MSFT_StockPriceForecast

February 1, 2022

1 Part 0: Set up environment and load data

[1]:
```
from pydrive.auth import GoogleAuth
from pydrive.drive import GoogleDrive
from google.colab import auth
from oauth2client.client import GoogleCredentials

from tabulate import tabulate
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
import statsmodels.api as sm
import seaborn as sns
from pylab import rcParams
from statsmodels.tsa.arima_model import ARMA

import itertools
import warnings
from statsmodels.stats.diagnostic import acorr_ljungbox
from sklearn import preprocessing
from sklearn.preprocessing import MinMaxScaler
from keras.models import Sequential
from keras.layers import Dense
from keras.layers import LSTM
from keras.layers import Dropout
from keras.layers import *
from sklearn.metrics import mean_squared_error
from sklearn.metrics import mean_absolute_error
from sklearn.model_selection import train_test_split
from keras.callbacks import EarlyStopping
```

```
/usr/local/lib/python3.7/dist-packages/statsmodels/tools/_testing.py:19:
FutureWarning: pandas.util.testing is deprecated. Use the functions in the
public API at pandas.testing instead.
  import pandas.util.testing as tm
```

[2]:
```python
auth.authenticate_user()
gauth = GoogleAuth()
gauth.credentials = GoogleCredentials.get_application_default()
drive = GoogleDrive(gauth)
```

Data could be downloaded from Yahoo.com

[3]:
```python
link = 'https://drive.google.com/open?id=1wdf3FfKdR_xNh2rJeYWL4ye0_FUZ9WM7'


fluff, id = link.split('=')
file = drive.CreateFile({'id':id})
file.GetContentFile('MSFT_Stock.csv')
#read in data, take date as the index
microsoft  = pd.read_csv('MSFT_Stock.csv', index_col='Date',␣
 ↪parse_dates=['Date'])
microsoft.head()
```

[3]:

Date	Open	High	Low	Close	Volume
2015-04-01 16:00:00	40.60	40.76	40.31	40.72	36865322
2015-04-02 16:00:00	40.66	40.74	40.12	40.29	37487476
2015-04-06 16:00:00	40.34	41.78	40.18	41.55	39223692
2015-04-07 16:00:00	41.61	41.91	41.31	41.53	28809375
2015-04-08 16:00:00	41.48	41.69	41.04	41.42	24753438

[4]:
```python
len(microsoft)
```

[4]: 1511

[5]:
```python
TS_Monthly_df   = pd.read_csv('MSFT_Stock.csv')
TS_df = microsoft
```

2 Part 1: Data Exploration

3 Part 1.1 Raw Dataset

[6]:
```python
TS_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1511 entries, 2015-04-01 16:00:00 to 2021-03-31 16:00:00
Data columns (total 5 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Open    1511 non-null   float64
```

```
 1   High    1511 non-null   float64
 2   Low     1511 non-null   float64
 3   Close   1511 non-null   float64
 4   Volume  1511 non-null   int64
dtypes: float64(4), int64(1)
memory usage: 70.8 KB
```

[7]:
```
TS_df.nunique()
```

[7]:
```
Open      1409
High      1400
Low       1397
Close     1398
Volume    1511
dtype: int64
```

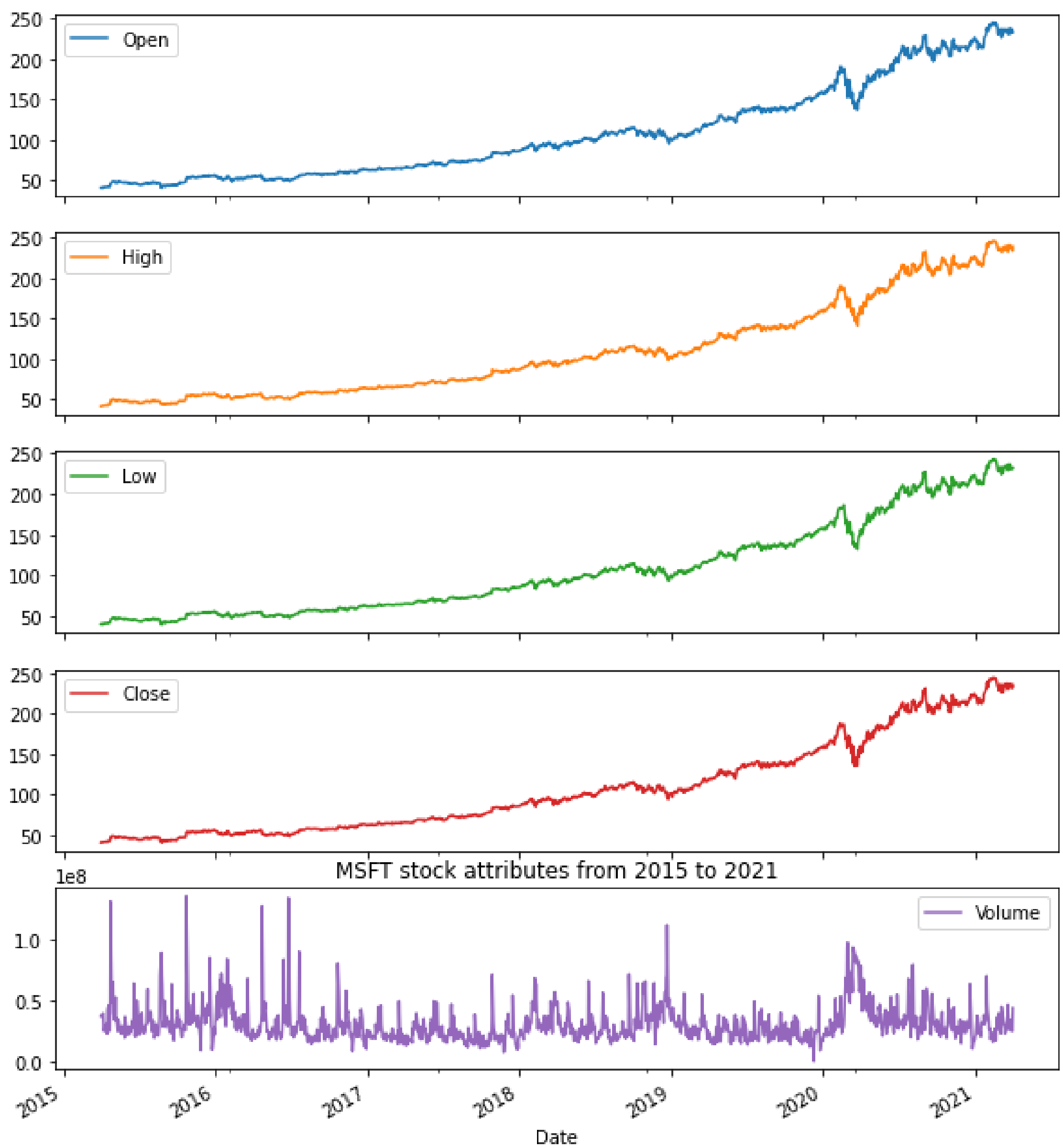
[8]:
```
TS_df.isnull().sum()
```

[8]:
```
Open      0
High      0
Low       0
Close     0
Volume    0
dtype: int64
```

4 Part 1.2 EDA

[9]:
```
TS_df['2015':'2021'].plot(subplots=True, figsize=(10,12))
plt.title('MSFT stock attributes from 2015 to 2021')
```

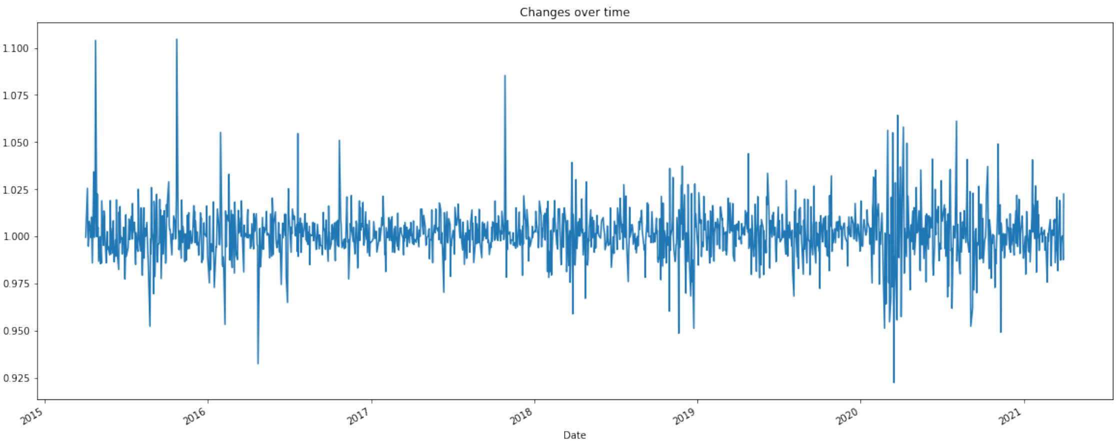
[9]:
```
Text(0.5, 1.0, 'MSFT stock attributes from 2015 to 2021')
```



There's an upward trend of open, high, low, close price.

[10]:
```
#shift the high price by one day
TS_df['Change'] = TS_df.High.div(TS_df.High.shift())
TS_df['Change'].plot(figsize=(20,8))
plt.title("Changes over time")
```

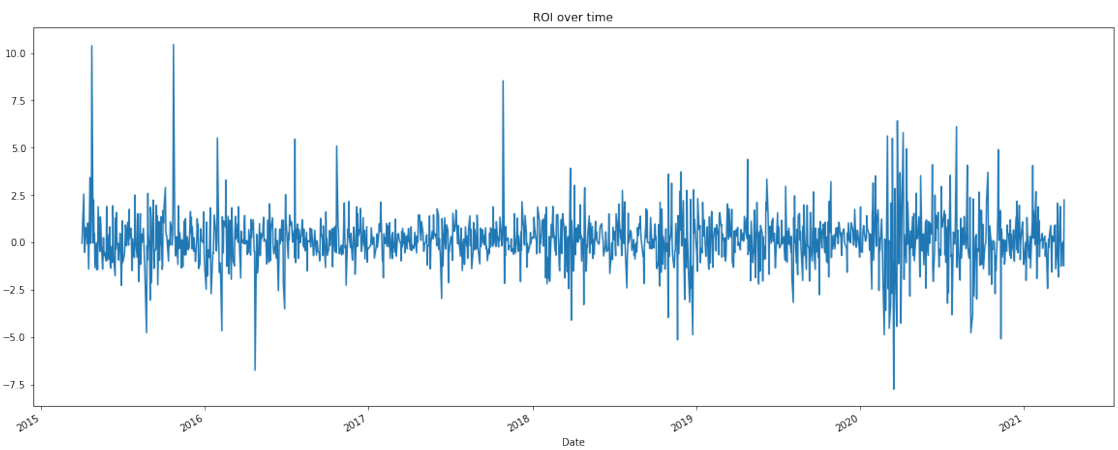
[10]: `Text(0.5, 1.0, 'Changes over time')`



"Return on investment (ROI) is an approximate measure of an investment's profitability.ROI is calculated by subtracting the initial value of the investment from the final value of the investment (which equals the net return), then dividing this new number (the net return) by the cost of the investment, then finally, multiplying it by 100."

[11]:
```
TS_df['Return'] = TS_df.Change.sub(1).mul(100)
TS_df['Return'].plot(figsize=(20,8))
plt.title("ROI over time")
```

[11]:
```
Text(0.5, 1.0, 'ROI over time')
```



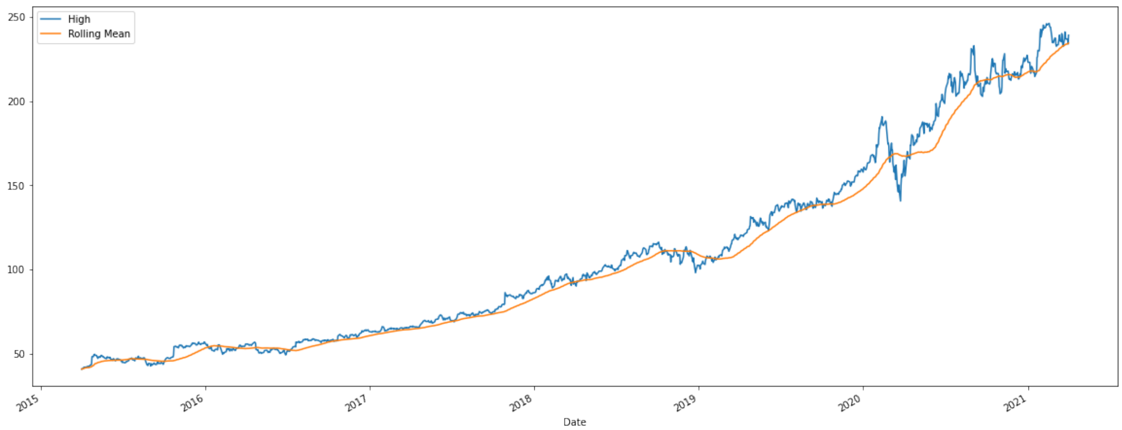
Apply window functions

[12]:
```
rolling_MSFT = TS_df.High.rolling('90D').mean() #mean of high price within 90␣
 ↪days
# rolling_MSFT
TS_df.High.plot(figsize=(20,8))
```

```
rolling_MSFT.plot()

plt.legend(['High','Rolling Mean'])
```

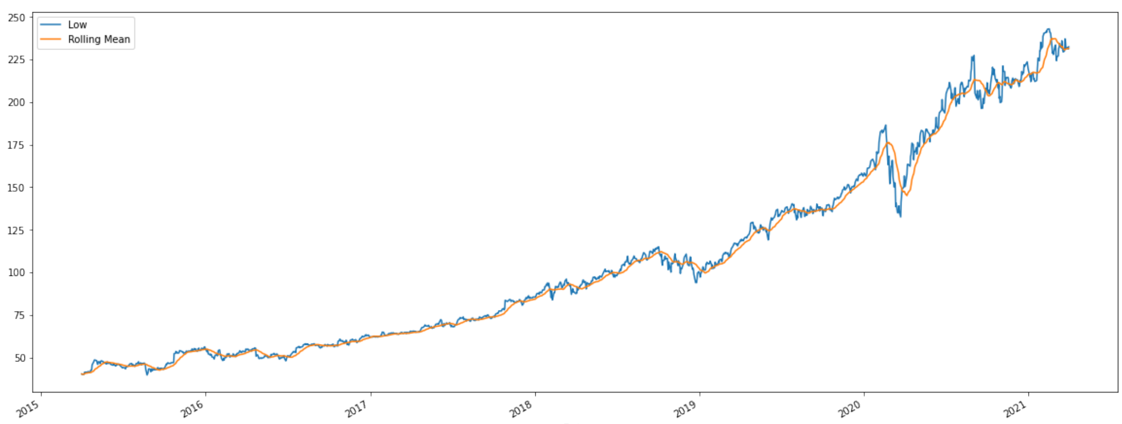
[12]: <matplotlib.legend.Legend at 0x7fbf79d81950>



[13]:
```
rolling_MSFT_low = TS_df.Low.rolling('30D').mean() #mean of low price within 90␣
↪days
TS_df.Low.plot(figsize=(20,8))
rolling_MSFT_low.plot()

plt.legend(['Low','Rolling Mean'])
```

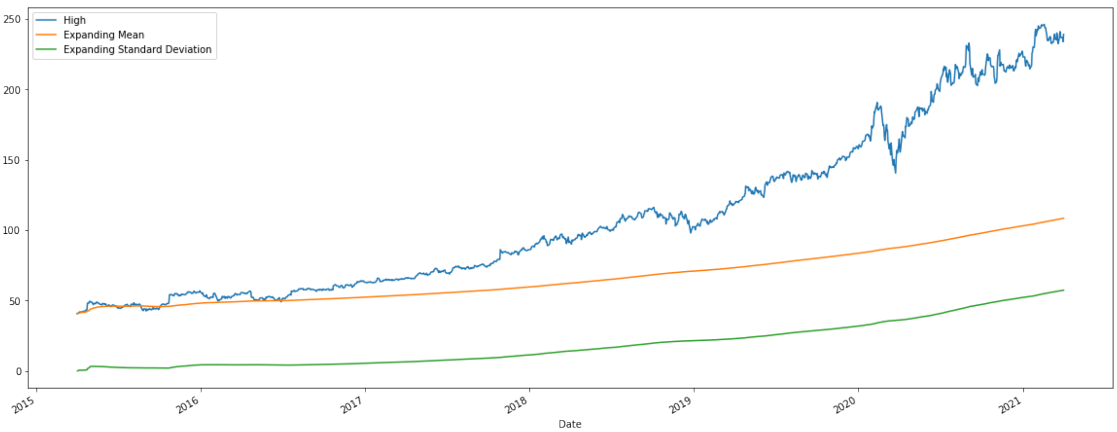
[13]: <matplotlib.legend.Legend at 0x7fbf798c4ad0>



[14]:

```
microsoft_mean = TS_df.High.expanding().mean()
microsoft_std = TS_df.High.expanding().std()
TS_df.High.plot(figsize=(20,8))
microsoft_mean.plot()
microsoft_std.plot()
plt.legend(['High','Expanding Mean','Expanding Standard Deviation'])
```

[14]: <matplotlib.legend.Legend at 0x7fbf78f78390>

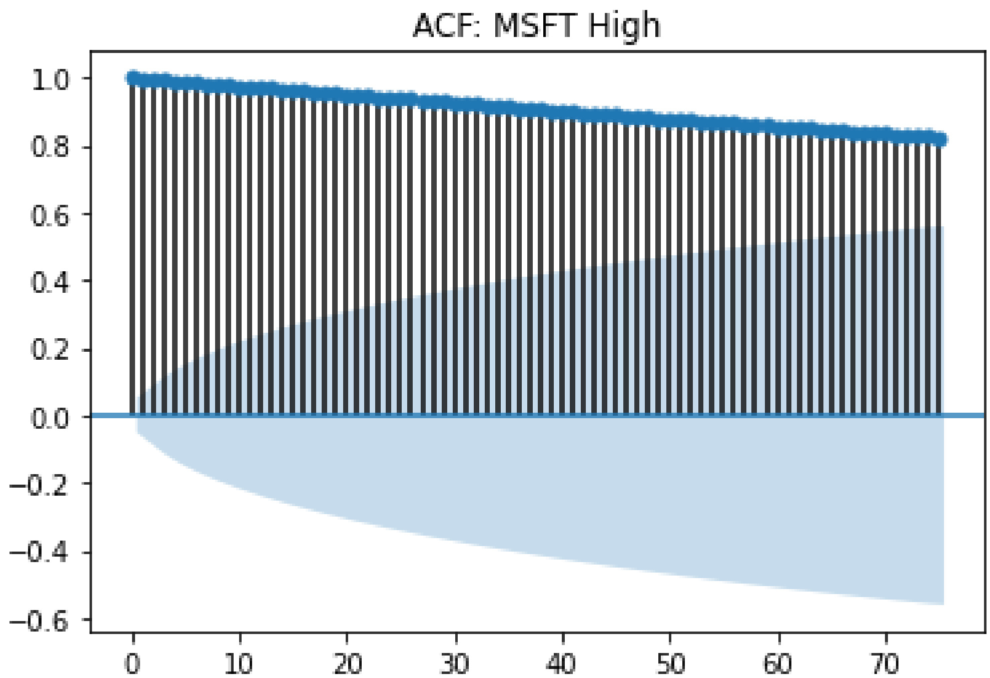


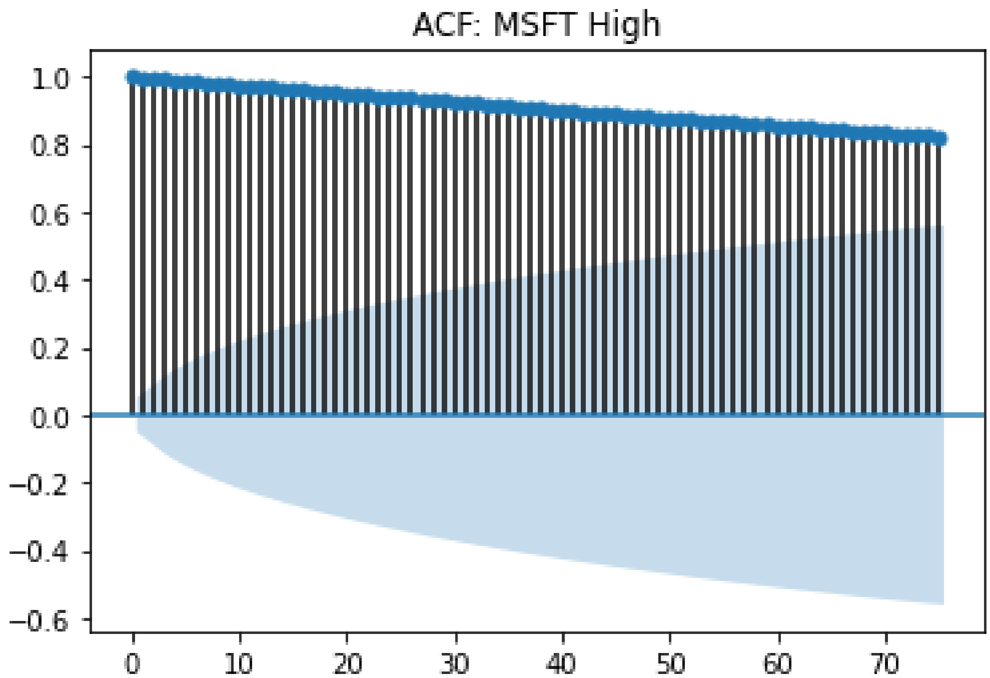
Check acf and pacf plots

[15]:

```
plot_acf(TS_df.High,lags=75,title="ACF: MSFT High")
```

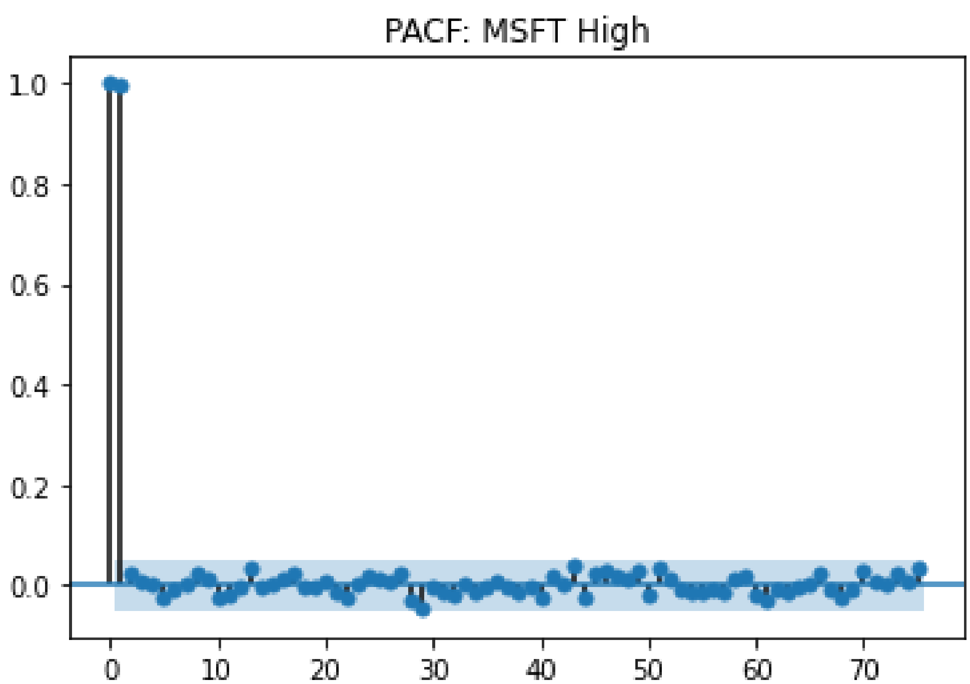
[15]:

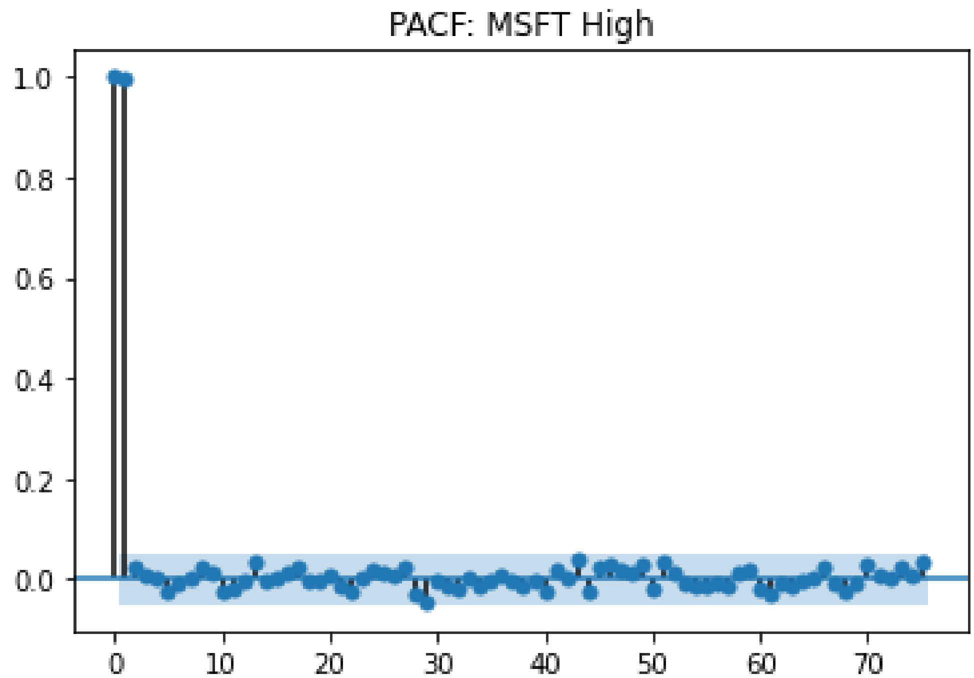





```
[16]: plot_pacf(TS_df.High,lags=75,title="PACF: MSFT High")
```

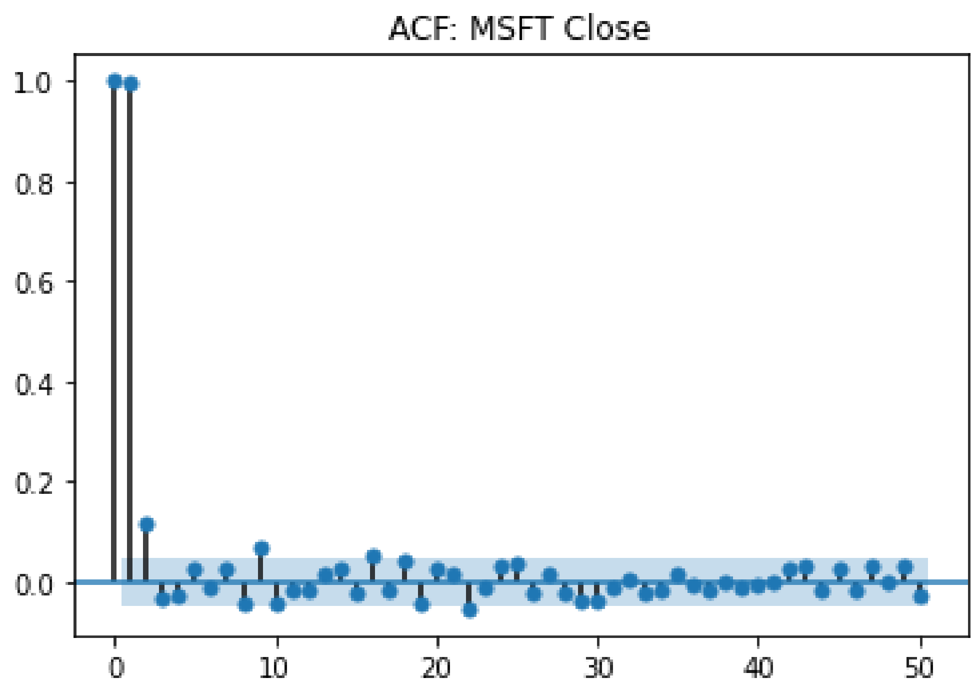
[16]:

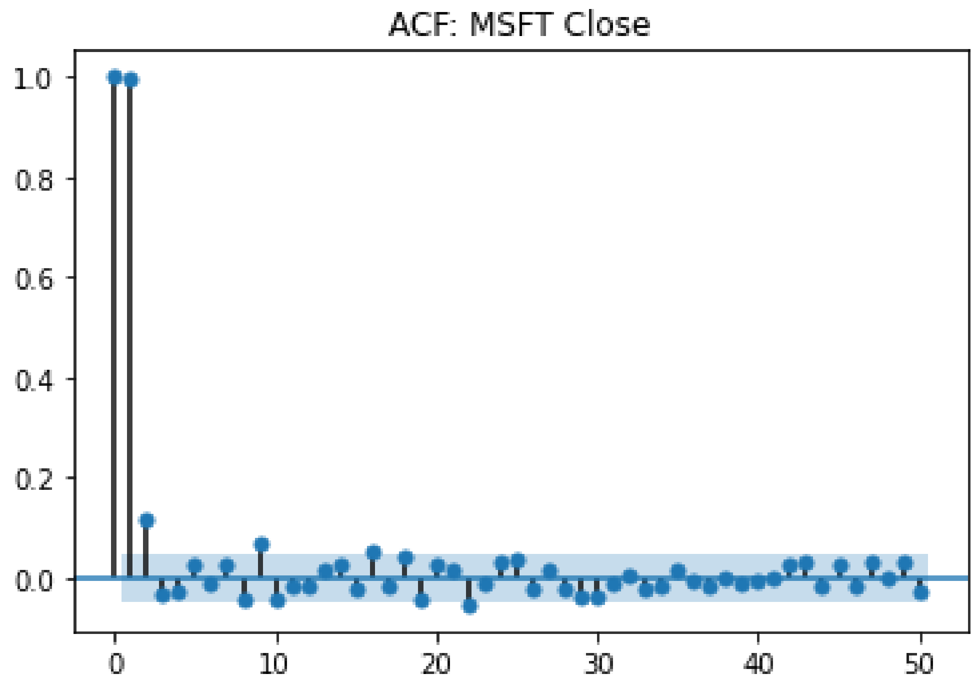




[17]:
```
plot_pacf(TS_df["Close"],lags=50,title="ACF: MSFT Close")
```

[17]:





[18]:
```
TS_Monthly_df['dateN']=pd.to_datetime(TS_Monthly_df['Date'])
TS_Monthly_df.set_index('dateN',inplace=True)
TS_Monthly_df.head()
```

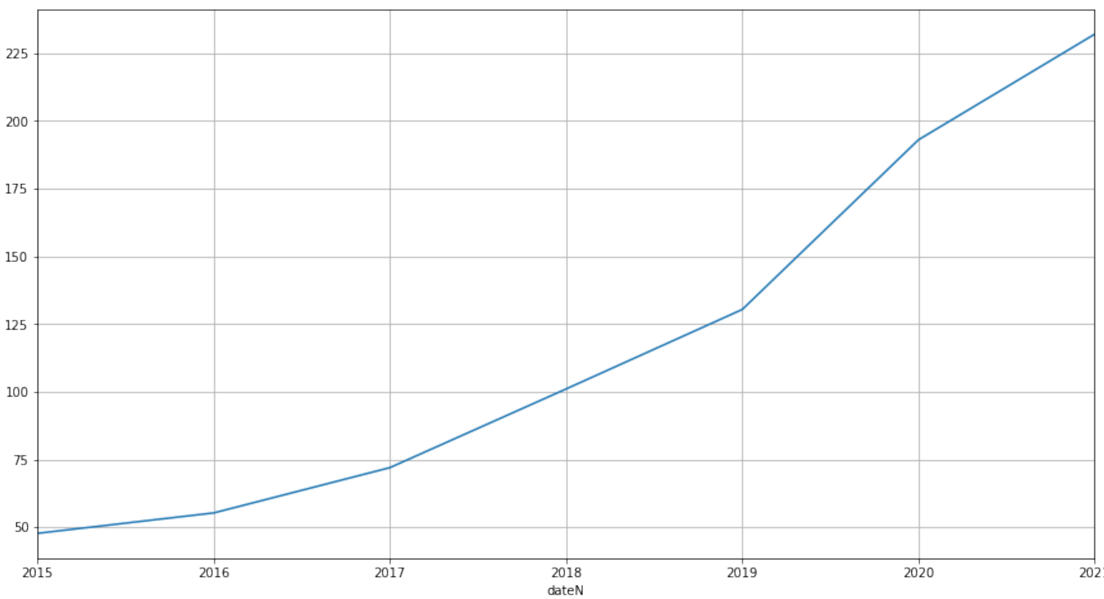
[18]:

dateN	Date	Open	High	Low	Close	Volume
2015-04-01 16:00:00	4/1/2015 16:00:00	40.60	40.76	40.31	40.72	36865322
2015-04-02 16:00:00	4/2/2015 16:00:00	40.66	40.74	40.12	40.29	37487476
2015-04-06 16:00:00	4/6/2015 16:00:00	40.34	41.78	40.18	41.55	39223692
2015-04-07 16:00:00	4/7/2015 16:00:00	41.61	41.91	41.31	41.53	28809375
2015-04-08 16:00:00	4/8/2015 16:00:00	41.48	41.69	41.04	41.42	24753438

plot the mean of each year's close price

[19]:
```
TS_Monthly_df['Close'].resample('Y').mean().plot(figsize=(15,8), grid = True)
```

[19]: <matplotlib.axes._subplots.AxesSubplot at 0x7fbf70403b50>



[20]:
```
TS_Monthly_df.describe()
```

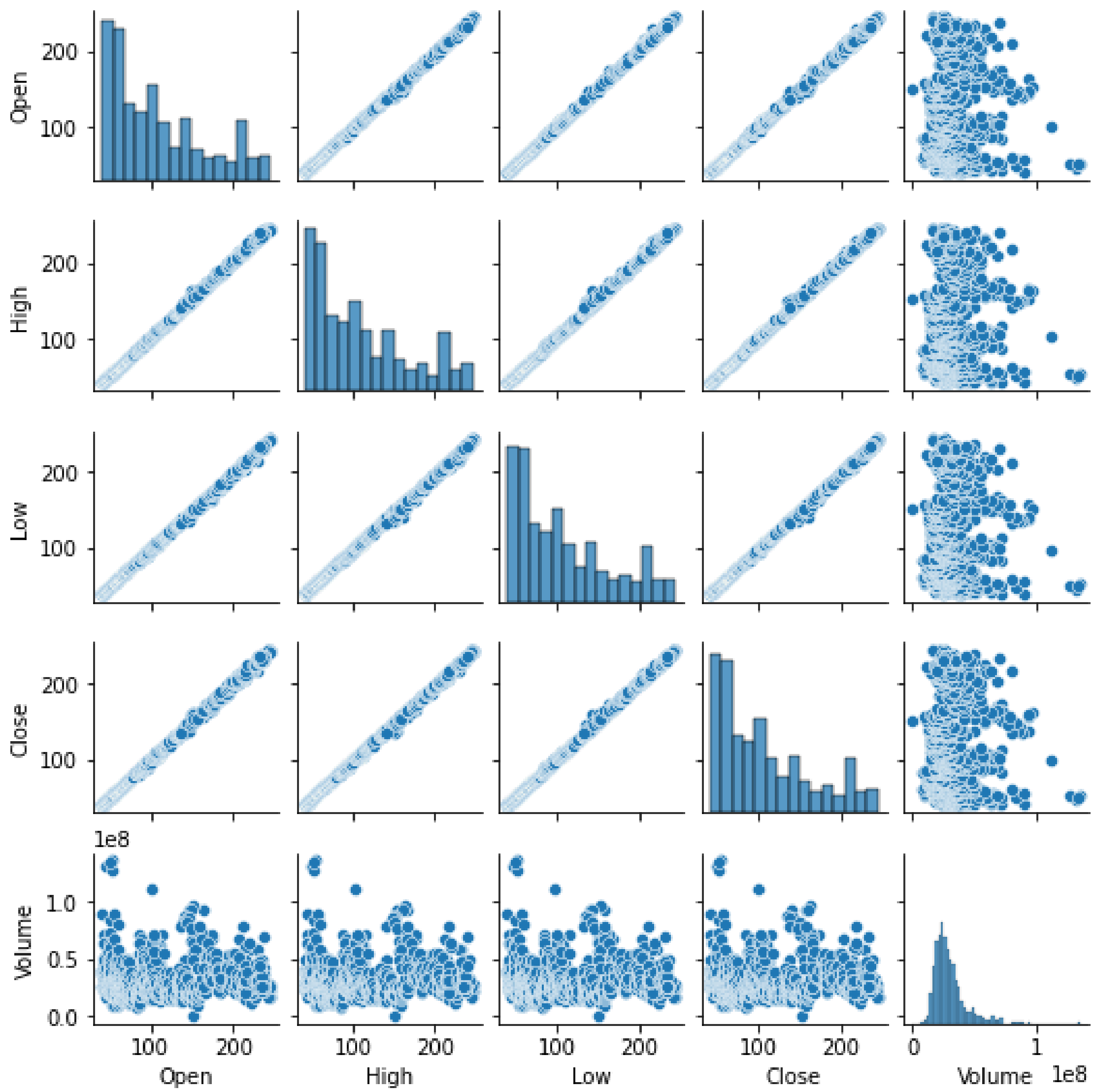
[20]:

	Open	High	Low	Close	Volume
count	1511.000000	1511.000000	1511.000000	1511.000000	1.511000e+03
mean	107.385976	108.437472	106.294533	107.422091	3.019863e+07
std	56.691333	57.382276	55.977155	56.702299	1.425266e+07
min	40.340000	40.740000	39.720000	40.290000	1.016120e+05
25%	57.860000	58.060000	57.420000	57.855000	2.136213e+07
50%	93.990000	95.100000	92.920000	93.860000	2.662962e+07
75%	139.440000	140.325000	137.825000	138.965000	3.431962e+07
max	245.030000	246.130000	242.920000	244.990000	1.352271e+08

5 Part 2: Data Cleaning and Feature Preprocessing

[21]:
```
sns.pairplot(data=TS_Monthly_df, height=1.5)
```

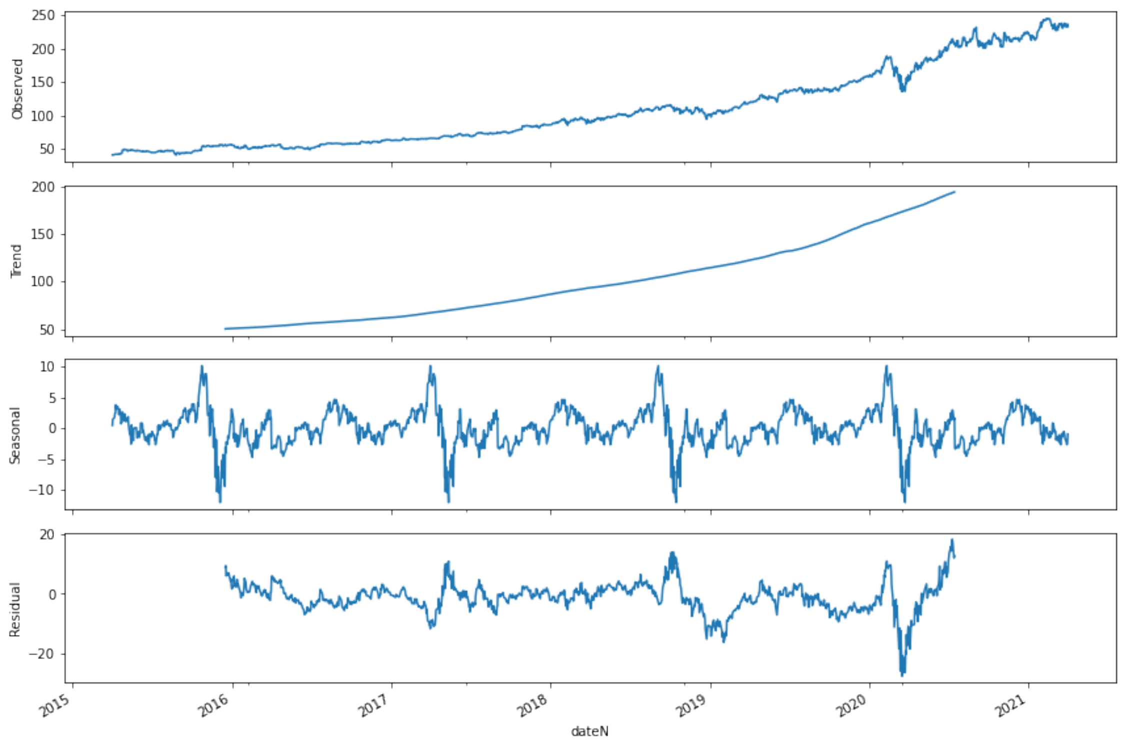
[21]: <seaborn.axisgrid.PairGrid at 0x7fbf70267110>



Open, High, Low, Close have positive relationships between each two.

Conduct a seasonal decomposition on close price by yearly frequence, to get rid of trend and seasonality.

[22]:
```
rcParams['figure.figsize'] = 12, 8
pred_df_sim1_new = sm.tsa.seasonal_decompose(TS_Monthly_df.Close,␣
↪model='additive', freq=360)
pred_df_sim2_full = TS_Monthly_df.Close
figure = pred_df_sim1_new.plot()
plt.show()
```



Get rid of missing value

[23]:
```
len(pred_df_sim1_new.resid)
#pred_df_sim1_new.resid.isnull().sum() #360
```

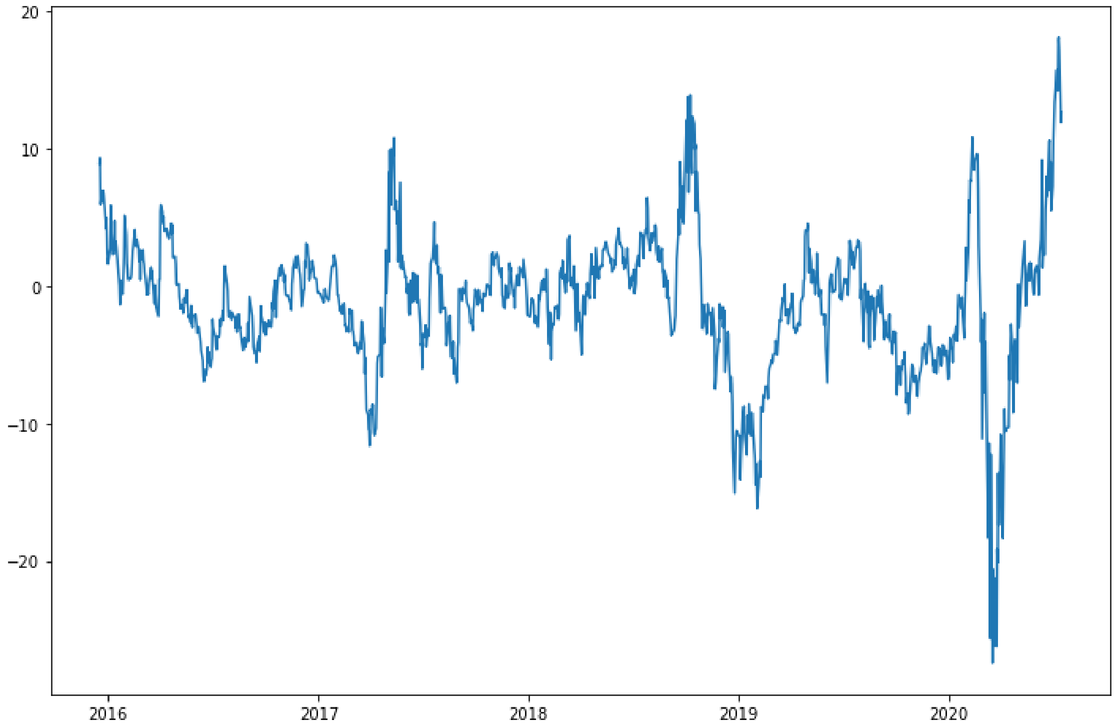
[23]: 1511

[24]:
```
sim1=pred_df_sim1_new.resid.dropna()
sim2 = pred_df_sim2_full.dropna()
```

6 Part 3: Modeling

[25]:
```
plt.plot(sim1)
```

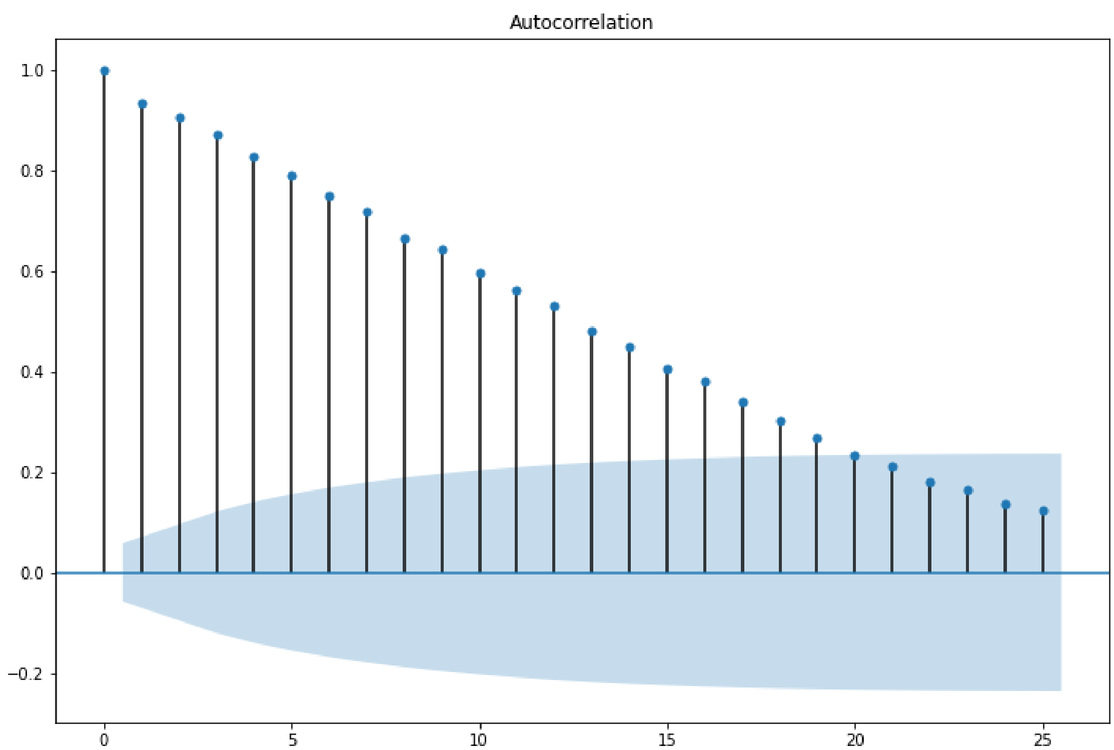
[25]: [<matplotlib.lines.Line2D at 0x7fbf6f5b2cd0>]

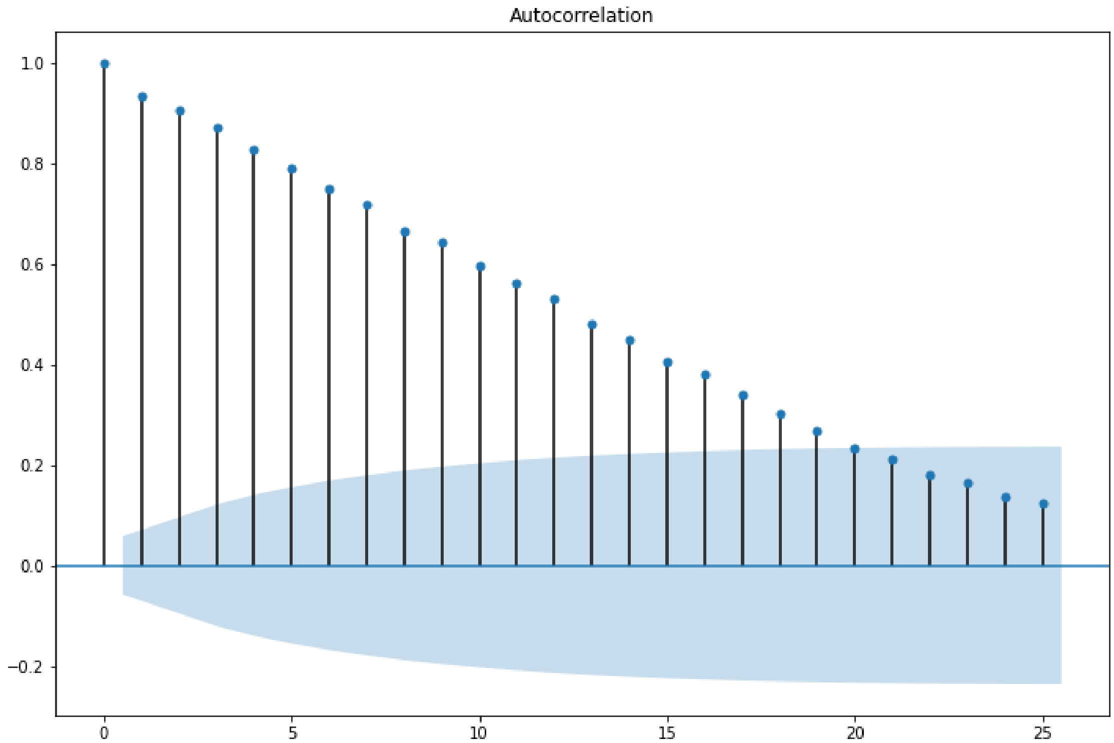


[26]:

```
plot_acf(sim1, lags = 25)
```

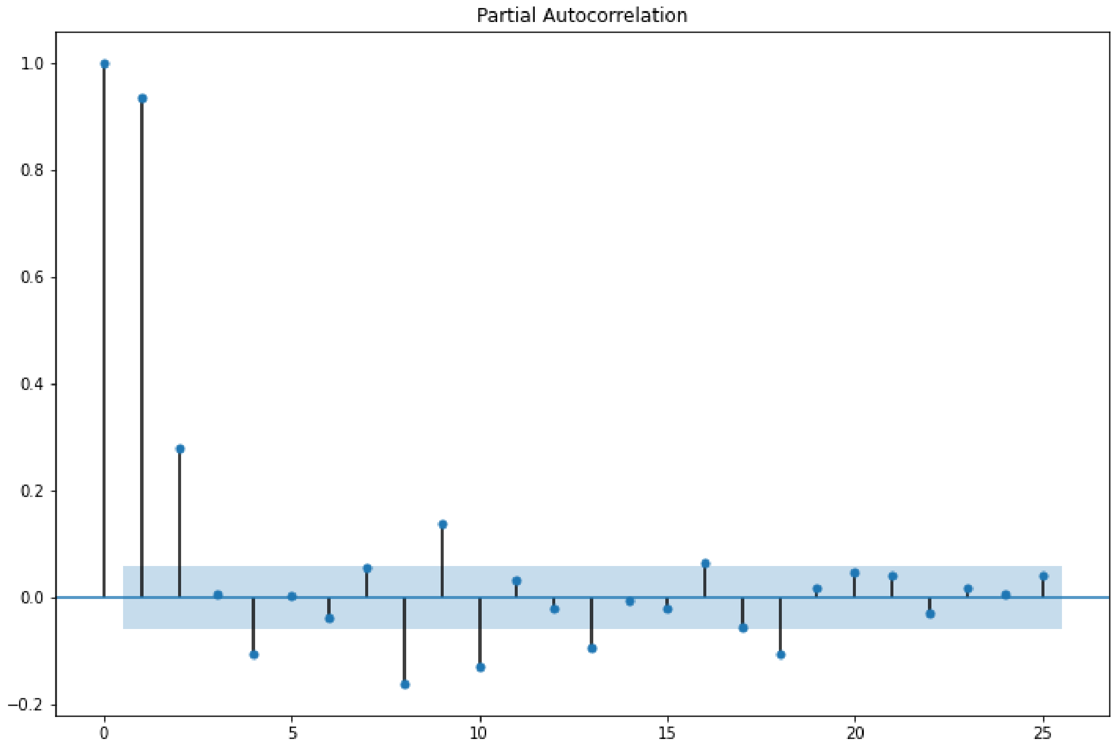
[26]:

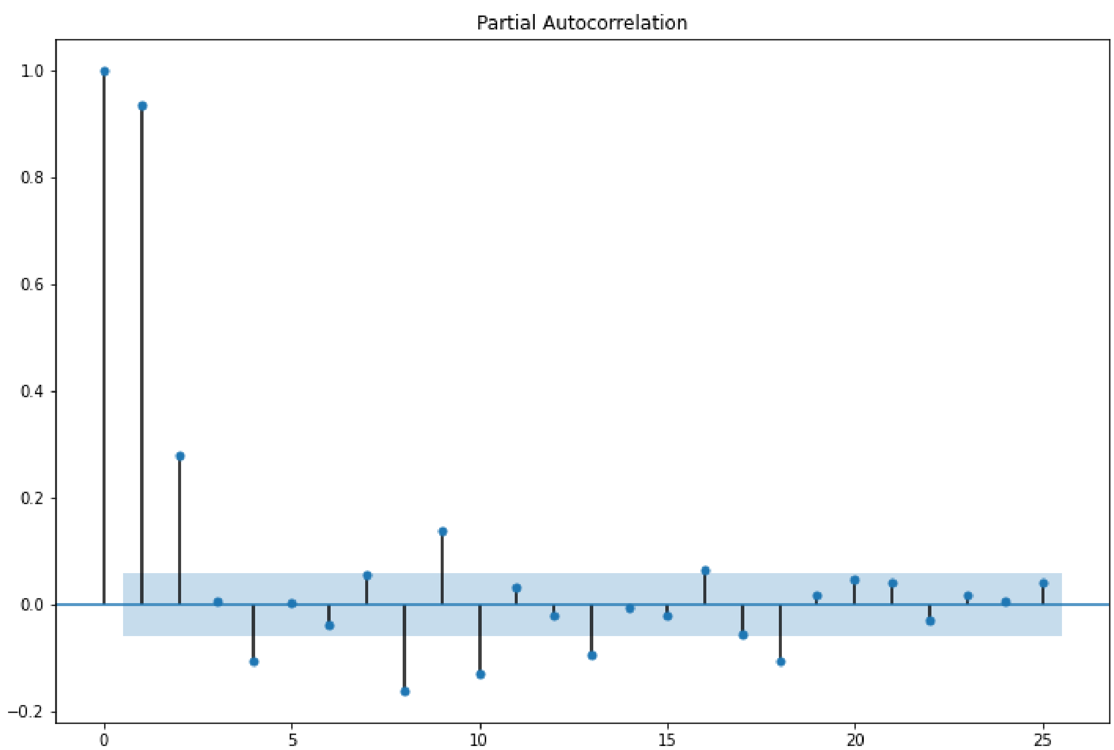




[27]:
```
plot_pacf(sim1, lags=25)
```

[27]:


Partial Autocorrelation
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0
5
10
15
20
25


Partial Autocorrelation
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0
5
10
15
20
25

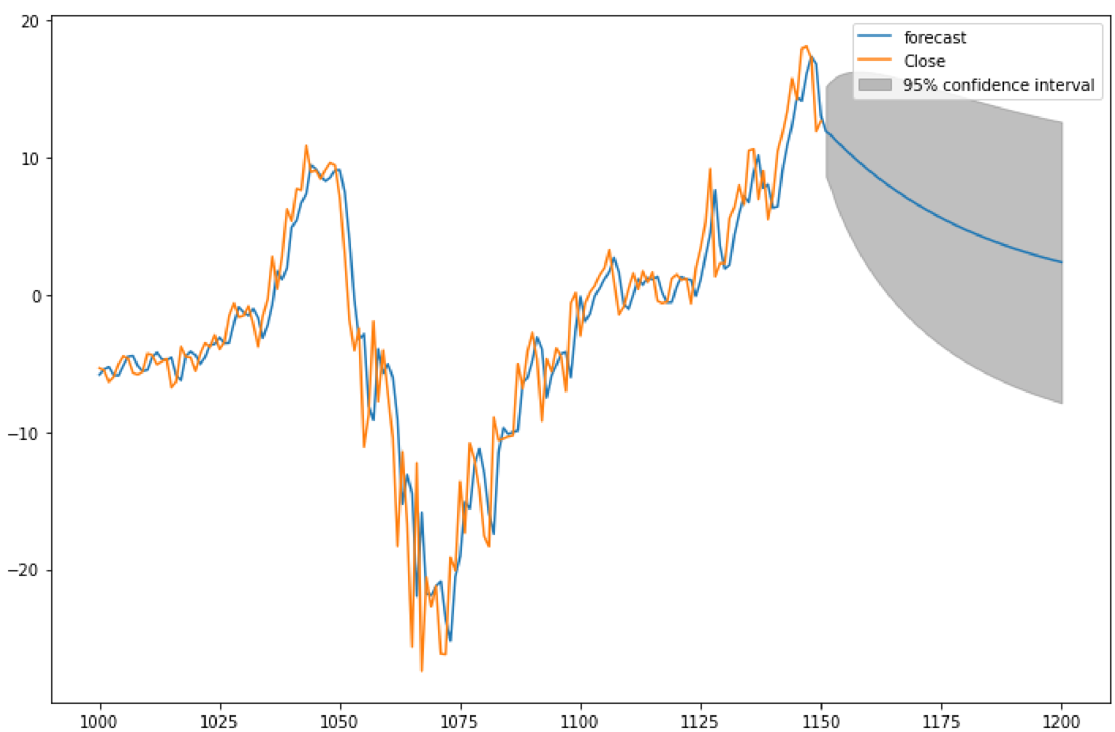
PACF ACF AR PACF p=2.

[28]:
```python
#fit an AR(2) model
model = ARMA(sim1, order=(2,0))
result = model.fit()
```

```
/usr/local/lib/python3.7/dist-packages/statsmodels/tsa/base/tsa_model.py:219:
ValueWarning: A date index has been provided, but it has no associated frequency
information and so will be ignored when e.g. forecasting.
  ' ignored when e.g. forecasting.', ValueWarning)
```

[29]:
```python
# Predicting simulated AR(2) model
result.plot_predict(start=1000, end=1200) #Plot forecasts
plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/statsmodels/tsa/base/tsa_model.py:576:
ValueWarning: No supported index is available. Prediction results will be given
with an integer index beginning at `start`.
  ValueWarning)
/usr/local/lib/python3.7/dist-packages/statsmodels/tsa/base/tsa_model.py:576:
ValueWarning: No supported index is available. Prediction results will be given
with an integer index beginning at `start`.
  ValueWarning)
```

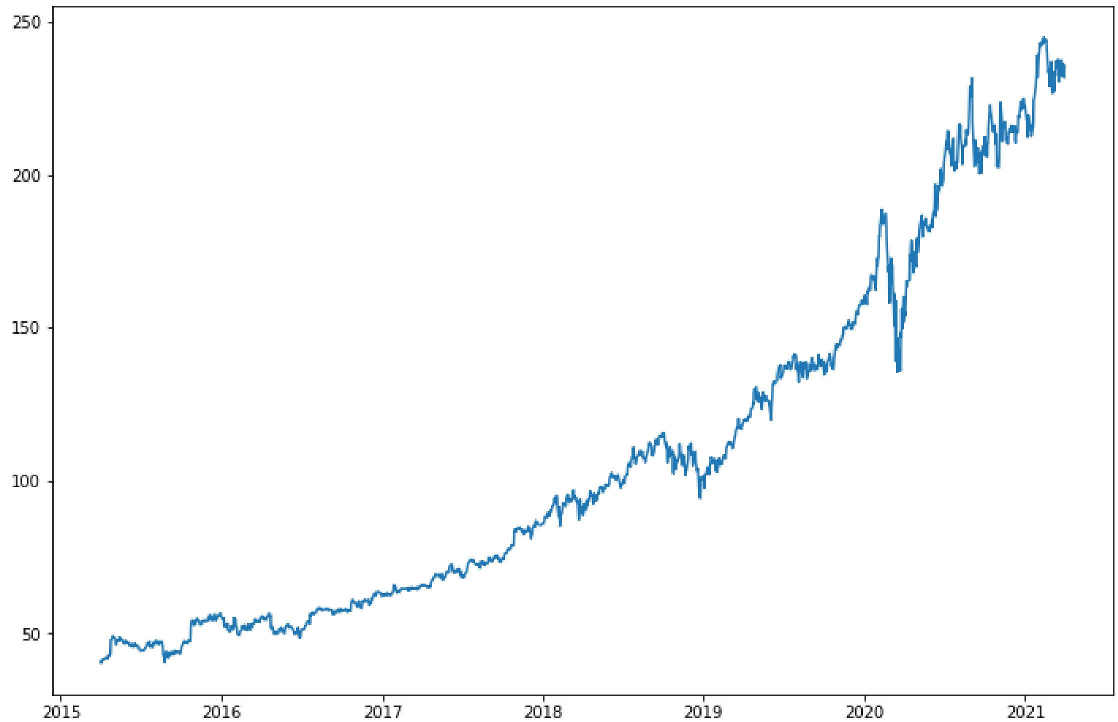


The forecast line stayed close to the ‘Close’ price

[30]:

```
plt.plot(sim2)
```

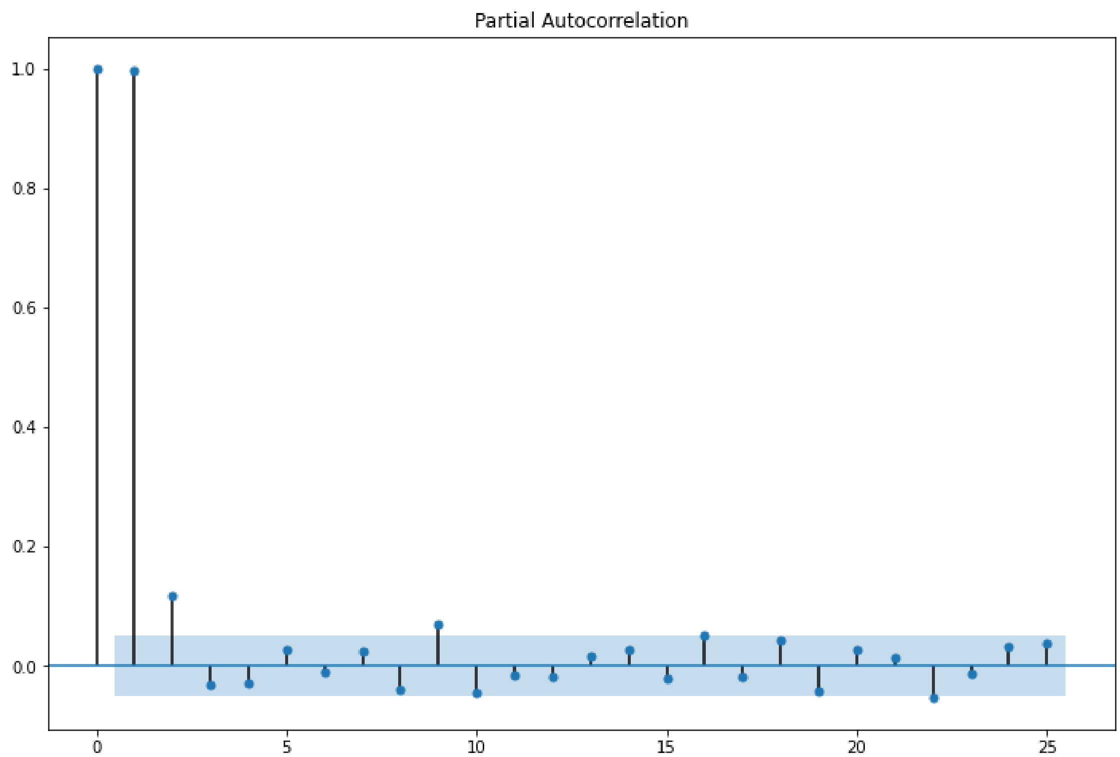
[30]: [<matplotlib.lines.Line2D at 0x7fbf6f3b4590>]

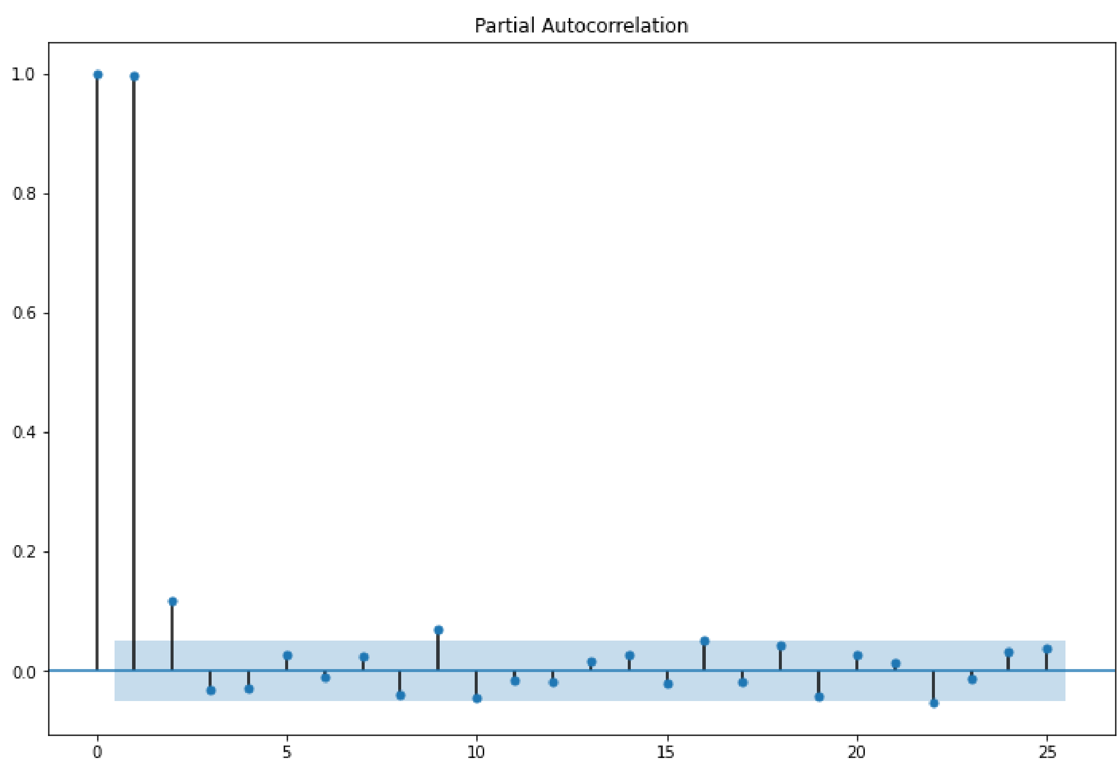


[31]:

```
plot_pacf(sim2, lags=25)
```

[31]:

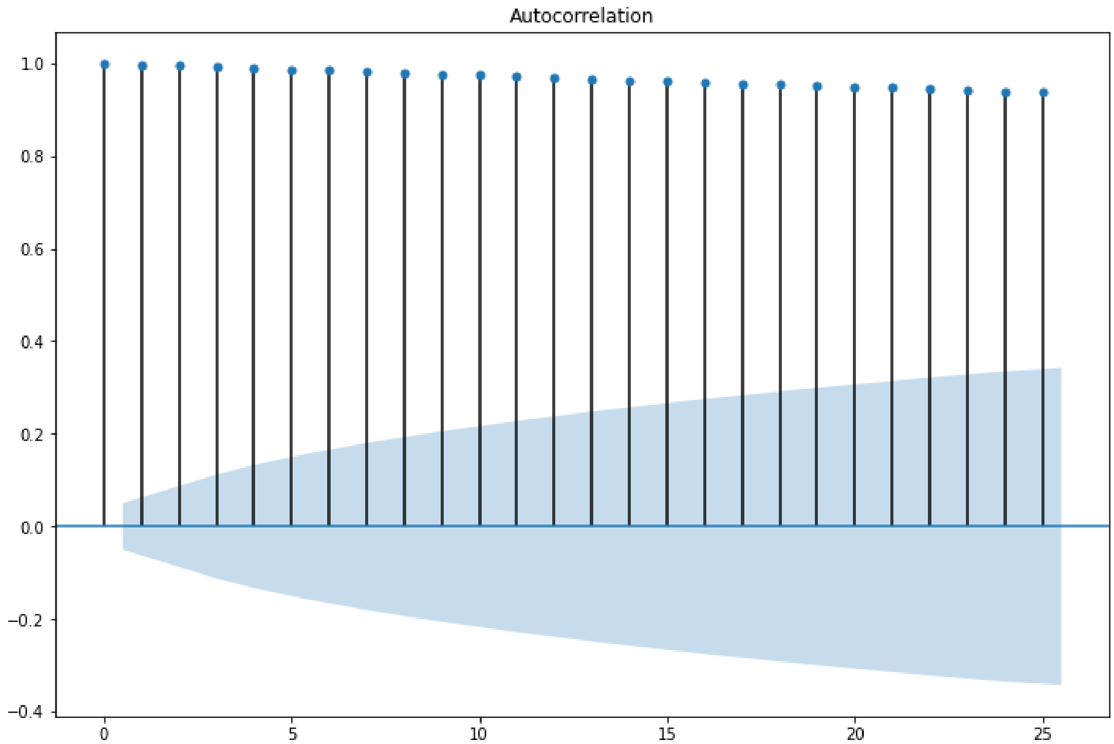

Partial Autocorrelation
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25

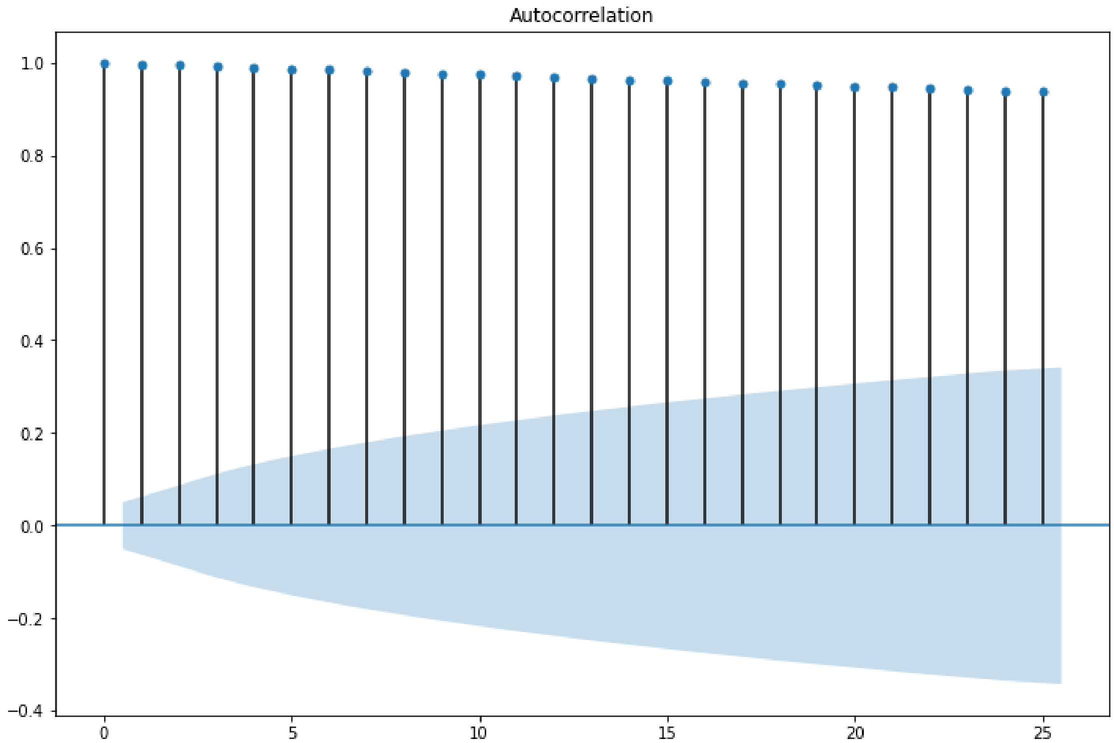

Partial Autocorrelation
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25

[32]:

```
plot_acf(sim2, lags=25)
```

[32]:





[33]:
```
model_s = sm.tsa.statespace.SARIMAX(sim2, order=(2, 3, 3),)
MSFTresults = model_s.fit()
print(MSFTresults.summary().tables[1])
```

```
/usr/local/lib/python3.7/dist-packages/statsmodels/tsa/base/tsa_model.py:219:
ValueWarning: A date index has been provided, but it has no associated frequency
information and so will be ignored when e.g. forecasting.
  ' ignored when e.g. forecasting.', ValueWarning)
/usr/local/lib/python3.7/dist-
packages/statsmodels/tsa/statespace/sarimax.py:961: UserWarning: Non-invertible
starting MA parameters found. Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'

==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -1.2739      0.014    -93.913      0.000      -1.300      -1.247
ar.L2         -0.2756      0.010    -28.467      0.000      -0.295      -0.257
ma.L1         -0.9969      0.194     -5.149      0.000      -1.376      -0.617
ma.L2         -0.9999      0.386     -2.588      0.010      -1.757      -0.243
ma.L3          0.9968      0.193      5.166      0.000       0.619       1.375
sigma2         5.1430      0.946      5.436      0.000       3.289       6.997
==============================================================================
```

[34]:
```
MSFTresults.aic
```

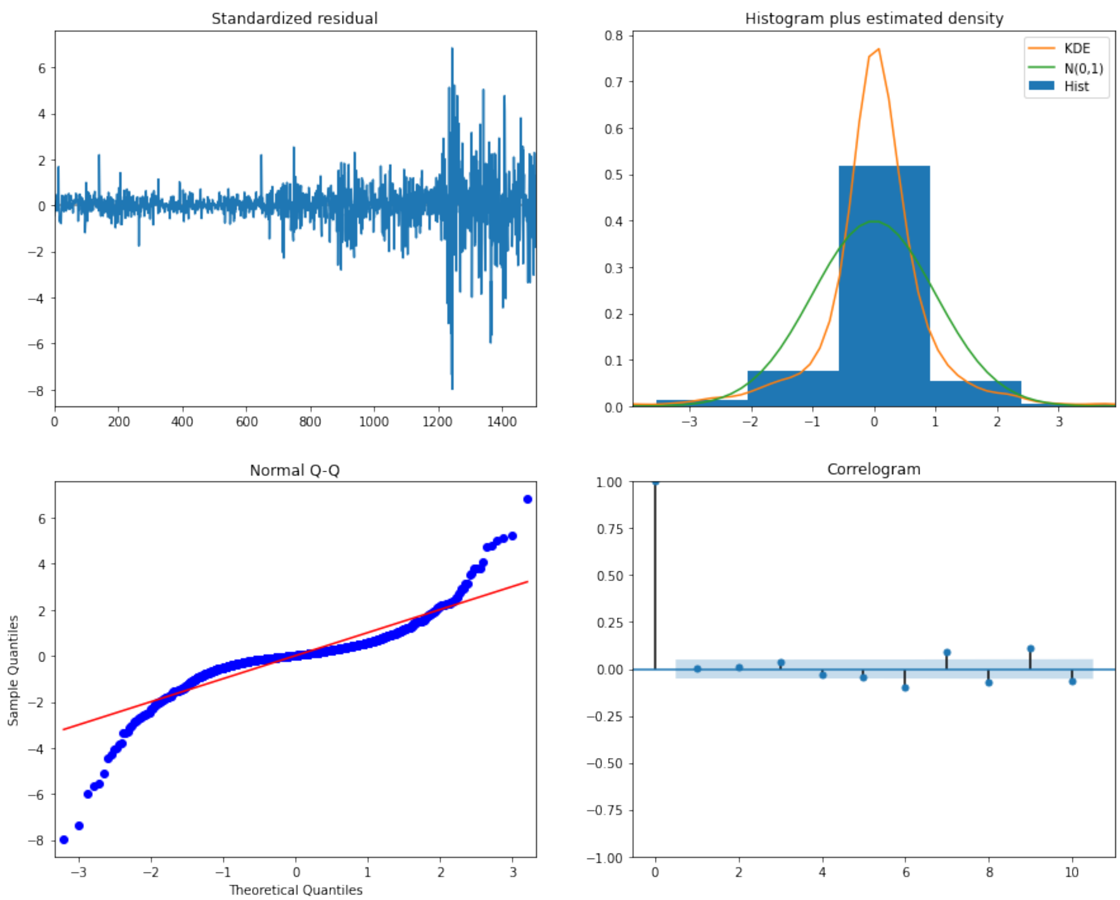
[34]: 6782.356564439854

[35]:
```
MSFTresults.bic
```

[35]: 6814.267801731262

[36]:
```
# model_s = sm.tsa.statespace.SARIMAX(sim2, order=(2, 3, 2),)
# MSFTresults = model_s.fit()
# MSFTresults.aic, MSFTresults.aic
```

[37]:
```
MSFTresults.plot_diagnostics(figsize=(15, 12))
plt.show()
```



[38]:
```
print(acorr_ljungbox(MSFTresults.resid, lags=6))
```

```
(array([50.66277686, 54.63603046, 55.21055957, 56.14009268, 57.84783489,
       64.57148204]), array([1.09680103e-12, 1.36752958e-12, 6.19146244e-12,
```

```
1.87404274e-11,
       3.38122173e-11, 5.27665989e-12]))
```

<0.05:not white noise

[39]:
```
pred = MSFTresults.get_prediction(start=1400, dynamic=False)
```

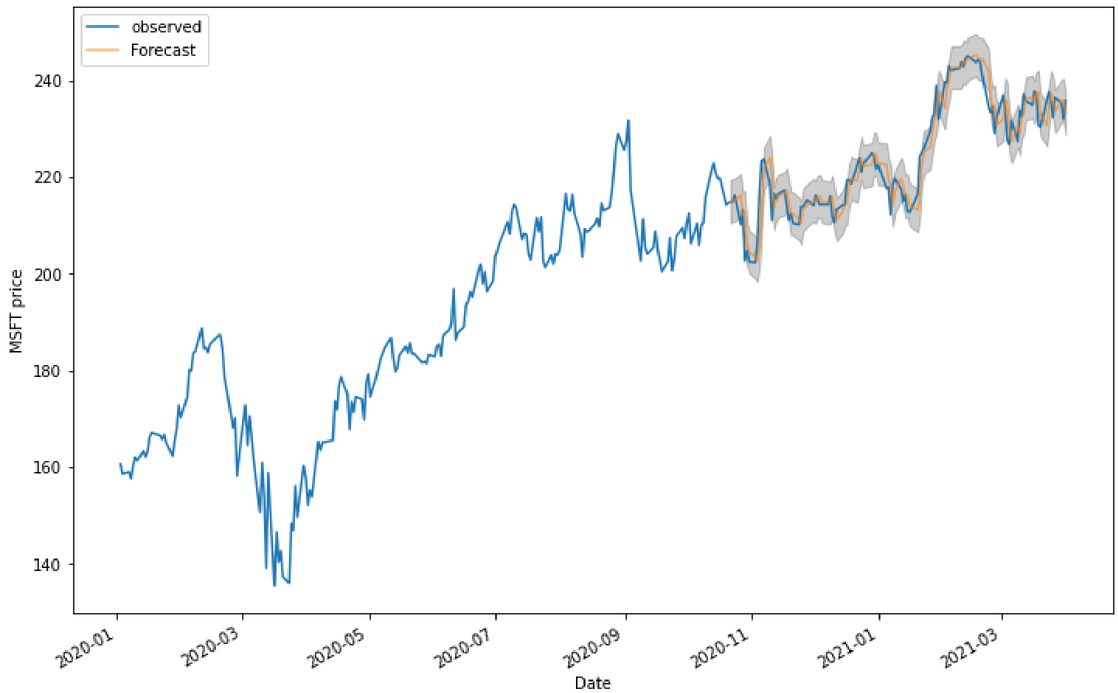
dynamic=False

[40]:
```
pred_ci = pred.conf_int() #Returns the confidence interval of the fitted␣
 ↪parameters.
pred_ci
```

[40]:
```
                     lower Close  upper Close
dateN
2020-10-21 16:00:00   210.444469   219.336598
2020-10-22 16:00:00   210.684671   219.576799
2020-10-23 16:00:00   210.778006   219.670130
2020-10-26 16:00:00   211.791749   220.683873
2020-10-27 16:00:00   207.662210   216.554329
…                            …            …
2021-03-25 16:00:00   231.991145   240.883018
2021-03-26 16:00:00   229.080594   237.972468
2021-03-29 16:00:00   231.292094   240.183963
2021-03-30 16:00:00   231.463283   240.355151
2021-03-31 16:00:00   228.720952   237.612816

[111 rows x 2 columns]
```

[41]:
```
ax = sim2['2020':].plot(label='observed')
pred.predicted_mean.plot(ax=ax, label='Forecast', alpha=.6)
ax.fill_between(pred_ci.index, pred_ci.iloc[:, 0], pred_ci.iloc[:, 1],␣
 ↪color='k', alpha=.2)
ax.set_xlabel('Date')
ax.set_ylabel('MSFT price')
plt.legend()
plt.show()
```



7 Part 4: Model Evaluation & Tuning parameters

[42]:
```
y_forecasted = pred.predicted_mean
y_truth1 = TS_df.Close['2020-10-21 16:00:00':]
```

[43]:
```
# Compute the mean square error
mse = ((y_forecasted - y_truth1) ** 2).mean()
print('The Mean Squared Error of our forecast 1 is {}'.format(round(mse, 2)))
```

```
The Mean Squared Error of our forecast 1 is 12.8
```

Use AIC&BIC to choose the best parameters

[44]:
```
p_min=0
d_min=0
q_min=0
p_max=4
d_max=4
q_max=4

# Initialize a DataFrame to store the results
results_bic = pd.DataFrame(index=['AR{}'.format(i) for i in␣
 ↪range(p_min,p_max+1)],
```

```
                            columns=['MA{}'.format(i) for i in␣
↪range(q_min,q_max+1)])
# get the results of different combination of p,d,q
for p,d,q in itertools.product(range(p_min,p_max+1),
                               range(d_min,d_max+1),
                               range(q_min,q_max+1)):
    if p==0 and d==0 and q==0:
        results_bic.loc['AR{}'.format(p), 'MA{}'.format(q)] = np.nan
        continue
    try:
        model = sm.tsa.SARIMAX(sim2, order=(p, d, q),
                               #enforce_stationarity=False,
                               #enforce_invertibility=False,
                              )
        results = model.fit()
## print(model_results.summary())
## print(model_results.summary().tables[1])
        # print("results.bic",results.bic)
        # print("results.aic",results.aic)
        results_bic.loc['AR{}'.format(p), 'MA{}'.format(q)] = results.bic
    except:
        continue
results_bic = results_bic[results_bic.columns].astype(float)
```

```
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```

[45]:

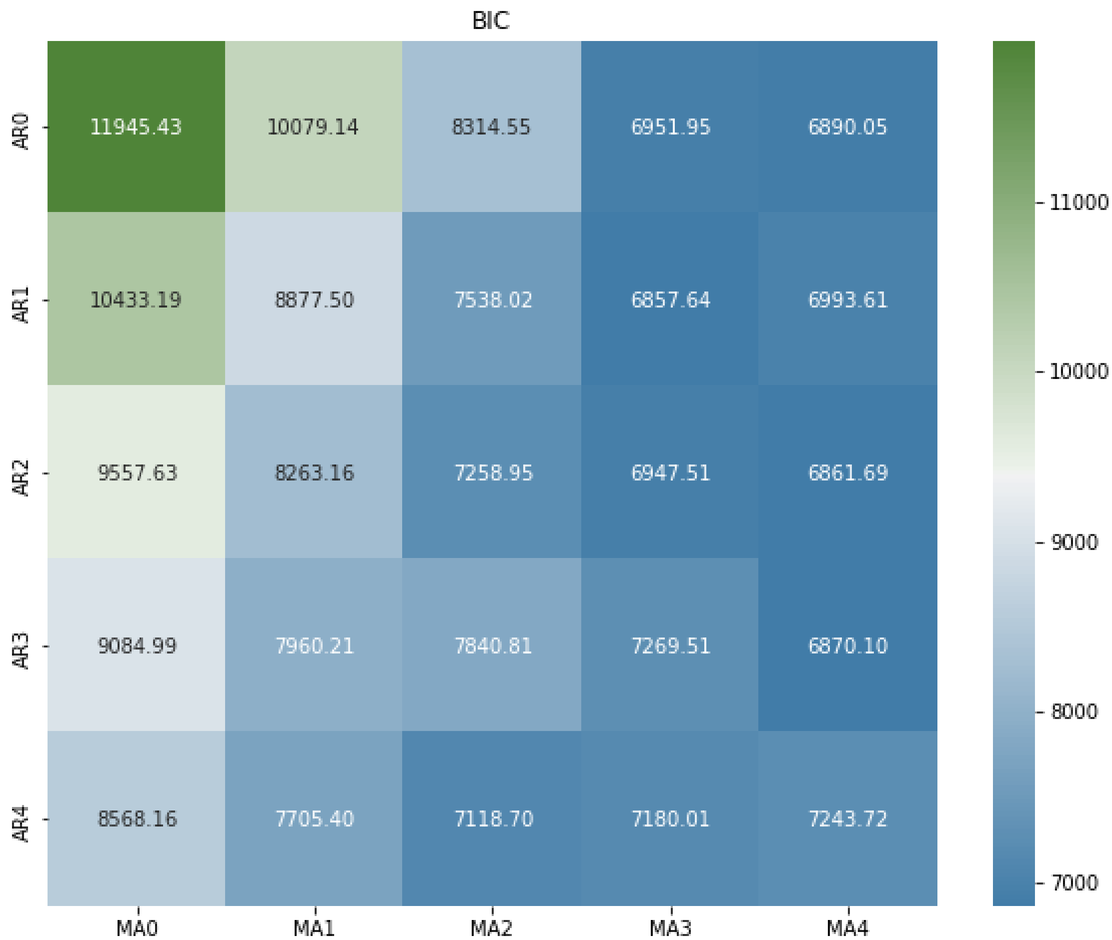
```
results_bic
```

[45]:

	MA0	MA1	MA2	MA3	MA4
AR0	11945.429849	10079.143693	8314.554687	6951.952223	6890.047378
AR1	10433.187927	8877.503402	7538.021441	6857.642363	6993.608345
AR2	9557.634952	8263.163274	7258.946861	6947.507030	6861.687751
AR3	9084.986716	7960.211770	7840.806028	7269.507393	6870.099061
AR4	8568.162696	7705.398067	7118.696819	7180.013914	7243.720247

[46]:

```
fig, ax = plt.subplots(figsize=(10, 8))
ax = sns.heatmap(results_bic,
                 mask=results_bic.isnull(),
                 cmap=sns.diverging_palette(6000, 12000, n=200),
                 ax=ax,
                 annot=True,
                 fmt='.2f',
                 );
ax.set_title('BIC');
```



ARMA(1,,3) gives the lowest BIC.

[47]:
```
# Initialize a DataFrame to store the results
results_aic = pd.DataFrame(index=['AR{}'.format(i) for i in␣
↪range(p_min,p_max+1)],
                           columns=['MA{}'.format(i) for i in␣
↪range(q_min,q_max+1)])
# get the results of different combination of p,d,q
for p,d,q in itertools.product(range(p_min,p_max+1),
                               range(d_min,d_max+1),
                               range(q_min,q_max+1)):
    if p==0 and d==0 and q==0:
        results_aic.loc['AR{}'.format(p), 'MA{}'.format(q)] = np.nan
        continue
    try:
        model = sm.tsa.SARIMAX(sim2, order=(p, d, q),
                               #enforce_stationarity=False,
                               #enforce_invertibility=False,
```

```
                              )
        results = model.fit()
## print(model_results.summary())
## print(model_results.summary().tables[1])
        # print("results.bic",results.bic)
        # print("results.aic",results.aic)
        results_aic.loc['AR{}'.format(p), 'MA{}'.format(q)] = results.aic
    except:
        continue
results_aic = results_aic[results_aic.columns].astype(float)
```

```
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/usr/local/lib/python3.7/dist-
packages/statsmodels/tsa/statespace/sarimax.py:961: UserWarning: Non-invertible
starting MA parameters found. Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
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```

```
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```
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ValueWarning: A date index has been provided, but it has no associated frequency
information and so will be ignored when e.g. forecasting.
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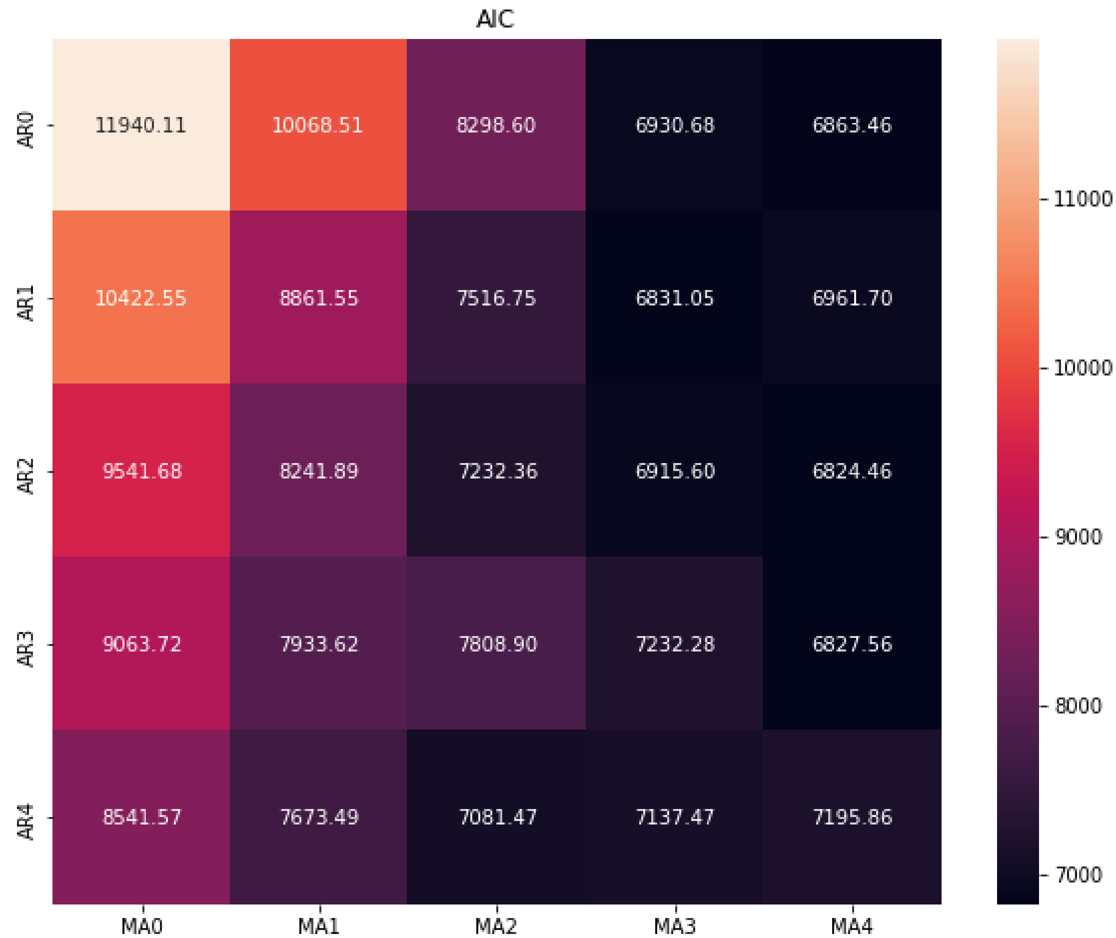
/usr/local/lib/python3.7/dist-packages/statsmodels/base/model.py:512:
ConvergenceWarning: Maximum Likelihood optimization failed to converge. Check
mle_retvals
  "Check mle_retvals", ConvergenceWarning)
```

[48]:
```
fig, ax = plt.subplots(figsize=(10, 8))
ax = sns.heatmap(results_aic,
                 mask=results_aic.isnull(),
                 #cmap=sns.diverging_palette(6000, 12000, n=200),
                 ax=ax,
                 annot=True,
                 fmt='.2f',
                 );
ax.set_title('AIC');
```



ARMA(3,,4) gives the smallest aic.

Try modelling ARMA(1,3,3)

[49]:
```
model1 = sm.tsa.statespace.SARIMAX(sim2, order=(1, 3, 3),)
result1 = model1.fit()
print(result1.summary().tables[1])
```

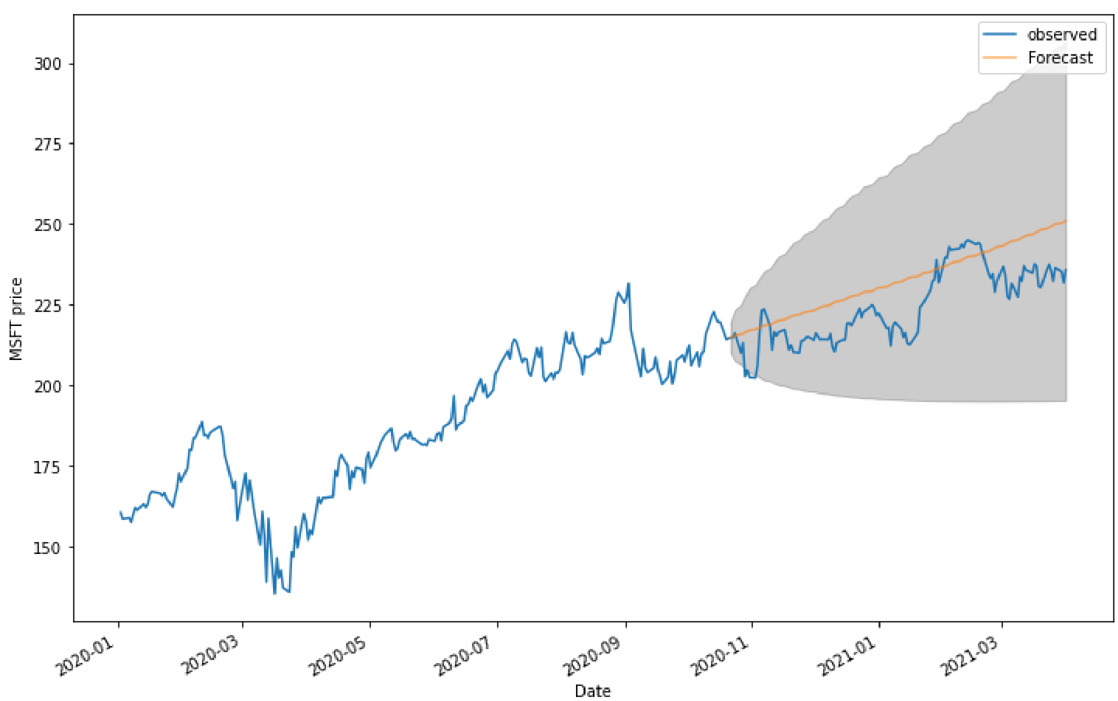
```
/usr/local/lib/python3.7/dist-packages/statsmodels/tsa/base/tsa_model.py:219:
```

```
ValueWarning: A date index has been provided, but it has no associated frequency
information and so will be ignored when e.g. forecasting.
  ' ignored when e.g. forecasting.', ValueWarning)

==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -0.9940      0.004   -241.495      0.000      -1.002      -0.986
ma.L1         -0.9991      0.171     -5.840      0.000      -1.334      -0.664
ma.L2         -1.0000      0.340     -2.938      0.003      -1.667      -0.333
ma.L3          0.9991      0.170      5.872      0.000       0.666       1.333
sigma2         5.5415      0.937      5.915      0.000       3.705       7.378
==============================================================================
```

[50]:

```python
pred1 = result1.get_prediction(start=1400, dynamic=True)
pred1_ci = pred1.conf_int()
ax = sim2['2020':].plot(label='observed')
pred1.predicted_mean.plot(ax=ax, label='Forecast', alpha=.6)
ax.fill_between(pred1_ci.index, pred1_ci.iloc[:, 0], pred1_ci.iloc[:, 1],
 color='k', alpha=.2)
ax.set_xlabel('Date')
ax.set_ylabel('MSFT price')
plt.legend()
plt.show()
```



[51]:
```python
y_forecasted1 = pred1.predicted_mean
mse = ((y_forecasted1 - y_truth1) ** 2).mean()
mse
```

[51]: 110.52439405166038

ARMA(3,3,4)

[52]:
```python
model2 = sm.tsa.statespace.SARIMAX(sim2, order=(3, 3, 4),)
result2 = model2.fit()
print(result2.summary().tables[1])
```

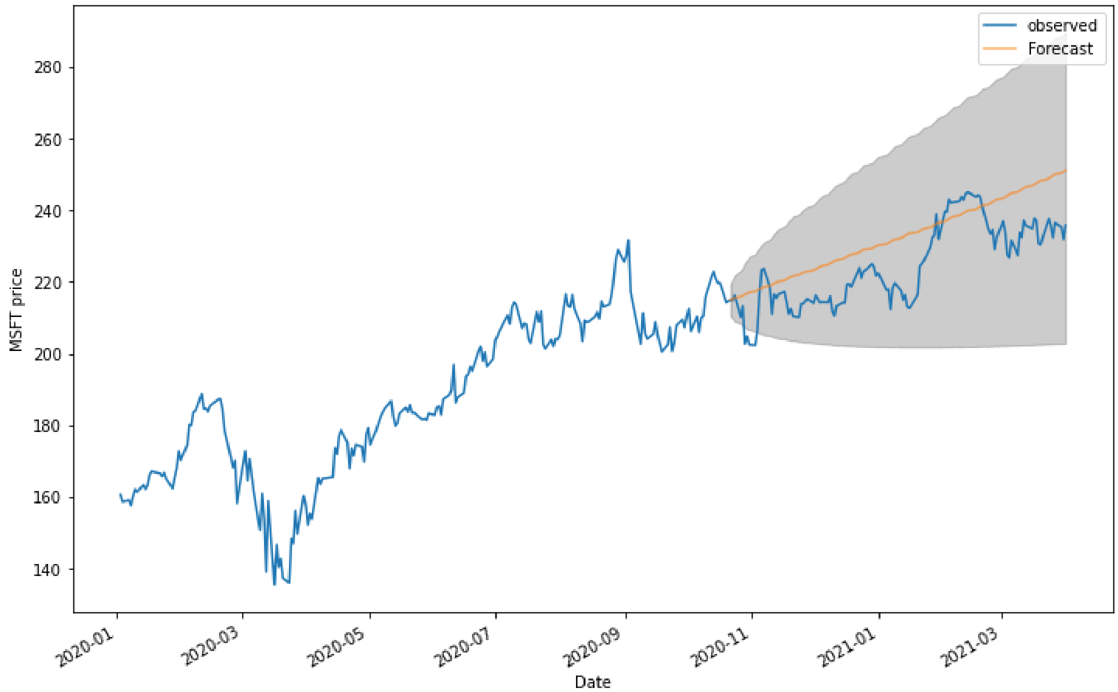
```
/usr/local/lib/python3.7/dist-packages/statsmodels/tsa/base/tsa_model.py:219:
ValueWarning: A date index has been provided, but it has no associated frequency
information and so will be ignored when e.g. forecasting.
  ' ignored when e.g. forecasting.', ValueWarning)
/usr/local/lib/python3.7/dist-
packages/statsmodels/tsa/statespace/sarimax.py:961: UserWarning: Non-invertible
starting MA parameters found. Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'

==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -2.2304      0.010   -217.519      0.000      -2.251      -2.210
ar.L2         -1.5386      0.019    -79.499      0.000      -1.577      -1.501
ar.L3         -0.2807      0.010    -28.272      0.000      -0.300      -0.261
ma.L1         -0.0346      0.009     -3.902      0.000      -0.052      -0.017
ma.L2         -1.9233      0.009   -218.187      0.000      -1.941      -1.906
ma.L3         -0.0382      0.009     -4.190      0.000      -0.056      -0.020
ma.L4          0.9962      0.009    109.728      0.000       0.978       1.014
sigma2         5.0820      0.093     54.425      0.000       4.899       5.265
==============================================================================

/usr/local/lib/python3.7/dist-packages/statsmodels/base/model.py:512:
ConvergenceWarning: Maximum Likelihood optimization failed to converge. Check
mle_retvals
  "Check mle_retvals", ConvergenceWarning)
```

[53]:
```python
pred2 = result2.get_prediction(start=1400, dynamic=True)
pred2_ci = pred2.conf_int()
ax = sim2['2020':].plot(label='observed')
pred1.predicted_mean.plot(ax=ax, label='Forecast', alpha=.6)
ax.fill_between(pred2_ci.index, pred2_ci.iloc[:, 0], pred2_ci.iloc[:, 1],␣
 ↪color='k', alpha=.2)
ax.set_xlabel('Date')
ax.set_ylabel('MSFT price')
plt.legend()
```

```
plt.show()
```



[54]:
```
y_forecasted2 = pred2.predicted_mean
mse = ((y_forecasted2 - y_truth1) ** 2).mean()
mse
```

[54]: 78.24950793106625

8 Part 5: Improvement

Use LSTM

9 Part 5.1: Data Preprocessing

[55]:
```
MSFT_df = pd.read_csv('MSFT_Stock.csv')
```

[56]:
```
MSFT_df.head()
```

[56]:

	Date	Open	High	Low	Close	Volume
0	4/1/2015 16:00:00	40.60	40.76	40.31	40.72	36865322
1	4/2/2015 16:00:00	40.66	40.74	40.12	40.29	37487476

```
2  4/6/2015 16:00:00  40.34  41.78  40.18  41.55  39223692
3  4/7/2015 16:00:00  41.61  41.91  41.31  41.53  28809375
4  4/8/2015 16:00:00  41.48  41.69  41.04  41.42  24753438
```

Split training and testing set

[57]:
```
train = MSFT_df.iloc[:1000, 4:5].values
test = MSFT_df.iloc[1000:, 4:5].values
```

[58]:
```
train.shape, test.shape
```

[58]:
```
((1000, 1), (511, 1))
```

Normalization: scale the feature into range (0,1)

[59]:
```
scaler = MinMaxScaler(feature_range=(0,1))
train_scaled = scaler.fit_transform(train)
```

[60]:
```
train_scaled.shape
```

[60]:
```
(1000, 1)
```

Separate training set into training data and labels: 60 time-steps corresponding to 1 output

[61]:
```
x_train, y_train = [], []
for i in range(60,1000):
  x_train.append(train_scaled[i-60:i, 0])
  y_train.append(train_scaled[i, 0])
```

[62]:
```
x_train, y_train = np.array(x_train), np.array(y_train)
```

[63]:
```
x_train.shape, y_train.shape
```

[63]:
```
((940, 60), (940,))
```

[64]:
```
x_train = np.reshape(x_train, (x_train.shape[0], x_train.shape[1], 1))
```

10 Part 5.2: Modeling

build LSTM with 50 neurons and 4 hidden layers

[65]:
```
model = Sequential()
#setting return sequences to True to access the hidden state output for each␣
↪input time step.
model.add(LSTM(units = 50, return_sequences = True, input_shape = (x_train.
↪shape[1], 1)))
```

```
model.add(Dropout(0.2))
model.add(LSTM(units = 50, return_sequences = True))
model.add(Dropout(0.2))
model.add(LSTM(units = 50, return_sequences = True))
model.add(Dropout(0.2))
model.add(Dense(units = 1))
```

[66]:
```
model.compile(optimizer = 'adam', loss = 'mean_squared_error')
```

[67]:
```
model.fit(x_train, y_train, epochs = 100, batch_size = 32)
```

```
Epoch 1/100
30/30 [==============================] - 9s 97ms/step - loss: 0.1217
Epoch 2/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0850
Epoch 3/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0831
Epoch 4/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0818
Epoch 5/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0815
Epoch 6/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0812
Epoch 7/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0808
Epoch 8/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0796
Epoch 9/100
30/30 [==============================] - 3s 100ms/step - loss: 0.0796
Epoch 10/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0795
Epoch 11/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0786
Epoch 12/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0788
Epoch 13/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0782
Epoch 14/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0788
Epoch 15/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0776
Epoch 16/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0779
Epoch 17/100
30/30 [==============================] - 4s 132ms/step - loss: 0.0777
Epoch 18/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0779
```

```
Epoch 19/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0777
Epoch 20/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0773
Epoch 21/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0792
Epoch 22/100
30/30 [==============================] - 4s 136ms/step - loss: 0.0778
Epoch 23/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0775
Epoch 24/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0774
Epoch 25/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0784
Epoch 26/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0773
Epoch 27/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0772
Epoch 28/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0773
Epoch 29/100
30/30 [==============================] - 3s 100ms/step - loss: 0.0771
Epoch 30/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0769
Epoch 31/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0770
Epoch 32/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0776
Epoch 33/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0771
Epoch 34/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0770
Epoch 35/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0771
Epoch 36/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0769
Epoch 37/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0768
Epoch 38/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0768
Epoch 39/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0769
Epoch 40/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0770
Epoch 41/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0768
Epoch 42/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0768
```

```
Epoch 43/100
30/30 [==============================] - 3s 95ms/step - loss: 0.0772
Epoch 44/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0769
Epoch 45/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0767
Epoch 46/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0767
Epoch 47/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0767
Epoch 48/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0769
Epoch 49/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0768
Epoch 50/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0768
Epoch 51/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0770
Epoch 52/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0768
Epoch 53/100
30/30 [==============================] - 4s 129ms/step - loss: 0.0766
Epoch 54/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0767
Epoch 55/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0767
Epoch 56/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0771
Epoch 57/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0768
Epoch 58/100
30/30 [==============================] - 4s 134ms/step - loss: 0.0767
Epoch 59/100
30/30 [==============================] - 3s 101ms/step - loss: 0.0767
Epoch 60/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0767
Epoch 61/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0771
Epoch 62/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0766
Epoch 63/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0768
Epoch 64/100
30/30 [==============================] - 3s 95ms/step - loss: 0.0767
Epoch 65/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0765
Epoch 66/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0770
```

```
Epoch 67/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0772
Epoch 68/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0773
Epoch 69/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0766
Epoch 70/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0768
Epoch 71/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0769
Epoch 72/100
30/30 [==============================] - 4s 129ms/step - loss: 0.0770
Epoch 73/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0765
Epoch 74/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0767
Epoch 75/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0764
Epoch 76/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0773
Epoch 77/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0766
Epoch 78/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0769
Epoch 79/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0767
Epoch 80/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0766
Epoch 81/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0766
Epoch 82/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0765
Epoch 83/100
30/30 [==============================] - 3s 100ms/step - loss: 0.0765
Epoch 84/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0766
Epoch 85/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0766
Epoch 86/100
30/30 [==============================] - 3s 96ms/step - loss: 0.0765
Epoch 87/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0766
Epoch 88/100
30/30 [==============================] - 3s 97ms/step - loss: 0.0765
Epoch 89/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0764
Epoch 90/100
30/30 [==============================] - 3s 100ms/step - loss: 0.0765
```

```
Epoch 91/100
30/30 [==============================] - 3s 102ms/step - loss: 0.0767
Epoch 92/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0764
Epoch 93/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0765
Epoch 94/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0764
Epoch 95/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0765
Epoch 96/100
30/30 [==============================] - 3s 98ms/step - loss: 0.0765
Epoch 97/100
30/30 [==============================] - 3s 100ms/step - loss: 0.0765
Epoch 98/100
30/30 [==============================] - 3s 103ms/step - loss: 0.0764
Epoch 99/100
30/30 [==============================] - 3s 100ms/step - loss: 0.0767
Epoch 100/100
30/30 [==============================] - 3s 99ms/step - loss: 0.0765
```

[67]:
```
<keras.callbacks.History at 0x7fbf6f9618d0>
```

Prepare testing set

[86]:
```
test_scaled = scaler.fit_transform(test)
test_scaled.shape
```

[86]:
```
(511, 1)
```

[82]:
```
# dataset_train = MSFT_df.iloc[:1000, 4:5]
# dataset_test = MSFT_df.iloc[1000:, 4:5]
# dataset_total = pd.concat((dataset_train, dataset_test), axis = 0)
# dataset_total
```

[83]:
```
# inputs = dataset_total[len(dataset_total) - len(dataset_test) - 60:].values
# inputs = inputs.reshape(-1,1)
# inputs = scaler.transform(inputs)
# inputs[:10]
```

[84]:
```
# x_test = []
# for i in range(60, 571):
#     x_test.append(inputs[i-60:i, 0])
# x_test = np.array(x_test)
# x_test = np.reshape(x_test, (x_test.shape[0], x_test.shape[1], 1))
# x_test.shape
```

[ ]:
```
#test = test.reshape(-1, 1)
# test_scaled = scaler.fit_transform(test)
# test_scaled.shape
```

[ ]:
```
# test_scaled[:10]
```

[ ]:
```
# x_test = []
# for i in range(60, 511):
#   x_test.append(test_scaled[i-60:i, 0])
```

[ ]:
```
# x_test = np.array(x_test)
# x_test = np.reshape(x_test, (x_test.shape[0], x_test.shape[1], 1))
# x_test.shape
```

Make predictions using the test set

[122]:
```
y_pred = model.predict(test_scaled)
y_pred.shape
```

[122]:
```
(511, 1, 1)
```

[124]:
```
y_pred[:5]
```

[124]:
```
array([[[0.4128948 ]],

       [[0.41292536]],

       [[0.41293788]],

       [[0.41288072]],

       [[0.41288877]]], dtype=float32)
```

[111]:
```
y_pred = y_pred.reshape((-1,1))
y_pred.shape
```

[111]:
```
(511, 1)
```

[120]:
```
y_pred[:5]
```

[120]:
```
array([[[0.4128948 ]],

       [[0.41292536]],

       [[0.41293788]],

       [[0.41288072]],
```

```
        [[0.41288877]]], dtype=float32)
```

[112]:
```
predicted_close_price = scaler.inverse_transform(y_pred)
```

[113]:
```
predicted_close_price.shape
```

[113]:
```
(511, 1)
```

[125]:
```
predicted_close_price[:5]
```

[125]:
```
array([[169.71136],
       [169.71529],
       [169.71689],
       [169.70956],
       [169.71059]], dtype=float32)
```

Visualize the results

[116]:
```
plt.figure(figsize=(20, 8))
plt.plot(test, color = 'red', label = 'Real MSFT Close Price')
plt.plot(predicted_close_price, color = 'blue', label = 'Predicted MSFT Close␣
 ↪Price')
plt.xticks(np.arange(0,510,100))
plt.title('MSFT Close Price Prediction')
plt.xlabel('Time')
plt.ylabel('MSFT Close Price')
plt.legend()
plt.show()
```