Actividad modulo 31 - Series de tiempo II

In [ ]:
```
# Libreria de Base
import warnings
warnings.filterwarnings('ignore')
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
import statsmodels.api as sm
import os
```

Importación de datos de stocks del ejercicio anterior

In [ ]:
```
# Se importa el archivo con datos
os.chdir('E:\WORK IN PROGRESS\Data Analytics course\parte 2 python\week 31')

# Uso de la funcion read_csv
df_ecopetrol = pd.read_csv('ecopetrol.csv',index_col='Date', parse_dates=['Date'])
#df_terpel = pd.read_csv('terpel.csv',index_col='Date',parse_dates=['Date'])
```

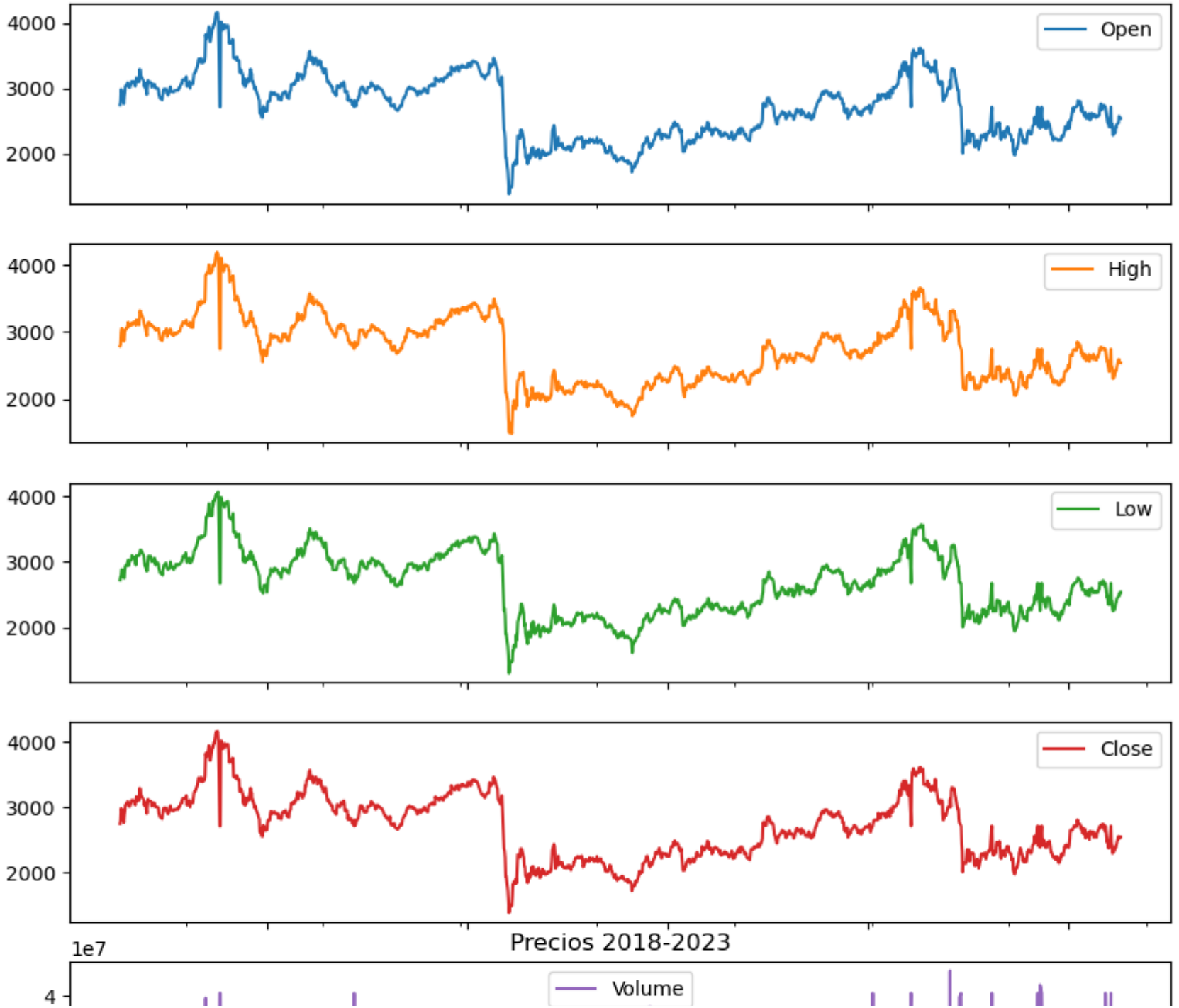
In [ ]:
```
df_ecopetrol.sample(5)
```

Out[ ]:

Date	Unnamed: 0	Open	High	Low	Close	Volume
2022-05-03	1061	3313.0	3324.0	3233.0	3313.0	9994912.0
2020-10-09	654	1938.0	1972.0	1925.0	1938.0	4220206.0
2019-03-26	251	3470.0	3525.0	3450.0	3470.0	9346452.0
2019-08-21	357	2740.0	2765.0	2725.0	2740.0	6668753.0
2020-07-03	584	2100.0	2100.0	2075.0	2100.0	521127.0

In [ ]:
```
df_ecopetrol.drop(['Unnamed: 0'],axis=1,inplace=True)
```

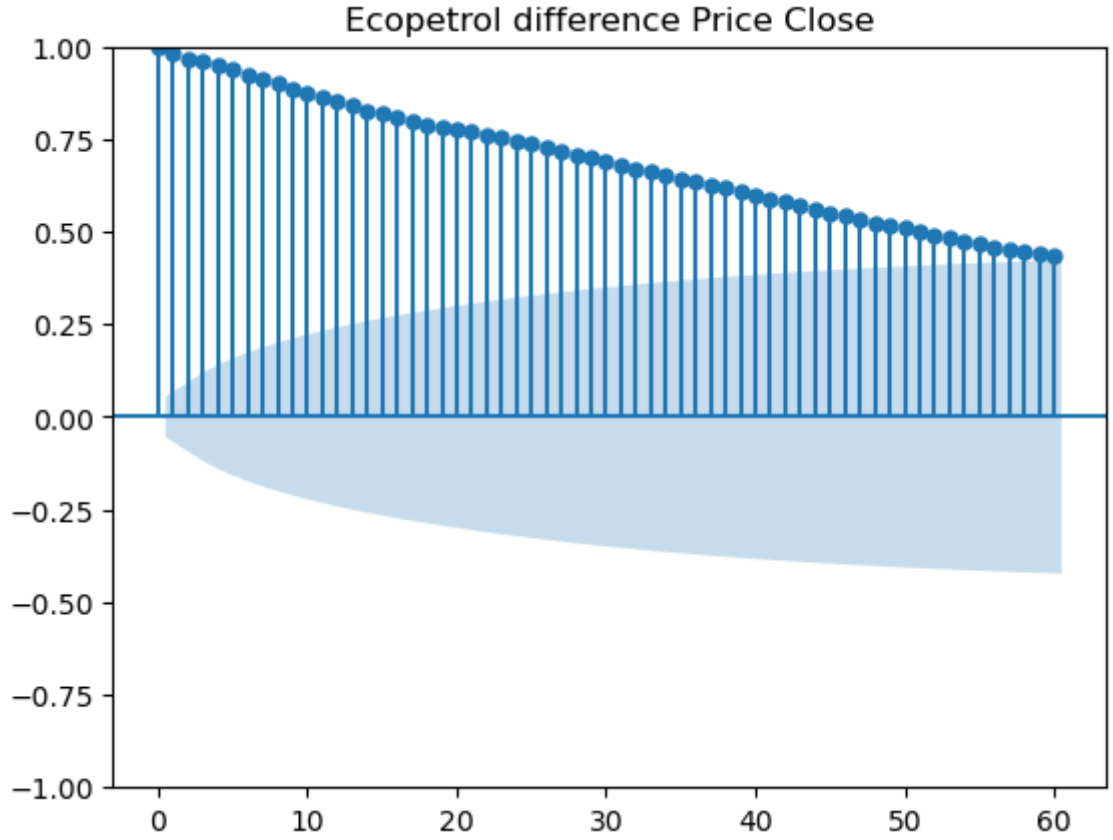
In [ ]:
```
# Visualizacion Basica a traves de rangos
# Usando matplotlib
df_ecopetrol['2018':'2023'].plot(subplots=True, figsize=(10,12))
plt.title('Precios 2018-2023')
plt.show()
```


Open
High
Low
Close
Volume
4000
3000
2000
1e7
4
Precios 2018-2023

In [ ]:
```
# Librerias para uso estadistico y de series de tiempo
import chart_studio.plotly as py
from plotly.offline import init_notebook_mode, iplot
init_notebook_mode(connected=True)
import plotly.graph_objs as go
import plotly.figure_factory as ff
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
import math
from sklearn.metrics import mean_squared_error
from statsmodels.tsa.arima_model import ARMA
from statsmodels.tsa.stattools import adfuller
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
from statsmodels.tsa.arima_process import ArmaProcess
from statsmodels.tsa.arima_model import ARIMA
```

ACF and PACF

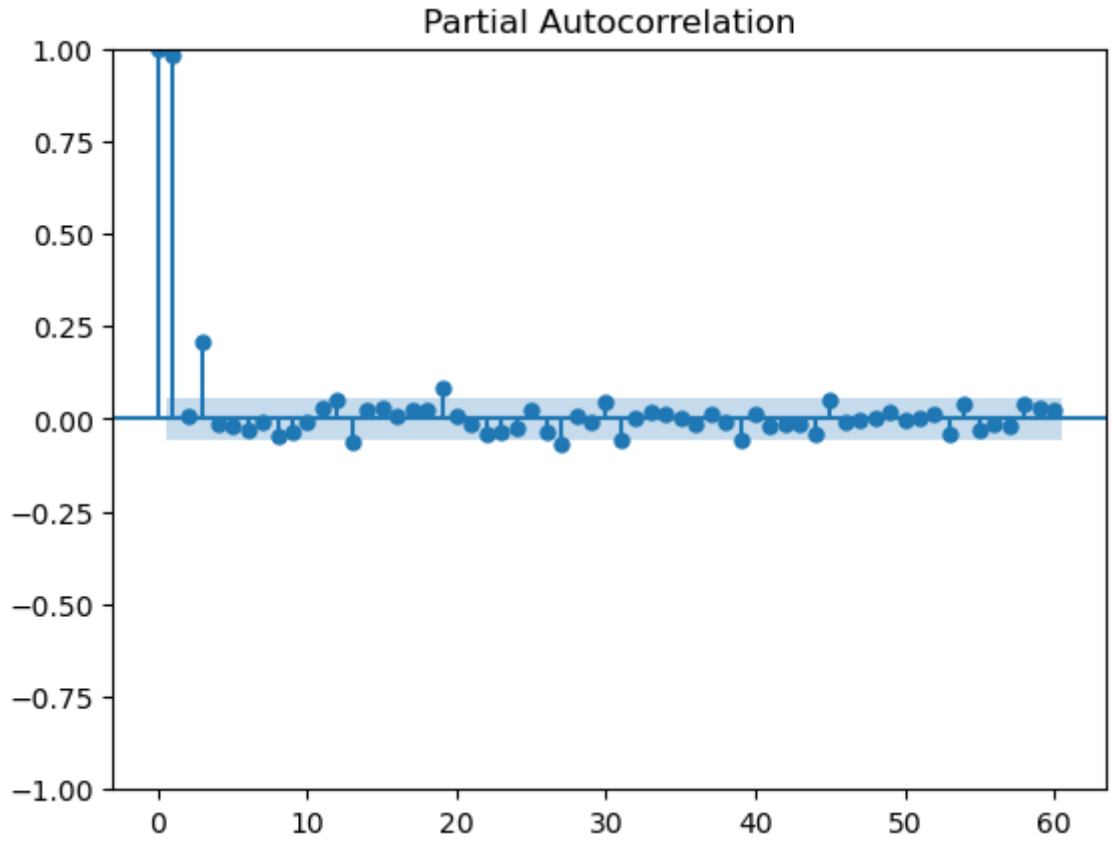
In [ ]:
```
# Autocorrelation of Ecopetrol price Close
# Los lags van en el Eje x y las correlaciones en el Eje y
plot_acf(df_ecopetrol['Close'], lags=60,title='Ecopetrol difference Price Close')
plt.show()
```



Insights:

- Valores de precios pasados tienen una influencia sobre el precio actual.
- Especificamente para este caso valores más alla de la 59th posición no tienen poder significativo predictivo sobre el precio actual

In [ ]:
```
# Funcion Parcial de Autocorrelacion
# https://www.statsmodels.org/dev/generated/statsmodels.graphics.tsaplots.plot_pacf.html
# Esta funcion genera la correlacion parcial entre los valores de una serie de tiempo y sus lags anteriores
# La correlacion parcial es un calculo de correlacion que toma en cuenta las observaciones de la serie de tiempo
# separadas por sus lags, luego de ajustar por la presencia de otros terminos con lags mas pequenos (lo que la diferencia de ACF)
# Tambien nos indica cual es la importancia de los lags en la prediccion

plot_pacf(df_ecopetrol['Close'], lags=60)
plt.show()
```



In [ ]:
```python
from statsmodels.tsa.stattools import adfuller

def check_stationarity(series):
    # Copied from https://machinelearningmastery.com/time-series-data-stationary-python/

    result = adfuller(series.values)

    print('ADF Statistic: %f' % result[0])
    print('p-value: %f' % result[1])
    print('Critical Values:')
    for key, value in result[4].items():
        print('\t%s: %.3f' % (key, value))

    if (result[1] <= 0.05) & (result[4]['5%'] > result[0]):
        print("\u001b[32mStationary\u001b[0m")
```

```
    else:
        print("\x1b[31mNon-stationary\x1b[0m")
```

In [ ]:
```
check_stationarity(df_ecopetrol['Close'])
```

```
ADF Statistic: -2.642439
p-value: 0.084539
Critical Values:
        1%: -3.435
        5%: -2.864
        10%: -2.568
Non-stationary
```

Insights:

- Dado que la serie no es estacionaria se procede a usar la diferencia (comando diff()) del precio

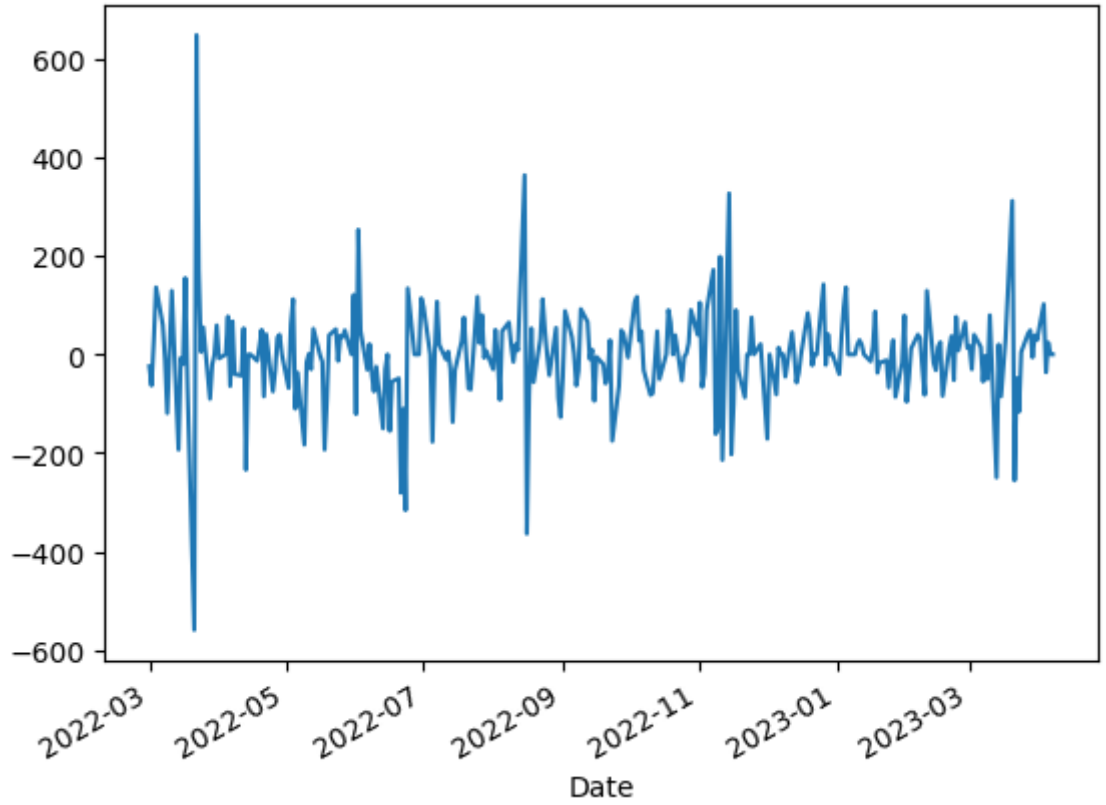
In [ ]:
```
df_ecopetrol['Close_diff'] = df_ecopetrol['Close'].diff().fillna(0)
```

In [ ]:
```
check_stationarity(df_ecopetrol['Close_diff'])
```

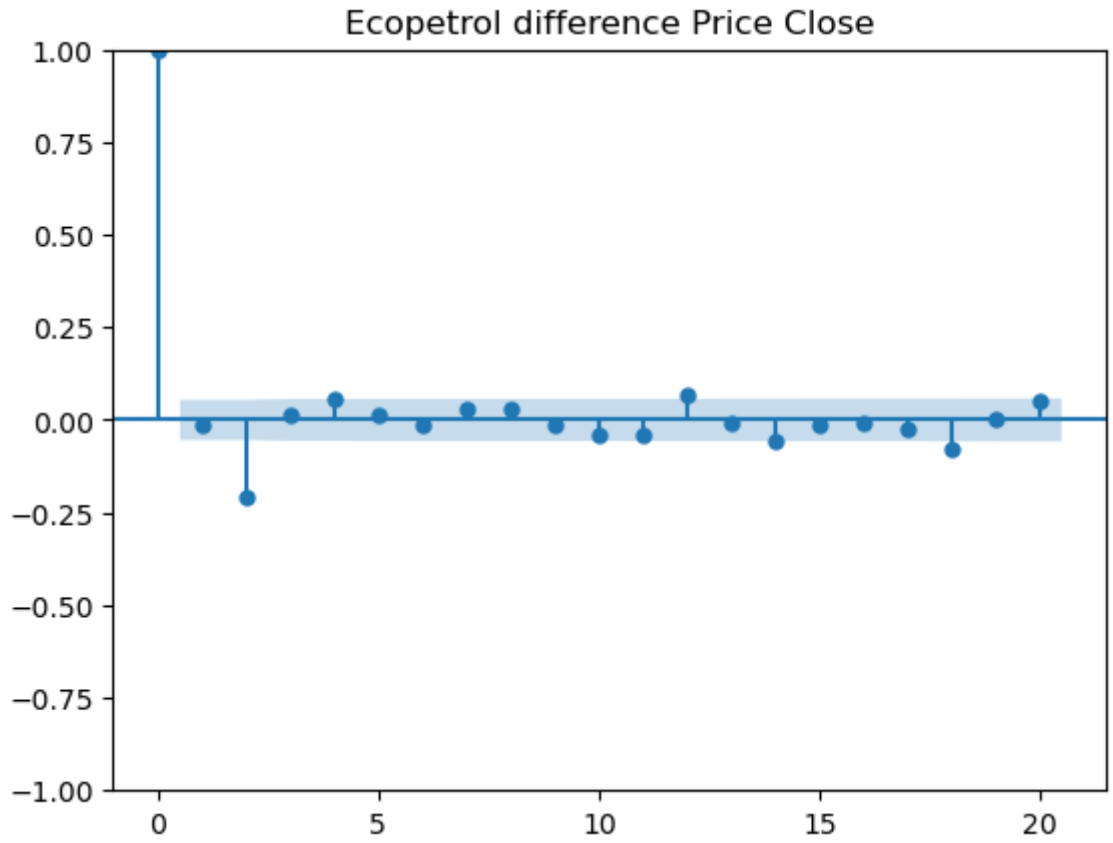
```
ADF Statistic: -31.721912
p-value: 0.000000
Critical Values:
        1%: -3.435
        5%: -2.864
        10%: -2.568
Stationary
```

In [ ]:
```
df_ecopetrol['Close_diff']['2022-3':].plot()
```

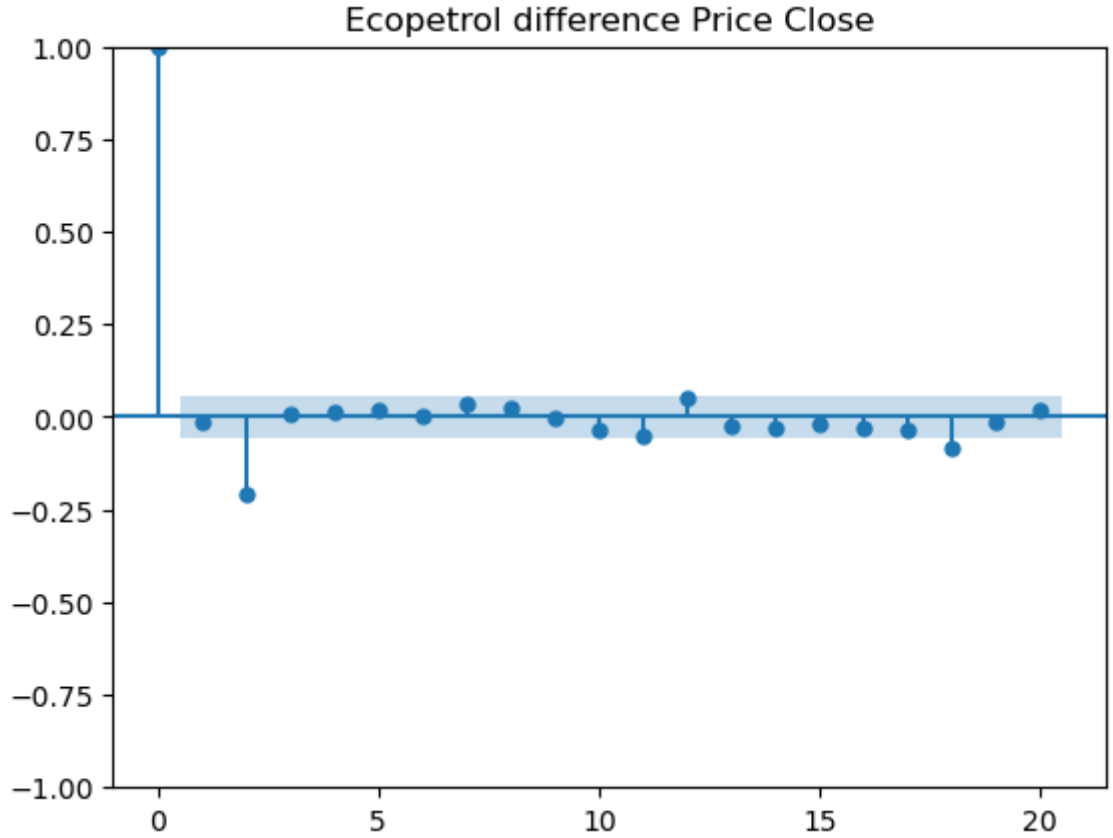
Out[ ]:
```
<AxesSubplot: xlabel='Date'>
```



In [ ]:
```
plot_acf(df_ecopetrol['Close_diff'], lags=20,title='Ecopetrol difference Price Close')
plt.show()
```



In [ ]:
```
plot_pacf(df_ecopetrol['Close_diff'], lags=20,title='Ecopetrol difference Price Close')
plt.show()
```



In [ ]:
```
df_ecopetrol['Close_diff']['2022':].describe()
```

Out[ ]:
```
count    327.000000
mean      -0.458716
std       97.195082
min     -558.528594
25%      -37.000000
50%        0.000000
75%       40.000000
max      647.528594
Name: Close_diff, dtype: float64
```

Serie Geometric Brownian Motion

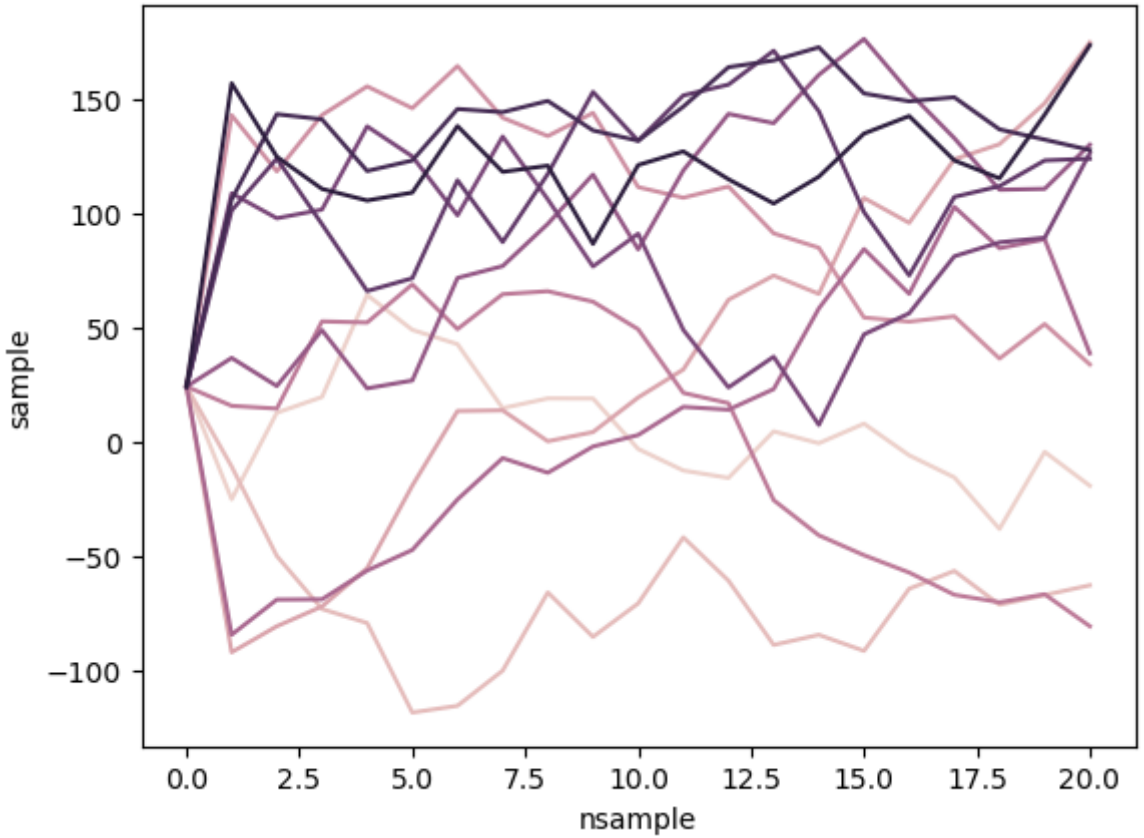
In [ ]:
```
from scipy.stats import norm
import pandas as pd

#Parametros del proceso
delta=-0.46
dt=97.2
#Punto inicio
x=0
xini=24
# Numero de trayectorias
ntra = 10
# NUmero de Iteraciones
n=20
# Se pueden guardar los caminos diferentes en un dataframe
res=[]
dfres=pd.DataFrame().assign(traj=0, nsample=0, sample=0)
```

In [ ]:
```
# Genera las trayectorias en un dataframe (dfres)
for i in range(ntra+1):
    for k in range(1,n+1):
         x= x+norm.rvs(scale=delta**2*dt)
         res.append(x)
         df2={'traj':i,'nsample':k,'sample':x}
         dfres=dfres.append(df2,ignore_index= True)
```

In [ ]:
```
# Genera los puntos iniciales
for i in range(ntra+1):
    df2 = {'traj':i,'nsample':0,'sample':xini}
    dfres= dfres.append(df2,ignore_index=True)
```

In [ ]:
```
# Plot de las muestras
import seaborn as sns
sns.lineplot(data=dfres, x='nsample',y='sample', legend=None,ci=None, hue='traj')
```

Out[ ]:
```
<AxesSubplot: xlabel='nsample', ylabel='sample'>
```



In [ ]:
```
# Se pueden obtener las trayectorias
pd.pivot_table(dfres, index=['traj'],columns=['nsample'])
```

Out[ ]:

nsample	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	...	11.0	12.0
traj													
0.0	24.0	-25.334082	12.542647	19.413445	64.093366	48.809642	42.544265	14.528709	18.809297	18.772612	...	-12.757714	-15.995093
1.0	24.0	-11.035214	-50.178928	-73.382765	-79.532412	-118.717510	-115.780706	-100.376600	-66.144212	-85.599441	...	-42.017854	-60.989596
2.0	24.0	-92.331498	-80.955245	-72.277292	-55.531429	-19.366874	13.286752	13.586234	0.031888	4.064507	...	31.467709	62.005411
3.0	24.0	142.779549	118.208604	142.865925	155.420342	145.859563	164.335796	141.682947	133.656411	143.798039	...	106.668059	111.575727
4.0	24.0	15.550859	14.352393	52.513010	52.034998	68.724665	49.144244	64.428490	65.725928	61.156098	...	21.211684	16.712921
5.0	24.0	-84.661605	-69.282520	-69.148392	-56.550126	-47.540413	-25.444230	-7.330824	-13.729803	-2.256956	...	15.106348	13.857329
6.0	24.0	36.519594	24.224784	48.700628	23.196156	26.672336	71.546501	76.724443	95.231920	116.845268	...	118.614299	143.373800
7.0	24.0	108.601016	97.680361	101.475878	137.905434	124.761895	98.938891	133.458053	105.946166	76.576289	...	48.788408	23.608536
8.0	24.0	101.088415	123.806184	95.093867	65.796239	71.411993	114.298643	87.270151	117.104963	152.974198	...	151.452579	156.197290
9.0	24.0	105.918165	143.255055	140.982054	118.367229	122.972198	145.520697	144.126636	149.050222	136.143139	...	146.565328	163.828069
10.0	24.0	156.773578	124.617158	110.533937	105.448227	108.922656	138.056518	117.987835	120.685361	86.466239	...	126.953861	114.753577

11 rows × 21 columns

modelo de Reversión a la Media

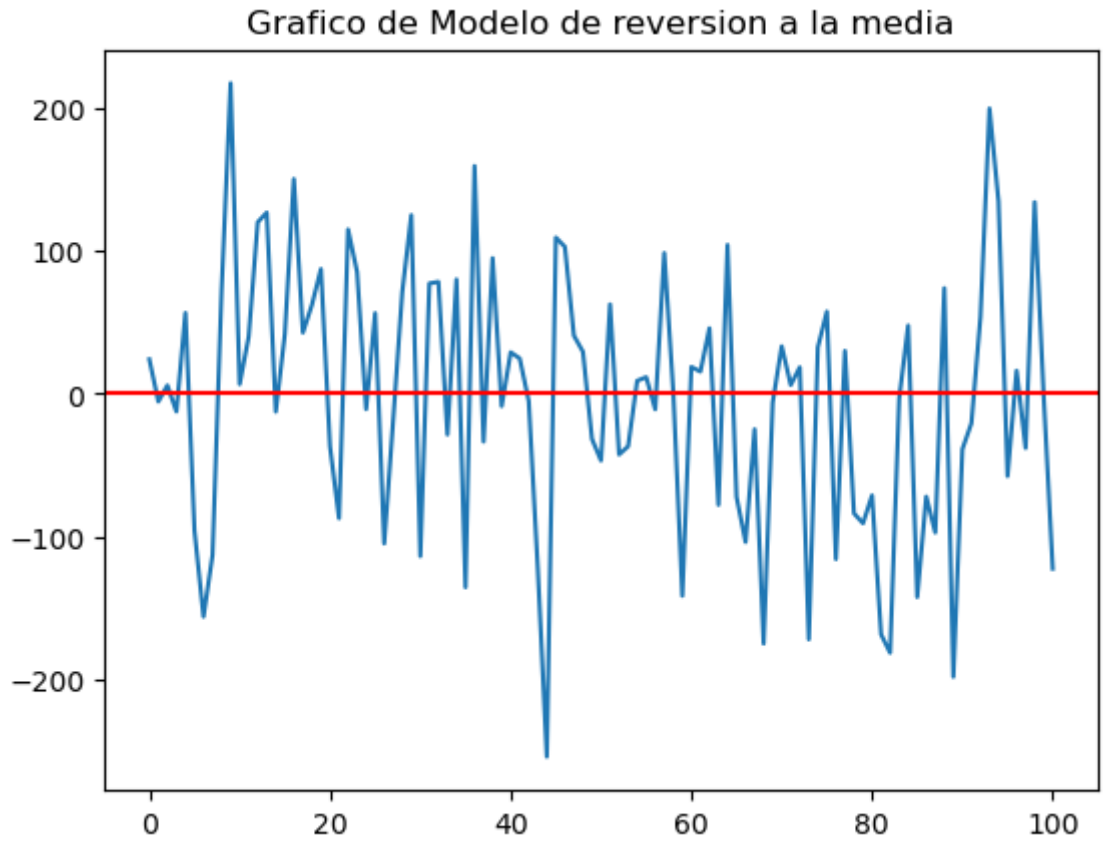
In [ ]:
```
df_ecopetrol['Close_diff'].describe()
```

Out[ ]:
```
count    1302.000000
mean       -0.157450
std        88.018973
min     -1368.528594
25%       -25.000000
50%         0.000000
75%        30.000000
max      1303.528594
Name: Close_diff, dtype: float64
```

In [ ]:
```python
def mod_vasicek(r0,K,theta,sigma,T=1.,N=10,seed=777):
    np.random.seed(seed)
    dt= T/float(N)
    rates=[r0]
    for i in range(N):
        dr = K*(theta-rates[-1])*dt + sigma*np.random.normal()
        rates.append(rates[-1]+dr)
    return range(N+1), rates
```

In [ ]:
```python
# Parametros para la serie de tiempo
r0 = 24    # The starting price - 24 porque es el último valor de la serie de la diferencia de precios de ecopetrol
K = 10     # speed of reversion parameter
theta = -0.15   # long-term mean interest rate level correction - media de la serie de la diferencia de precios de ecopetrol
sigma = 88  # instantaneous volatility - de la serie de la diferencia de precios de ecopetrol
T = 10      # end modelling time
N = 100    #
seed = np.random.randint(100,900)
# Llama a la funcion Vasicek
x, y = mod_vasicek(r0,K, theta,sigma,T,N,seed)
```

In [ ]:
```python
# Generacion de grafica del modelo de Reversion a la media
plt.plot(x,y)
plt.title('Grafico de Modelo de reversion a la media')
plt.axhline(theta, color='red')
plt.show()
```



Modelo autoregresivo y de moving average

Ejercicio de predicción de modelos

Visualización simple de Series de Tiempo

In [ ]:
```
# Prediccion de Precio de Ecopetrol
from statsmodels.graphics.tsaplots import plot_predict
from statsmodels.tsa.arima.model import ARIMA
```

Dado que la libreria statsmodels tuvo una actualización reciente cambiando el uso de los modelos ARMA, se usa el modelo ARIMA con d=0

In [ ]:
```
ecopetrol_price=ARIMA(df_ecopetrol['Close_diff'],order=(1,0,0))
res=ecopetrol_price.fit()
fig, ax = plt.subplots()
ax = df_ecopetrol['Close_diff'].loc['2023':].plot(ax=ax)
plot_predict(res,'2023-3','2023-4-7',ax=ax)
plt.show()
```

```
c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: 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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A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.
```
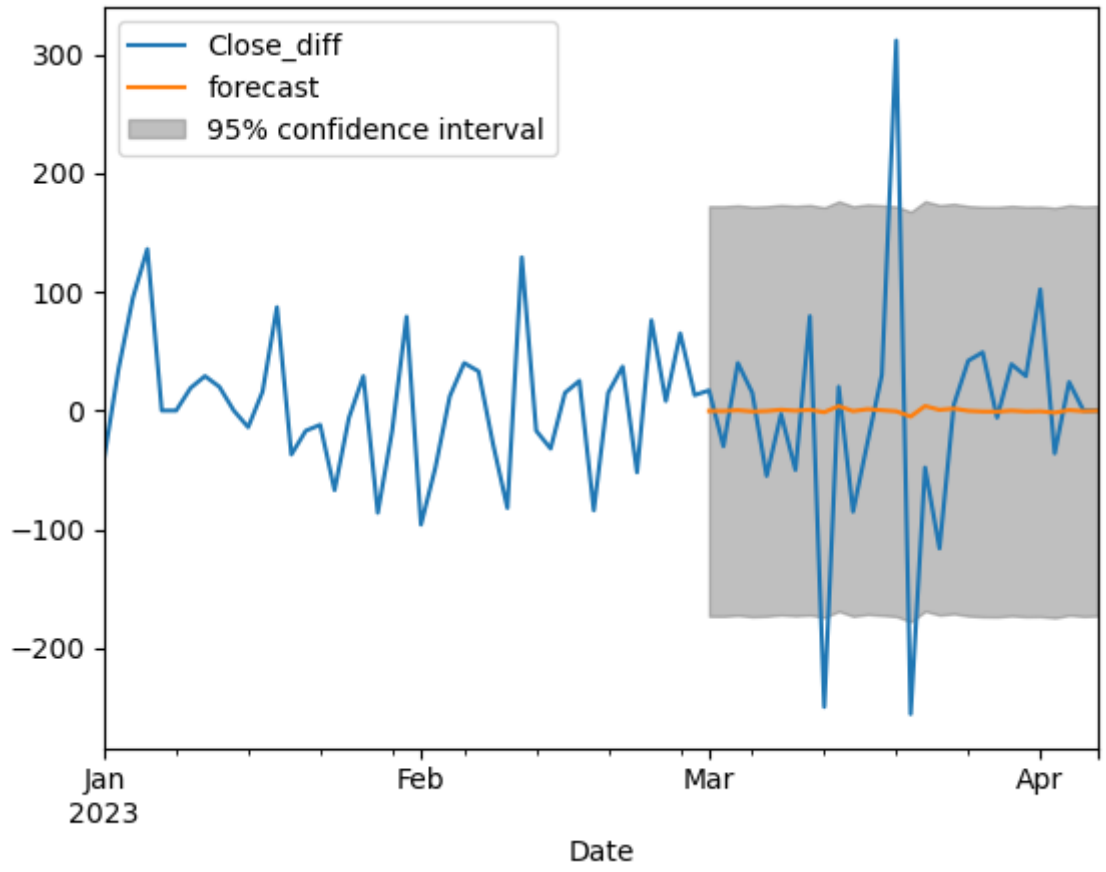



In [ ]:
```
print('μ={} θ={}'.format(res.params[0],res.params[1]))
print(res.summary())
```

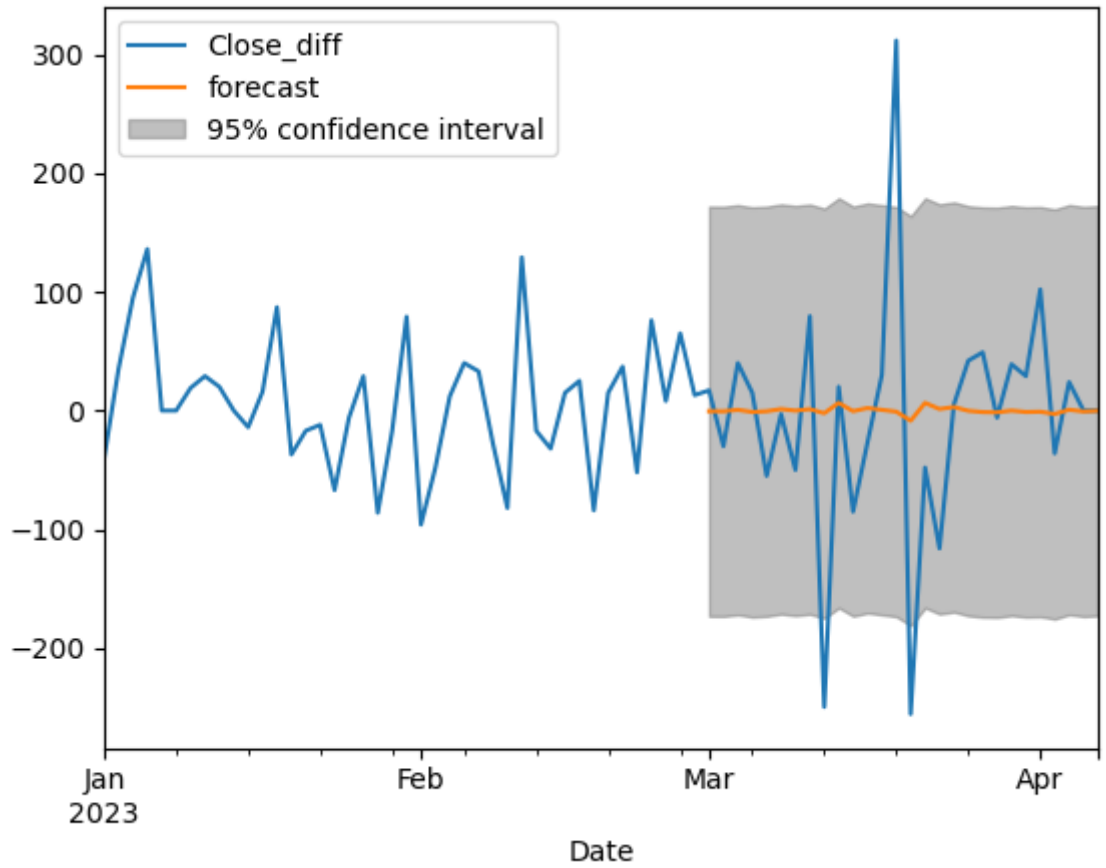
```
μ=-0.15745007794760113 θ=-0.015658942600525076
                               SARIMAX Results
==============================================================================
Dep. Variable:             Close_diff   No. Observations:                 1302
Model:                 ARIMA(1, 0, 0)   Log Likelihood               -7676.571
Date:                Tue, 18 Apr 2023   AIC                          15359.143
Time:                        01:52:26   BIC                          15374.657
Sample:                             0   HQIC                         15364.963
                                - 1302
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.1575      2.495     -0.063      0.950      -5.048       4.733
ar.L1         -0.0157      0.017     -0.942      0.346      -0.048       0.017
sigma2      7745.4334     45.832    168.996      0.000    7655.604    7835.262
===================================================================================
Ljung-Box (L1) (Q):                   0.01   Jarque-Bera (JB):            406915.38
Prob(Q):                              0.91   Prob(JB):                         0.00
Heteroskedasticity (H):               0.64   Skew:                            -0.60
Prob(H) (two-sided):                  0.00   Kurtosis:                        89.60
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

In [ ]:
```
rmse=math.sqrt(mean_squared_error(df_ecopetrol['Close_diff'].loc['2023-3':'2023-4-7'].values,res.predict(start='2023-3',end='202
print('RMSE={}'.format(rmse))
```

```
RMSE=100.12597823175223
```

In [ ]:
```
ecopetrol_price=ARIMA(df_ecopetrol['Close_diff'],order=(0,0,1))
res=ecopetrol_price.fit()
fig, ax = plt.subplots()
ax = df_ecopetrol['Close_diff'].loc['2023':].plot(ax=ax)
plot_predict(res,'2023-3','2023-4-7',ax=ax)
plt.show()
```

```
c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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



In [ ]:
```
print('μ={} θ={}'.format(res.params[0],res.params[1]))
print(res.summary())
```

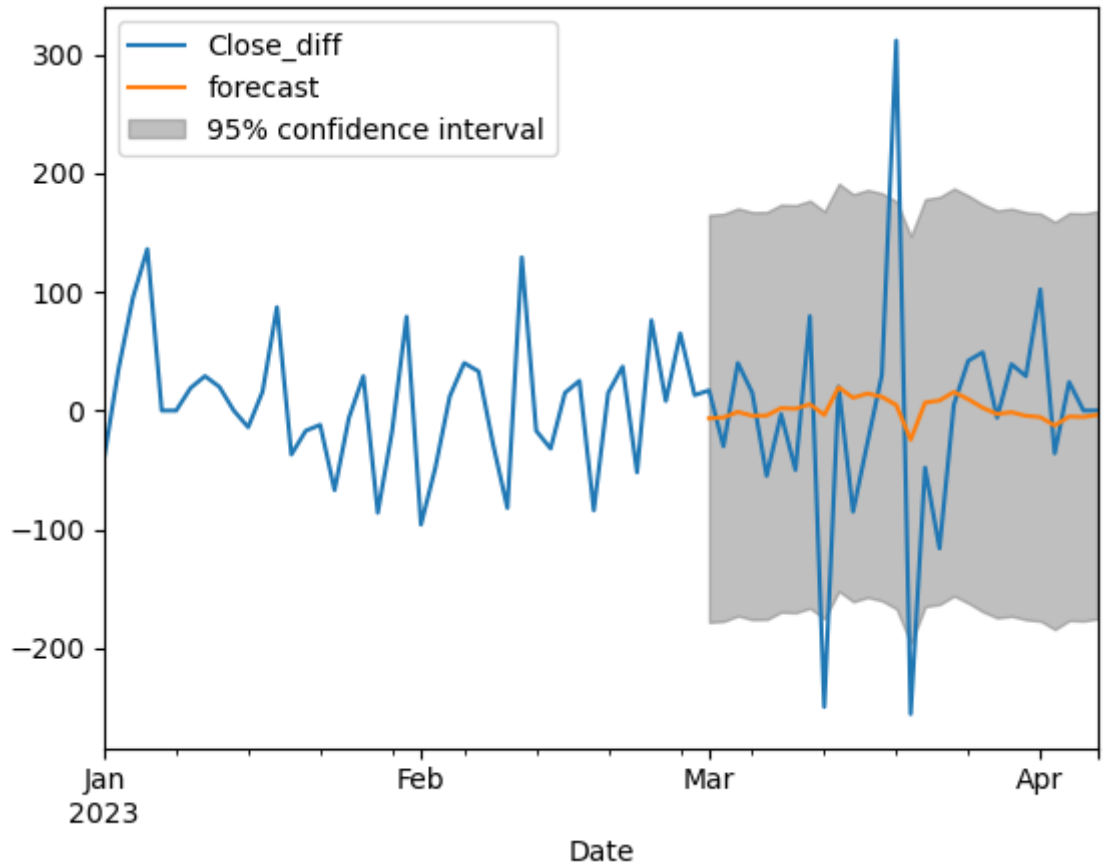
```
μ=-0.15745009090647907 θ=-0.026807072684995874
                               SARIMAX Results
==============================================================================
Dep. Variable:             Close_diff   No. Observations:                 1302
Model:                 ARIMA(0, 0, 1)   Log Likelihood               -7676.457
Date:                Tue, 18 Apr 2023   AIC                          15358.915
Time:                        01:54:22   BIC                          15374.430
Sample:                             0   HQIC                         15364.735
                                - 1302
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.1575      2.529     -0.062      0.950      -5.115       4.800
ma.L1         -0.0268      0.017     -1.606      0.108      -0.060       0.006
sigma2      7733.0594     45.746    169.045      0.000    7643.399    7822.719
===================================================================================
Ljung-Box (L1) (Q):                   0.04   Jarque-Bera (JB):            406667.18
Prob(Q):                              0.84   Prob(JB):                         0.00
Heteroskedasticity (H):               0.63   Skew:                            -0.62
Prob(H) (two-sided):                  0.00   Kurtosis:                        89.57
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

In [ ]:
```
rmse=math.sqrt(mean_squared_error(df_ecopetrol['Close_diff'].loc['2023-3':'2023-4-7'].values,res.predict(start='2023-3',end='202
print('RMSE={}'.format(rmse))
```

```
RMSE=99.83057802026822
```

In [ ]:
```
ecopetrol_price=ARIMA(df_ecopetrol['Close_diff'],order=(1,0,1))
res=ecopetrol_price.fit()
fig, ax = plt.subplots()
ax = df_ecopetrol['Close_diff'].loc['2023':].plot(ax=ax)
plot_predict(res,'2023-3','2023-4-7',ax=ax)
plt.show()
```

```
c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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



In [ ]:
```
print('μ={} θ={}'.format(res.params[0],res.params[1]))
print(res.summary())
```

```
μ=-0.17204115638053777 θ=0.5548174501481203
                               SARIMAX Results
==============================================================================
Dep. Variable:             Close_diff   No. Observations:                 1302
Model:                 ARIMA(1, 0, 1)   Log Likelihood               -7669.425
Date:                Tue, 18 Apr 2023   AIC                          15346.850
Time:                        01:55:37   BIC                          15367.537
Sample:                             0   HQIC                         15354.611
                                - 1302
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.1720      2.519     -0.068      0.946      -5.110       4.766
ar.L1          0.5548      0.115      4.825      0.000       0.329       0.780
ma.L1         -0.6432      0.105     -6.124      0.000      -0.849      -0.437
sigma2      7654.7803     69.473    110.183      0.000    7518.615    7790.946
===================================================================================
Ljung-Box (L1) (Q):                   4.26   Jarque-Bera (JB):            348706.32
Prob(Q):                              0.04   Prob(JB):                         0.00
Heteroskedasticity (H):               0.65   Skew:                            -1.15
Prob(H) (two-sided):                  0.00   Kurtosis:                        83.14
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

In [ ]:
```
rmse=math.sqrt(mean_squared_error(df_ecopetrol['Close_diff'].loc['2023-3':'2023-4-7'].values,res.predict(start='2023-3',end='202
print('RMSE={}'.format(rmse))
```

```
RMSE=98.30667623563063
```

In [ ]:
```
ecopetrol_price=ARIMA(df_ecopetrol['Close_diff'],order=(2,0,0))
res=ecopetrol_price.fit()
fig, ax = plt.subplots()
ax = df_ecopetrol['Close_diff'].loc['2023':].plot(ax=ax)
plot_predict(res,'2023-3','2023-4-7',ax=ax)
plt.show()
```

```
c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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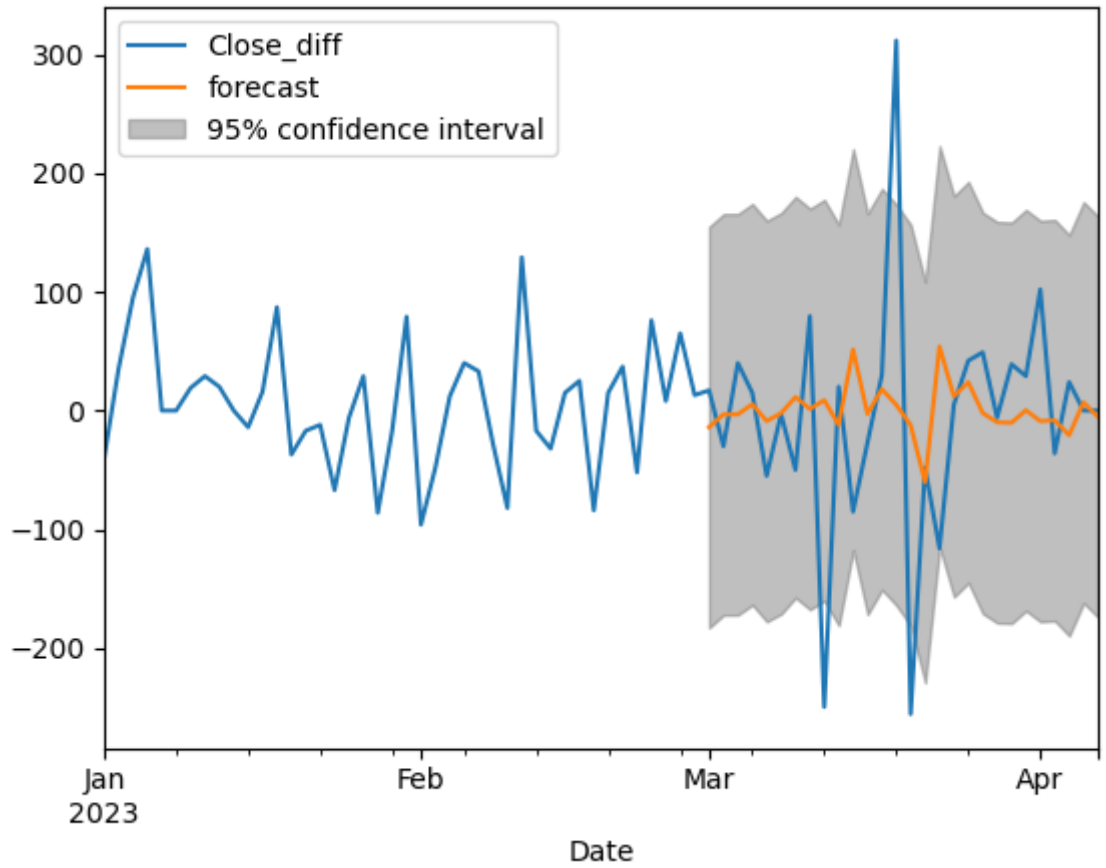



In [ ]:
```
print('μ={} θ={}'.format(res.params[0],res.params[1]))
print(res.summary())
```

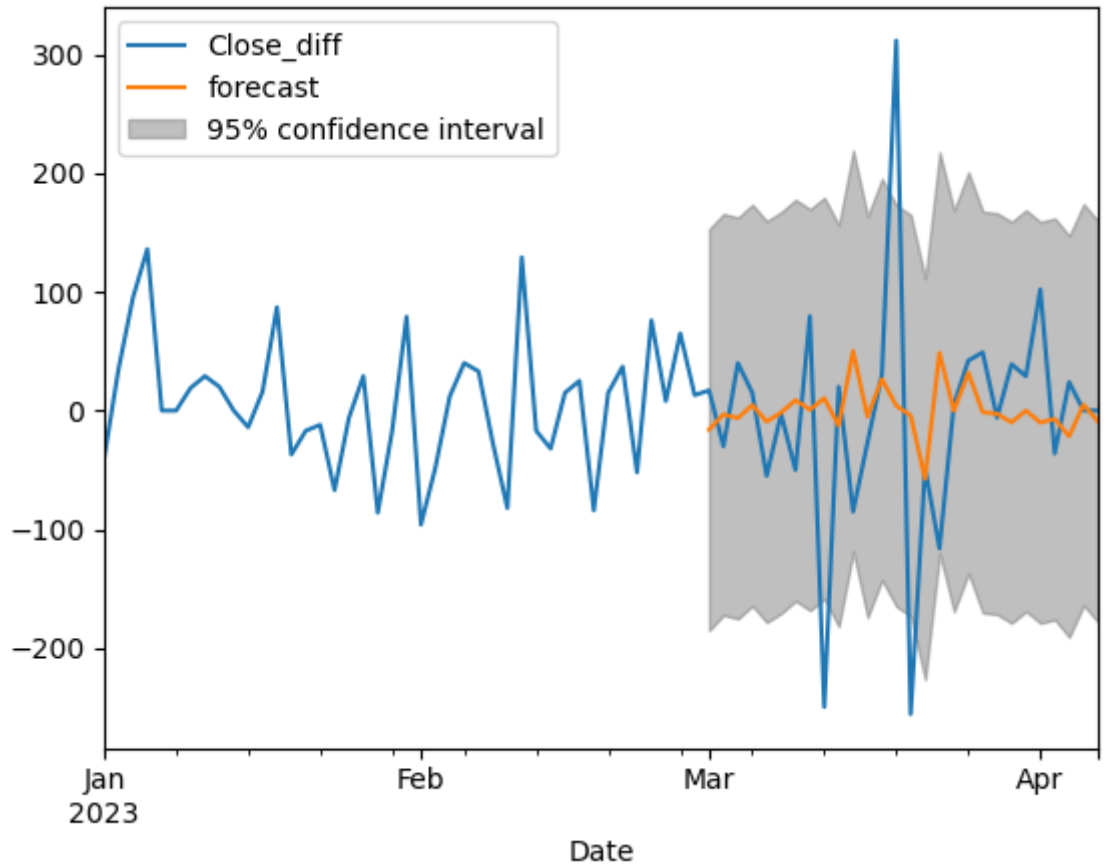
```
μ=-0.15745272483226536 θ=-0.018937760797467073
                               SARIMAX Results
==============================================================================
Dep. Variable:             Close_diff   No. Observations:                 1302
Model:                 ARIMA(2, 0, 0)   Log Likelihood               -7647.625
Date:                Tue, 18 Apr 2023   AIC                          15303.250
Time:                        02:01:29   BIC                          15323.936
Sample:                             0   HQIC                         15311.011
                                - 1302
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.1575      2.418     -0.065      0.948      -4.896       4.581
ar.L1         -0.0189      0.016     -1.154      0.248      -0.051       0.013
ar.L2         -0.2084      0.007    -30.509      0.000      -0.222      -0.195
sigma2      7412.2637     63.803    116.174      0.000    7287.212    7537.315
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):            250936.02
Prob(Q):                              0.95   Prob(JB):                         0.00
Heteroskedasticity (H):               0.74   Skew:                            -2.02
Prob(H) (two-sided):                  0.00   Kurtosis:                        70.89
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

In [ ]:
```
rmse=math.sqrt(mean_squared_error(df_ecopetrol['Close_diff'].loc['2023-3':'2023-4-7'].values,res.predict(start='2023-3',end='202
print('RMSE={}'.format(rmse))
```

```
RMSE=104.57478927097281
```

In [ ]:
```
ecopetrol_price=ARIMA(df_ecopetrol['Close_diff'],order=(0,0,2))
res=ecopetrol_price.fit()
fig, ax = plt.subplots()
ax = df_ecopetrol['Close_diff'].loc['2023':].plot(ax=ax)
plot_predict(res,'2023-3','2023-4-7',ax=ax)
plt.show()
```

```
c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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



In [ ]:
```
print('μ={} θ={}'.format(res.params[0],res.params[1]))
print(res.summary())
```

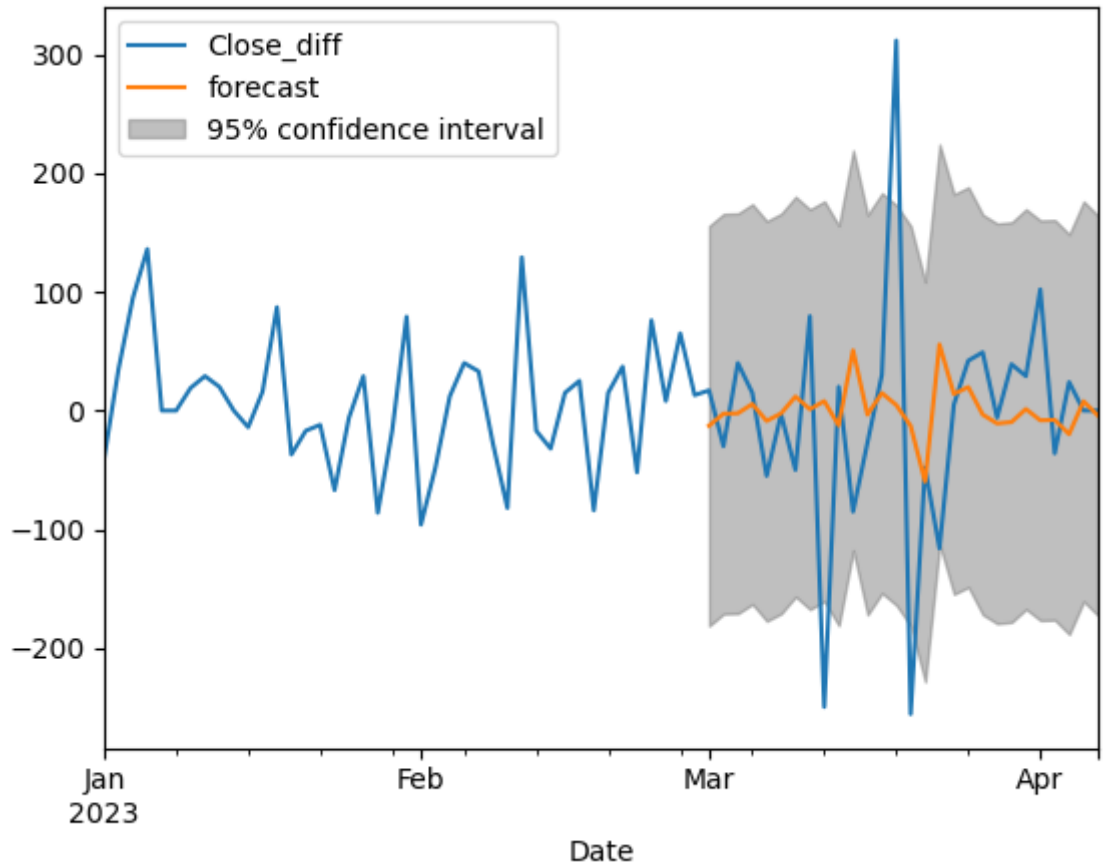
```
μ=-0.16716830443385736 θ=-0.010788786416524594
                               SARIMAX Results
==============================================================================
Dep. Variable:             Close_diff   No. Observations:                 1302
Model:                 ARIMA(0, 0, 2)   Log Likelihood               -7649.627
Date:                Tue, 18 Apr 2023   AIC                          15307.254
Time:                        02:02:45   BIC                          15327.941
Sample:                             0   HQIC                         15315.015
                                - 1302
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.1672      2.403     -0.070      0.945      -4.877       4.542
ma.L1         -0.0108      0.017     -0.641      0.521      -0.044       0.022
ma.L2         -0.1949      0.007    -27.634      0.000      -0.209      -0.181
sigma2      7425.5270     64.903    114.410      0.000    7298.319    7552.735
===================================================================================
Ljung-Box (L1) (Q):                   0.03   Jarque-Bera (JB):            257035.20
Prob(Q):                              0.86   Prob(JB):                         0.00
Heteroskedasticity (H):               0.74   Skew:                            -1.94
Prob(H) (two-sided):                  0.00   Kurtosis:                        71.72
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

In [ ]:
```
rmse=math.sqrt(mean_squared_error(df_ecopetrol['Close_diff'].loc['2023-3':'2023-4-7'].values,res.predict(start='2023-3',end='202
print('RMSE={}'.format(rmse))
```

```
RMSE=105.14053013295596
```

In [ ]:
```
ecopetrol_price=ARIMA(df_ecopetrol['Close_diff'],order=(2,0,2))
res=ecopetrol_price.fit()
fig, ax = plt.subplots()
ax = df_ecopetrol['Close_diff'].loc['2023':].plot(ax=ax)
plot_predict(res,'2023-3','2023-4-7',ax=ax)
plt.show()
```

```
c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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

c:\Users\oscah\anaconda3\envs\analyticscourse\lib\site-packages\statsmodels\tsa\base\tsa_model.py:471: ValueWarning:

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



In [ ]:
```
print('μ={} θ={}'.format(res.params[0],res.params[1]))
print(res.summary())
```

```
μ=-0.15747144488505752 θ=-0.044624490212892255
                               SARIMAX Results
==============================================================================
Dep. Variable:             Close_diff   No. Observations:                 1302
Model:                 ARIMA(2, 0, 2)   Log Likelihood               -7647.481
Date:                Tue, 18 Apr 2023   AIC                          15306.962
Time:                        01:59:50   BIC                          15337.992
Sample:                             0   HQIC                         15318.604
                                - 1302
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.1575      2.480     -0.064      0.949      -5.018       4.703
ar.L1         -0.0446      0.116     -0.385      0.700      -0.272       0.182
ar.L2         -0.2679      0.116     -2.318      0.020      -0.494      -0.041
ma.L1          0.0269      0.119      0.227      0.820      -0.206       0.259
ma.L2          0.0617      0.118      0.522      0.602      -0.170       0.294
sigma2      7375.1721     65.405    112.761      0.000    7246.980    7503.364
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):            252278.43
Prob(Q):                              0.99   Prob(JB):                         0.00
Heteroskedasticity (H):               0.74   Skew:                            -2.00
Prob(H) (two-sided):                  0.00   Kurtosis:                        71.08
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

In [ ]:
```
rmse=math.sqrt(mean_squared_error(df_ecopetrol['Close_diff'].loc['2023-3':'2023-4-7'].values,res.predict(start='2023-3',end='202
print('RMSE={}'.format(rmse))
```

```
RMSE=104.56294393695131
```

Insights:

- De todos los modelos analizados, el que tuvo un rmse más bajo fue el arma(1,1). Sin embargo, el valor de la constante no es estadísticamente significativo.