report

June 25, 2024

1 Global Stock Market Analytics

in this project we will look at predicting the open direction of the Nifty 50 index by looking at other indices and indicators. We will break the project up into three parts:

- preparing the master data from the global indices
- predictive modelling of open direction of Nifty 50
- sentiment analysis of X / Twitter data relating to Nifty 50

1.1 Prepare the Master Data

we begin by preparing the master data that we will be working with. We import the libraries we will be using, and declare some constants.

[ ]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns

import statsmodels.api as sm
import yfinance as yf
import ta

from scipy import stats

from statsmodels.api import Logit
from statsmodels.stats.outliers_influence import variance_inflation_factor

from sklearn.metrics import classification_report, roc_curve, roc_auc_score
from sklearn.model_selection import train_test_split



plt.style.use("ggplot")
sns.set_style("darkgrid")
sns.set_context("paper")


INDICES  = ['NSEI', 'DJI', 'IXIC', 'HSI', 'N225', 'GDAXI', 'VIX']
```

```
COLUMNS  = [f"{index}_DAILY_RETURNS" for index in INDICES]
```

next, we declare a function that we will use to download the OHLC data:

```
[ ]: def retrieve_data(index, start_date = '2017-12-1', end_date = '2024-1-31',␣
      ↪progress = False):
         data = yf.download(f'^{index}', start_date, end_date, progress = progress)

         # create daily returns for each index
         data['Daily Returns'] = data.Close.pct_change() * 100

         # rename columns - prefix with index name
         data.columns = ["_".join(c.upper() for c in column.split()) for column in␣
      ↪data.columns]
         data.columns = [f"{index}_{column}" for column in data.columns]

         return data
```

next, we...

```
[ ]: def test_normality(data, column_name, index_name):
         print()
         print(f"\t Index {index_name}")
         print(f"\tColumn {column_name}")
         print()

         data = data[column_name].dropna()

         if data.shape[0] < 50:
             print("\t     Shapiro-Wilks Test:")
             result = stats.shapiro(data)
         else:
             print("\tKolmogorov-Smirnov Test:")
             result = sm.stats.diagnostic.lilliefors(data)

         print(f"\t                p-value: {result[1]}")

         if result[1] < 0.05:
             print("\treject null hypothesis - data is not drawn from a normal␣
      ↪distribution")
         else:
             print("\tfail to reject null hypothesis - data is drawn from a normal␣
      ↪distribution")

         print()
```

next, we...

[ ]:
```
def qq_plots(data, title, count = 6):
    fig, axes = plt.subplots(3, 2, sharex = True, figsize = (16, 12))
    fig.suptitle(title)

    for index in range(count):
        axes[index // 2, index % 2].set_title(INDICES[index])
        sm.graphics.qqplot(data[index][COLUMNS[index]].dropna(), line = "45",␣
 ↪fit = True, ax = axes[index // 2, index % 2])
        axes[index // 2, index % 2].set_xlabel("")
```

next, we...

[ ]:
```
def merge_data(data, start_date = '2018-01-02', end_date = '2023-12-29'):
    # merge data with outer join
    merged = pd.concat(data, axis = 1)

    # impute missing data using LOCF (forward fill)
    merged.ffill(inplace = True)

    # add indicators for MONTH, QUARTER, and YEAR
    merged['MONTH']   = merged.index.month
    merged['QUARTER'] = merged.index.quarter
    merged['YEAR']    = merged.index.year

    return merged[start_date:end_date]
```

next, we...

[ ]:
```
data = [retrieve_data(index) for index in INDICES]
```

next, we...

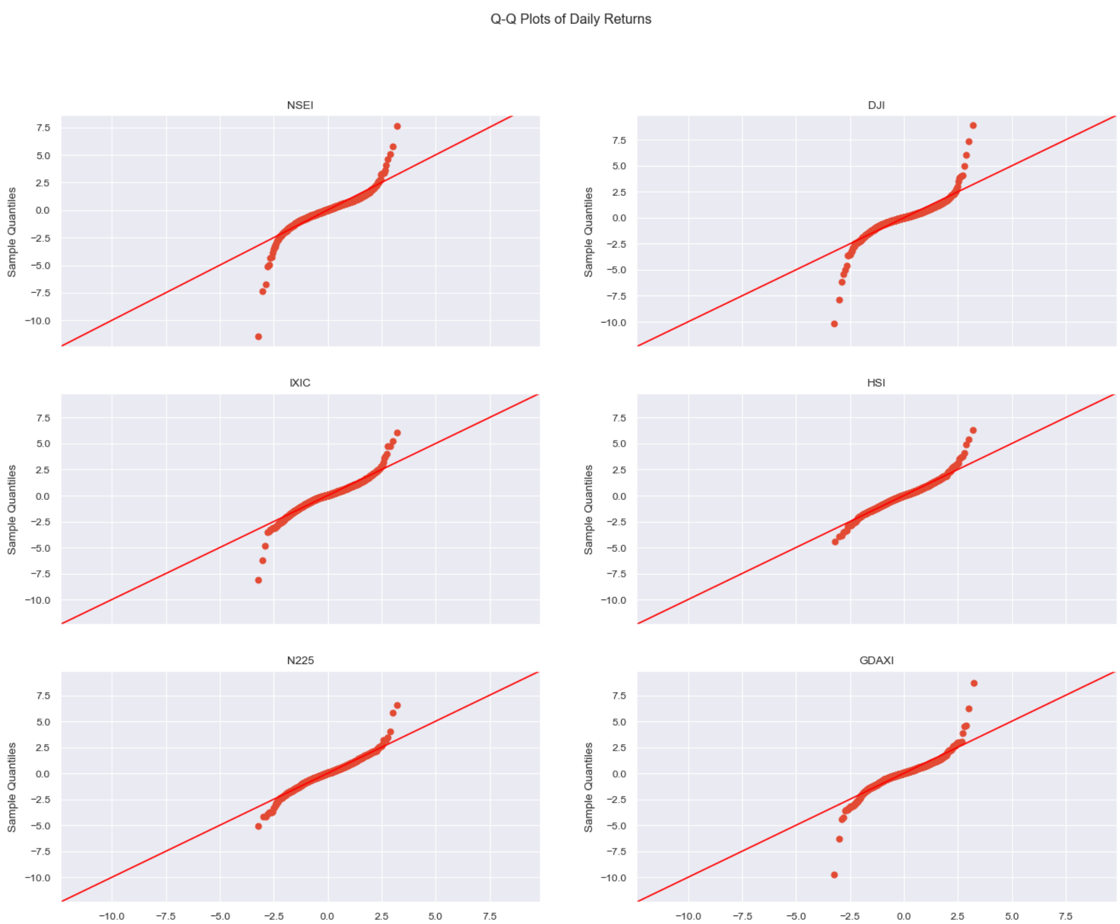
[ ]:
```
for d, c, i in zip(data, COLUMNS, INDICES):
    # check daily returns follows Normal distribution
    test_normality(d, c, i)
```

```
 Index NSEI
Column NSEI_DAILY_RETURNS

Kolmogorov-Smirnov Test:
                p-value: 0.0009999999999998899
reject null hypothesis - data is not drawn from a normal distribution


 Index DJI
Column DJI_DAILY_RETURNS

Kolmogorov-Smirnov Test:
```

```
                p-value: 0.0009999999999998899
reject null hypothesis - data is not drawn from a normal distribution


 Index IXIC
Column IXIC_DAILY_RETURNS

Kolmogorov-Smirnov Test:
                p-value: 0.0009999999999998899
reject null hypothesis - data is not drawn from a normal distribution


 Index HSI
Column HSI_DAILY_RETURNS

Kolmogorov-Smirnov Test:
                p-value: 0.0009999999999998899
reject null hypothesis - data is not drawn from a normal distribution


 Index N225
Column N225_DAILY_RETURNS

Kolmogorov-Smirnov Test:
                p-value: 0.0009999999999998899
reject null hypothesis - data is not drawn from a normal distribution


 Index GDAXI
Column GDAXI_DAILY_RETURNS

Kolmogorov-Smirnov Test:
                p-value: 0.0009999999999998899
reject null hypothesis - data is not drawn from a normal distribution


 Index VIX
Column VIX_DAILY_RETURNS

Kolmogorov-Smirnov Test:
                p-value: 0.0009999999999998899
reject null hypothesis - data is not drawn from a normal distribution
```

next, we...

[ ]:
```
# check daily returns follows Normal distribution
qq_plots(data, "Q-Q Plots of Daily Returns")
```



next, we...

[ ]:
```
master = merge_data(data)
```

at which point we have our master data

[ ]:
```
CONDITIONS = [(master.index <= '2020-01-30'), ('2022-05-05' <= master.index)]
CHOICES    = ['PRE_COVID', 'POST_COVID']
```

next, we...

[ ]:
```
master['PANDEMIC'] = np.select(CONDITIONS, CHOICES, 'COVID')
master['PANDEMIC'] = pd.Categorical(master['PANDEMIC'], categories = ['PRE_COVID', 'COVID', 'POST_COVID'], ordered = True)
```

next, we...

[ ]:
```
master["NSEI_OPEN_DIR"] = np.where(master["NSEI_OPEN"] > master["NSEI_CLOSE"].shift(), 1, 0)
```

next, we...

```
[ ]: def performance_analytics_tables(data, group_by, count = 6):
         for index in range(count):
             table = data.groupby(group_by, observed = False)[COLUMNS[index]].agg(['count', 'mean', 'std', 'var'])
             print(f"\n{INDICES[index]}\n\n{table}\n\n")
```

next, we...

```
[ ]: def performance_analytics_box_plots(data, group_by, title, count = 6):
         fig, axes = plt.subplots(3, 2, sharex = True, figsize = (16, 12))
         fig.suptitle(title)

         for index in range(count):
             axes[index // 2, index % 2].set_title(INDICES[index])
             sns.boxplot(x = data[group_by], y = data[COLUMNS[index]], ax = axes[index // 2, index % 2])
             axes[index // 2, index % 2].set_xlabel("")
```

next, we...

```
[ ]: def performance_analytics_bar_plots(data, group_by, title, count = 6, aggfunc = "median"):
         fig, axes = plt.subplots(3, 2, sharex = True, figsize = (16, 12))
         fig.suptitle(title)

         for index in range(count):
             axes[index // 2, index % 2].set_title(INDICES[index])
             table = data.groupby(group_by, observed = False)[COLUMNS[index]].agg([aggfunc])
             sns.barplot(x = table.index, y = table[aggfunc], ax = axes[index // 2, index % 2])
             axes[index // 2, index % 2].set_xlabel("")
```

next, we...

```
[ ]: def performance_analytics_heat_maps(data, group_by, title, column = "QUARTER", count = 6, aggfunc = "median"):
         fig, axes = plt.subplots(3, 2, sharex = True, figsize = (16, 12))
         fig.suptitle(title)

         for index in range(count):
             axes[index // 2, index % 2].set_title(INDICES[index])
             table = pd.pivot_table(data, values = COLUMNS[index], index = [group_by], columns = [column], aggfunc = aggfunc, observed = False)
             sns.heatmap(table, ax = axes[index // 2, index % 2])
             axes[index // 2, index % 2].set_xlabel("")
```

next, we...

```python
[ ]: def correlation_matrix(data):
        plt.figure(figsize = (9, 6))
        matrix = data[COLUMNS[:-1]].corr()

        ax = sns.heatmap(matrix, annot = True)
        ax.set_xticklabels(
            ax.get_xticklabels(),
            rotation = 30,
            horizontalalignment = "right"
        )
```

next, we...

```python
[ ]: performance_analytics_tables(master, "YEAR")
```

```
NSEI

      count      mean       std       var
YEAR
2018    260  0.011858  0.804320  0.646931
2019    260  0.061655  0.862269  0.743508
2020    262  0.059276  2.003775  4.015114
2021    261  0.093951  0.979932  0.960268
2022    260  0.054513  1.096428  1.202155
2023    260  0.079254  0.620049  0.384461



DJI

      count      mean       std       var
YEAR
2018    260 -0.034755  1.142622  1.305584
2019    260  0.098867  0.783563  0.613972
2020    262  0.056509  2.277254  5.185886
2021    261  0.074976  0.772875  0.597336
2022    260 -0.024515  1.237294  1.530896
2023    260  0.059685  0.708875  0.502504



IXIC

      count      mean       std       var
YEAR
2018    260 -0.020231  1.329736  1.768199
2019    260  0.132933  0.974714  0.950068
```

2020	262	0.170412	2.199609	4.838279
2021	261	0.095541	1.123517	1.262289
2022	260	-0.124394	2.000332	4.001327
2023	260	0.156594	1.084932	1.177078

HSI

	count	mean	std	var
YEAR				
2018	260	-0.034949	1.243767	1.546955
2019	260	0.033120	0.980864	0.962095
2020	262	0.026129	1.444816	2.087493
2021	261	-0.028481	1.262121	1.592949
2022	260	-0.020744	2.054467	4.220835
2023	260	-0.052676	1.408653	1.984302

N225

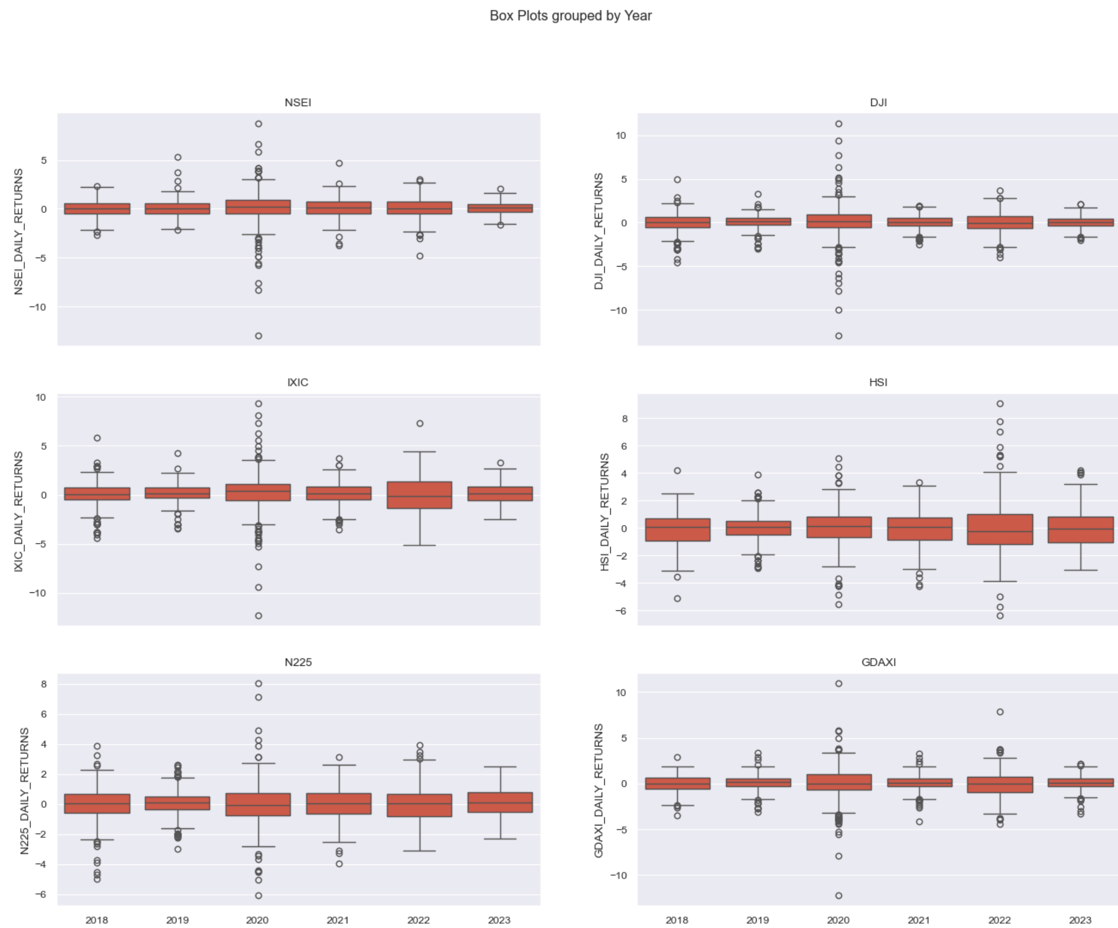
	count	mean	std	var
YEAR				
2018	260	-0.047420	1.198187	1.435653
2019	260	0.065377	0.860102	0.739776
2020	262	0.013181	1.614888	2.607863
2021	261	0.028503	1.152231	1.327636
2022	260	-0.036233	1.261568	1.591553
2023	260	0.105084	0.998616	0.997234

GDAXI

	count	mean	std	var
YEAR				
2018	260	-0.055542	0.975185	0.950985
2019	260	0.084212	0.887599	0.787832
2020	262	0.042611	2.063860	4.259519
2021	261	0.070506	0.898895	0.808012
2022	260	-0.034584	1.460441	2.132887
2023	260	0.082085	0.809460	0.655225

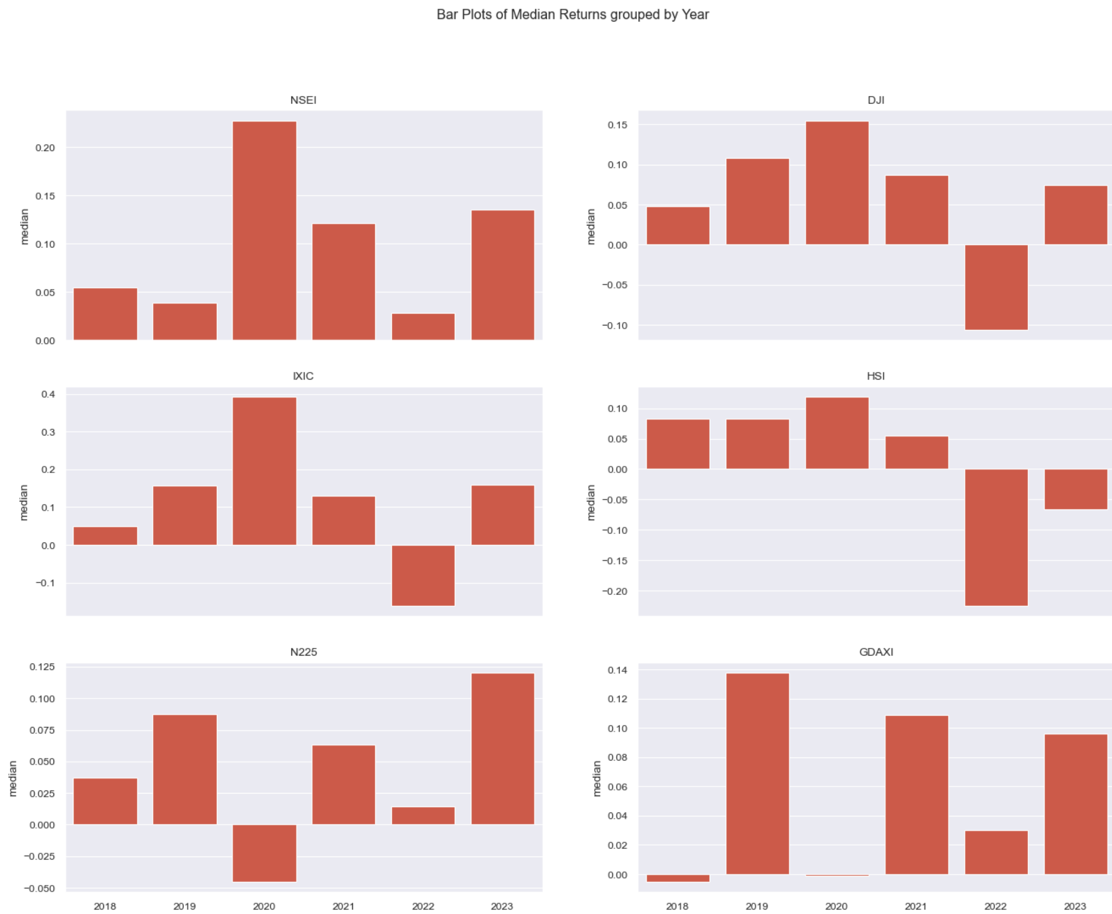
next, we...

```
[ ]: performance_analytics_box_plots(master, "YEAR", "Box Plots grouped by Year")
```



next, we...

```
[ ]: performance_analytics_bar_plots(master, "YEAR", "Bar Plots of Median Returns␣
     ↪grouped by Year")
```

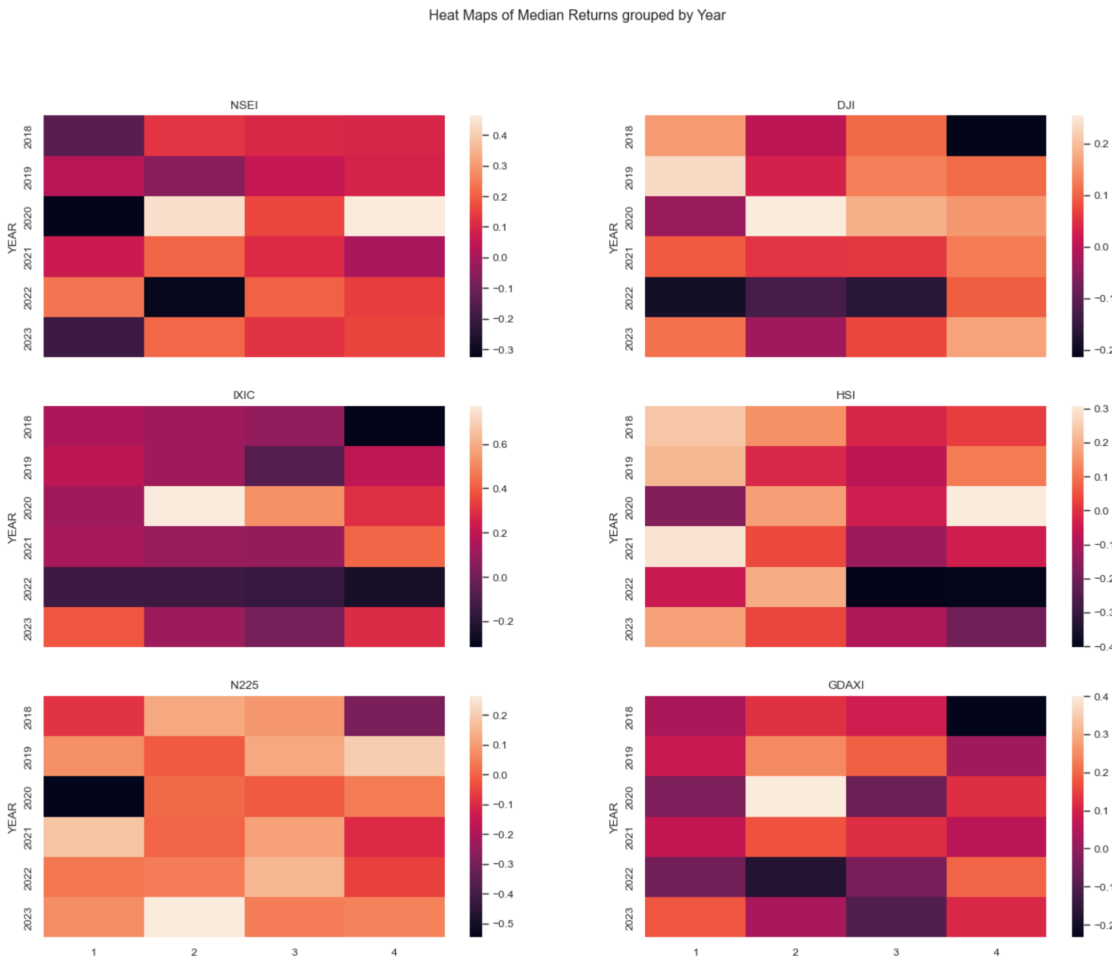


next, we...

```
[ ]: performance_analytics_heat_maps(master, "YEAR", "Heat Maps of Mean Returns␣
     ↪grouped by Year", aggfunc = "mean")
```

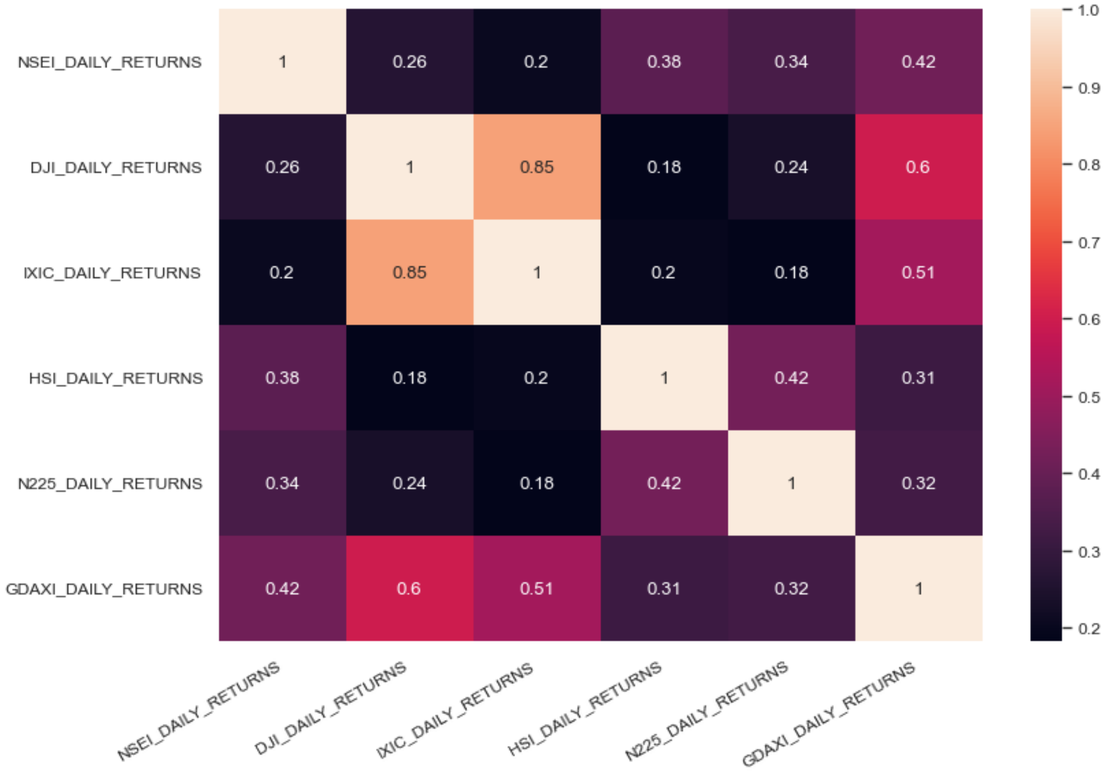
next, we...

```
[ ]: performance_analytics_heat_maps(master, "YEAR", "Heat Maps of Median Returns␣
     ↪grouped by Year")
```



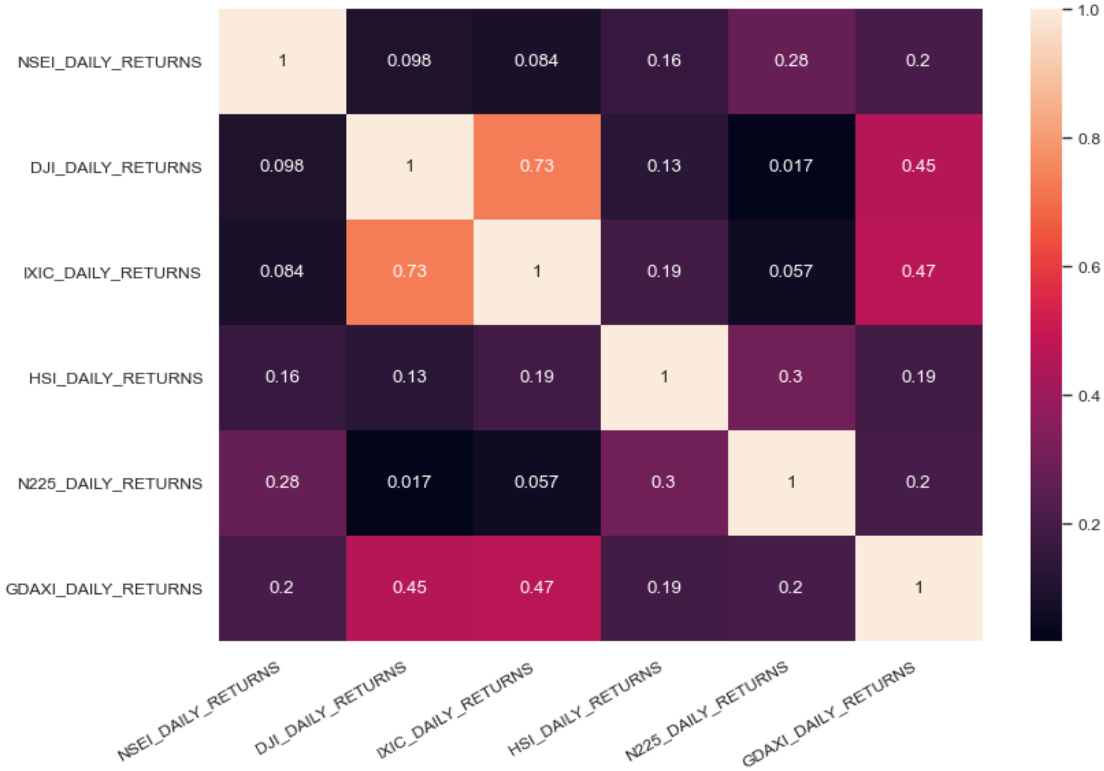
next, we...

```
[ ]: correlation_matrix(master)
```



next, we...

[ ]:
```
correlation_matrix(master['2023-01-02':'2023-12-29'])
```



next, we...

```
[ ]: performance_analytics_tables(master, "PANDEMIC")
```

NSEI

	count	mean	std	var
PANDEMIC				
PRE_COVID	542	0.033358	0.830382	0.689535
COVID	589	0.068626	1.562565	2.441611
POST_COVID	432	0.082045	0.777193	0.604029

DJI

	count	mean	std	var
PANDEMIC				
PRE_COVID	542	0.033705	0.968612	0.938208
COVID	589	0.042948	1.656938	2.745443
POST_COVID	432	0.038478	0.980846	0.962060

```
IXIC

            count      mean       std       var
PANDEMIC
PRE_COVID     542  0.061950  1.153434  1.330409
COVID         589  0.077150  1.812437  3.284927
POST_COVID    432  0.065371  1.525190  2.326205
```

```
HSI

            count      mean       std       var
PANDEMIC
PRE_COVID     542 -0.012615  1.126131  1.268172
COVID         589  0.011764  1.507990  2.274035
POST_COVID    432 -0.046861  1.664055  2.769080
```

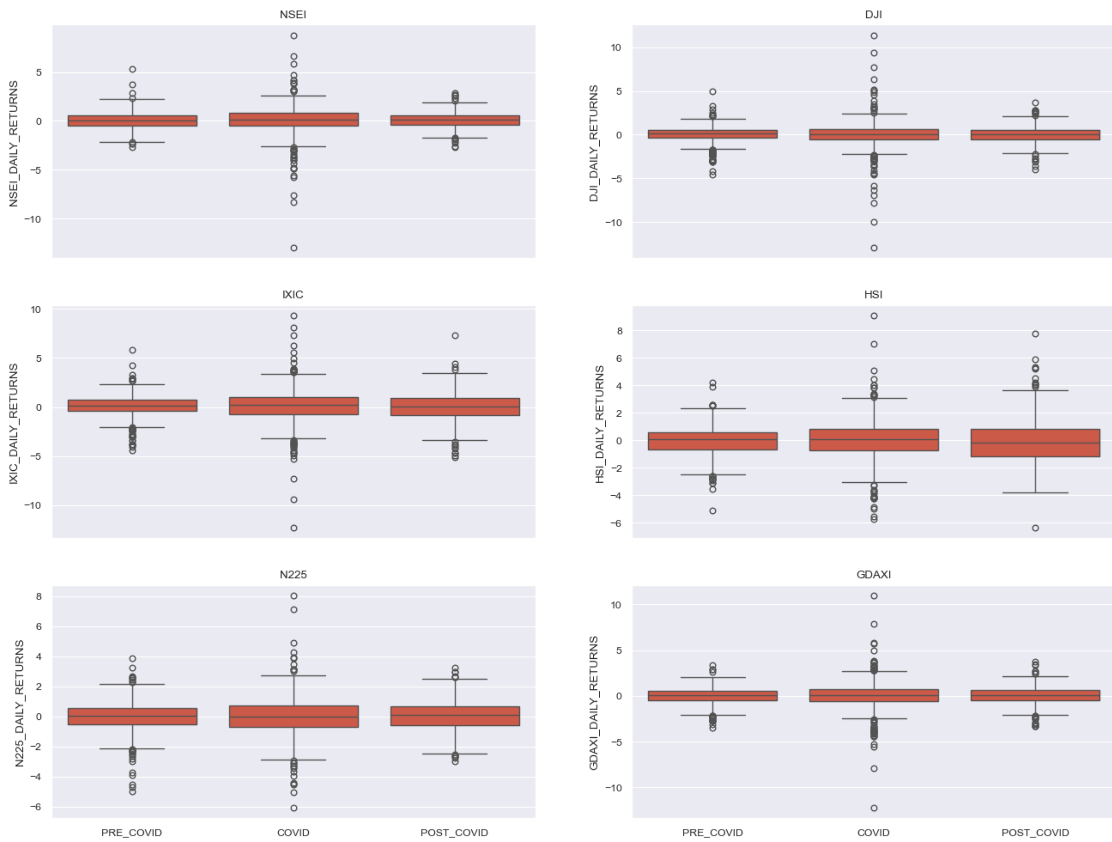
```
N225

            count      mean       std       var
PANDEMIC
PRE_COVID     542  0.000132  1.046461  1.095080
COVID         589  0.016520  1.417410  2.009052
POST_COVID    432  0.054771  1.065944  1.136236
```

```
GDAXI

            count      mean       std       var
PANDEMIC
PRE_COVID     542  0.011435  0.935235  0.874665
COVID         589  0.034896  1.634397  2.671252
POST_COVID    432  0.052360  1.027366  1.055480
```

next, we...

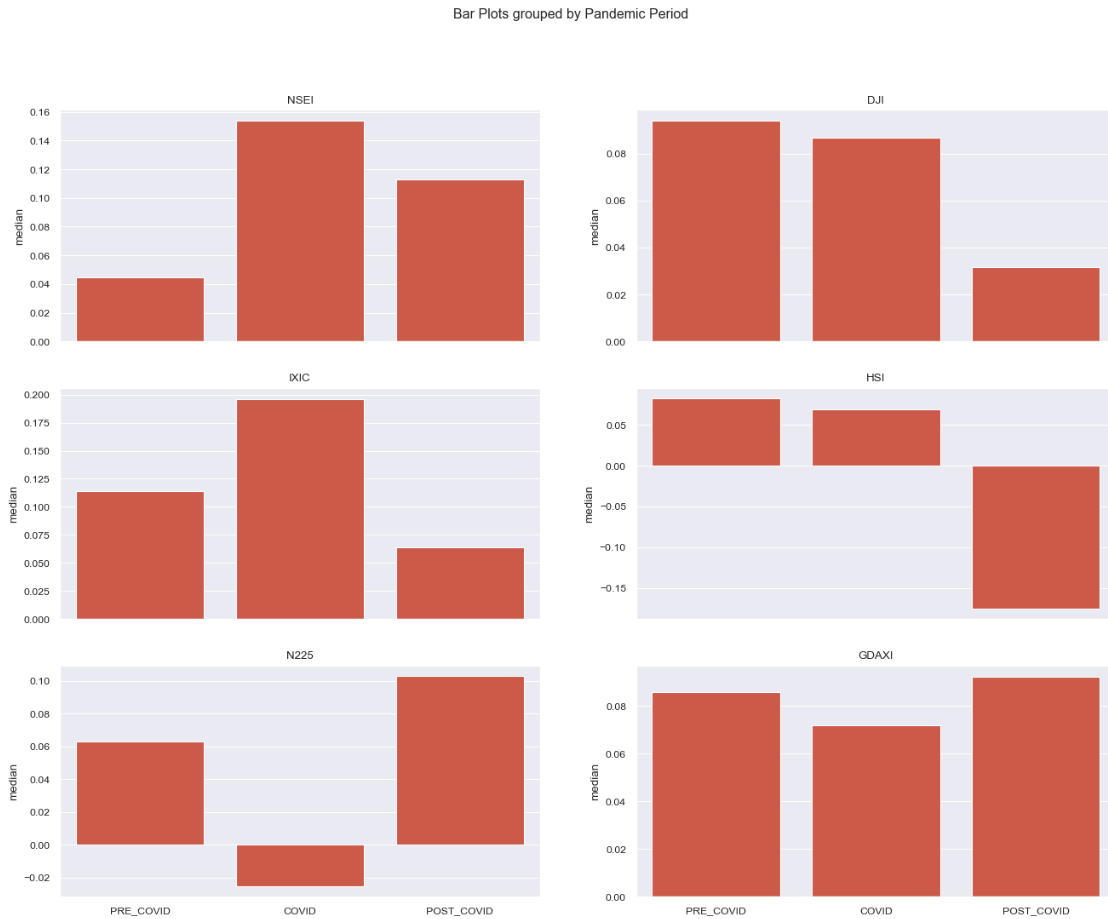
[ ]:
```
performance_analytics_box_plots(master, "PANDEMIC", "Box Plots grouped by␣
↪Pandemic Period")
```

Box Plots grouped by Pandemic Period



next, we...

[ ]:
```
performance_analytics_bar_plots(master, "PANDEMIC", "Bar Plots grouped by␣
↪Pandemic Period")
```



next, we...

```
[ ]: performance_analytics_heat_maps(master, "PANDEMIC", "Heat Maps of Mean Returns␣
     ↪grouped by Pandemic Period", aggfunc = "mean")
```

next, we...

```
[ ]: performance_analytics_heat_maps(master, "PANDEMIC", "Heat Maps of Median␣
      ↪Returns grouped by Pandemic Period")
```

next, we...

```
[ ]: for i in range(6):
         pre_covid  = master.loc[(master['PANDEMIC'] == 'PRE_COVID'),  [COLUMNS[i]]]
         post_covid = master.loc[(master['PANDEMIC'] == 'POST_COVID'), [COLUMNS[i]]]

         mean_pre   = pre_covid.values.mean()
         post_count = np.where(post_covid[COLUMNS[i]].ge(mean_pre).values ==␣
      ↪True)[0][0]
         post_date  = post_covid.index[post_covid[COLUMNS[i]].ge(mean_pre)][0].date()

         print(f"{INDICES[i].rjust(5)} returned to pre-covid levels (mean {mean_pre:␣
      ↪2.4f}) on {post_date} after {post_count} trading day(s)")
```

```
 NSEI returned to pre-covid levels (mean  0.0334) on 2022-05-16 after 7 trading
day(s)
  DJI returned to pre-covid levels (mean  0.0337) on 2022-05-13 after 6 trading
day(s)
```

 IXIC returned to pre-covid levels (mean 0.0619) on 2022-05-10 after 3 trading day(s)
  HSI returned to pre-covid levels (mean -0.0126) on 2022-05-11 after 4 trading day(s)
 N225 returned to pre-covid levels (mean 0.0001) on 2022-05-06 after 1 trading day(s)
GDAXI returned to pre-covid levels (mean 0.0114) on 2022-05-10 after 3 trading day(s)

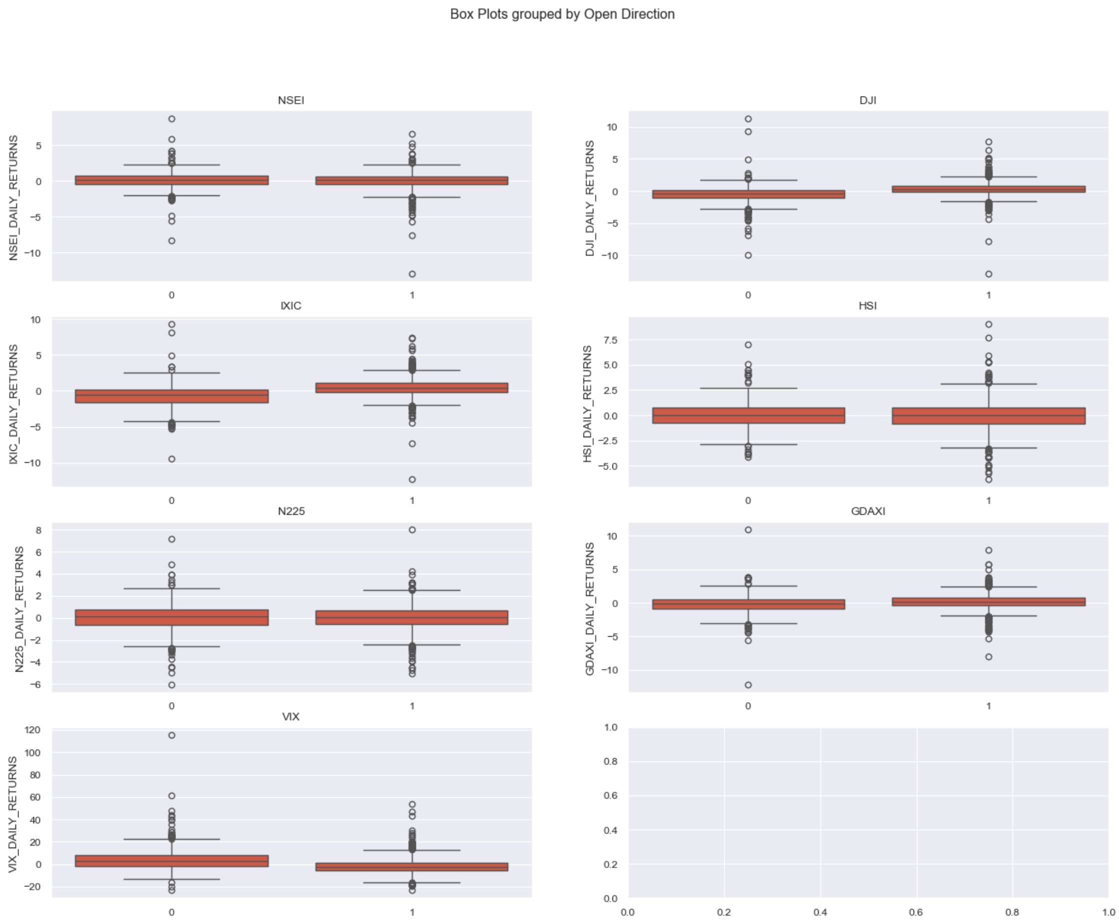
next, we...

[ ]:
```
table1 = master.groupby("YEAR", observed = False)[["NSEI_OPEN_DIR"]].sum()
table2 = master.groupby("YEAR", observed = False)[["NSEI_OPEN_DIR"]].count()
table  = ((table1["NSEI_OPEN_DIR"] / table2["NSEI_OPEN_DIR"]) * 100).round(2)

print("\nNifty Fifty Daily Movement\n")
print(f"\n{table}\n")
```

```
Nifty Fifty Daily Movement


YEAR
2018    70.38
2019    69.23
2020    70.61
2021    71.65
2022    59.23
2023    67.31
Name: NSEI_OPEN_DIR, dtype: float64
```

next we...

[ ]:
```
fig, axes = plt.subplots(4, 2, figsize = (16, 12))
fig.suptitle("Box Plots grouped by Open Direction")

for index in range(7):
    axes[index // 2, index % 2].set_title(INDICES[index])
    sns.boxplot(x = master["NSEI_OPEN_DIR"], y = master[COLUMNS[index]].
 ↪shift(), ax = axes[index // 2, index % 2])
    axes[index // 2, index % 2].set_xlabel("")
```



next, we...

```
RATIOS     = ["NSEI_HL_RATIO", "DJI_HL_RATIO"]
INDICATORS = ["NSEI_RSI", "DJI_RSI", "NSEI_TSI", "DJI_TSI"]
ALL_COLS   = COLUMNS + RATIOS + INDICATORS
```

next, we...

```
master["NSEI_HL_RATIO"] = master["NSEI_HIGH"] / master["NSEI_LOW"]
master["DJI_HL_RATIO"]  = master["DJI_HIGH"]  / master["DJI_LOW"]
```

next, we...

```
master["NSEI_RSI"] = ta.momentum.rsi(master["NSEI_CLOSE"])
master["DJI_RSI"]  = ta.momentum.rsi(master["DJI_CLOSE"])

master["NSEI_TSI"] = ta.momentum.tsi(master["NSEI_CLOSE"])
master["DJI_TSI"]  = ta.momentum.tsi(master["DJI_CLOSE"])
```

next, we...

```
[ ]: data = pd.concat([master["NSEI_OPEN_DIR"].shift(-1), master[ALL_COLS]], axis =
      1)
     data.dropna(inplace = True)
     data.head()
```

```
[ ]:             NSEI_OPEN_DIR  NSEI_DAILY_RETURNS  DJI_DAILY_RETURNS  \
     Date
     2018-02-22            1.0           -0.141862           0.664177
     2018-02-23            1.0            1.043559           1.392128
     2018-02-26            1.0            0.872647           1.577556
     2018-02-27            0.0           -0.267418          -1.163939
     2018-02-28            0.0           -0.582229          -1.498739

                 IXIC_DAILY_RETURNS  HSI_DAILY_RETURNS  N225_DAILY_RETURNS  \
     Date
     2018-02-22           -0.112772          -1.483242           -1.066738
     2018-02-23            1.765585           0.973627            0.719252
     2018-02-26            1.145773           0.740168            1.191496
     2018-02-27           -1.227654          -0.729999            1.066320
     2018-02-28           -0.782232          -1.355797           -1.436450

                 GDAXI_DAILY_RETURNS  VIX_DAILY_RETURNS  NSEI_HL_RATIO  \
     Date
     2018-02-22            -0.068803          -6.493512       1.005502
     2018-02-23             0.175574         -11.912391       1.009854
     2018-02-26             0.346449          -4.184352       1.006915
     2018-02-27            -0.289850          17.658227       1.008959
     2018-02-28            -0.439373           6.777839       1.007069

                 DJI_HL_RATIO   NSEI_RSI    DJI_RSI   NSEI_TSI   DJI_TSI
     Date
     2018-02-22      1.012146  35.462139  46.645122 -30.229045 -9.335285
     2018-02-23      1.011394  43.991068  52.167111 -27.688141 -7.175461
     2018-02-26      1.013160  50.003304  57.597238 -23.576140 -3.663260
     2018-02-27      1.015449  48.278103  52.762870 -20.700940 -2.074670
     2018-02-28      1.022129  44.673823  47.319430 -19.286991 -2.368269
```

next, we...

```
[ ]: X = data[ALL_COLS]
     y = data['NSEI_OPEN_DIR']
```

next, we...

```
[ ]: X.insert(loc = 0, column = "Intercept", value = 1)
```

next, we...

[ ]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2,␣
↪random_state = 1337)
```

next, we...

[ ]:
```
def prune(X, y, verbose = True):
    dropped = []
    while True:
        model = Logit(y, X).fit(disp = 0)

        insignificant = [p for p in zip(model.pvalues.index[1:], model.
↪pvalues[1:]) if p[1] > 0.05]

        values   = [variance_inflation_factor(model.model.exog, i) for i in␣
↪range(1, model.model.exog.shape[1])]
        colinear = [val for val in zip(model.model.exog_names[1:], values) if␣
↪val[1] > 5]

        if insignificant:
            insignificant.sort(key = lambda p: -p[1])

            if verbose:
                print(f"dropping {insignificant[0][0]} with p-value␣
↪{insignificant[0][1]}")

            X = X.drop([insignificant[0][0]], axis = 1)
            dropped.append(insignificant[0][0])

        elif colinear:
            colinear.sort(key = lambda c: -c[1])

            if verbose:
                print(f"dropping {colinear[0][0]} with vif {colinear[0][1]}")

            X = X.drop([colinear[0][0]], axis = 1)
            dropped.append(colinear[0][0])

        else:
            return model, dropped
```

next, we...

[ ]:
```
model, dropped = prune(X_train, y_train)
```

```
dropping DJI_DAILY_RETURNS with p-value 0.7234766099769976
dropping GDAXI_DAILY_RETURNS with p-value 0.6162105670377191
dropping NSEI_HL_RATIO with p-value 0.42776185052464266
dropping DJI_HL_RATIO with p-value 0.15630559889450327
```

```
dropping NSEI_DAILY_RETURNS with p-value 0.13281329048460586
dropping NSEI_TSI with vif 5.865700460659149
dropping NSEI_RSI with p-value 0.7783762272652992
```

next, we...

[ ]:
```
model.summary()
```

[ ]:

Dep. Variable:	NSEI_OPEN_DIR	**No. Observations:**	1220
Model:	Logit	**Df Residuals:**	1213
Method:	MLE	**Df Model:**	6
Date:	Tue, 25 Jun 2024	**Pseudo R-squ.:**	0.1375
Time:	20:24:32	**Log-Likelihood:**	-660.02
converged:	True	**LL-Null:**	-765.23
Covariance Type:	nonrobust	**LLR p-value:**	1.141e-42

	coef	**std err**	**z**	**P> |z|**	**[0.025**	**0.975]**
Intercept	-1.4041	0.656	-2.139	0.032	-2.690	-0.118
IXIC_DAILY_RETURNS	0.4552	0.075	6.093	0.000	0.309	0.602
HSI_DAILY_RETURNS	-0.1395	0.053	-2.632	0.008	-0.243	-0.036
N225_DAILY_RETURNS	-0.1960	0.068	-2.897	0.004	-0.329	-0.063
VIX_DAILY_RETURNS	-0.0397	0.013	-3.054	0.002	-0.065	-0.014
DJI_RSI	0.0447	0.013	3.415	0.001	0.019	0.070
DJI_TSI	-0.0205	0.008	-2.660	0.008	-0.036	-0.005

next, we...

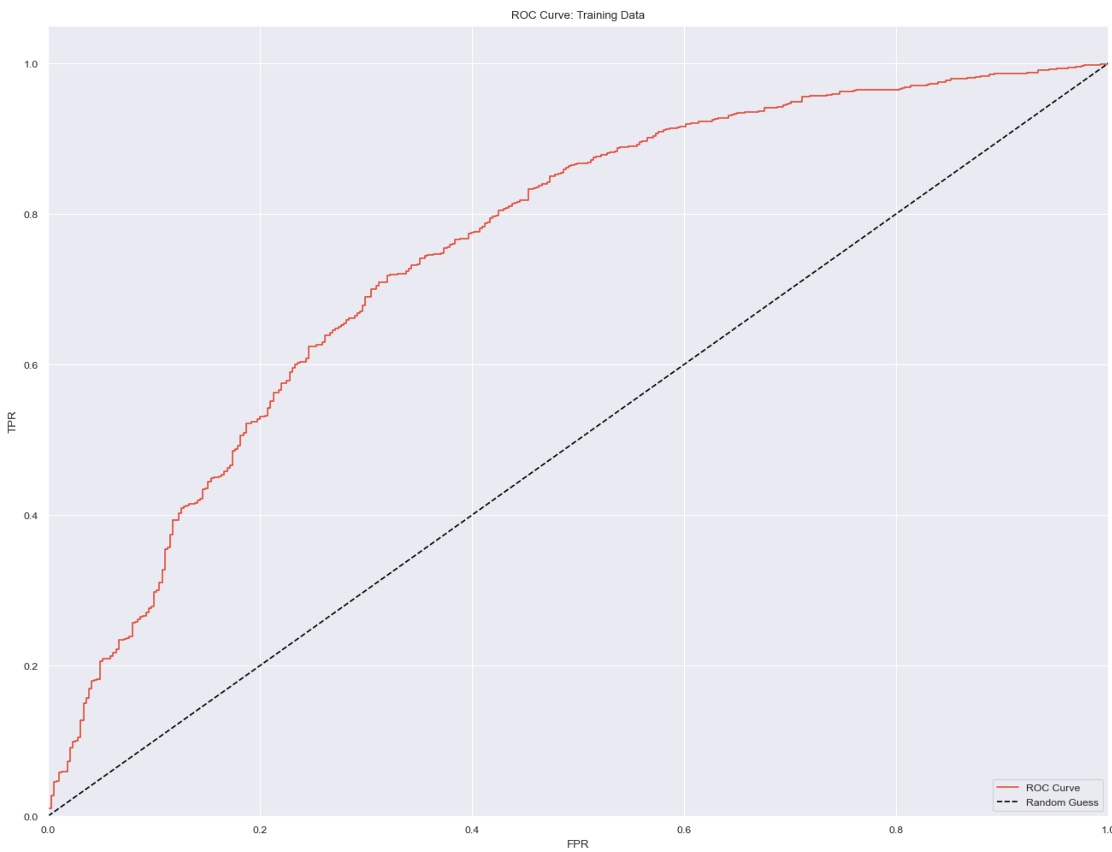
[ ]:
```
vif_data = pd.DataFrame()
vif_data["Feature"] = model.model.exog_names[1:]
vif_data["VIF"]     = [variance_inflation_factor(model.model.exog, i) for i in␣
 ↪range(1, model.model.exog.shape[1])]
vif_data
```

[ ]:
```
              Feature       VIF
0  IXIC_DAILY_RETURNS  2.073867
1   HSI_DAILY_RETURNS  1.244922
2  N225_DAILY_RETURNS  1.353286
3   VIX_DAILY_RETURNS  1.994009
4             DJI_RSI  4.850250
5             DJI_TSI  4.379409
```

next, we...

[ ]:
```
y_pred = model.predict(X_train.drop(dropped, axis = 1))
fpr, tpr, thresholds = roc_curve(y_train, y_pred)

plt.figure(figsize = (16, 12))

plt.plot(fpr, tpr, label = 'ROC Curve')
plt.plot([0, 1], [0, 1], 'k--', label = 'Random Guess')
```

```
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])

plt.title(f"ROC Curve: Training Data")
plt.xlabel('FPR')
plt.ylabel('TPR')

plt.legend(loc = 'lower right')
plt.show()
```



next, we...

```
[ ]: optimal_threshold = round(thresholds[np.argmax(tpr - fpr)], 3)
print(f'Best Threshold: {optimal_threshold}')
```

```
Best Threshold: 0.684
```

next, we...

[ ]:
```
auc_roc = roc_auc_score(y_train, y_pred)
print(f'AUC ROC: {auc_roc}')
```

```
AUC ROC: 0.7529115595469844
```

next, we…

[ ]:
```
y_pred_class = np.where(y_pred <= optimal_threshold, 0, 1)
print(classification_report(y_train, y_pred_class))
```

```
              precision    recall  f1-score   support

         0.0       0.53      0.68      0.60       391
         1.0       0.83      0.72      0.77       829

    accuracy                           0.70      1220
   macro avg       0.68      0.70      0.68      1220
weighted avg       0.73      0.70      0.71      1220
```

next, we…

[ ]:
```
table = pd.crosstab(y_pred_class, y_train)
print(table)
```

```
NSEI_OPEN_DIR  0.0  1.0
row_0
0              265  234
1              126  595
```

next, we…

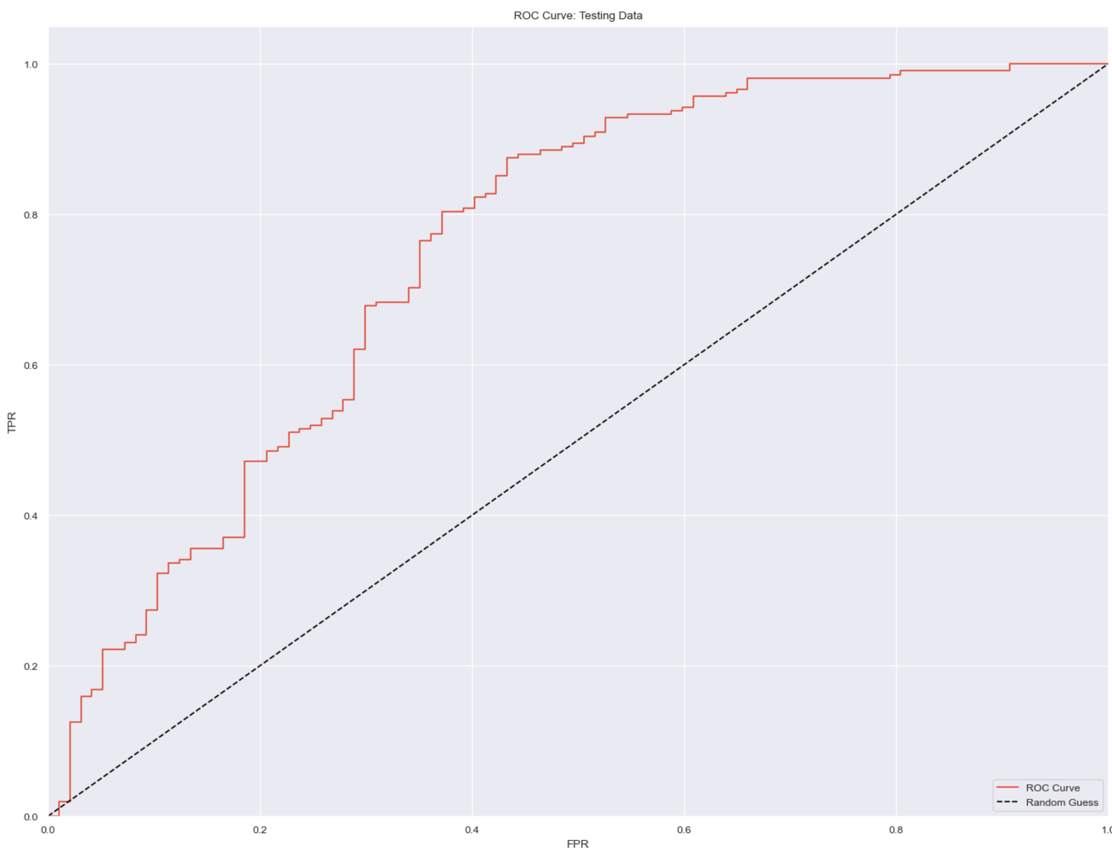
[ ]:
```
sensitivity = round((table.iloc[1, 1] / (table.iloc[0, 1] + table.iloc[1, 1]))␣
 ↪* 100, 2)
specificity = round((table.iloc[0, 0] / (table.iloc[0, 0] + table.iloc[1, 0]))␣
 ↪* 100, 2)

print(f"Sensitivity: {sensitivity}%")
print(f"Specificity: {specificity}%")
```

```
Sensitivity: 71.77%
Specificity: 67.77%
```

next, we…

[ ]:
```
y_test_pred = model.predict(X_test.drop(dropped, axis = 1))

fpr, tpr, thresholds = roc_curve(y_test, y_test_pred)

plt.figure(figsize = (16, 12))
```

```
plt.plot(fpr, tpr, label = 'ROC Curve')
plt.plot([0, 1], [0, 1], 'k--', label = 'Random Guess')

plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])

plt.title(f"ROC Curve: Testing Data")
plt.xlabel('FPR')
plt.ylabel('TPR')

plt.legend(loc = 'lower right')
plt.show()
```



next, we...

[ ]:
```
auc_roc = roc_auc_score(y_test, y_test_pred)
print(f'AUC ROC: {auc_roc}')
```

```
AUC ROC: 0.7520816812053925
```

next, we...

[ ]:
```
y_test_pred_class = np.where(y_test_pred <= optimal_threshold,  0, 1)
print(classification_report(y_test, y_test_pred_class))
```

```
              precision    recall  f1-score   support

         0.0       0.53      0.65      0.58        97
         1.0       0.82      0.73      0.77       208

    accuracy                           0.70       305
   macro avg       0.67      0.69      0.67       305
weighted avg       0.72      0.70      0.71       305
```

next, we...

[ ]:
```
table = pd.crosstab(y_test_pred_class, y_test)
print(table)
```

```
NSEI_OPEN_DIR  0.0  1.0
row_0
0               63   57
1               34  151
```

next, we...

[ ]:
```
sensitivity = round((table.iloc[1, 1] / (table.iloc[0, 1] + table.iloc[1, 1]))
 ↪* 100, 2)
specificity = round((table.iloc[0, 0] / (table.iloc[0, 0] + table.iloc[1, 0]))
 ↪* 100, 2)

print(f"Sensitivity: {sensitivity}%")
print(f"Specificity: {specificity}%")
```

```
Sensitivity: 72.6%
Specificity: 64.95%
```