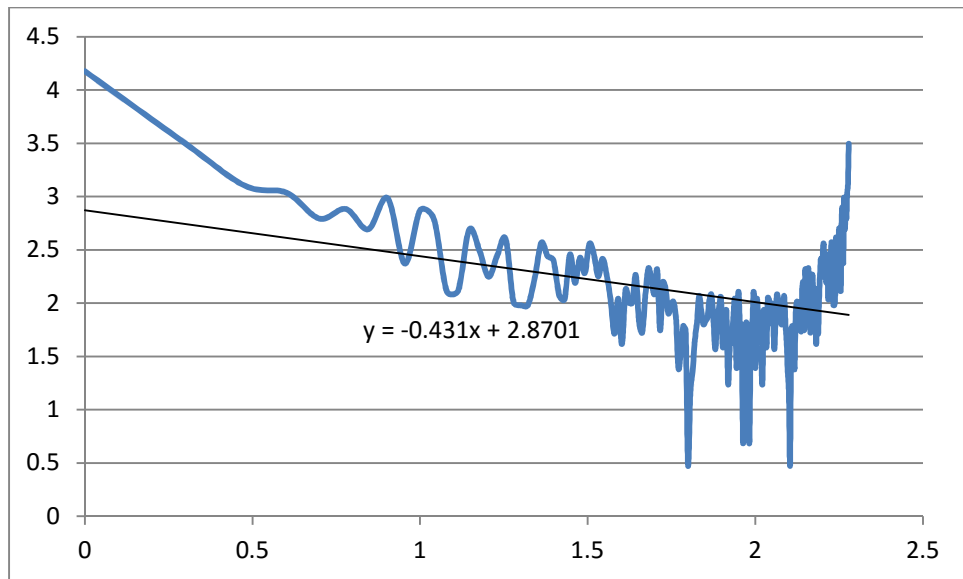
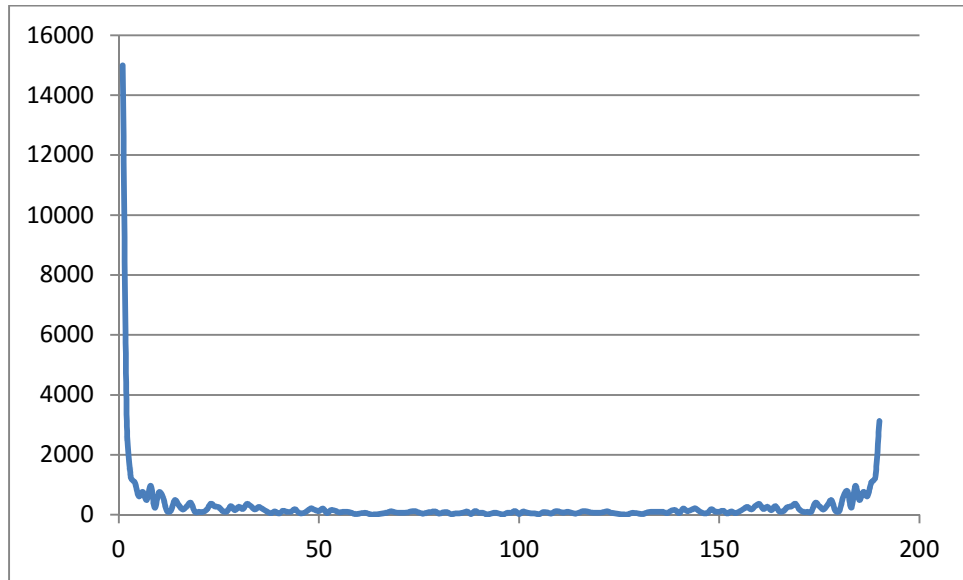
$\alpha = 0.4233$

19. State Bank of India



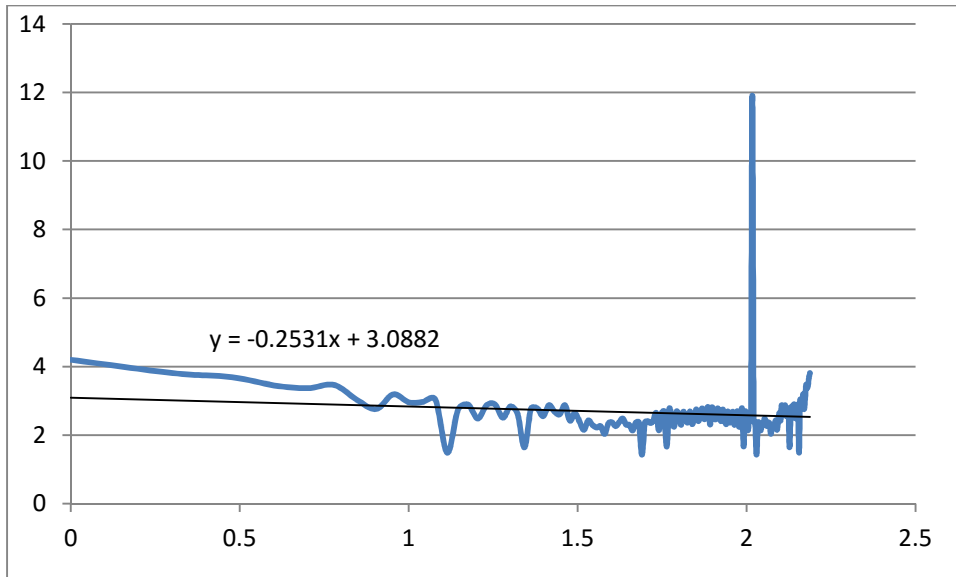
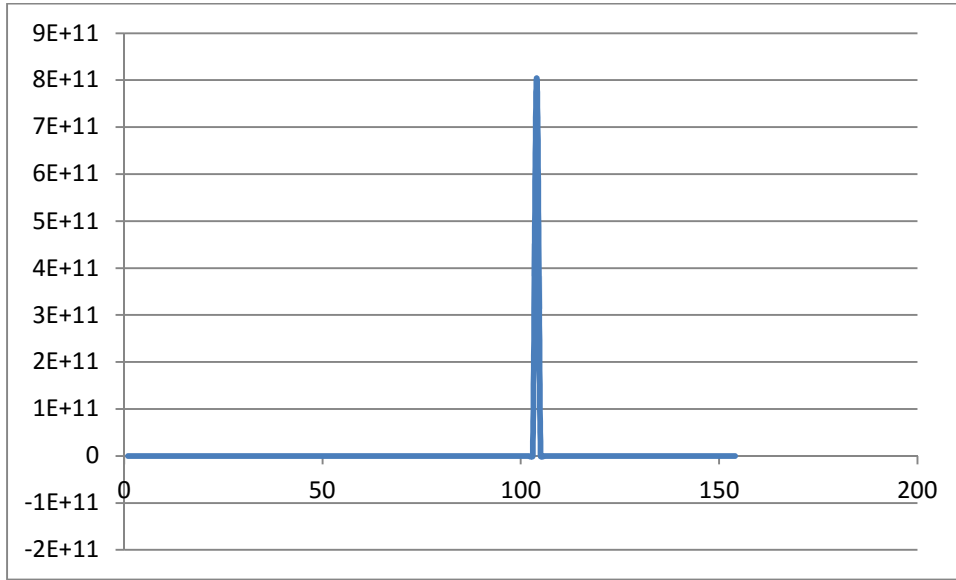
$$\alpha = 0.4375$$

20. Syndicate Bank



$$\alpha = 0.431$$

21. Yes Bank



$$\alpha = 0.2531$$

Chapter 03:

CROSS CORRELATION-

It is a measure of similarity of two series as a function of displacement of one relative to another. Correlation functions have been studied for open-close, open-low, open-high, high-low, high-close and low-close conditions for the banks.

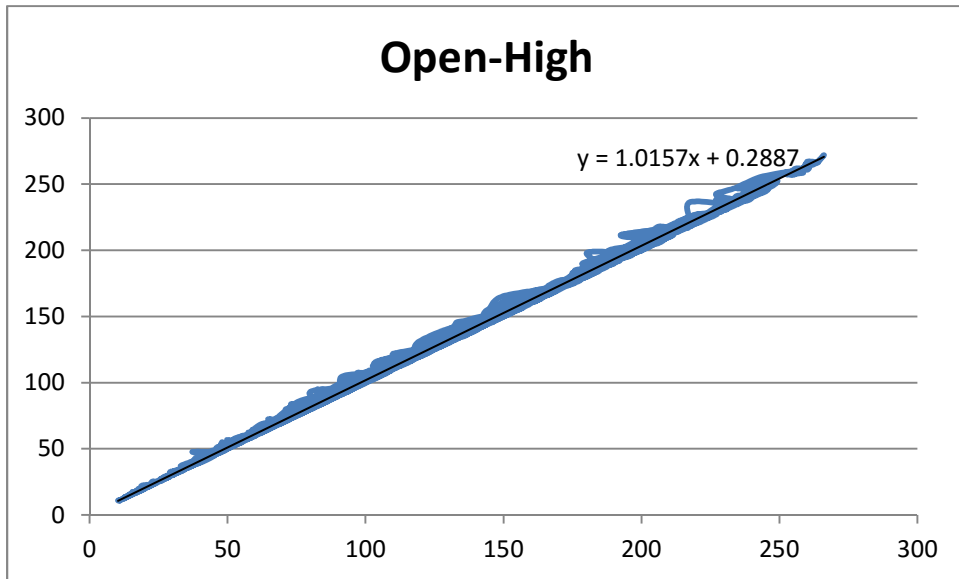
ANNEXURE-C: Cross- Correlation graphs

Correlation graphs between open-high, open-low, open-close, high-low, high-close and low-close have been drawn for all the banks.

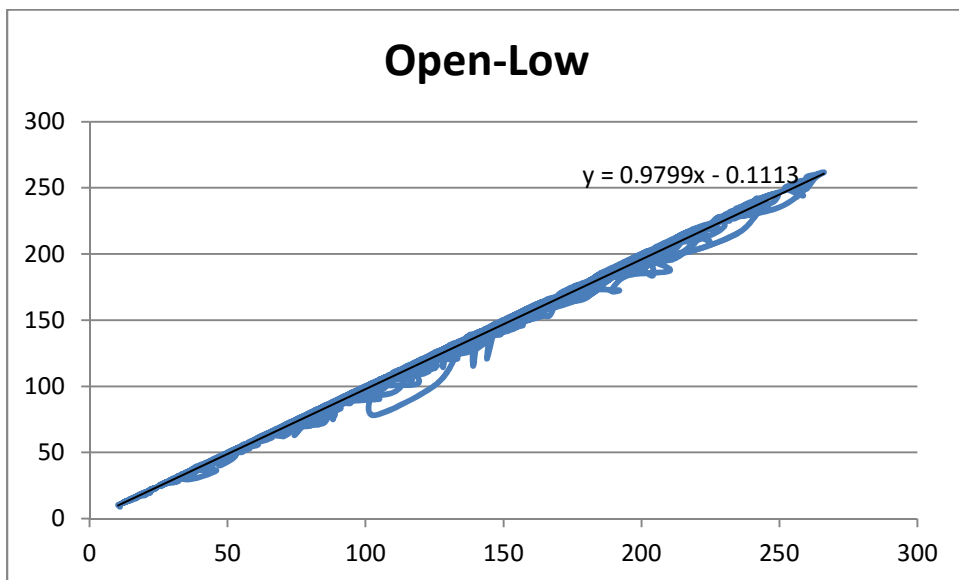
All the banks have been seen to follow a linear trend as far as correlation is considered with a few points falling out of the straight line.

1. Allahabad Bank

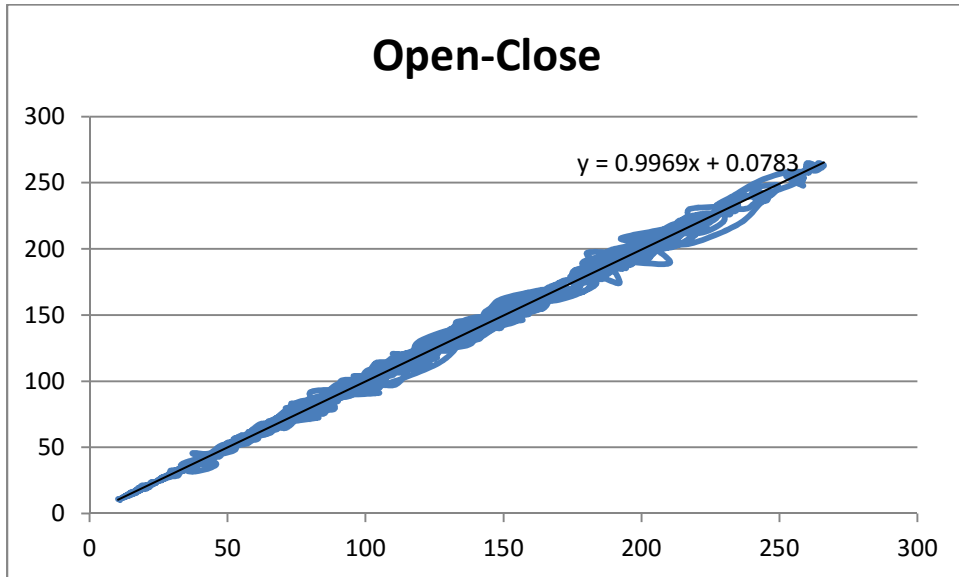
Open-High



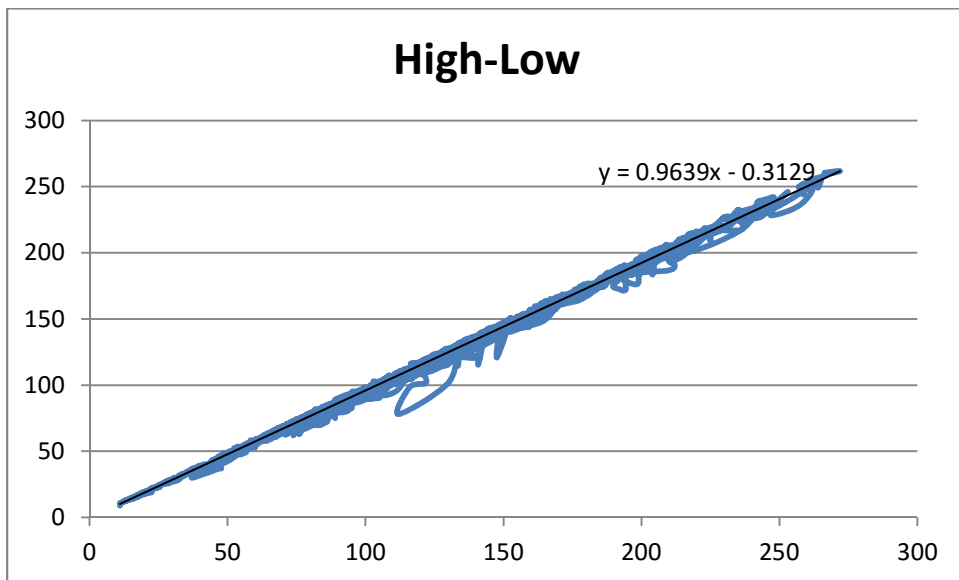
Open-Low



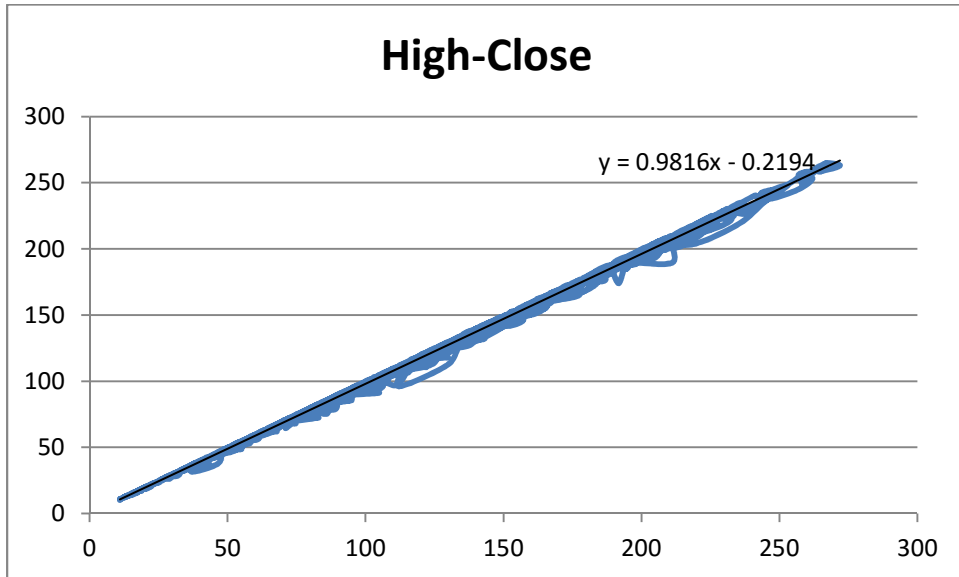
Open-Close



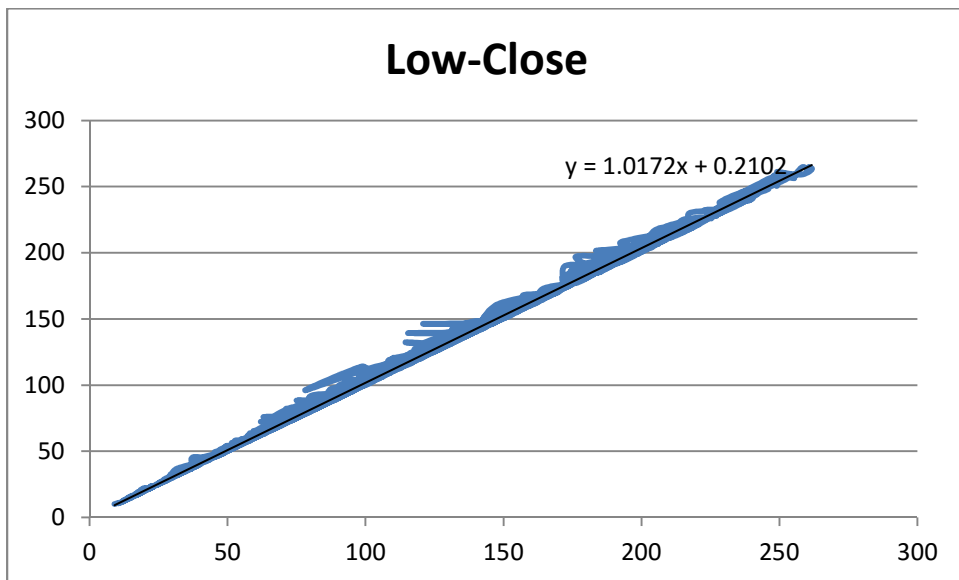
High-Low



High-Close

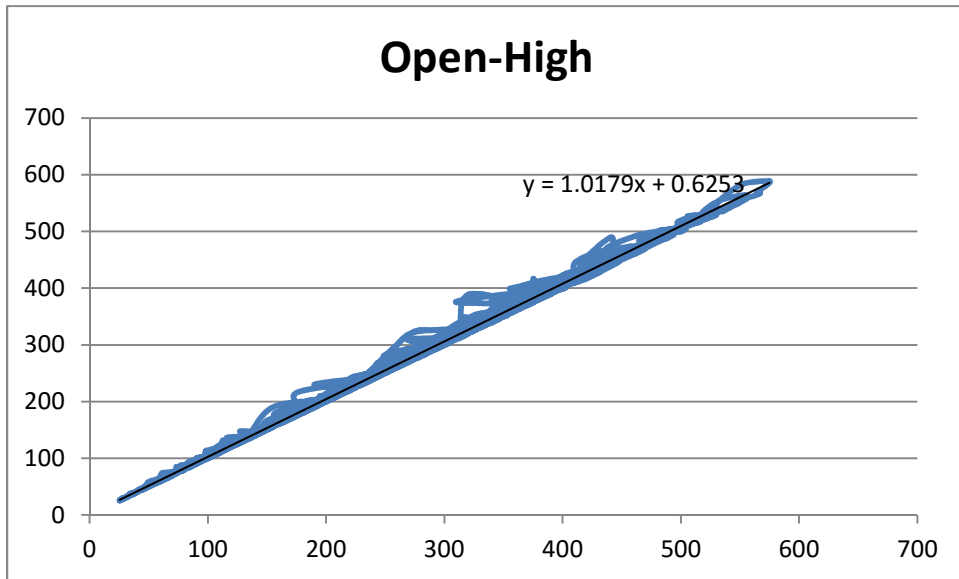


Low-Close

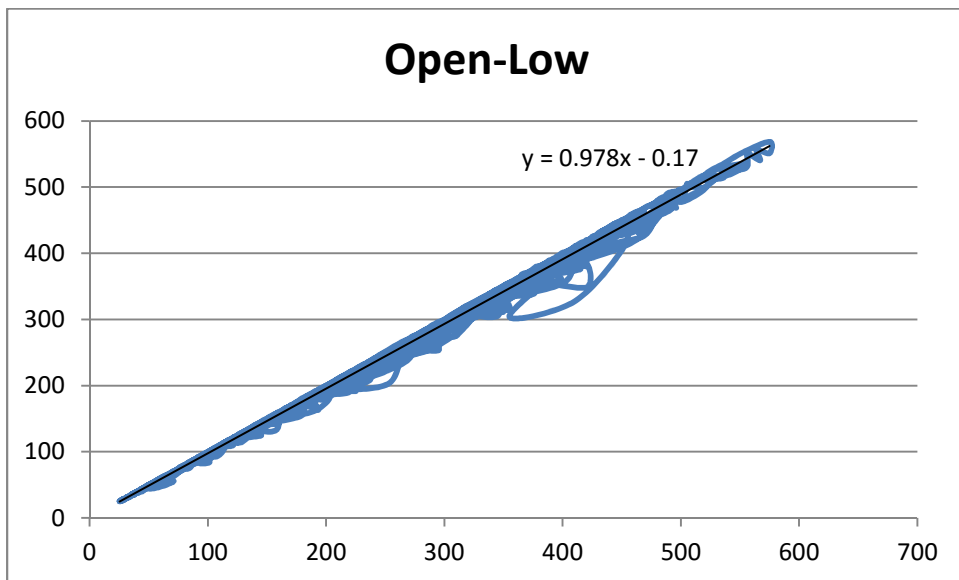


2. Bank of India

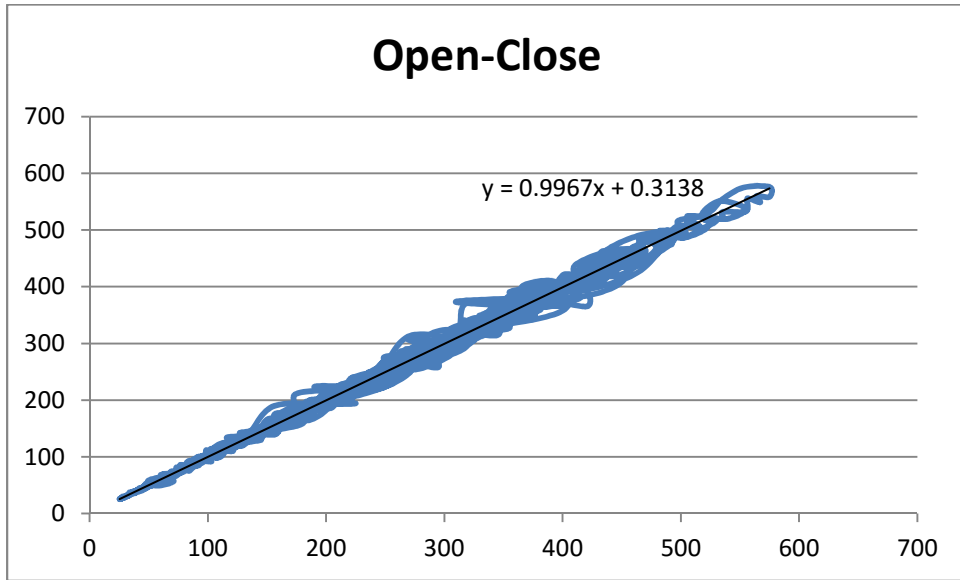
Open-High



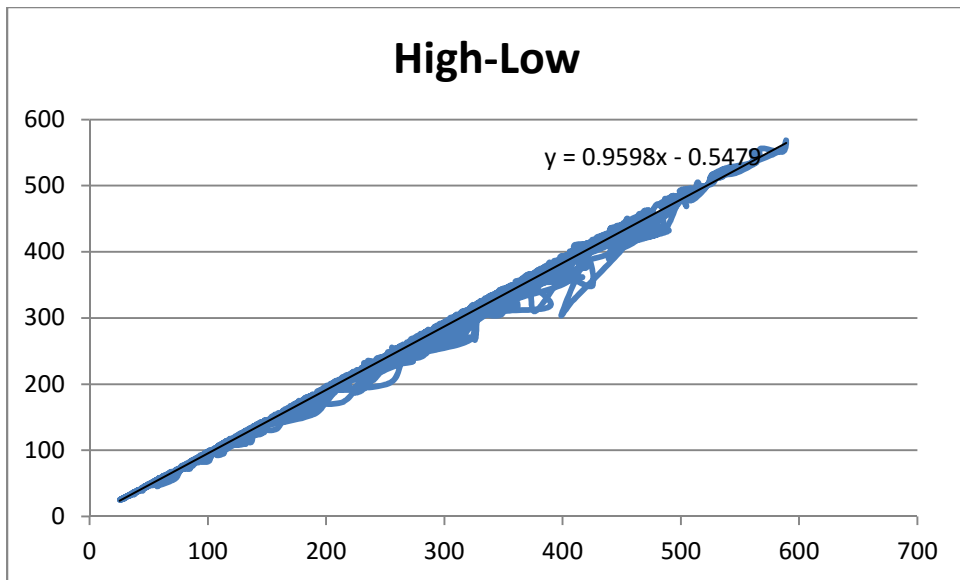
Open-Low



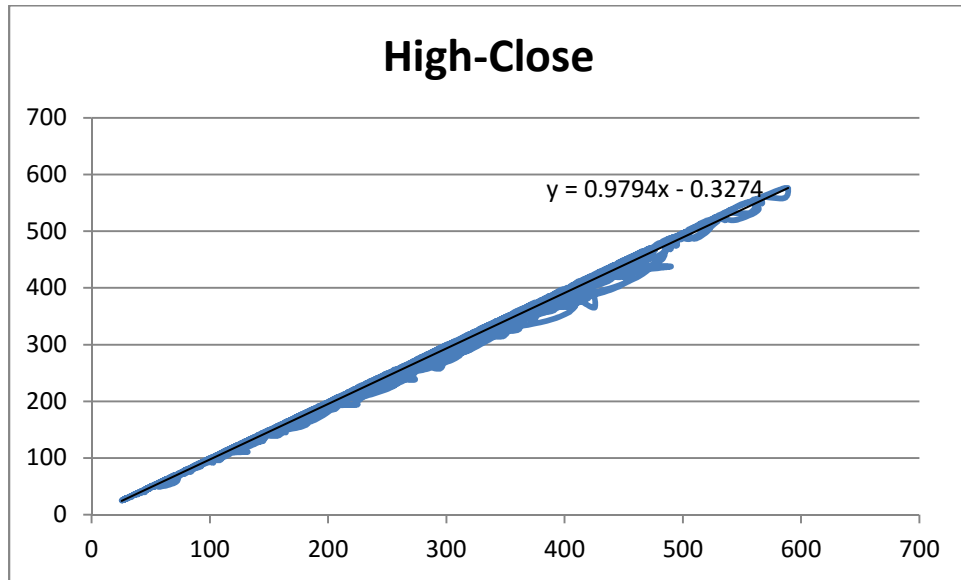
Open-Close



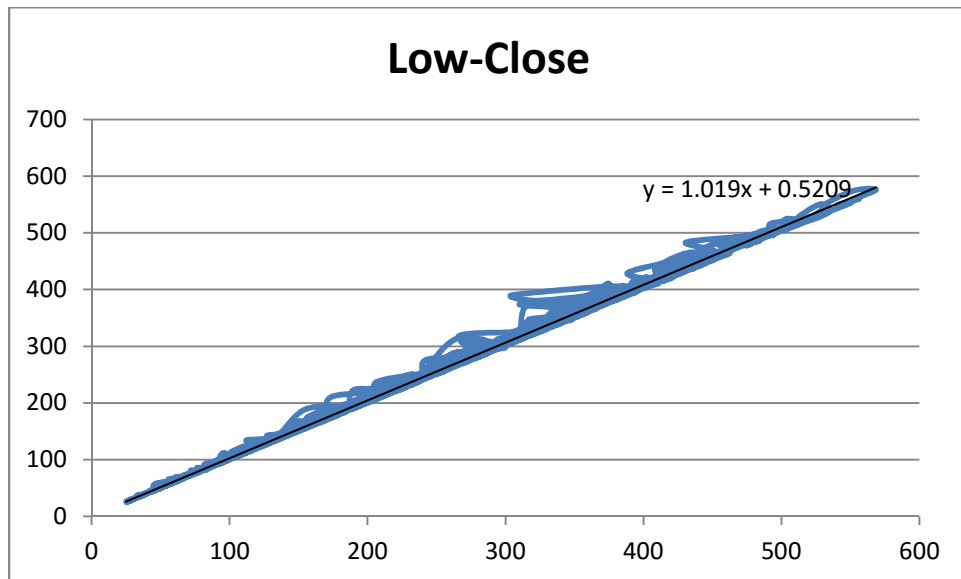
High-Low



High-Close

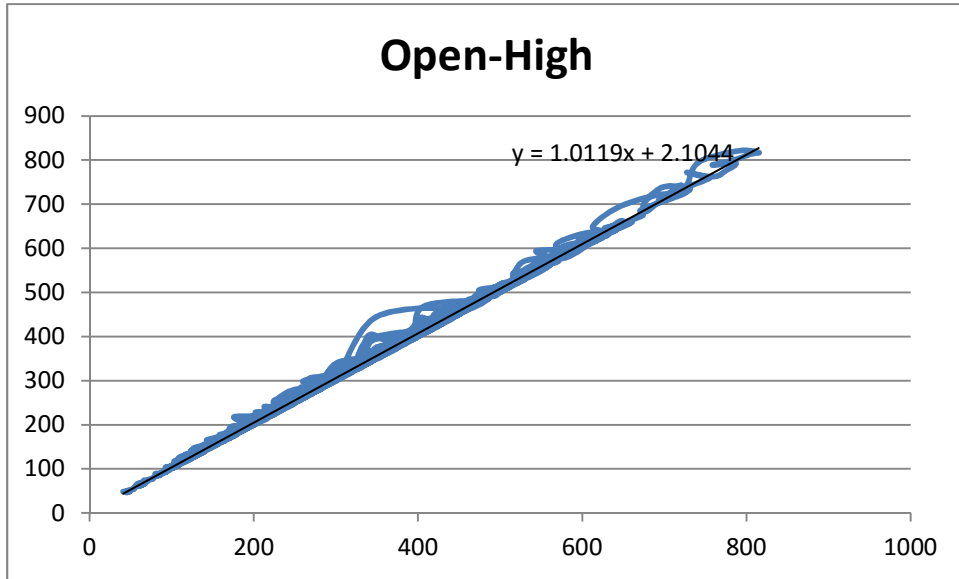


Low-Close

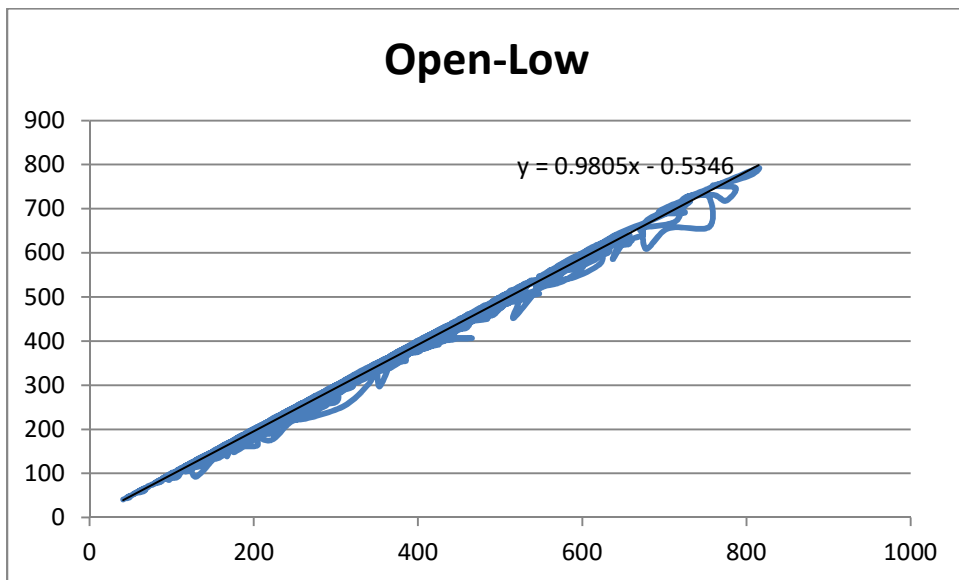


3. Canara Bank

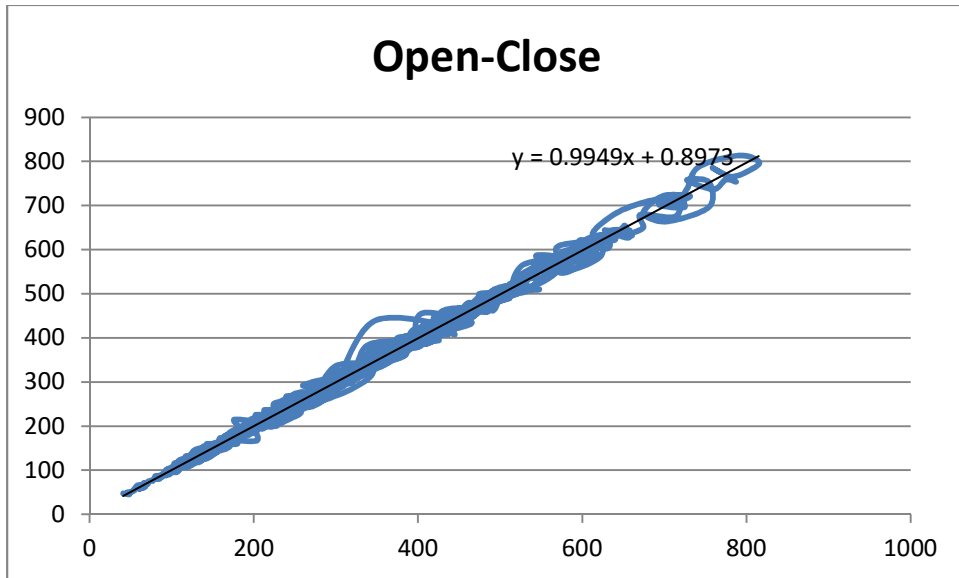
Open-High



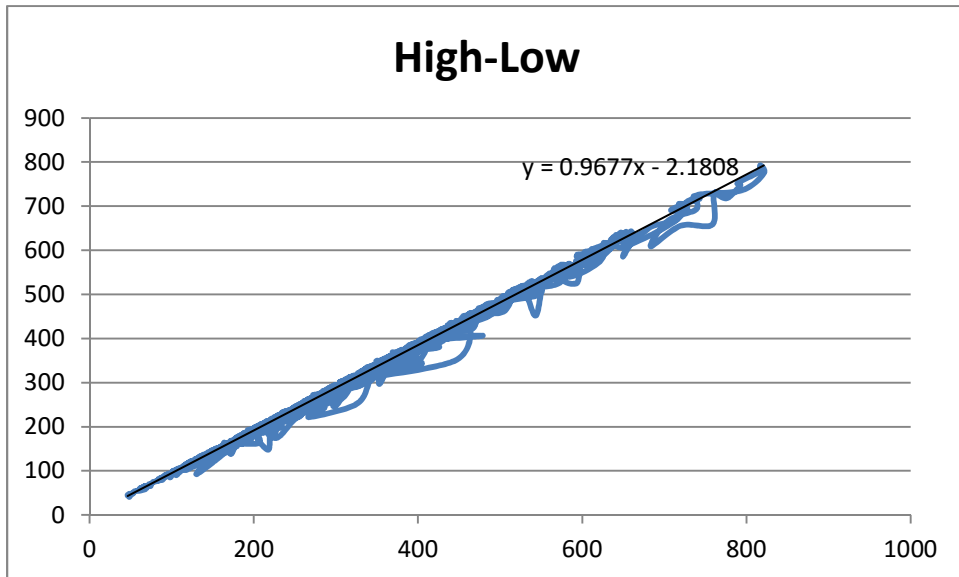
Open-Low



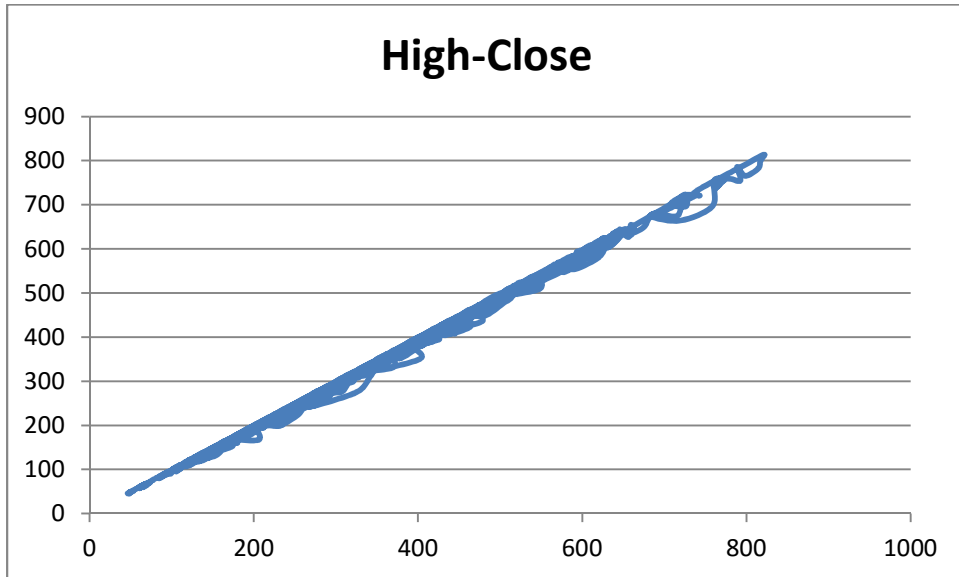
Open-Close



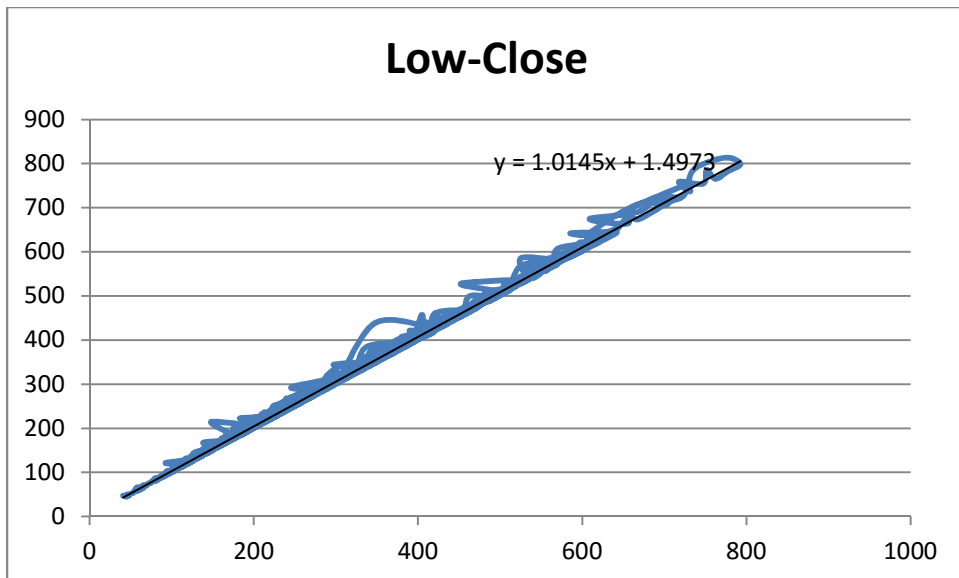
High-Low



High-Close

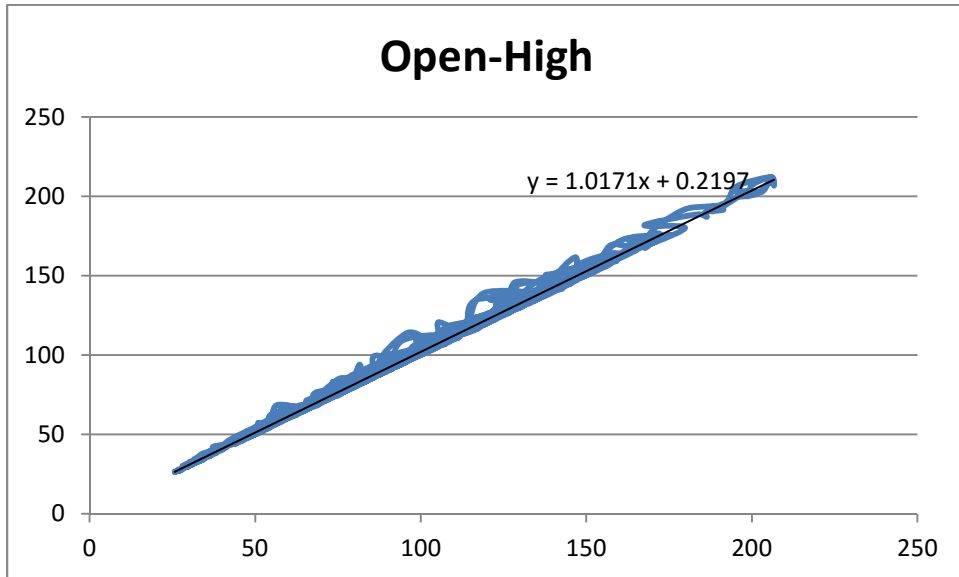


Low-Close

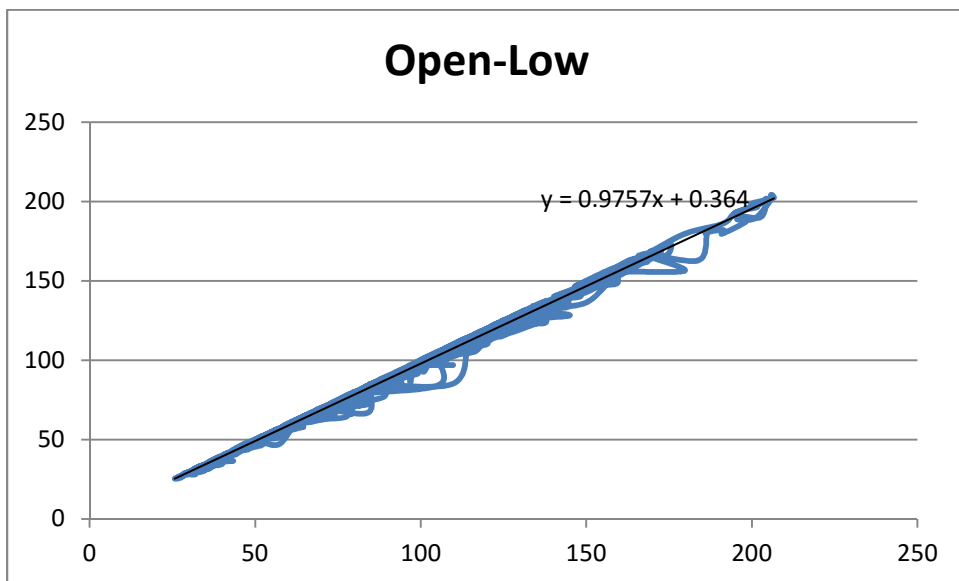


4. Central Bank

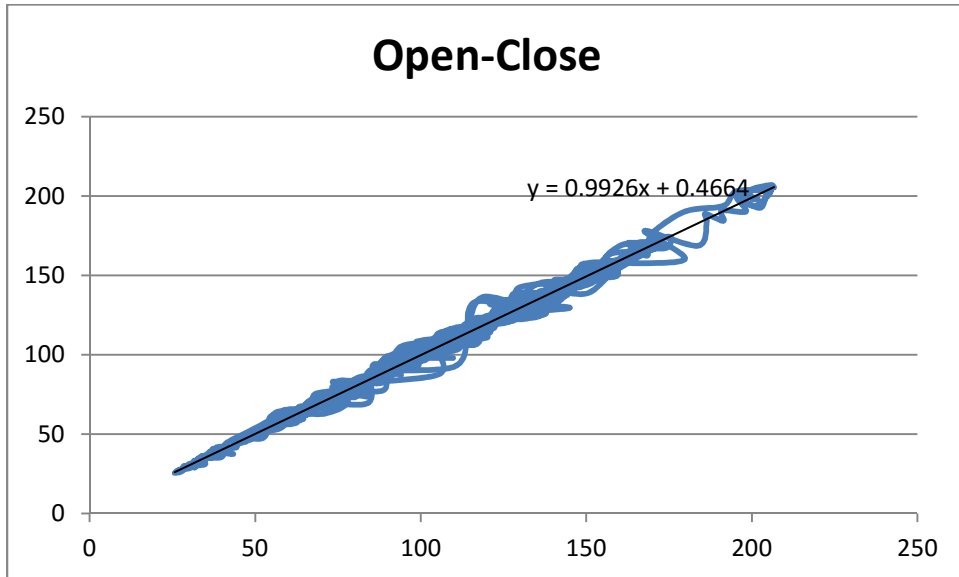
Open-High



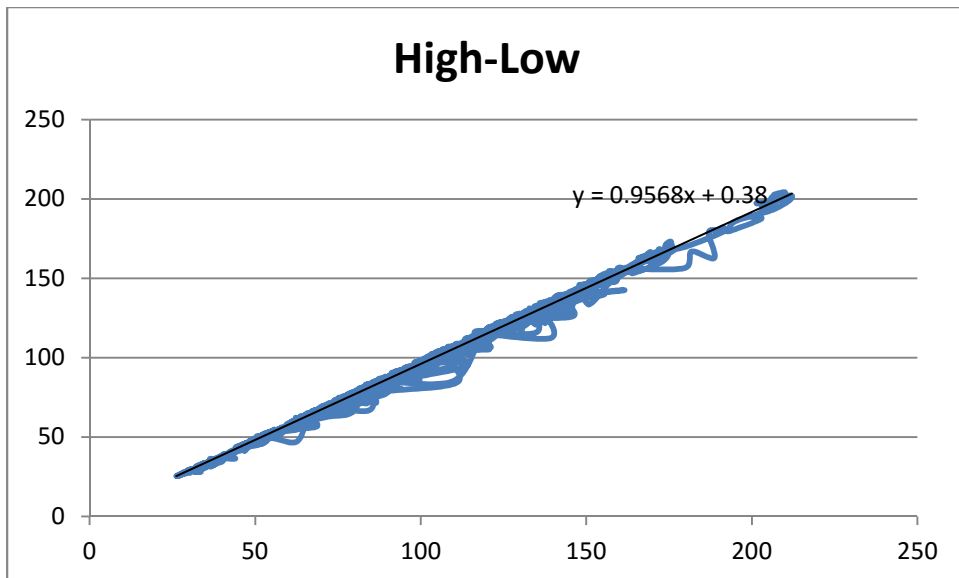
Open-Low



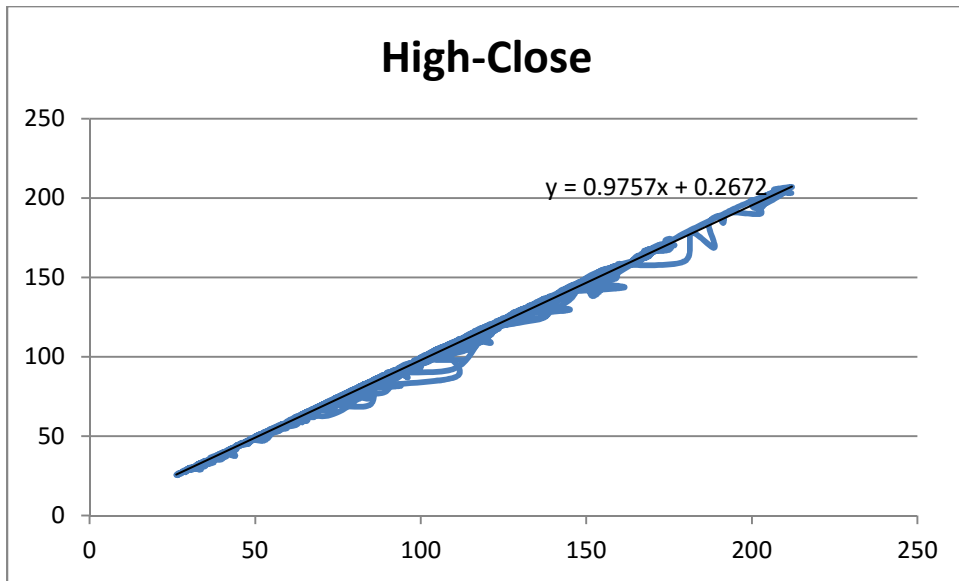
Open-Close



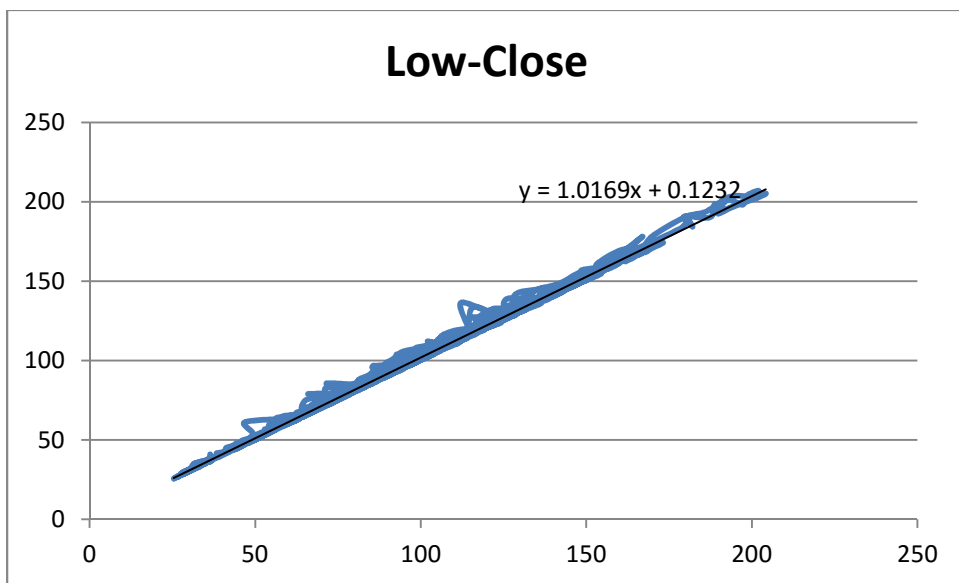
High-Low



High-Close

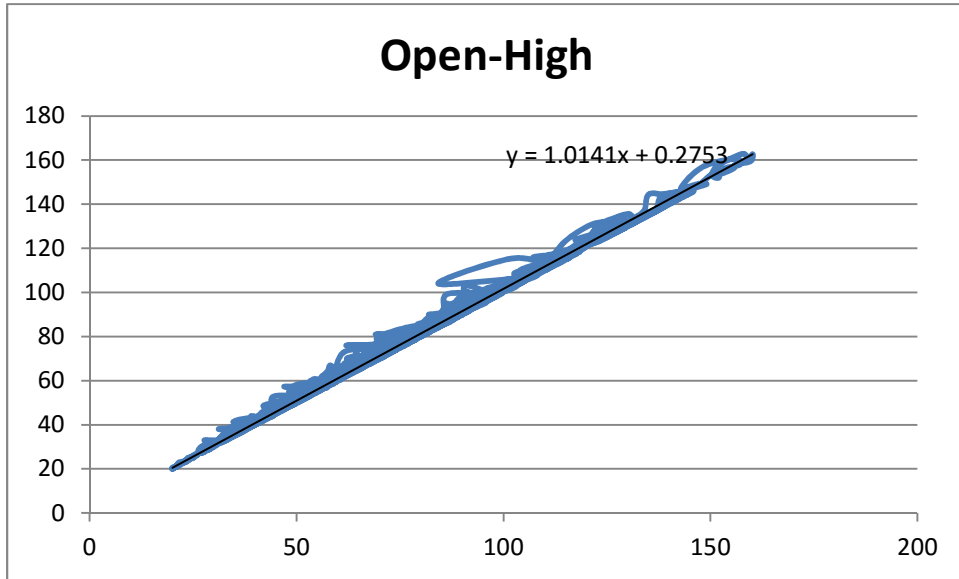


Low-Close

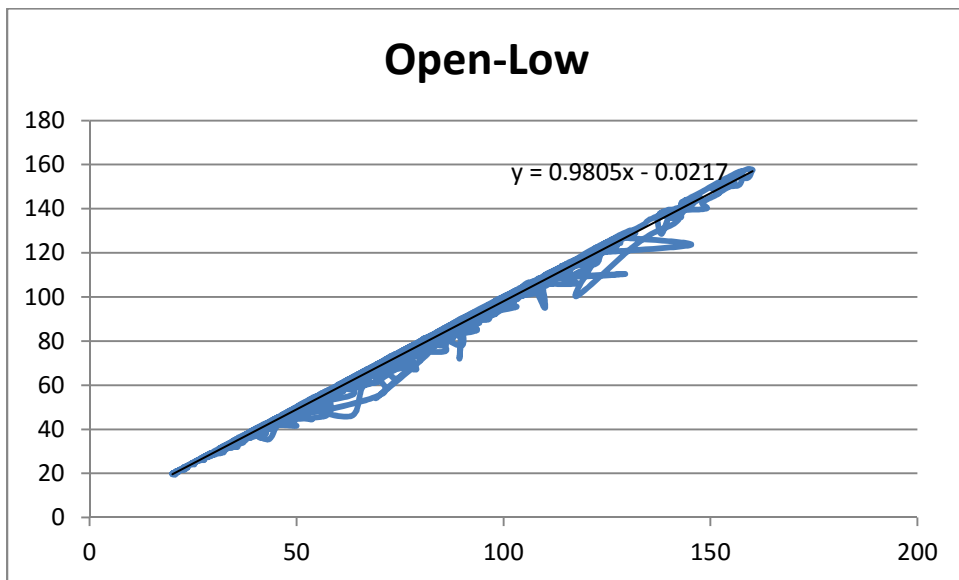


5. Corporation Bank

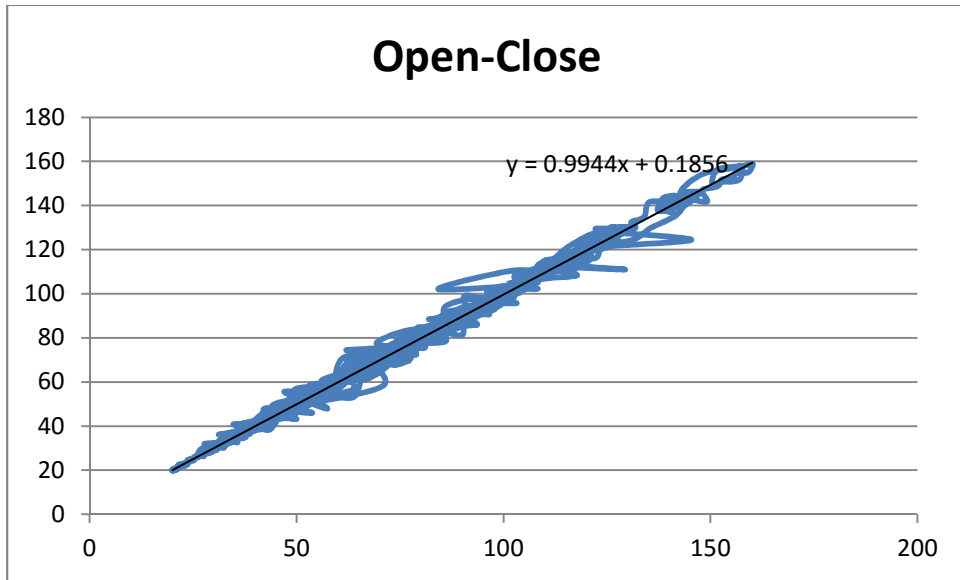
Open-High



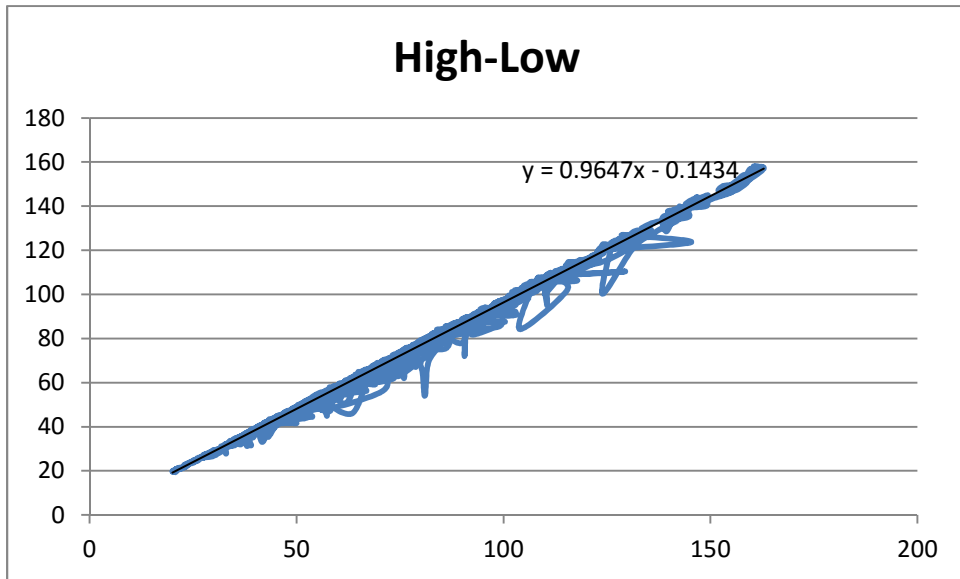
Open-Low



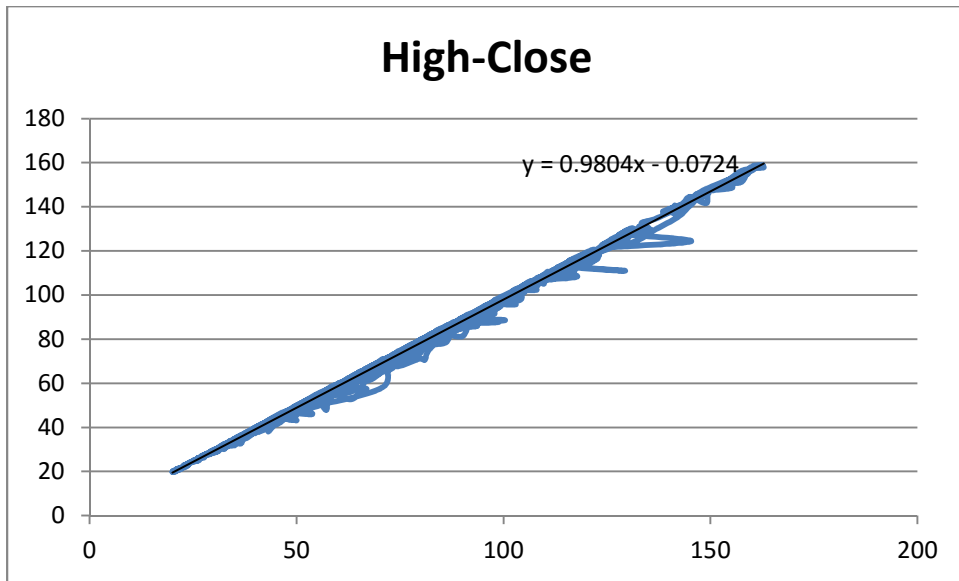
Open-Close



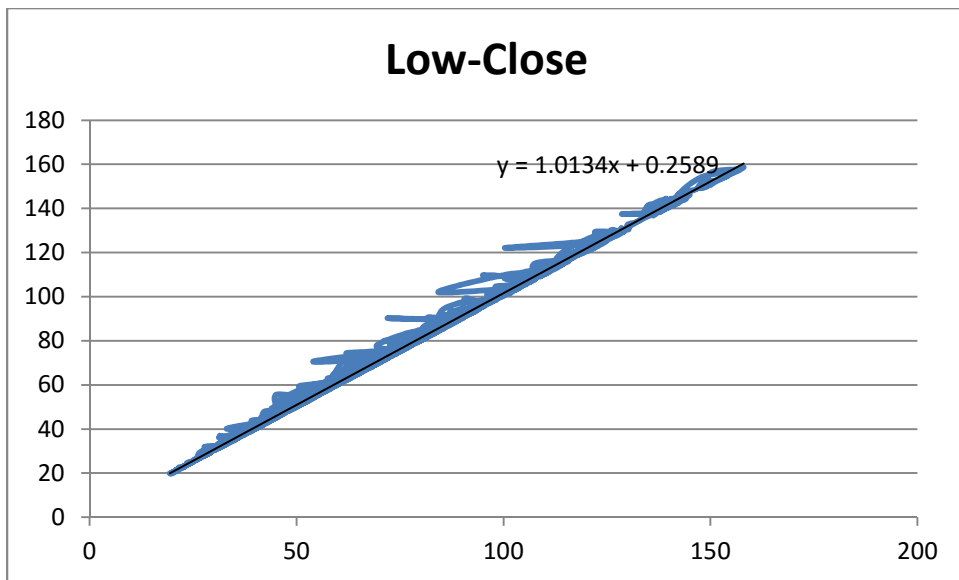
High-Low



High-Close

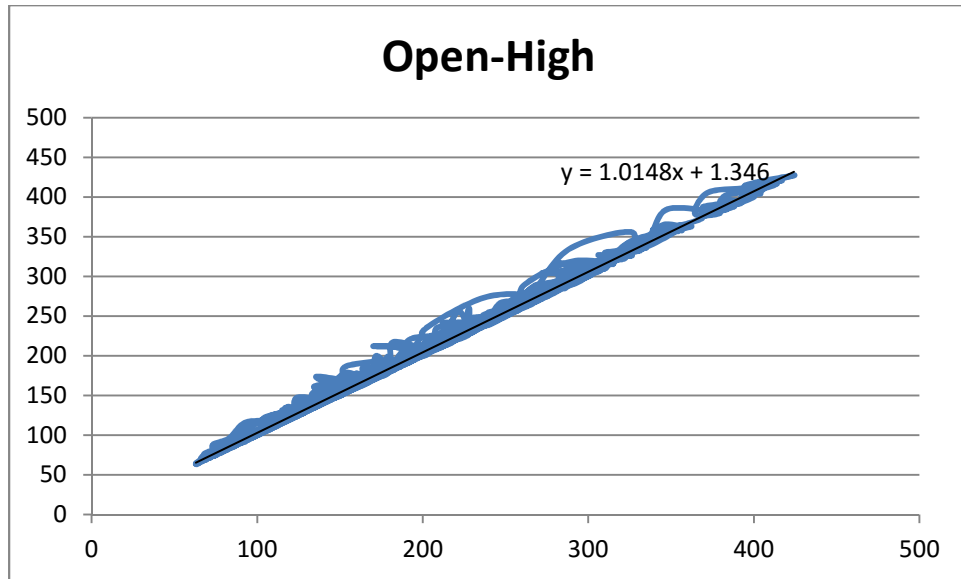


Low-Close

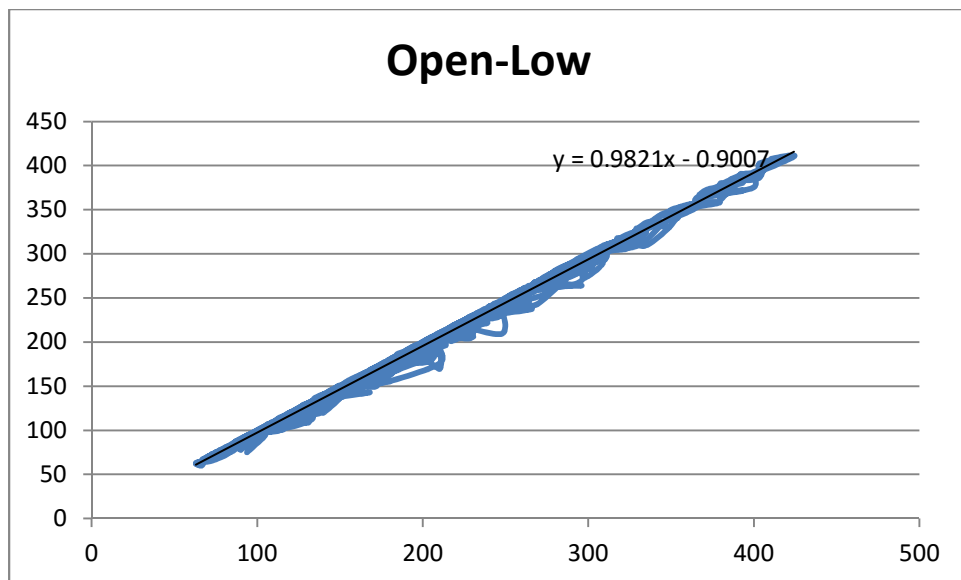


6. Indian Bank

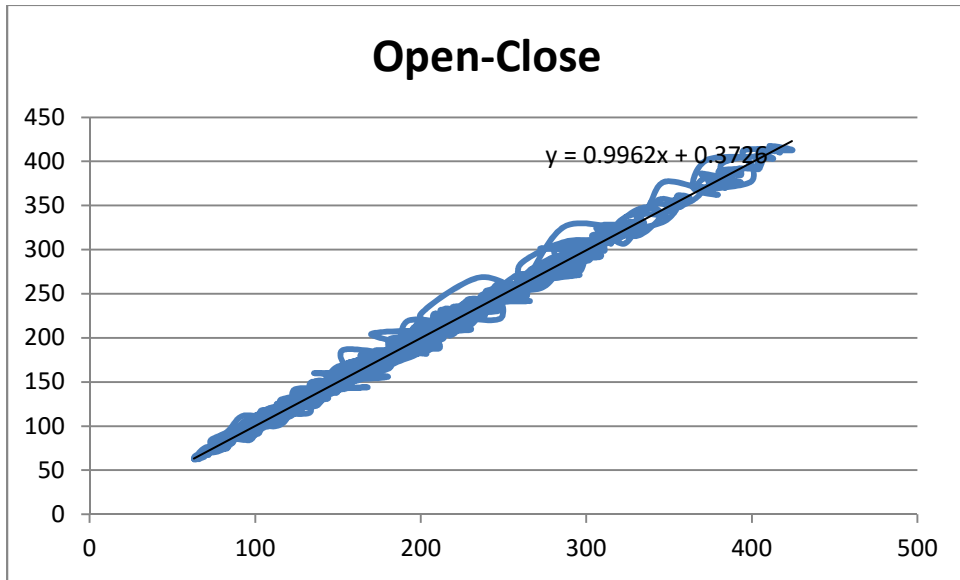
Open-High



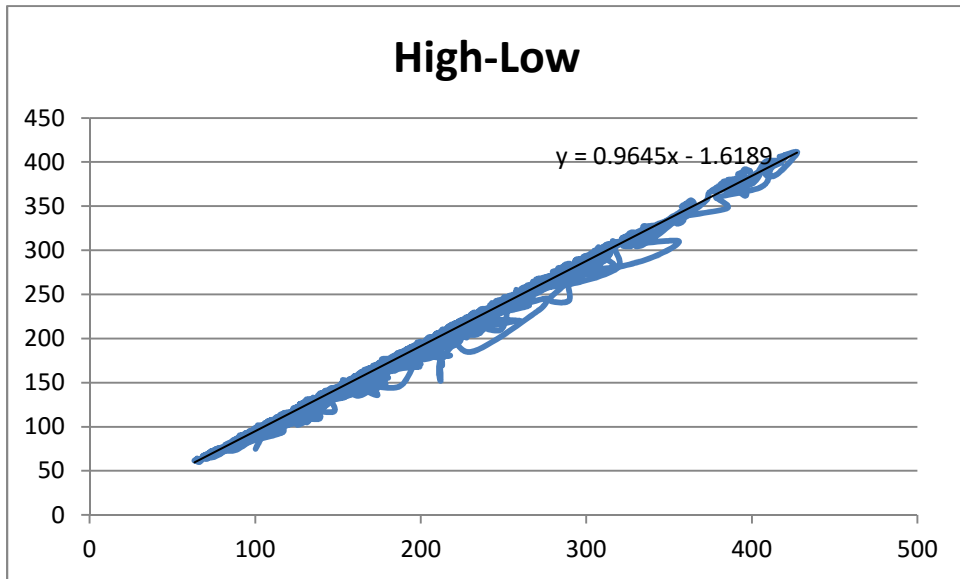
Open-Low



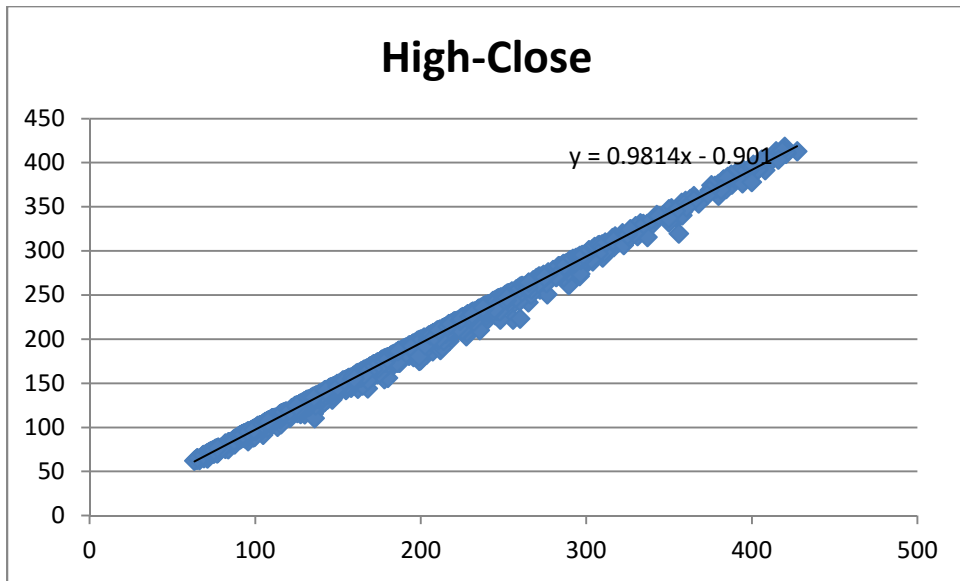
Open-Close



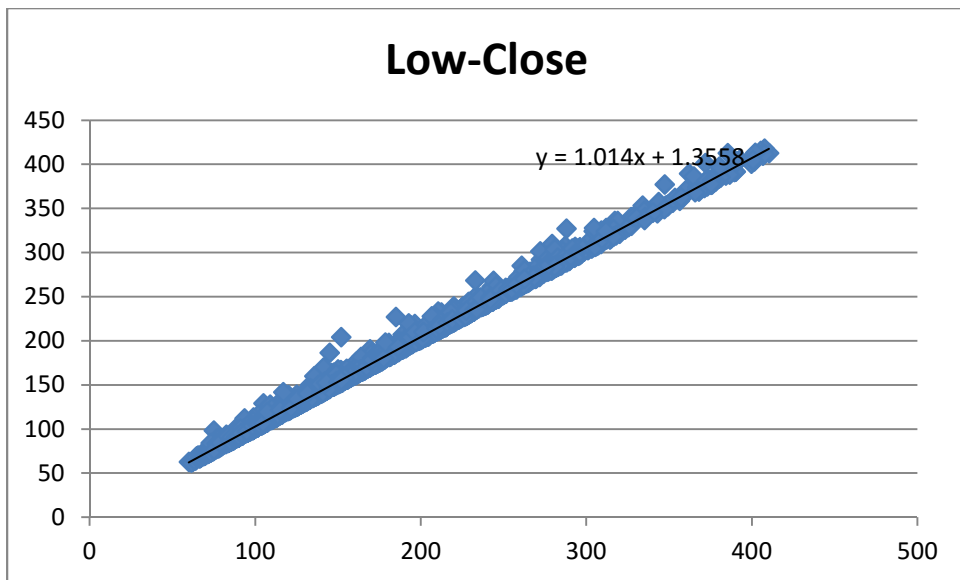
High-Low



High-Close

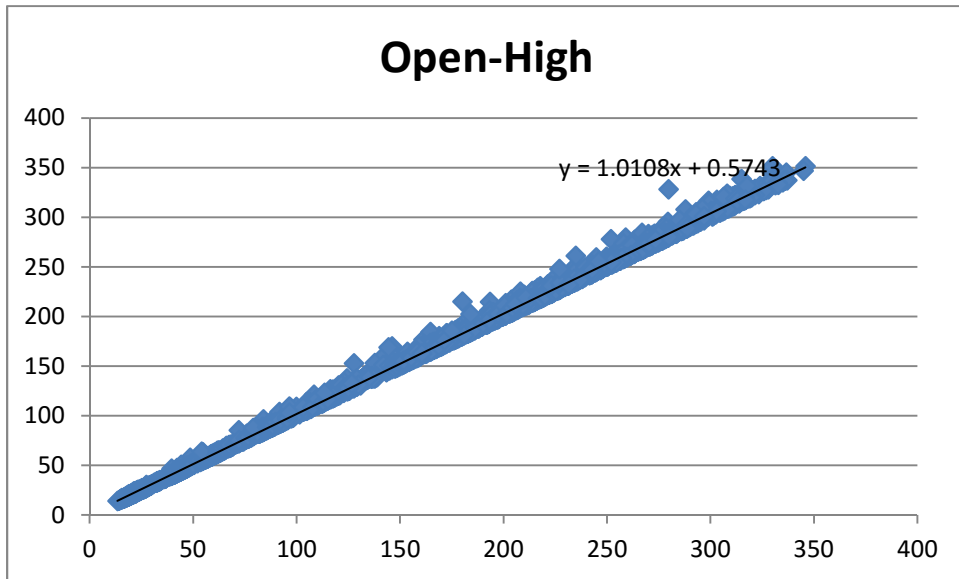


Low-Close

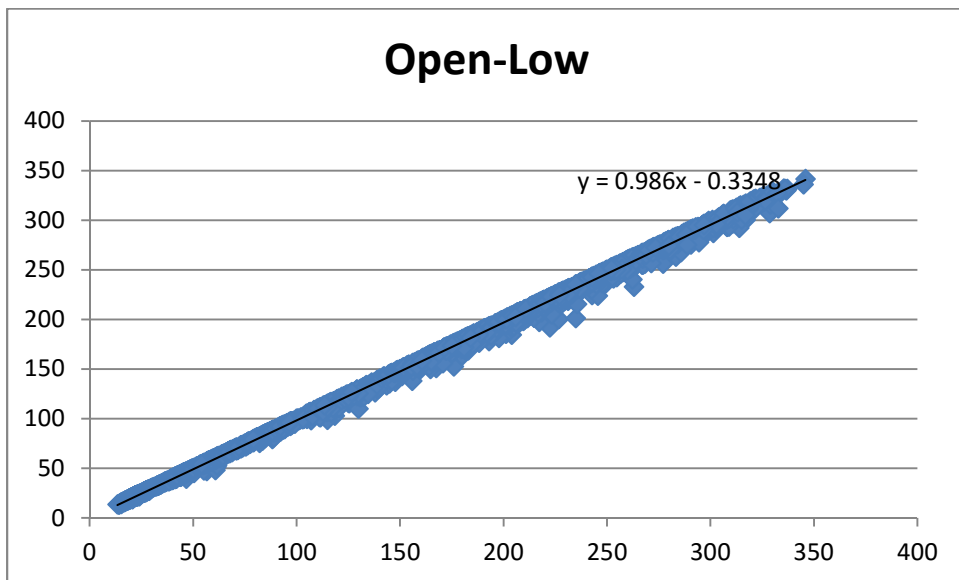


7. State Bank of India

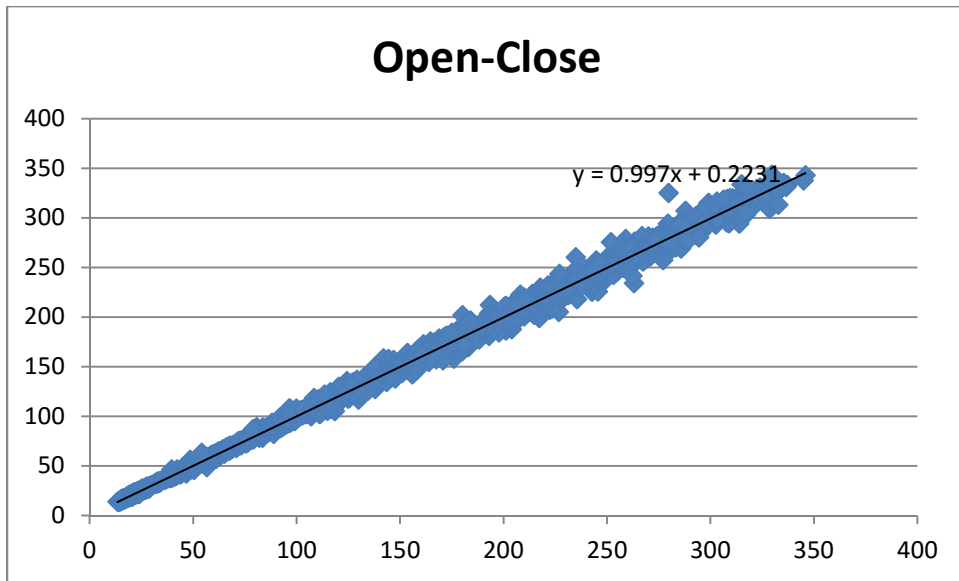
Open-High



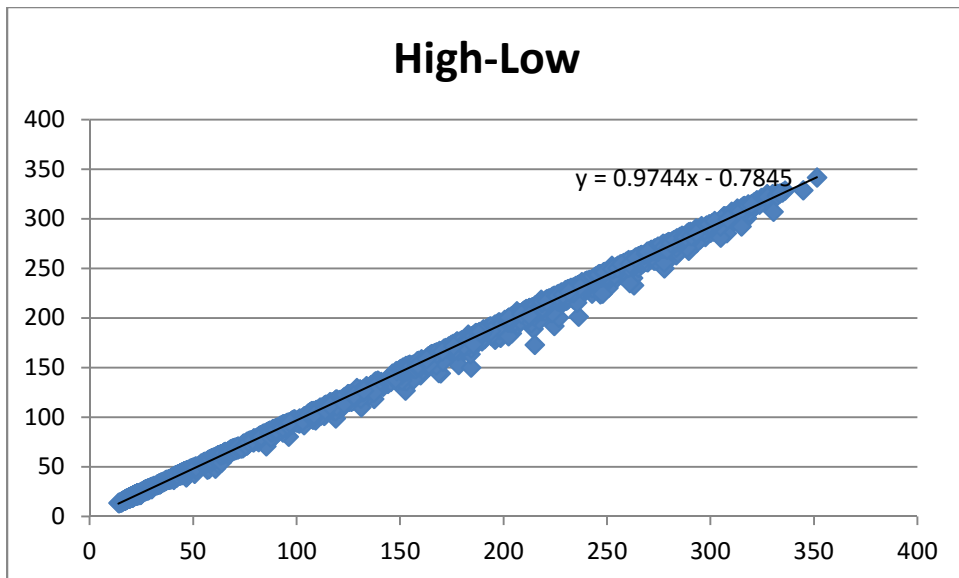
Open-Low



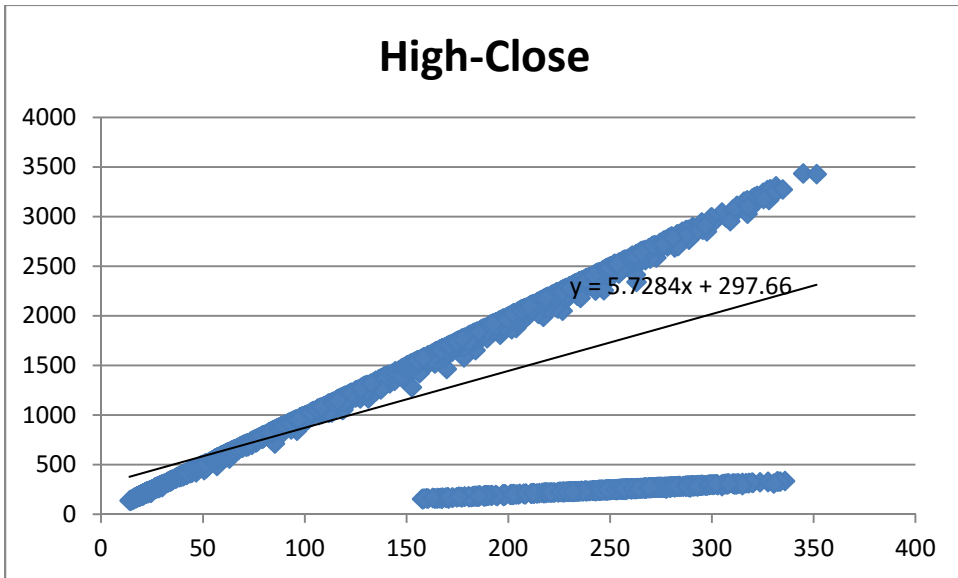
Open-Close



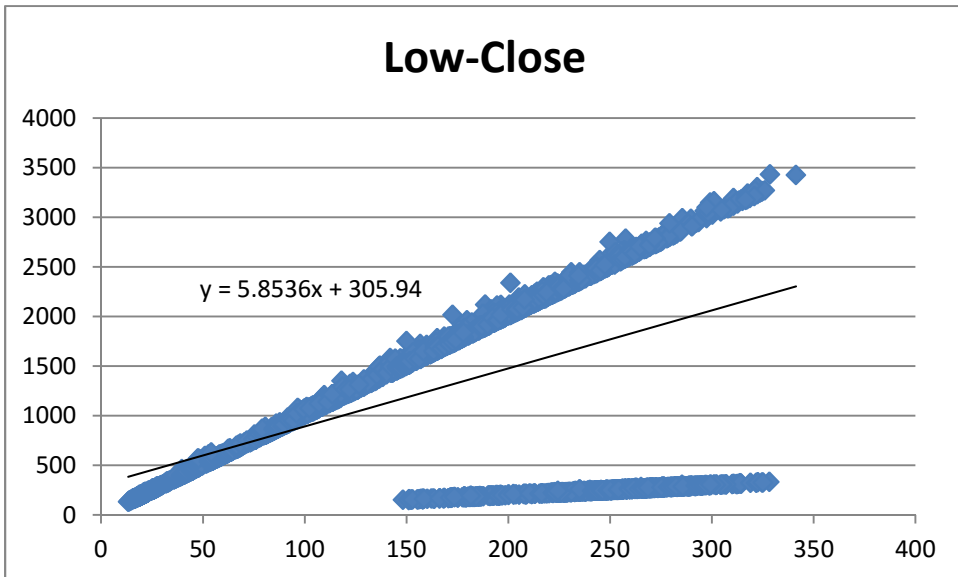
High-Low



High-Close

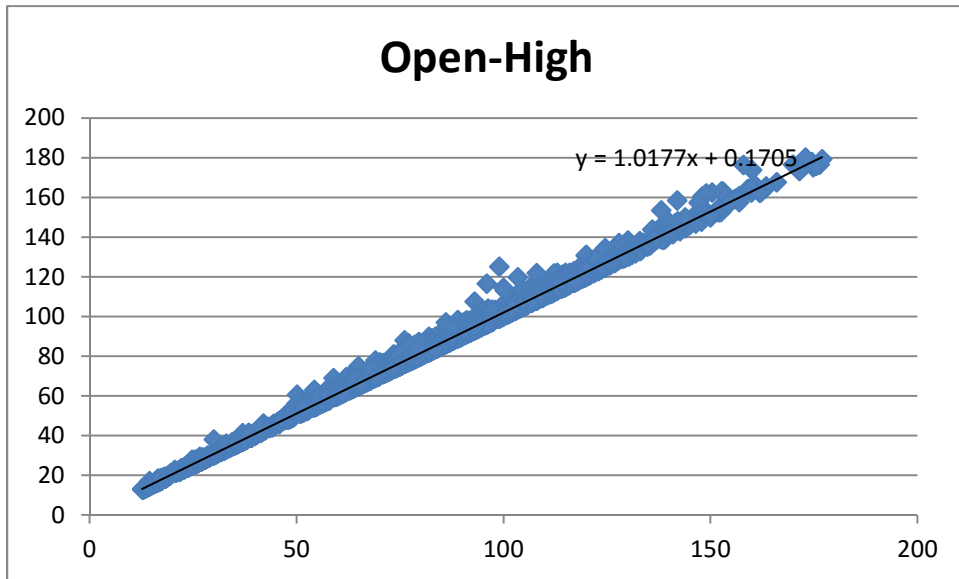


Low-Close

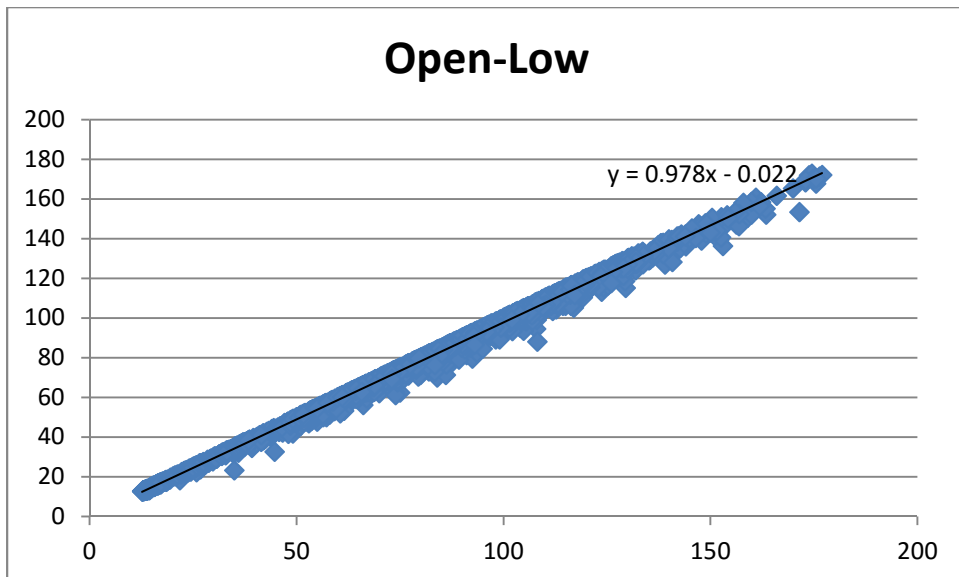


8. Syndicate Bank

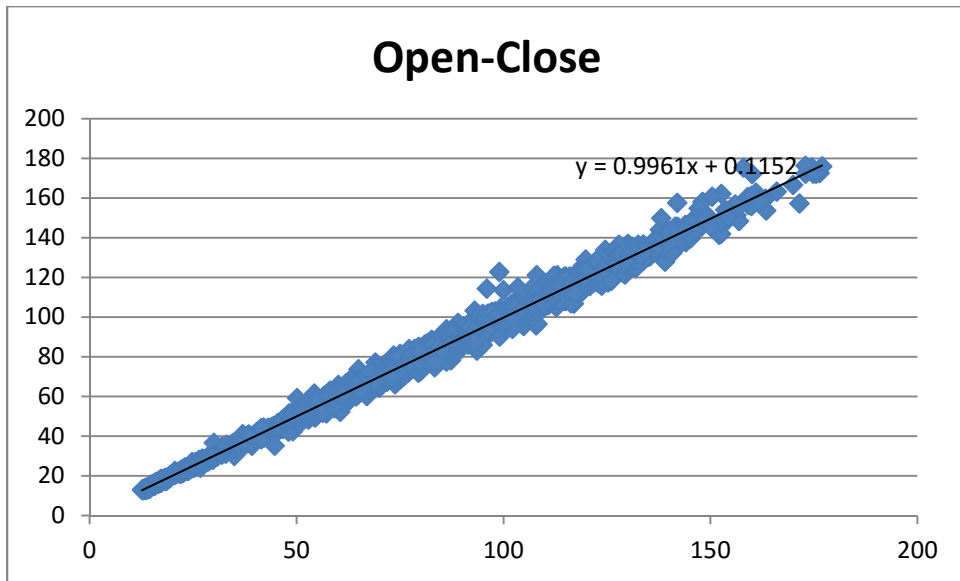
Open-High



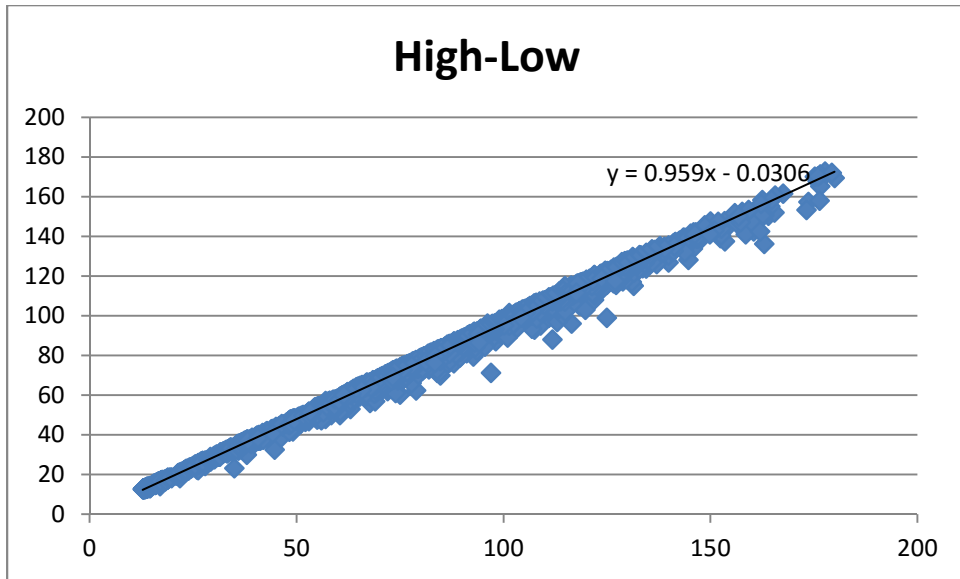
Open-Low



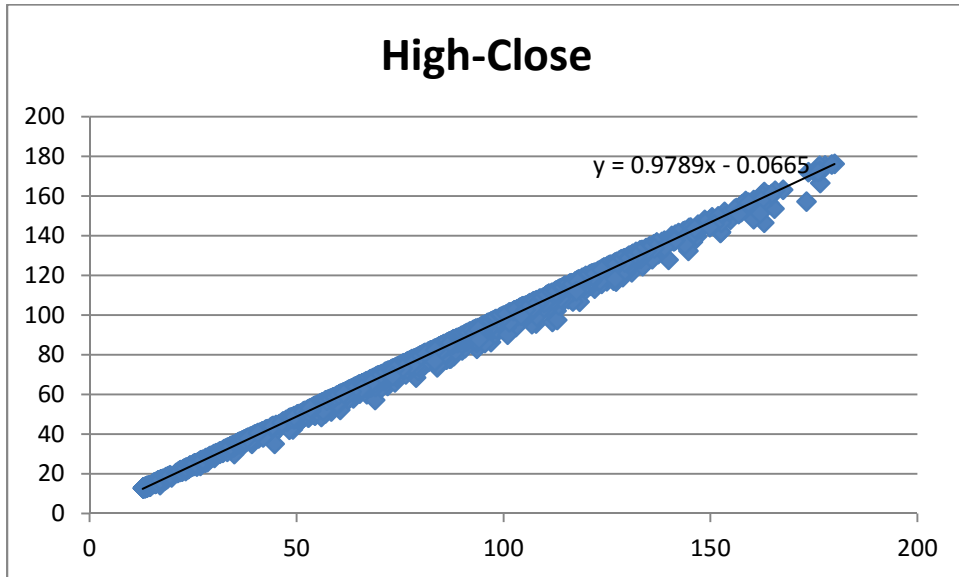
Open-Close



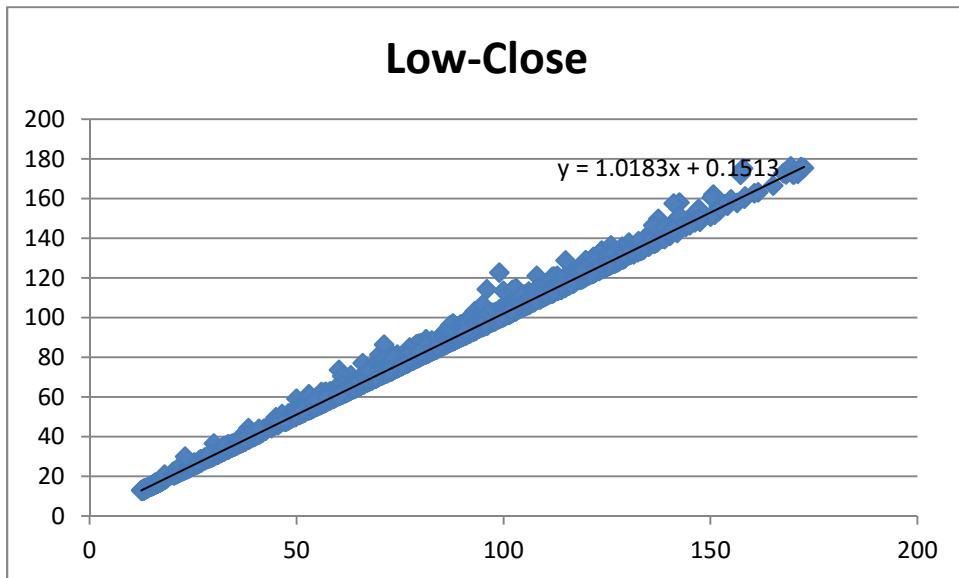
High-Low



High-Close

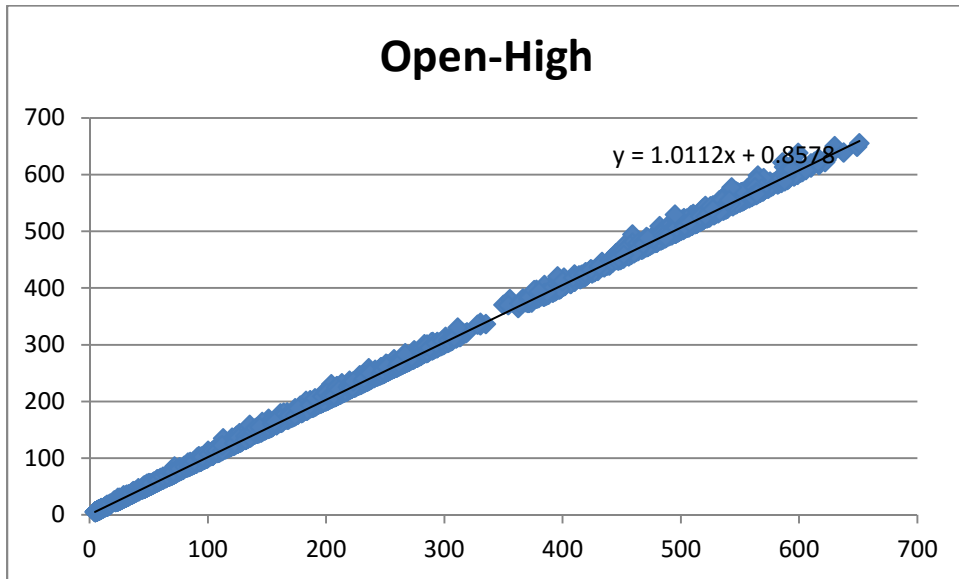


Low-Close

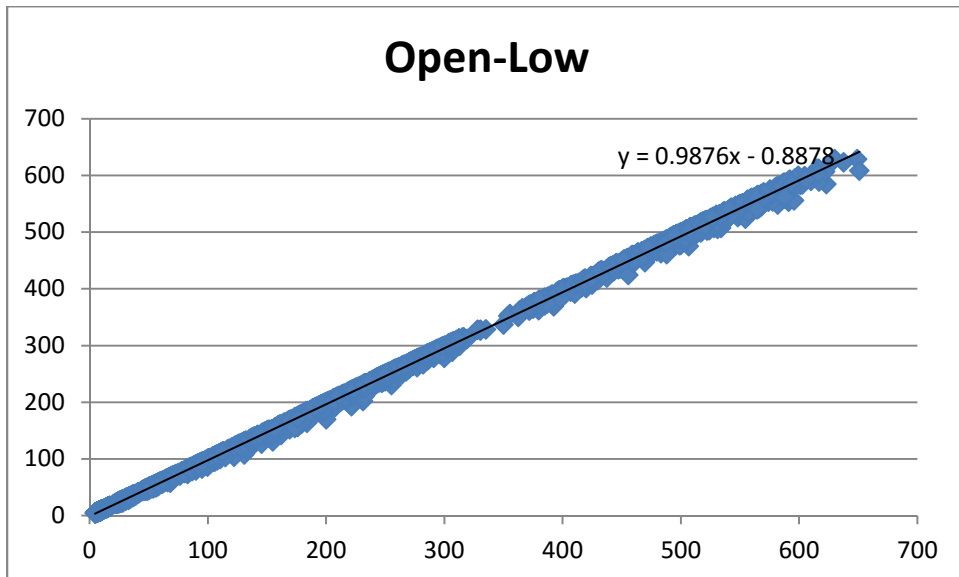


9. Axis Bank

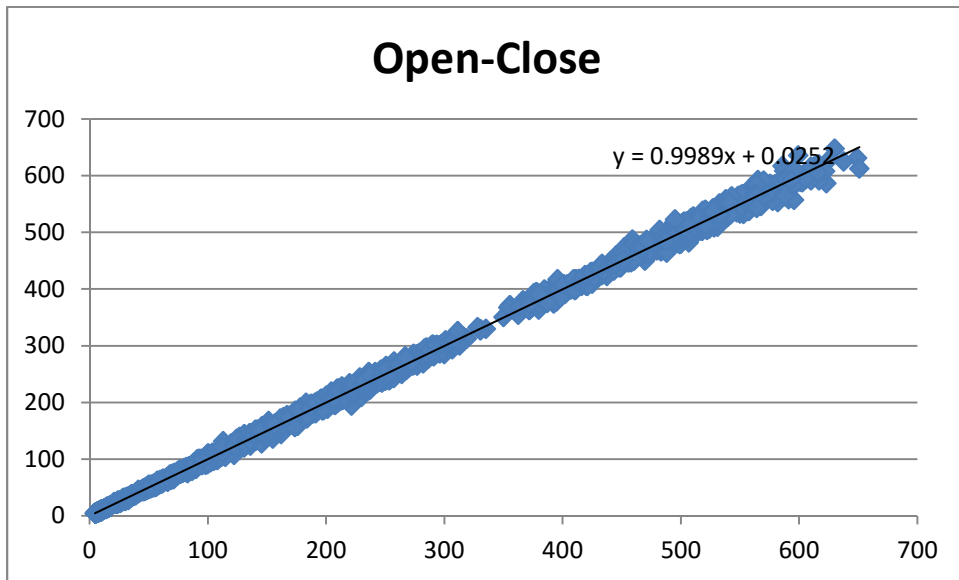
Open-High



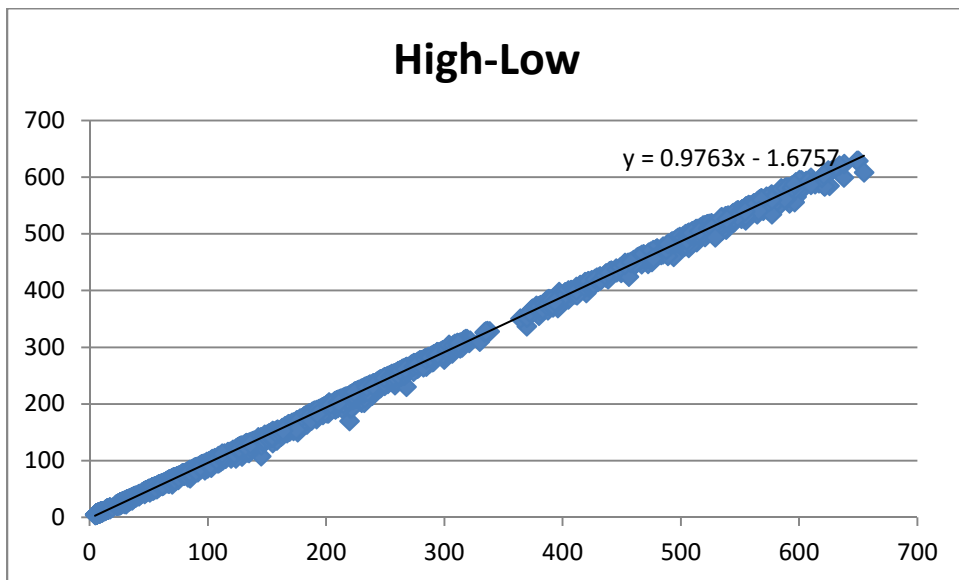
Open-Low



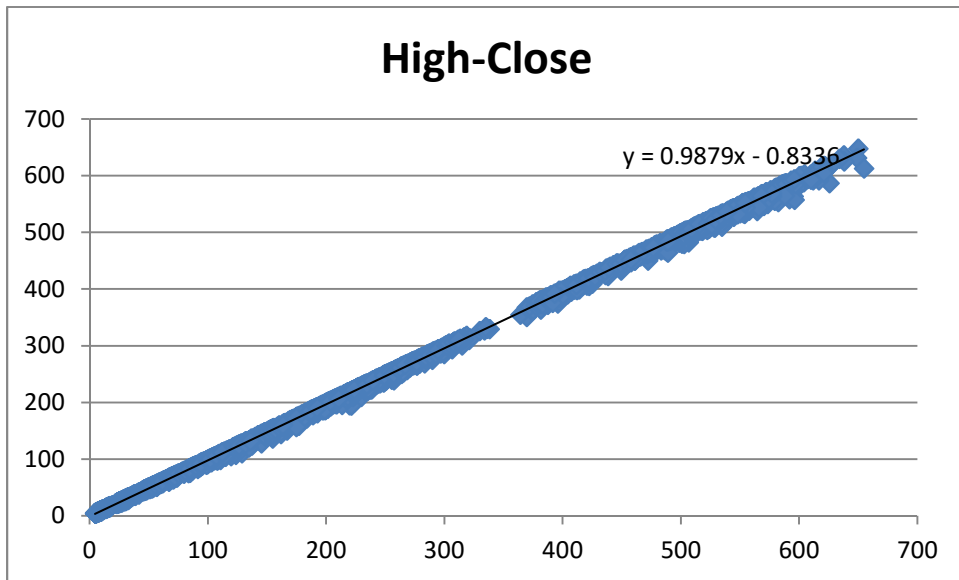
Open-Close



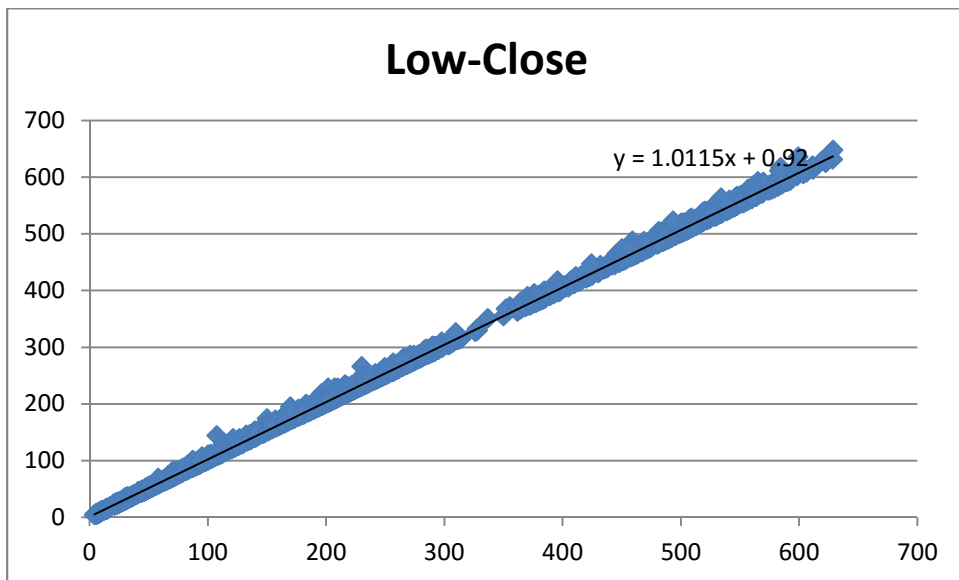
High-Low



High-Close

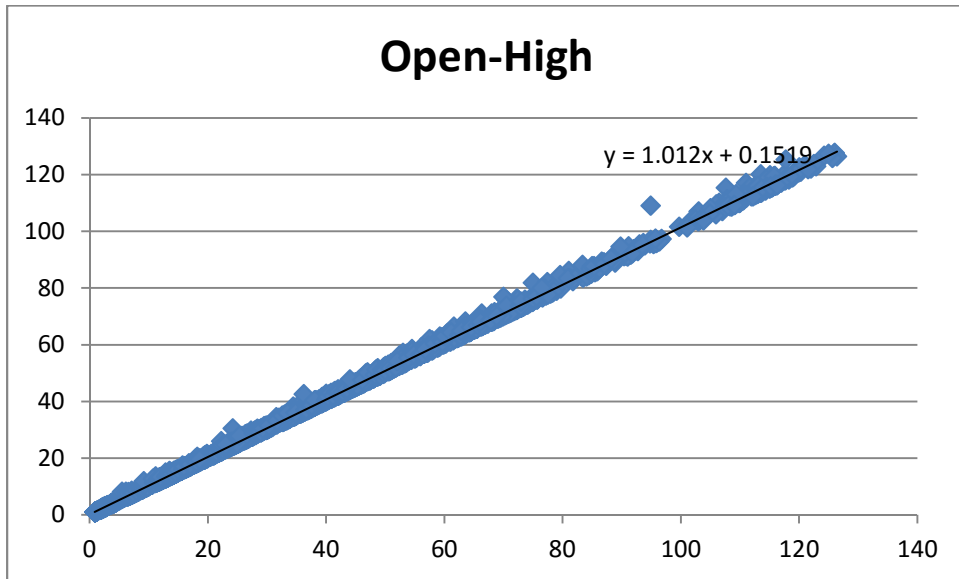


Low-Close

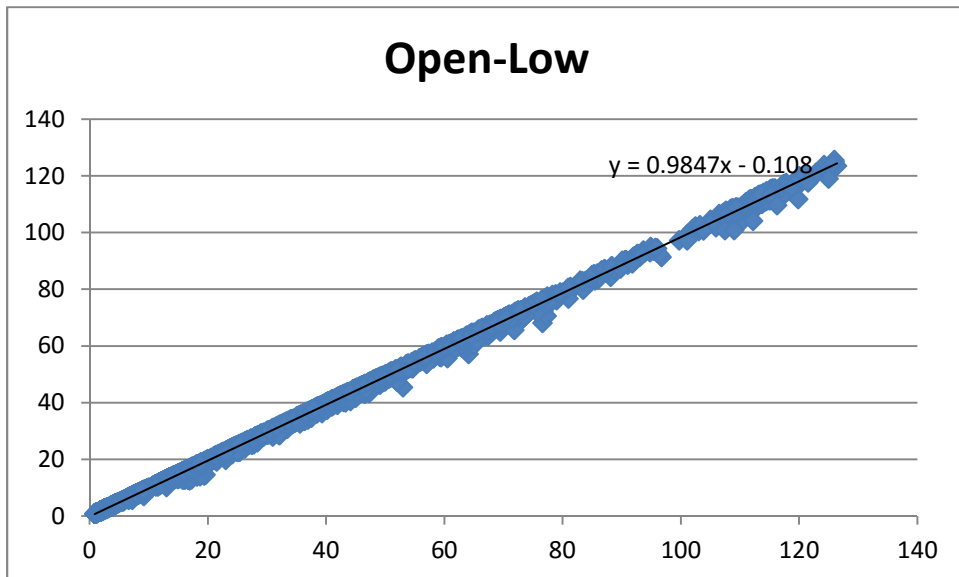


10. Federal Bank

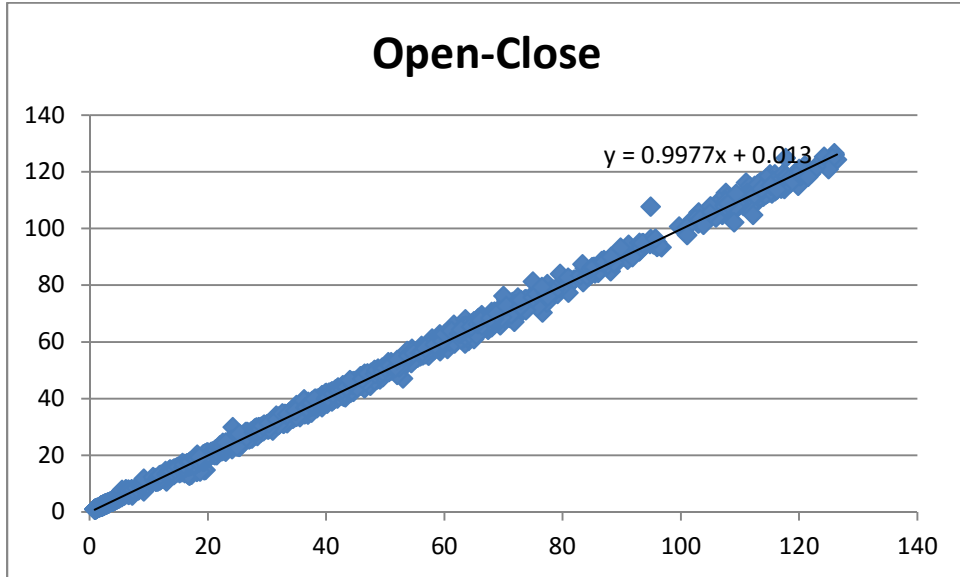
Open-High



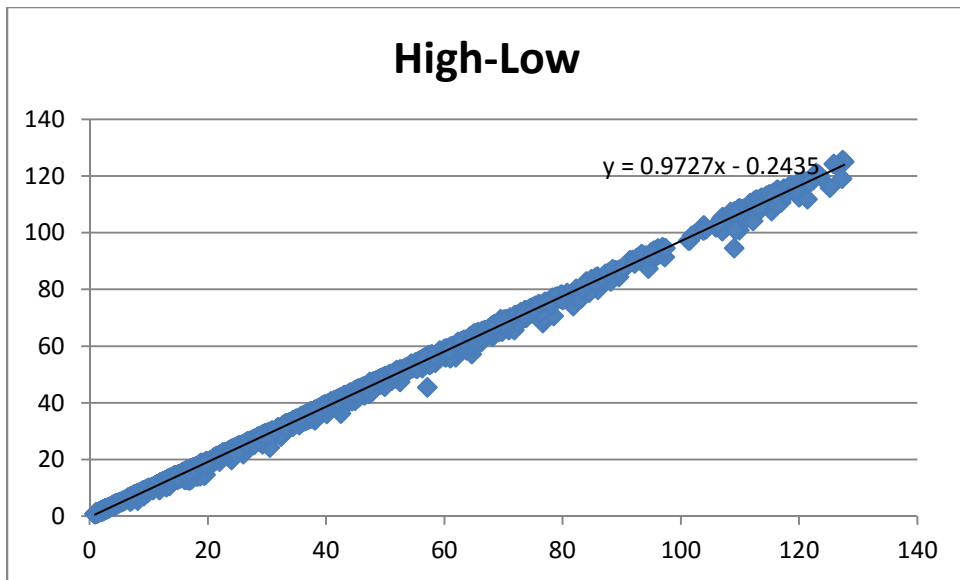
Open-Low



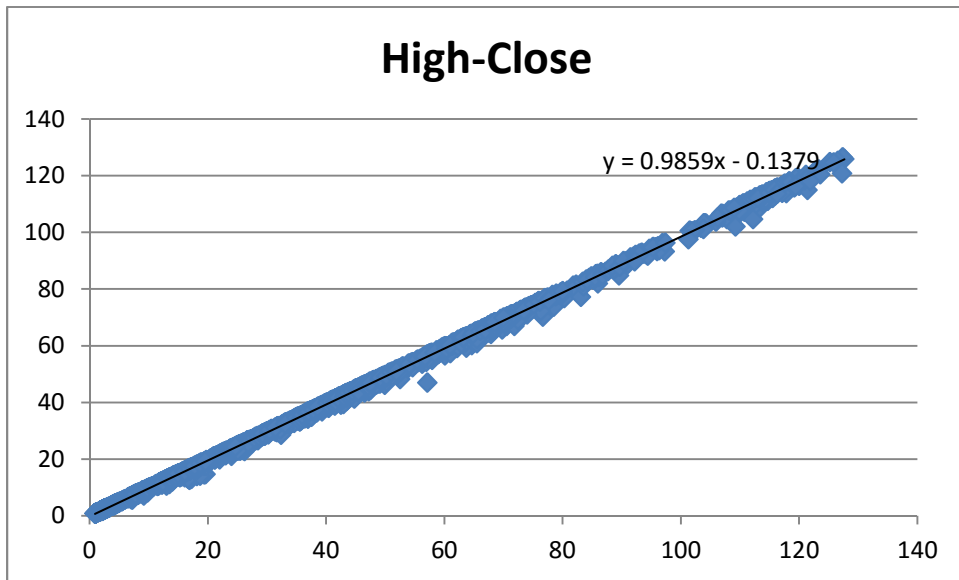
Open-Close



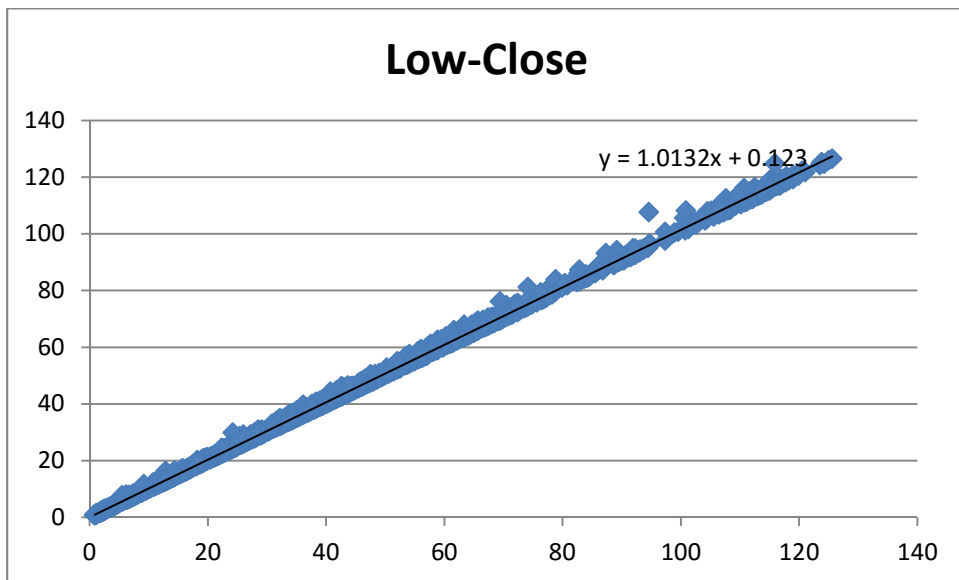
High-Low



High-Close

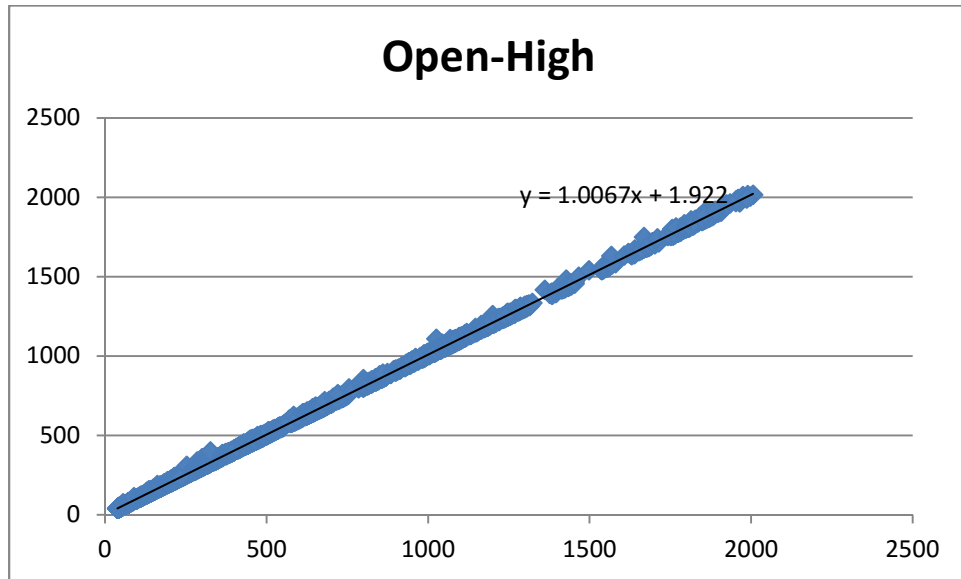


Low-Close

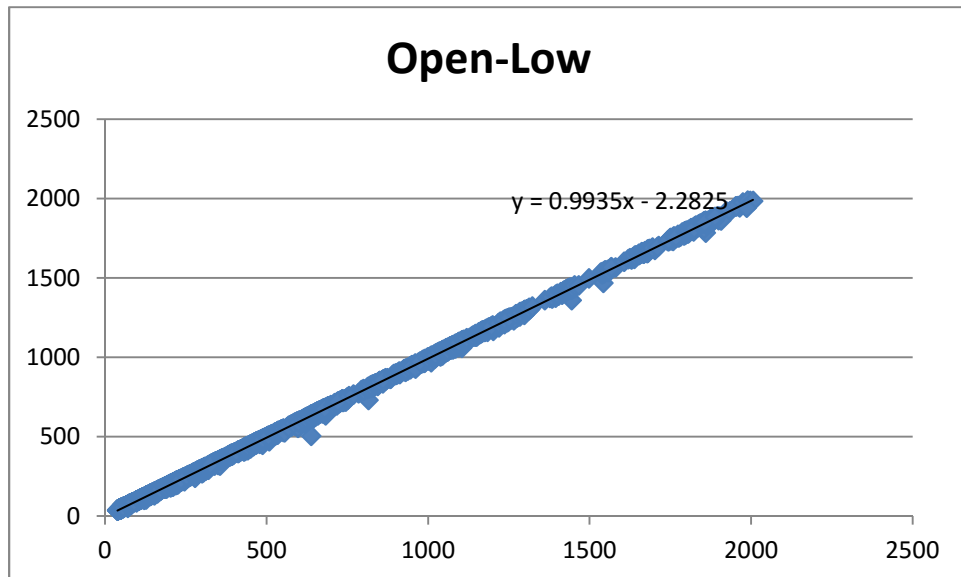


11. HDFC Bank

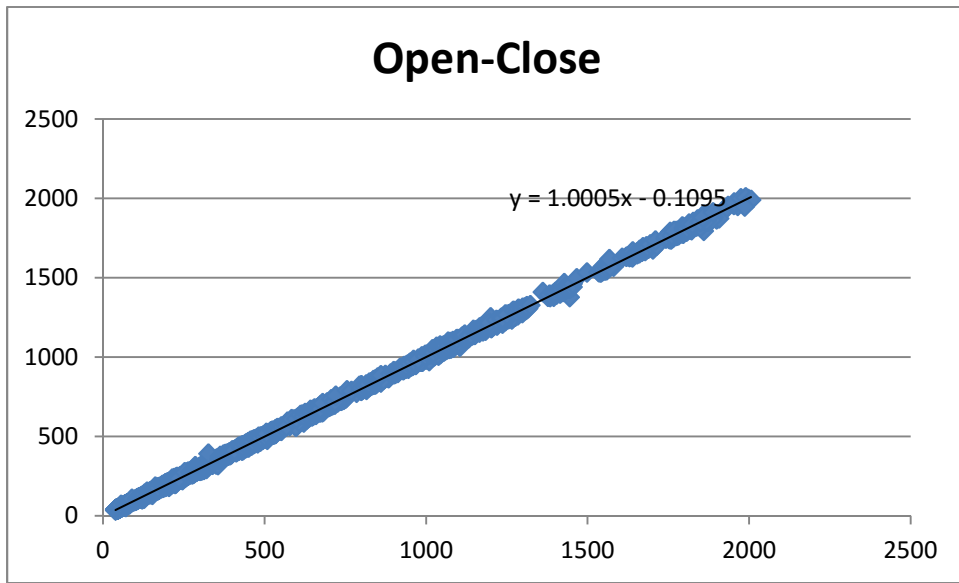
Open-High



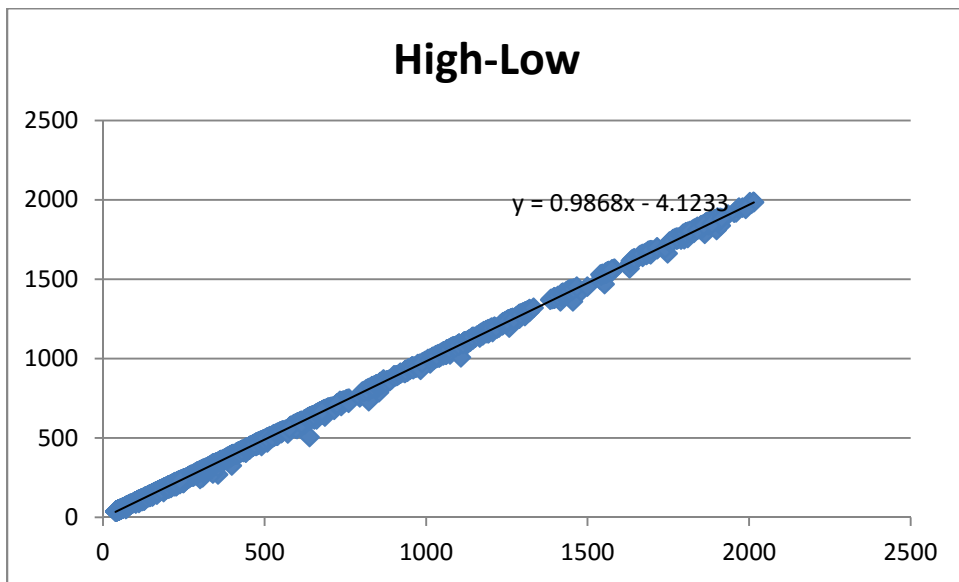
Open-Low



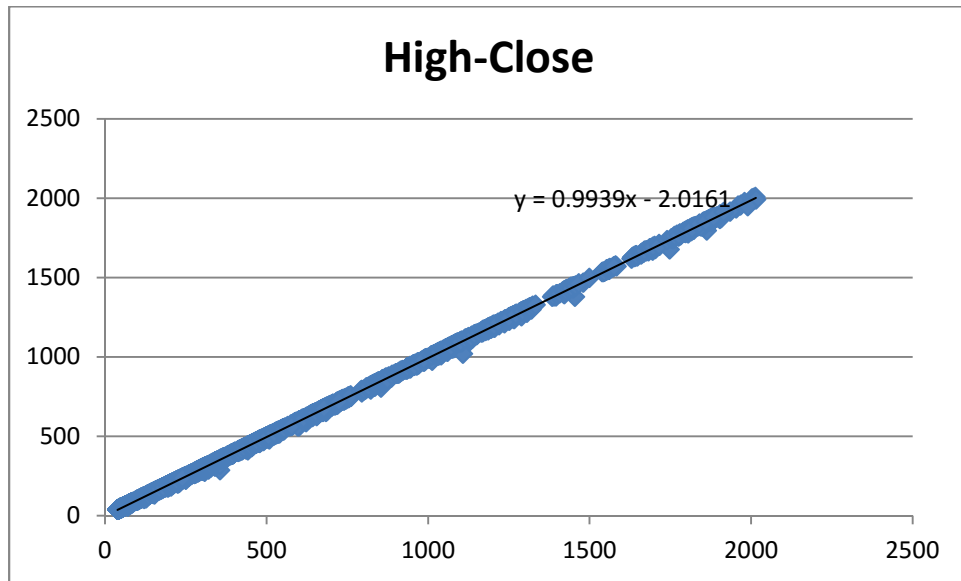
Open-Close



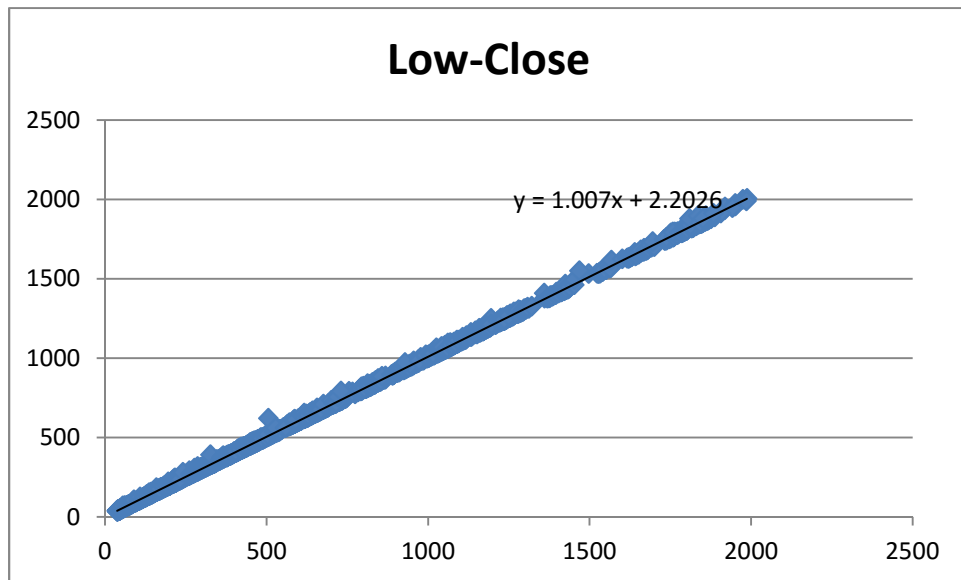
High-Low



High-Close

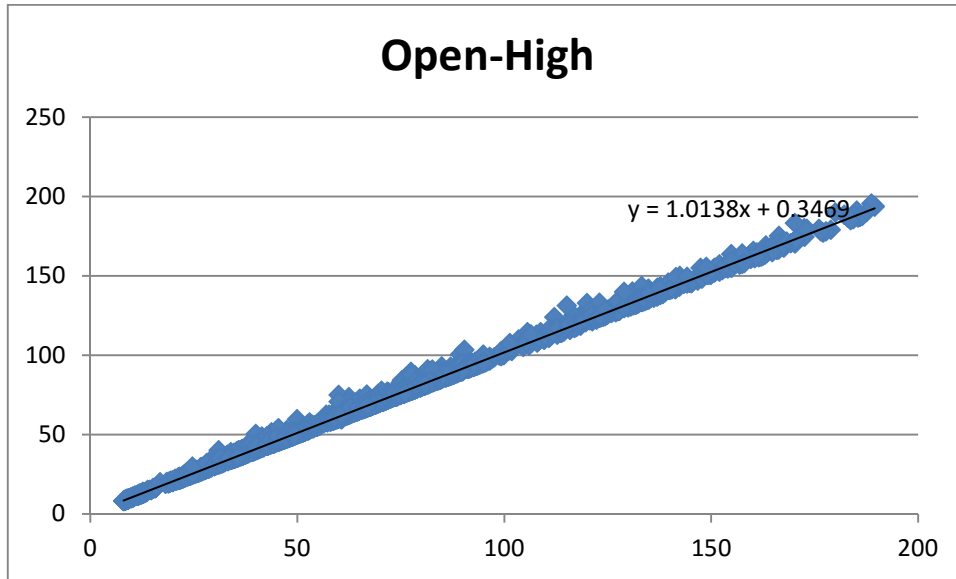


Low-Close

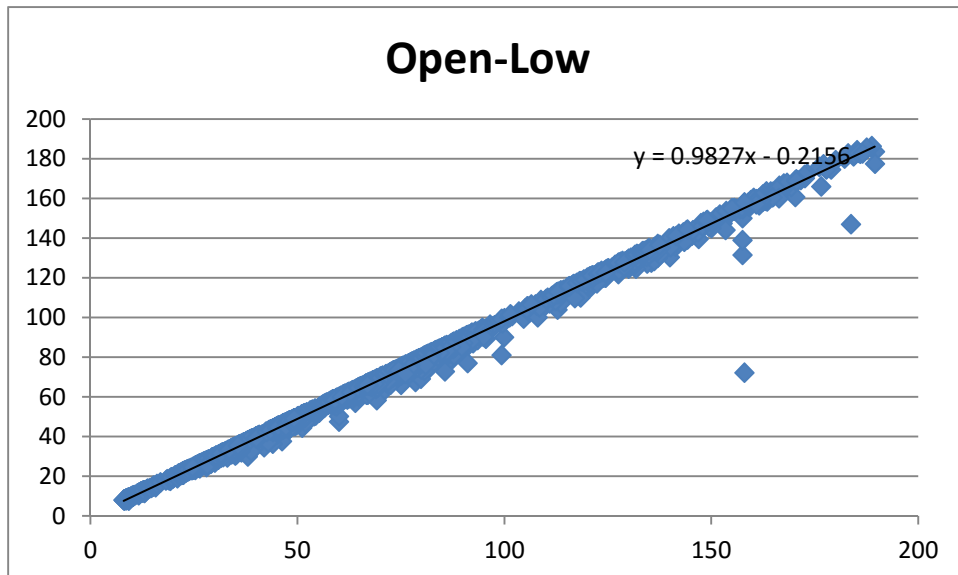


12. J&K Bank

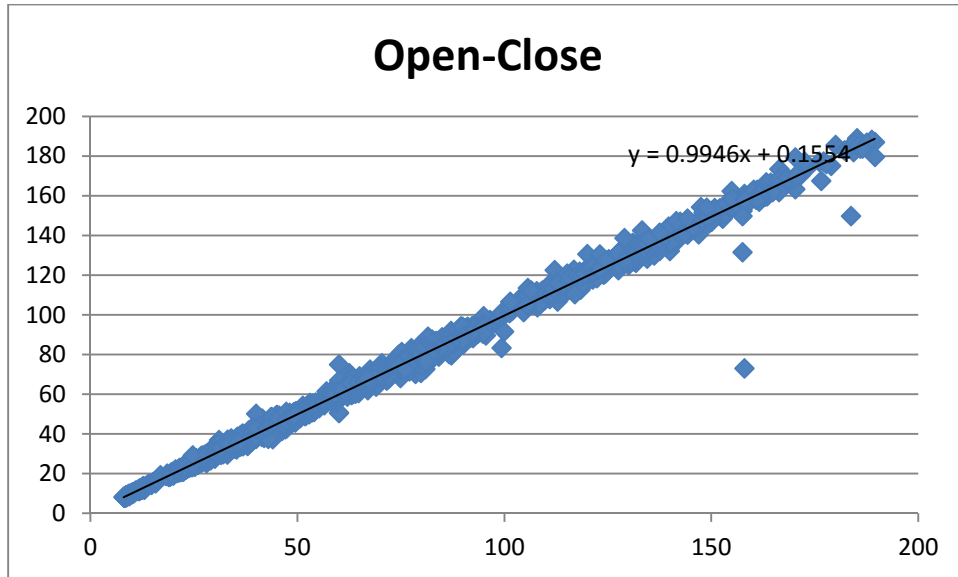
Open-High



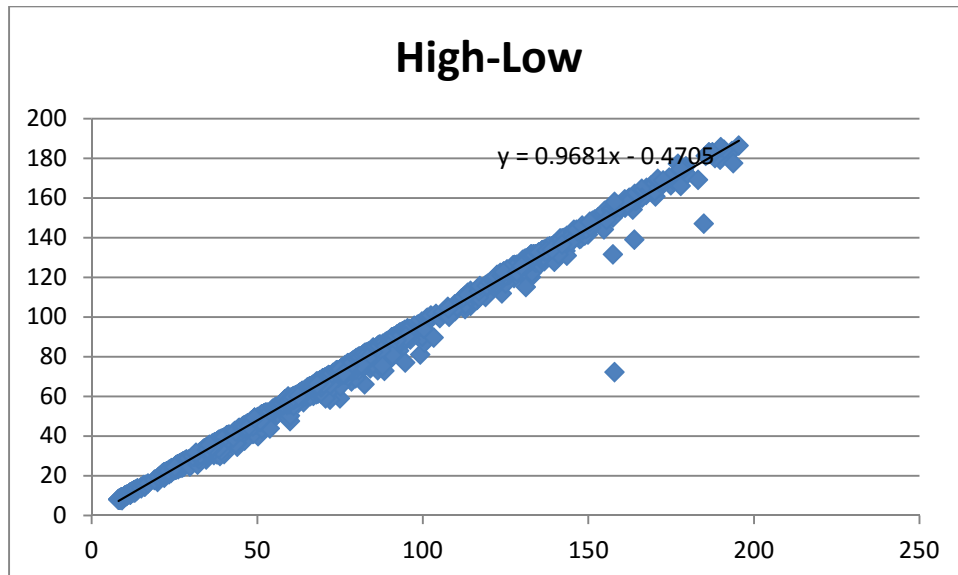
Open-Low



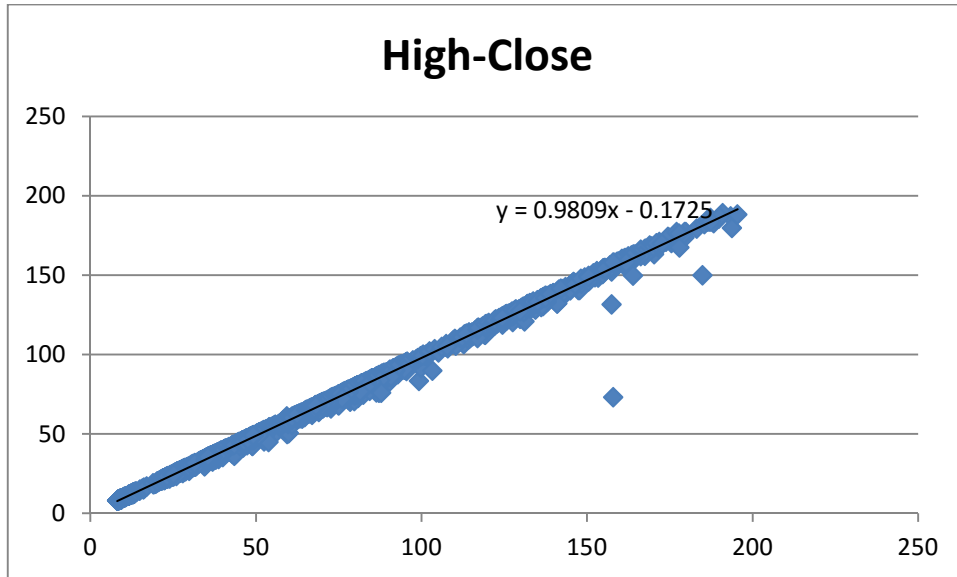
Open-Close



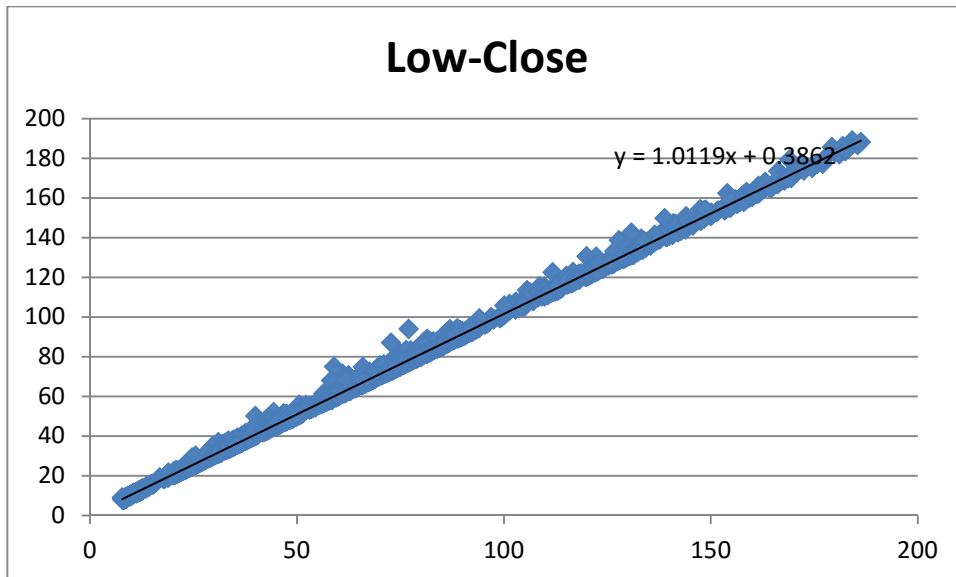
High-Low



High-Close

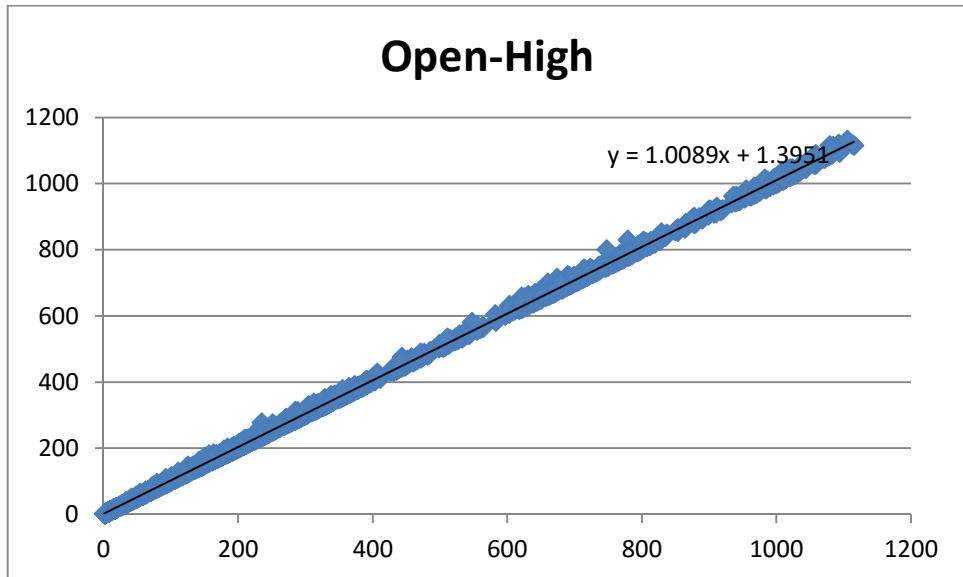


Low-Close

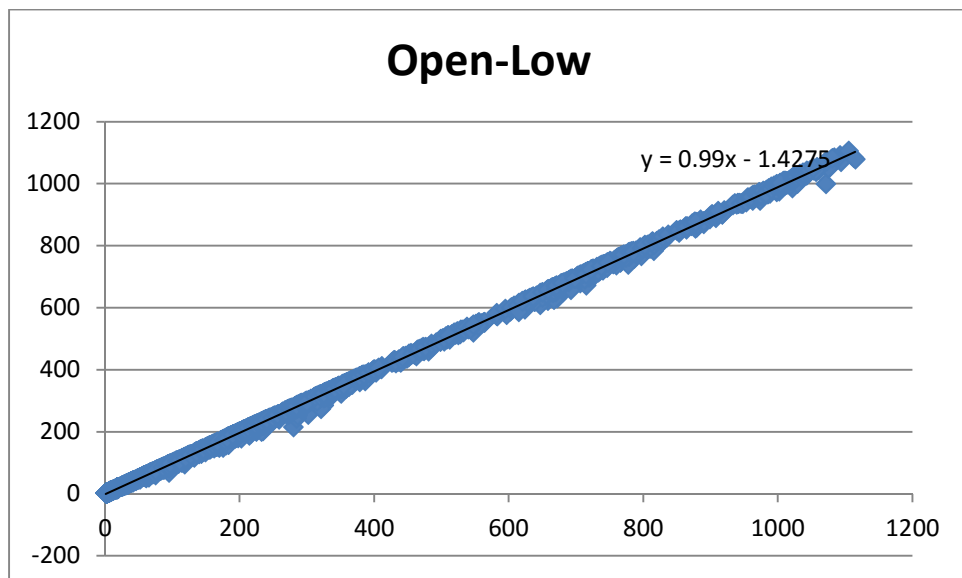


13. Kotak Bank

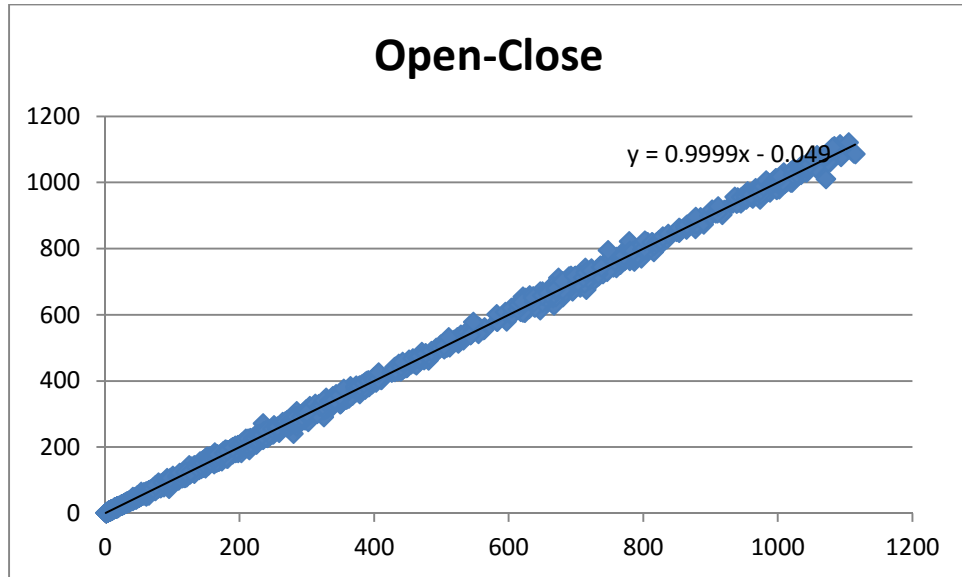
Open-High



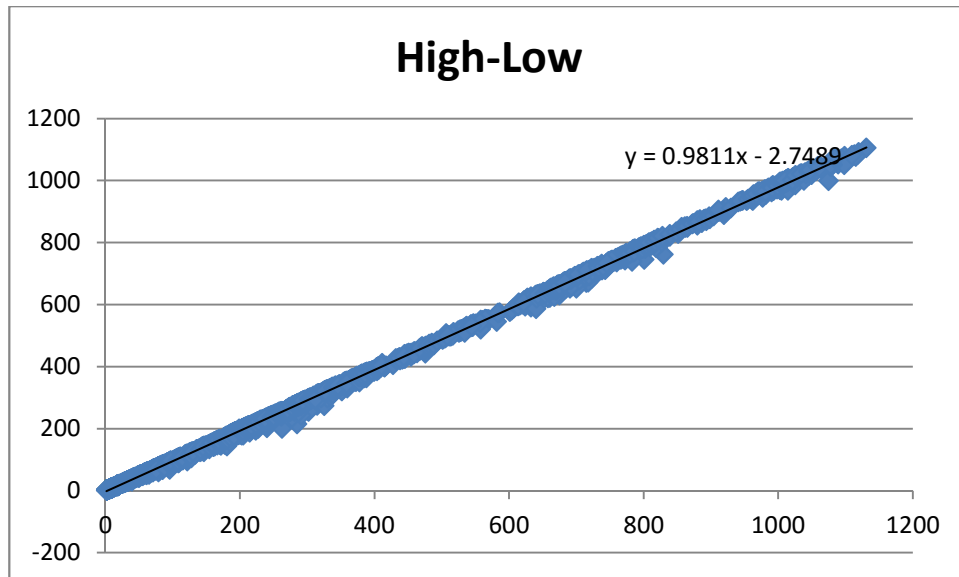
Open-Low



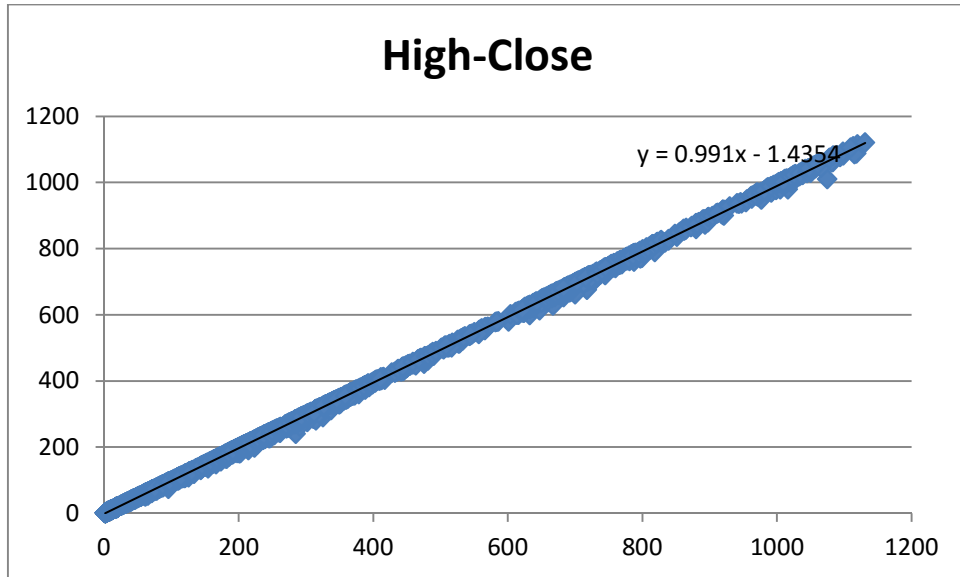
Open-Close



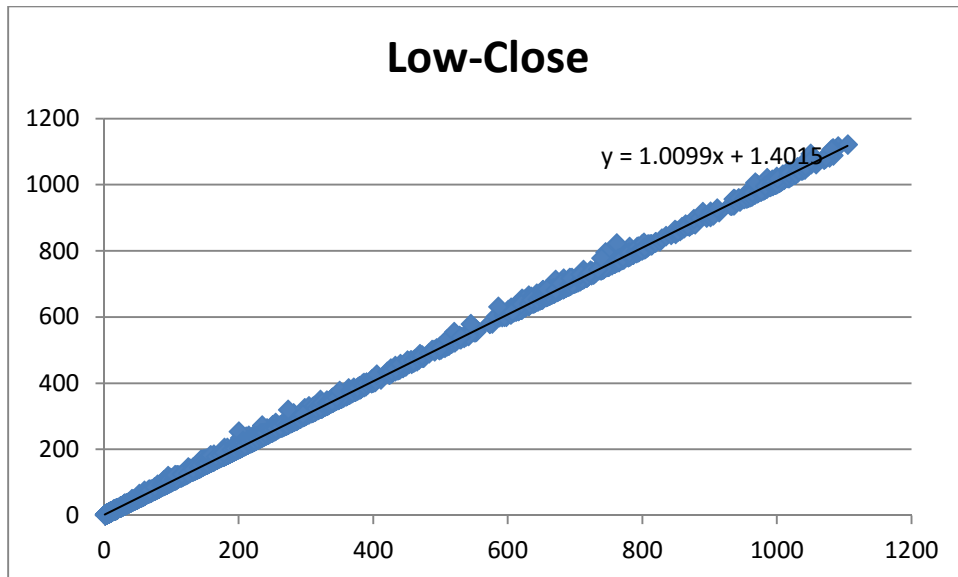
High-Low



High-Close

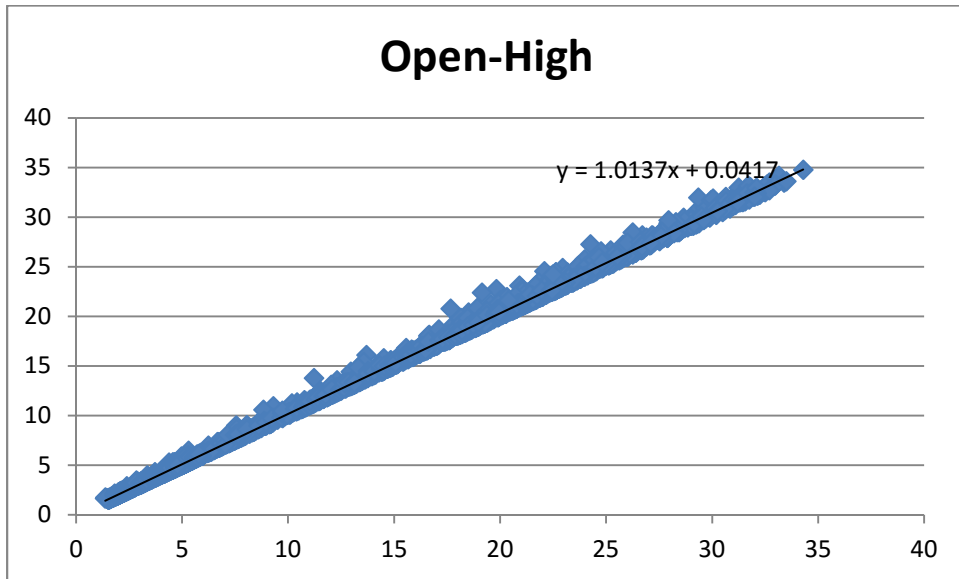


Low-Close

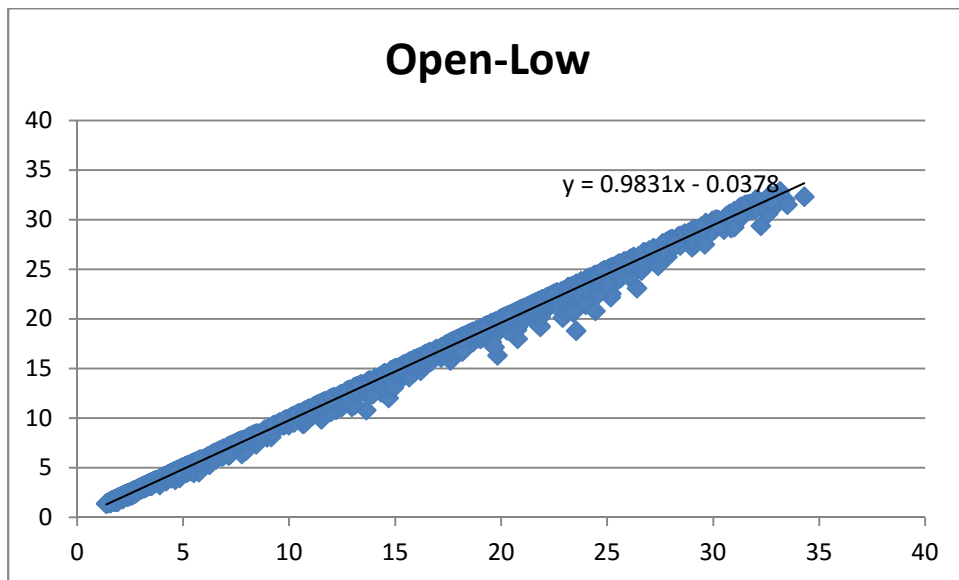


14. South Bank

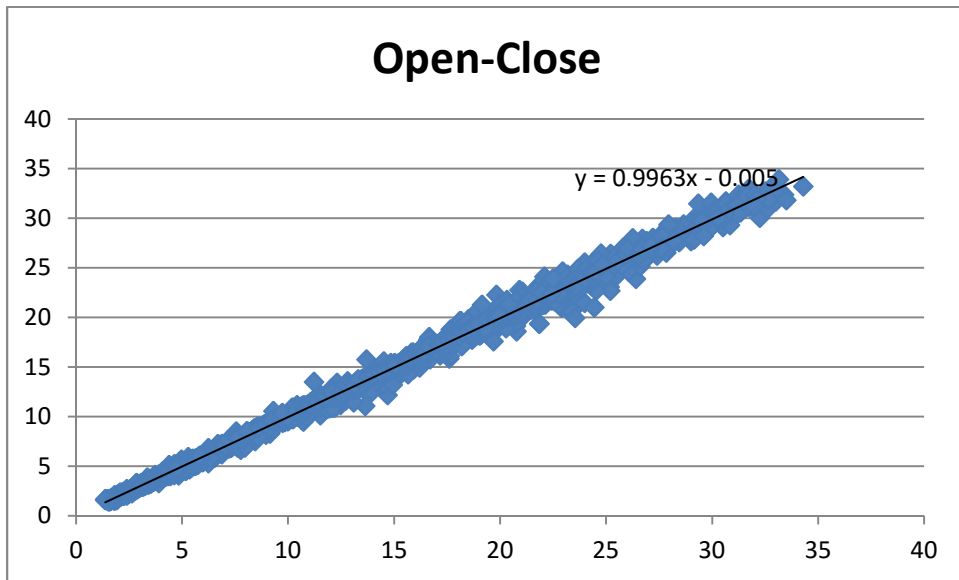
Open-High



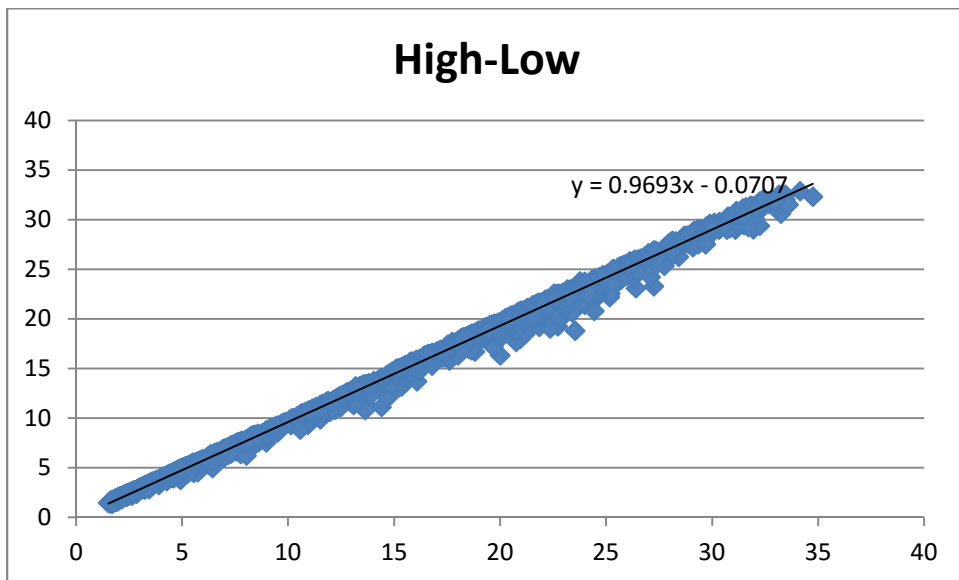
Open-Low



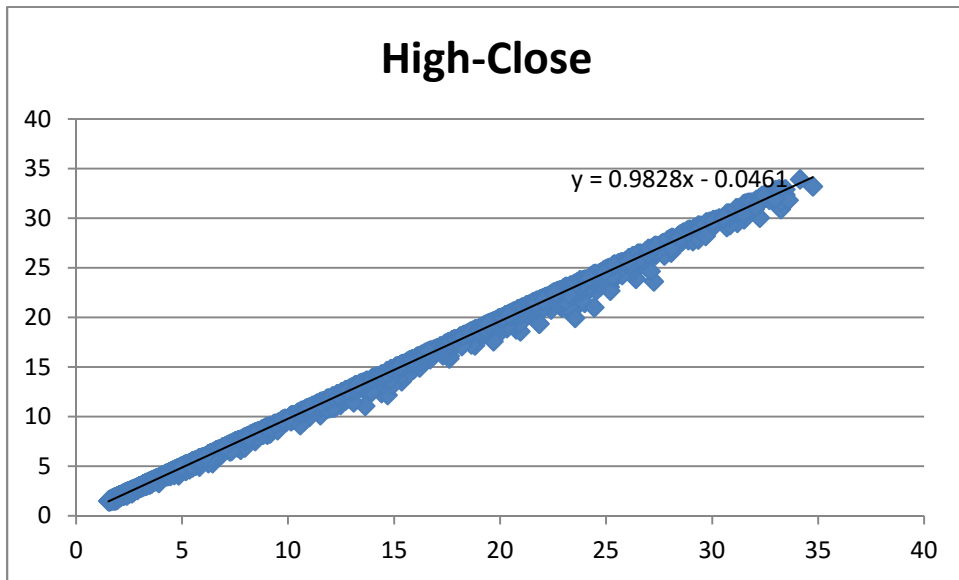
Open-Close



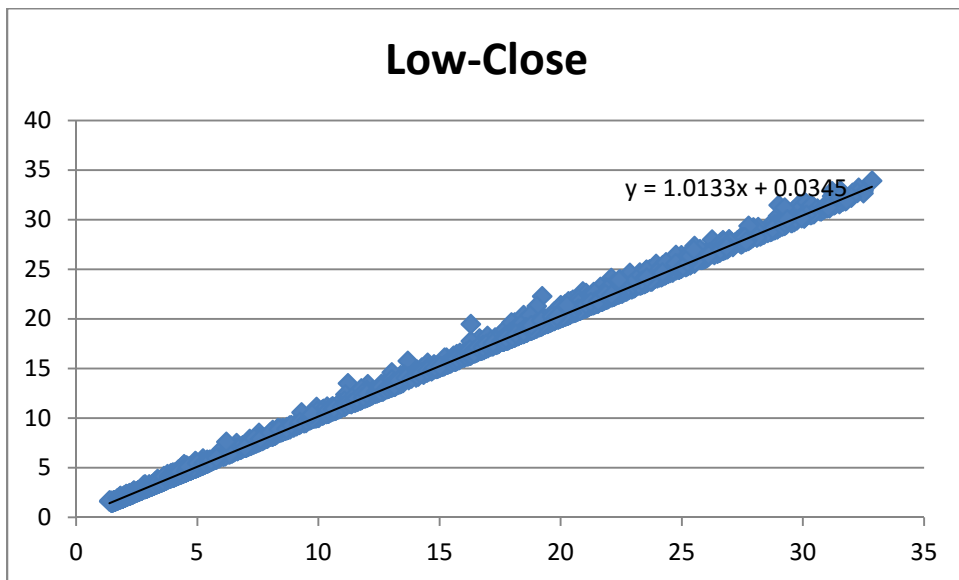
High-Low



High-Close

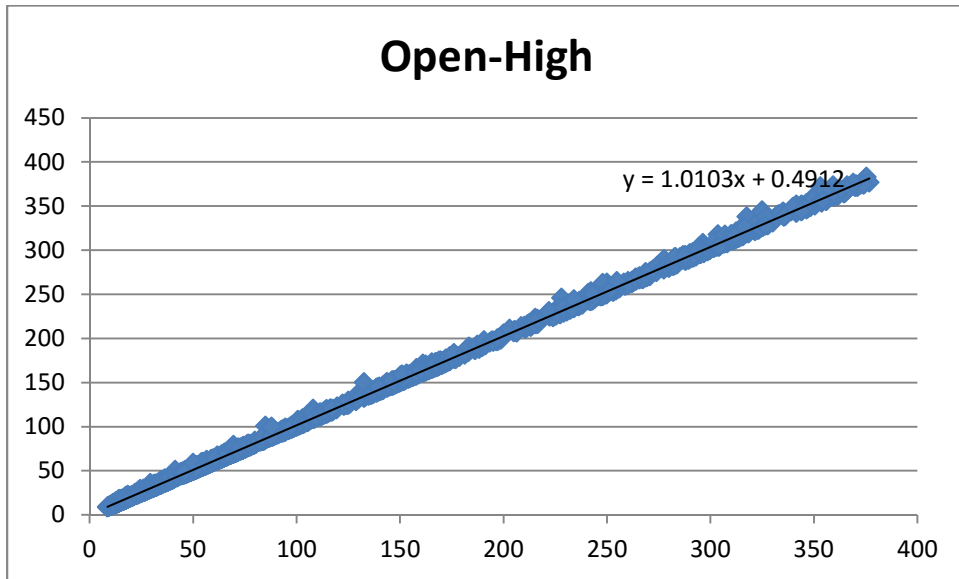


Low-Close

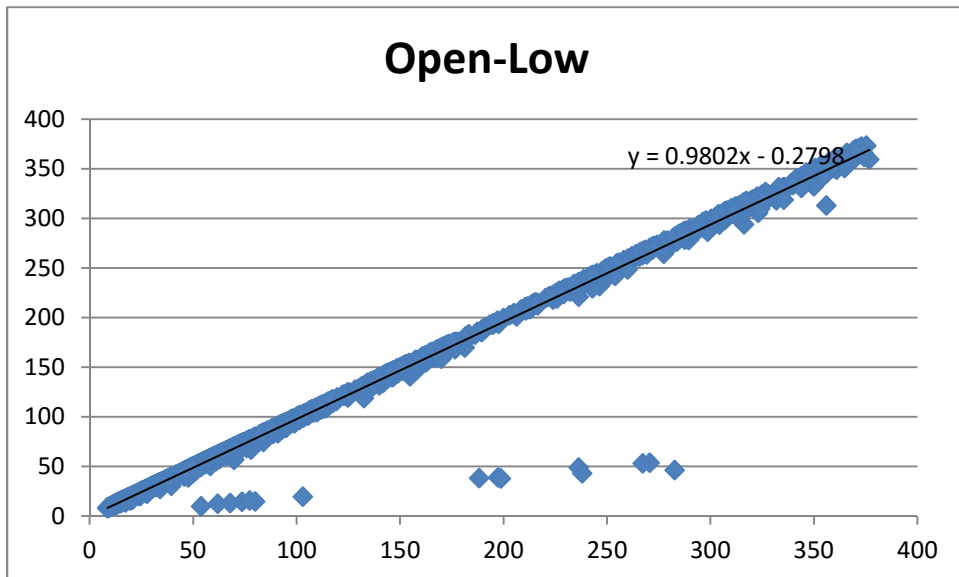


15. Yes Bank

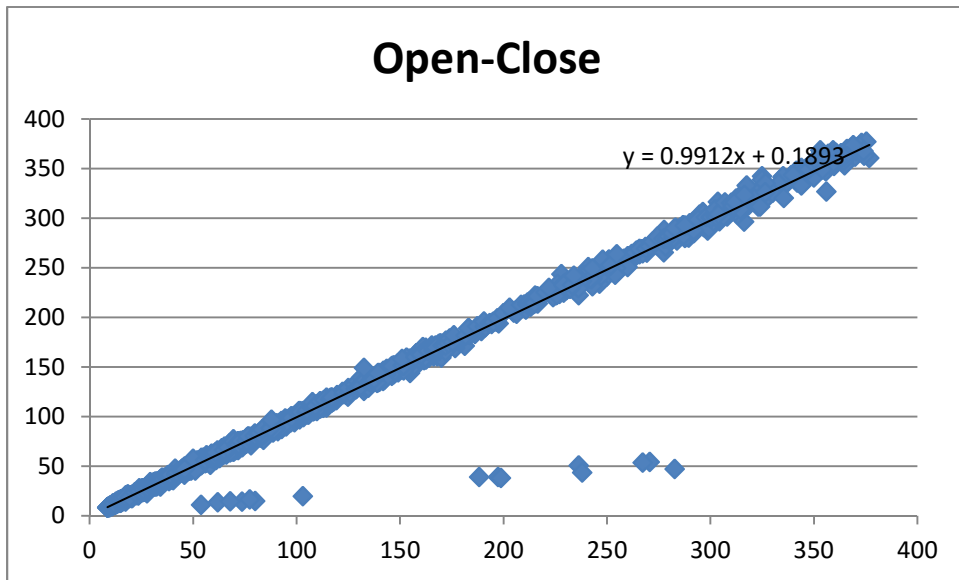
Open-High



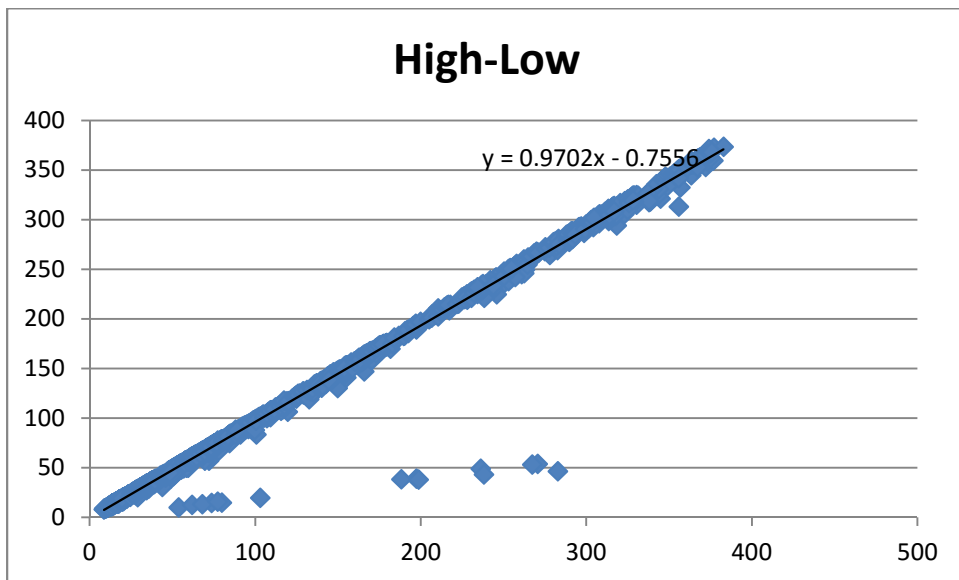
Open-Low



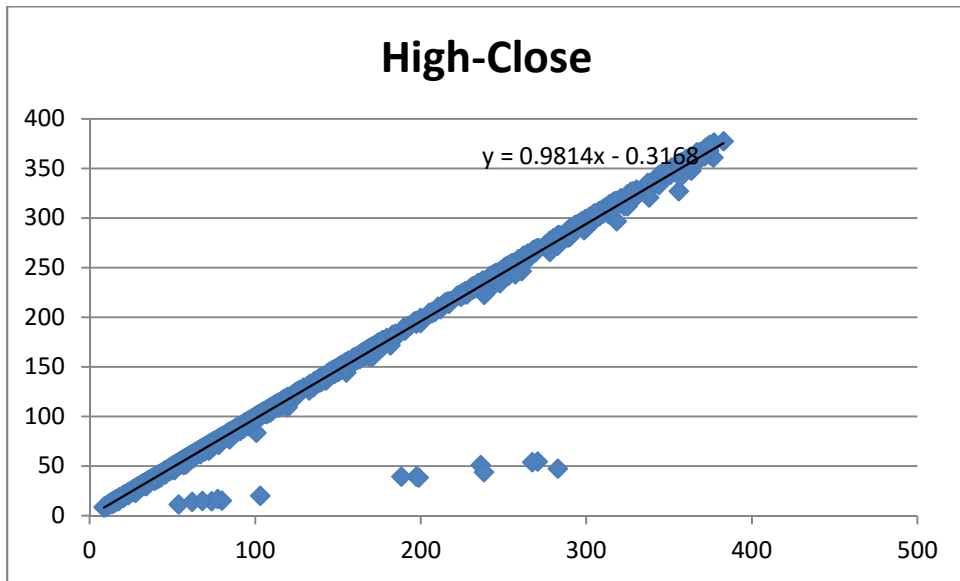
Open-Close



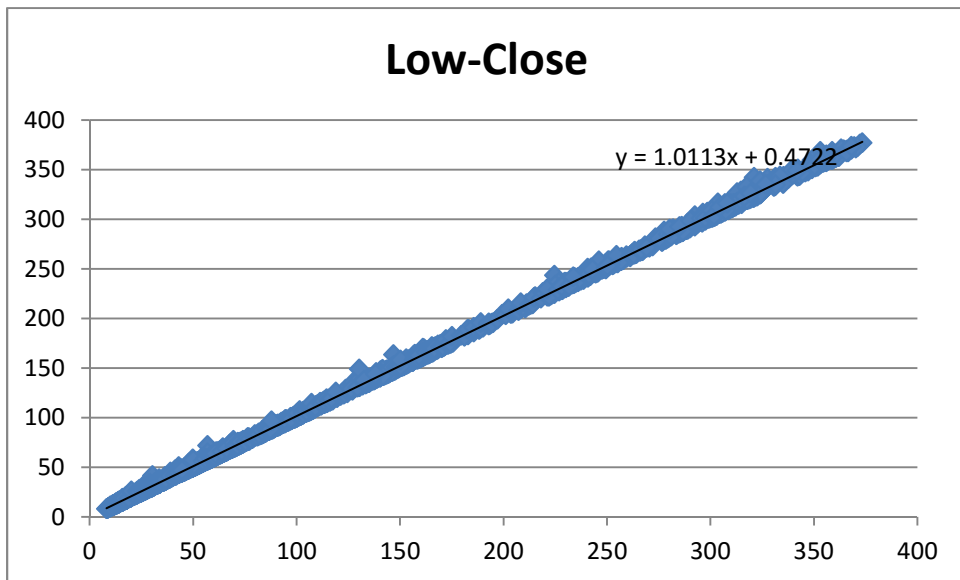
High-Low



High-Close

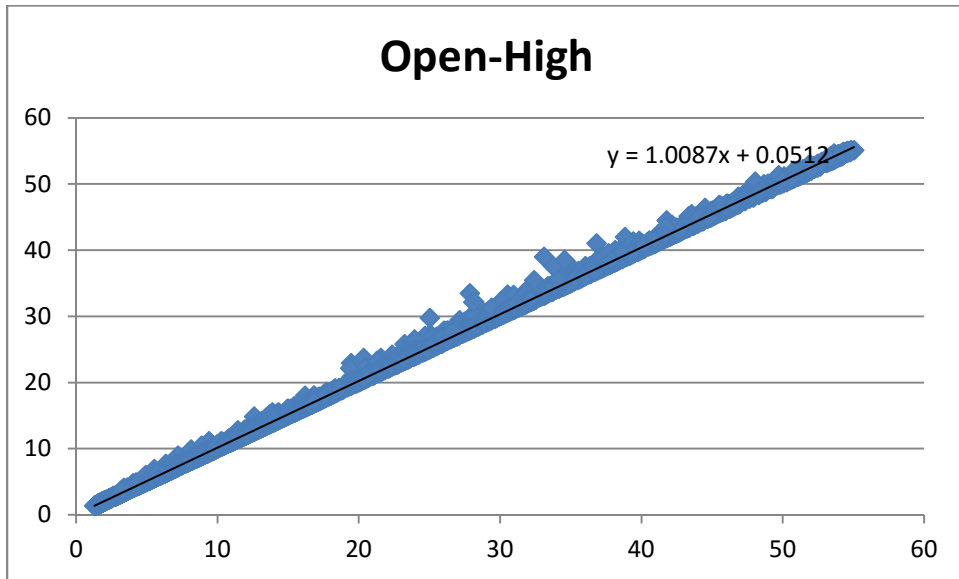


Low-Close

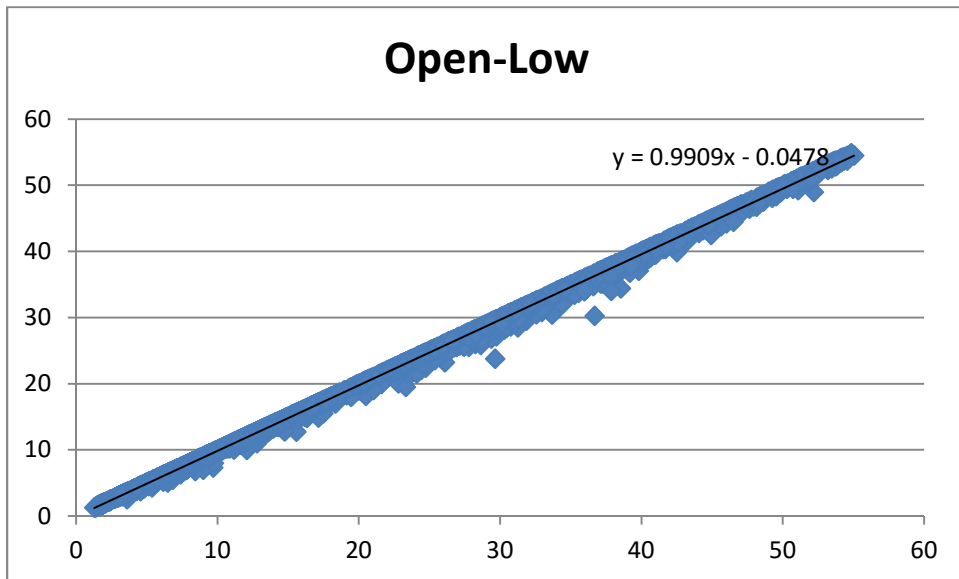


16. BAC Florida Bank

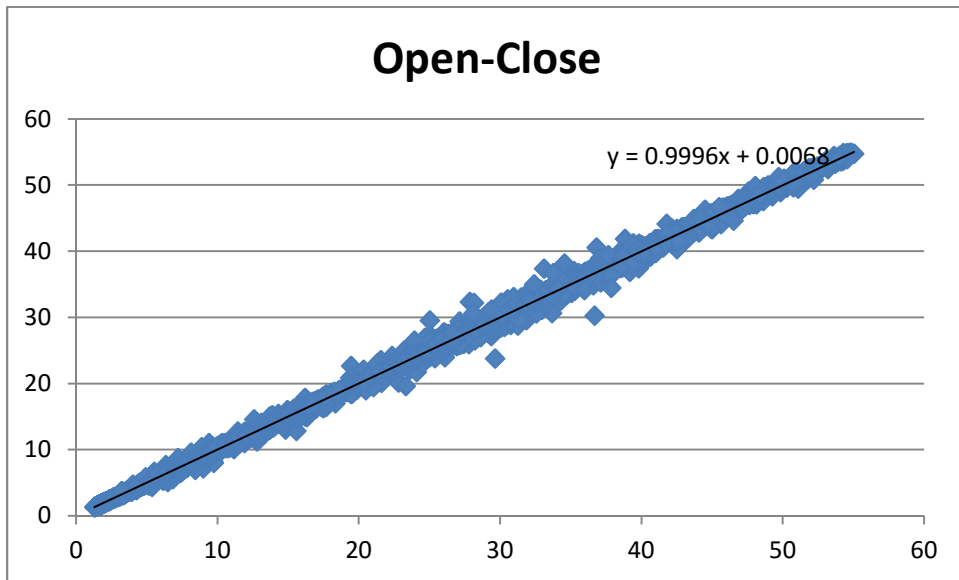
Open-High



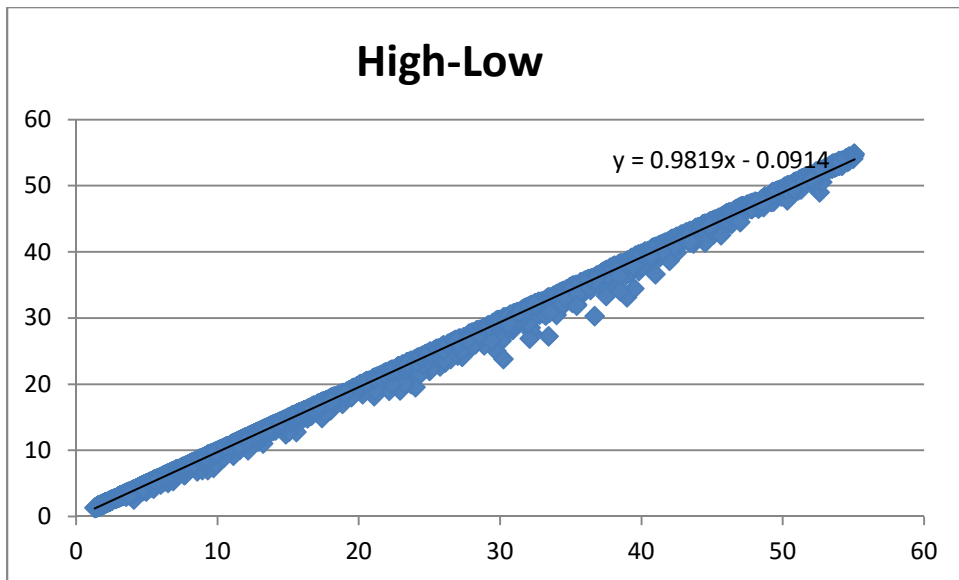
Open-Low



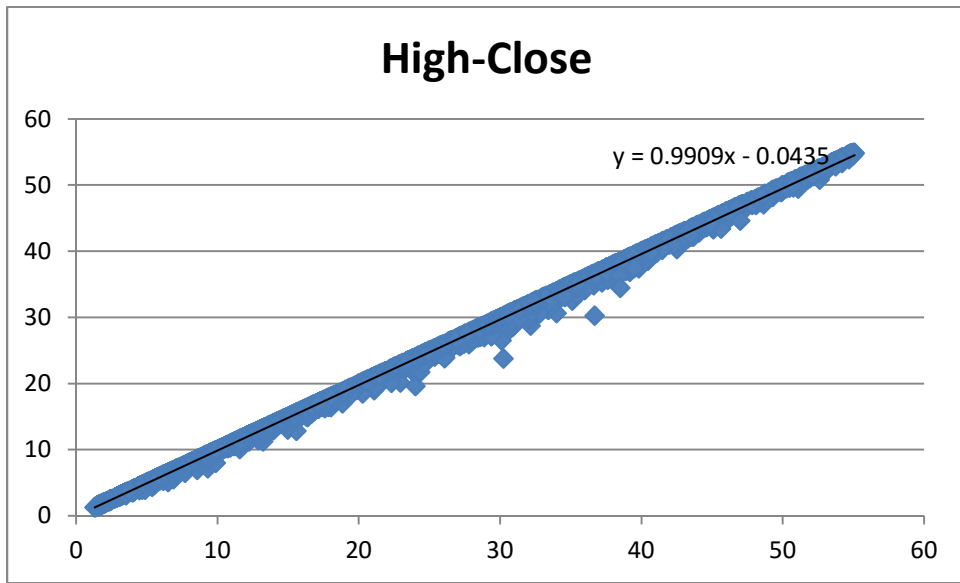
Open-Close



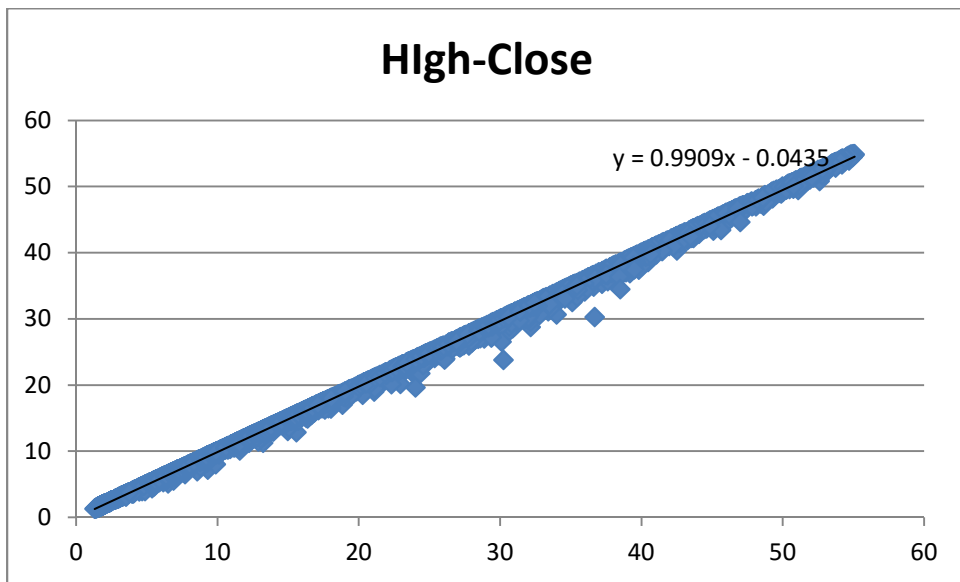
High-Low



High-Close

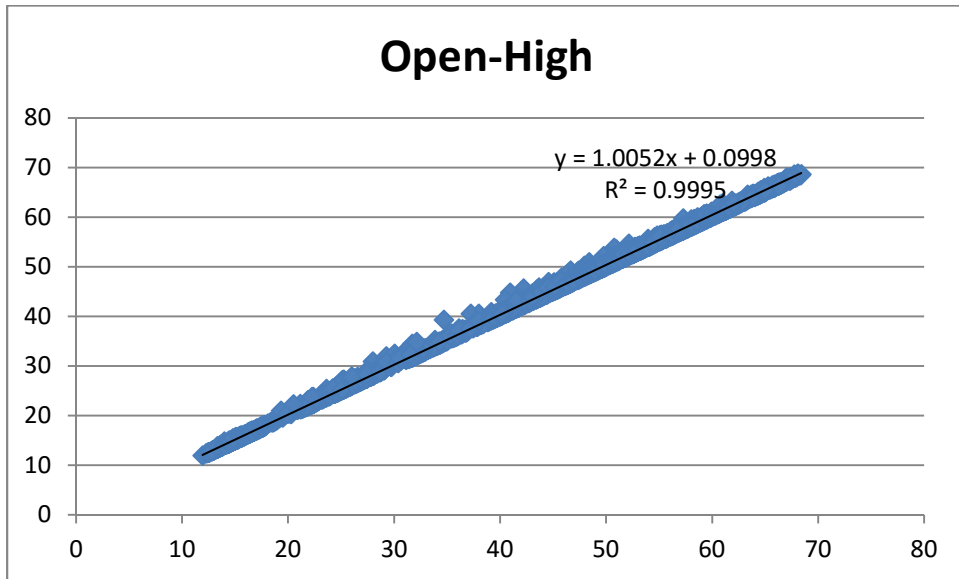


Low-Close

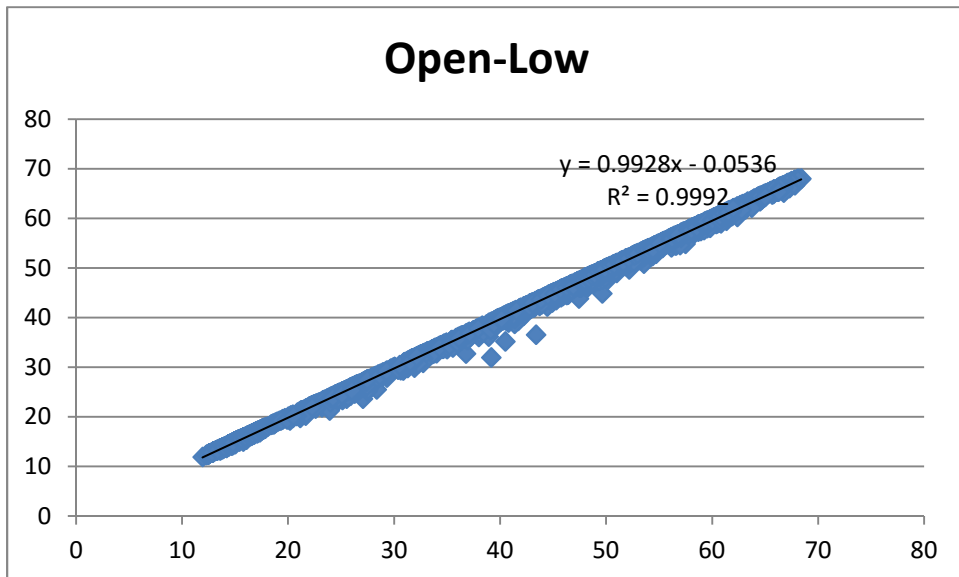


17. Bank of Nova Scotia

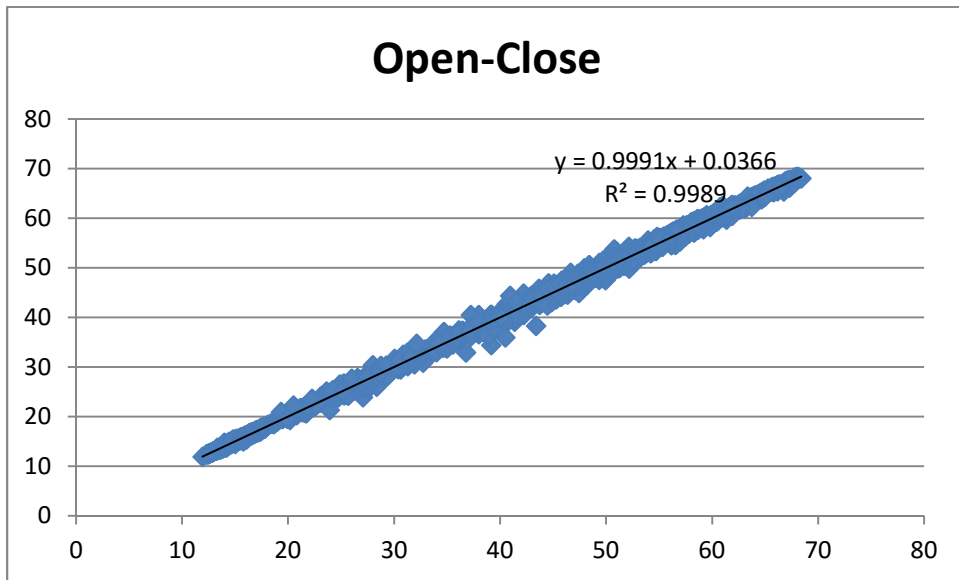
Open-High



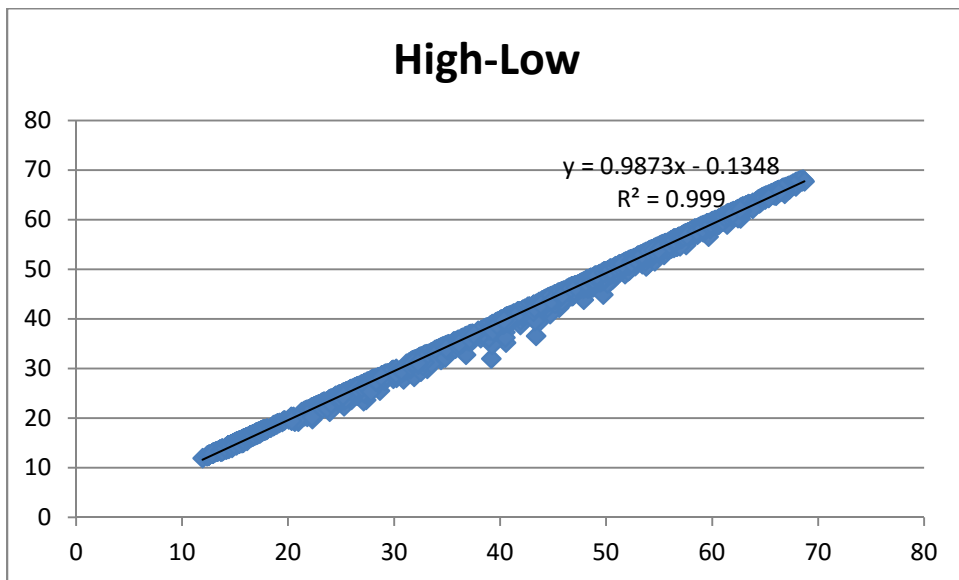
Open-Low



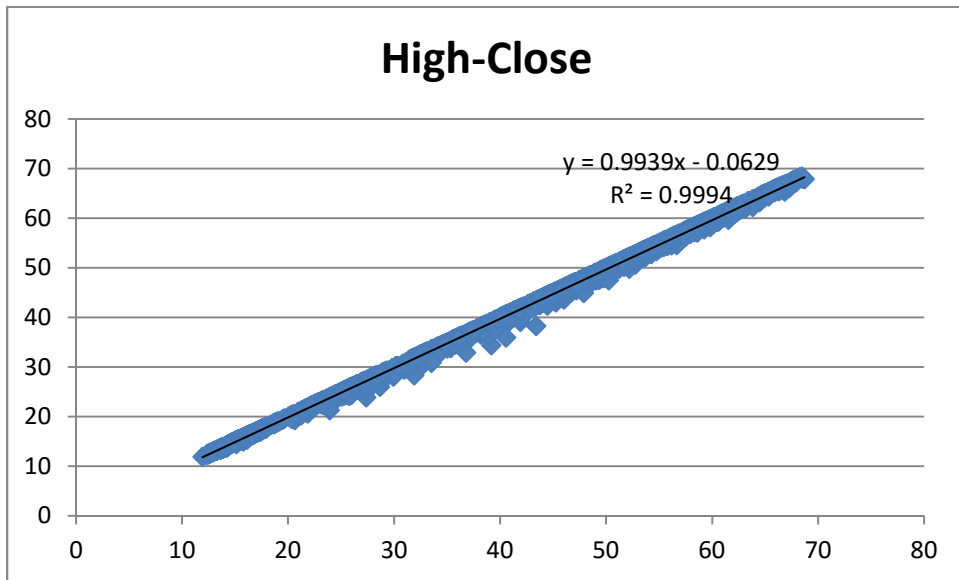
Open-Close



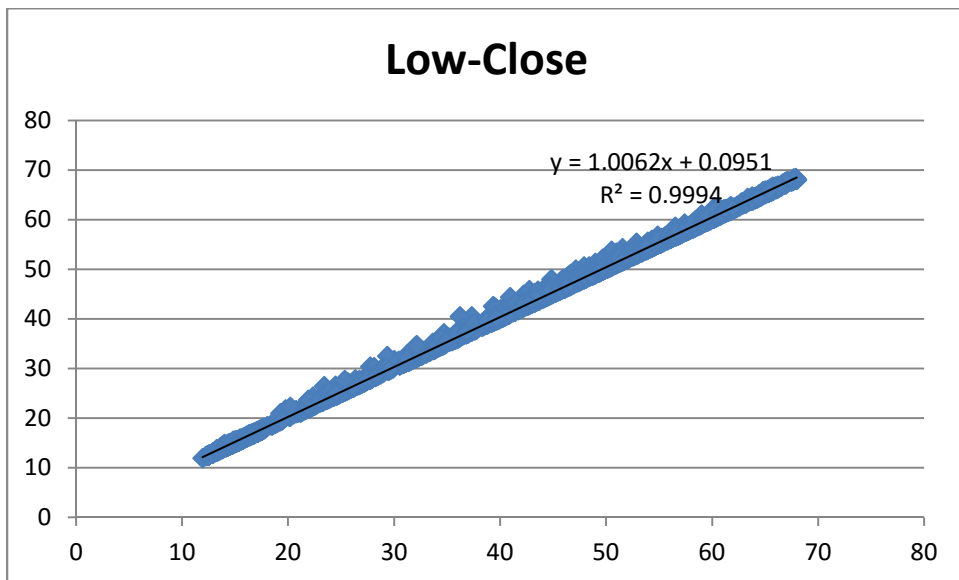
High-Low



High-Close

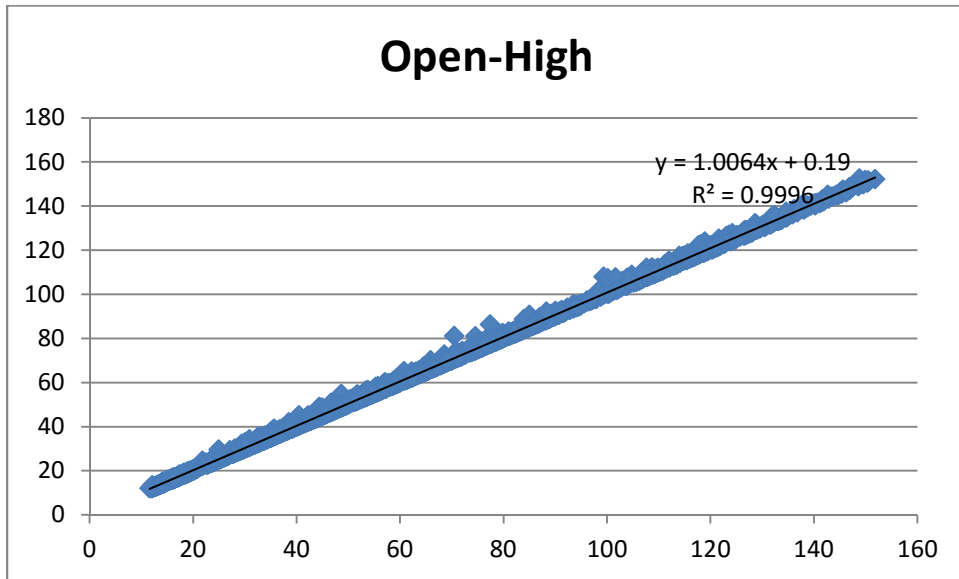


Low-Close

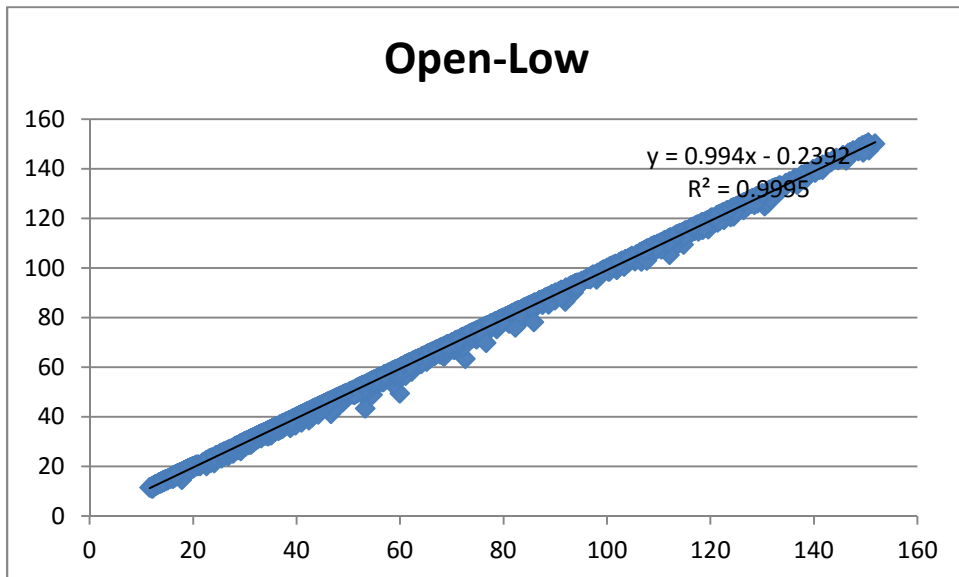


18. Commonwealth Bank of Australia

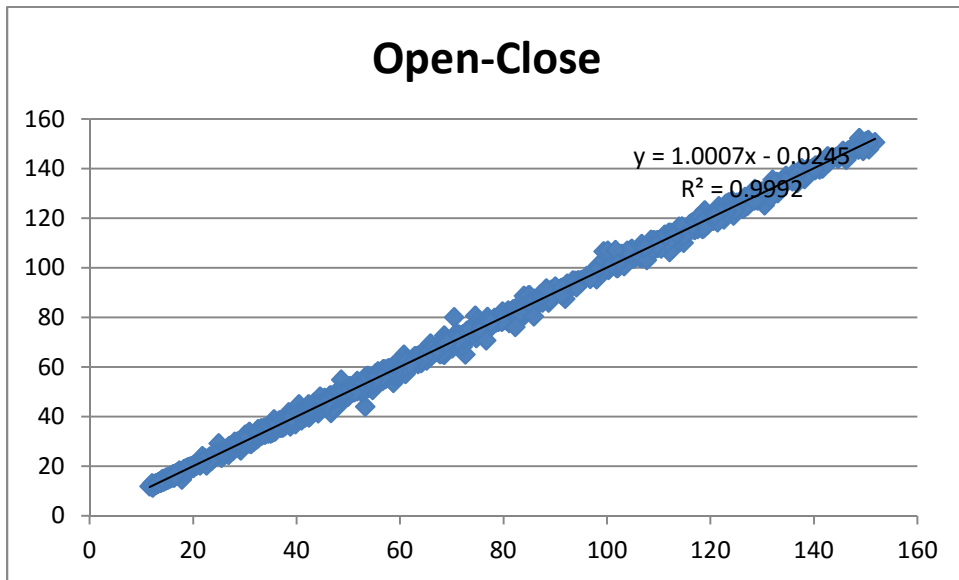
Open-High



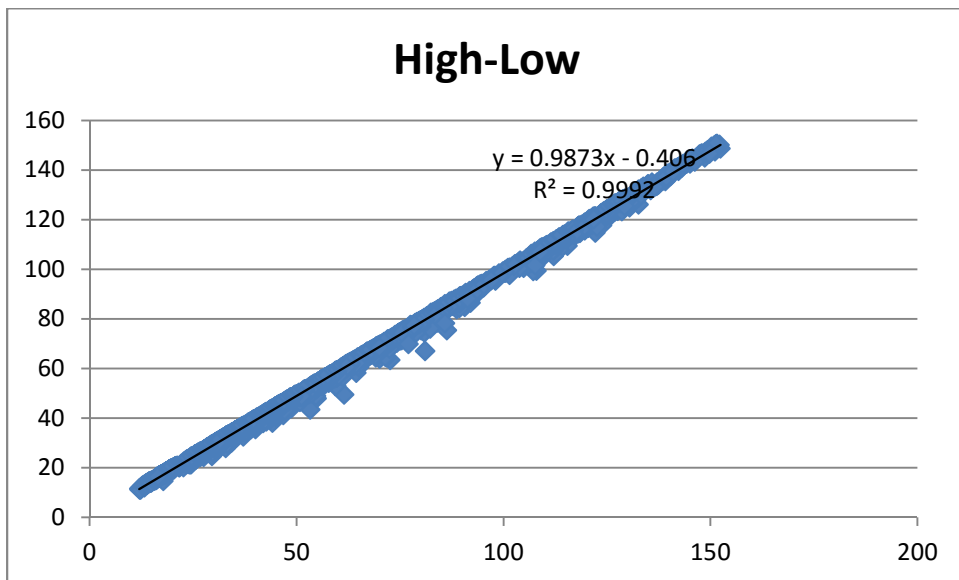
Open-Low



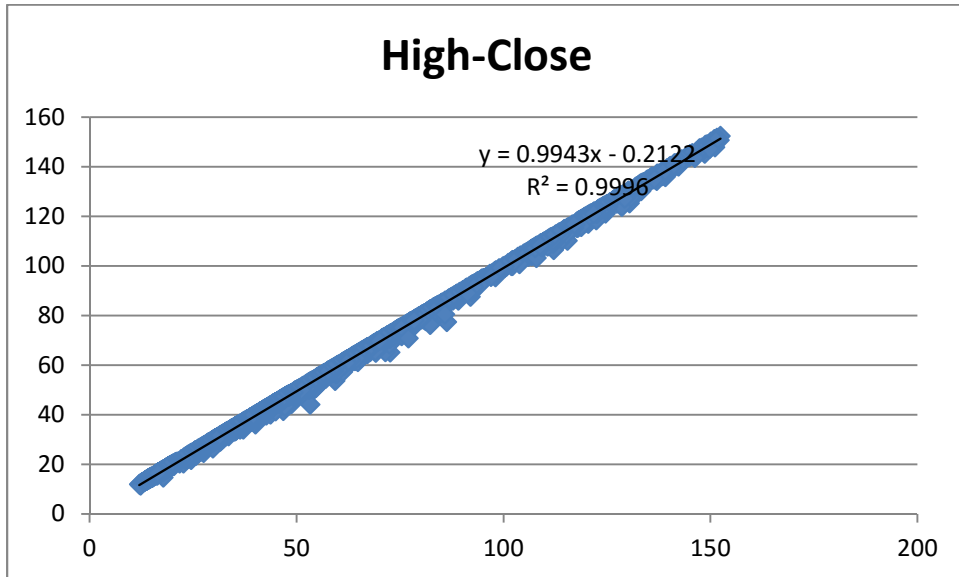
Open-Close



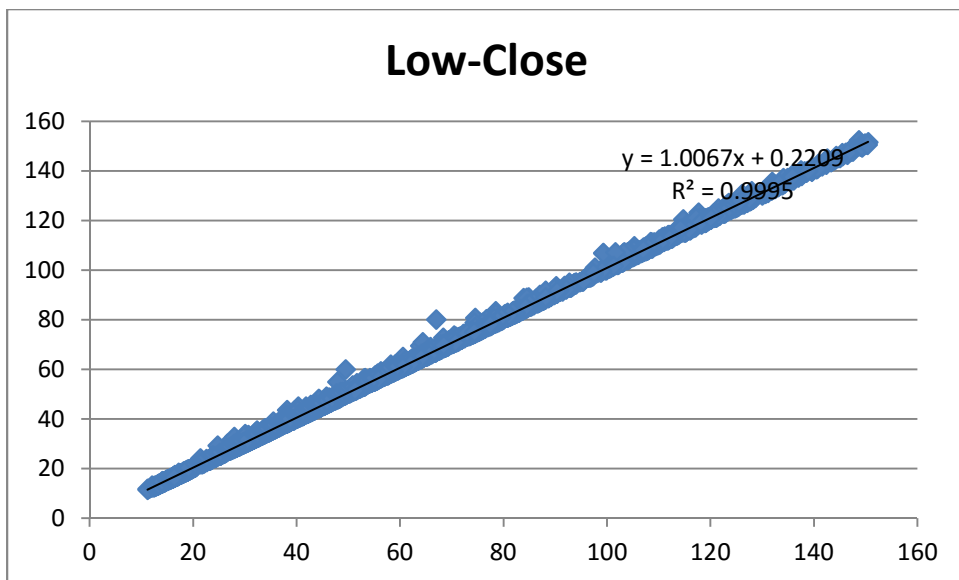
High-Low



High-Close

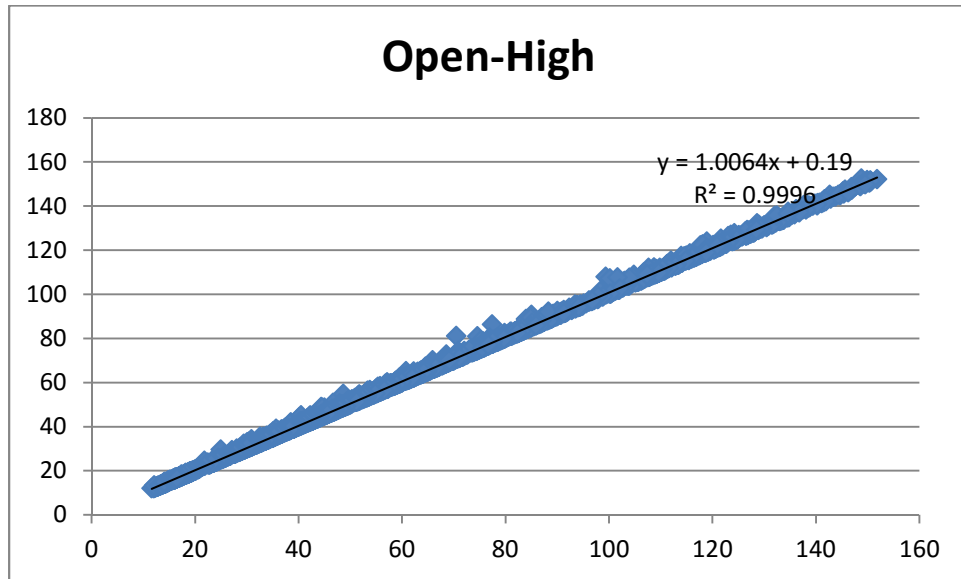


Low-Close

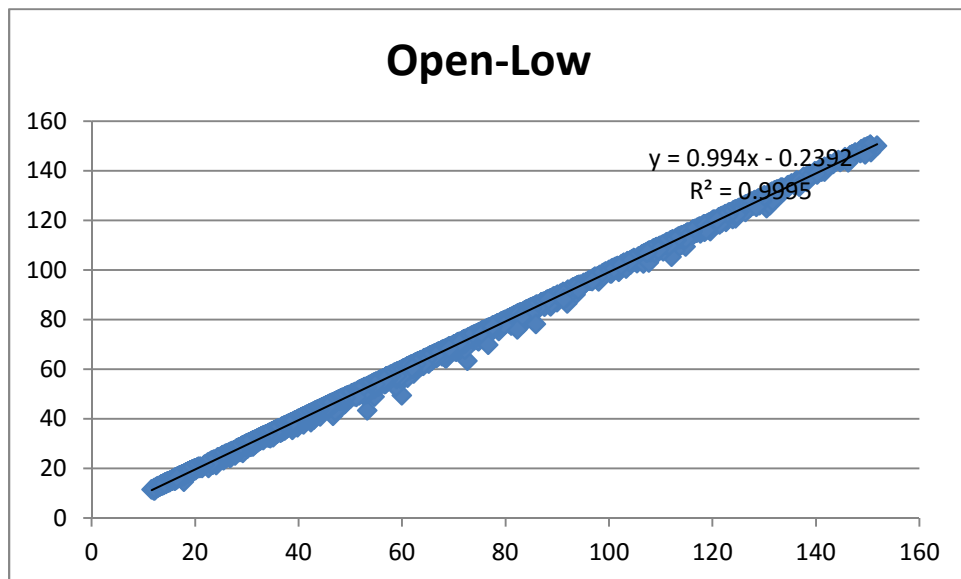


19. Deutsche Bank

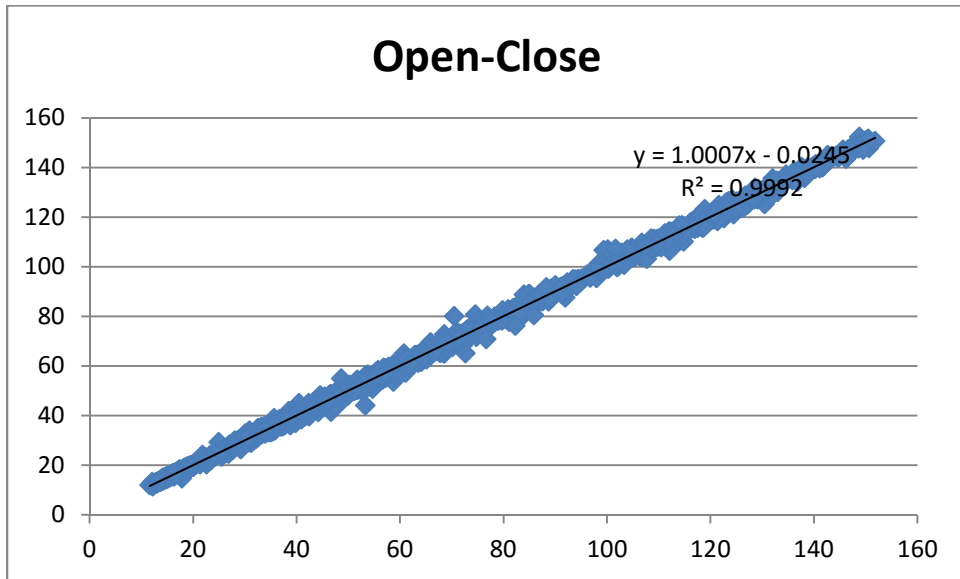
Open-High



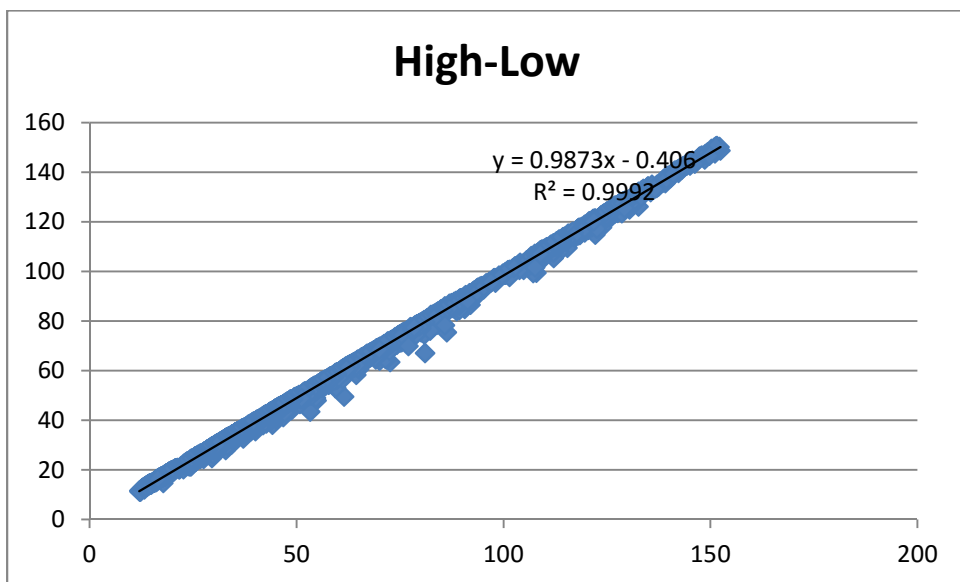
Open-Low



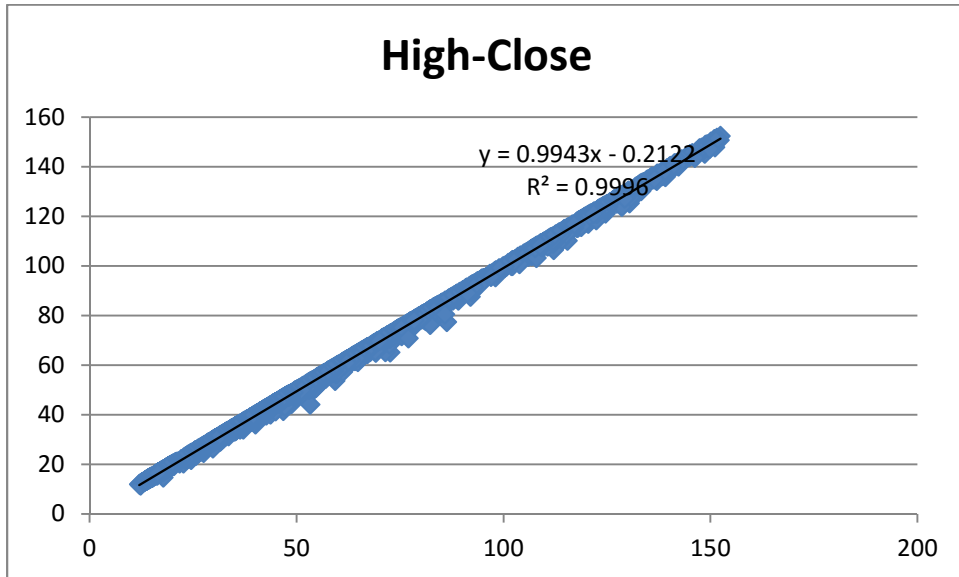
Open-Close



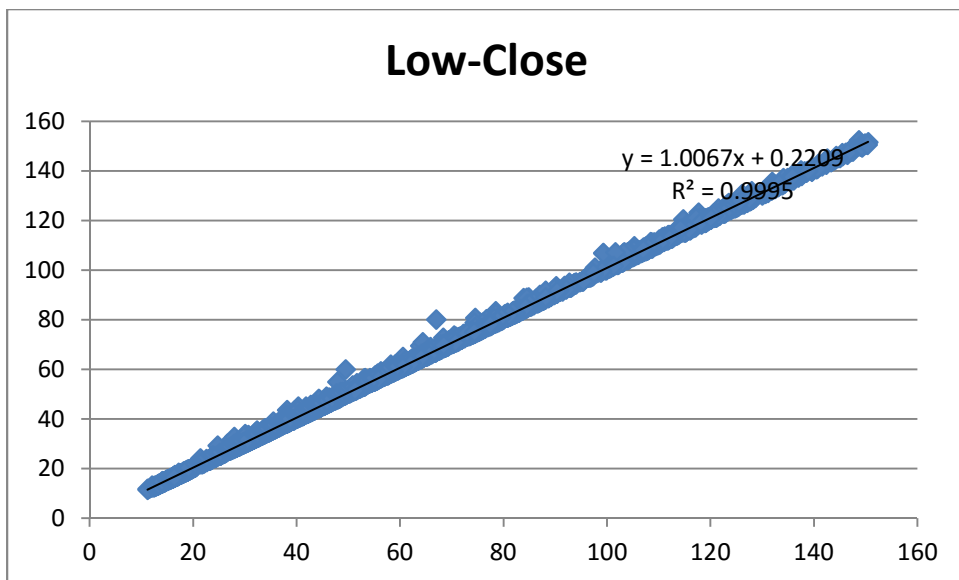
High-Low



High-Close

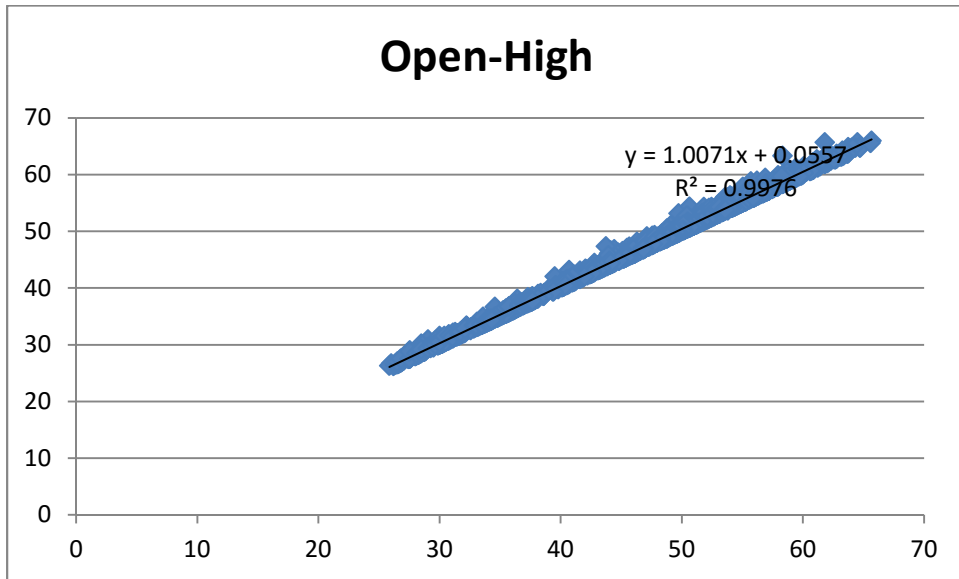


Low-Close

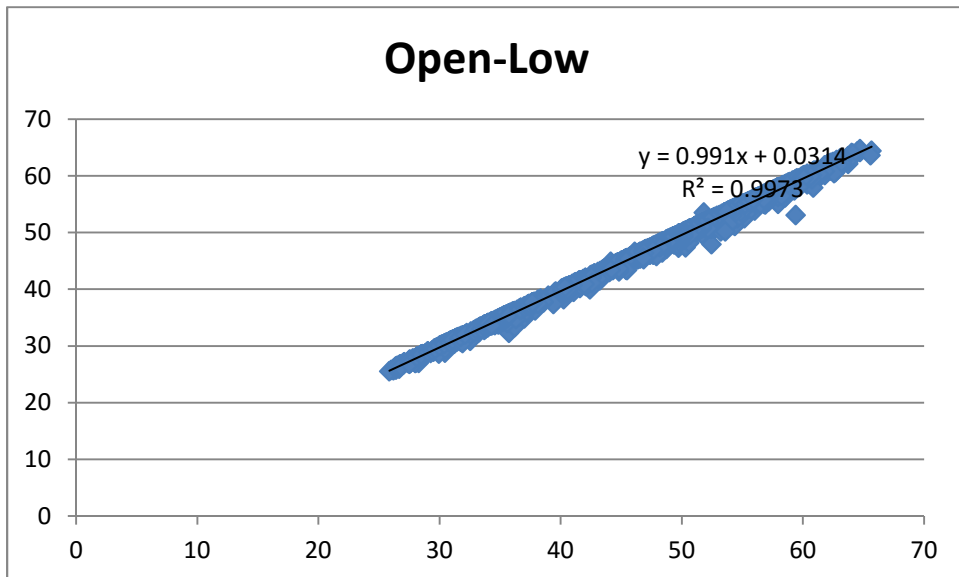


20. DHBK Bank

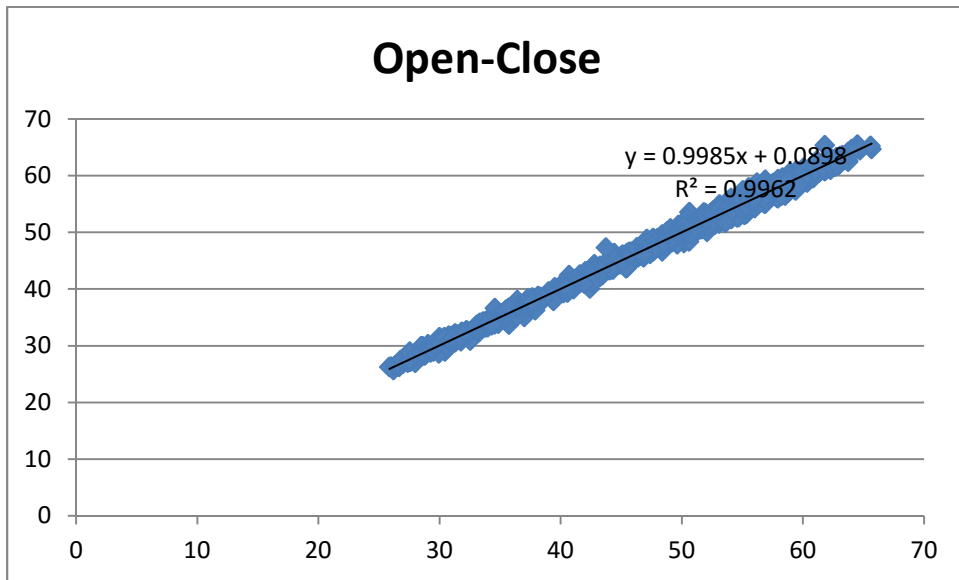
Open-High



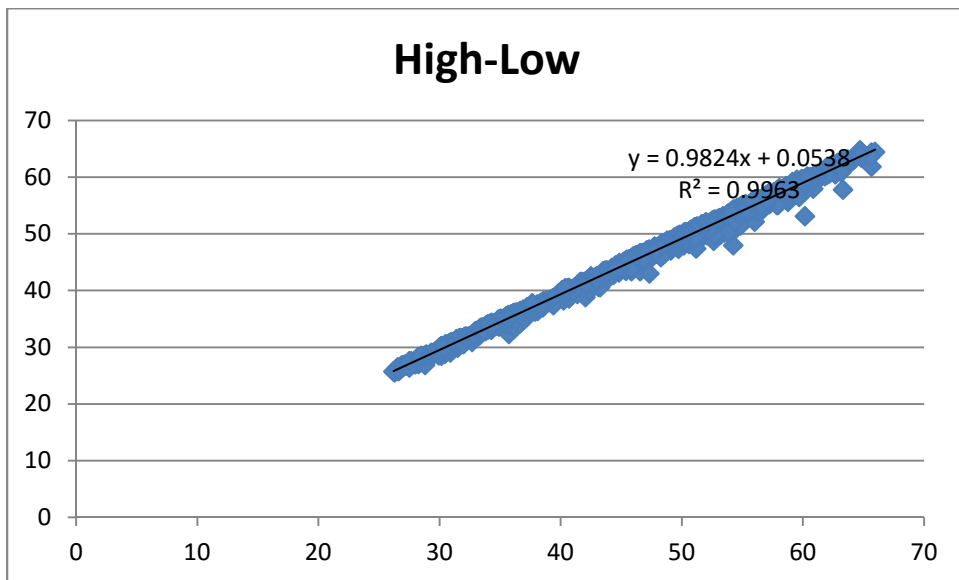
Open-Low



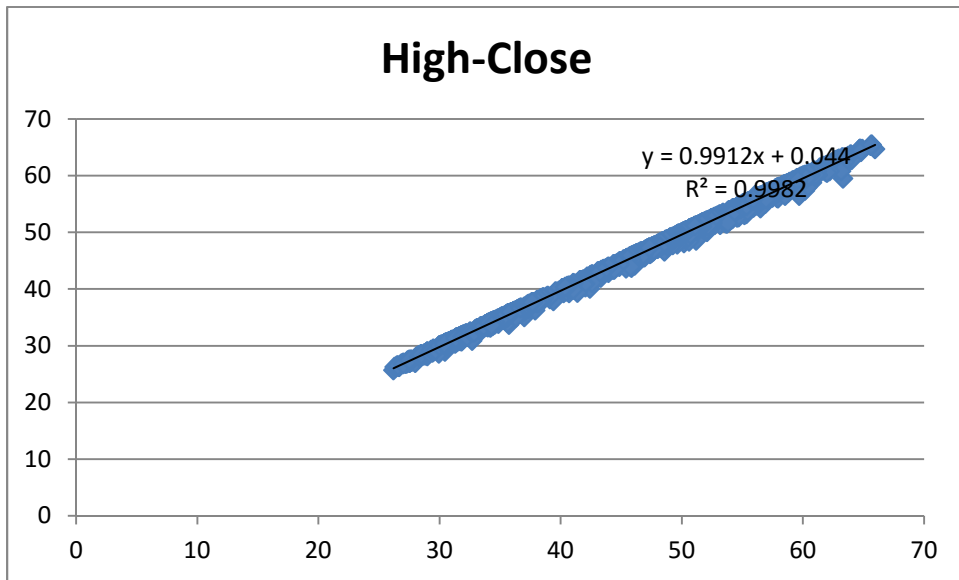
Open-Close



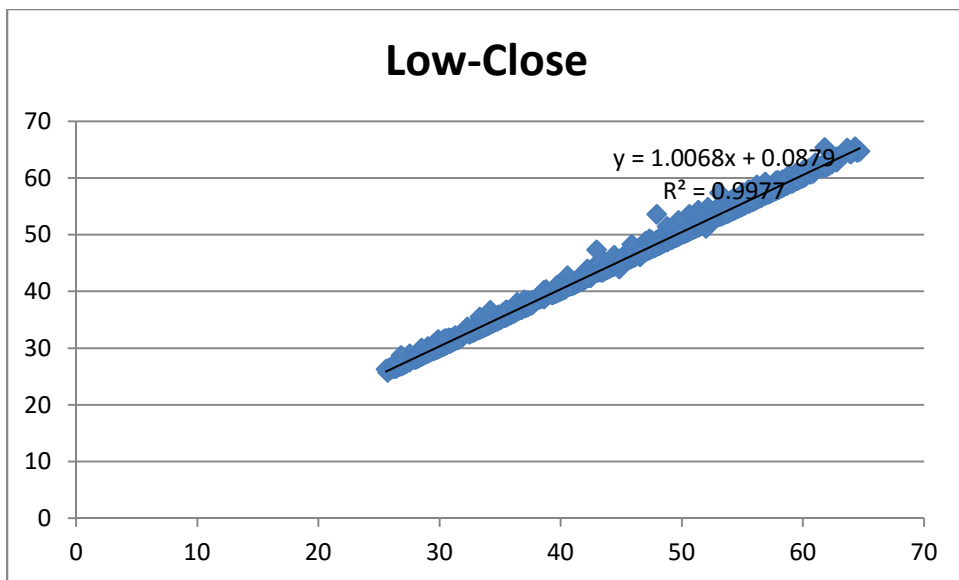
High-Low



High-Close

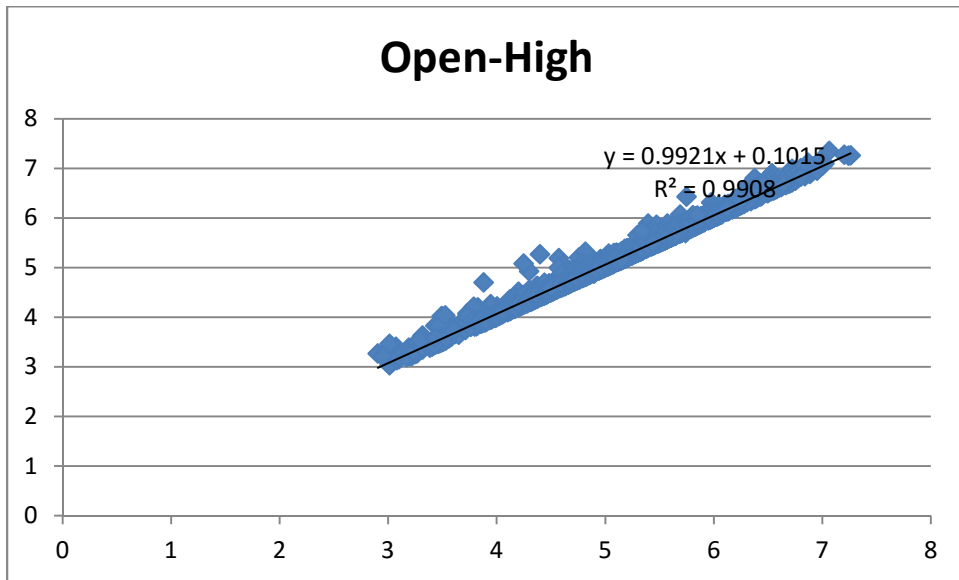


Low-Close

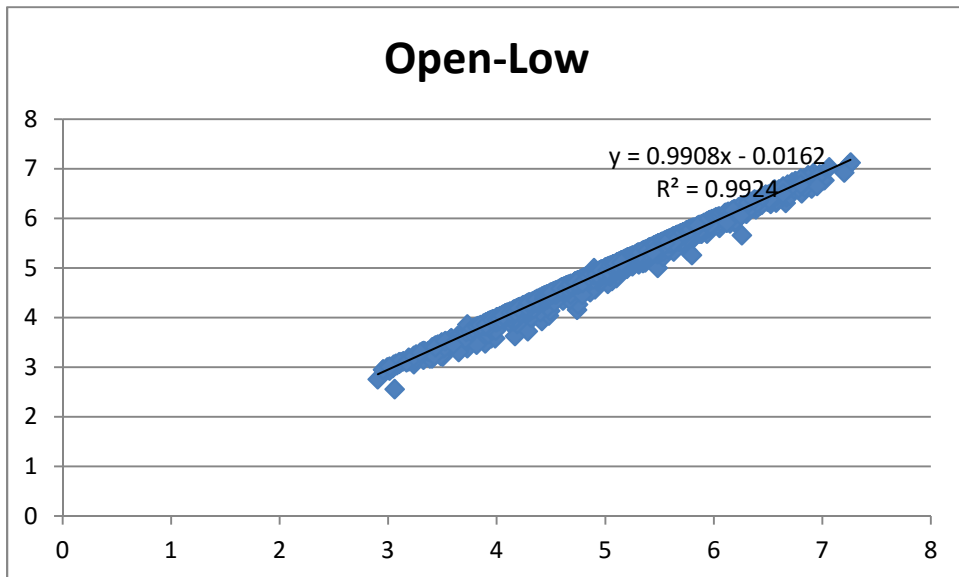


21. HSBC Bank

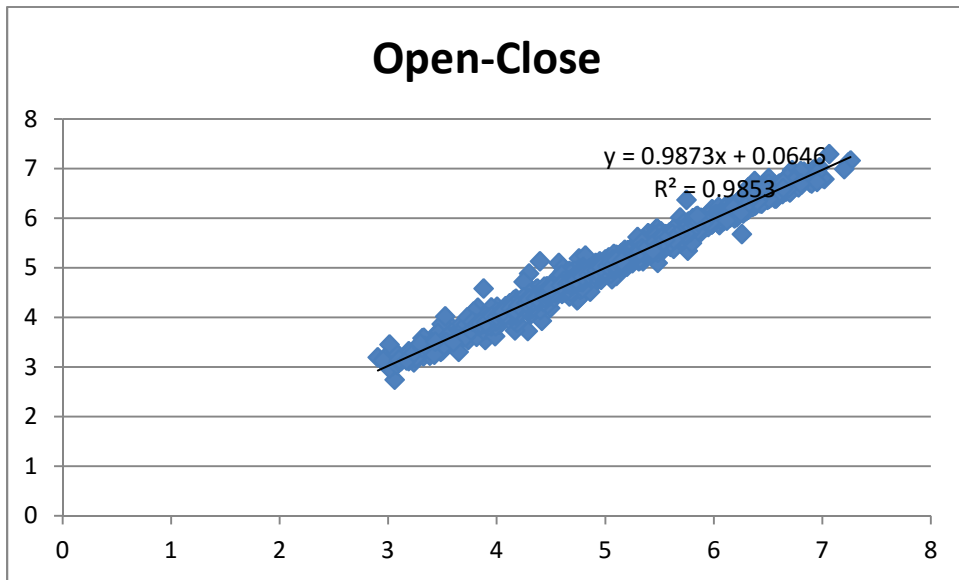
Open-High



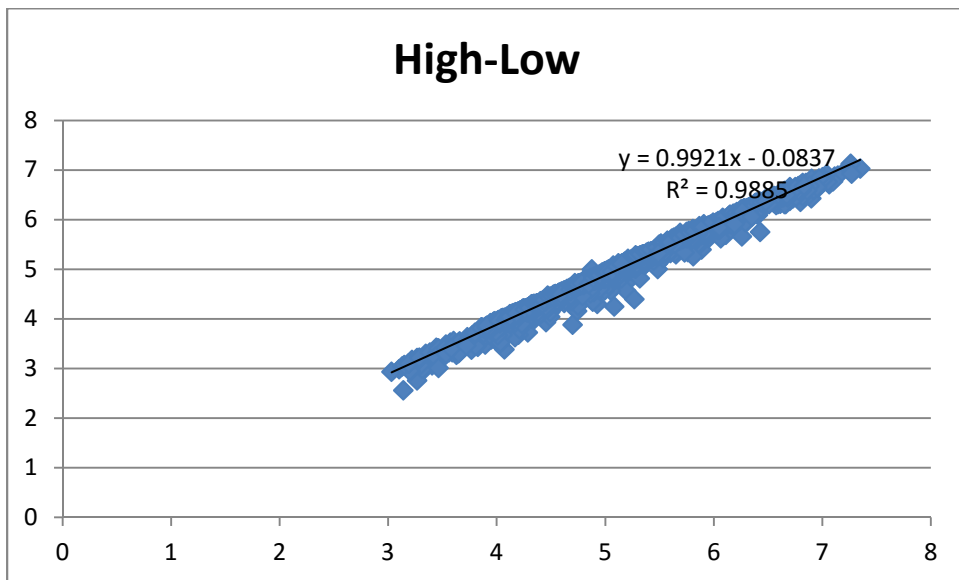
Open-Low



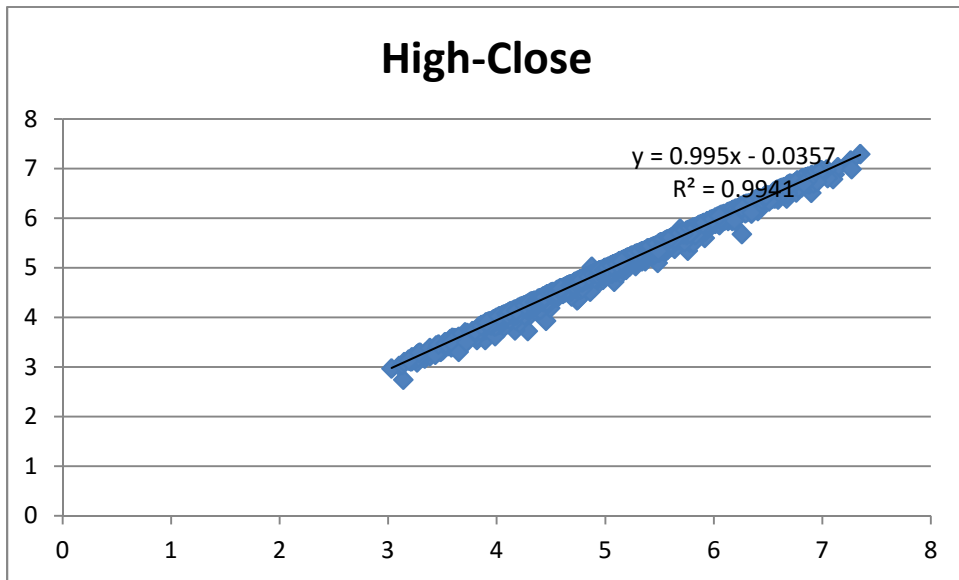
Open-Close



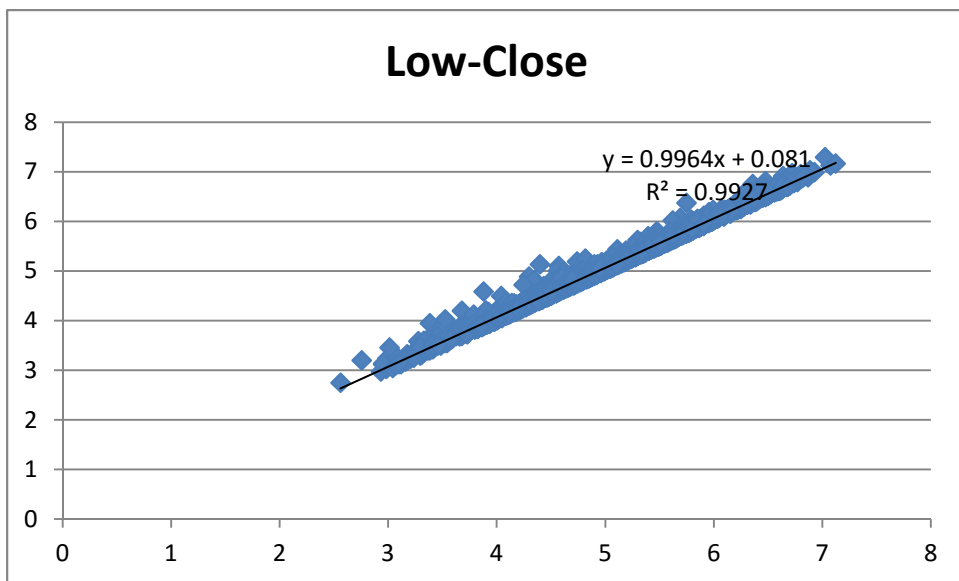
High-Low



High-Close



Low-Close



Part 02: EVEN SEMESTER

The report sites reference from 2 papers- (i) Modeling birth of a liquidity market; (ii) A study on the chaos model of liquidity in the stock market.

Liquidity is defined as availability of liquid assets in a market or company. Cash is one of the integral parts of liquid money. Market liquidity is the market's ability to purchase or sell an asset without causing a drastic change in asset's price. Example- cash can be sold for goods and services instantly with no loss of value. However, liquidity maintenance is one critical problem. It is described in terms of bid or offer spread and market depth.

Chapter 04:

CHAOS MODEL OF LIQUIDITY

Schmidt describes market liquidity in terms of number of buyers and sellers into two equations:

$$dn_{+}/dt = (v_{+-} n_{-} - v_{-+} n_{+}) + \sum_{i=1}^3 R_{+i} + \rho_{+}$$

$$dn_{-}/dt = (v_{-+} n_{+} - v_{+-} n_{-}) + \sum_{i=1}^3 R_{-i} + \rho_{-}$$

Where:

1. Functions v_{+-} and v_{-+} are determined by trader strategies.
2. n_{+} : number of buyers; n_{-} : number of sellers.
3. v_{+-} : transfer from sellers to buyers.
4. v_{-+} : transfer from buyers to sellers.
5. $v_{+-} = v \cdot \exp(u)$ and $v_{-+} = v \cdot \exp(-u)$
6. $u = \alpha \cdot p_{-1} dp/dt + \beta(p_f - p)$

1st term in utility function, u , characterizes the chartist behavior i.e. buying and selling when price falls.

2nd term describes fundamentalist pattern that promotes buying or selling depending on whether current price is lower/higher than fundamental value of an asset. u may include terms responsible for risk-free asset allocation and peer pressure.

P_f : fundamental value of an asset

α , β and v : coefficients that define specifics of trade behavior.

METHODOLOGY-

1. We assume that some traders stop trading immediately after completing a trade as they've limited resources and or need some time for making new decisions. Given a fixed time, trading value is determined by total number of traders.
 - a. If number of buyers and sellers are the same, Schmidt equation is satisfied.
 - b. $n_+ > n_-$ trading volume depends on number of sellers.
 - c. $n_+ < n_-$ trading volume depends on number of buyers.

$$\begin{aligned}
 R_{+1} = R_{-1} &= -b * n_+ n_- \text{ when } n_+ = n_- \\
 &= -b * n_-^2 \text{ when } n_+ > n_- \\
 &= -b * n_+^2 \text{ when } n_+ < n_-
 \end{aligned}$$

2. We assume that some current traders and a number of newcomers informed by current traders will be coming in market. Therefore, inflow is proportional to current number of traders. In addition, continual rise or fall of price in market will attract more buyers or sellers in the market. (term not in the Schmidt model)

$$R_{+2} = a(n_+ + n_-) + D_1(dp/dt)$$

$$R_{-2} = a(n_+ + n_-) + D_2(dp/dt)$$

Where:

$$\begin{aligned}
 D_1(dp/dt) &= a' dp/dt, \quad dp/dt > 0 \\
 &= 0, \quad dp/dt < 0 \quad a > 0
 \end{aligned}$$

$$\begin{aligned}
 D_2(dp/dt) &= a' dp/dt, \quad dp/dt < 0 \\
 &= 0, \quad dp/dt > 0 \quad a > 0
 \end{aligned}$$

3. Account for unsatisfied traders leaving the market. These buyers aren't able to find the trading counter-parts within reasonable time. So, they leave an emerging market.

$$R_{+3} = -c*(n_+ - n_-), \quad n_+ > n_-$$

$$= 0 \quad , \quad n_+ \leq n_-$$

$$R_{-3} = -c*(-n_+ + n_-), \quad n_+ < n_-$$

$$= 0 \quad , \quad n_+ \geq n_-$$

Where, c is the Impatience Factor.

4. The effect of stochastic factor on changing number of buyers and sellers. When the market is operating there are many uncertain factors that affect it. So, they affect the changing rate of number of traders ρ_+ , ρ_- . The price $p(t)$ is determined by excess demand D_{ex}

$$dp/dt = \gamma'' D_{ex} + \varepsilon(t)$$

Where:

$$D_{ex} = \gamma' (n_+ - n_-)$$

D_{ex} : excess number of buyers

ANALYSIS OF LYAPUNOV EXPONENTS-

$$dn_+/dt = f_1, \quad dn_-/dt = f_2, \quad dp/dt = f_3, \quad dp/dt > 0$$

$$\partial f_1 / \partial n_+ = \alpha p^{-1} \delta v \exp(u) n_- + v(\alpha p^{-1} \delta n_+ - 1) \exp(-u) + a + a' \delta - c,$$

$$\partial f_1 / \partial n_- = v(1 - \alpha p^{-1} \delta n_-) \exp(u) - \alpha p^{-1} \exp(-u) n_+ - 2b n_- + a - a' \delta + c,$$

$$\partial f_1 / \partial p = -v[n_- \exp(u) + n_+ \exp(-u)] \cdot \alpha \delta (n_+ - n_-) p^{-2} + \beta,$$

$$\partial f_2 / \partial n_+ = -\alpha p^{-1} \delta v \exp(u) n_- + v(1 - \alpha p^{-1} \delta n_+) \exp(-u) + a,$$

$$\partial f_2 / \partial n_- = v(\alpha p^{-1} \delta n_- - 1) \exp(u) + \alpha p^{-1} \delta v \exp(-u) n_+ - 2b n_- + a,$$

$$\partial f_2 / \partial p = v[n_- \exp(u) + n_+ \exp(-u)] \cdot (\alpha \delta (n_+ - n_-) p^{-2} + \beta),$$

$$\partial f_3 / \partial n_+ = \delta, \quad \partial f_3 / \partial n_- < -\delta, \quad \partial f_3 / \partial p = 0$$

Chapter 05:

CONCLUSION-

1. In a fitted condition of number of buyers, sellers and total traders there can emerge chaos. When a, b, c are changing, complexity extent will be influenced.
2. Market liquidity is influenced by a, b and c . a, b determine total number of traders. $n_{\infty} = 4b/a$ (asymptotic solution)
3. Higher the impatience factor (c), less time will be needed for a lucky combination of number of buyers and sellers arriving simultaneously to be able to launch liquid markets.
4. Schmidt Conclusion:

Condition	Conclusion(chaos in)
$n_{\pm k} > (a+1)/b$ or $n_{\pm k} < a/b$	Buyers and sellers
$n_k < 2a/b$ or $n_k > 2(a+1)/b$	Total traders
$n_{+k} < a/b$ or $n_{+k} > (a+1 + b\delta\exp(-c))/b$	Buyers
$n_{-k} < a/b$ or $n_{-k} > (a+1)/b$	Sellers
$n_k > (2a + 2 + b\delta\exp(-c))/b$	Traders

ANNEXURE D

AUXILLARY CODES IN C++ AND PYTHON

1. To do a time-series plot of the data and do an FFT of the data points in Python

```
import numpy as np
np.set_printoptions(threshold='nan')
import matplotlib.pyplot as plt
import scipy.fftpack
x= np.array([1,2,3,4, ..... , 3770,3771,3772,3773,3774])
y = np.array([11,10.3,11,.....,69.3739,59.103,33.2902,26.1768])
yf = scipy.fftpack.fft(y)
print(yf)
fig, ax = plt.subplots()
ax.plot(x, y)
plt.show()
fig, ax2 = plt.subplots()
ax2.plot(x, y2)
plt.show()
```

Chapter 06:

Phase space is a vector space in which two or more points are plotted to study the smaller variations with respect to other. So, all possible states of a system are represented, with each possible state corresponding to one unique point in phase space. The concept of phase space was developed by Ludwig Boltzmann, Henri Poincare and Willard Gibbs in the late 19th century.

Here, every degree of freedom is represented as an axis of a multidimensional space.

Annexure E:

1. To apply Euler method to different conditions to obtain the data series for further plotting in 3-dimensions.

```

#include <iostream>
#include <cmath>
#include <fstream>
using namespace std;
int main()
{
    int n = 10000;
    float tx[n], ty[n], tz[n], x[n], y[n], z[n];
    float a = 1, b = 1, c = 1, k = 1, delta1 = 1, h1, h2, h3;
    cout <<"Step-size in n+: ";
    cin >> h1;
    cout <<"Step-size in n-: ";
    cin >> h2;
    cout <<"Step-size in n: ";
    cin >> h3;
    ofstream myfile;
    myfile.open ("example1.txt");
    tx[0] = 1;
    ty[0] = 1;
    tz[0] = 1;
    for(int i=0; i<n; i++)
    {
        t = i*h1;
        x[i+1] = (2*a + 1)*tx[i] - b*(tx[i] - delta1*exp(-c*k))*(tx[i] - delta1*exp(-c*k)) - (a +
c)*delta1*exp(-c*k);
        tx[i+1] = tx[i] + h1*x[i];
        y[i+1] = (2*a + 1)*ty[i] - a*delta1*(exp(-c*k) - b*ty[i]*ty[i]);
        ty[i+1] = ty[i] + h2*y[i];
        z[i+1] = (2*a + 1)*tz[i] - 2*b*((tz[i] - delta1*exp(-c*k))/2)*((tz[i] - delta1*exp(-
c*k))/2) - c*delta1*exp(-c*k);
        tz[i+1] = tz[i] + h3*z[i];
        myfile << "n1: " << x[i+1] << " ";
        myfile << "n2: " << y[i+1] << " ";
        myfile << "n: " << z[i+1] << endl;
        //cout << "n1: " << x[i+1] << " ";
    }
}

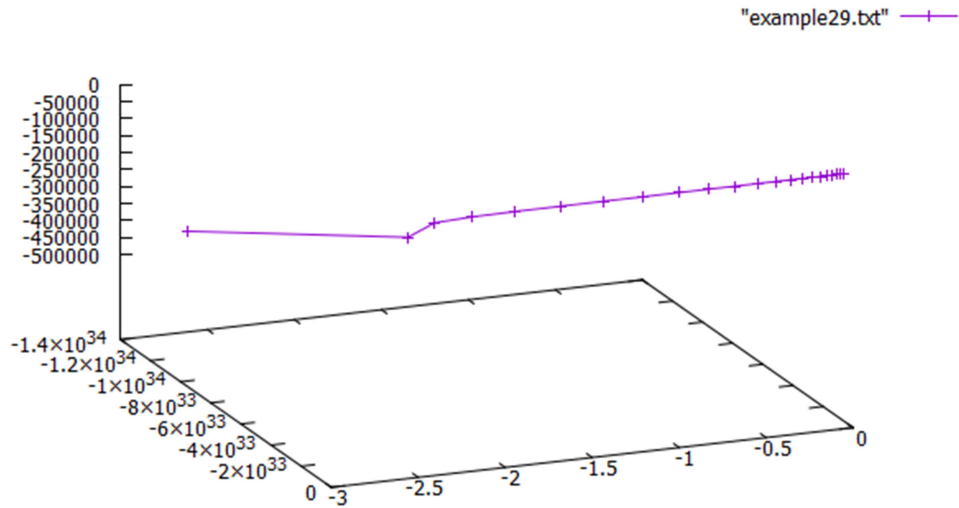
```

```
    //cout << "n2: " << y[i+1] << " ";  
    //cout << "n: " << z[i+1] << endl;  
}  
cout << "File saved. " << endl;  
myfile.close();  
}
```

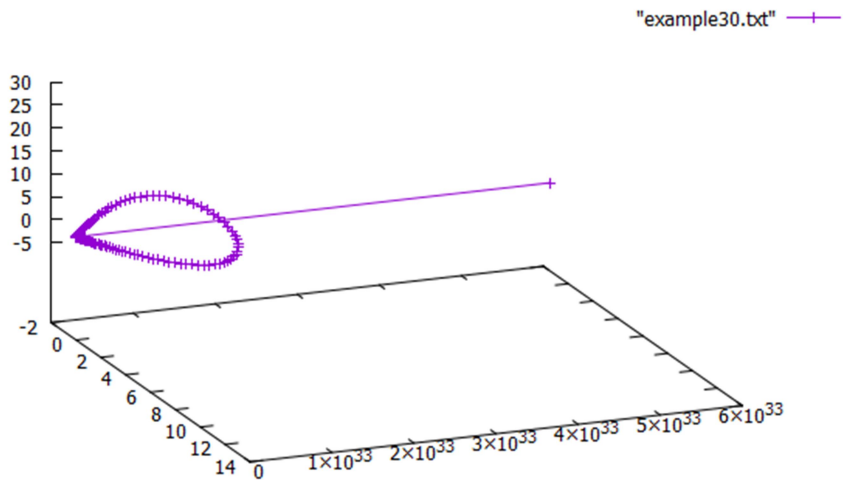
2. Further in GNUplot
plot "example1.txt" w lp

PHASE SPACE PORTRAITS

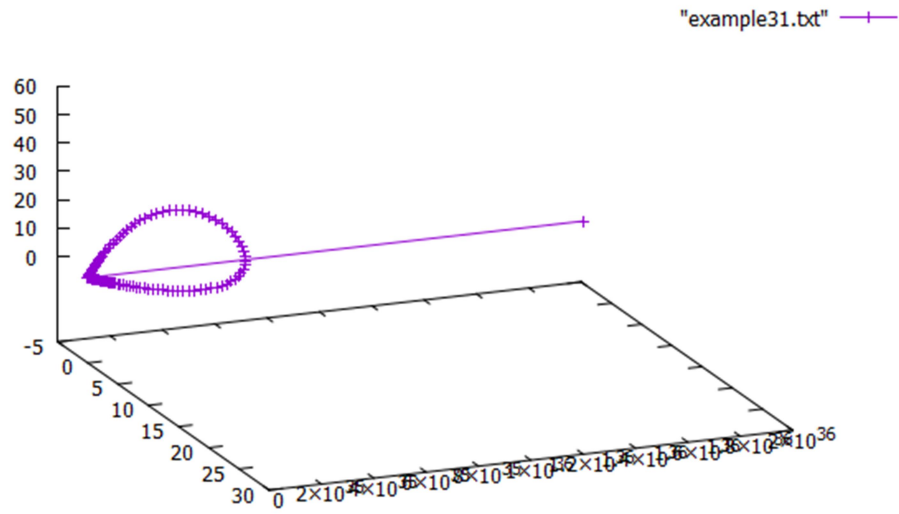
1. $a = 1, b = 1, c = 1, k = 1, \text{delta1} = 1$



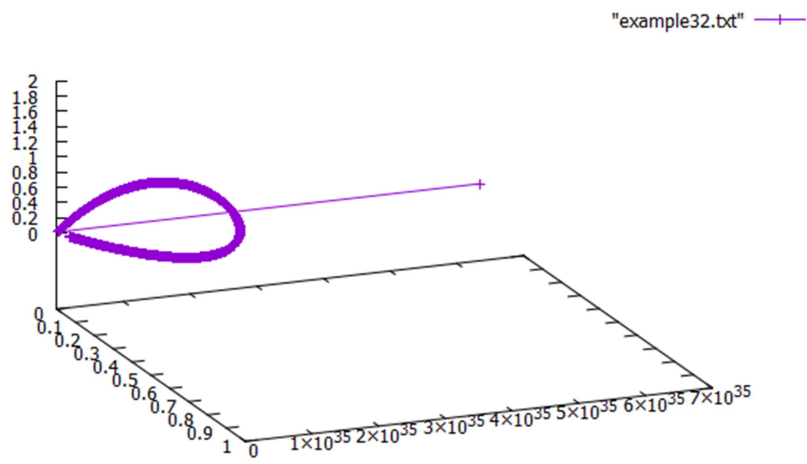
2. $a = 0.01, b = 0.02, c = 0.03, k = 0.04, \text{delta1} = 0.05$



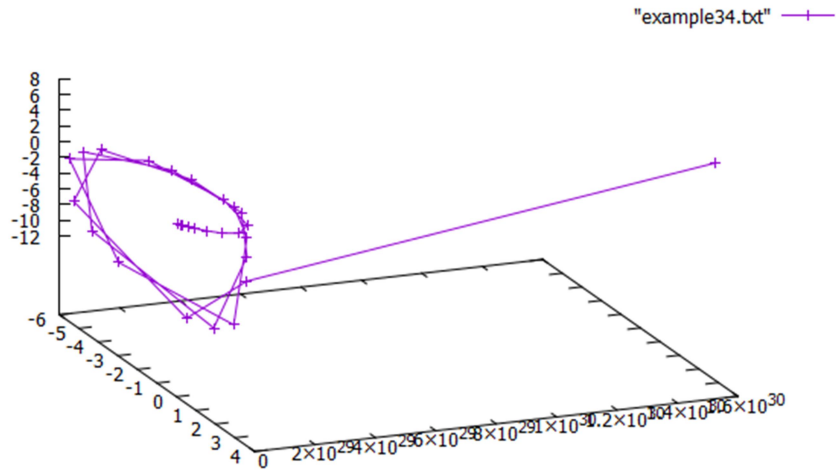
3. $a = 0.01, b=0.01, c= 0.08, k =0.08, \text{delta1} = 0.05$



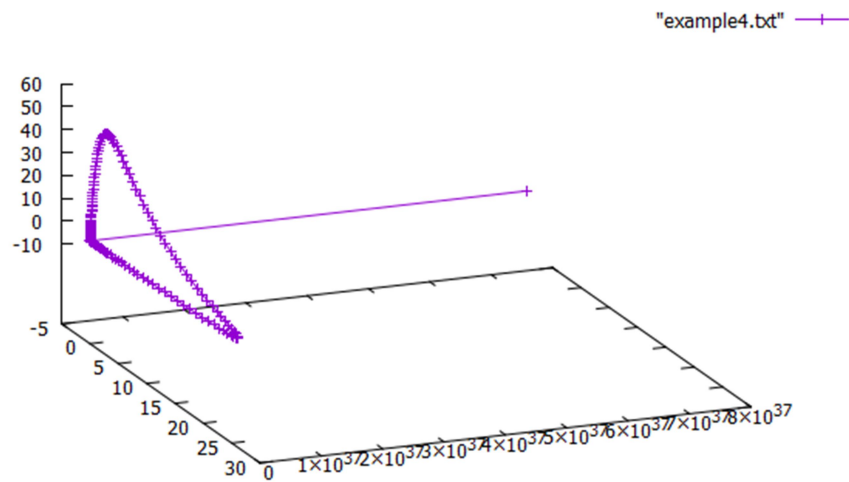
4. $a = 0.04, b = 0.3, c=0.8, k = 0.08, \text{delta1} =0.05$



5. $a = 0.1, b=0.1, c=0.1, k=0.1, \text{delta} = 0.1$



6. $a = 0.01, b = 0.01, c = 0.01, k = 0.01, \text{delta1} = 0.01$



BIBLIOGRAPHY:

1. A study on the chaos model of liquidity in stock markets by You, Zhang and Song.
2. Modeling the birth of a liquid market by Anatoly B Schmidt.
3. <https://en.wikipedia.org/wiki/Cross-correlation>
4. https://en.wikipedia.org/wiki/Spectral_density#Spectrum_analysis
5. https://en.wikipedia.org/wiki/Pink_noise
6. http://www.scholarpedia.org/article/1/f_noise
7. <https://in.finance.yahoo.com/quote/%5EXAX/history?p=XAX> 8. <http://www.itl.nist.gov/div898/handbook/pmc/section4/pmc4.htm>