

Feasibility for Utilizing Engineered Financial Network features for Predicting Markets' Next Day Price Movements

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1.0 Abstract

Stock Market predictions is one of the most research field in Finance. The main objective of such studies is predicting the price directions of specific stocks or market indexes. Per Reference 1, most of the research and corresponding analysis involves utilizing different measures for returns and volatility, namely, daily, 5-day moving average, volatility, etc.

The authors of Reference 1 claimed that there is seldom consideration for the comovement among stocks in the same market, and consequently a topic of research that deserves evaluation. The research conducted can not ascertain the validity of such claim. However, it is agreed that it is a well worth effort to conduct experiments to validate the usefulness of the consideration, and research if there is any positive impacts on forecasting market trends.

2.0 Project Objective

1. To validate that the Network Topology Characteristics of a set of related markets' indexes assist in forecasting the direction of price movements of an index in such network

- The underlying hypothesis of the authors consists of the treatment of a set of related markets, namely, S&P 500, Dow Jones Industrial, and Nasdaq Composite as components of a complex network. And most importantly, that the underlying network characteristics of such combine markets can assist and enhance the forecasting of individual stocks or a market index.
- The mathematics of Complex Networks, is a highly research field, and heavily utilized in the understanding of social media networks. An explanation of the mathematical concepts of Complex Networks is out-of-the scope of this project, the reader is refer to references (2-6) for further details.
- A brief explanation of the underlying network topology engineered measures used by the author's of reference 1 is described succinctly in this notebook, as well as the application to stock market financial data. The purpose is to provide reader a high level understanding of the derived measures, their corresponding formulas, and direct applicability.

2. Design, conduct, and execute empirical experiments that validate and add to existing knowledge stated by the authors of Reference 1

1. Validate results stated by Reference 1, by utilizing the same market indexes, time periods, and daily data, as well as the same exact network engineered measures and derivations employed.

- Validation of derived Network Topology features by comparison to graphs of the same parameters presented in Reference 1
- Execution of the same Statistical Tests against the Network Topology features to further validate the correct derivation of such parameters
- Application of the same Machine Learning methods and cross validation with the same size Training and Test data sets

2. Additional experiments will be conducted to further validate or negate the results, including:

- Conduct the same experiment as in 1. but against a complete different set of market indexes, and different time periods for the training and test sets
- Evaluate the importance or lack-thereof of the derived Network Topology features
- Explore the use of additional Machine Learning methods no used by Reference 1, as well as Neural Networks

3. Analyze the distribution of price movements of the studied markets to ensure that forecasting results provide "learning" value

- Histogram of Indexes' Classifications
- Indexes' Classification vs Time Graphs
- Summary Statistics for Transitions from one Classification to Another Classification
- Pareto Charts for Transitions
- Analysis of Daily Log Returns per Index Classification

4. In order to minimize duplication of code, and assist in different sets of permutations of the experiments, a few Python functions will be implemented to assist in the execution of the project.

- The goal is to minimize code duplication and consequently human errors by such procedure.
- The aim is to allow team members to easily perform, optimized and tune, create graphs, summary tables, and performance analysis for any condition, dataset, or Machine Learning method

3. Implementation of a complete machine learning project and draw conclusions

- All analysis and Machine Learning modeling is included and coded in Python.
- All financial measures and network topology measures will be directly coded in Python or via a standard Python library
- Based on the efficacy of the set of exploratory Machine Learning models selected for analysis, a subset will be optimized via hyper-parameter tuning. The two Machine Learning methods employed by Reference 1 will be optimized regardless of the results of exploratory analysis.
- Conclusions based on a comprehensive set of experiments will be summarized, as well as observations that are deemed to be important during the execution of the experiments

3.0 Concise Theoretical Summary

3.1 Network Topology

This section describes the formulas and network classification methodology for each stock index, concluding with the visual representation of a sample network to aid in the reader's understanding. The contents are exactly replicated from section 3.1 and 3.2 of Reference 1, and summarized and further explained here for convenience and clarification.

Step 1: Classification of each Stock Market Index



Step 2: Identification of the Nodes for a Network

- Once, each stock index has been classified per Step 1, the nodes for a network can be identified for a given day. This is achieved by combining the patterns of each stock index, then the corresponding combination symbolic pattern for each day is obtained.
- Assuming the study of three stock indexes, we can obtain a maximum of 64 (4^3) combination modes.
 - Where 4 is the the number of possible classifications for each index, and 3 is the number of different stock market indexes considered for the network.
- An example is further detailed for clarification.
 - Taking the daily combination patterns as the nodes of the network, the edges and weights of the network can be determined in time order. If the pattern on day t is S1S4S4 and that on day t+1 is S2S2S2, there is a directed edge from S1S4S4 to S2S2S2 with a weight of 1. If the conversion frequency from S1S4S4 to S2S2S2 is w, the weight of the directed edges from S1S4S4 to S2S2S2 is w. For example, if the current patterns of the S&P 500, NASDAQ, and DJIA are S1, S3, and , S4 respectively, the current price combination pattern is S1S3S4.
 - Suppose that the pattern transformation over a certain period of time is S1S4S4, S2S2S2, S1S1S1, S1S4S4, S3S1S4, S2S2S2, S1S1S1. Then, we can obtain the directed weighted network shown below.



Step 3: Creation of Sliding Windows (Network Size)

- The key to the sliding window selection problem is how to effectively keep the quality and quantity of original time series information while reducing the computational complexity to the most extent [34]. In the study conducted by Reference 1, a sliding window with a length of 30 days (about one month in daily life and half a quarter in the stock market) and a step of one day to the stock indexes time series. So we can obtain a pattern network every 30 days. The figure below shows the process of using the sliding window.



Step 4: Computing Network Topology Characteristic Variables for each Sliding Window

- There are four network topology measures calculated for each sliding window, see section 3.2 of Reference 1 and below for their definition per Reference 1.

- For a given set of 30 days, the four network measures are calculated and assigned to the last day of the sliding window (it is assumed the authors of Reference 1 assigned to the last day of the sliding window, this information was not specified)
 - For the experiments conducted in this project the network topology parameters are assigned two days past the end of the sliding window. This recommendation is per Professor Bahman Angoshtari to ensure there is not leaking of future information.

Network Topology Measures

1. Network Average Degree Centrality

- Measures the ratio of the actual number of connections between nodes to the maximum number of potential connections, the edge density of the network.



2. Average Network Strength



3. Network Average Shortest Path Length



4. Network Closeness Centrality



3.2 Machine Learning Algorithms

- The following Machine Learning algorithms are evaluated in the project: SGD, SVC, KNN, Random Forest.
- For a comprehensive description of the algorithms see Reference 8

4.0 Rational

This section provides a summary of the rational for utilizing Complex Network Analysis Theory and Machine Learning methods for forecasting price movements. The content is accredited to the authors of Reference 1. The inclusion here is just to provide a quick reference to the most important points for the rational behind the use of Network Topology to understand the comovement of stocks and market indexes. The reader can refer to Reference 1 for the complete summary.

- *Stock price volatility patterns classification and prediction is a very important problem in stock market research. The prediction of stock price trends is actually a classified prediction of stock price fluctuation patterns. Literature showed that forecasting stock price patterns is sufficient to generate profitable trades and enable the execution of profitable trading strategies. Therefore, many studies have focused on predicting stock price patterns rather than predicting the absolute prices of stocks.*
- *To date, most studies have focused on the volatility patterns of a single stock based on its own historical attributes and have paid less attention to the comovement of related stocks and information pertaining to the overall market. A few studies have used historical information regarding related stocks as the input variables for prediction and shown that the price fluctuations in a single stock are not isolated and are often influenced by the trends of multiple related stocks. Thus, how to extract the comovement of multiple stocks and apply this information to the prediction of the fluctuation patterns of a single stock is a problem worth studying.*
- *Complex network analysis provides a new explanation for stock market behavior from a systematic perspective. Using complex network theory to study stock prices not only allows us to analyze the relationship between different stocks, but also allows us to explore the macroaspects of the comovement characteristics of the market in different periods. Of all the network construction methods, the symbolic pattern network is favored by many scholars because it can more accurately reflect the degree of correlation and direction of the primitive elements in a complex system [10, 20, 23, 24].*
- *In a stock price volatility pattern network, each volatility pattern is regarded as a network node, and the relationship between patterns is regarded as a connection between nodes [10]. By analyzing the topological properties of the network, the characteristics of stock price fluctuations can be better understood.*
- **Most of the existing studies on stock price volatility pattern networks have focused on univariate time series. On this basis, we propose a new network construction method to build the volatility pattern networks of the three most important indexes in the US stock market, namely, the Standard & Poor's 500 Index (S&P 500), the NASDAQ Composite Index (NASDAQ), and the Dow Jones Industrial Average (DJIA). Firstly, the combination symbolic patterns for the three stock indexes are derived using a coarse-grained method. Then, the combination symbolic patterns are used as the nodes of the network, and the frequencies and directions of the conversion of the patterns are used as the weights and directions*

of the network connections. Finally, we construct directed and weighted networks for the US stock market. By analyzing the network topology properties, we can identify periods of sharp fluctuations in the market.*

5.0 Methodology For Predicting Stock Indexes Price Patterns

1. Load, Transform & Validate financial indexes datasets sourced from Bloomberg
2. Visualize Indexes' Price data
3. Create Financial Indexes derived parameters
4. Visualize Financial Indexes derived parameters
5. Create Stock Indexes' Classifications
6. Analyze and Visualize Stock Indexes Classifications Distributions
7. Create Network Topological Characteristics
8. Analysis of Network Topological Characteristics
 - Visualize each Network Topological measure in respect to the indexes
 - Validate correctness of each derived measured by comparing to the graphs provided by Reference 1, section 4.2
9. Next-Day Stock Pattern Predictions
 - Create Labels for ML Algorithms
 - Create Training & Test Sets for each dataset
 - Conduct exploratory analysis against each stock index on each dataset
 - Utilize several Machine Learning classification algorithms
 - Evaluate different sets of features and the impact of the networking derived measures on results
 - Conduct initial classification analysis via the Confusion Matrix and its underlying derived parameters, that is, Precision, Recall, and Accuracy.
 - Narrow selection of ML algorithms and conduct optimizaton
 - Run final analysis on optimized Machine Learning algorithms against validation and test sets
 - Summarize results in tables for all permutations of the experiments conducted
 - Analysis of results

6.0 Empirical Results and Analysis

6.0 Environment Setup

- All analysis is conducted in Python, the following libraries and versions are required:
 - Python version 3.5 or greater
 - sklearn version 0.20 or greater
 - tensorflow version 20 or greater
 - networkX version 2.4 or greater
 - Other libraries: numpy, pandas, matplotlib
- The Data for all indexes should be located in the same directory where this Jupyter Notebook is executed
- The first set of indexes (to re-create the white paper dataset) is expected to be: **IndexesDataForProject_Set_1.csv**
- The second set of indexes to validate against a complete set of indexes and time periods is: **IndexesDataForProject_Set_2.csv**
- The csv file format header column for the first set of indexes is: **Date, S&P_500, Nasdaq, DJI**
- The csv file format header column for the second set of indexes is: **Date, MXUS, MSDUUK, MSDUJN**
- The csv file data format is: Date in month/day/year-last-2-digits follow by daily closing prices
- All price data was sourced from Bloomberg

```
In [1]: # Python ≥3.5 is required
import sys
assert sys.version_info >= (3, 5)

# Scikit-Learn ≥0.20 is required
import sklearn
assert sklearn.__version__ >= "0.20"

# Common imports
import numpy as np
import os

try:
    # %tensorflow_version only exists in Colab.
    %tensorflow_version 2.x
except Exception:
    pass

# TensorFlow ≥2.0 is required
import tensorflow as tf
assert tf.__version__ >= "2.0"

# networkX ≥ 2.4 is required
import networkx as nx
assert nx.__version__ >= "2.4"

# to make this notebook's output stable across runs
np.random.seed(42)

# To plot pretty figures
%matplotlib inline
import matplotlib as mpl
import matplotlib.pyplot as plt
mpl.rc('axes', labelsize=14)
mpl.rc('xtick', labelsize=12)
mpl.rc('ytick', labelsize=12)

# Ignore useless warnings (see SciPy issue #5998)
import warnings
warnings.filterwarnings(action="ignore", message="^internal gelsd")

from sklearn.metrics import accuracy_score
```

6.1 Data Processing

6.1.1 Load, Transform & Validate Indexes Data

Inputs for Analysis

```
In [2]: import pandas as pd

index_data_file_set1 = "IndexesDataForProject_Set_1.csv"
index_data_file_set2 = "IndexesDataForProject_Set_2.csv"

indexes_set_1 = [ "Nasdaq", "S&P_500", "DJI"]
indexes_set_2 = [ "MXUS", "MSDUUK", "MSDUJN"]

indexes_data_set1 = pd.read_csv(index_data_file_set1, parse_dates=True).dropna()
indexes_data_set2 = pd.read_csv(index_data_file_set2, parse_dates=True).dropna()
```

```
In [3]: indexes_data_set1.info()

<class 'pandas.core.frame.DataFrame'>
Int64Index: 5124 entries, 0 to 5123
Data columns (total 4 columns):
Date      5124 non-null object
S&P_500   5124 non-null float64
Nasdaq    5124 non-null float64
DJI       5124 non-null float64
dtypes: float64(3), object(1)
memory usage: 200.2+ KB
```

```
In [4]: indexes_data_set2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3952 entries, 0 to 3951
Data columns (total 4 columns):
Date      3952 non-null object
MXUS     3952 non-null float64
MSDUUK    3952 non-null float64
MSDUJN    3952 non-null float64
dtypes: float64(3), object(1)
memory usage: 154.4+ KB
```

```
In [5]: # convert date column from object type to Date format for indexing
```

```
def convertDatesAndFormat(df, datasetName):
    df[ "Date" ] = pd.to_datetime( df[ "Date" ], errors="coerce", infer_datetime_format=True)
    df = df.dropna()
    print(datasetName)
    print(df.info())
    return df
```

```
In [6]: indexes_data_set1 = convertDatesAndFormat(df = indexes_data_set1, datasetName = "Dataset 1: \n")
```

```
Dataset 1:
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 5124 entries, 0 to 5123
Data columns (total 4 columns):
Date      5124 non-null datetime64[ns]
S&P_500   5124 non-null float64
Nasdaq    5124 non-null float64
DJI       5124 non-null float64
dtypes: datetime64[ns](1), float64(3)
memory usage: 200.2 KB
None
```

```
In [7]: indexes_data_set2 = convertDatesAndFormat(df = indexes_data_set2, datasetName = "Dataset 2: \n")
```

Dataset 2:

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3952 entries, 0 to 3951
Data columns (total 4 columns):
Date      3952 non-null datetime64[ns]
MXUS      3952 non-null float64
MSDUUK    3952 non-null float64
MSDUJN    3952 non-null float64
dtypes: datetime64[ns](1), float64(3)
memory usage: 154.4 KB
None
```

6.1.2 Visualize Indexes

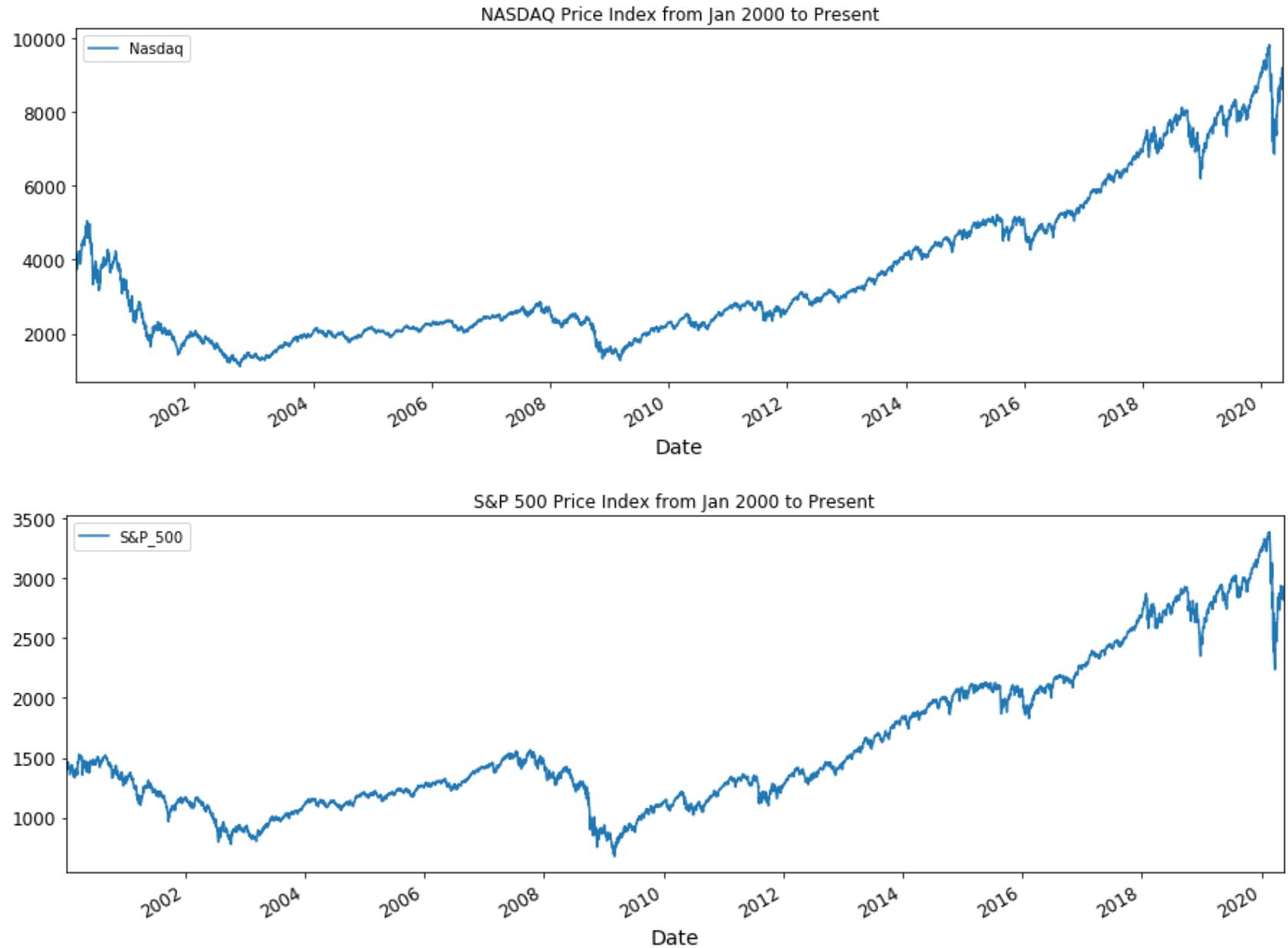
Dataset 1

```
In [8]: indexes_data_set1.plot( figsize=(15,5), x="Date", y="Nasdaq",
                           title="NASDAQ Price Index from Jan 2000 to Present")

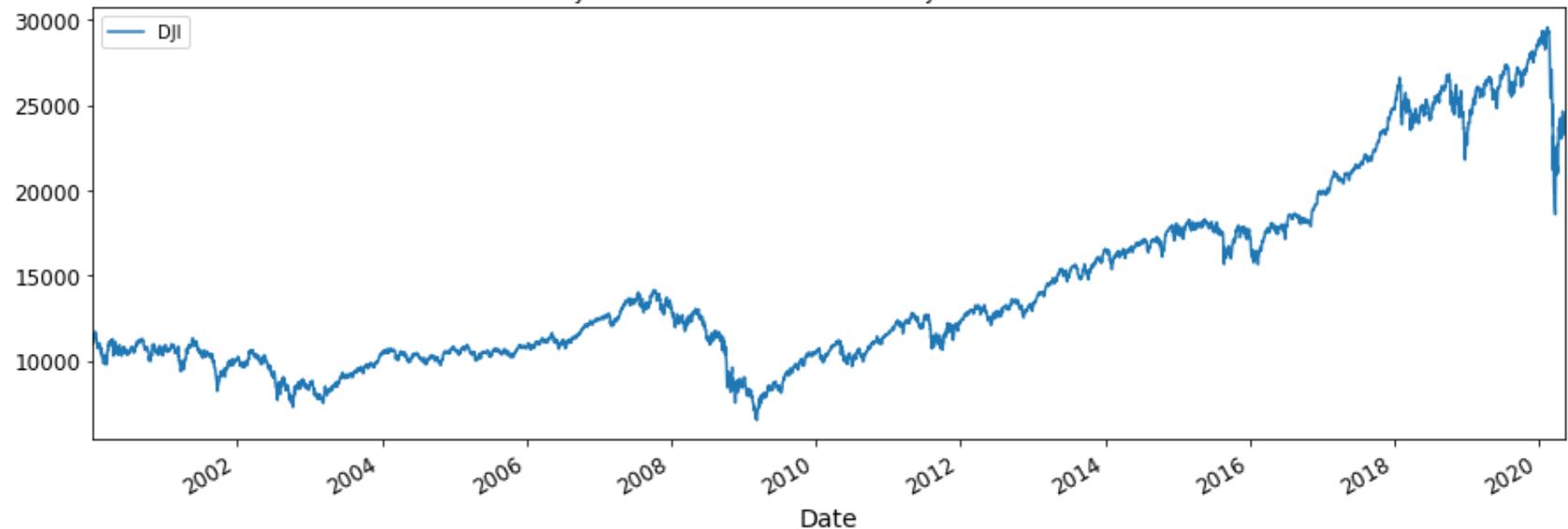
indexes_data_set1.plot(figsize=(15,5), x="Date", y="S&P_500",
                      title="S&P 500 Price Index from Jan 2000 to Present")

indexes_data_set1.plot( figsize=(15,5), x="Date", y="DJI",
                           title="Dow Jones Industrial Price Index from Jan 2000 to Present")
```

Out[8]: <matplotlib.axes._subplots.AxesSubplot at 0x7faa68beb4d0>



Dow Jones Industrial Price Index from Jan 2000 to Present



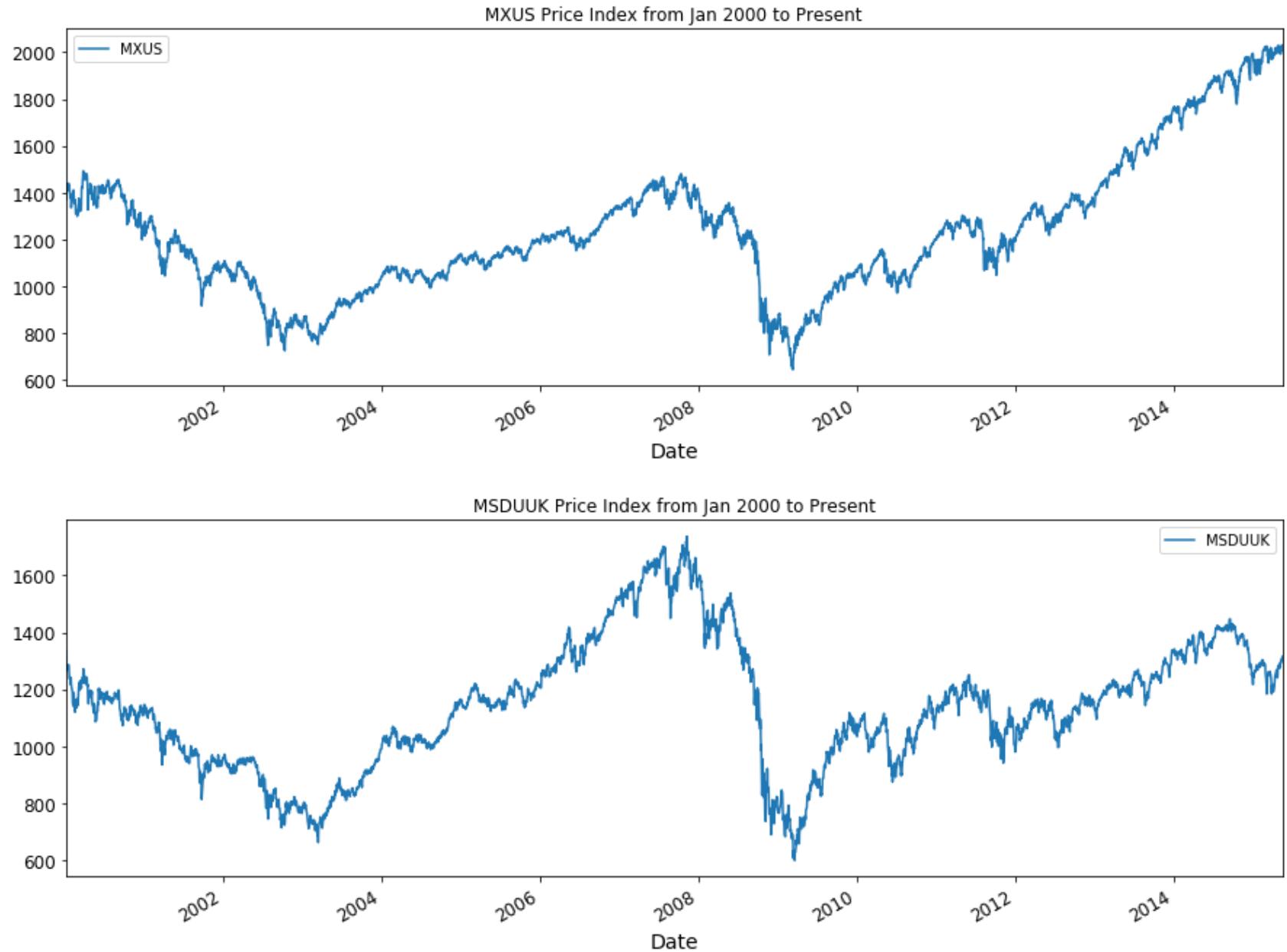
Dataset 2

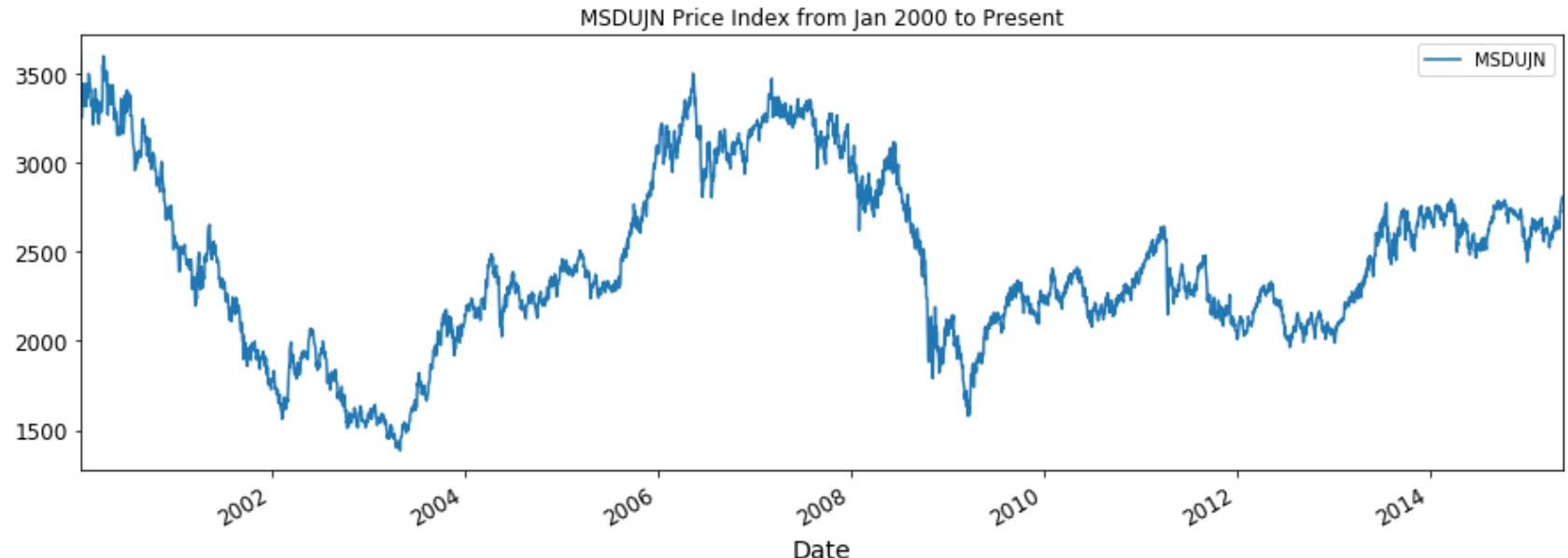
```
In [9]: indexes_data_set2.plot( figsize=(15,5), x="Date", y="MXUS",
                           title="MXUS Price Index from Jan 2000 to Present")

indexes_data_set2.plot(figsize=(15,5), x="Date", y="MSDUUK",
                      title="MSDUUK Price Index from Jan 2000 to Present")

indexes_data_set2.plot( figsize=(15,5), x="Date", y="MSDUJN",
                           title="MSDUJN Price Index from Jan 2000 to Present")
```

Out[9]: <matplotlib.axes._subplots.AxesSubplot at 0x7faa4897a150>





6.1.3 Create Financial Indexes Derived Parameters

```
In [10]: indexes_set_1 = [ "Nasdaq", "S&P_500", "DJI"]
indexes_set_2 = [ "MXUS", "MSDUUK", "MSDUJN"]
```

```
In [11]: # In order to align with the notation define in the formulas, the derived financial parameters will be named
# accordingly, i.e.
#
# r_index_name = daily log returns
# R_index_name = 5-day log returns
# V_index_name = 5-day volatility (based on daily log returns)
# V_Ave_index_name = 5-day volatility average
# V_Ave_All_Indexes = (V_index_name_1 ... V_index_name_N)/N

def createFinancialDerivedParameters(indexes_names, df):

    num_indexes = len(indexes_names)
    for i in range(num_indexes) :

        # *** Log Daily Returns for Index
        df['r_' + indexes_names[i]] = np.log(df[indexes_names[i]] / df[indexes_names[i]].shift(1))

        # *** 5-day Log Returns for each Index
        df['R_' + indexes_names[i]] = np.log(df[indexes_names[i]] / df[indexes_names[i]].shift(5))

        # *** 5-day Volatility of Log Returns for each Index
        df['V_' + indexes_names[i]] = df['r_' + indexes_names[i] ].rolling(window=5).std() * np.sqrt
(5)

        # *** 5-day Volatility Average of V for each Index
        df['V_Ave_' + indexes_names[i]] = df['V_' + indexes_names[i] ].rolling(window=5).mean()

    # Calculate Volatility Average for all Indexes

    v_ave_all_indexes = np.zeros( df['V_' + indexes_names[i]].shape, dtype="float64" )
    for j in range(num_indexes) :
        v_ave_all_indexes += df['V_' + indexes_names[j]].to_numpy()
        #v_ave_all_indexes += df['V_Ave_' + indexes_names[j]].to_numpy()

    df['V_Ave_All_Indexes'] = v_ave_all_indexes/num_indexes

    df.dropna(inplace = True)
    return df

indexes_data_set1 = createFinancialDerivedParameters( indexes_names = indexes_set_1, df = indexes_da
ta_set1)
```

```
indexes_data_set2 = createFinancialDerivedParameters( indexes_names = indexes_set_2, df = indexes_da  
ta_set2)
```

```
In [12]: indexes_data_set1[ [ "Date", "r_DJI", "R_DJI", "V_DJI", "V_Ave_DJI", "V_Ave_All_Indexes" ] ].head()
```

Out[12]:

	Date	r_DJI	R_DJI	V_DJI	V_Ave_DJI	V_Ave_All_Indexes
9	2000-01-14	0.012061	0.017244	0.013779	0.026648	0.037254
10	2000-01-18	-0.013937	-0.000992	0.021992	0.021544	0.036147
11	2000-01-19	-0.006192	-0.001889	0.022269	0.021237	0.027987
12	2000-01-20	-0.012090	-0.017449	0.024255	0.021249	0.022507
13	2000-01-21	-0.008811	-0.028969	0.023292	0.021117	0.019437

```
In [13]: indexes_data_set1[ [ "Date", "V_Nasdaq", "V_S&P_500", "V_DJI", "V_Ave_All_Indexes" ] ].head()
```

Out[13]:

	Date	V_Nasdaq	V_S&P_500	V_DJI	V_Ave_All_Indexes
9	2000-01-14	0.072440	0.025542	0.013779	0.037254
10	2000-01-18	0.061509	0.024941	0.021992	0.036147
11	2000-01-19	0.042427	0.019264	0.022269	0.027987
12	2000-01-20	0.022656	0.020610	0.024255	0.022507
13	2000-01-21	0.018719	0.016299	0.023292	0.019437

```
In [14]: indexes_data_set2[ [ "Date", "r_MSDUUK", "R_MSDUUK", "V_MSDUUK", "V_Ave_MSDUUK" ] ].head()
```

Out[14]:

	Date	r_MSDUUK	R_MSDUUK	V_MSDUUK	V_Ave_MSDUUK
9	2000-01-14	0.010235	0.016236	0.018065	0.022793
10	2000-01-17	-0.000630	0.002539	0.013329	0.018163
11	2000-01-18	-0.018486	-0.009800	0.023134	0.017648
12	2000-01-19	-0.006837	-0.016347	0.023468	0.018770
13	2000-01-20	-0.012684	-0.028403	0.024829	0.020565

6.1.4 Visualize Indexes Derived Parameters

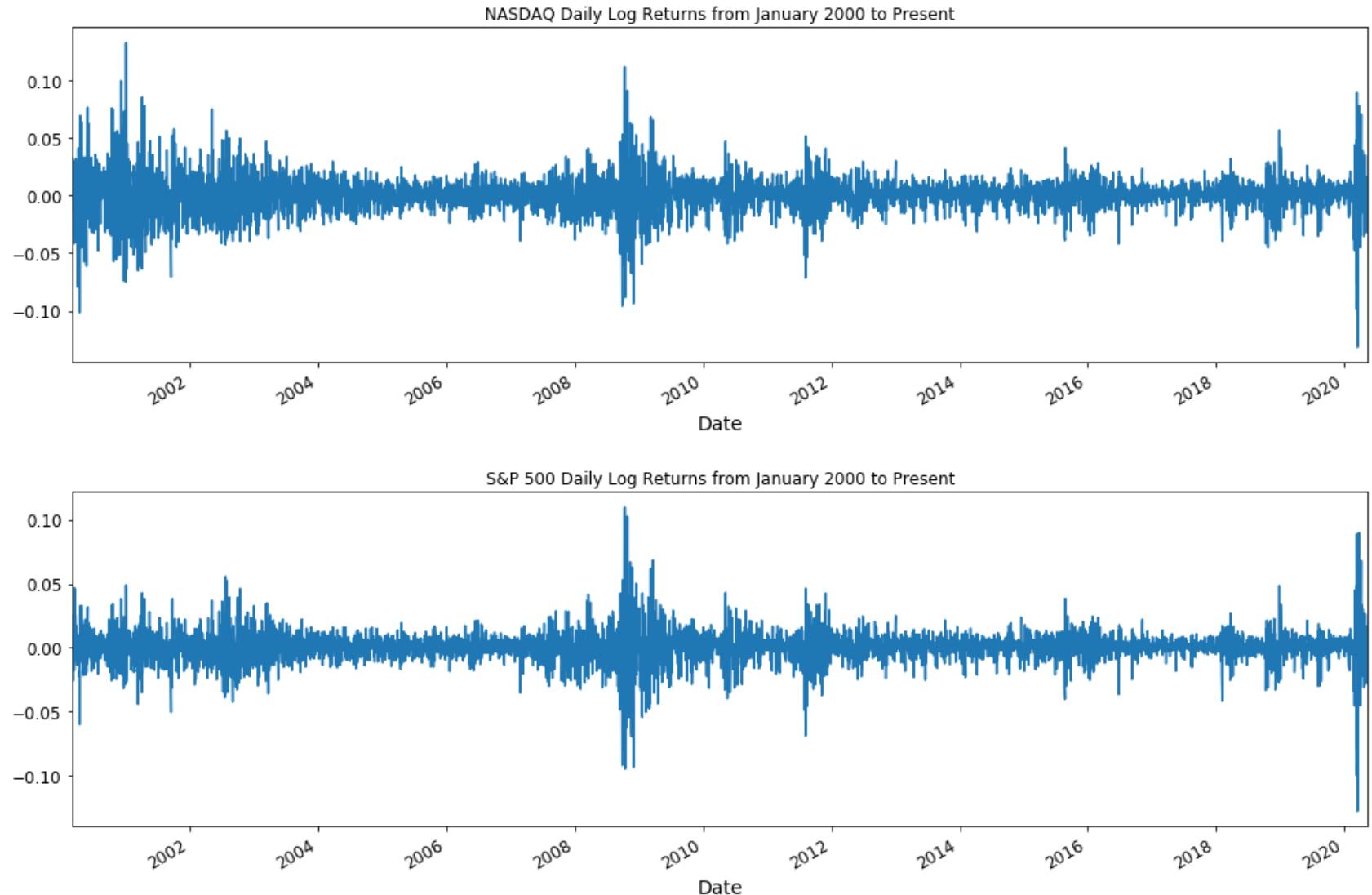
Indexes Daily Log Returns

```
In [88]: indexes_data_set1.plot(figsize=(17,5), x="Date", y="r_Nasdaq", legend=False,
                           title="NASDAQ Daily Log Returns from January 2000 to Present")

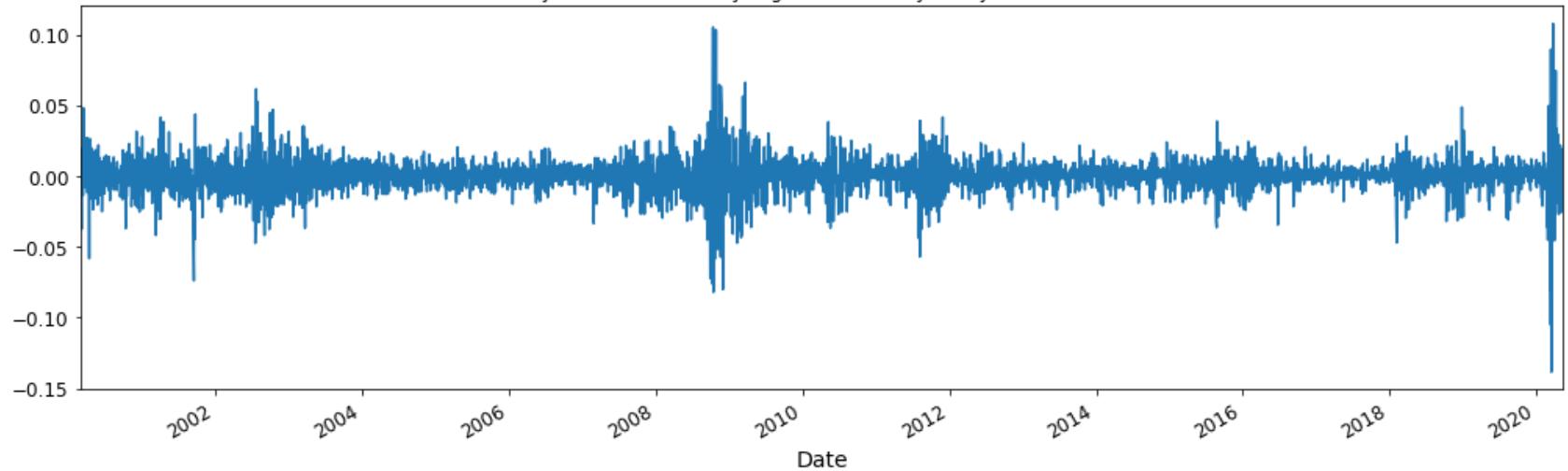
indexes_data_set1.plot(figsize=(17,5), x="Date", y="r_S&P_500", legend=False,
                       title="S&P 500 Daily Log Returns from January 2000 to Present")

indexes_data_set1.plot(figsize=(17,5), x="Date", y="r_DJI", legend=False,
                       title="Dow Jones Industrial Daily Log Returns from January 2000 to Present")
```

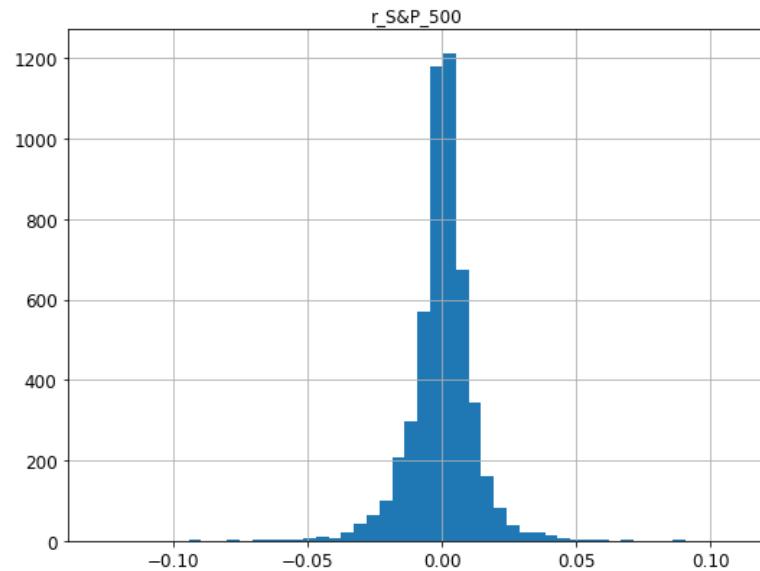
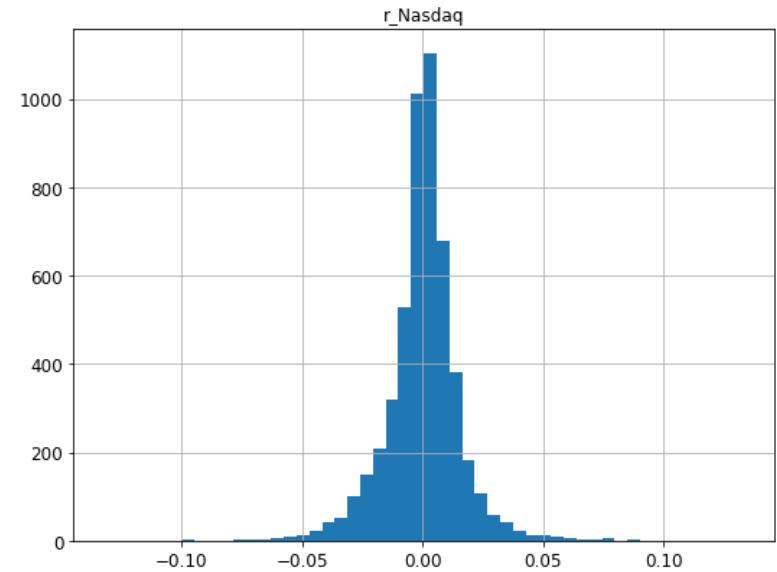
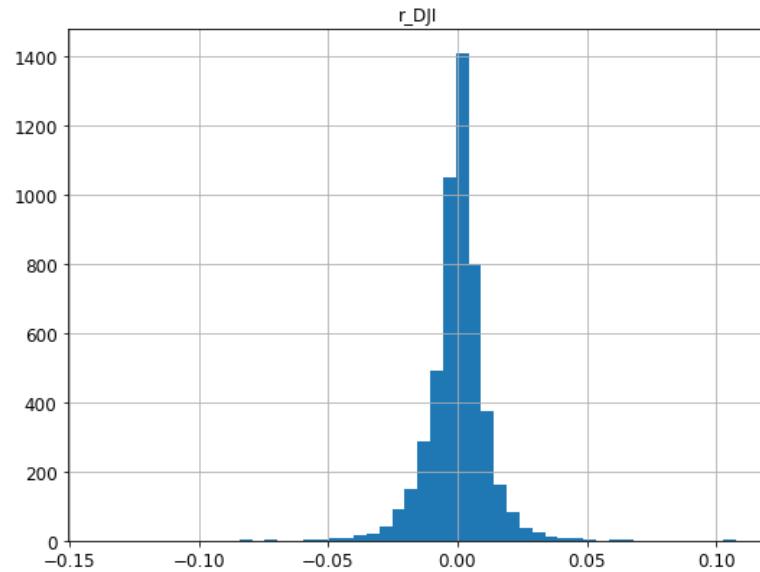
Out[88]: <matplotlib.axes._subplots.AxesSubplot at 0x7faa8d159ad0>



Dow Jones Industrial Daily Log Returns from January 2000 to Present



```
In [16]: indexes_data_set1[ ["Date", "r_Nasdaq", "r_S&P_500", "r_DJI" ] ].hist(bins=50, figsize=(20,15))  
plt.show()
```



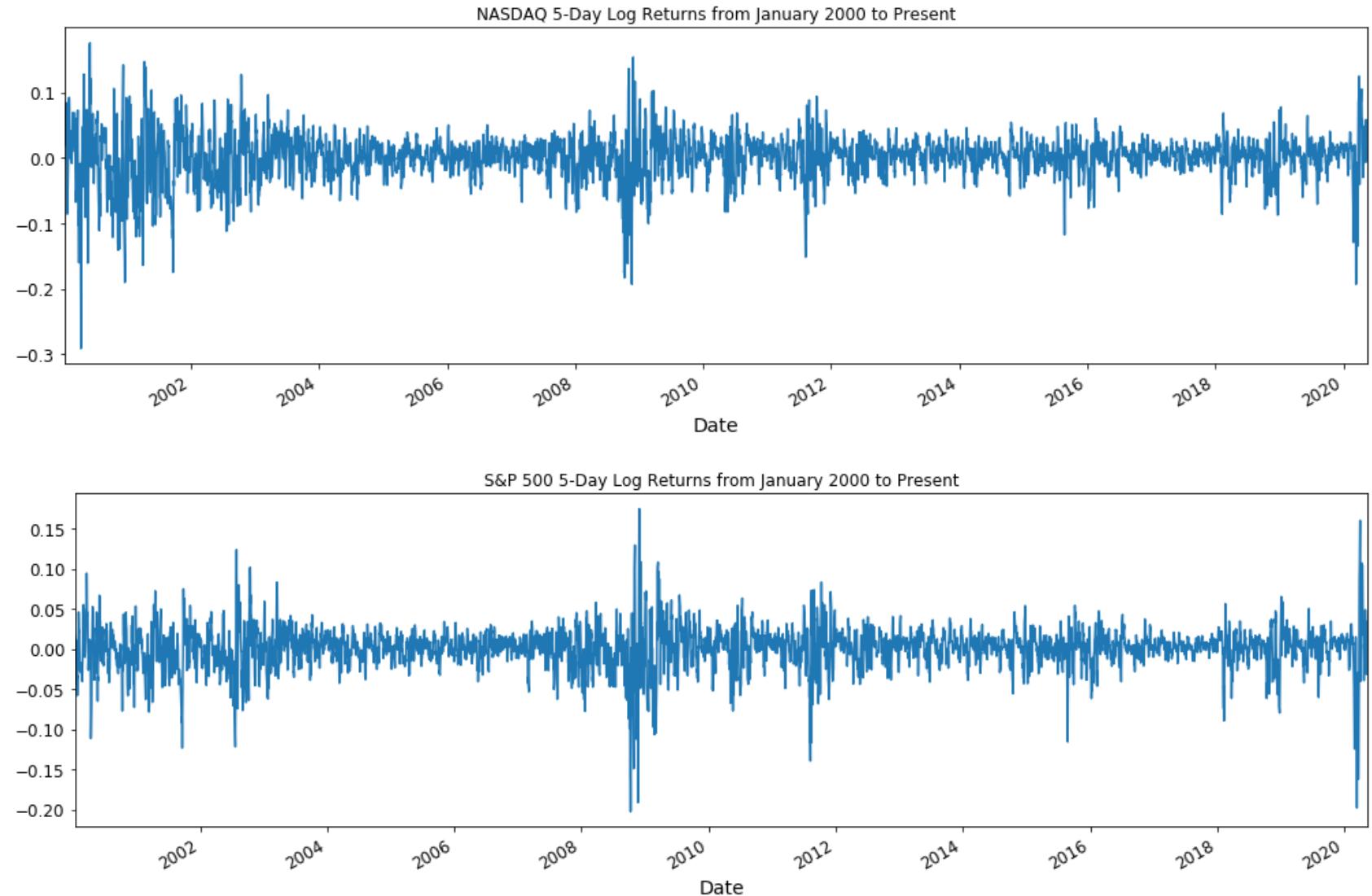
Indexes 5-day Log Returns

```
In [17]: indexes_data_set1.plot(figsize=(17,5), x="Date", y="R_Nasdaq", legend=False,
                           title="NASDAQ 5-Day Log Returns from January 2000 to Present")

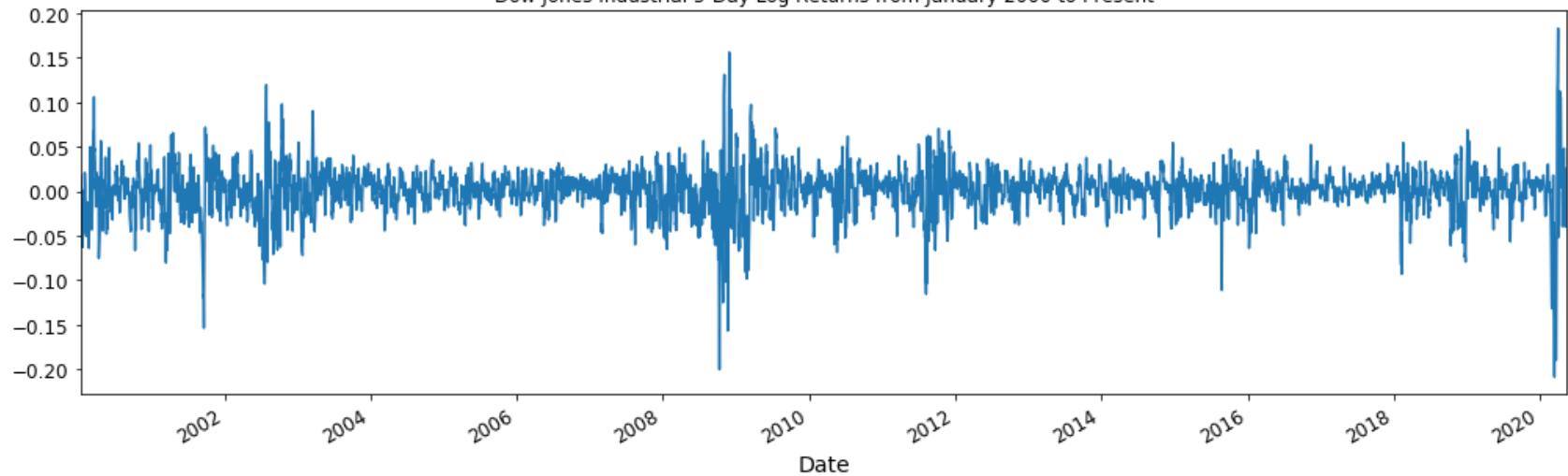
indexes_data_set1.plot(figsize=(17,5), x="Date", y="R_S&P_500", legend=False,
                       title="S&P 500 5-Day Log Returns from January 2000 to Present")

indexes_data_set1.plot(figsize=(17,5), x="Date", y="R_DJI", legend=False,
                       title="Dow Jones Industrial 5-Day Log Returns from January 2000 to Present")
```

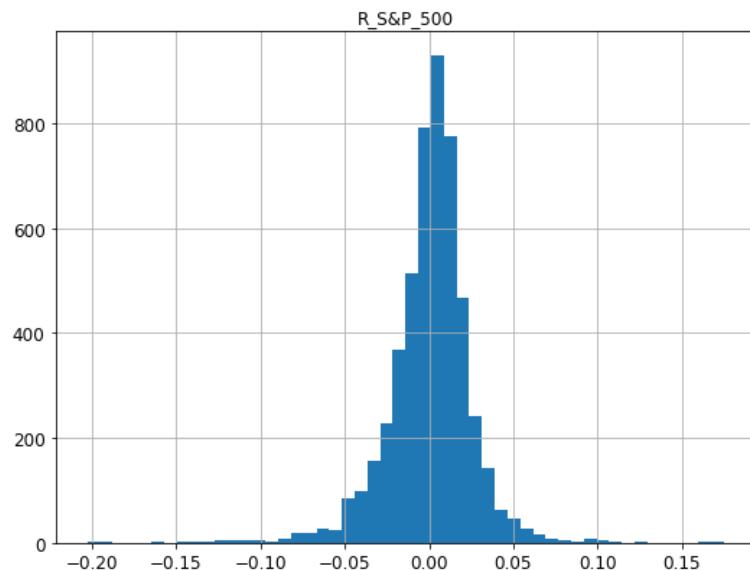
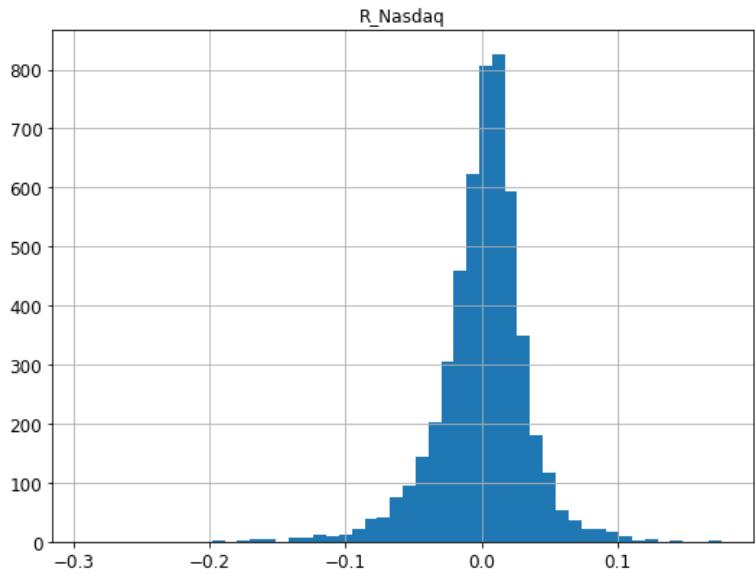
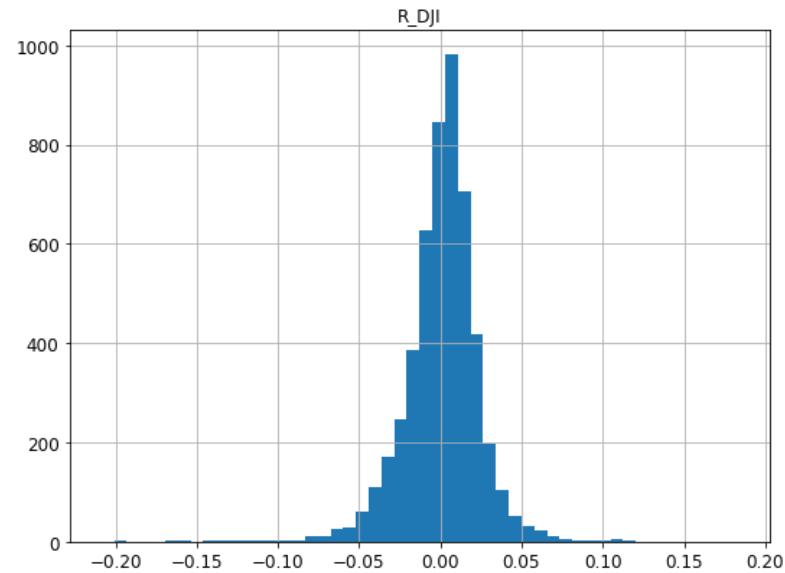
Out[17]: <matplotlib.axes._subplots.AxesSubplot at 0x7faa584256d0>



Dow Jones Industrial 5-Day Log Returns from January 2000 to Present



```
In [18]: indexes_data_set1[ ["Date", "R_Nasdaq", "R_S&P_500", "R_DJI" ] ].hist(bins=50, figsize=(20,15))  
plt.show()
```



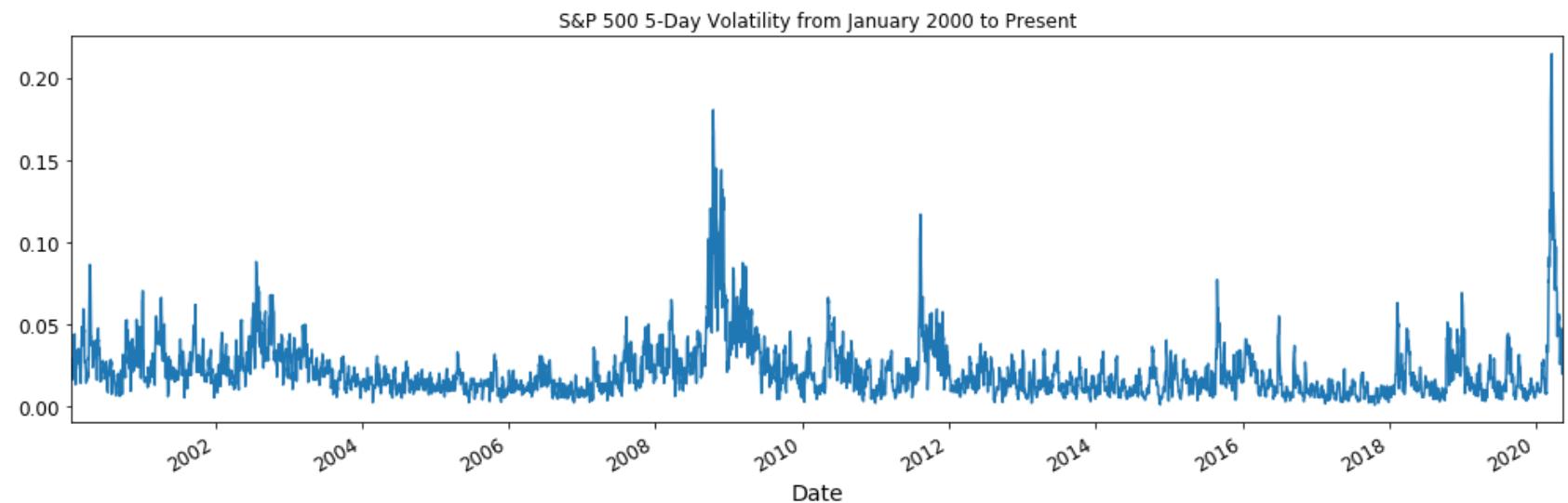
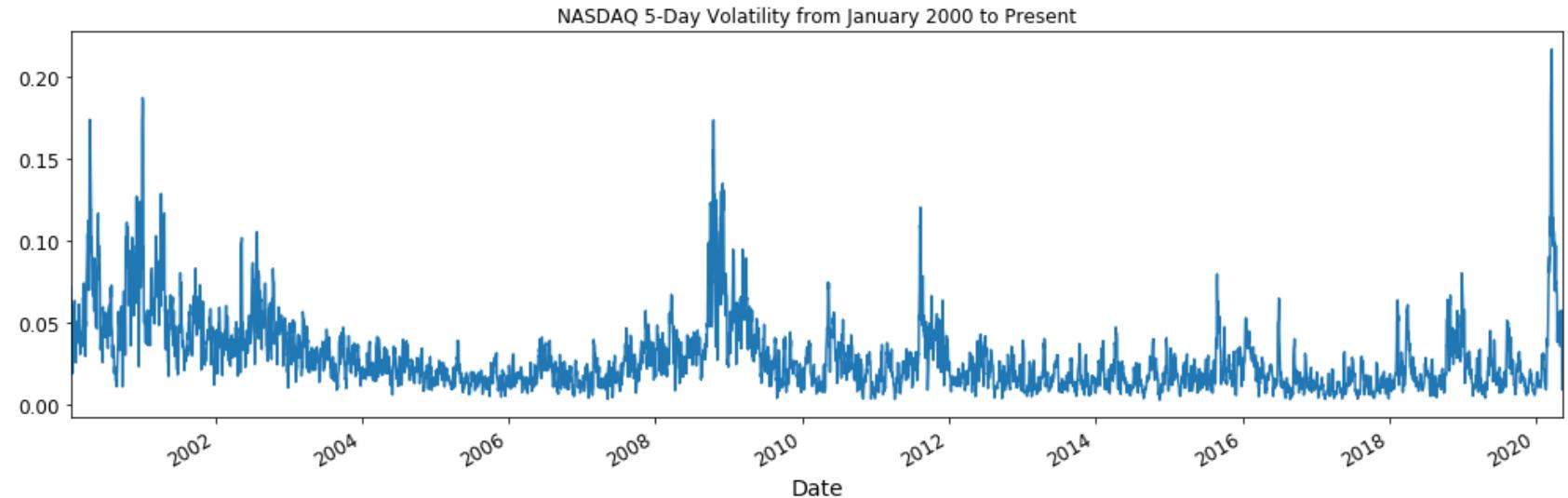
Indexes 5-day Volatility of Log Returns

```
In [19]: indexes_data_set1.plot(figsize=(17,5), x="Date", y="V_Nasdaq", legend=False,
                           title="NASDAQ 5-Day Volatility from January 2000 to Present")

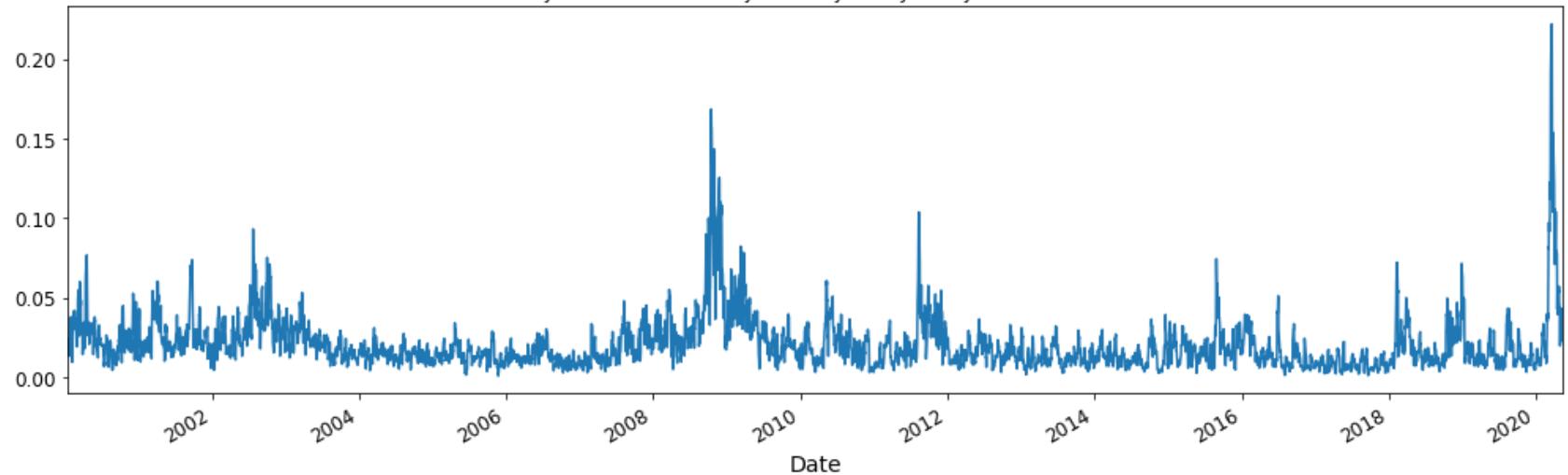
indexes_data_set1.plot(figsize=(17,5), x="Date", y="V_S&P_500", legend=False,
                       title="S&P 500 5-Day Volatility from January 2000 to Present")

indexes_data_set1.plot(figsize=(17,5), x="Date", y="V_DJI", legend=False,
                       title="Dow Jones Industrial 5-Day Volatility from January 2000 to Present")
```

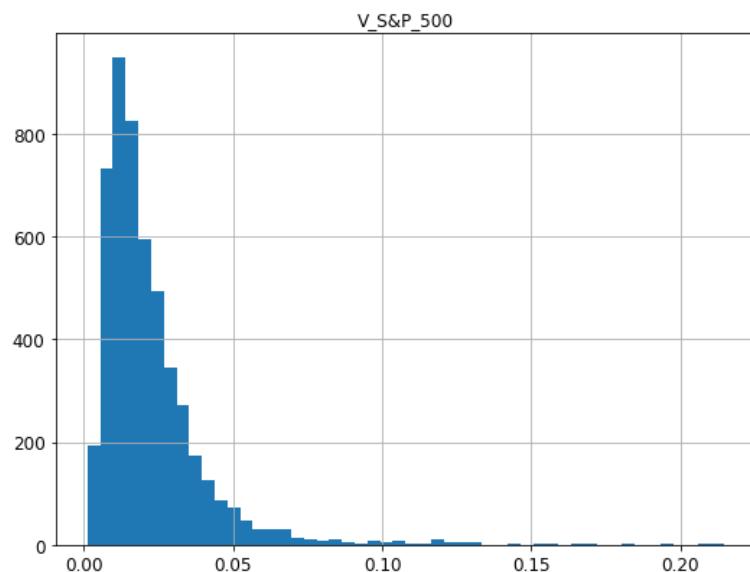
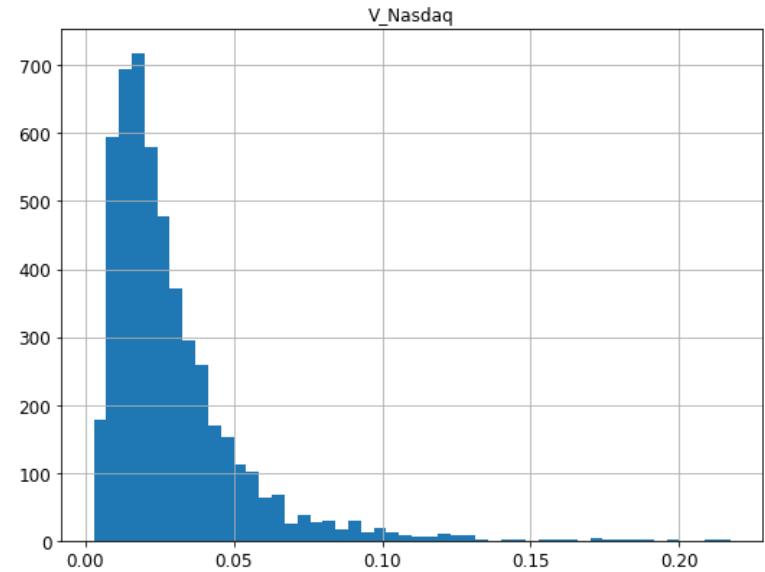
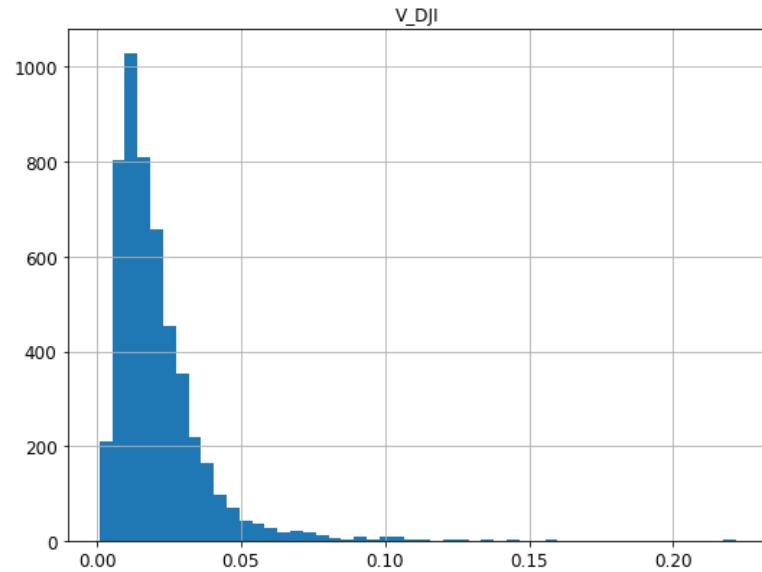
Out[19]: <matplotlib.axes._subplots.AxesSubplot at 0x7faa99fe17d0>



Dow Jones Industrial 5-Day Volatility from January 2000 to Present



```
In [20]: indexes_data_set1[ ["Date", "V_Nasdaq", "V_S&P_500", "V_DJI" ] ].hist(bins=50, figsize=(20,15))  
plt.show()
```



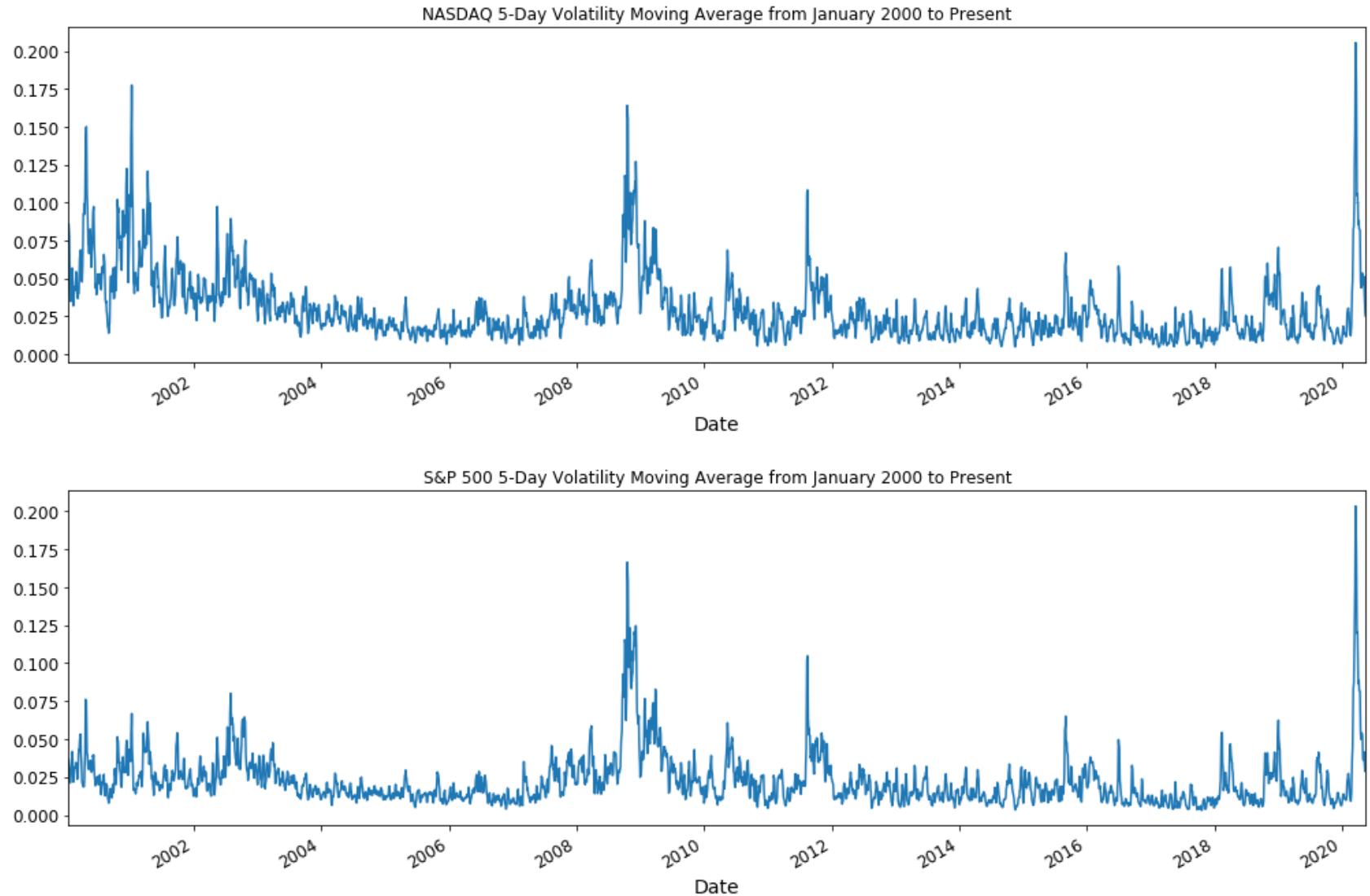
Indexes 5-day Moving Average for Volatility

```
In [21]: indexes_data_set1.plot(figsize=(17,5), x="Date", y="V_Ave_Nasdaq", legend=False,
                           title="NASDAQ 5-Day Volatility Moving Average from January 2000 to Present")

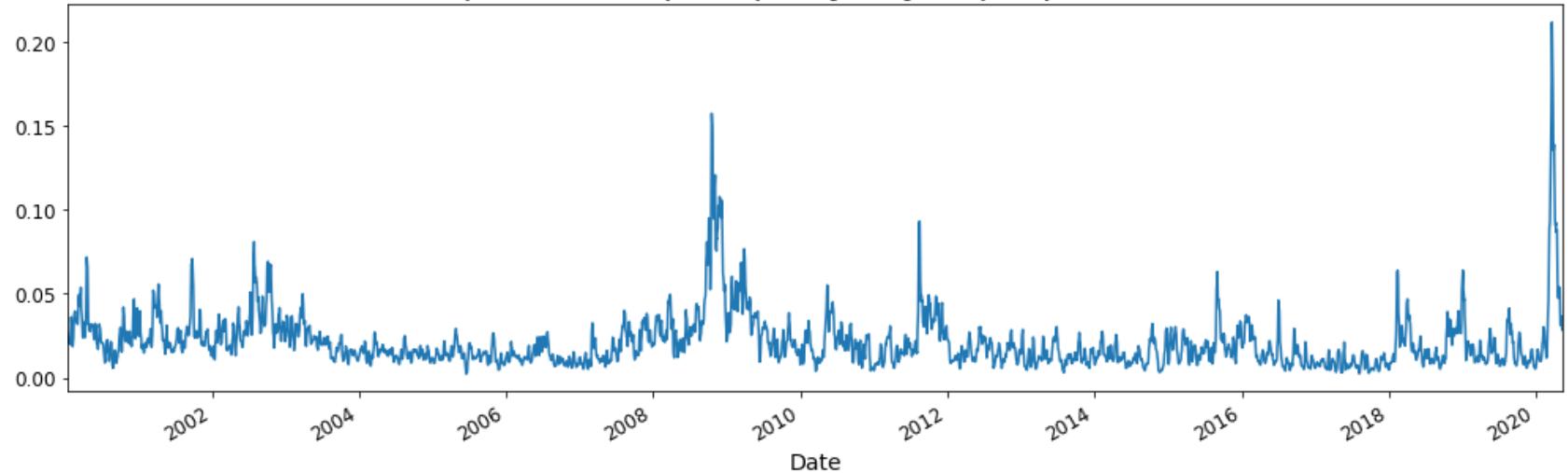
indexes_data_set1.plot(figsize=(17,5), x="Date", y="V_Ave_S&P_500", legend=False,
                           title="S&P 500 5-Day Volatility Moving Average from January 2000 to Present")

indexes_data_set1.plot(figsize=(17,5), x="Date", y="V_Ave_DJI", legend=False,
                           title="Dow Jones Industrial 5-Day Volatility Moving Average from January 2000 to P
resent")
```

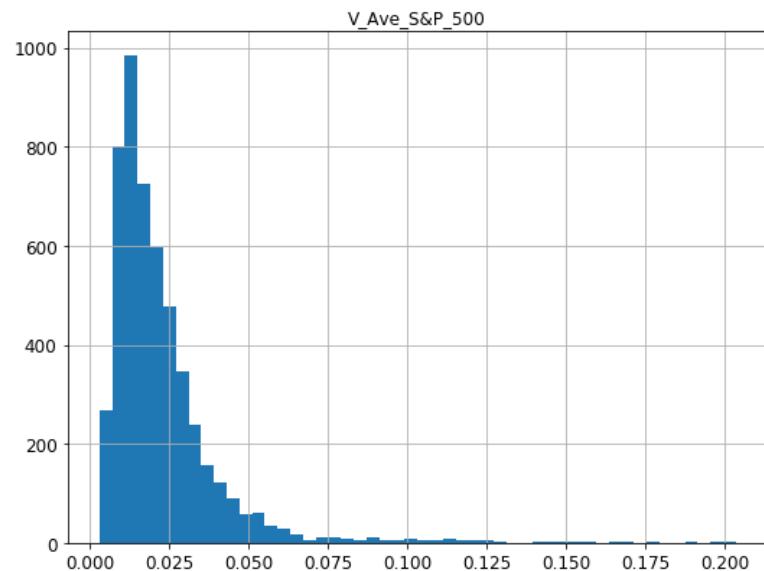
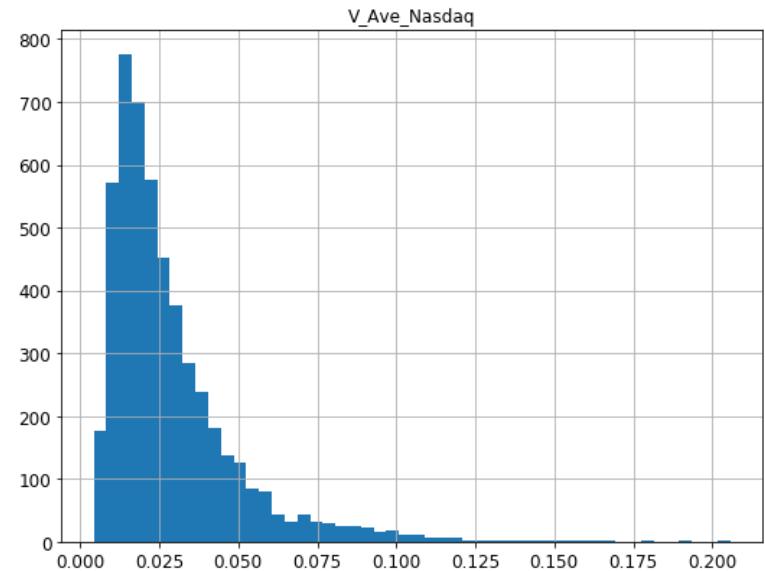
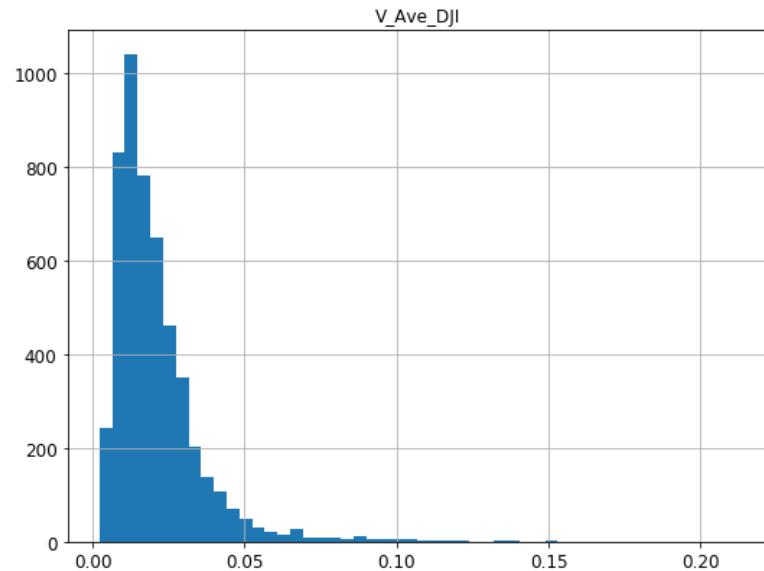
Out[21]: <matplotlib.axes._subplots.AxesSubplot at 0x7faa68bb7ed0>



Dow Jones Industrial 5-Day Volatility Moving Average from January 2000 to Present



```
In [22]: indexes_data_set1[ ["Date", "V_Ave_Nasdaq", "V_Ave_S&P_500", "V_Ave_DJI" ] ].hist(bins=50, figsize=(20,15))
plt.show()
```



6.1.5 Create Stock Indexes' Classifications

In [23]: # *** Classified the Stock Indexes, according to the rules in equation 13 of the white paper

*** Classifications for each index will be in the format:

*** f_IndexName

```
def getStockIndexClassForDay(R_day, V_day, V_Ave_day):
```

```
    if R_day >= 0 and V_day >= V_Ave_day :  
        # Sharp Rise Day  
        return "S1"  
    elif R_day >= 0 and V_day < V_Ave_day :  
        # Stable Rise Day  
        return "S2"  
    elif R_day < 0 and V_day < V_Ave_day :  
        # Stable Decline  
        return "S3"  
    elif R_day < 0 and V_day >= V_Ave_day :  
        # Sharp Decline  
        return "S4"  
    else :  
        print("Error, this should not happen")  
        return "Invalid"
```

```
def getStockIndexClass(IndexName, df):
```

```
    stock_index_Name = IndexName  
    R_stock_index_col_name = "R_" + stock_index_Name  
    V_stock_index_col_name = "V_" + stock_index_Name  
    V_Ave_stock_index_col_name = "V_Ave_" + stock_index_Name  
    V_Ave_All_Indexes_col_name = "V_Ave_All_Indexes"
```

```
    num_rows = df.shape[0]  
    stock_class = np.empty( [df.shape[0], 1], dtype='<U2' )
```

```
    R      = df[R_stock_index_col_name].to_numpy()  
    V      = df[V_stock_index_col_name].to_numpy()  
    V_Ave = df[V_Ave_stock_index_col_name].to_numpy()  
    V_Ave_AllIndexes = df[V_Ave_All_Indexes_col_name].to_numpy()
```

```
    for current_day in range(num_rows):  
        stock_class[current_day] = getStockIndexClassForDay( R_day = R[current_day],  
                                                       V_day = V[current_day],  
                                                       #V_Ave_day = V_Ave[current_day],  
                                                       V_Ave_day = V_Ave_AllIndexes[current_da
```

```

y]

)

return stock_class

# *** Classify each stock Index

indexes_data_set1["f_Nasdaq"] = getStockIndexClass(IndexName = "Nasdaq", df = indexes_data_set1)
indexes_data_set1["f_S&P_500"] = getStockIndexClass(IndexName = "S&P_500", df = indexes_data_set1)
indexes_data_set1["f_DJI"] = getStockIndexClass(IndexName = "DJI", df = indexes_data_set1)

indexes_data_set2["f_MXUS"] = getStockIndexClass(IndexName = "MXUS", df = indexes_data_set2)
indexes_data_set2["f_MSDUUK"] = getStockIndexClass(IndexName = "MSDUUK", df = indexes_data_set2)
indexes_data_set2["f_MSDUJN"] = getStockIndexClass(IndexName = "MSDUJN", df = indexes_data_set2)

```

In [24]:

```

# *** Create Combination Symbolic Patter for each Day
#
# That is: f_Index_1 + f_Index_2 + f_Index_N for a day
# This combine symbolic information will constitute a node in the Network Topology that will be created next

indexes_data_set1["Node"] = indexes_data_set1["f_Nasdaq"] + indexes_data_set1["f_S&P_500"] + \
                           indexes_data_set1["f_DJI"]

indexes_data_set2["Node"] = indexes_data_set2["f_MXUS"] + indexes_data_set2["f_MSDUUK"] + \
                           indexes_data_set2["f_MSDUJN"]

```

In [25]:

```
indexes_data_set1[ ["Date", "R_DJI", "V_DJI", "V_Ave_All_Indexes", "f_DJI", "f_Nasdaq", "f_S&P_500", "Node"]].head()
```

Out[25]:

	Date	R_DJI	V_DJI	V_Ave_All_Indexes	f_DJI	f_Nasdaq	f_S&P_500	Node
9	2000-01-14	0.017244	0.013779	0.037254	S2	S1	S2	S1S2S2
10	2000-01-18	-0.000992	0.021992	0.036147	S3	S1	S3	S1S3S3
11	2000-01-19	-0.001889	0.022269	0.027987	S3	S1	S2	S1S2S3
12	2000-01-20	-0.017449	0.024255	0.022507	S4	S1	S2	S1S2S4
13	2000-01-21	-0.028969	0.023292	0.019437	S4	S2	S3	S2S3S4

```
In [26]: indexes_data_set1[ ["Date", "f_Nasdaq", "f_S&P_500", "f_DJI", "Node"]].tail()
```

Out[26]:

	Date	f_Nasdaq	f_S&P_500	f_DJI	Node
5119	2020-05-08	S2	S1	S1	S2S1S1
5120	2020-05-11	S2	S1	S1	S2S1S1
5121	2020-05-12	S2	S1	S4	S2S1S4
5122	2020-05-13	S2	S3	S4	S2S3S4
5123	2020-05-14	S3	S3	S4	S3S3S4

```
In [27]: indexes_data_set2[ ["Date", "f_MXUS", "f_MSDUUK", "f_MSDUJN", "Node"]].head()
```

Out[27]:

	Date	f_MXUS	f_MSDUUK	f_MSDUJN	Node
9	2000-01-14	S2	S2	S1	S2S2S1
10	2000-01-17	S2	S2	S1	S2S2S1
11	2000-01-18	S2	S3	S1	S2S3S1
12	2000-01-19	S2	S3	S4	S2S3S4
13	2000-01-20	S3	S3	S4	S3S3S4

```
In [28]: indexes_data_set2[ ["Date", "f_MXUS", "f_MSDUUK", "f_MSDUJN", "Node"]].tail()
```

Out[28]:

	Date	f_MXUS	f_MSDUUK	f_MSDUJN	Node
3947	2015-05-08	S1	S2	S1	S1S2S1
3948	2015-05-11	S4	S2	S2	S4S2S2
3949	2015-05-12	S1	S2	S1	S1S2S1
3950	2015-05-13	S1	S2	S1	S1S2S1
3951	2015-05-14	S1	S2	S2	S1S2S2

```
In [29]: print("Number of Unique Nodes in dataset-1 = ", len(indexes_data_set1["Node"].unique()) )
print("Number of Unique Nodes in dataset-2 = ", len(indexes_data_set2["Node"].unique()) )
```

```
Number of Unique Nodes in dataset-1 =  48
Number of Unique Nodes in dataset-2 =  48
```

6.1.6 Analysis & Visualization of Stock Indexes Classifications' Distributions

Dataset 1

```
In [30]: fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(18,4))
fig.suptitle('Histograms of State Distributions for All Indexes', fontsize=18, y=1.07)

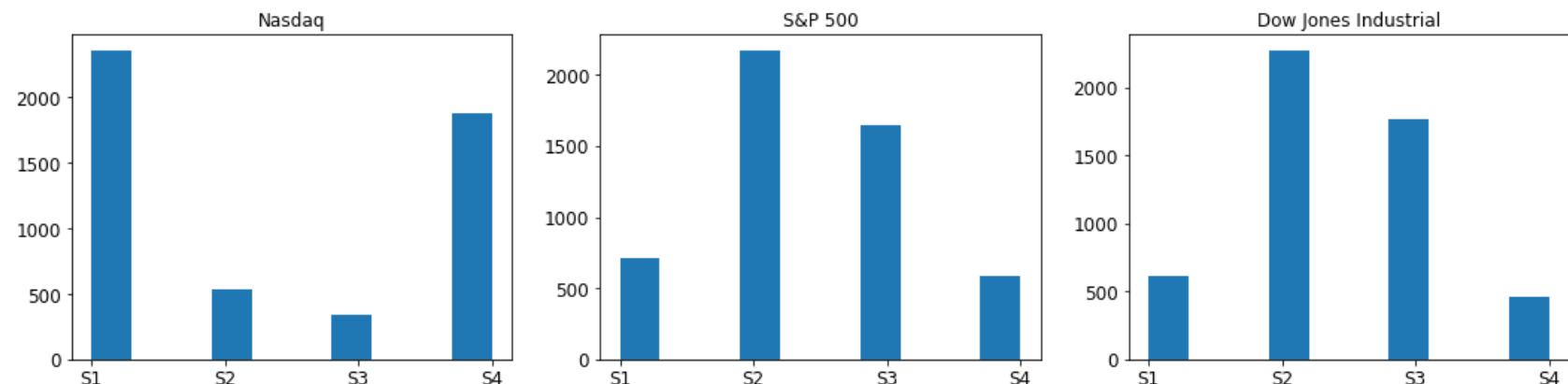
ax1.hist(indexes_data_set1['f_Nasdaq'].sort_values())
ax1.set_title("Nasdaq" )

ax2.hist(indexes_data_set1['f_S&P_500'].sort_values())
ax2.set_title("S&P 500" )

ax3.hist(indexes_data_set1['f_DJI'].sort_values())
ax3.set_title("Dow Jones Industrial" )

plt.show()
```

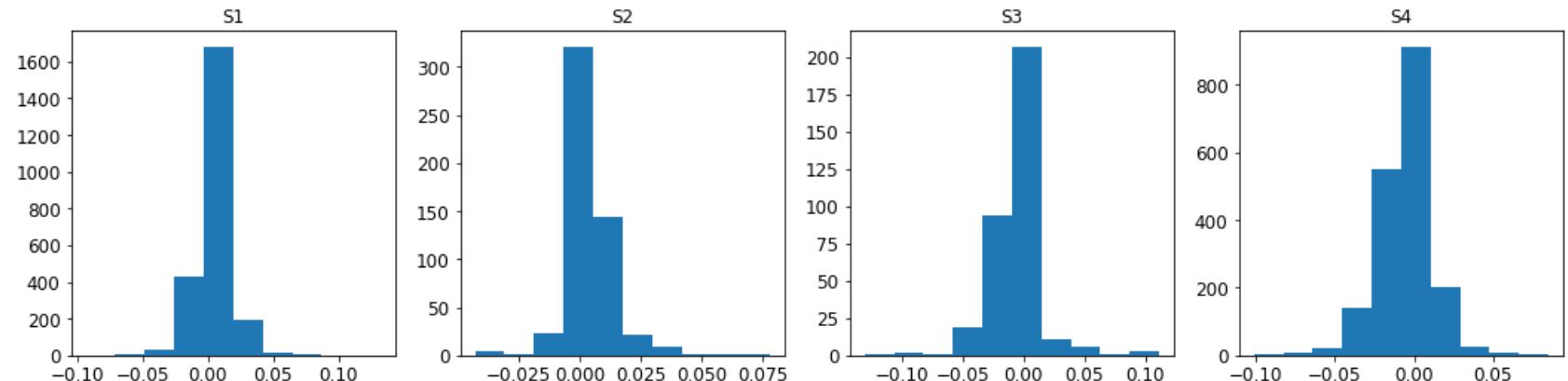
Histograms of State Distributions for All Indexes



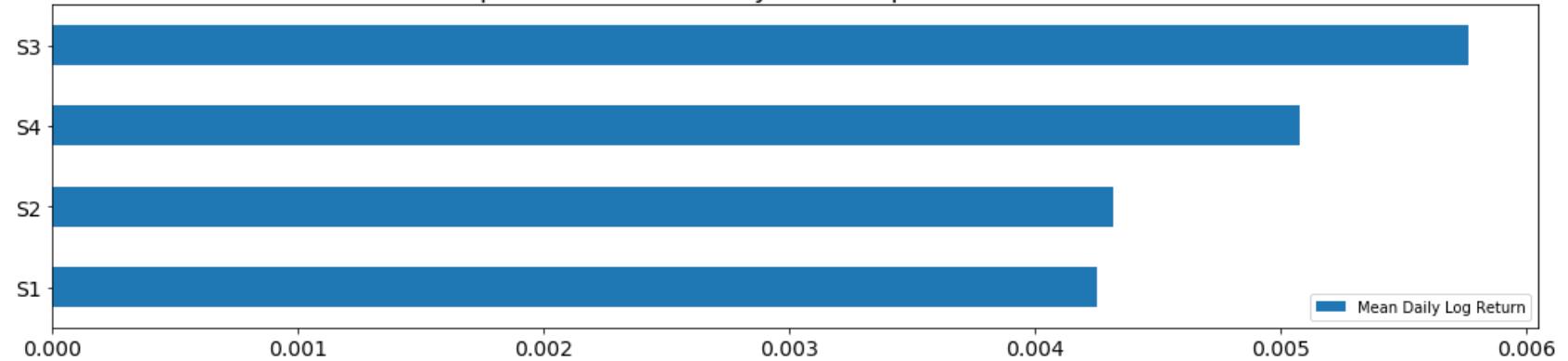
```
In [31]: def createPlotsForStockClassification(indexes_data_set, index_name_var, title_1, title_2, index_col ) :  
:  
    fig, (ax1, ax2, ax3, ax4) = plt.subplots(1, 4, figsize=(18,4))  
    fig.suptitle(title_1, fontsize=18, y=1.07)  
  
    ax1.hist( indexes_data_set[ index_col == "S1" ][index_name_var] )  
    ax1.set_title("S1")  
  
    ax2.hist( indexes_data_set[ index_col == "S2" ][index_name_var] )  
    ax2.set_title("S2")  
  
    ax3.hist( indexes_data_set[ index_col == "S3" ][index_name_var] )  
    ax3.set_title("S3")  
  
    ax4.hist( indexes_data_set[ index_col == "S4" ][index_name_var] )  
    ax4.set_title("S4")  
  
    plt.show()  
    print("\n")  
  
    nasdaq_mean_ret = []  
    nasdaq_mean_ret.append( np.mean( indexes_data_set[ index_col == "S1" ][index_name_var] ) )  
    nasdaq_mean_ret.append( np.mean( indexes_data_set[ index_col == "S2" ][index_name_var] ) )  
    nasdaq_mean_ret.append( np.mean( indexes_data_set[ index_col == "S3" ][index_name_var] ) )  
    nasdaq_mean_ret.append( np.mean( indexes_data_set[ index_col == "S4" ][index_name_var] ) )  
  
    nasdaq_mean_ret = np.abs(nasdaq_mean_ret)  
    nasdaq_class_mean_ret_df = pd.DataFrame ( { 'Mean Daily Log Return' : nasdaq_mean_ret,  
                                              'Stock Classification' : [ "S1", "S2", "S3", "S4" ] }  
,  
                                         index = [ "S1", "S2", "S3", "S4" ] )  
  
    nasdaq_class_mean_ret_df = nasdaq_class_mean_ret_df.sort_values('Mean Daily Log Return')  
    ax_nasdaq = nasdaq_class_mean_ret_df.plot.barh(y='Mean Daily Log Return', figsize=(18,4), fontsize=14 )  
    ax_nasdaq.set_title(title_2, fontsize=18)
```

```
In [32]: ax_plot = createPlotsForStockClassification(indexes_data_set = indexes_data_set1,
                                                 index_name_var = "r_Nasdaq",
                                                 title_1 = 'Histograms of Daily Returns for the NASDAQ for all Classifications',
                                                 title_2 = "Nasdaq Absolute Mean Daily Returns per Stock Classification",
                                                 index_col = indexes_data_set1.f_Nasdaq)
ax_plot
```

Histograms of Daily Returns for the NASDAQ for all Classifications

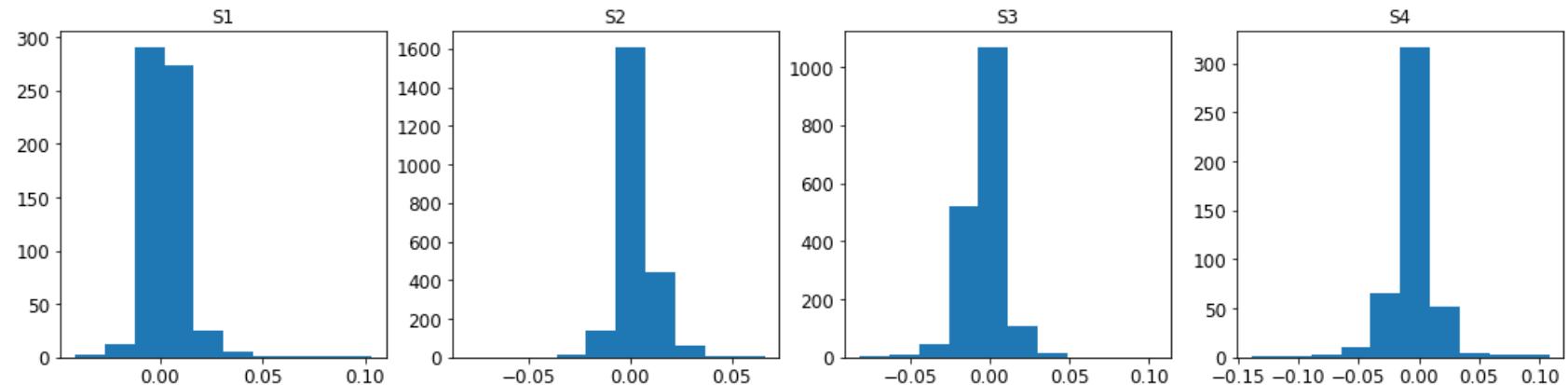


Nasdaq Absolute Mean Daily Returns per Stock Classification

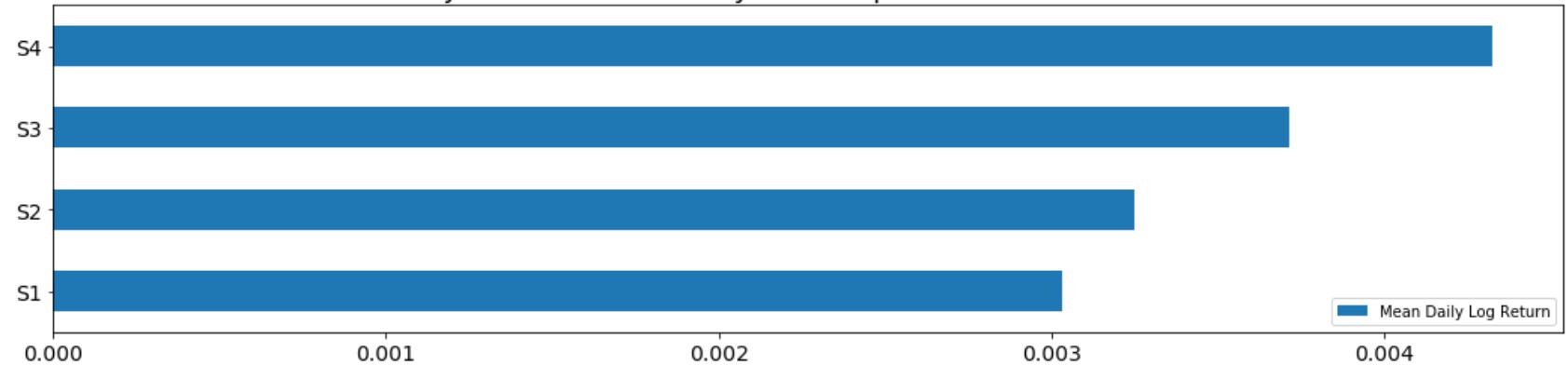


```
In [33]: ax_plot = createPlotsForStockClassification(indexes_data_set = indexes_data_set1,
                                                 index_name_var = "r_DJI",
                                                 title_1 = 'Histograms of Daily Returns for the DJI for all Classifications',
                                                 title_2 = "DJI Absolute Mean Daily Returns per Stock Classification",
                                                 index_col = indexes_data_set1.f_DJI)
ax_plot
```

Histograms of Daily Returns for the DJI for all Classifications



DJI Absolute Mean Daily Returns per Stock Classification

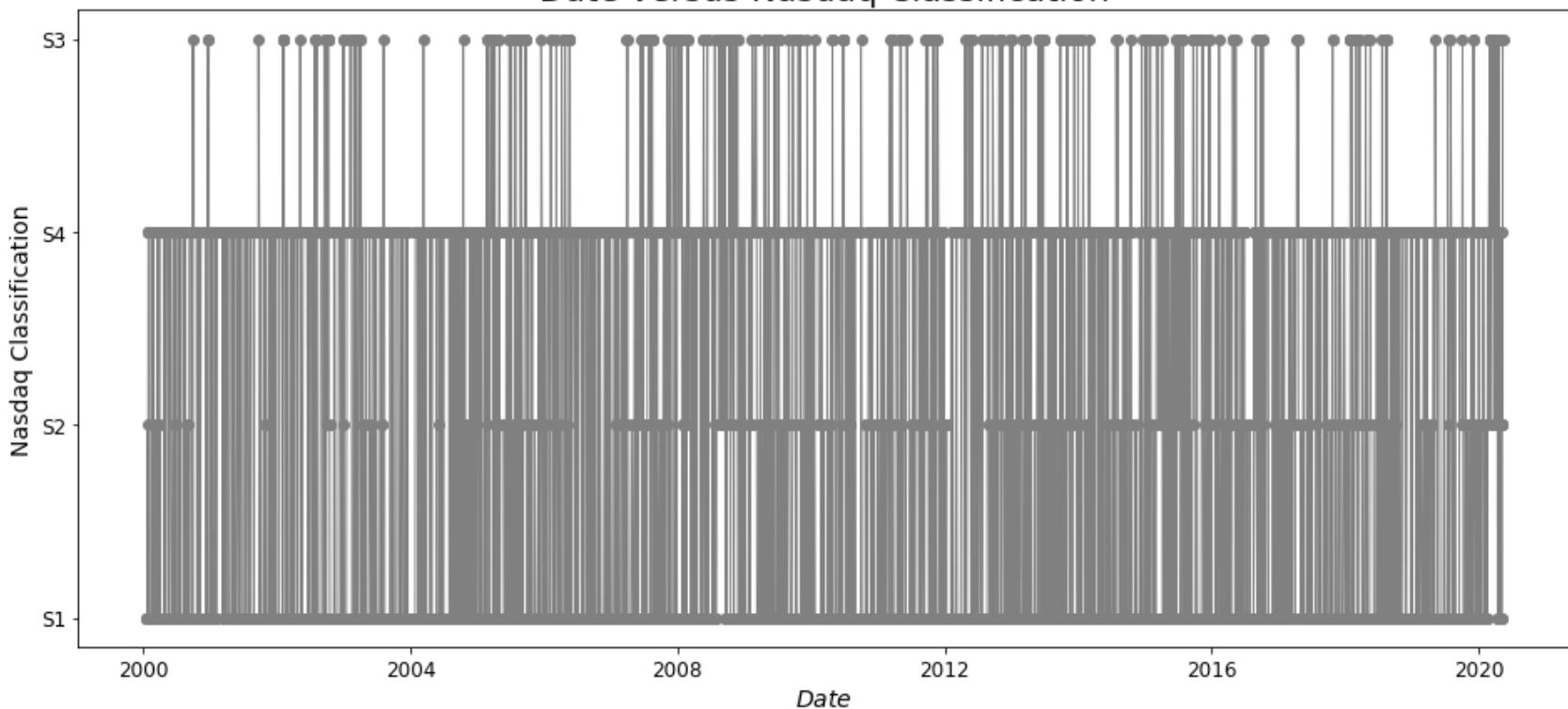


Stock Index Classification versus Date Plots

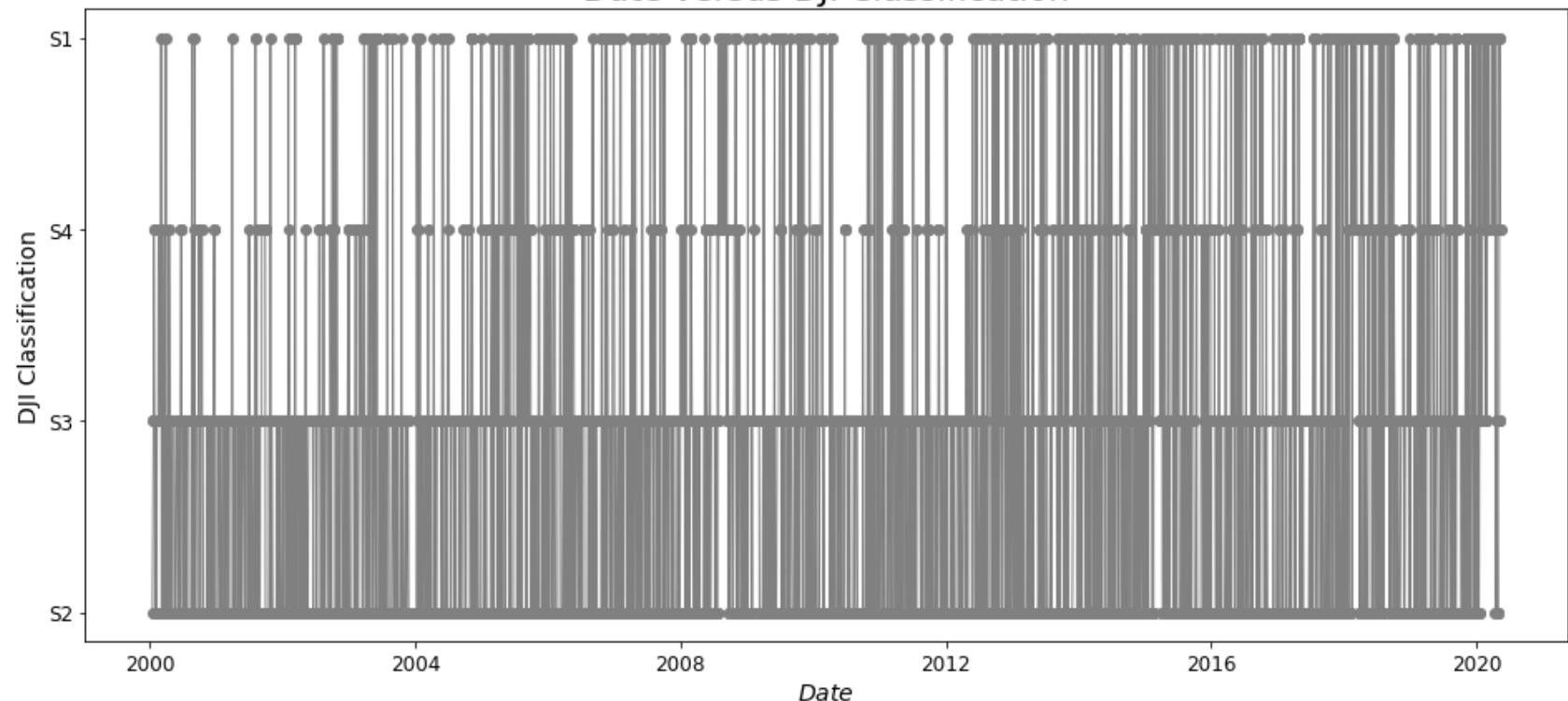
```
In [34]: print("\n")
plt.figure(figsize=(16, 7))
plt.plot(indexes_data_set1['Date'], indexes_data_set1['f_Nasdaq'], "o-", color="gray", linewidth=1)
plt.title("Date versus Nasdaq Classification", fontsize=20)
plt.xlabel("$Date$", fontsize=14)
plt.ylabel("Nasdaq Classification", fontsize=14)
plt.show()

print("\n")
plt.figure(figsize=(16, 7))
plt.plot(indexes_data_set1['Date'], indexes_data_set1['f_DJI'], "o-", color="gray", linewidth=1)
plt.title("Date versus DJI Classification", fontsize=20)
plt.xlabel("$Date$", fontsize=14)
plt.ylabel("DJI Classification", fontsize=14)
plt.show()
```

Date versus Nasdaq Classification



Date versus DJI Classification



Summary Statistics for Transitions from one Classification to Another Classification

```
In [35]: indexes_classifications = ["f_DJI", "f_S&P_500", "f_Nasdaq"]

import pandas as pd
import matplotlib.pyplot as plt
from matplotlib.ticker import PercentFormatter

def _plot_pareto_by(df_, group_by, column, title):

    df = df_.groupby(group_by)[column].sum().reset_index()
    df = df.sort_values(by=column, ascending=False)

    df[ "cumpercentage" ] = df[column].cumsum()/df[column].sum()*100

    fig, ax = plt.subplots(figsize=(20,5))
    ax.set_title(title, fontsize = 20 )
    ax.bar(df[group_by], df[column], color="C0")
    ax2 = ax.twinx()
    ax2.plot(df[group_by], df[ "cumpercentage" ], color="C1", marker="D", ms=7)
    ax2.yaxis.set_major_formatter(PercentFormatter())

    ax.tick_params(axis="y", colors="C0")
    ax2.tick_params(axis="y", colors="C1")

    for tick in ax.get_xticklabels():
        tick.set_rotation(45)
    plt.show()

def calculateClassificationTransitions(df, f_index_name) :

    ndays = len(df)
    f_index = df[f_index_name].to_numpy().astype('<U2')

    num_transitions_index_S1S2_S1S2 = 0
    num_transitions_index_S1S2_S3S4 = 0
    num_transitions_index_S3S4_S3S4 = 0
    num_transitions_index_S3S4_S1S2 = 0

    num_transitions_index_S1_to_S1 = 0
    num_transitions_index_S1_to_S2 = 0
```

```
num_transitions_index_S1_to_S3 = 0
num_transitions_index_S1_to_S4 = 0

num_transitions_index_S2_to_S2 = 0
num_transitions_index_S2_to_S1 = 0
num_transitions_index_S2_to_S3 = 0
num_transitions_index_S2_to_S4 = 0

num_transitions_index_S3_to_S3 = 0
num_transitions_index_S3_to_S1 = 0
num_transitions_index_S3_to_S2 = 0
num_transitions_index_S3_to_S4 = 0

num_transitions_index_S4_to_S4 = 0
num_transitions_index_S4_to_S1 = 0
num_transitions_index_S4_to_S2 = 0
num_transitions_index_S4_to_S3 = 0

for i in range(ndays-1) :

    if f_index[i] == "S1" :

        if f_index[i+1] == "S2" :
            num_transitions_index_S1_to_S2 += 1
        elif f_index[i+1] == "S3" :
            num_transitions_index_S1_to_S3 += 1
        elif f_index[i+1] == "S4" :
            num_transitions_index_S1_to_S4 += 1
        elif f_index[i+1] == "S1" :
            num_transitions_index_S1_to_S1 += 1

    elif f_index[i] == "S2" :

        if f_index[i+1] == "S1" :
            num_transitions_index_S2_to_S1 += 1
        elif f_index[i+1] == "S3" :
            num_transitions_index_S2_to_S3 += 1
        elif f_index[i+1] == "S4" :
            num_transitions_index_S2_to_S4 += 1
        elif f_index[i+1] == "S2" :
            num_transitions_index_S2_to_S2 += 1

    elif f_index[i] == "S3" :
```

```

    if f_index[i+1] == "S1" :
        num_transitions_index_S3_to_S1 += 1
    elif f_index[i+1] == "S2" :
        num_transitions_index_S3_to_S2 += 1
    elif f_index[i+1] == "S4" :
        num_transitions_index_S3_to_S4 += 1
    elif f_index[i+1] == "S3" :
        num_transitions_index_S3_to_S3 += 1

elif f_index[i] == "S4" :

    if f_index[i+1] == "S1" :
        num_transitions_index_S4_to_S1 += 1
    elif f_index[i+1] == "S2" :
        num_transitions_index_S4_to_S2 += 1
    elif f_index[i+1] == "S3" :
        num_transitions_index_S4_to_S3 += 1
    elif f_index[i+1] == "S4" :
        num_transitions_index_S4_to_S4 += 1

else :
    print("Error, unknown classifier value")

data = { 'index' : [f_index_name],
         'num_days' : [ndays],
         'S1_to_S1%' : [100*num_transitions_index_S1_to_S1/ndays],
         'S1_to_S2%' : [100*num_transitions_index_S1_to_S2/ndays],
         'S1_to_S3%' : [100*num_transitions_index_S1_to_S3/ndays],
         'S1_to_S4%' : [100*num_transitions_index_S1_to_S4/ndays],

         'S2_to_S1%' : [100*num_transitions_index_S2_to_S1/ndays],
         'S2_to_S2%' : [100*num_transitions_index_S2_to_S2/ndays],
         'S2_to_S3%' : [100*num_transitions_index_S2_to_S3/ndays],
         'S2_to_S4%' : [100*num_transitions_index_S2_to_S4/ndays],

         'S3_to_S1%' : [100*num_transitions_index_S3_to_S1/ndays],
         'S3_to_S2%' : [100*num_transitions_index_S3_to_S2/ndays],
         'S3_to_S3%' : [100*num_transitions_index_S3_to_S3/ndays],
         'S3_to_S4%' : [100*num_transitions_index_S3_to_S4/ndays],

         'S4_to_S1%' : [100*num_transitions_index_S4_to_S1/ndays],
         'S4_to_S2%' : [100*num_transitions_index_S4_to_S2/ndays],

```

```

        'S4_to_S3%' : [100*num_transitions_index_S4_to_S3/ndays],
        'S4_to_S4%' : [100*num_transitions_index_S4_to_S4/ndays]
    }

    num_transitions_index_S1S2_S1S2 = num_transitions_index_S1_to_S1 + num_transitions_index_S1_to_S2
+ \
                                num_transitions_index_S2_to_S1 + num_transitions_index_S2_to_S2

    num_transitions_index_S1S2_S3S4 = num_transitions_index_S1_to_S3 + num_transitions_index_S1_to_S4
+ \
                                num_transitions_index_S2_to_S3 + num_transitions_index_S2_to_S4

    num_transitions_index_S3S4_S3S4 = num_transitions_index_S3_to_S3 + num_transitions_index_S3_to_S4
+ \
                                num_transitions_index_S4_to_S3 + num_transitions_index_S4_to_S4

    num_transitions_index_S3S4_S1S2 = num_transitions_index_S3_to_S1 + num_transitions_index_S3_to_S2
+ \
                                num_transitions_index_S4_to_S1 + num_transitions_index_S4_to_S2

    data_agg = { 'index'      : [f_index_name],
                 'num_days'   : [ndays],
                 'S1S2_to_S1S2%' : [100*num_transitions_index_S1S2_S1S2/ndays],
                 'S1S2_to_S3S4%' : [100*num_transitions_index_S1S2_S3S4/ndays],
                 'S3S4_to_S3S4%' : [100*num_transitions_index_S3S4_S3S4/ndays],
                 'S3S4_to_S1S2%' : [100*num_transitions_index_S3S4_S1S2/ndays] }

    return pd.DataFrame(data), pd.DataFrame(data_agg),

```

results_stats_df = pd.DataFrame()
results_stats_agg_df = pd.DataFrame()

first = **True**
for index_clf **in** indexes_classifications :

```

curr_results_stats_df, curr_results_agg_stats_df = \
    calculateClassificationTransitions(df = indexes_data_set1, f_index_name = index_clf)
results_stats_df = results_stats_df.append(curr_results_stats_df)
results_stats_agg_df = results_stats_agg_df.append(curr_results_agg_stats_df)

```

results_stats_df = results_stats_df.reset_index(drop=**True**).T.reset_index(). \
rename(columns={**"index"**: **"Transition"**, 0: **"DJI"**, 1 : **"S&P_500"**, 2 : **"Nasdaq"**})

```

results_stats_df = results_stats_df.iloc[2: len(results_stats_df)]

results_stats_agg_df_T = results_stats_agg_df.reset_index(drop=True).T.reset_index(). \
    rename(columns={"index": "Transition", 0: "DJI", 1 : "S&P_500", 2 : "Nasdaq"}). \
    iloc[2: 6]

```

Detail Transition Classification Summary from any S classification to any S classification

In [36]: results_stats_df

Out[36]:

	Transition	DJI	S&P_500	Nasdaq
2	S1_to_S1%	7.03812	8.25024	34.8387
3	S1_to_S2%	2.9521	2.8739	2.9521
4	S1_to_S3%	2.03324	2.8348	8.3871
5	S1_to_S4%	0	0	0
6	S2_to_S1%	3.0694	2.85435	2.93255
7	S2_to_S2%	33.392	32.219	6.00196
8	S2_to_S3%	7.25318	6.54936	0.762463
9	S2_to_S4%	0.762463	0.860215	0.684262
10	S3_to_S1%	0.664712	0.762463	0.625611
11	S3_to_S2%	7.23363	6.35386	0.821114
12	S3_to_S3%	24.477	23.089	3.51906
13	S3_to_S4%	2.18964	1.87683	1.75953
14	S4_to_S1%	1.25122	2.09189	7.76149
15	S4_to_S2%	0.879765	1.01662	0.606061
16	S4_to_S3%	2.09189	1.56403	1.66178
17	S4_to_S4%	4.69208	6.78397	26.6667

Aggregate Transition Classification Summary (S1S2 to S1S2, S1S2 to S3S4, S3S4 to S3S4, S3S4 to S2S1)

```
In [37]: #results_stats_agg_df  
results_stats_agg_df_T
```

Out[37]:

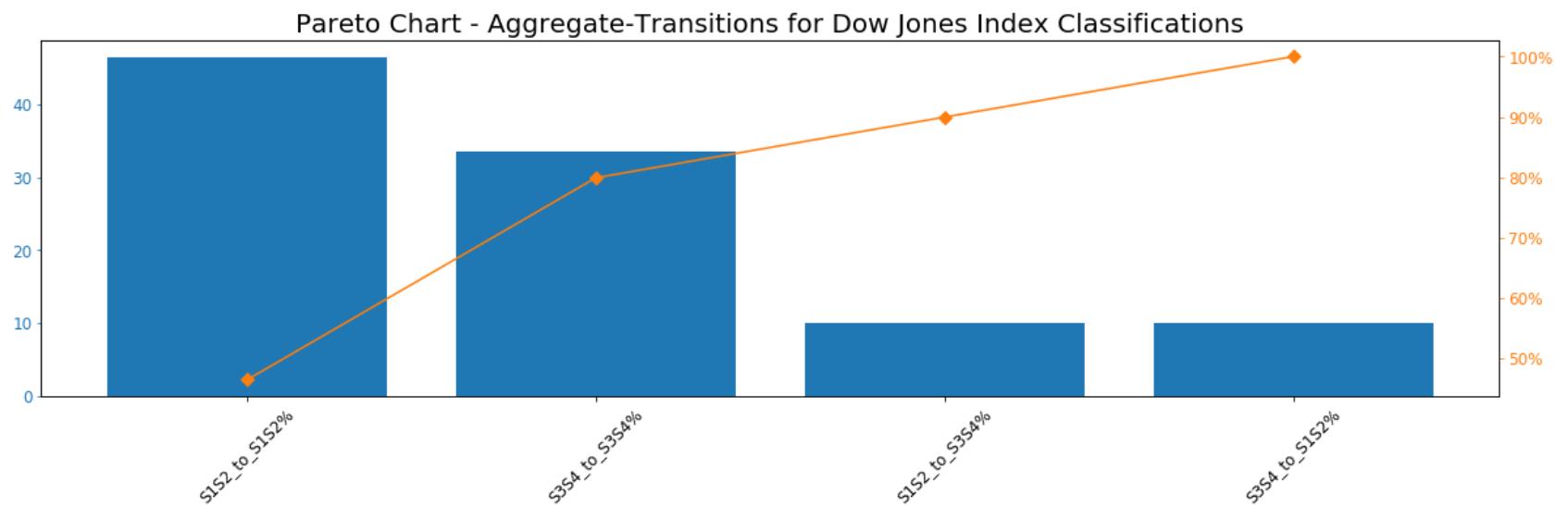
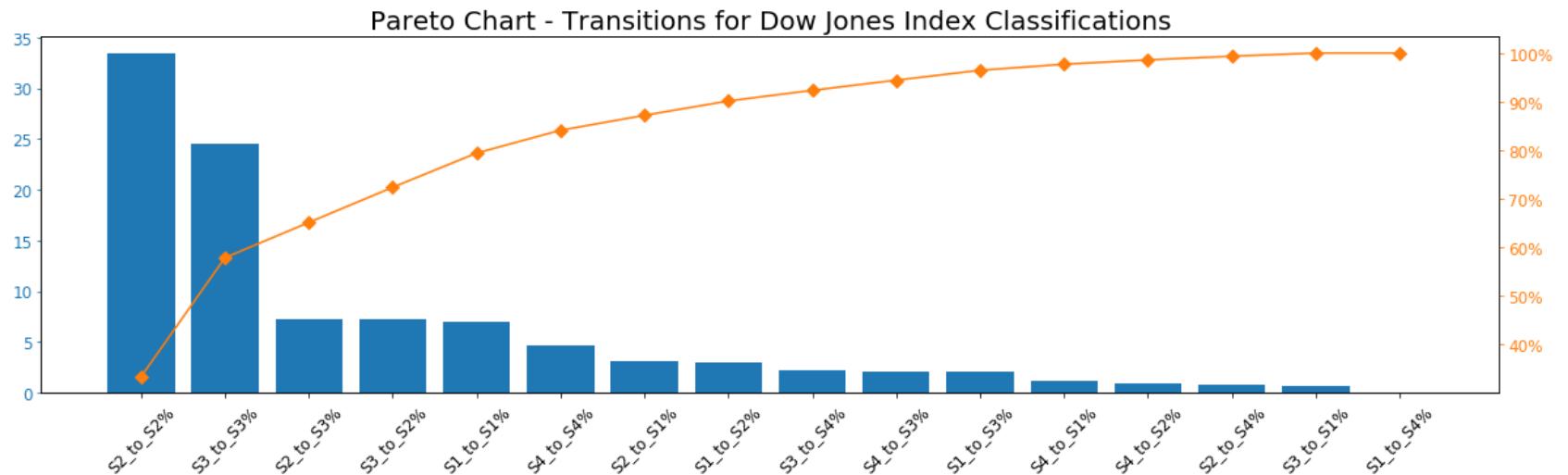
	Transition	DJI	S&P_500	Nasdaq
2	S1S2_to_S1S2%	46.4516	46.1975	46.7253
3	S1S2_to_S3S4%	10.0489	10.2444	9.83382
4	S3S4_to_S3S4%	33.4506	33.3138	33.607
5	S3S4_to_S1S2%	10.0293	10.2248	9.81427

Pareto Charts for Transitions Statistics from one Classification to Another Classification

DJI

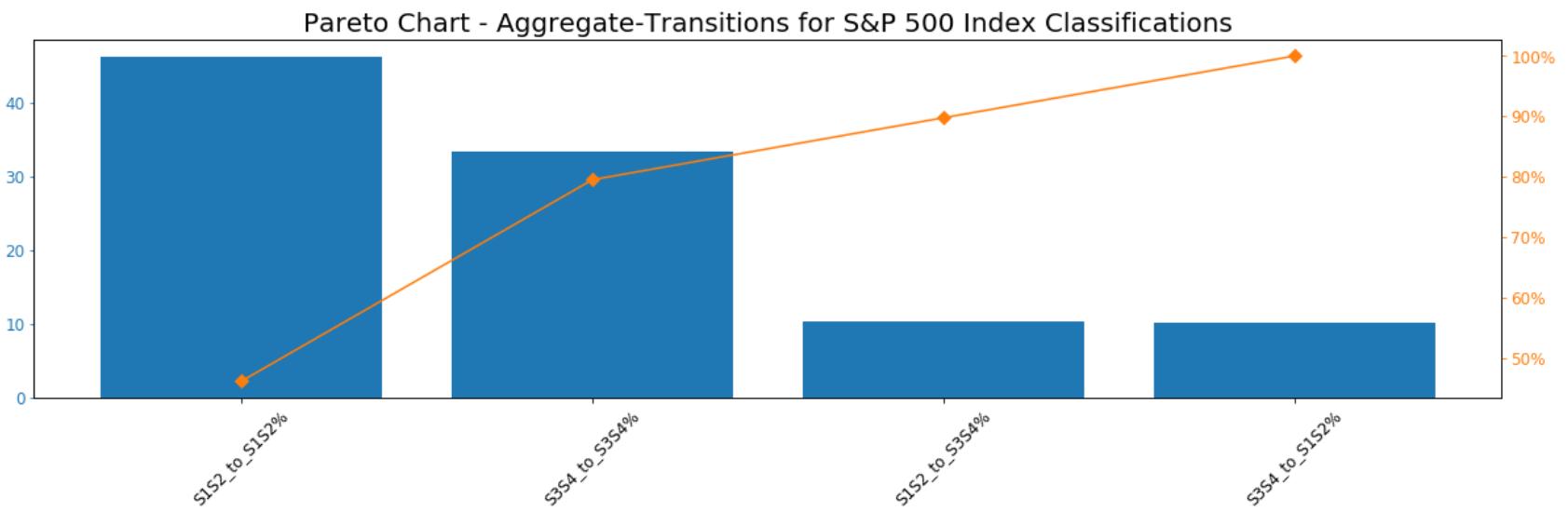
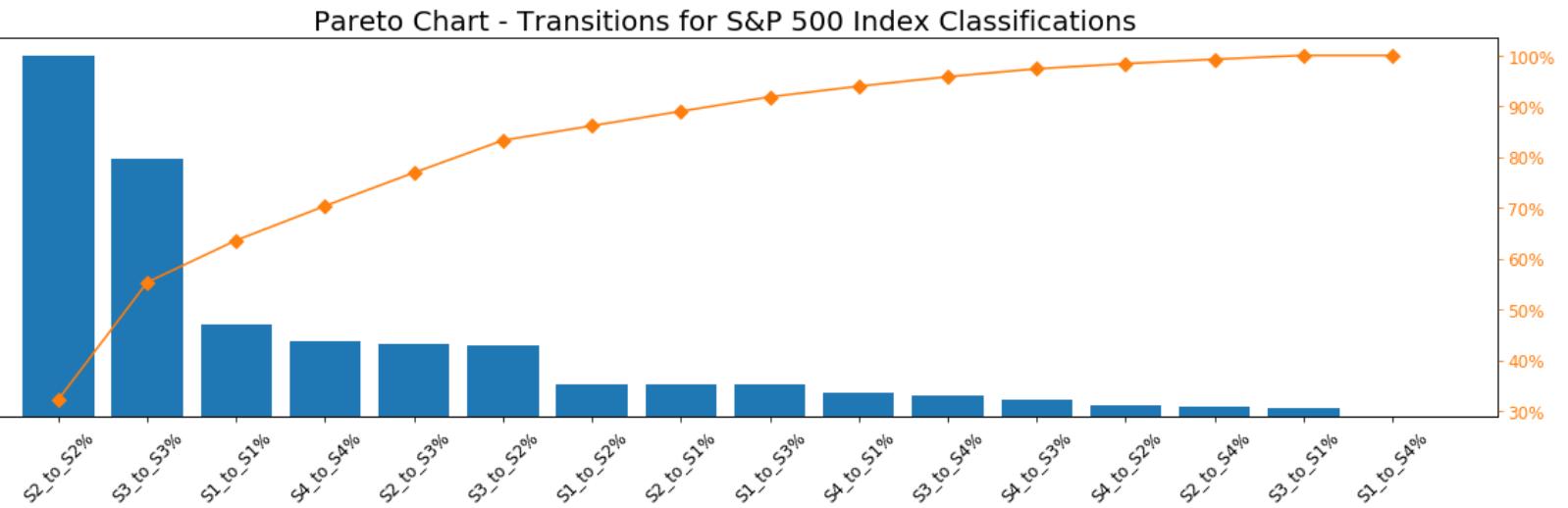
```
In [38]: _plot_pareto_by(df_ = results_stats_df, group_by = "Transition", column = "DJI",
                     title = "Pareto Chart - Transitions for Dow Jones Index Classifications")

_plot_pareto_by(df_ = results_stats_agg_df_T, group_by = "Transition", column = "DJI",
                 title = "Pareto Chart - Aggregate-Transitions for Dow Jones Index Classifications")
```



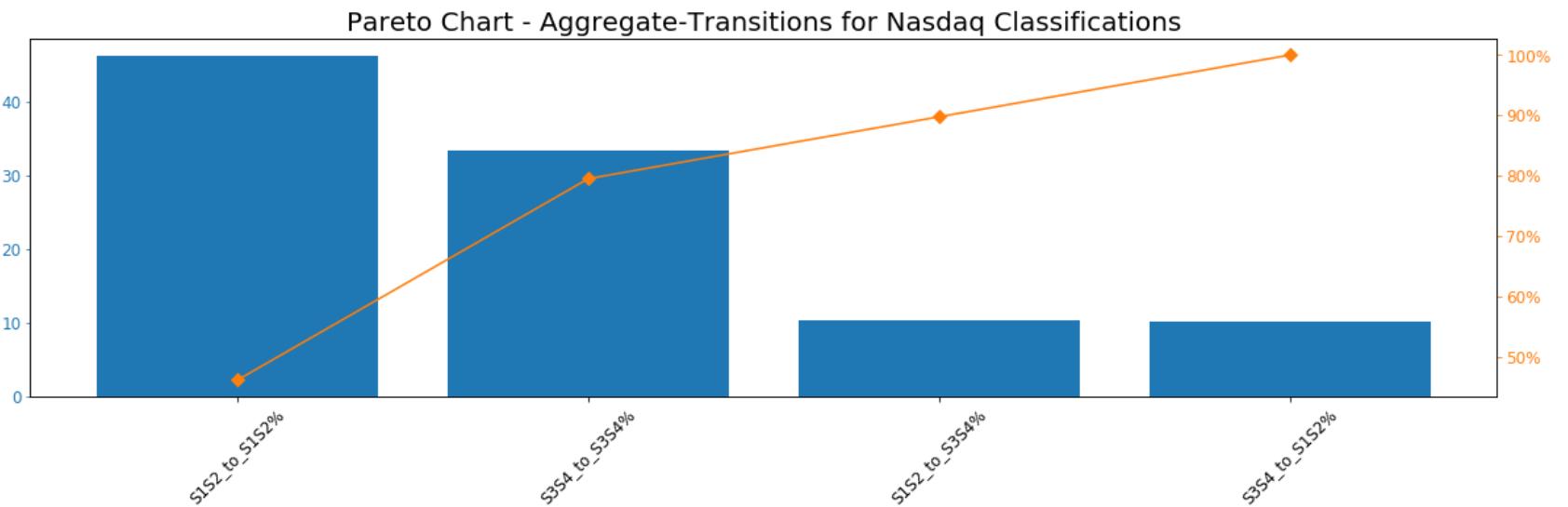
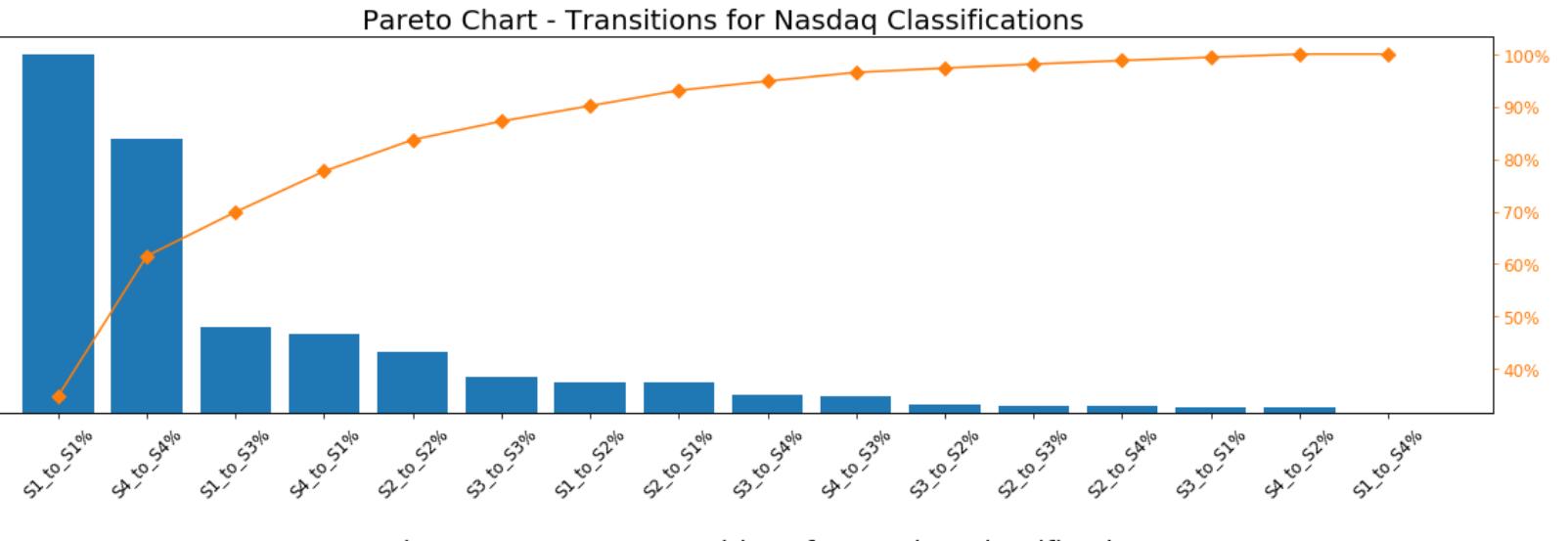
```
In [39]: _plot_pareto_by(df_ = results_stats_df, group_by = "Transition", column = "S&P_500",
                     title = "Pareto Chart - Transitions for S&P 500 Index Classifications")

_plot_pareto_by(df_ = results_stats_agg_df_T, group_by = "Transition", column = "S&P_500",
                 title = "Pareto Chart - Aggregate-Transitions for S&P 500 Index Classifications")
```



```
In [40]: _plot_pareto_by(df_ = results_stats_df, group_by = "Transition", column = "Nasdaq",
                     title = "Pareto Chart - Transitions for Nasdaq Classifications")

_plot_pareto_by(df_ = results_stats_agg_df_T, group_by = "Transition", column = "S&P_500",
                 title = "Pareto Chart - Aggregate-Transitions for Nasdaq Classifications")
```



```
In [41]: fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(18,4))
fig.suptitle('Histograms of State Distributions for All Indexes', fontsize=18, y=1.07)

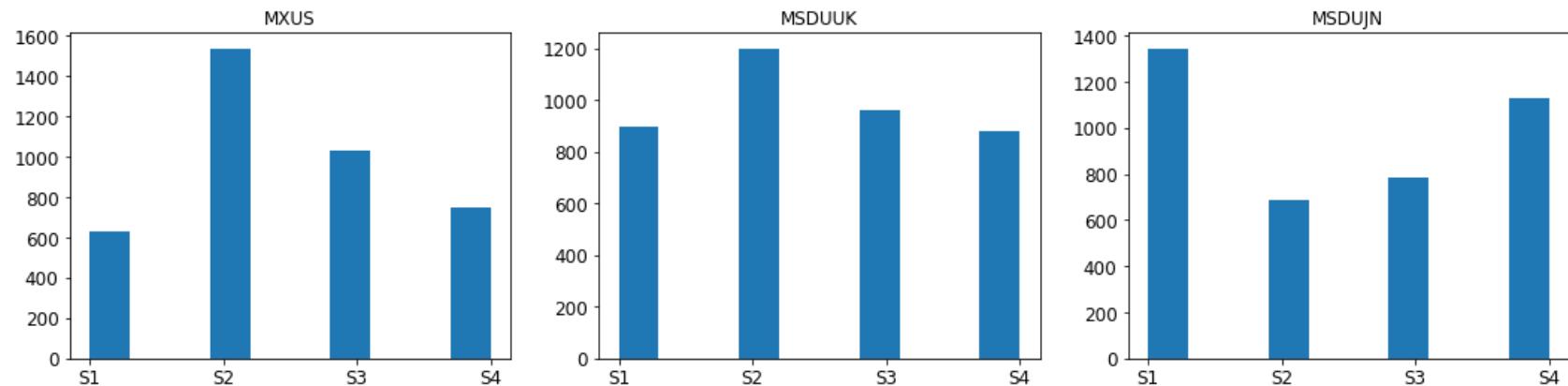
ax1.hist(indexes_data_set2['f_MXUS'].sort_values())
ax1.set_title("MXUS" )

ax2.hist(indexes_data_set2['f_MSDUUK'].sort_values())
ax2.set_title("MSDUUK" )

ax3.hist(indexes_data_set2['f_MSDUJN'].sort_values())
ax3.set_title("MSDUJN" )

plt.show()
```

Histograms of State Distributions for All Indexes



6.1.7 Create Network Topological Characteristics

```
In [42]: import networkx as nx
import matplotlib.pyplot as plt
from collections import Counter
import statistics as stat

# The following function calculates the topology parameters
#     index_start : dataframe where to start calculations
#     sliding_window_size : size of sliding window, default = 30 (days)
#     save_results_end_of_window : [True, False], Day where to save the results in the window
#                                     results should be saved at the end, to avoid
#                                     looking in the future
#
#                                     The option of "False" will save at the start of each
#                                     window
#     save_results_ndays_pass_window : unsigned integer, default = 0
#                                     - This parameter is only applicable if save_results_end_of_window = True, it will save
#                                     the sliding window derived parameters, n days past the window. This suggestion was
#                                     recommended by Professor Bahman to ensure there is not leakage of looking into future
#                                     data.

def getNetworkTopologyParameters(df, index_start = 9,
                                  sliding_window_size = 30,
                                  save_results_end_of_window = True,
                                  save_results_ndays_pass_window = 0 ):

    # ***Create node pairs

    nodes1 = df[ "Node" ]
    pairs_list = []
    for i in range(index_start, len(nodes1), 1):
        one = nodes1[i]
        two = nodes1[i + 1]
        pairs_list.append((one, two))

    # Arrays to save network parameters

    Ave_Deg_Centrality = np.empty( [df.shape[0], 1], dtype='double' )
    Ave_Deg_Centrality[:] = np.NaN
    Ave_Network_Strength = np.empty( [df.shape[0], 1], dtype='double' )
    Ave_Network_Strength[:] = np.NaN
    Ave_Shortest_PathLen = np.empty( [df.shape[0], 1], dtype='double' )
    Ave_Shortest_PathLen[:] = np.NaN
    Closenes_Centrality = np.empty( [df.shape[0], 1], dtype='double' )
```

```

Closenes_Centrality[ :] = np.NaN

# Iterate through All Dates - Creating Sliding Windows for Network Parameters
# Each sliding window is one day apart, see table-1 of white paper

num_rows = df.shape[0]

for current_day in range(num_rows):

    # - Check There are still enough days for a 30 day window, if there are not, then stop
    # creating sliding windows, and exit the loop
    # - Another exit of the loop, is, if there are not enough records to save the results, in
    # case, the save_results_ndays_pass_window is specified

    if (current_day + sliding_window_size + save_results_ndays_pass_window ) > num_rows:
        break

    # Create Sliding Window Start and End positions, and Data

    window_start = current_day
    window_end = current_day + sliding_window_size
    curr_sliding_win_pairs = pairs_list[window_start : window_end]

    # Determine location where to save results from sliding widow

    loc_to_save_results = window_end - 1

    if save_results_end_of_window == False :
        loc_to_save_results = window_start
    elif save_results_ndays_pass_window > 0 :
        loc_to_save_results += save_results_ndays_pass_window

    # *** Create Network Graph & Compute network parameters for the current window

    H = nx.DiGraph()
    EDGES = curr_sliding_win_pairs

    # calculate the weight of DIGraph
    H = nx.DiGraph((x, y, {'weight': v}) for (x, y), v in Counter(EDGES).items())

    # (1) Average Degree Centrality
    Ave_Deg_Centrality[loc_to_save_results] = stat.mean( nx.degree_centrality(H).values() )/2.0 #

```



```
        save_results_end_of_window = True,  
        save_results_ndays_pass_window = 2 )
```

In [43]: # *** Save Results in Data Frames with all financial metrics for each set

```
indexes_data_set1[ "Ave_Deg_Centrality" ] = Ave_Deg_Centrality  
indexes_data_set1[ "Ave_Network_Strength" ] = Ave_Network_Strength  
indexes_data_set1[ "Ave_Shortest_PathLen" ] = Ave_Shortest_PathLen  
indexes_data_set1[ "Closenes_Centrality" ] = Closenes_Centrality  
  
indexes_data_set2[ "Ave_Deg_Centrality" ] = Ave_Deg_Centrality_Set2  
indexes_data_set2[ "Ave_Network_Strength" ] = Ave_Network_Strength_Set2  
indexes_data_set2[ "Ave_Shortest_PathLen" ] = Ave_Shortest_PathLen_Set2  
indexes_data_set2[ "Closenes_Centrality" ] = Closenes_Centrality_Set2  
  
# Delete all dates with NaN, this will get rid of the first 29 days before doing the network calculations,  
# as the first sliding window results are saved the last day of the window  
  
indexes_data_set1.dropna(inplace = True)  
indexes_data_set2.dropna(inplace = True)
```

In [44]: indexes_data_set1.head()

Out[44]:

	Date	S&P_500	Nasdaq	DJI	r_Nasdaq	R_Nasdaq	V_Nasdaq	V_Ave_Nasdaq	r_S&P_500	R_S&P_500	...	V_Ave_DJI	V_Ave_
40	2000-03-01	1379.19	4784.08	10137.93	0.018436	0.050094	0.030678	0.046648	0.009302	0.013504	...	0.034552	
41	2000-03-02	1381.76	4754.51	10164.92	-0.006200	0.029208	0.033670	0.041145	0.001862	0.020716	...	0.035364	
42	2000-03-03	1409.17	4914.79	10367.20	0.033155	0.068260	0.038893	0.037444	0.019643	0.055299	...	0.032763	
43	2000-03-06	1391.28	4904.85	10170.51	-0.002025	0.068995	0.038511	0.036634	-0.012777	0.031565	...	0.031754	
44	2000-03-07	1355.62	4847.84	9796.04	-0.011691	0.031675	0.042097	0.036770	-0.025965	-0.007935	...	0.034210	

5 rows × 25 columns

```
In [45]: indexes_data_set2.head()
```

Out[45]:

	Date	MXUS	MSDUUK	MSDUJN	r_MXUS	R_MXUS	V_MXUS	V_Ave_MXUS	r_MSDUUK	R_MSDUUK	...	V_Ave_MSDUJN	V_A
40	2000-02-28	1314.81	1143.658	3357.611	0.011189	0.002681	0.023714	0.027985	-0.019126	0.007459	...	0.032564	
41	2000-02-29	1333.28	1161.518	3325.178	0.013950	0.013098	0.027366	0.027359	0.015496	0.012426	...	0.031059	
42	2000-03-01	1343.29	1188.530	3412.178	0.007480	0.012970	0.027337	0.026206	0.022989	0.019463	...	0.030321	
43	2000-03-02	1350.08	1197.153	3392.979	0.005042	0.022237	0.025985	0.024828	0.007229	0.039068	...	0.030586	
44	2000-03-03	1376.15	1211.296	3348.599	0.019126	0.056787	0.012350	0.023351	0.011745	0.038333	...	0.029884	

5 rows × 25 columns

Summary of Derived Network Topology metrics to Compare with White Paper Training Data

```
In [46]: metrics = ["Ave_Deg_Centrality", "Ave_Network_Strength", "Ave_Shortest_PathLen", "Closenes_Centralit
y" ]
data_training = indexes_data_set1[ indexes_data_set1['Date'].dt.strftime('%Y-%m-%d') < '2015-01-01'].dropna()

print("Number of records in training dataset = ", len(data_training) )
print("Number of Unique Nodes in training dataset = ", len(data_training['Node'].unique()) )

data_training[ metrics ].describe()
```

Number of records in training dataset = 3733
Number of Unique Nodes in training dataset = 48

Out[46]:

	Ave_Deg_Centrality	Ave_Network_Strength	Ave_Shortest_PathLen	Closenes_Centrality
count	3733.000000	3733.000000	3733.000000	3733.000000
mean	0.280017	3.526614	2.433852	0.376800
std	0.149958	1.222717	0.706530	0.113185
min	0.088235	1.666667	0.833333	0.149405
25%	0.181818	2.727273	1.928571	0.292942
50%	0.233333	3.333333	2.333333	0.358871
75%	0.357143	4.285714	2.818182	0.446723
max	2.000000	15.000000	6.400000	1.000000

Comparison of Training Records and Network Derived Data vs Reported in White Paper

- The number of training records derived is 3735 for the date range defined in the white paper (Jan 31, 2000 to Dec 31 2014). The paper reports the following in section 4.3 : *The training set and the testing set contained 3769 and 755 records*
 - The difference is due to the number of records that have NaN as a result of the calculation of the financial parameters and network topology, i.e.:
 - 1 day due to calculation of daily returns
 - 4 days due to the calculation of 5 day moving averages
 - 29 days due to the calculation of the network parameters with a sliding window of 30 days
 - 2 days due to saving 2 days past the window
 - Total : 36 records with blanks
 - $3733 + 36 = 3769$, which matches the size of the training data set in the white paper, as referred above.

6.1.8 Cluster Analysis with Unsupervised Learning

Create Clusters Per Index

```
In [320]: from sklearn.cluster import KMeans

def calculateClustersForIndexes(dataset, stock_indexes) :

    inertias_dict = {}
    kmeans_per_k_dict = {}

    for index in stock_indexes :

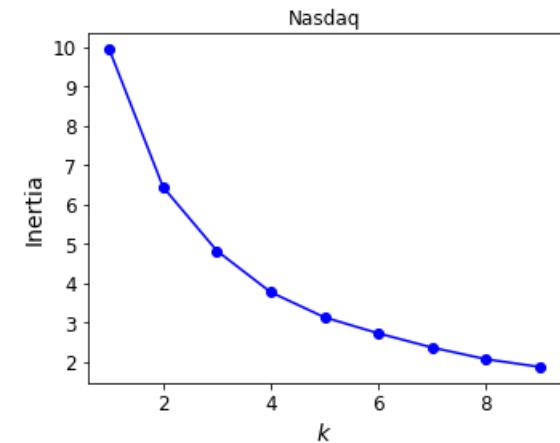
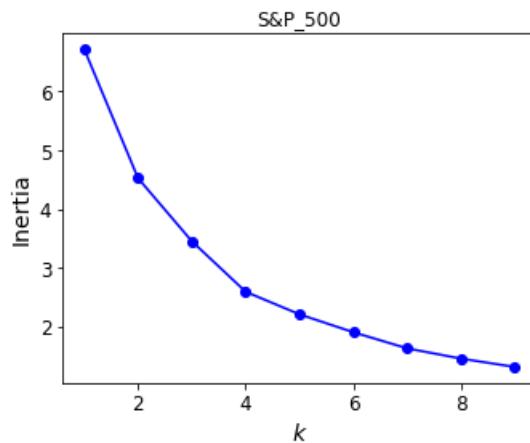
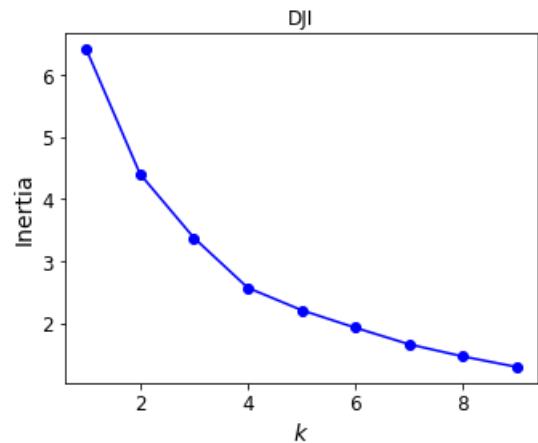
        X_train_cluster = dataset[ [ "R_" + index, "V_" + index, "V_Ave_All_Indexes" ] ].to_numpy()
        kmeans_per_k = [KMeans(n_clusters=k, random_state=42).fit(X_train_cluster) for k in range(1,
10)]
        inertias = [model.inertia_ for model in kmeans_per_k]
        inertias_dict[index] = inertias
        kmeans_per_k_dict[index] = kmeans_per_k
    return inertias_dict, kmeans_per_k_dict

dat1_inertias_dict, dat1_kmeans_per_k_dict = calculateClustersForIndexes(dataset = indexes_data_set1,
                           stock_indexes = [ "DJI", "S&P_500", "Nasdaq" ]
)
dat2_inertias_dict, dat2_kmeans_per_k_dict = calculateClustersForIndexes(dataset = indexes_data_set2,
                           stock_indexes = [ "MXUS", "MSDUUK", "MSDUJN" ]
)
```

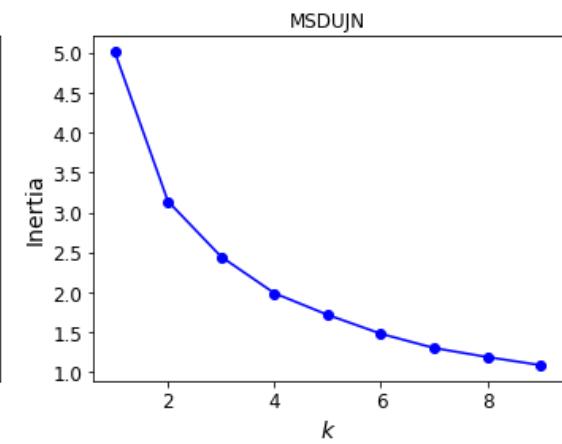
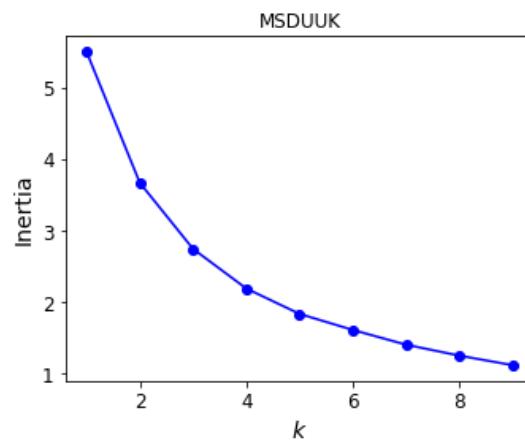
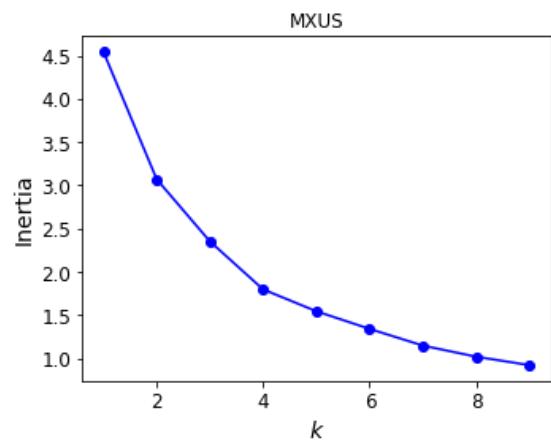
Plot Inertias vs K For All Indexes

```
In [322]: def plotInertias_For_All_Indexes(inertia_dict, stock_indexes) :  
  
    fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(18,4))  
    fig.suptitle('Inertias vs K for All Indexes', fontsize=18, y=1.07)  
  
    ax1.plot( range(1, 10), inertia_dict[stock_indexes[0]], "bo-" )  
    ax1.set_xlabel("$k$", fontsize=14)  
    ax1.set_ylabel("Inertia", fontsize=14)  
    ax1.set_title( stock_indexes[0] )  
  
    ax2.plot( range(1, 10), inertia_dict[ stock_indexes[1] ], "bo-" )  
    ax2.set_xlabel("$k$", fontsize=14)  
    ax2.set_ylabel("Inertia", fontsize=14)  
    ax2.set_title( stock_indexes[1] )  
  
    ax3.plot( range(1, 10), inertia_dict[ stock_indexes[2] ], "bo-" )  
    ax3.set_xlabel("$k$", fontsize=14)  
    ax3.set_ylabel("Inertia", fontsize=14)  
    ax3.set_title(stock_indexes[2] )  
  
    plt.show()  
  
plotInertias_For_All_Indexes( inertia_dict = dat1_inertias_dict,  
                           stock_indexes = [ "DJI", "S&P_500", "Nasdaq" ] )  
  
plotInertias_For_All_Indexes( inertia_dict = dat2_inertias_dict,  
                           stock_indexes = [ "MXUS", "MSDUUK", "MSDUJN" ] )
```

Inertias vs K for All Indexes



Inertias vs K for All Indexes



Centroids for all Indexes for K=4

```
In [359]: import numpy as np
import pandas as pd
from IPython.display import display_html

def displayCentroidsForAllIndexes(dat_kmeans_per_k_dict, stock_indexes, k) :

    html_dat = ""
    for index in stock_indexes:

        a = dat_kmeans_per_k_dict[ index ][k-1].cluster_centers_
        kmeans_opt_centroid = np.einsum('ij->ij', a[a[:,0].argsort(),:])
        df_a = pd.DataFrame(kmeans_opt_centroid).rename( columns={0: "R_" + index,
                                                                1: "V_" + index,
                                                                2 : "V_Ave_All_Indexes"} )

        df1_styler = df_a.style.set_table_attributes("style='display:inline'"). \
            set_caption(index + ' Centroids'). \
            set_table_styles([{
                'selector': 'caption',
                'props': [
                    ('color', 'blue'),
                    ('font-size', '16px'),
                    ('text-align', 'center') ]
            }])

        html_dat += df1_styler._repr_html_() + " &ampnbsp&ampnbsp&ampnbsp&ampnbsp&ampnbsp&ampnbsp&ampnbsp"

    print("\n")
    display_html(html_dat, raw=True)

displayCentroidsForAllIndexes(dat_kmeans_per_k_dict = dat1_kmeans_per_k_dict,
                             stock_indexes = ["DJI", "S&P_500", "Nasdaq"], k = 4 )

displayCentroidsForAllIndexes(dat_kmeans_per_k_dict = dat2_kmeans_per_k_dict,
                             stock_indexes = ["MXUS", "MSDUUK", "MSDUJN"], k = 4 )
```

DJI Centroids

	R_DJI	V_DJI	V_Ave_All_Indexes
0	-0.0492546	0.0941522	0.0983676
1	-0.0235677	0.0265586	0.030316
2	0.00677049	0.0129709	0.0148565
3	0.0298591	0.0365303	0.042341

S&P_500 Centroids

	R_S&P_500	V_S&P_500	V_Ave_All_Indexes
0	-0.0546674	0.101313	0.101457
1	-0.0245752	0.0291085	0.0316298
2	0.00691808	0.0135997	0.0149289
3	0.0330099	0.0399647	0.0431455

Nasdaq Centroids

	R_Nasdaq	V_Nasdaq	V_Ave_All_Indexes
0	-0.0757562	0.0810681	0.0660092
1	-0.024924	0.0323096	0.0269447
2	0.0124658	0.0175666	0.0151691
3	0.0473658	0.0588896	0.0474487

MXUS Centroids

	R_MXUS	V_MXUS	V_Ave_All_Indexes
0	-0.0605353	0.0896649	0.0800013
1	-0.0238612	0.0280177	0.0281822
2	0.0072913	0.0150212	0.0195132
3	0.0357966	0.0383795	0.0390106

MSDUUK Centroids

	R_MSDUUK	V_MSDUUK	V_Ave_All_Indexes
0	-0.0684867	0.0769637	0.0663507
1	-0.0240379	0.0281672	0.0271886
2	0.00798854	0.0173268	0.0193995
3	0.0403084	0.0406009	0.0367707

MSDUJN Centroids

	R_MSDUJN	V_MSDUJN	V_Ave_All_Indexes
0	-0.0437838	0.0771822	0.0739504
1	-0.0305874	0.0290289	0.0274579
2	0.00343401	0.0231735	0.0210083
3	0.0366376	0.0308732	0.0264983

6.2 Analysis of Network Topological Characteristics

Explanation of Similarities and Differences between this project and Reference 1

- The following section compares the network parameters derived with the ones published by Reference 1, for convenience their graphs are plotted next to one another to assist on the comparison
- All network parameters derived have about the same range of values as the ones published
- All network graphs have the same patterns, except with exceptions of some peaks, they are more pronounced in the reference implementations of the network measures.
- Even so Reference 1 uses the same Python library, NetworkX (Reference 7). Reference 1 was published (March 2019, most likely using version 2.2, version 2.3 was release on April 2019, version 2.4 October 2019. Significantly it should be noted that version 2.4 had a major number fixes, including new and updates to several of the networking measures derived with the package, see Pulls Requests in the 2.4 release
(https://networkx.github.io/documentation/stable/release/release_2.4.html)
(https://networkx.github.io/documentation/stable/release/release_2.4.html)
- Another comparison of the similarities is the number of unique network nodes derived, Reference 1 publishes 47, and our analysis 48 for the same dataset and time period.
- Finally, as all numerical features will be standarized, it is not expected to cause differences in the Machine Learning modeling.

6.2.1 Visualization of Network Parameters

```
In [47]: def plotNetworkParameterVsStockIndexes(df,
                                                index1_colname,
                                                index2_colname,
                                                index3_colname,
                                                network_parameter_column = "Ave_Deg_Centrality",
                                                network_parameter_column_name = "Average Degree Centrality",
                                                Figure_Num = "1",
                                                ) :
    data_training = df
    fig,ax = plt.subplots( figsize=(12,7) )
    #fig.set_figsize(figsize=(16, 7))
    ax.plot(data_training[ 'Date' ], data_training[index1_colname], "g--", linewidth=1 , label=index1_colname)
    ax.plot(data_training[ 'Date' ], data_training[index2_colname], "b--", linewidth=1 , label=index2_colname)
    ax.plot(data_training[ 'Date' ], data_training[index3_colname], "r--", linewidth=1 , label=index3_colname)
    ax.set_title("Figure " + Figure_Num + ". Date vs. Indexes Price & " + network_parameter_column_name,
               fontsize="18")
    ax.set_xlabel("$Date$", fontsize=14)
    ax.set_ylabel("Closing Price", fontsize=14)
    #fig.legend(loc='upper left', shadow=False, fontsize='x-large')

    # twin object for two different y-axis on the sample plot
    ax2=ax.twinx()
    # make a plot with different y-axis using second axis object
    ax2.plot(data_training[ 'Date' ], data_training[network_parameter_column], "--", linewidth=1 ,
              label=network_parameter_column_name, color ="gray")
    ax2.set_ylabel(network_parameter_column_name, fontsize=14)

    # Put a legend below current axis
    fig.legend(loc='lower center', bbox_to_anchor=(0.465, -0.01),
               fancybox=True, shadow=True, ncol=4, fontsize=12)

    plt.show()

from IPython.core.display import HTML
def center_plot () :
    return HTML("""
<style>
.output_png {
```

```
        display: table-cell;
        text-align: center;
        horizontal-align: middle;
    }

```

</style>

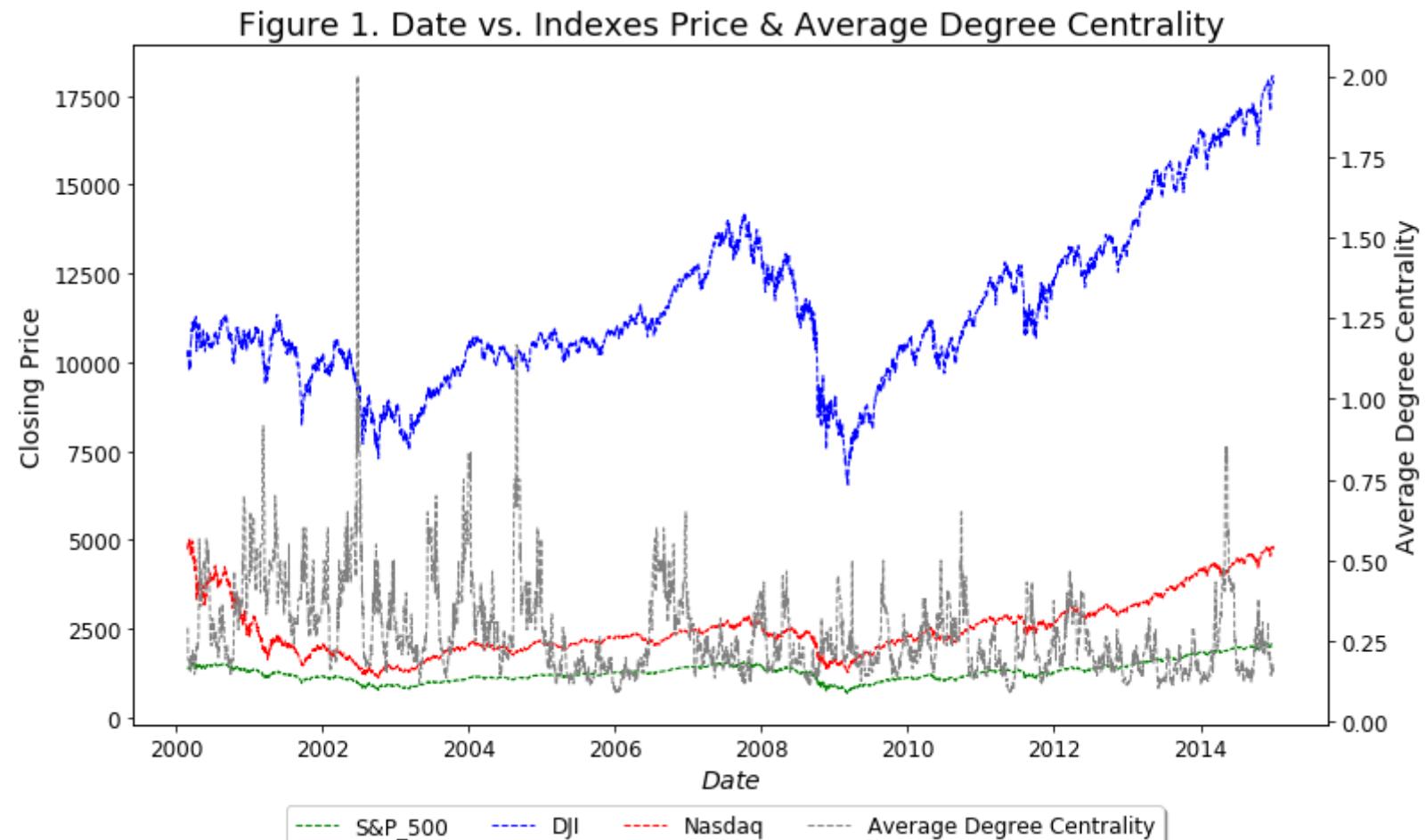
""")

6.2.1.1 Dataset 1 (*Dataset that matches the white paper*)

Average Degree Centrality

```
In [48]: plotNetworkParameterVsStockIndexes(df = data_training,
                                            network_parameter_column = "Ave_Deg_Centrality",
                                            network_parameter_column_name = "Average Degree Centrality",
                                            index1_colname = 'S&P_500', index2_colname = 'DJI', index3_colname = 'Nasd
                                            aq',
                                            Figure_Num = "1")

center_plot()
```



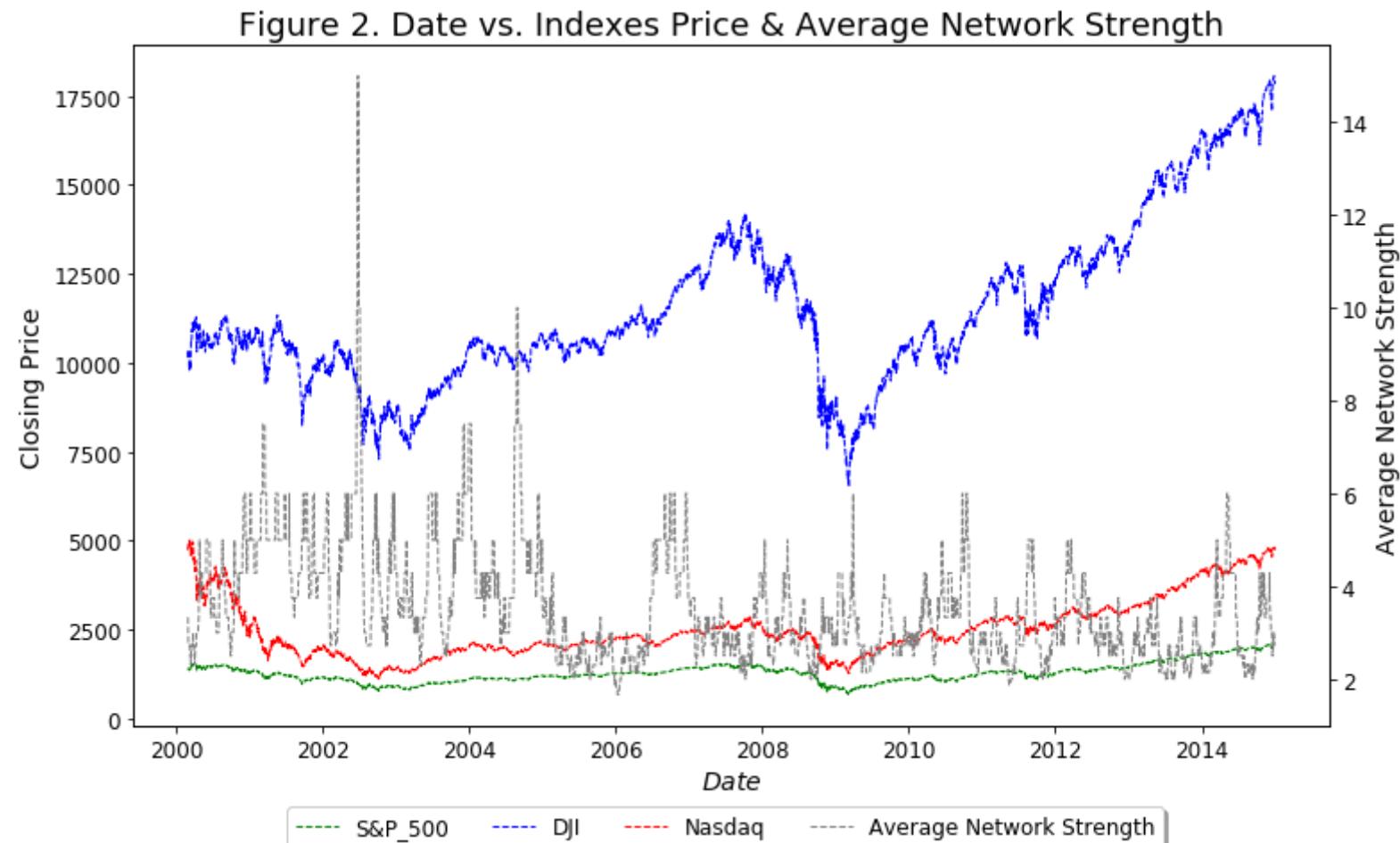
Out[48]:

Reference 1, Figure 7. Average Degree Centrality



Average Network Strength

```
In [49]: print("\n")
plotNetworkParameterVsStockIndexes(df = data_training,
                                    network_parameter_column = "Ave_Network_Strength",
                                    network_parameter_column_name = "Average Network Strength",
                                    index1_colname = 'S&P_500', index2_colname = 'DJI', index3_colname = 'Nasd
aq',
                                    Figure_Num = "2")
center_plot()
```



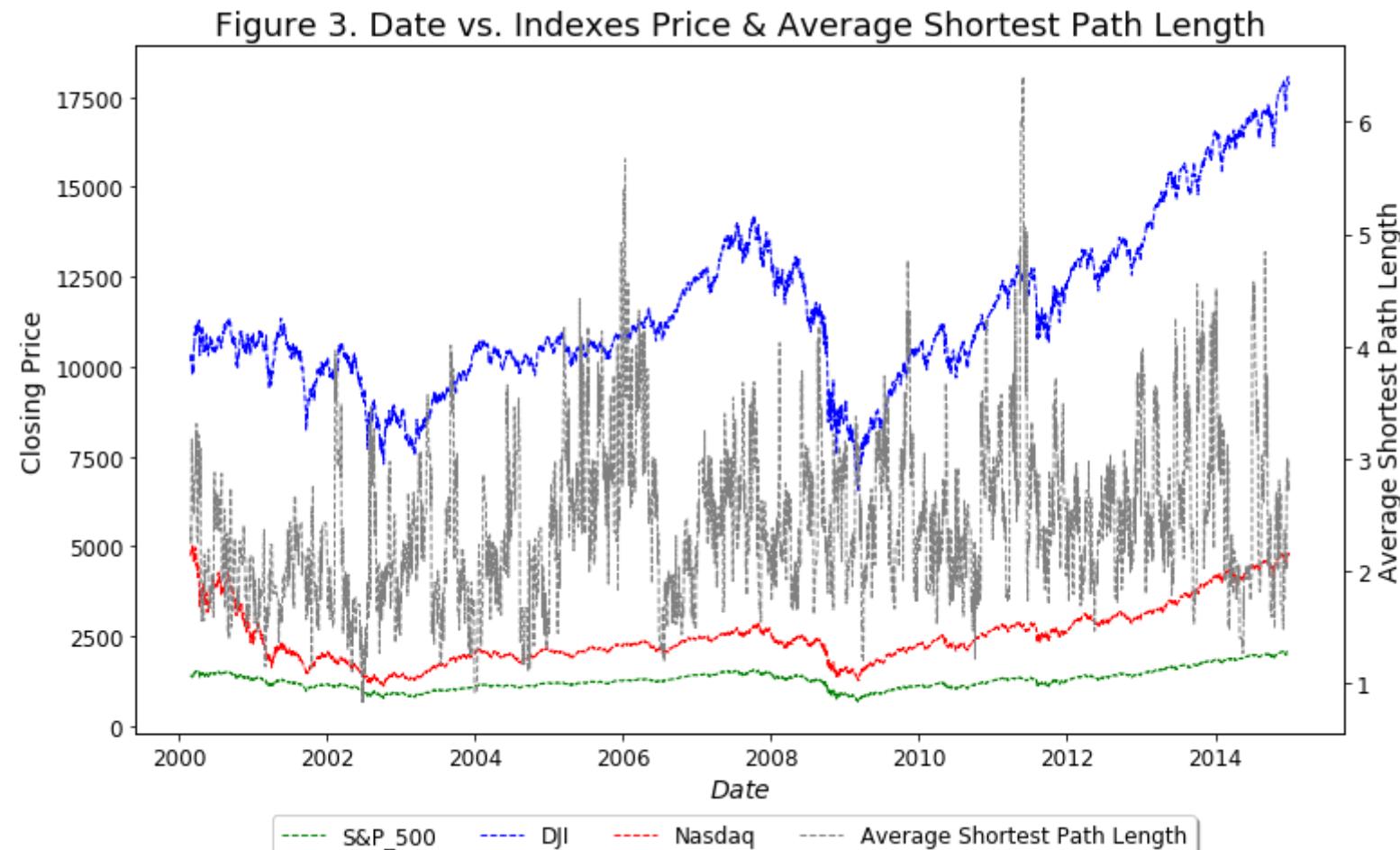
Out[49]:

Reference 1, Figure 4. Average Network Strength



Average Shortest Path Length

```
In [50]: print("\n")
plotNetworkParameterVsStockIndexes(df = data_training,
                                    network_parameter_column = "Ave_Shortest_PathLen",
                                    network_parameter_column_name = "Average Shortest Path Length",
                                    index1_colname = 'S&P_500', index2_colname = 'DJI', index3_colname = 'Nasd
aq',
                                    Figure_Num = "3")
center_plot()
```



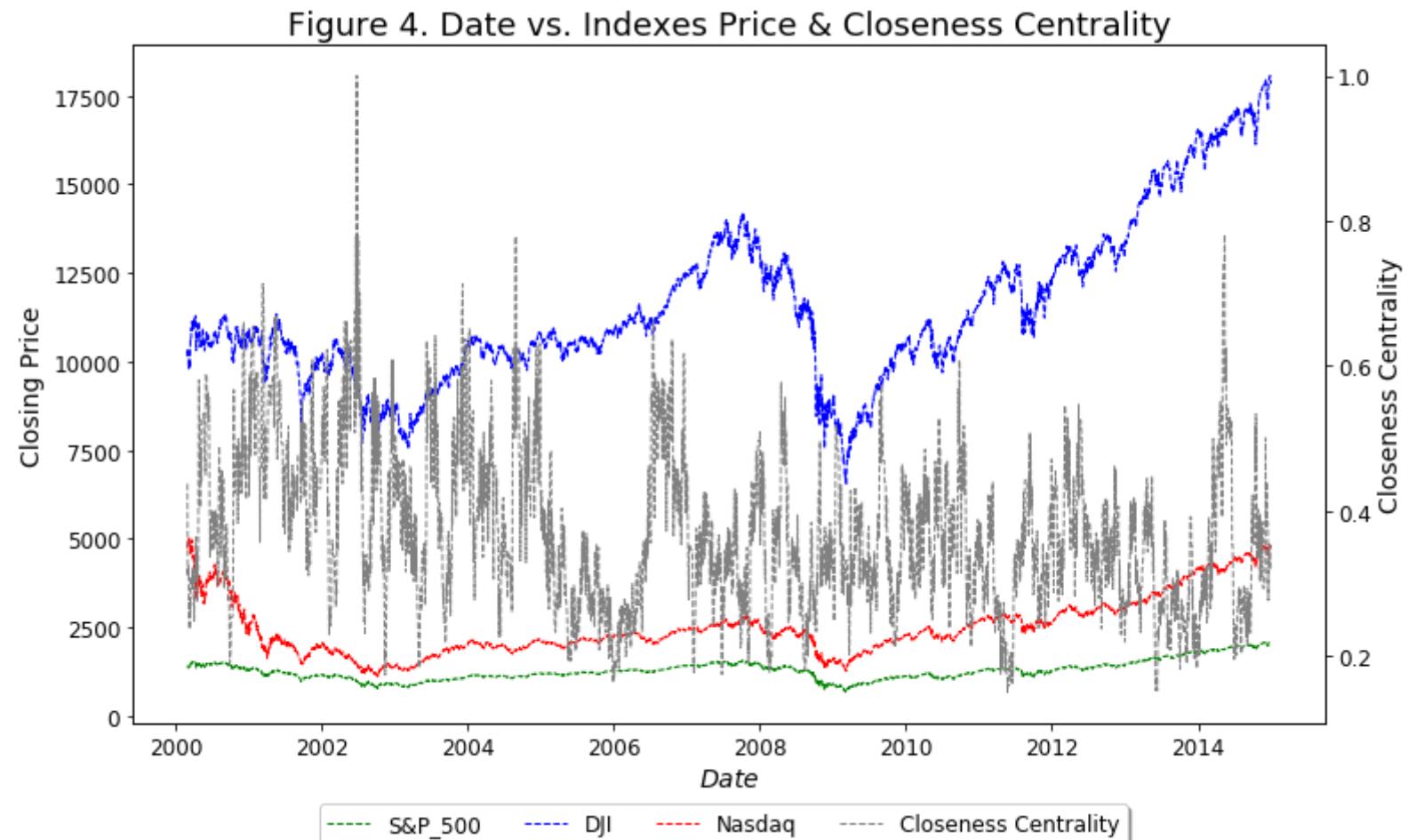
Out[50]:

Reference 1, Figure 5. Average Shortest Path Length



Closeness Centrality

```
In [51]: print("\n")
plotNetworkParameterVsStockIndexes(df = data_training,
                                    network_parameter_column = "Closenes_Centrality",
                                    network_parameter_column_name = "Closeness Centrality",
                                    index1_colname = 'S&P_500', index2_colname = 'DJI', index3_colname = 'Nasd
aq',
                                    Figure_Num = "4")
center_plot()
```



Out[51]:

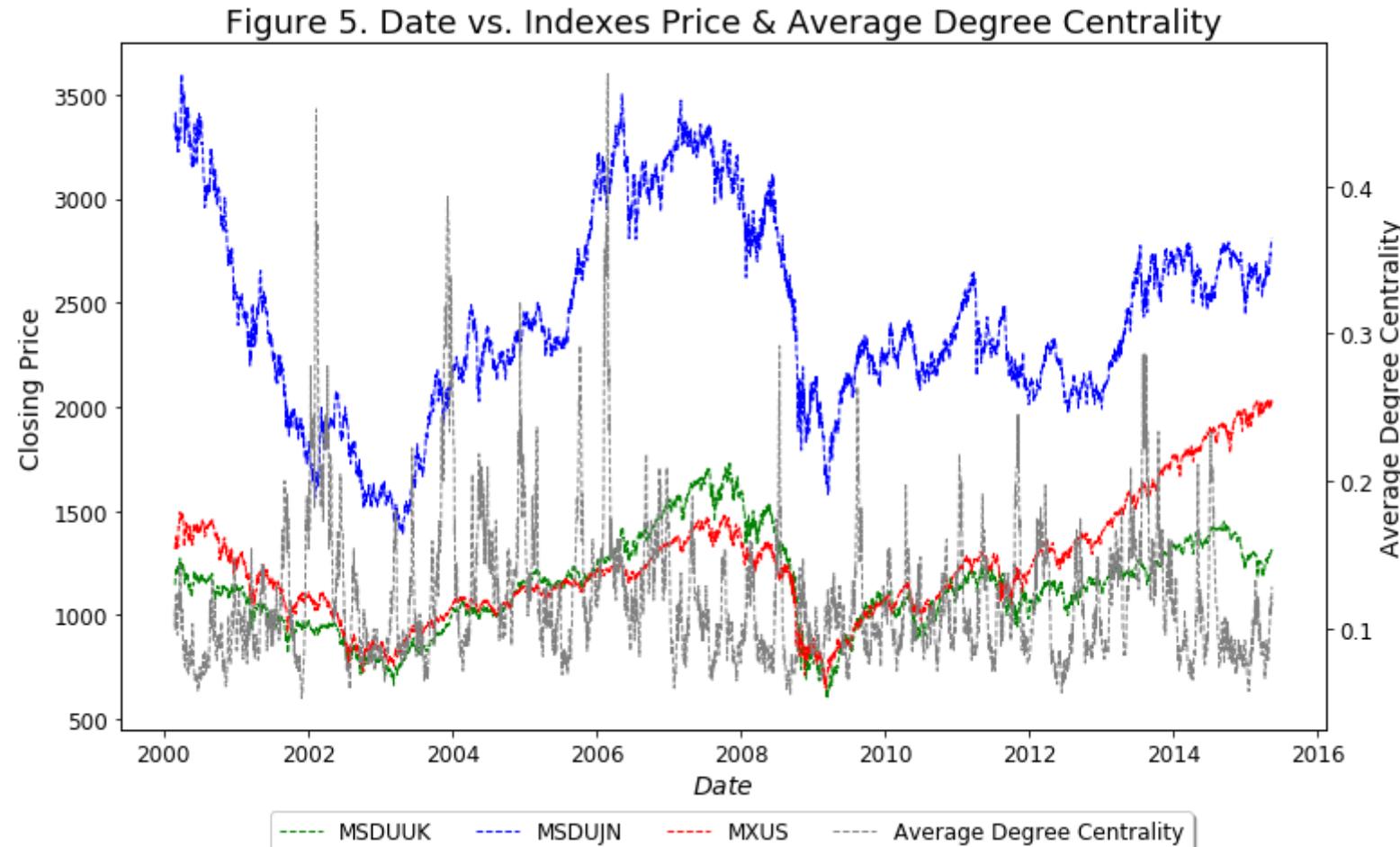
Reference 1, Figure 6. Closeness Centrality



6.2.1.2 Dataset 2

Average Degree Centrality

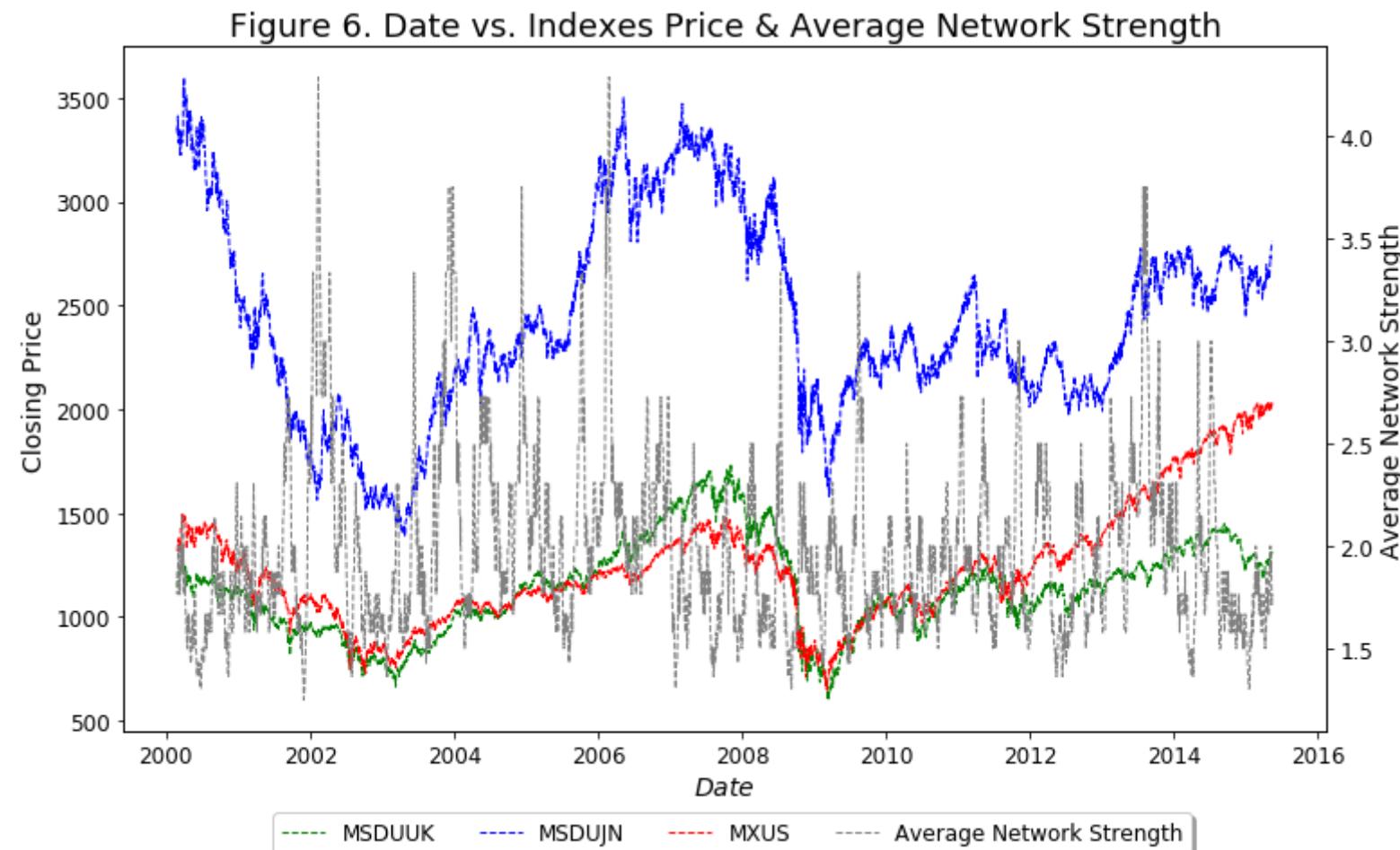
```
In [52]: plotNetworkParameterVsStockIndexes(df = indexes_data_set2,
                                             network_parameter_column = "Ave_Deg_Centrality",
                                             network_parameter_column_name = "Average Degree Centrality",
                                             index1_colname = 'MSDUUK', index2_colname = 'MSDUJN', index3_colname = 'MXUS',
                                             Figure_Num = "5")
center_plot()
```



Out[52]:

Average Network Strength

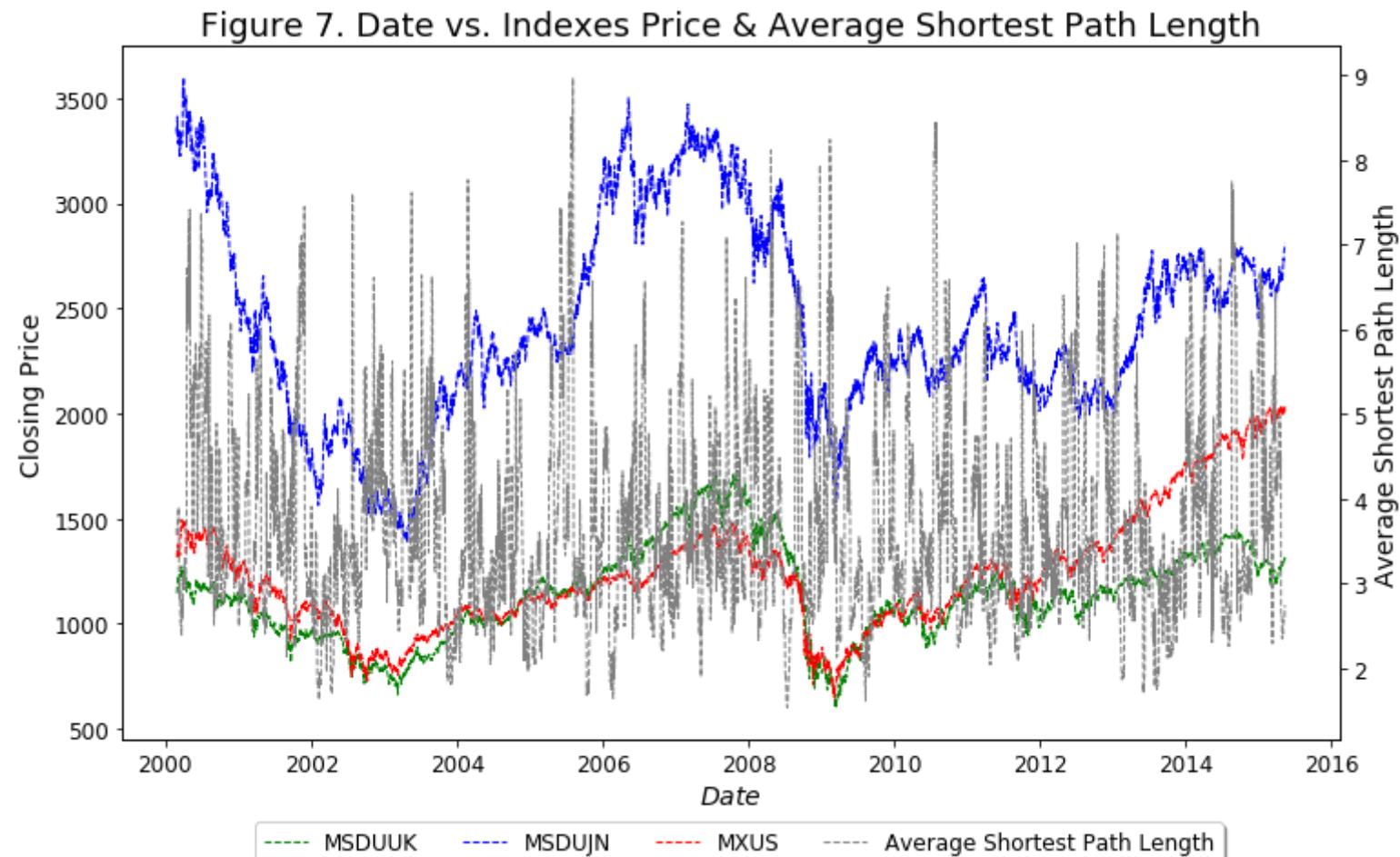
```
In [53]: print("\n")
plotNetworkParameterVsStockIndexes(df = indexes_data_set2,
                                    network_parameter_column = "Ave_Network_Strength",
                                    network_parameter_column_name = "Average Network Strength",
                                    index1_colname = 'MSDUUK', index2_colname = 'MSDUJN', index3_colname = 'MX
US',
                                    Figure_Num = "6")
center_plot()
```



Out[53]:

Average Shortest Path Length

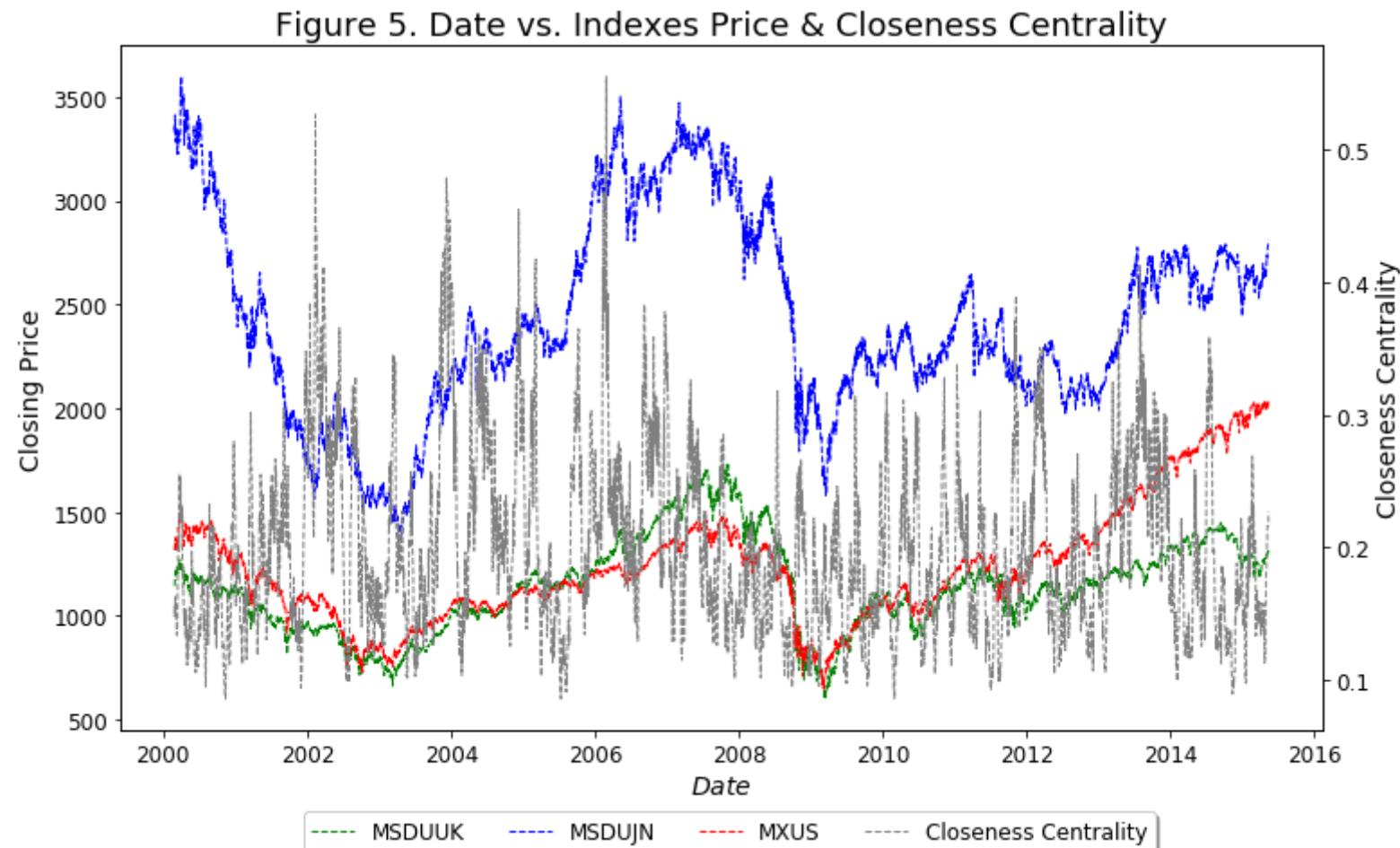
```
In [54]: print("\n")
plotNetworkParameterVsStockIndexes(df = indexes_data_set2,
                                    network_parameter_column = "Ave_Shortest_PathLen",
                                    network_parameter_column_name = "Average Shortest Path Length",
                                    index1_colname = 'MSDUUK', index2_colname = 'MSDUJN', index3_colname = 'MX
US',
                                    Figure_Num = "7")
center_plot()
```



Out[54]:

Closeness Centrality

```
In [55]: print("\n")
plotNetworkParameterVsStockIndexes(df = indexes_data_set2,
                                    network_parameter_column = "Closenes_Centrality",
                                    network_parameter_column_name = "Closeness Centrality",
                                    index1_colname = 'MSDUUK', index2_colname = 'MSDUJN', index3_colname = 'MX
US',
                                    Figure_Num = "5")
center_plot()
```



Out[55]:

6.3 Next-Day Stock Pattern Prediction Using Machine Learning Algorithms

6.3.1 Create Labels for ML Algorithms

- Per **section 4.3** of the white paper "**KNN and SVM algorithms are used to predict the next-day patterns of each stock index when the combination patterns of the three stock indexes and the corresponding 30-day network topological characteristics for the current day are known.**"
- Three binary labels will be created for classification, one for each index per dataset
- The binary labels for each index will have the following naming convention, and the value derived as follows:
 - `label_IndexName = 0 or 1`
 - If the daily return for the day is < 0, then the stock index label is set to **0**
 - If the daily return for the day is >= 0, then the stock index label is set to **1**
- Three multi-labels columns will be created for classification, one for each index per dataset
- The multi labels for each index will have the following naming convention, and the value derived as follows:
 - `f_label_IndexName = One of { S1, S2, S3, S4 }`
 - This is the index classification for the following day

```
In [56]: # returns two sets of labels for each day:  
#   label_Index      = [1,0]          ( 1 = next day's return is positive, 0 = next day's return is negative)  
#   label_f_Index = [S1,S2,S3,S4]  ( The index's network mode for the next day, this indicates the  
#                                     predicted behavior from the network topology parameters)  
  
def getStockIndexLabels(IndexName, df):  
  
    stock_index_Name = IndexName  
    r_stock_index_col_name = "r_" + stock_index_Name  
    f_stock_index_col_name = "f_" + stock_index_Name  
  
    num_rows = df.shape[0]  
    labels = np.empty( [df.shape[0], 1], dtype='uint8' )  
    f_labels_index = np.empty( [df.shape[0], 1], dtype='<U2' )  
  
    r       = df[r_stock_index_col_name].to_numpy()  
    f_index = df[f_stock_index_col_name].to_numpy()  
  
    for current_day in range(num_rows):  
  
        if (current_day + 1 < num_rows) :  
  
            if r[current_day+1] >= 0.00000 :  
                labels[current_day] = 1  
            else :  
                labels[current_day] = 0  
  
            f_labels_index[current_day] = f_index[current_day+1]  
  
        else :  
            # Last day, set the last day to the same value, no the following day  
            f_labels_index[current_day] = f_index[current_day]  
  
            if r[current_day] >= 0.00000 :  
                labels[current_day] = 1  
            else :  
                labels[current_day] = 0  
  
    return labels, f_labels_index  
  
# *** Classify each stock Index
```

```

indexes_data_set1["label_Nasdaq"], indexes_data_set1["f_label_Nasdaq"] = \
    getStockIndexLabels(IndexName = "Nasdaq", df = indexes_data_set1)
indexes_data_set1["label_S&P_500"], indexes_data_set1["f_label_S&P_500"] = \
    getStockIndexLabels(IndexName = "S&P_500", df = indexes_data_set1)
indexes_data_set1["label_DJI"], indexes_data_set1["f_label_DJI"] = \
    getStockIndexLabels(IndexName = "DJI", df = indexes_data_set1)

indexes_data_set2["label_MXUS"], indexes_data_set2["f_label_MXUS"] = \
    getStockIndexLabels(IndexName = "MXUS", df = indexes_data_set2)
indexes_data_set2["label_MSDUUK"], indexes_data_set2["f_label_MSDUUK"] = \
    getStockIndexLabels(IndexName = "MSDUUK", df = indexes_data_set2)
indexes_data_set2["label_MSDUJN"], indexes_data_set2["f_label_MSDUJN"] = \
    getStockIndexLabels(IndexName = "MSDUJN", df = indexes_data_set2)

```

In [57]: `indexes_data_set1[["Date", "f_Nasdaq", "f_label_Nasdaq", "f_S&P_500", "f_label_S&P_500", "f_DJI", "f_label_DJI"]].head()`

Out[57]:

	Date	f_Nasdaq	f_label_Nasdaq	f_S&P_500	f_label_S&P_500	f_DJI	f_label_DJI
40	2000-03-01	S2	S1	S2	S2	S4	S1
41	2000-03-02	S1	S1	S2	S2	S1	S2
42	2000-03-03	S1	S1	S2	S2	S2	S2
43	2000-03-06	S1	S2	S2	S3	S2	S4
44	2000-03-07	S2	S2	S3	S3	S4	S4

```
In [58]: indexes_data_set2[ ["Date", "f_MXUS", "f_label_MXUS", "f_MSDUUK", "f_label_MSDUUK",  
                      "f_MSDUJN", "f_label_MSDUJN"]].head()
```

Out[58]:

	Date	f_MXUS	f_label_MXUS	f_MSDUUK	f_label_MSDUUK	f_MSDUJN	f_label_MSDUJN
40	2000-02-28	S2	S2	S1	S1	S2	S2
41	2000-02-29	S2	S2	S1	S1	S2	S2
42	2000-03-01	S2	S2	S1	S1	S2	S1
43	2000-03-02	S2	S2	S1	S1	S1	S1
44	2000-03-03	S2	S1	S1	S2	S1	S4

```
In [59]: indexes_data_set1[ ["Date", "r_Nasdaq", "label_Nasdaq", "r_S&P_500", "label_S&P_500", "r_DJI", "label_DJI"]].head()
```

Out[59]:

	Date	r_Nasdaq	label_Nasdaq	r_S&P_500	label_S&P_500	r_DJI	label_DJI
40	2000-03-01	0.018436		0	0.009302	1	0.000949
41	2000-03-02	-0.006200		1	0.001862	1	0.002659
42	2000-03-03	0.033155		0	0.019643	0	0.019704
43	2000-03-06	-0.002025		0	-0.012777	0	-0.019155
44	2000-03-07	-0.011691		1	-0.025965	1	-0.037514

```
In [60]: indexes_data_set2[ ["Date", "r_MXUS", "label_MXUS", "r_MSDUUK", "label_MSDUUK",  
                      "r_MSDUJN", "label_MSDUJN"]].head()
```

Out[60]:

	Date	r_MXUS	label_MXUS	r_MSDUUK	label_MSDUUK	r_MSDUJN	label_MSDUJN
40	2000-02-28	0.011189		1	-0.019126	1	0.011675
41	2000-02-29	0.013950		1	0.015496	1	-0.009707
42	2000-03-01	0.007480		1	0.022989	1	0.025828
43	2000-03-02	0.005042		1	0.007229	1	-0.005643
44	2000-03-03	0.019126		0	0.011745	1	-0.013166

6.3.2 Create Training & Test Sets

Dataset 1

Split

- The training and testing sets are created according to the same time periods define in section 4.3 of the white paper
- Section 4.3 : *Based on the theory of cross-validation [42], and in order to keep the year intact and ensure the continuity of the years, we used the closing prices of the S&P 500, NASDAQ, and DJIA from 1 January 2000 to 31 December 2014 as the training sample data set. The testing sample data set used the closing prices of the three indices from 1 January 2015 to 31 December 2017.*

```
In [61]: indexes_data_training_set_1 = \
    indexes_data_set1[ indexes_data_set1['Date'].dt.strftime('%Y-%m-%d') < '2015-01-01'].dropna()
indexes_data_testing_set_1 = \
    indexes_data_set1[ indexes_data_set1['Date'].dt.strftime('%Y-%m-%d') >= '2015-01-01']
indexes_data_testing_set_1 = \
    indexes_data_testing_set_1[ indexes_data_testing_set_1['Date'].dt.strftime('%Y-%m-%d') < '2018-01-01']

print("Length of training set = ", len(indexes_data_training_set_1) )
print("Length of testing set = ", len(indexes_data_testing_set_1) )
print(np.unique( indexes_data_training_set_1['f_label_Nasdaq'], return_counts = True))
print(np.unique( indexes_data_training_set_1['f_label_DJI'], return_counts = True))
print(np.unique( indexes_data_training_set_1['f_label_S&P_500'], return_counts = True))
```

```
Length of training set = 3733
Length of testing set = 755
(array(['S1', 'S2', 'S3', 'S4'], dtype=object), array([1708, 328, 255, 1442]))
(array(['S1', 'S2', 'S3', 'S4'], dtype=object), array([ 338, 1754, 1367, 274]))
(array(['S1', 'S2', 'S3', 'S4'], dtype=object), array([ 559, 1488, 1178, 508]))
```

```
In [62]: indexes_data_training_set_1.head()
```

Out[62]:

	Date	S&P_500	Nasdaq	DJI	r_Nasdaq	R_Nasdaq	V_Nasdaq	V_Ave_Nasdaq	r_S&P_500	R_S&P_500	...	Ave_Deg_Centrality
40	2000-03-01	1379.19	4784.08	10137.93	0.018436	0.050094	0.030678	0.046648	0.009302	0.013504	...	0.291667
41	2000-03-02	1381.76	4754.51	10164.92	-0.006200	0.029208	0.033670	0.041145	0.001862	0.020716	...	0.233333
42	2000-03-03	1409.17	4914.79	10367.20	0.033155	0.068260	0.038893	0.037444	0.019643	0.055299	...	0.190909
43	2000-03-06	1391.28	4904.85	10170.51	-0.002025	0.068995	0.038511	0.036634	-0.012777	0.031565	...	0.190909
44	2000-03-07	1355.62	4847.84	9796.04	-0.011691	0.031675	0.042097	0.036770	-0.025965	-0.007935	...	0.190909

5 rows × 31 columns

Dataset 2

Split

- The training and testing sets are created to be different than dataset 1 to test the methodology with different indexes and different time periods

```
In [63]: indexes_data_training_set_2 = \
    indexes_data_set2[ ( indexes_data_set2['Date'].dt.strftime('%Y-%m-%d') >= '2002-01-01' ) & \
                      ( indexes_data_set2['Date'].dt.strftime('%Y-%m-%d') < '2013-01-01' ) ].dropna()

indexes_data_testing_set_2 = \
    indexes_data_set2[ indexes_data_set2['Date'].dt.strftime('%Y-%m-%d') >= '2013-01-01' ].dropna()

print("Length of training set = ", len(indexes_data_training_set_2) )
print("Length of testing set = ", len(indexes_data_testing_set_2) )
```

Length of training set = 2835

Length of testing set = 596

6.3.3 Re-usable Functions to Create and Execute Different Experiments

```
In [64]: from sklearn.preprocessing import StandardScaler, OneHotEncoder, MinMaxScaler, LabelEncoder
from sklearn.linear_model import SGDClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from sklearn.neighbors import KNeighborsClassifier
from sklearn.cluster import KMeans

from sklearn.model_selection import TimeSeriesSplit
from sklearn.metrics import precision_score, recall_score
from sklearn.model_selection import cross_val_predict
from sklearn.metrics import confusion_matrix

import warnings
warnings.filterwarnings('ignore')

# ***
# *** Function to create experiment datasets (X, y_binary_label, y_multi_label)
# ***

def createExperimentDatasets (dataset, x_features_names, y_label_name, y_ml_label_name) :

    X_train      = dataset[x_features_names]
    y_train      = dataset[y_label_name]
    y_train_ml   = dataset[y_ml_label_name]

    X_train      = X_train.to_numpy()
    y_train      = y_train.to_numpy()
    y_train_ml   = y_train_ml.to_numpy()

    #y_train.shape=(y_train.shape[0], 1)
    #y_test.shape=(y_test.shape[0],1)

    y_train_ml = y_train_ml.astype('<U2')

    return X_train, y_train, y_train_ml

# *** test function: createExperimentDatasets

x_features_names = [ "Ave_Deg_Centrality", "Ave_Network_Strength", "Ave_Shortest_PathLen",
                     "Closenes_Centrality", "r_S&P_500", "R_S&P_500", "V_S&P_500" ]
y_label_name     = [ "label_S&P_500" ]
y_ml_label_name = [ "f_label_S&P_500" ]
```

```

x_train, y_train, y_train_ml = \
    createExperimentDatasets(dataset = indexes_data_training_set_1,
                            x_features_names = x_features_names, y_label_name = y_label_name,
                            y_ml_label_name = y_ml_label_name)

# ***
# *** Function to transform experiment datasets
# ***

def transfromExperimentDatasets (x_train, y_train, y_train_ml) :

    scaler = MinMaxScaler()
    std_scaler = StandardScaler()
    str_encoder = LabelEncoder()

    x_train = std_scaler.fit_transform(x_train)
    y_train_ml = str_encoder.fit_transform(y_train_ml)
    y_train = y_train.reshape(-1,1)
    y_train_ml = y_train_ml.reshape(-1,1)

    return x_train, y_train, y_train_ml

# *** test function: transfromExperimentDatasets

x_train, y_train, y_train_ml = transfromExperimentDatasets (x_train, y_train, y_train_ml)

# ***
# *** This function takes a Confusion Matrix that is 4 x 4, and reduces it to a 2 x 2
# *** Combines S1 and S2 together, and S3 and S4 together
# ***

def calculateCombineClassificationsMeasures( confusion_matrix_4_by_4, print_results = False ) :
    cm_ml = confusion_matrix_4_by_4
    s1_s2_q1 = cm_ml[0,0] + cm_ml[0,1] + cm_ml[1,0] + cm_ml[1,1]
    s3_s4_q3 = cm_ml[2,0] + cm_ml[3,0] + cm_ml[2,1] + cm_ml[3,1]
    s1_s2_q2 = cm_ml[0,2] + cm_ml[0,3] + cm_ml[1,2] + cm_ml[1,3]
    s3_s4_q4 = cm_ml[2,2] + cm_ml[2,3] + cm_ml[3,2] + cm_ml[3,3]
    compacted_confusion_matrix = np.array ( [s1_s2_q1, s1_s2_q2, s3_s4_q3, s3_s4_q4 ] )
    compacted_confusion_matrix = compacted_confusion_matrix.reshape(2,2)

    accuracy = ( (s1_s2_q1 + s3_s4_q4)/(s1_s2_q1 + s3_s4_q3 + s1_s2_q2 + s3_s4_q4 ) )
    precision = ( s3_s4_q4/( s3_s4_q4 + s1_s2_q2 ) )

```

```

recall = ( s3_s4_q4/( s3_s4_q4 + s3_s4_q3) )

if print_results == True :
    print("\nCompacted CM: \n", compacted_confusion_matrix)
    print("S1S2 & S3S4 Accuracy = ", accuracy )
    print("S1S2 & S3S4 Precision = ", precision )
    print("S1S2 & S3S4 Recall. = ", recall )

return compacted_confusion_matrix, accuracy, precision, recall

# ***
# *** Execute an experiment
# ***
# ***      Returns:  dataframe_results, dataframe_exp_details, confusion_matrix_for_binary_label
# ***                  confusion_matrix_for_multi_label, confusion_matrix_for_combine_multi_label

def executeExperiment(model_clf, experiment_name, index_name, dataset_name,
                      dataset,
                      x_features_names, y_label_name, y_ml_label_name,
                      cv = 10, print_results = True, description = "") :

    # *** Create specific set of features for the experiment

    X_train, y_train, y_train_ml = createExperimentDatasets(dataset, x_features_names,
                                                            y_label_name, y_ml_label_name)

    # *** Transform features for the experiment

    X_train, y_train, y_train_ml = transfromExperimentDatasets (X_train, y_train, y_train_ml)

    # *** Cross Validate Analysis on Binary Label

    y_train_predict = cross_val_predict(model_clf, X_train, y_train, cv=cv, n_jobs = -1)
    cm = confusion_matrix(y_train, y_train_predict)

    if model_clf.__class__.__name__ != "KMeans" :
        precision_score_ml = precision_score(y_train, y_train_predict)
        recall_score_ml     = recall_score(y_train, y_train_predict)
        accuracy_score_ml   = accuracy_score(y_train, y_train_predict)
    else :
        precision_score_ml = precision_score(y_train, y_train_predict, average="weighted")
        recall_score_ml     = recall_score(y_train, y_train_predict, average="weighted")
        accuracy_score_ml   = accuracy_score(y_train, y_train_predict)

```

```

# Cross Validate Analysis Multi_Label

y_train_predict_ml = cross_val_predict(model_clf, x_train, y_train_ml, cv=cv, n_jobs = -1)
cm_ml = confusion_matrix(y_train_ml, y_train_predict_ml)
precision_score_ml = precision_score(y_train_ml, y_train_predict_ml, average="weighted")
recall_score_ml = recall_score(y_train_ml, y_train_predict_ml, average="weighted")
accuracy_score_ml = accuracy_score(y_train_ml, y_train_predict_ml)

# Compact ML results ( that is: S1S2 & S3S4)
cm_ml_compact, accuracy_cp, precision_cp, recall_cp = \
    calculateCombineClassificationsMeasures(cm_ml, print_results = False )

if print_results == True :
    print("***** Results for Estimator: ", model_clf.__class__.__name__)

    print("\n\t*** Binary Label [0,1] Cross Validation Analysis Summary")
    print("\t\tConfusion Matrix: \n", cm)
    print("\t\tPrecision score: ", precision_score_ml )
    print("\t\tRecall score: ", recall_score_ml )
    print("\t\tAccuracy score: ", accuracy_score_ml )

    print("\n\t*** Multi Label [S1,S2,S3,S4] Cross Validation Analysis Summary")
    print("\t\tConfusion Matrix: \n", cm_ml)
    print("\t\tPrecision score: ", precision_score_ml )
    print("\t\tRecall score: ", recall_score_ml )
    print("\t\tAccuracy score: ", accuracy_score_ml )

    print("\n\t*** Compacted Multi Label [S1S2, S3S4] Analysis Summary")
    print("\t\tConfusion Matrix: \n", cm_ml_compact)
    print("\t\tPrecision score: ", precision_cp )
    print("\t\tRecall score: ", recall_cp)
    print("\t\tAccuracy score: ", accuracy_cp )

# Save results to a Data Frame

data = { 'Experiment Name' : [experiment_name],
         'Experiment Description' : [description],
         'Dataset' : [dataset_name],
         'Index' : [ index_name ],
         'Classifier' : [model_clf.__class__.__name__],
         'CV' : [cv],
         'BL_Precision' : [precision_score_ml], 'BL_Recall' : [recall_score_ml],

```

```

        'BL_Accuracy' : [accuracy_score_b1],
        'ML_Precision' : [precision_score_ml], 'ML_Recall' : [recall_score_ml],
        'ML_Accuracy' : [accuracy_score_ml],
        'Combine_ML_Precision' : [precision_cp], 'Combine_ML_Recall' : [recall_cp],
        'Combine_ML_Accuracy' : [accuracy_cp]
    }

    data_experiment_details = { 'Experiment Name' : [experiment_name],
                                'Description' : [description],
                                'Features' : [x_features_names],
                                'y_label_col' : [y_label_name],
                                'y_ml_label_col' : [y_ml_label_name]
    }

    return pd.DataFrame(data), pd.DataFrame(data_experiment_details), cm, cm_ml, cm_ml_compact, model_clf
}

# *** test function: executeExperiment

index_name = "S&P_500"
experiment_name = "Experiment 1"
dataset_name = "US Market Indexes"
dataset = indexes_data_training_set_1

x_features_names = [ "Ave_Deg_Centrality", "Ave_Network_Strength", "Ave_Shortest_PathLen",
                     "Closenes_Centrality", "r_" + index_name, "R_" + index_name, "V_" + index_name ]
y_label_name = [ "label_" + index_name]
y_ml_label_name = [ "f_label_" + index_name]

# *** SGD Classifier
results_df_1, results_df_exp_details, cm_1, cm_ml_1, cm_ml_compact_1, model_clf_fitted =\
    executeExperiment(model_clf = SGDClassifier(random_state=42), experiment_name = experiment_name,
                      index_name = index_name, dataset_name = dataset_name,
                      dataset = dataset,
                      x_features_names = x_features_names, y_label_name = y_label_name,
                      y_ml_label_name = y_ml_label_name, cv = 10, print_results = False,
                      description = "some random experiment")
# ***
# *** Execute a set of experiments
# ***
# ***      The f() executes the same of permutations pass in the dictionary variable, experiments

```



```

        y_ml_label_name = y_ml_label_name,
        cv = experiment.get("cv"),
        print_results = False,
        description = experiment.get("description"))

    curr_results_df[ "Model_Params" ] = str( model_clf.get_params() )
    curr_results_df[ "Job_ID" ] = i
    results_df = results_df.append(curr_results_df)
    results_df_details = results_df_details.append(curr_results_df_exp_details)
    models_dict[i] = model_clf_fitted
    i += 1

    return results_df, results_df_details, models_dict

def getBestClassifiersForEachIndex (results_df, metric = "Combine_ML_Accuracy") :
    results_df_reindex = results_df.reset_index(drop=True)
    idx = results_df_reindex. \
        groupby(['Classifier', 'Index'])[metric]. \
        transform(max) == results_df_reindex[metric]
    #print(results_df_reindex[idx])
    #print("len after drop: " , len( results_df_reindex[idx].drop_duplicates(subset = ['Index']) ) )
    return results_df_reindex[idx].drop_duplicates(subset = ['Index'])

def getOptimizedModelsDict (results_df, models_fitted, metric = "Combine_ML_Accuracy" ) :
    # *** Find best classifiers per Index
    optimum_models_metrics_df = getBestClassifiersForEachIndex(results_df, metric)

    # *** Create Each Model and Save in a Dictionary

    models_dict = {}
    nmodels = len(optimum_models_metrics_df)

    #classifier_name = optimum_models_metrics_knn_df[ "Classifier" ].to_numpy()
    #index = optimum_models_metrics_knn_df[ "Index" ].to_numpy()
    #model_params = optimum_models_metrics_knn_df[ "Model_Params" ].to_numpy()
    #for n in range(nmodels) :
    #    #print("Loaded Params: \n", model_params[n])
    #    params = eval( model_params[n] )
    #    model_clf = eval(classifier_name[n])()
    #    model_clf.set_params( **params )

```

```

#     #print("Re-loaded from created model: \n", model_clf.get_params())
#     models_dict[index[n]] = model_clf

# Create dictionary of fitted models

indexes = optimum_models_metrics_df[ "Index" ].to_numpy()
job_key = optimum_models_metrics_df[ "Job_ID" ].to_numpy()

for n in range(nmodels) :
    #print("Index : ", indexes[n], "Job = ", job_key[n] )
    models_dict[ indexes[n] ] = models_fitted[ job_key[n] ]

# return fit models & summary of their metrics

return models_dict, optimum_models_metrics_df


def executePrediction(model_clf,
                      FitModels,
                      prediction_name,
                      index_name,
                      dataset_name,
                      dataset,
                      x_features_names,
                      y_label_name,
                      y_ml_label_name,
                      print_results = False,
                      description = " " ) :

    # *** Create specific set of features for the experiment

    X_train, y_train, y_train_ml = createExperimentDatasets(dataset, x_features_names,
                                                            y_label_name, y_ml_label_name)
    # *** Transform features for the experiment

    X_train, y_train, y_train_ml = transfromExperimentDatasets (X_train, y_train, y_train_ml)

    # Predict Using Multi_Label
    if FitModels == True :
        model_clf.fit(X_train, y_train_ml)
    y_train_predict_ml = model_clf.predict(X_train)
    cm_ml              = confusion_matrix(y_train_ml, y_train_predict_ml)
    precision_score_ml = precision_score(y_train_ml, y_train_predict_ml, average="weighted")

```

```

recall_score_ml      = recall_score(y_train_ml, y_train_predict_ml, average="weighted")
accuracy_score_ml   = accuracy_score(y_train_ml, y_train_predict_ml)

# Compact ML results ( that is: S1S2 & S3S4)
cm_ml_compact, accuracy_cp, precision_cp, recall_cp = \
                                calculateCombineClassificationsMeasures(cm_ml, print_results = False )

# Save results to a Data Frame

data1 = { 'Classifier' : [model_clf.__class__.__name__],
          'Model'      : [ "Combine ML"],
          'Metric'     : [ "Accuracy"],
          index_name   : [ accuracy_cp ] }

data2 = { 'Classifier' : [model_clf.__class__.__name__],
          'Model'      : [ "Combine ML"],
          'Metric'     : [ "Precision"],
          index_name   : [ precision_cp ] }

data3 = { 'Classifier' : [model_clf.__class__.__name__],
          'Model'      : [ "Combine ML"],
          'Metric'     : [ "Recall"],
          index_name   : [ recall_cp ] }

data4 = { 'Classifier' : [model_clf.__class__.__name__],
          'Model'      : [ "Multi Label"],
          'Metric'     : [ "Accuracy"],
          index_name   : [ accuracy_score_ml ] }

data5 = { 'Classifier' : [model_clf.__class__.__name__],
          'Model'      : [ "Multi Label"],
          'Metric'     : [ "Precision"],
          index_name   : [ precision_score_ml ] }

data6 = { 'Classifier' : [model_clf.__class__.__name__],
          'Model'      : [ "Multi Label"],
          'Metric'     : [ "Recall"],
          index_name   : [ recall_score_ml ] }

results_df  = pd.DataFrame(data1)
results_df = results_df.append( pd.DataFrame(data2) )
results_df = results_df.append( pd.DataFrame(data3) )
results_df = results_df.append( pd.DataFrame(data4) )

```



```

        y_ml_label_name = y_ml_label_name,
        print_results = False,
        description = prediction.get("description"))

    if job == 0 :
        results_df = results_df.append(curr_results_df)
    else :
        results_df[index_name] = curr_results_df[index_name].to_numpy()

    # Save Model, Confusion Matrix for ML, Confusion Matrix Combine ML in a dictionary
    # dict key = {classifier_name}_{index_name}
    models_dict[model_clf_return.__class__.__name__ + index_name] = model_clf_return
    cm_ml_dict[model_clf_return.__class__.__name__ + index_name] = cm_ml
    cm_ml_compact_dict[model_clf_return.__class__.__name__ + index_name] = cm_ml_compact

    n += 1
    job += 1

    return results_df, models_dict, cm_ml_dict, cm_ml_compact_dict

```

6.3.4 Initial Exploratory Modeling for Analysis

6.3.4.1 Execute Experiments against Several Machine Learning Models, Datasets, Features' Set

- **Description of Experiments**

- **Each experiment consists of:**
 - Evaluating a set of features against a set of models, classifiers, two distinct datasets with different time periods, and three different stock indexes per training dataset.
 - Run five different classifiers: SGD, SVC, KNN, Random Forest
 - Classification analysis against two distinct labels:
 - Binary Label: [0,1], 0 = Next Day Closing Price will be lower, 1 = Next Day Price will be higher
 - Multi Label: [S1, S2, S3, S4], These labels are indications of the magnitude of price changes, either up or down. S1 & S2 are associated with a next day higher closing price, and S3 & S4 with next day lower price.
 - Cross validation analysis:
 - Apply each classifier against a Binary Label for predicting price change using a ten-fold cross validation against entire dataset
 - Apply each classifier against a Multi Label for predicting price movement using a ten-fold cross validation against entire dataset
 - Derive Combine results of Multi Label Analysis, merging S1 & S2 labels, and S3 & S4 labels
- **Experiment 1:**
 - Purpose: Evaluate all Network Derived Features & all Financial Index Measures
 - Evaluate three different market indexes: S&P 500, Nasdaq, DJI
- **Experiment 2:**
 - Purpose: Evaluate Only Network Features
 - Evaluate three different market indexes: S&P 500, Nasdaq, DJI
- **Experiment 3:**
 - Purpose: Evaluate Only Financial Index Features
 - Evaluate three different market indexes: S&P 500, Nasdaq, DJI
- **Experiment 4:**
 - Purpose: Evaluate all Network Derived Features & all Financial Index Measures
 - Evaluate three different market indexes: MXUS, MSDUUK, MSDUJN
- **Experiment 5:**
 - Purpose: Evaluate Only Network Features
 - Evaluate three different market indexes: MXUS, MSDUUK, MSDUJN
- **Experiment 6:**
 - Purpose: Evaluate Only Financial Index Features
 - Evaluate three different market indexes: MXUS, MSDUUK, MSDUJN

```
In [109]: models = [ SGDClassifier(random_state=42), SVC(random_state=42, kernel="rbf"), KNeighborsClassifier(n_jobs=-1),
                    RandomForestClassifier(n_jobs=-1, random_state=42, max_depth = 40, oob_score = True) ]
```



```
experiment_1 = { 'experiment_name' : "Experiment 1",
                 'description' : "Evaluate all Network Features & all Financial Index Measures",
                 #'indexes' : [ "S&P_500" ],
                 'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                 'dataset_name' : "US Market Indexes",
                 'x_features_names' : [ "Ave_Deg_Centrality", "Ave_Network_Strength", "Ave_Shortest_PathLen",
                                         "Closenes_Centrality", "r_{}", "R_{}",
                                         "V_{}" ],
                 'y_label_name' : "label_{}",
                 'y_ml_label_name' : "f_label_{}",
                 'cv' : 10,
                 'models' : models,
                 'dataset' : indexes_data_training_set_1 }
```



```
experiment_2 = { 'experiment_name' : "Experiment 2",
                 'description' : "Evaluate Only Network Features",
                 'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                 'dataset_name' : "US Market Indexes",
                 'x_features_names' : [ "Ave_Deg_Centrality", "Ave_Network_Strength", "Ave_Shortest_PathLen",
                                         "Closenes_Centrality" ],
                 'y_label_name' : "label_{}",
                 'y_ml_label_name' : "f_label_{}",
                 'cv' : 10,
                 'models' : models,
                 'dataset' : indexes_data_training_set_1 }
```



```
experiment_3 = { 'experiment_name' : "Experiment 3",
                 'description' : "Evaluate Only Financial Index Features",
                 'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                 'dataset_name' : "US Market Indexes",
                 'x_features_names' : [ "r_{}", "R_{}", "V_{}" ],
                 'y_label_name' : "label_{}",
                 'y_ml_label_name' : "f_label_{}",
                 'cv' : 10,
                 'models' : models,
```

```

        'dataset' : indexes_data_training_set_1 }

experiment_4 = { 'experiment_name' : "Experiment 4",
                 'description' : "Evaluate all Network Features & all Financial Index Measures",
                 'indexes' : [ "MXUS", "MSDUUK", "MSDUJN"],
                 'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                 'x_features_names' : [ "Ave_Deg_Centrality", "Ave_Network_Strength", "Ave_Shortest_PathLen",
                                         "Closenes_Centrality", "r_{}", "R_{}", "V_{}" ],
                 'y_label_name' : "label_{}",
                 'y_ml_label_name' : "f_label_{}",
                 'cv' : 10,
                 'models' : models,
                 'dataset' : indexes_data_training_set_2 }

experiment_5 = { 'experiment_name' : "Experiment 5",
                 'description' : "Evaluate Only Network Features",
                 'indexes' : [ "MXUS", "MSDUUK", "MSDUJN"],
                 'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                 'x_features_names' : [ "Ave_Deg_Centrality", "Ave_Network_Strength", "Ave_Shortest_PathLen",
                                         "Closenes_Centrality" ],
                 'y_label_name' : "label_{}",
                 'y_ml_label_name' : "f_label_{}",
                 'cv' : 10,
                 'models' : models,
                 'dataset' : indexes_data_training_set_2 }

experiment_6 = { 'experiment_name' : "Experiment 6",
                 'description' : "Evaluate Only Financial Index Features",
                 'indexes' : [ "MXUS", "MSDUUK", "MSDUJN"],
                 'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                 'x_features_names' : [ "r_{}", "R_{}", "V_{}" ],
                 'y_label_name' : "label_{}",
                 'y_ml_label_name' : "f_label_{}",
                 'cv' : 10,
                 'models' : models,
                 'dataset' : indexes_data_training_set_2 }

results_df, results_df_details, models_fitted_dict = \
    executeExperimentSet ( experiments = [ experiment_1, experiment_2,

```

```
experiment_3, experiment_4,  
experiment_5, experiment_6] )
```

Job # 1 er	Executing Experiment = Experiment 1	Index_Name = S&P_500	ML Model = SGDClassifi
Job # 2	Dataset = US Market Indexes	Index_Name = S&P_500	ML Model = SVC
Job # 3 lassifier	Executing Experiment = Experiment 1	Index_Name = S&P_500	ML Model = KNeighborsC
Job # 4 tClassifier	Dataset = US Market Indexes	Index_Name = S&P_500	ML Model = RandomFores
Job # 5 r	Executing Experiment = Experiment 1	Index_Name = Nasdaq	ML Model = SGDClassifie
Job # 6	Dataset = US Market Indexes	Index_Name = Nasdaq	ML Model = SVC
Job # 7 assifier	Dataset = US Market Indexes	Index_Name = Nasdaq	ML Model = KNeighborsCl
Job # 8 Classifier	Executing Experiment = Experiment 1	Index_Name = Nasdaq	ML Model = RandomForest
Job # 9	Dataset = US Market Indexes	Index_Name = DJI	ML Model = SGDClassifier
Job # 10	Executing Experiment = Experiment 1	Index_Name = DJI	ML Model = SVC
Job # 11 ifier	Dataset = US Market Indexes	Index_Name = DJI	ML Model = KNeighborsClass
Job # 12 ssifier	Executing Experiment = Experiment 1	Index_Name = DJI	ML Model = RandomForestCla
Job # 13 er	Dataset = US Market Indexes	Index_Name = S&P_500	ML Model = SGDClassifi
Job # 14	Executing Experiment = Experiment 2	Index_Name = S&P_500	ML Model = SVC
Job # 15 lassifier	Dataset = US Market Indexes	Index_Name = S&P_500	ML Model = KNeighborsC
Job # 16 tClassifier	Executing Experiment = Experiment 2	Index_Name = S&P_500	ML Model = RandomFores
	Dataset = US Market Indexes		

Job # 17 Executing Experiment = Experiment 2 Index_Name = Nasdaq ML Model = SGDClassifier
r
Dataset = US Market Indexes
Job # 18 Executing Experiment = Experiment 2 Index_Name = Nasdaq ML Model = SVC
Dataset = US Market Indexes
Job # 19 Executing Experiment = Experiment 2 Index_Name = Nasdaq ML Model = KNeighborsClassifier
assifier
Dataset = US Market Indexes
Job # 20 Executing Experiment = Experiment 2 Index_Name = Nasdaq ML Model = RandomForestClassifier
Classifier
Dataset = US Market Indexes
Job # 21 Executing Experiment = Experiment 2 Index_Name = DJI ML Model = SGDClassifier
Dataset = US Market Indexes
Job # 22 Executing Experiment = Experiment 2 Index_Name = DJI ML Model = SVC
Dataset = US Market Indexes
Job # 23 Executing Experiment = Experiment 2 Index_Name = DJI ML Model = KNeighborsClassifier
ifier
Dataset = US Market Indexes
Job # 24 Executing Experiment = Experiment 2 Index_Name = DJI ML Model = RandomForestClassifier
ssifier
Dataset = US Market Indexes
Job # 25 Executing Experiment = Experiment 3 Index_Name = S&P_500 ML Model = SGDClassifier
er
Dataset = US Market Indexes
Job # 26 Executing Experiment = Experiment 3 Index_Name = S&P_500 ML Model = SVC
Dataset = US Market Indexes
Job # 27 Executing Experiment = Experiment 3 Index_Name = S&P_500 ML Model = KNeighborsClassifier
lassifier
Dataset = US Market Indexes
Job # 28 Executing Experiment = Experiment 3 Index_Name = S&P_500 ML Model = RandomForestClassifier
tClassifier
Dataset = US Market Indexes
Job # 29 Executing Experiment = Experiment 3 Index_Name = Nasdaq ML Model = SGDClassifier
r
Dataset = US Market Indexes
Job # 30 Executing Experiment = Experiment 3 Index_Name = Nasdaq ML Model = SVC
Dataset = US Market Indexes
Job # 31 Executing Experiment = Experiment 3 Index_Name = Nasdaq ML Model = KNeighborsClassifier
assifier
Dataset = US Market Indexes
Job # 32 Executing Experiment = Experiment 3 Index_Name = Nasdaq ML Model = RandomForestClassifier
Classifier
Dataset = US Market Indexes

Job # 33 Executing Experiment = Experiment 3 Index_Name = DJI ML Model = SGDClassifier
Dataset = US Market Indexes

Job # 34 Executing Experiment = Experiment 3 Index_Name = DJI ML Model = SVC
Dataset = US Market Indexes

Job # 35 ififier Executing Experiment = Experiment 3 Index_Name = DJI ML Model = KNeighborsClass
Dataset = US Market Indexes

Job # 36 ssifier Executing Experiment = Experiment 3 Index_Name = DJI ML Model = RandomForestCla
Dataset = US Market Indexes

Job # 37 Executing Experiment = Experiment 4 Index_Name = MXUS ML Model = SGDClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 38 Executing Experiment = Experiment 4 Index_Name = MXUS ML Model = SVC
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 39 sifier Executing Experiment = Experiment 4 Index_Name = MXUS ML Model = KNeighborsClas
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 40 assifier Executing Experiment = Experiment 4 Index_Name = MXUS ML Model = RandomForestCl
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 41 r Executing Experiment = Experiment 4 Index_Name = MSDUUK ML Model = SGDClassifie
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 42 Executing Experiment = Experiment 4 Index_Name = MSDUUK ML Model = SVC
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 43 assifier Executing Experiment = Experiment 4 Index_Name = MSDUUK ML Model = KNeighborsCl
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 44 Classifier Executing Experiment = Experiment 4 Index_Name = MSDUUK ML Model = RandomForest
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 45 r Executing Experiment = Experiment 4 Index_Name = MSDUJN ML Model = SGDClassifie
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 46 Executing Experiment = Experiment 4 Index_Name = MSDUJN ML Model = SVC
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 47 assifier Executing Experiment = Experiment 4 Index_Name = MSDUJN ML Model = KNeighborsCl
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 48 Classifier Executing Experiment = Experiment 4 Index_Name = MSDUJN ML Model = RandomForest
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 49 Executing Experiment = Experiment 5 Index_Name = MXUS ML Model = SGDClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 50 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MXUS ML Model = SVC
Job # 51 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MXUS ML Model = KNeighborsClassifier
Job # 52 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MXUS ML Model = RandomForestClassifier
Job # 53 r Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUUK ML Model = SGDClassifier
Job # 54 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUUK ML Model = SVC
Job # 55 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUUK ML Model = KNeighborsClassifier
Job # 56 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUUK ML Model = RandomForestClassifier
Job # 57 r Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUJN ML Model = SGDClassifier
Job # 58 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUJN ML Model = SVC
Job # 59 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUJN ML Model = KNeighborsClassifier
Job # 60 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 5 Index_Name = MSDUJN ML Model = RandomForestClassifier
Job # 61 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 6 Index_Name = MXUS ML Model = SGDClassifier
Job # 62 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 6 Index_Name = MXUS ML Model = SVC
Job # 63 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 6 Index_Name = MXUS ML Model = KNeighborsClassifier
Job # 64 Classifier Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 6 Index_Name = MXUS ML Model = RandomForestClassifier
Job # 65 r Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 6 Index_Name = MSDUUK ML Model = SGDClassifier

Job # 66 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 6 Index_Name = MSDUUK ML Model = SVC
Job # 67 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Classifier Executing Experiment = Experiment 6 Index_Name = MSDUUK ML Model = KNeighborsCl
Job # 68 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Classifier Executing Experiment = Experiment 6 Index_Name = MSDUUK ML Model = RandomForest
Job # 69 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
r Executing Experiment = Experiment 6 Index_Name = MSDUJN ML Model = SGDClassifie
Job # 70 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
 Executing Experiment = Experiment 6 Index_Name = MSDUJN ML Model = SVC
Job # 71 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Classifier Executing Experiment = Experiment 6 Index_Name = MSDUJN ML Model = KNeighborsCl
Job # 72 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Classifier Executing Experiment = Experiment 6 Index_Name = MSDUJN ML Model = RandomForest
 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

```
In [110]: results_df.sort_values(by=[ 'Classifier', 'Experiment Name', 'Index']).head(20)
```

Out[110]:

		Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_I
0	Experiment 1	Evaluate all Network Features & all Financial ...		US Market Indexes	DJI	KNeighborsClassifier	10	0.504085	0.531678	0.476025	0.548250	0.5
0	Experiment 1	Evaluate all Network Features & all Financial ...		US Market Indexes	Nasdaq	KNeighborsClassifier	10	0.496451	0.526606	0.462363	0.523254	0.5
0	Experiment 1	Evaluate all Network Features & all Financial ...		US Market Indexes	S&P_500	KNeighborsClassifier	10	0.500732	0.513771	0.465845	0.454748	0.4
0	Experiment 2	Evaluate Only Network Features		US Market Indexes	DJI	KNeighborsClassifier	10	0.485615	0.496199	0.455934	0.350756	0.3
0	Experiment 2	Evaluate Only Network Features		US Market Indexes	Nasdaq	KNeighborsClassifier	10	0.486111	0.509538	0.450844	0.341632	0.3
0	Experiment 2	Evaluate Only Network Features		US Market Indexes	S&P_500	KNeighborsClassifier	10	0.505351	0.543816	0.471203	0.271092	0.2
0	Experiment 3	Evaluate Only Financial Index Features		US Market Indexes	DJI	KNeighborsClassifier	10	0.528707	0.536746	0.502277	0.553134	0.6
0	Experiment 3	Evaluate Only Financial Index Features		US Market Indexes	Nasdaq	KNeighborsClassifier	10	0.524786	0.552711	0.494241	0.566910	0.6

	Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_I
0	Experiment 3	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	KNeighborsClassifier	10	0.532573	0.560841	0.501741	0.482158	0.5
0	Experiment 4	Evaluate all Network Features & all Financial ...	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUJN	KNeighborsClassifier	10	0.479605	0.502412	0.466314	0.403252	0.4
0	Experiment 4	Evaluate all Network Features & all Financial ...	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUUK	KNeighborsClassifier	10	0.523553	0.521448	0.498413	0.480437	0.4
0	Experiment 4	Evaluate all Network Features & all Financial ...	MSUS-MSDUUK-MSDUJN Market Indexes	MXUS	KNeighborsClassifier	10	0.546603	0.585696	0.507231	0.489485	0.5
0	Experiment 5	Evaluate Only Network Features	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUJN	KNeighborsClassifier	10	0.498321	0.511371	0.486420	0.242809	0.2
0	Experiment 5	Evaluate Only Network Features	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUUK	KNeighborsClassifier	10	0.531150	0.554290	0.507937	0.231626	0.2
0	Experiment 5	Evaluate Only Network Features	MSUS-MSDUUK-MSDUJN Market Indexes	MXUS	KNeighborsClassifier	10	0.537628	0.575387	0.496649	0.246437	0.2
0	Experiment 6	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUJN	KNeighborsClassifier	10	0.495935	0.504480	0.483951	0.439151	0.4

	Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_I
0	Experiment 6	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUUK	KNeighborsClassifier	10	0.529831	0.547587	0.506173	0.512925	0.5
0	Experiment 6	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN Market Indexes	MXUS	KNeighborsClassifier	10	0.530348	0.579897	0.488889	0.526871	0.5
0	Experiment 1	Evaluate all Network Features & all Financial	US Market Indexes	DJI	RandomForestClassifier	10	0.486850	0.403447	0.459952	0.550732	0.5
0	Experiment 1	Evaluate all Network Features & all Financial	US Market Indexes	Nasdaq	RandomForestClassifier	10	0.481697	0.416165	0.449504	0.540342	0.5
		...									

In [111]: results_df_details.head()

Out[111]:

	Experiment Name	Description	Features	y_label_col	y_ml_label_col
0	Experiment 1	Evaluate all Network Features & all Financial ...	[Ave_Deg_Centrality, Ave_Network_Strength, Ave...	label_S&P_500	f_label_S&P_500
0	Experiment 1	Evaluate all Network Features & all Financial ...	[Ave_Deg_Centrality, Ave_Network_Strength, Ave...	label_S&P_500	f_label_S&P_500
0	Experiment 1	Evaluate all Network Features & all Financial ...	[Ave_Deg_Centrality, Ave_Network_Strength, Ave...	label_S&P_500	f_label_S&P_500
0	Experiment 1	Evaluate all Network Features & all Financial ...	[Ave_Deg_Centrality, Ave_Network_Strength, Ave...	label_S&P_500	f_label_S&P_500
0	Experiment 1	Evaluate all Network Features & all Financial ...	[Ave_Deg_Centrality, Ave_Network_Strength, Ave...	label_Nasdaq	f_label_Nasdaq

#

6.3.4.2 Analyze Experiment's Results

6.3.4.2.1 Compare Performance between Datasets

```
In [112]: dataset_1_results = results_df[ results_df.Dataset == "US Market Indexes" ]
dataset_2_results = results_df[ results_df.Dataset != "US Market Indexes" ]
analysis_columns = [ "Experiment Description", "Classifier",
                     "Combine_ML_Precision", "Combine_ML_Recall", "Combine_ML_Accuracy" ]

dat1_results_stats = \
    dataset_1_results[analysis_columns].groupby(['Experiment Description', 'Classifier']).mean()
dat2_results_stats = \
    dataset_2_results[analysis_columns].groupby(['Experiment Description', 'Classifier']).mean()
```

Dataset 1: Mean Values of Precision, Recall, and Accuracy for Combine ML Model

(Results are group by: Experiment Type and Classifier)

```
In [113]: dat1_results_stats.style.format("{:.2%}")
```

Out[113]:

			Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
	Experiment Description	Classifier			
Evaluate Only Financial Index Features	KNeighborsClassifier	KNeighborsClassifier	76.37%	67.36%	76.02%
		RandomForestClassifier	75.49%	69.84%	76.30%
		SGDClassifier	78.28%	71.22%	78.22%
	SVC	SVC	78.62%	73.32%	79.11%
Evaluate Only Network Features	KNeighborsClassifier	KNeighborsClassifier	41.42%	33.89%	48.83%
		RandomForestClassifier	40.10%	36.18%	47.05%
		SGDClassifier	41.96%	29.66%	50.08%
	SVC	SVC	22.46%	2.02%	52.84%
Evaluate all Network Features & all Financial Index Measures	KNeighborsClassifier	KNeighborsClassifier	73.11%	62.67%	72.90%
		RandomForestClassifier	74.28%	67.74%	75.01%
		SGDClassifier	74.93%	69.61%	75.88%
	SVC	SVC	76.79%	71.11%	77.40%

Dataset 2: Mean Values of Precision, Recall, and Accuracy for Combine ML Model

(Results are group by: Experiment Type and Classifier)

```
In [116]: dat2_results_stats.style.format("{:.2%}")
```

Out[116]:

			Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
	Experiment Description	Classifier			
Evaluate Only Financial Index Features		KNeighborsClassifier	76.41%	67.81%	75.46%
		RandomForestClassifier	74.90%	70.32%	75.41%
		SGDClassifier	77.62%	68.48%	76.21%
Evaluate Only Network Features		SVC	78.64%	73.42%	78.52%
		KNeighborsClassifier	45.67%	34.78%	50.97%
		RandomForestClassifier	47.24%	42.01%	51.62%
Evaluate all Network Features & all Financial Index Measures		SGDClassifier	46.07%	32.64%	51.30%
		SVC	43.17%	18.44%	53.12%
		KNeighborsClassifier	75.57%	64.44%	73.96%
Evaluate all Network Features & all Financial Index Measures		RandomForestClassifier	75.33%	69.89%	75.53%
		SGDClassifier	74.69%	67.99%	74.59%
		SVC	77.74%	73.16%	77.94%

Percent Differences between Datasets for Combine ML Models

(Results are group by: Experiment Type and Classifier)

```
In [159]: (dat1_results_stats.sub(dat2_results_stats)/dat1_results_stats).style.format("{:.2%}")
```

Out[159]:

			Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
	Experiment Description	Classifier			
Evaluate Only Financial Index Features	KNeighborsClassifier		-0.05%	-0.66%	0.73%
	RandomForestClassifier		0.78%	-0.69%	1.16%
	SGDClassifier		0.83%	3.85%	2.57%
Evaluate Only Network Features	SVC		-0.02%	-0.14%	0.74%
	KNeighborsClassifier		-10.25%	-2.62%	-4.39%
	RandomForestClassifier		-17.78%	-16.12%	-9.71%
Evaluate all Network Features & all Financial Index Measures	SGDClassifier		-9.79%	-10.06%	-2.42%
	SVC		-92.19%	-812.72%	-0.54%
	KNeighborsClassifier		-3.36%	-2.82%	-1.45%
Evaluate all Network Features & all Financial Index Measures	RandomForestClassifier		-1.41%	-3.17%	-0.70%
	SGDClassifier		0.32%	2.33%	1.70%
	SVC		-1.24%	-2.87%	-0.70%

Summary of Analysis

- Differences between the datasets is mostly small, except for SVC with Only Network Features, the other experiment type differences are less than 4%

6.3.4.2.2 Compare Performance Between Experiment Types (different feature sets)

```
In [118]: analysis_columns = ["Experiment_Description",
                           "Combine_ML_Precision", "Combine_ML_Recall", "Combine_ML_Accuracy"]

results_stats = results_df[analysis_columns].groupby(['Experiment_Description']).mean()
```

Mean Values of Precision, Recall, and Accuracy for Combine ML Model all datasets

(Results are group by: Experiment Type)

```
In [119]: results_stats.style.format("{:.2%}")
```

Out[119]:

Experiment Description	Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
Evaluate Only Financial Index Features	77.04%	70.22%	76.91%
Evaluate Only Network Features	41.01%	28.70%	50.73%
Evaluate all Network Features & all Financial Index Measures	75.30%	68.33%	75.40%

Summary of Analysis

- The experiments with only financial index features provide the best results overall across all conducted experiments, 76.91% mean accuracy, slightly higher than 75.40% when using all Network & Financial index features

6.3.4.2.3 Compare Performance Between Classifiers for best Experiment Type (Evaluate Only Financial Index Features)

```
In [120]: analysis_columns = ["Classifier",
                           "Combine_ML_Precision", "Combine_ML_Recall", "Combine_ML_Accuracy"]

results_df_subset = results_df[ results_df["Experiment Description"] == \
                               "Evaluate Only Financial Index Features"]
results_stats = results_df_subset[analysis_columns].groupby(['Classifier']).mean()
```

Mean Values of Precision, Recall, and Accuracy for Combine ML Model all datasets

- Results are group by: Classifier & derived only for the best Experiment Type

```
In [126]: results_stats.sort_values(['Combine_ML_Accuracy'], ascending=False).style.format("{:.2%}")
```

Out[126]:

Classifier	Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
SVC	78.63%	73.37%	78.81%
SGDClassifier	77.95%	69.85%	77.22%
RandomForestClassifier	75.20%	70.08%	75.86%
KNeighborsClassifier	76.39%	67.58%	75.74%

Summary of Analysis

- The best classifiers from all the experiments are: SVC and SGD

6.3.4.2.4 Summary of Experiments

- There are only minor differences due to difference datasets, that is, different market indexes, and different time periods
- The best label to use for predicting price movement pattern, it is the Multi Label, combining the S1 and S2, and S3 and S4 via the confusion matrix
- The best experiment type is the one including only Financial Indexes derived features
- The best performing models across all evaluated classifiers are: SGD and SVC
- The performance of KNN and Random Forest classifiers are very close to the SGD and SVC algorithms
- It is recommended to optimize KNN and Random Forest with SGD and SVC to utilized them all in emsemble classifiers, which may provide better overall results than a single classifier

6.3.5 Models Optimization

6.3.5.1 Models Optimization

6.3.5.1.1 KNN Optimization

```
In [127]: from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import ParameterGrid

# ***
# *** Each classifier, needs to be optimzed for each Stock Index
# ***
# ***      Note: This is a customized optimization, since we are optimizing the accuracy of the
# ***          Combine Multi-Label, which can only be infered after evaluating the Multi_Label case
# ***

param_grid_knn = ParameterGrid( {'n_neighbors': [3, 4, 5, 7, 10, 15, 20],
                                'weights' : ["uniform", "distance"],
                                'algorithm' : ["auto", "ball_tree", "kd_tree"],
                                'leaf_size' : [25, 30, 40, 60, 80]} )

#param_grid_knn = ParameterGrid( {'n_neighbors': [5, 10, 15, 20, 30, 40, 50] } )
models = []

for i, params in enumerate(param_grid_knn):
    knn_clf = KNeighborsClassifier(**params, n_jobs = -1)
    models.append(knn_clf)

optimization_eval_1 = {'experiment_name' : "Evaluate KNN Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                      'dataset_name' : "US Market Indexes",
                      'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                      'y_label_name' : "label_{\{}",
                      'y_ml_label_name' : "f_label_{\{}",
                      'cv' : 10,
                      'models' : models,
                      'dataset' : indexes_data_training_set_1 }

optimization_eval_2 = {'experiment_name' : "Evaluate KNN Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "MXUS", "MSDUUK", "MSDUJN" ],
                      'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                      'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                      'y_label_name' : "label_{\{}",
                      'y_ml_label_name' : "f_label_{\{}",
                      'cv' : 10,
```

```
'models'           : models,
'dataset'          : indexes_data_training_set_2 }

results_df_knn, results_df_details_knn, models_fitted_dict_knn = \
executeExperimentSet ( experiments = [optimization_eval_1, optimization_eval_2] )
```

Job # 1 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 2 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 3 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 4 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 5 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 6 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 7 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 8 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 9 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 10 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 11 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 12 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 13 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 14 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
 Dataset = US Market Indexes

Job # 15 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei

```
ghborsClassifier
    Dataset = US Market Indexes
Job # 16      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 17      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 18      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 19      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 20      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 21      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 22      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 23      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 24      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 25      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 26      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 27      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 28      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 29      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
```

Dataset = US Market Indexes
Job # 30 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 31 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 32 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 33 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 34 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 35 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 36 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 37 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 38 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 39 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 40 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 41 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 42 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 43 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 44 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 45 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 46 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 47 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 48 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 49 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 50 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 51 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 52 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 53 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 54 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 55 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 56 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 57 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 58 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei

```
ghborsClassifier
    Dataset = US Market Indexes
Job # 59      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 60      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 61      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 62      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 63      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
Job # 65      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 66      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 67      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 68      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 69      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
Job # 71      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
    Dataset = US Market Indexes
Job # 72      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
```

Dataset = US Market Indexes
Job # 73 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 74 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 75 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 76 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 77 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
Job # 79 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 80 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
Job # 83 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 84 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 85 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 86 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 87 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 88 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 89 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

Job # 91 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 92 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 93 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 94 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 95 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 96 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 97 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 98 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 99 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 100 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 101 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei

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ghborsClassifier
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
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ghborsClassifier
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ghborsClassifier
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ghborsClassifier
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Job # 115      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
```

Dataset = US Market Indexes
Job # 116 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
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Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
Job # 127 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 128 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
Job # 129 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 130 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 131 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

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Dataset = US Market Indexes

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Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

Job # 141 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 142 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 143 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 144 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei

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ghborsClassifier
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ghborsClassifier
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
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    Dataset = US Market Indexes
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    Dataset = US Market Indexes
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```

Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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Dataset = US Market Indexes
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Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
Job # 167 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes
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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

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ghborsClassifier
Dataset = US Market Indexes

Job # 185 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 186 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
Dataset = US Market Indexes

Job # 187 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei

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ghborsClassifier
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ghborsClassifier
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ghborsClassifier
    Dataset = US Market Indexes
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ghborsClassifier
    Dataset = US Market Indexes
Job # 200      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
ghborsClassifier
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Job # 201      Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNei
```

Dataset = US Market Indexes
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Dataset = US Market Indexes
Job # 203 Executing Experiment = Evaluate KNN Models Index_Name = S&P_500 ML Model = KNeighborsClassifier
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Job # 212 Executing Experiment = Evaluate KNN Models Index_Name = Nasdaq ML Model = KNeighborsClassifier
Dataset = US Market Indexes
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Dataset = US Market Indexes
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Dataset = US Market Indexes
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Dataset = US Market Indexes

Job # 216 Executing Experiment = Evaluate KNN Models Index_Name = Nasdaq ML Model = KNeig
hborsClassifier
Dataset = US Market Indexes

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hborsClassifier
Dataset = US Market Indexes

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hborsClassifier
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hborsClassifier
Dataset = US Market Indexes

Job # 230 Executing Experiment = Evaluate KNN Models Index_Name = Nasdaq ML Model = KNeig

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hborsClassifier
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hborsClassifier
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                Executing Experiment = Evaluate KNN Models Index_Name = Nasdaq ML Model = KNeig
hborsClassifier
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                Executing Experiment = Evaluate KNN Models Index_Name = Nasdaq ML Model = KNeig
hborsClassifier
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hborsClassifier
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hborsClassifier
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hborsClassifier
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                Executing Experiment = Evaluate KNN Models Index_Name = Nasdaq ML Model = KNeig
hborsClassifier
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Job # 627          Dataset = US Market Indexes
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Job # 632
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Job # 1128 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1129 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1130 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1131 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1132 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1133 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig

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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1163 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Job # 1164 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Job # 1166 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Job # 1169 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1170 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1171 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1172 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1173 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1174 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1175 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1176 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig

Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1191 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1197 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1198 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1199 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1200 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1201 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1202 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1203 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1204 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1205 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1206 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1207 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1208 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1209 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1210 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Job # 1211 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1212 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1213 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Job # 1214 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Job # 1215 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
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Job # 1216 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Job # 1217 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
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Job # 1218 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 1219 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig

```
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1220 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1221 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1222 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1223 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1224 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1225 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1226 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1227 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1228 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1229 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1230 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1231 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1232 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1233 Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
```



```
Job # 1248      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1249      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1250      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1251      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1252      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1253      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1254      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1255      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1256      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1257      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1258      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1259      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1260      Executing Experiment = Evaluate KNN Models Index_Name = MSDUJN ML Model = KNeig
hborsClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```

Permutations Executed for KNN Model

```
In [128]: print("Total number of KNN models evaluated for optimization = ", len(results_df_knn))
results_df_knn.head() # Just display the top 5
```

Total number of KNN models evaluated for optimization = 1260

Out[128]:

	Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_Recall
0	Evaluate KNN Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	KNeighborsClassifier	10	0.538351	0.562344	0.507902	0.454545	0.454326
0	Evaluate KNN Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	KNeighborsClassifier	10	0.534433	0.551828	0.503081	0.445812	0.457541
0	Evaluate KNN Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	KNeighborsClassifier	10	0.522909	0.360040	0.481918	0.474580	0.486740
0	Evaluate KNN Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	KNeighborsClassifier	10	0.539093	0.559339	0.508438	0.461532	0.481114
0	Evaluate KNN Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	KNeighborsClassifier	10	0.532573	0.560841	0.501741	0.482158	0.505759

Select Best Models for each Index for KNN

```
In [129]: analysis_columns = ["Classifier", "Job_ID", "Index",
                           "Combine_ML_Precision", "Combine_ML_Recall", "Combine_ML_Accuracy"]

best_knn_models_dict, optimum_models_metrics_knn_df = \
    getOptimizedModelsDict(results_df = results_df_knn,
                           models_fitted = models_fitted_dict_knn,
                           metric = "Combine_ML_Accuracy")

optimum_models_metrics_knn_df[analysis_columns]
```

Out[129]:

	Classifier	Job_ID	Index	Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
10	KNeighborsClassifier	11	S&P_500	0.781270	0.722420	0.783284
222	KNeighborsClassifier	223	Nasdaq	0.796215	0.743665	0.796946
432	KNeighborsClassifier	433	DJI	0.770588	0.718464	0.782213
640	KNeighborsClassifier	641	MXUS	0.797954	0.728972	0.793651
852	KNeighborsClassifier	853	MSDUUK	0.787182	0.741486	0.790829
1062	KNeighborsClassifier	1063	MSDUJN	0.778140	0.707191	0.764727

Validate Best Models For Each Index With Training Set for QA

```
In [130]: models_1 = [ best_knn_models_dict.get('S&P_500'), best_knn_models_dict.get('Nasdaq'),
                    best_knn_models_dict.get('DJI') ]

models_2 = [ best_knn_models_dict.get('MXUS'), best_knn_models_dict.get('MSDUUK'),
                    best_knn_models_dict.get('MSDUJN') ]

predictions_eval_1 = { 'prediction_name' : "Predict KNN Models",
                        'description' : "Evaluate Only Financial Index Features",
                        'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                        'dataset_name' : "US Market Indexes",
                        'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                        'y_label_name' : "label_{\{}",
                        'y_ml_label_name' : "f_label_{\{}",
                        'cv' : 10,
                        'models' : models_1,
                        'dataset' : indexes_data_training_set_1 }

predictions_eval_2 = { 'prediction_name' : "Predict KNN Models",
                        'description' : "Evaluate Only Financial Index Features",
                        'indexes' : [ "MXUS", "MSDUUK", "MSDUJN" ],
                        'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                        'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                        'y_label_name' : "label_{\{}",
                        'y_ml_label_name' : "f_label_{\{}",
                        'cv' : 10,
                        'models' : models_2,
                        'dataset' : indexes_data_training_set_2 }

predictions_knn_df, models_knn_fitted_dict, cm_ml_knn_dict, cm_ml_compact_knn_dict = \
    executePredictionsSet ( predictions = [predictions_eval_1, predictions_eval_2], FitModels =
True )
```

```
In [131]: knn_training_results_df = predictions_knn_df[ predictions_knn_df.Model == "Combine ML" ]
analysis_columns = [ "Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN" ]

knn_training_results_stats_df = \
    knn_training_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

knn_training_results_stats_df.style.format("{:.2%}")
```

Out[131]:

		DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
Classifier	Metric						
	Accuracy	80.74%	80.55%	81.60%	80.95%	80.67%	78.41%
KNeighborsClassifier	Precision	79.90%	80.85%	81.80%	82.01%	80.15%	80.13%
	Recall	75.08%	74.61%	76.55%	74.22%	76.55%	72.65%

6.3.5.1.2 Random Forest Optimization

```
In [132]: from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import ParameterGrid

# ***
# *** Each classifier, needs to be optimzed for each Stock Index
# ***
# ***      Note: This is a customized optimization, since we are optimizing the accuracy of the
# ***          Combine Multi-Label, which can only be infered after evaluating the Multi_Label case
# ***

param_grid_rf = ParameterGrid( {'n_estimators' : [3, 6, 10, 20, 40, 70, 100, 130 ],
                                'max_depth'   : [None, 5, 10, 20, 50],
                                'max_features': ["auto", "log2", None],
                                'bootstrap'   : [True, False] } )
models = []

for i, params in enumerate(param_grid_rf):
    rf_clf = RandomForestClassifier(**params, n_jobs = -1, random_state = 42)
    models.append(rf_clf)

optimization_eval_1 = { 'experiment_name' : "Evaluate Random Forest Models",
                        'description'     : "Evaluate Only Financial Index Features",
                        'indexes'         : [ "S&P_500", "Nasdaq", "DJI" ],
                        'dataset_name'    : "US Market Indexes",
                        'x_features_names': [ "r_{\{} \", "R_{\{} \", "V_{\{} " ] ,
                        'y_label_name'    : "label_{\{}",
                        'y_ml_label_name': "f_label_{\{}",
                        'cv'              : 10,
                        'models'          : models,
                        'dataset'         : indexes_data_training_set_1 }

optimization_eval_2 = { 'experiment_name' : "Evaluate Random Forest Models",
                        'description'     : "Evaluate Only Financial Index Features",
                        'indexes'         : [ "MXUS", "MSDUUK", "MSDUJN" ],
                        'dataset_name'    : "MSUS-MSDUUK-MSDUJN Market Indexes",
                        'x_features_names': [ "r_{\{} \", "R_{\{} \", "V_{\{} " ] ,
                        'y_label_name'    : "label_{\{}",
                        'y_ml_label_name': "f_label_{\{}",
                        'cv'              : 10,
                        'models'          : models,
                        'dataset'         : indexes_data_training_set_2 }
```

```
results_df_rf, results_df_details_rf, models_fitted_dict_rf = \
executeExperimentSet ( experiments = [optimization_eval_1, optimization_eval_2] )
```

```
Job # 1          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 2          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 3          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 4          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 5          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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          Dataset = US Market Indexes
Job # 6          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 7          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 8          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 9          Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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          Dataset = US Market Indexes
Job # 10         Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 11         Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 12         Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 13         Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 14         Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
          Dataset = US Market Indexes
Job # 15         Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
```

```
el = RandomForestClassifier
        Dataset = US Market Indexes
Job # 16      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
        Dataset = US Market Indexes
Job # 17      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
        Dataset = US Market Indexes
Job # 18      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
        Dataset = US Market Indexes
Job # 19      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
        Dataset = US Market Indexes
Job # 20      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
        Dataset = US Market Indexes
Job # 21      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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        Dataset = US Market Indexes
Job # 22      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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        Dataset = US Market Indexes
Job # 23      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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        Dataset = US Market Indexes
Job # 24      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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        Dataset = US Market Indexes
Job # 25      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
el = RandomForestClassifier
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Job # 26      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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Job # 29      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
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```

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```

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```

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el = RandomForestClassifier
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```

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Job # 230      Executing Experiment = Evaluate Random Forest Models Index_Name = S&P_500 ML Mod
```

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```

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Job # 287 Executing Experiment = Evaluate Random Forest Models Index_Name = Nasdaq ML Mode
l = RandomForestClassifier
```

```
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l = RandomForestClassifier
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```

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```

```
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```

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l = RandomForestClassifier
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Job # 781 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
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Job # 789 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model

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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 941 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 942 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 943 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 944 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 945 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 946 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 947 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 948 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 949 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 950 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 951 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 952 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 953 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 954 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 955 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 956 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 957 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 958 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 959 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 960 Executing Experiment = Evaluate Random Forest Models Index_Name = MXUS ML Model
= RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 961 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode

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l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 962      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 963      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 964      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 965      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 966      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 967      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 968      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 969      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 970      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 971      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 972      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 973      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 974      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 975      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
```

```
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 976 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 977 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 978 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 979 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 980 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 981 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 982 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 983 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 984 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 985 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 986 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 987 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 988 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 989 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```

```
Job # 990      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 991      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 992      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 993      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 994      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 995      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 996      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 997      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 998      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 999      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1000     Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1001     Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1002     Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1003     Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1004     Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
```

```
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1005 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1006 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1007 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1008 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1009 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1010 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1011 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1012 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1013 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1014 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1015 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1016 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1017 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1018 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
```

```
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1019      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1020      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1021      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1022      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1023      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1024      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1025      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1026      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1027      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1028      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1029      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1030      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1031      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1032      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```



```
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1048 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1049 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1050 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1051 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1052 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1053 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1054 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1055 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1056 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1057 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1058 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1059 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1060 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1061 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
```

```
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1062      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1063      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1064      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1065      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1066      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1067      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1068      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1069      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
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Job # 1070      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
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Job # 1071      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1072      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1073      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1074      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1075      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```



```
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1091 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1092 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1093 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1094 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1095 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1096 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1097 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1098 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1099 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1100 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1101 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1102 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1103 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1104 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
```

```
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1105      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1106      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1107      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1108      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1109      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1110      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1111      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1112      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1113      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1114      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1115      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1116      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1117      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1118      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```



```
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1134 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1135 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1136 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1137 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1138 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1139 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1140 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1141 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1142 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1143 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1144 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1145 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1146 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1147 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
```

```
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1148      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1149      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1150      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1151      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1152      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1153      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1154      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1155      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1156      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1157      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1158      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1159      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1160      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1161      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```



```
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1177 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1178 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1179 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1180 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1181 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1182 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1183 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1184 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1185 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1186 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1187 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1188 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1189 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1190 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
```

```
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1191      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1192      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1193      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1194      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1195      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1196      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1197      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1198      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1199      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1200      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUUK ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1201      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1202      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1203      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1204      Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```



```
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1220 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1221 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1222 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1223 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1224 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1225 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1226 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1227 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1228 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1229 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1230 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1231 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1232 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1233 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
```



```
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1263 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1264 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1265 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1266 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1267 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1268 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1269 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1270 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1271 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1272 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1273 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1274 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1275 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1276 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
```



```
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1306 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1307 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1308 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1309 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1310 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1311 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1312 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1313 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1314 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1315 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1316 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1317 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1318 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1319 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
```



```
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1349 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1350 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1351 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1352 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1353 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1354 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1355 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1356 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1357 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1358 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1359 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1360 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1361 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1362 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
```



```
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1392 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1393 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1394 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1395 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1396 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1397 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1398 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1399 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1400 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1401 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1402 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1403 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1404 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
    Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1405 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
```



```
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1435 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1436 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1437 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1438 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1439 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
Job # 1440 Executing Experiment = Evaluate Random Forest Models Index_Name = MSDUJN ML Mode
l = RandomForestClassifier
        Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
```

Permutations Executed for Random Forest Model

```
In [133]: print("Total number of Random Forest models evaluated for optimization = ", len(results_df_rf))
results_df_rf.head() # Just display the top 5
```

Total number of Random Forest models evaluated for optimization = 1440

Out[133]:

	Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_Recall
0	Evaluate Random Forest Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	RandomForestClassifier	10	0.536623	0.528292	0.503616	0.445693	0.440592
0	Evaluate Random Forest Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	RandomForestClassifier	10	0.531188	0.405108	0.490490	0.461260	0.473088
0	Evaluate Random Forest Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	RandomForestClassifier	10	0.535591	0.467201	0.498259	0.467460	0.495101
0	Evaluate Random Forest Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	RandomForestClassifier	10	0.526870	0.500751	0.492365	0.468518	0.504250
0	Evaluate Random Forest Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	RandomForestClassifier	10	0.537475	0.545819	0.505759	0.470998	0.514500

Select Best Models for each Index for Random Forest

```
In [134]: analysis_columns = ["Classifier", "Job_ID", "Index",
                           "Combine_ML_Precision", "Combine_ML_Recall", "Combine_ML_Accuracy"]

best_rf_models_dict, optimum_models_metrics_rf_df = \
    getOptimizedModelsDict(results_df = results_df_rf,
                           models_fitted = models_fitted_dict_rf,
                           metric = "Combine_ML_Accuracy")

optimum_models_metrics_rf_df[analysis_columns]
```

Out[134]:

	Classifier	Job_ID	Index	Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
27	RandomForestClassifier	28	S&P_500	0.791250	0.750890	0.798018
390	RandomForestClassifier	391	Nasdaq	0.784417	0.789039	0.805518
521	RandomForestClassifier	522	DJI	0.775111	0.747715	0.793732
746	RandomForestClassifier	747	MXUS	0.798203	0.760903	0.804586
989	RandomForestClassifier	990	MSDUUK	0.768773	0.800310	0.799295
1245	RandomForestClassifier	1246	MSDUJN	0.787589	0.733877	0.779189

Validate Best Models For Each Index With Training Set for QA

```
In [135]: models_1 = [ best_rf_models_dict.get('S&P_500'), best_rf_models_dict.get('Nasdaq'),
                  best_rf_models_dict.get('DJI') ]

models_2 = [ best_rf_models_dict.get('MXUS'), best_rf_models_dict.get('MSDUUK'),
              best_rf_models_dict.get('MSDUJN') ]

predictions_eval_1 = { 'prediction_name' : "Predict Random Forest Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                      'dataset_name' : "US Market Indexes",
                      'x_features_names' : [ "r_{}", "R_{}", "V_{}" ] ,
                      'y_label_name' : "label_{}",
                      'y_ml_label_name' : "f_label_{}",
                      'cv' : 10,
                      'models' : models_1,
                      'dataset' : indexes_data_training_set_1 }

predictions_eval_2 = { 'prediction_name' : "Predict Random Forest Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "MXUS", "MSDUUK", "MSDUJN" ],
                      'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                      'x_features_names' : [ "r_{}", "R_{}", "V_{}" ] ,
                      'y_label_name' : "label_{}",
                      'y_ml_label_name' : "f_label_{}",
                      'cv' : 10,
                      'models' : models_2,
                      'dataset' : indexes_data_training_set_2 }

predictions_rf_df, models_rf_fitted_dict, cm_ml_rf_dict, cm_ml_compact_rf_dict = \
executePredictionsSet ( predictions = [predictions_eval_1, predictions_eval_2], FitModels =
True )
```

```
In [136]: rf_training_results_df = predictions_rf_df[ predictions_rf_df.Model == "Combine ML" ]
analysis_columns = [ "Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN" ]

rf_training_results_stats_df = \
    rf_training_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

rf_training_results_stats_df.style.format("{:.2%}")
```

Out[136]:

	DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN	
Classifier	Metric						
	Accuracy	81.44%	80.85%	81.54%	81.66%	81.59%	79.12%
RandomForestClassifier	Precision	80.04%	80.29%	79.47%	81.31%	78.77%	80.35%
	Recall	76.97%	76.33%	80.08%	77.26%	81.58%	74.28%

6.3.5.2 Additional Models Optimization

6.3.5.2.1 SVC Classifier

```
In [137]: from sklearn.svm import SVC
from sklearn.model_selection import ParameterGrid

# ***
# *** Each classifier, needs to be optimzed for each Stock Index
# ***
# ***      Note: This is a customized optimization, since we are optimizing the accuracy of the
# ***          Combine Multi-Label, which can only be infered after evaluating the Multi_Label case
# ***

param_grid_svc = ParameterGrid( { 'gamma': [1e-1, 1e-2, 1e-3],
                                  'C': [1, 10, 50, 100] } )

models = []

for i, params in enumerate(param_grid_svc):
    SVC_clf = SVC(**params, kernel="rbf", random_state=42)
    models.append(SVC_clf)

optimization_eval_svc_1 = { 'experiment_name' : "Evaluate SVC Models",
                            'description' : "Evaluate Only Financial Index Features",
                            'indexes' : ["S&P_500", "Nasdaq", "DJI"],
                            'dataset_name' : "US Market Indexes",
                            'x_features_names' : [ "r_{}", "R_{}", "V_{}" ] ,
                            'y_label_name' : "label_{}",
                            'y_ml_label_name' : "f_label_{}",
                            'cv' : 10,
                            'models' : models,
                            'dataset' : indexes_data_training_set_1 }

optimization_eval_svc_2 = { 'experiment_name' : "Evaluate SVC Models",
                            'description' : "Evaluate Only Financial Index Features",
                            'indexes' : [ "MXUS", "MSDUUK", "MSDUJN" ],
                            'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                            'x_features_names' : [ "r_{}", "R_{}", "V_{}" ] ,
                            'y_label_name' : "label_{}",
                            'y_ml_label_name' : "f_label_{}",
                            'cv' : 10,
                            'models' : models,
                            'dataset' : indexes_data_training_set_2 }
```

```
results_df_svc, results_df_details_svc, models_fitted_dict_svc = \
    executeExperimentSet ( experiments = [optimization_eval_svc_1, optimization_eval_
svc_2
] )
```


	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			
Job # 66	Executing Experiment = Evaluate SVC Models	Index_Name = MSDUJN	ML Model = SVC	
	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			
Job # 67	Executing Experiment = Evaluate SVC Models	Index_Name = MSDUJN	ML Model = SVC	
	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			
Job # 68	Executing Experiment = Evaluate SVC Models	Index_Name = MSDUJN	ML Model = SVC	
	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			
Job # 69	Executing Experiment = Evaluate SVC Models	Index_Name = MSDUJN	ML Model = SVC	
	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			
Job # 70	Executing Experiment = Evaluate SVC Models	Index_Name = MSDUJN	ML Model = SVC	
	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			
Job # 71	Executing Experiment = Evaluate SVC Models	Index_Name = MSDUJN	ML Model = SVC	
	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			
Job # 72	Executing Experiment = Evaluate SVC Models	Index_Name = MSDUJN	ML Model = SVC	
	Dataset = MSUS-MSDUUK-MSDUJN Market Indexes			

Permutations Executed for SVC Model

```
In [138]: print("Total number of SVC models evaluated for optimization = ", len(results_df_svc))
results_df_svc.head(108) # Just display the top 5
```

Total number of SVC models evaluated for optimization = 72

Out[138]:

	Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_Recall	ML_Accuracy
0	Evaluate SVC Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SVC	10	0.528217	0.937406	0.518618	0.498028	0.572462	
0	Evaluate SVC Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SVC	10	0.532845	0.982974	0.529869	0.515678	0.572462	
0	Evaluate SVC Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SVC	10	0.534853	0.998998	0.534691	0.539098	0.540852	
0	Evaluate SVC Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SVC	10	0.531295	0.922384	0.523172	0.490534	0.569247	
0	Evaluate SVC Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SVC	10	0.530807	0.974962	0.525583	0.488412	0.571926	
...
0	Evaluate SVC Models	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUJN	SVC	10	0.512440	0.951068	0.511817	0.431238	0.473369	
0	Evaluate SVC Models	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN Market Indexes	MSDUJN	SVC	10	0.511817	1.000000	0.511817	0.390730	0.481834	

	Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_Recall	ML_A
0	Evaluate SVC Models	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN	MSDUJN	SVC	10	0.519091	0.740179	0.516049	0.494079	0.496649	
0	Evaluate SVC Models	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN	MSDUJN	SVC	10	0.513168	0.940041	0.512875	0.445252	0.474780	
0	Evaluate SVC Models	Evaluate Only Financial Index Features	MSUS-MSDUUK-MSDUJN	MSDUJN	SVC	10	0.511825	0.999311	0.511817	0.581739	0.483951	

72 rows × 17 columns

Select Best Models for each Index for SVC

```
In [139]: analysis_columns = ["Classifier", "Job_ID", "Index",
                           "Combine_ML_Precision", "Combine_ML_Recall", "Combine_ML_Accuracy"]

best_svc_models_dict, optimum_models_metrics_svc_df = \
    getOptimizedModelsDict(results_df = results_df_svc,
                           models_fitted = models_fitted_dict_svc,
                           metric = "Combine_ML_Accuracy")

optimum_models_metrics_svc_df[analysis_columns]
```

Out[139]:

	Classifier	Job_ID	Index	Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
8	SVC	9	S&P_500	0.797811	0.734875	0.796143
23	SVC	24	Nasdaq	0.815324	0.733648	0.803375
29	SVC	30	DJI	0.800827	0.708105	0.794267
40	SVC	41	MXUS	0.795082	0.755452	0.801058
53	SVC	54	MSDUUK	0.819298	0.722910	0.801058
64	SVC	65	MSDUJN	0.795885	0.716827	0.777778

Validate Best Models For Each Index With Training Set for QA

```
In [140]: models_1 = [ best_svc_models_dict.get('S&P_500'), best_svc_models_dict.get('Nasdaq'),
                    best_svc_models_dict.get('DJI') ]

models_2 = [ best_svc_models_dict.get('MXUS'), best_svc_models_dict.get('MSDUUK'),
                    best_svc_models_dict.get('MSDUJN') ]

predictions_eval_svc_1 = { 'prediction_name' : "Predict SVC Models",
                           'description' : "Evaluate Only Financial Index Features",
                           'indexes' : ["S&P_500", "Nasdaq", "DJI"],
                           'dataset_name' : "US Market Indexes",
                           'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                           'y_label_name' : "label_{\{}",
                           'y_ml_label_name' : "f_label_{\{}",
                           'cv' : 10,
                           'models' : models_1,
                           'dataset' : indexes_data_training_set_1 }

predictions_eval_svc_2 = { 'prediction_name' : "Predict SVC Models",
                           'description' : "Evaluate Only Financial Index Features",
                           'indexes' : ["MXUS", "MSDUUK", "MSDUJN"],
                           'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                           'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                           'y_label_name' : "label_{\{}",
                           'y_ml_label_name' : "f_label_{\{}",
                           'cv' : 10,
                           'models' : models_2,
                           'dataset' : indexes_data_training_set_2 }

predictions_svc_df, models_svc_fitted_dict, cm_ml_svc_dict, cm_ml_compact_svc_dict = \
    executePredictionsSet ( predictions = [predictions_eval_svc_1, predictions_eval_svc_2],
                           FitModels = True )
```

```
In [141]: svc_training_results_df = predictions_svc_df[ predictions_svc_df.Model == "Combine ML" ]
analysis_columns = [ "Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN" ]

svc_training_results_stats_df = \
    svc_training_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

svc_training_results_stats_df
```

Out[141]:

Classifier	Metric	DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
SVC	Accuracy	0.796678	0.797750	0.803643	0.800705	0.803175	0.779189
	Precision	0.804558	0.797825	0.815033	0.793469	0.819686	0.798021
	Recall	0.709933	0.739620	0.734826	0.757009	0.728328	0.717569

6.3.5.2.2 SGD Classifier

```
In [142]: from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import ParameterGrid

# ***
# *** Each classifier, needs to be optimzed for each Stock Index
# ***
# *** Note: This is a customized optimization, since we are optimizing the accuracy of the
# *** Combine Multi-Label, which can only be infered after evaluating the Multi_Label case
# ***

param_grid_sgd = ParameterGrid( { "loss"      : [ "hinge", "log", "squared_hinge", "modified_huber" ],
                                 "alpha"     : [ 0.0001, 0.001, 0.01, 0.1],
                                 "penalty"   : [ "l2", "l1", "none" ]})

models = []

for i, params in enumerate(param_grid_sgd):
    SGD_clf = SGDClassifier(**params, max_iter=1000, tol=1e-3, random_state=42)
    models.append(SGD_clf)

optimization_eval_sgd_1 = { 'experiment_name' : "Evaluate SGD Models",
                            'description'   : "Evaluate Only Financial Index Features",
                            'indexes'       : [ "S&P_500", "Nasdaq", "DJI" ],
                            'dataset_name'  : "US Market Indexes",
                            'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{} " ] ,
                            'y_label_name'  : "label_{\{}",
                            'y_ml_label_name': "f_label_{\{}",
                            'cv'           : 10,
                            'models'        : models,
                            'dataset'       : indexes_data_training_set_1 }

optimization_eval_sgd_2 = { 'experiment_name' : "Evaluate SGD Models",
                            'description'   : "Evaluate Only Financial Index Features",
                            'indexes'       : [ "MXUS", "MSDUUK", "MSDUJN" ],
                            'dataset_name'  : "MSUS-MSDUUK-MSDUJN Market Indexes",
                            'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{} " ] ,
                            'y_label_name'  : "label_{\{}",
                            'y_ml_label_name': "f_label_{\{}",
                            'cv'           : 10,
                            'models'        : models,
                            'dataset'       : indexes_data_training_set_2 }
```

```
results_df_sgd, results_df_details_sgd, models_fitted_dict_sgd = \
    executeExperimentSet ( experiments = [optimization_eval_sgd_1, optimization_eval_
sgd_2] )
```

Job # 1 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 2 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 3 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 4 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 5 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 6 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 7 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 8 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 9 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 10 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 11 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 12 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 13 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 14 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 15 Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

```
classifier
Job # 16
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 17
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 18
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 19
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 20
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 21
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Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 22
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Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 23
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 24
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 25
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 26
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 27
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 28
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC

Job # 29
classifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
```

Job # 30 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 31 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 32 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 33 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 34 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 35 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 36 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 37 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 38 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 39 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 40 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 41 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 42 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
Job # 43 lassifier	Dataset = US Market Indexes Executing Experiment = Evaluate SGD Models	Index_Name = S&P_500	ML Model = SGDC
	Dataset = US Market Indexes		

Job # 44 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 45 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 46 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 47 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 48 classifier Executing Experiment = Evaluate SGD Models Index_Name = S&P_500 ML Model = SGDC
Dataset = US Market Indexes

Job # 49 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 50 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 51 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 52 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 53 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 54 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 55 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 56 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
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Job # 57 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 58 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

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Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
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Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Job # 61 assifier
Dataset = US Market Indexes
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Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
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Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
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Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Job # 68 assifier
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Job # 69 assifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Job # 70 assifier
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Job # 71 assifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Job # 72 assifier
Dataset = US Market Indexes
Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 73 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 74 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

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Job # 76 assifier Dataset = US Market Indexes
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Job # 77 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 78 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 79 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 80 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 81 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 82 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 83 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 84 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 85 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Job # 86 assifier Dataset = US Market Indexes
 Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1

Dataset = US Market Indexes

Job # 87 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

Job # 88 classifier Executing Experiment = Evaluate SGD Models Index_Name = Nasdaq ML Model = SGDC1
Dataset = US Market Indexes

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Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 264 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 265 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 266 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 267 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 268 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 269 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 270 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 271 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 272 assifier Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

Job # 273 Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

assifier
Job # 274 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 275 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 276 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 277 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 278 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 279 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 280 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 281 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 282 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 283 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 284 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 285 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 286 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
assifier
Job # 287 Dataset = MSUS-MSDUUK-MSDUJN Market Indexes Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1

```

Job # 288          Dataset = MSUS-MSDUUK-MSDUJN Market Indexes
assifier          Executing Experiment = Evaluate SGD Models Index_Name = MSDUJN ML Model = SGDC1
                  Dataset = MSUS-MSDUUK-MSDUJN Market Indexes

```

Permutations Executed for SGD Model

```
In [143]: print("Total number of SGD models evaluated for optimization = ", len(results_df_sgd))
results_df_sgd.head() # Just display the top 5
```

Total number of SGD models evaluated for optimization = 288

Out[143]:

	Experiment Name	Experiment Description	Dataset	Index	Classifier	CV	BL_Precision	BL_Recall	BL_Accuracy	ML_Precision	ML_Recall	ML_
0	Evaluate SGD Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SGDClassifier	10	0.525988	0.719579	0.503081	0.478674	0.548620	
0	Evaluate SGD Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SGDClassifier	10	0.536946	0.491237	0.501205	0.474209	0.547549	
0	Evaluate SGD Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SGDClassifier	10	0.533000	0.748122	0.514600	0.464737	0.549424	
0	Evaluate SGD Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SGDClassifier	10	0.529079	0.701552	0.506295	0.470422	0.556389	
0	Evaluate SGD Models	Evaluate Only Financial Index Features	US Market Indexes	S&P_500	SGDClassifier	10	0.513037	0.364547	0.474953	0.503834	0.559068	

Select Best Models for each Index for SGD

```
In [144]: analysis_columns = ["Classifier", "Job_ID", "Index",
                           "Combine_ML_Precision", "Combine_ML_Recall", "Combine_ML_Accuracy"]

best_sgd_models_dict, optimum_models_metrics_sgd_df = \
    getOptimizedModelsDict(results_df = results_df_sgd,
                           models_fitted = models_fitted_dict_sgd,
                           metric = "Combine_ML_Accuracy")

optimum_models_metrics_sgd_df[analysis_columns]
```

Out[144]:

	Classifier	Job_ID	Index	Combine_ML_Precision	Combine_ML_Recall	Combine_ML_Accuracy
29	SGDClassifier	30	S&P_500	0.816940	0.709371	0.796946
77	SGDClassifier	78	Nasdaq	0.815274	0.736005	0.804179
125	SGDClassifier	126	DJI	0.799043	0.712371	0.794803
161	SGDClassifier	162	MXUS	0.817235	0.672118	0.783422
207	SGDClassifier	208	MSDUUK	0.807260	0.722910	0.795062
255	SGDClassifier	256	MSDUJN	0.807890	0.698295	0.777425

Validate Best Models For Each Index With Training Set for QA

```
In [145]: models_1 = [ best_sgd_models_dict.get('S&P_500'), best_sgd_models_dict.get('Nasdaq'),
                    best_sgd_models_dict.get('DJI') ]

models_2 = [ best_sgd_models_dict.get('MXUS'), best_sgd_models_dict.get('MSDUUK'),
                    best_sgd_models_dict.get('MSDUJN') ]

predictions_eval_sgd_1    = { 'prediction_name' : "Predict SGD Models",
                                'description'      : "Evaluate Only Financial Index Features",
                                'indexes'          : [ "S&P_500", "Nasdaq", "DJI" ],
                                'dataset_name'     : "US Market Indexes",
                                'x_features_names': [ "r_{\{\}}", "R_{\{\}}", "V_{\{\}}" ] ,
                                'y_label_name'     : "label_{\{\}}",
                                'y_ml_label_name' : "f_label_{\{\}}",
                                'cv'               : 10,
                                'models'           : models_1,
                                'dataset'          : indexes_data_training_set_1 }

predictions_eval_sgd_2    = { 'prediction_name' : "Predict SGD Models",
                                'description'      : "Evaluate Only Financial Index Features",
                                'indexes'          : [ "MXUS", "MSDUUK", "MSDUJN" ],
                                'dataset_name'     : "MSUS-MSDUUK-MSDUJN Market Indexes",
                                'x_features_names': [ "r_{\{\}}", "R_{\{\}}", "V_{\{\}}" ] ,
                                'y_label_name'     : "label_{\{\}}",
                                'y_ml_label_name' : "f_label_{\{\}}",
                                'cv'               : 10,
                                'models'           : models_2,
                                'dataset'          : indexes_data_training_set_2 }

predictions_sgd_df, models_sgd_fitted_dict, cm_ml_sgd_dict, cm_ml_compact_sgd_dict = \
    executePredictionsSet ( predictions = [predictions_eval_sgd_1, predictions_eval_sgd_2],
                            FitModels = True )
```

```
In [146]: sgd_training_results_df = predictions_sgd_df[ predictions_sgd_df.Model == "Combine ML" ]
analysis_columns = [ "Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN" ]

sgd_training_results_stats_df = \
    sgd_training_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

sgd_training_results_stats_df
```

Out[146]:

	DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
Classifier	Metric					

SGDClassifier	Accuracy	0.797214	0.799357	0.802572	0.781305	0.802116	0.774603
	Precision	0.810830	0.816768	0.812094	0.839468	0.799345	0.801871
	Recall	0.702620	0.716489	0.736005	0.639408	0.755418	0.699036

6.3.6 Summary of Results For Optimized Classifiers against the Training Sets Using Cross Validation

```
In [147]: # Aggregate all results from all optimized classifiers
```

```
summary_optimized_classifiers_training_set_df = knn_training_results_stats_df
summary_optimized_classifiers_training_set_df = \
    summary_optimized_classifiers_training_set_df.append(rf_training_results_stats_df)
summary_optimized_classifiers_training_set_df = \
    summary_optimized_classifiers_training_set_df.append(svc_training_results_stats_df)
summary_optimized_classifiers_training_set_df = \
    summary_optimized_classifiers_training_set_df.append(sgd_training_results_stats_df)

summary_optimized_classifiers_training_set_df.style.format("{:.2%}")
```

Out[147]:

		DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
	Classifier	Metric					
		Accuracy	80.74%	80.55%	81.60%	80.95%	80.67%
KNeighborsClassifier		Precision	79.90%	80.85%	81.80%	82.01%	80.15%
		Recall	75.08%	74.61%	76.55%	74.22%	76.55%
		Accuracy	81.44%	80.85%	81.54%	81.66%	81.59%
RandomForestClassifier		Precision	80.04%	80.29%	79.47%	81.31%	78.77%
		Recall	76.97%	76.33%	80.08%	77.26%	81.58%
		Accuracy	79.67%	79.77%	80.36%	80.07%	80.32%
SVC		Precision	80.46%	79.78%	81.50%	79.35%	81.97%
		Recall	70.99%	73.96%	73.48%	75.70%	72.83%
		Accuracy	79.72%	79.94%	80.26%	78.13%	80.21%
SGDClassifier		Precision	81.08%	81.68%	81.21%	83.95%	79.93%
		Recall	70.26%	71.65%	73.60%	63.94%	75.54%
							69.90%

6.3.7 Evaluate Performance with Test Datasets

6.3.7.1 Run Predictions against all indexes across datasets

6.3.7.1.1 KNN

```
In [148]: models_1 = [ best_knn_models_dict.get('S&P_500'), best_knn_models_dict.get('Nasdaq'),
                     best_knn_models_dict.get('DJI') ]

models_2 = [ best_knn_models_dict.get('MXUS'), best_knn_models_dict.get('MSDUUK'),
                     best_knn_models_dict.get('MSDUJN') ]

predictions_eval_1 = { 'prediction_name' : "Predict KNN Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                      'dataset_name' : "US Market Indexes",
                      'x_features_names' : [ "r_{\{}", "R_{\{}", "V_{\{}" ] ,
                      'y_label_name' : "label_{\{}",
                      'y_ml_label_name' : "f_label_{\{}",
                      'cv' : 10,
                      'models' : models_1,
                      'dataset' : indexes_data_testing_set_1 }

predictions_eval_2 = { 'prediction_name' : "Predict KNN Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "MXUS", "MSDUUK", "MSDUJN" ],
                      'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                      'x_features_names' : [ "r_{\{}", "R_{\{}", "V_{\{}" ] ,
                      'y_label_name' : "label_{\{}",
                      'y_ml_label_name' : "f_label_{\{}",
                      'cv' : 10,
                      'models' : models_2,
                      'dataset' : indexes_data_testing_set_2 }

predictions_test_knn_df, models_knn_fitted_dict, cm_ml_knn_dict, cm_ml_compact_knn_dict = \
    executePredictionsSet ( predictions = [predictions_eval_1, predictions_eval_2], FitModels =
False )
```

```
In [149]: knn_testing_results_df = predictions_test_knn_df[ predictions_test_knn_df.Model == "Combine ML" ]
analysis_columns = [ "Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN" ]

knn_testing_results_stats_df = \
    knn_testing_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

knn_testing_results_stats_df.style.format("{:.2%}")
```

Out[149]:

		DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
Classifier	Metric						
KNeighborsClassifier	Accuracy	76.42%	75.10%	78.68%	78.02%	79.87%	76.01%
	Precision	69.85%	68.00%	71.90%	67.82%	78.21%	71.71%
	Recall	73.94%	68.92%	74.58%	79.02%	75.85%	72.55%

6.3.7.1.2 Random Forest

```
In [150]: models_1 = [ best_rf_models_dict.get('S&P_500'), best_rf_models_dict.get('Nasdaq'),
                    best_rf_models_dict.get('DJI') ]

models_2 = [ best_rf_models_dict.get('MXUS'), best_rf_models_dict.get('MSDUUK'),
                    best_rf_models_dict.get('MSDUJN') ]

predictions_eval_1 = { 'prediction_name' : "Predict Random Forest Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "S&P_500", "Nasdaq", "DJI" ],
                      'dataset_name' : "US Market Indexes",
                      'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                      'y_label_name' : "label_{\{}",
                      'y_ml_label_name' : "f_label_{\{}",
                      'cv' : 10,
                      'models' : models_1,
                      'dataset' : indexes_data_testing_set_1 }

predictions_eval_2 = { 'prediction_name' : "Predict Random Forest Models",
                      'description' : "Evaluate Only Financial Index Features",
                      'indexes' : [ "MXUS", "MSDUUK", "MSDUJN" ],
                      'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                      'x_features_names' : [ "r_{\{} \", "R_{\{} \", "V_{\{}" ] ,
                      'y_label_name' : "label_{\{}",
                      'y_ml_label_name' : "f_label_{\{}",
                      'cv' : 10,
                      'models' : models_2,
                      'dataset' : indexes_data_testing_set_2 }

predictions_test_rf_df, models_rf_fitted_dict, cm_ml_rf_dict, cm_ml_compact_rf_dict = \
executePredictionsSet ( predictions = [predictions_eval_1, predictions_eval_2], FitModels =
False )
```

```
In [151]: rf_testing_results_df = predictions_test_rf_df[ predictions_test_rf_df.Model == "Combine ML" ]
analysis_columns = [ "Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN" ]

rf_testing_results_stats_df = \
    rf_testing_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

rf_testing_results_stats_df.style.format("{:.2%}")
```

Out[151]:

	DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
Classifier	Metric					

	Accuracy	77.88%	75.23%	78.54%	77.35%	80.37%	76.01%
RandomForestClassifier	Precision	72.29%	67.30%	69.50%	67.18%	75.87%	71.05%
	Recall	73.94%	71.62%	80.34%	77.68%	81.89%	74.12%

6.3.7.1.3 SVC

```
In [152]: models_1 = [ best_svc_models_dict.get('S&P_500'), best_svc_models_dict.get('Nasdaq'),
                    best_svc_models_dict.get('DJI') ]

models_2 = [ best_svc_models_dict.get('MXUS'), best_svc_models_dict.get('MSDUUK'),
                    best_svc_models_dict.get('MSDUJN') ]

predictions_eval_svc_1 = { 'prediction_name' : "Predict SVC Models",
                           'description' : "Evaluate Only Financial Index Features",
                           'indexes' : ["S&P_500", "Nasdaq", "DJI"],
                           'dataset_name' : "US Market Indexes",
                           'x_features_names' : [ "r_{\{} \bigr)", "R_{\{} \bigr)", "V_{\{} \bigr)" ],
                           'y_label_name' : "label_{\{} \bigr)",
                           'y_ml_label_name' : "f_label_{\{} \bigr)",
                           'cv' : 10,
                           'models' : models_1,
                           'dataset' : indexes_data_testing_set_1 }

predictions_eval_svc_2 = { 'prediction_name' : "Predict SVC Models",
                           'description' : "Evaluate Only Financial Index Features",
                           'indexes' : ["MXUS", "MSDUUK", "MSDUJN"],
                           'dataset_name' : "MSUS-MSDUUK-MSDUJN Market Indexes",
                           'x_features_names' : [ "r_{\{} \bigr)", "R_{\{} \bigr)", "V_{\{} \bigr)" ],
                           'y_label_name' : "label_{\{} \bigr)",
                           'y_ml_label_name' : "f_label_{\{} \bigr)",
                           'cv' : 10,
                           'models' : models_2,
                           'dataset' : indexes_data_testing_set_2 }

predictions_test_svc_df, models_svc_fitted_dict, cm_ml_svc_dict, cm_ml_compact_svc_dict = \
    executePredictionsSet ( predictions = [predictions_eval_svc_1, predictions_eval_svc_2],
                           FitModels = False )
```

```
In [153]: svc_testing_results_df = predictions_test_svc_df[ predictions_svc_df.Model == "Combine ML" ]
analysis_columns = [ "Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN" ]

svc_testing_results_stats_df = \
    svc_testing_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

svc_testing_results_stats_df
```

Out[153]:

		DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
Classifier	Metric						
SVC	Accuracy	0.772185	0.749669	0.788079	0.791946	0.817114	0.761745
	Precision	0.719870	0.677741	0.717042	0.704918	0.814516	0.725100
	Recall	0.719870	0.689189	0.755932	0.767857	0.762264	0.713725

6.3.7.1.4 SGD


```
In [155]: sgd_testing_results_df = predictions_test_sgd_df[ predictions_test_sgd_df.Model == "Combine ML" ]
analysis_columns = ["Classifier", "Metric", "DJI", "S&P_500", "Nasdaq", "MXUS", "MSDUUK", "MSDUJN"]

sgd_testing_results_stats_df = \
    sgd_testing_results_df[analysis_columns].groupby(['Classifier', 'Metric']).max()

sgd_testing_results_stats_df
```

Out[155]:

	DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
--	-----	---------	--------	------	--------	--------

Classifier	Metric					
SGDClassifier	Accuracy	0.789404	0.756291	0.794702	0.805369	0.820470
	Precision	0.755172	0.710526	0.755474	0.757143	0.831933
	Recall	0.713355	0.638514	0.701695	0.709821	0.725410

6.3.7.2 Summary of Results For Optimized Classifiers against the Testing Sets

```
In [158]: # Aggregate all results from all optimized classifiers
```

```
summary_optimized_classifiers_testing_set_df = knn_testing_results_stats_df
summary_optimized_classifiers_testing_set_df = \
    summary_optimized_classifiers_testing_set_df.append(rf_testing_results_stats_df)
summary_optimized_classifiers_testing_set_df = \
    summary_optimized_classifiers_testing_set_df.append(svc_testing_results_stats_df)
summary_optimized_classifiers_testing_set_df = \
    summary_optimized_classifiers_testing_set_df.append(sgd_testing_results_stats_df)

summary_optimized_classifiers_testing_set_df.style.format("{:.2%}")
```

Out[158]:

		DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
	Classifier	Metric					
KNeighborsClassifier		Accuracy	76.42%	75.10%	78.68%	78.02%	79.87%
		Precision	69.85%	68.00%	71.90%	67.82%	78.21%
		Recall	73.94%	68.92%	74.58%	79.02%	75.85%
RandomForestClassifier		Accuracy	77.88%	75.23%	78.54%	77.35%	80.37%
		Precision	72.29%	67.30%	69.50%	67.18%	75.87%
		Recall	73.94%	71.62%	80.34%	77.68%	81.89%
SVC		Accuracy	77.22%	74.97%	78.81%	79.19%	81.71%
		Precision	71.99%	67.77%	71.70%	70.49%	81.45%
		Recall	71.99%	68.92%	75.59%	76.79%	76.23%
SGDClassifier		Accuracy	78.94%	75.63%	79.47%	80.54%	82.05%
		Precision	75.52%	71.05%	75.55%	75.71%	83.19%
		Recall	71.34%	63.85%	70.17%	70.98%	74.72%

6.3.7.3 Comparison of Testing and Training Sets

```
In [168]: (summary_optimized_classifiers_testing_set_df. \
    sub(summary_optimized_classifiers_training_set_df) ). \
    style.format("{:.2%}")
```

Out[168]:

			DJI	S&P_500	Nasdaq	MXUS	MSDUUK	MSDUJN
	Classifier	Metric						
KNeighborsClassifier		Accuracy	-4.32%	-5.45%	-2.92%	-2.93%	-0.80%	-2.41%
		Precision	-10.05%	-12.85%	-9.91%	-14.20%	-1.94%	-8.43%
		Recall	-1.13%	-5.70%	-1.97%	4.80%	-0.70%	-0.10%
RandomForestClassifier		Accuracy	-3.56%	-5.61%	-3.00%	-4.31%	-1.22%	-3.11%
		Precision	-7.75%	-12.99%	-9.97%	-14.13%	-2.90%	-9.30%
		Recall	-3.02%	-4.71%	0.26%	0.42%	0.31%	-0.16%
SVC		Accuracy	-2.45%	-4.81%	-1.56%	-0.88%	1.39%	-1.74%
		Precision	-8.47%	-12.01%	-9.80%	-8.86%	-0.52%	-7.29%
		Recall	0.99%	-5.04%	2.11%	1.08%	3.39%	-0.38%
SGDClassifier		Accuracy	-0.78%	-4.31%	-0.79%	2.41%	1.84%	-1.79%
		Precision	-5.57%	-10.62%	-5.66%	-8.23%	3.26%	-7.65%
		Recall	1.07%	-7.80%	-3.43%	7.04%	-0.82%	-0.49%

- There is overfit across most Classifiers except for SGD (MXUS, MSDUUK) and SVC (MSDUUK)
- The range of overfit in percentages is between -0.80% to -5.61% in terms of accuracy

6.3.7.4 Testing set Confusion Matrixes for Best Classifier across Stock Indexes modeled

```
In [186]: # Find the Best Classifier Per Index based on Accuracy
```

```
test_set_results = knn_testing_results_df
test_set_results = test_set_results.append(rf_testing_results_df)
test_set_results = test_set_results.append(svc_testing_results_df)
test_set_results = test_set_results.append(sgd_testing_results_df)
test_set_results = test_set_results[test_set_results.Metric == "Accuracy" ].set_index('Classifier')
test_set_results
```

Out[186]:

	Model	Metric	S&P_500	Nasdaq	DJI	MXUS	MSDUUK	MSDUJN
Classifier								
KNeighborsClassifier	Combine ML	Accuracy	0.750993	0.786755	0.764238	0.780201	0.798658	0.760067
RandomForestClassifier	Combine ML	Accuracy	0.752318	0.785430	0.778808	0.773490	0.803691	0.760067
SVC	Combine ML	Accuracy	0.749669	0.788079	0.772185	0.791946	0.817114	0.761745
SGDClassifier	Combine ML	Accuracy	0.756291	0.794702	0.789404	0.805369	0.820470	0.756711

Best Stock Index for a given classifier

```
In [223]: best_classifiers_across_index = test_set_results[ ['S&P_500', 'Nasdaq', 'DJI', 'MXUS', 'MSDUUK', 'MSDUJN' ] ]. \
idxmax(axis=1)

best_classifiers_names = best_classifiers_across_index.index.to_numpy().astype('str')
best_classified_index = best_classifiers_across_index.to_numpy().astype('<U6')

best_classifiers_across_index
```

Out[223]: Classifier

KNeighborsClassifier	MSDUUK
RandomForestClassifier	MSDUUK
SVC	MSDUUK
SGDClassifier	MSDUUK

dtype: object

Confusion Matrixes for Best Modeled Stock Indexes

```
In [277]: from IPython.display import display, HTML

dict_confusion_matrixes_ml = {**cm_ml_knn_dict, **cm_ml_svc_dict, **cm_ml_rf_dict, **cm_ml_sgd_dict}
dict_confusion_matrixes_ml_compact = {**cm_ml_compact_knn_dict, **cm_ml_compact_svc_dict,
                                       **cm_ml_compact_rf_dict, **cm_ml_compact_sgd_dict}

for i in range( len(best_classifiers_names) ) :

    display(HTML("<br>"))
    msg = "***** Confusion Matrix for Classifier : " + best_classifiers_names[i] + \
          " for stock index : " + best_classified_index[i] + " *****"
    display(HTML(msg))
    display( HTML("4x4 C.M. For Multi Label (S1,S2,S3,S4)") )

    df = pd.DataFrame(dict_confusion_matrixes_ml[ best_classifiers_names[i] + best_classified_index[i] ],
                       index = [ 'S1', 'S2', 'S3', 'S4' ] ). \
        rename( columns={0: "S1", 1: "S2", 2 : "S3", 3 : "S4"} )
    display(HTML(df.to_html()))

    display( HTML("2x2 C.M. For Merge Multi Label (S1S2, S3S4)") )
    df_compact = pd.DataFrame(dict_confusion_matrixes_ml_compact[ best_classifiers_names[i] + \
                                                               best_classified_index[i] ], \
                               index = [ 'S1S2', 'S3S4' ] ). \
        rename( columns={0: "S1S2", 1: "S3S4"} )
    display(HTML(df_compact.to_html()))
```

***** Confusion Matrix for Classifier : KNeighborsClassifier for stock index : MSDUUK *****

4x4 C.M. For Multi Label (S1,S2,S3,S4)

	S1	S2	S3	S4
S1	71	8	6	13
S2	135	61	16	21
S3	28	17	62	69
S4	17	2	15	55

2x2 C.M. For Merge Multi Label (S1S2, S3S4)

	S1S2	S3S4
S1S2	275	56
S3S4	64	201

***** Confusion Matrix for Classifier : RandomForestClassifier for stock index : MSDUUK *****

4x4 C.M. For Multi Label (S1,S2,S3,S4)

	S1	S2	S3	S4
S1	55	15	6	22
S2	89	103	26	15
S3	16	16	74	70
S4	11	5	19	54

2x2 C.M. For Merge Multi Label (S1S2, S3S4)

	S1S2	S3S4
S1S2	262	69
S3S4	48	217

***** Confusion Matrix for Classifier : SVC for stock index : MSDUUK *****

4x4 C.M. For Multi Label (S1,S2,S3,S4)

	S1	S2	S3	S4
S1	55	26	4	13
S2	40	164	18	11
S3	14	29	78	55
S4	9	11	26	43

2x2 C.M. For Merge Multi Label (S1S2, S3S4)

	S1S2	S3S4
S1S2	285	46
S3S4	63	202

***** Confusion Matrix for Classifier : SGDClassifier for stock index : MSDUUK *****

4x4 C.M. For Multi Label (S1,S2,S3,S4)

	S1	S2	S3	S4
S1	80	1	4	13
S2	190	20	11	12
S3	36	6	74	60
S4	24	1	22	42

2x2 C.M. For Merge Multi Label (S1S2, S3S4)

	S1S2	S3S4
S1S2	291	40
S3S4	67	198

7.0 Conclusions

- The results presented by Reference 1 have been validated as demonstrated by comparison of Testing Sets' results.
 - (section 6.3.7.2 of Jupyter Notebook and Reference 1, Table 3)
- Derived financial Engineered Network Parameters were found NOT to improve forecasting results
 - (section 6.3.4.2.2 of Jupyter Notebook)
- The daily log returns, five-day moving average return, five-day rolling volatility, average 5-day volatility between markets, and the engineered stock index classifications were determined to be the critical features in forecasting a market's next day price pattern
 - (6.3.4.2.2 Compare Performance Between Experiment Types (different feature sets))
- The number stock index classifications levels (S1, S2, S3, S4) derived from the Engineered Formulas in Reference 1 were validated via clustering analysis using K-Means.
 - For all stock indexes, the optimum number of clusters/classifications per index is four using the inertia method.
 - In all cases, two clusters' centroid have a positive 5-day average log returns, and two a negative one, matching Ref 1 formula
 - Volatility values for each cluster centroids matches closely the logic use in Reference 1
 - (section 6.1.8 Cluster Analysis with Unsupervised Learning)
- The results were determined to be applicable to different markets and time periods
 - (6.3.4.2.1 Compare Performance between Datasets)
- Four independent Machine Learning algorithms were determined to provide forecasting accuracy between 75 to 82% depending on the market index
- Inspection of the Precision and Recall metrics and Confusion Matrix for each classifier further demonstrate the validity of the results.
 - (section 6.3.7.4 Testing set Confusion Matrixes for Best Classifier across Stock Indexes modeled)
- Analysis of Price Movements for Analyzed Markets with respect to Indexes' Classification further validate the results.
 - Transition's frequencies from one level to another were found to be lower than the accuracy rate of the classifiers.
 - (section 6.1.6 Analysis & Visualization of Stock Indexes Classifications' Distributions / Dataset 1)

8.0 Recommendations

- Evaluate the impact of different rolling volatility windows on forecasting results, that is: 20-day, 10-day, and 3-day
- Since the Derived financial Engineered Network Parameters were found NOT to improve forecasting results, evaluate if longer sliding windows can capture additional forecasting knowledge.
 - Evaluate 60, 90, 120, and 200 days sliding windows
- Evaluate Ensemble Methods
- Evaluate Deep Neural Networks
- Define a set of trading strategies and evaluate each in relation to the forecasting predictions
 - Across different sets of indexes, time periods
- Evaluate applicability of the forecasting method to different sectors within a market, and/or sectors across markets
- Use derived index classification via unsupervised learning for forecasting next day price movement for each stock index
 - Evaluate clusters with 4, 5, and 6 different levels
 - Compare results to engineered index classifications & against trading strategies

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10.0 References

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