In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
import scipy
from datetime import timedelta
from pylab import rcParams
import statsmodels.api as sm
from statsmodels.tsa.stattools import adfuller
from statsmodels.graphics import tsaplots

from statsmodels.tsa.api import ExponentialSmoothing, SimpleExpSmoothing, Ho
#from fbprophet import Prophet
!pip install pmdarima
from pmdarima import auto_arima

from statsmodels.tsa.tsatools import lagmat
from statsmodels.tsa.statespace.sarimax import SARIMAX

from sklearn.linear_model import LinearRegression, RidgeCV
from sklearn.ensemble import RandomForestRegressor, IsolationForest
from sklearn.metrics import r2_score
import re
```

```
Requirement already satisfied: pmdarima in ./anaconda3/lib/python3.10/site-p
ackages (2.0.4)
Requirement already satisfied: pandas>=0.19 in ./anaconda3/lib/python3.10/si
te-packages (from pmdarima) (1.5.3)
Requirement already satisfied: scikit-learn>=0.22 in ./anaconda3/lib/python
3.10/site-packages (from pmdarima) (1.2.1)
Requirement already satisfied: numpy>=1.21.2 in ./anaconda3/lib/python3.10/s
ite-packages (from pmdarima) (1.23.5)
Requirement already satisfied: Cython!=0.29.18,!=0.29.31,>=0.29 in ./anacond
a3/lib/python3.10/site-packages (from pmdarima) (3.0.12)
Requirement already satisfied: scipy>=1.3.2 in ./anaconda3/lib/python3.10/si
te-packages (from pmdarima) (1.10.0)
Requirement already satisfied: setuptools!=50.0.0,>=38.6.0 in ./anaconda3/li
b/python3.10/site-packages (from pmdarima) (65.6.3)
Requirement already satisfied: statsmodels>=0.13.2 in ./anaconda3/lib/python
3.10/site-packages (from pmdarima) (0.13.5)
Requirement already satisfied: joblib>=0.11 in ./anaconda3/lib/python3.10/si
te-packages (from pmdarima) (1.1.1)
Requirement already satisfied: urllib3 in ./anaconda3/lib/python3.10/site-pa
ckages (from pmdarima) (1.26.14)
Requirement already satisfied: packaging>=17.1 in ./anaconda3/lib/python3.1
0/site-packages (from pmdarima) (22.0)
Requirement already satisfied: python-dateutil>=2.8.1 in ./anaconda3/lib/pyt
hon3.10/site-packages (from pandas>=0.19->pmdarima) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in ./anaconda3/lib/python3.10/si
te-packages (from pandas>=0.19->pmdarima) (2022.7)
Requirement already satisfied: threadpoolctl>=2.0.0 in ./anaconda3/lib/pytho
n3.10/site-packages (from scikit-learn>=0.22->pmdarima) (2.2.0)
Requirement already satisfied: patsy>=0.5.2 in ./anaconda3/lib/python3.10/si
te-packages (from statsmodels>=0.13.2->pmdarima) (0.5.3)
Requirement already satisfied: six in ./anaconda3/lib/python3.10/site-packag
es (from patsy>=0.5.2->statsmodels>=0.13.2->pmdarima) (1.16.0)
```

In [2]:
```
df_Ad = pd.read_csv('/Users/Ramv/Downloads/AdEase.csv')
df_Ad
```

Out[2]:

	Page	2015-07-01	2015-07-02	2015-07-03	2015-07-04	2015-07-05
0	2NE1_zh.wikipedia.org_all-access_spider	18.0	11.0	5.0	13.0	14.0
1	2PM_zh.wikipedia.org_all-access_spider	11.0	14.0	15.0	18.0	11.0
2	3C_zh.wikipedia.org_all-access_spider	1.0	0.0	1.0	1.0	0.0
3	4minute_zh.wikipedia.org_all-access_spider	35.0	13.0	10.0	94.0	4.0
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	NaN	NaN	NaN	NaN	NaN
...	...	...	...	...	...	...
145058	Underworld_(serie_de_películas)_es.wikipedia.o...	NaN	NaN	NaN	NaN	NaN
145059	Resident_Evil:_Capítulo_Final_es.wikipedia.org...	NaN	NaN	NaN	NaN	NaN
145060	Enamorándome_de_Ramón_es.wikipedia.org_all-acc...	NaN	NaN	NaN	NaN	NaN
145061	Hasta_el_último_hombre_es.wikipedia.org_all-ac...	NaN	NaN	NaN	NaN	NaN
145062	Francisco_el_matemático_(serie_de_televisión_d...	NaN	NaN	NaN	NaN	NaN

145063 rows × 551 columns

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

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 145063 entries, 0 to 145062
Columns: 551 entries, Page to 2016-12-31
dtypes: float64(550), object(1)
memory usage: 609.8+ MB
```

In [4]:
```
df_Ad.isnull().sum()
```

Out[4]:
```
Page            0
2015-07-01    20740
2015-07-02    20816
2015-07-03    20544
2015-07-04    20654
              ...
2016-12-27     3701
2016-12-28     3822
2016-12-29     3826
2016-12-30     3635
2016-12-31     3465
Length: 551, dtype: int64
```

In [5]:
```
df_Ad = df_Ad.fillna(0)
```

In [6]:
```
tr_data = pd.melt(df_Ad, id_vars=["Page"], var_name='Date', value_name='Visi
tr_data.head(10)
```

Out[6]:

	Page	Date	Visits
0	2NE1_zh.wikipedia.org_all-access_spider	2015-07-01	18.0
1	2PM_zh.wikipedia.org_all-access_spider	2015-07-01	11.0
2	3C_zh.wikipedia.org_all-access_spider	2015-07-01	1.0
3	4minute_zh.wikipedia.org_all-access_spider	2015-07-01	35.0
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	2015-07-01	0.0
5	5566_zh.wikipedia.org_all-access_spider	2015-07-01	12.0
6	91Days_zh.wikipedia.org_all-access_spider	2015-07-01	0.0
7	A'N'D_zh.wikipedia.org_all-access_spider	2015-07-01	118.0
8	AKB48_zh.wikipedia.org_all-access_spider	2015-07-01	5.0
9	ASCII_zh.wikipedia.org_all-access_spider	2015-07-01	6.0

In [7]:
```
tr_data['Date'] = pd.DatetimeIndex(tr_data['Date'])
tr_data
```

Out[7]:

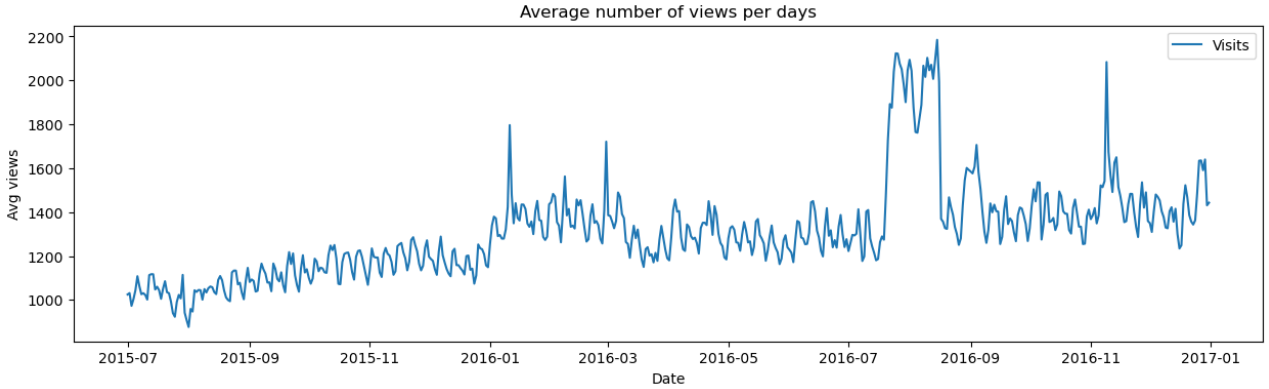
	Page	Date	Visits
0	2NE1_zh.wikipedia.org_all-access_spider	2015-07-01	18.0
1	2PM_zh.wikipedia.org_all-access_spider	2015-07-01	11.0
2	3C_zh.wikipedia.org_all-access_spider	2015-07-01	1.0
3	4minute_zh.wikipedia.org_all-access_spider	2015-07-01	35.0
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	2015-07-01	0.0
...	...	...	...
79784645	Underworld_(serie_de_películas)_es.wikipedia.o...	2016-12-31	10.0
79784646	Resident_Evil:_Capítulo_Final_es.wikipedia.org...	2016-12-31	0.0
79784647	Enamorándome_de_Ramón_es.wikipedia.org_all-acc...	2016-12-31	0.0
79784648	Hasta_el_último_hombre_es.wikipedia.org_all-ac...	2016-12-31	0.0
79784649	Francisco_el_matemático_(serie_de_televisión_d...	2016-12-31	0.0

79784650 rows × 3 columns

Data Visualisation to check the nature of the data

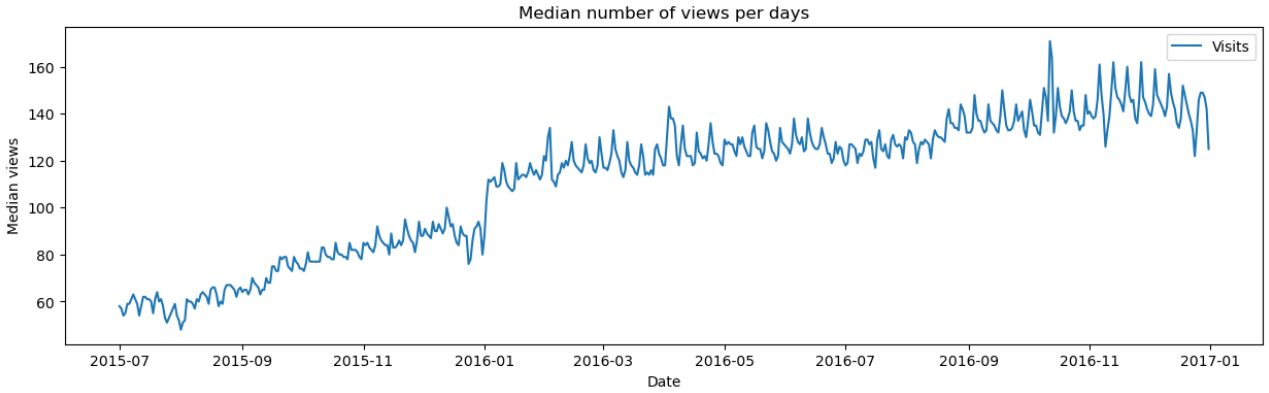
No. of views per day using Mean

In [8]:
```
tmp = tr_data.groupby('Date')['Visits'].mean()
plt.figure(figsize=(15,4))
plt.xlabel('Date')
plt.ylabel('Avg views')
plt.title('Average number of views per days')
plt.plot(tmp,label='Visits')
plt.legend()
plt.show()
```



No. of views per day using Median

In [9]:
```
tmp1 = tr_data.groupby('Date')['Visits'].median()
plt.figure(figsize=(15,4))
plt.xlabel('Date')
plt.ylabel('Median views')
plt.title('Median number of views per days')
plt.plot(tmp1,label='Visits')
plt.legend()
plt.show()
```



In [10]:
```
tr_data
```

Out[10]:

	Page	Date	Visits
0	2NE1_zh.wikipedia.org_all-access_spider	2015-07-01	18.0
1	2PM_zh.wikipedia.org_all-access_spider	2015-07-01	11.0
2	3C_zh.wikipedia.org_all-access_spider	2015-07-01	1.0
3	4minute_zh.wikipedia.org_all-access_spider	2015-07-01	35.0
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	2015-07-01	0.0
...	...	...	...
79784645	Underworld_(serie_de_películas)_es.wikipedia.o...	2016-12-31	10.0
79784646	Resident_Evil:_Capítulo_Final_es.wikipedia.org...	2016-12-31	0.0
79784647	Enamorándome_de_Ramón_es.wikipedia.org_all-acc...	2016-12-31	0.0
79784648	Hasta_el_último_hombre_es.wikipedia.org_all-ac...	2016-12-31	0.0
79784649	Francisco_el_matemático_(serie_de_televisión_d...	2016-12-31	0.0

79784650 rows × 3 columns

In [ ]:

In [11]:
```
tr_data['year']=tr_data.Date.dt.year
tr_data['month']=tr_data.Date.dt.month
tr_data['day']=tr_data.Date.dt.day
```

In [12]:
```
tr_data['month_num'] = tr_data['month']
tr_data['month'].replace('1','1 - January',inplace=True)
tr_data['month'].replace('2','2 - February',inplace=True)
tr_data['month'].replace('3','3 - March',inplace=True)
tr_data['month'].replace('4','4 - April',inplace=True)
tr_data['month'].replace('5','5 - May',inplace=True)
tr_data['month'].replace('6','6 - June',inplace=True)
tr_data['month'].replace('7','7 - July',inplace=True)
tr_data['month'].replace('8','8 - August',inplace=True)
tr_data['month'].replace('9','9 - September',inplace=True)
tr_data['month'].replace('10','10 - October',inplace=True)
tr_data['month'].replace('11','11 - November',inplace=True)
tr_data['month'].replace('12','12 - December',inplace=True)
```

In [13]:
```
tr_data
```

Out[13]:

	Page	Date	Visits	year	month	day
0	2NE1_zh.wikipedia.org_all-access_spider	2015-07-01	18.0	2015	7	1
1	2PM_zh.wikipedia.org_all-access_spider	2015-07-01	11.0	2015	7	1
2	3C_zh.wikipedia.org_all-access_spider	2015-07-01	1.0	2015	7	1
3	4minute_zh.wikipedia.org_all-access_spider	2015-07-01	35.0	2015	7	1
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	2015-07-01	0.0	2015	7	1
...	...	...	...	...	...	...
79784645	Underworld_(serie_de_películas)_es.wikipedia.o...	2016-12-31	10.0	2016	12	31
79784646	Resident_Evil:_Capítulo_Final_es.wikipedia.org...	2016-12-31	0.0	2016	12	31
79784647	Enamorándome_de_Ramón_es.wikipedia.org_all-acc...	2016-12-31	0.0	2016	12	31
79784648	Hasta_el_último_hombre_es.wikipedia.org_all-ac...	2016-12-31	0.0	2016	12	31
79784649	Francisco_el_matemático_(serie_de_televisión_d...	2016-12-31	0.0	2016	12	31

79784650 rows × 7 columns

In [14]:
```
tr_data['weekday'] = tr_data['Date'].apply(lambda x: x.weekday())
```

In [15]:
```
tr_data['weekday#'] = tr_data['weekday']
tr_data['weekday'].replace(0,'01 - Monday',inplace=True)
tr_data['weekday'].replace(1,'02 - Tuesday',inplace=True)
tr_data['weekday'].replace(2,'03 - Wednesday',inplace=True)
tr_data['weekday'].replace(3,'04 - Thursday',inplace=True)
tr_data['weekday'].replace(4,'05 - Friday',inplace=True)
tr_data['weekday'].replace(5,'06 - Saturday',inplace=True)
tr_data['weekday'].replace(6,'07 - Sunday',inplace=True)
```

In [16]:
```
tr_data
```

Out[16]:

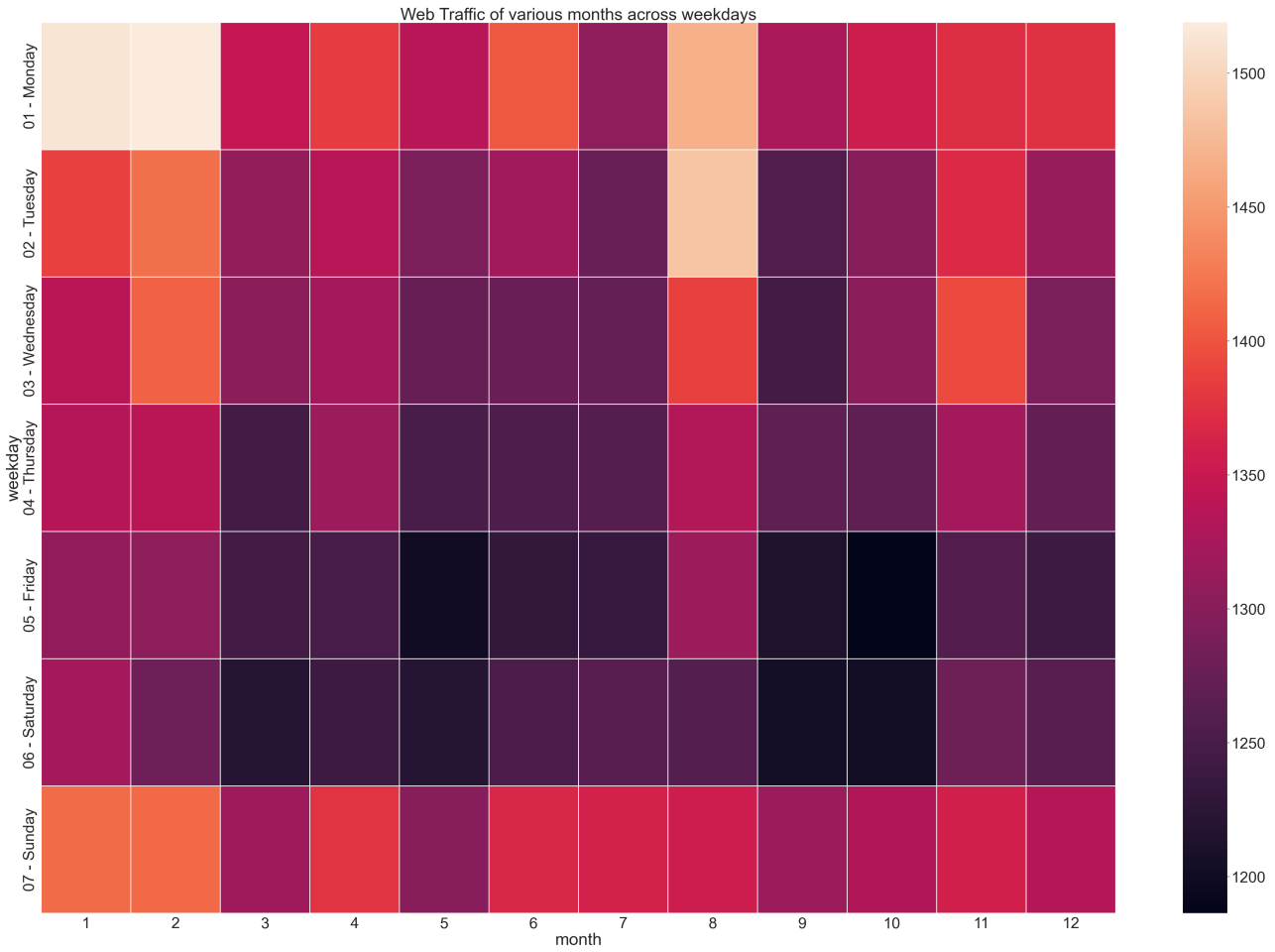
	Page	Date	Visits	year	month	day
0	2NE1_zh.wikipedia.org_all-access_spider	2015-07-01	18.0	2015	7	1
1	2PM_zh.wikipedia.org_all-access_spider	2015-07-01	11.0	2015	7	1
2	3C_zh.wikipedia.org_all-access_spider	2015-07-01	1.0	2015	7	1
3	4minute_zh.wikipedia.org_all-access_spider	2015-07-01	35.0	2015	7	1
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	2015-07-01	0.0	2015	7	1
...	...	...	...	...	...	...
79784645	Underworld_(serie_de_películas)_es.wikipedia.o...	2016-12-31	10.0	2016	12	31
79784646	Resident_Evil:_Capítulo_Final_es.wikipedia.org...	2016-12-31	0.0	2016	12	31
79784647	Enamorándome_de_Ramón_es.wikipedia.org_all-acc...	2016-12-31	0.0	2016	12	31
79784648	Hasta_el_último_hombre_es.wikipedia.org_all-ac...	2016-12-31	0.0	2016	12	31
79784649	Francisco_el_matemático_(serie_de_televisión_d...	2016-12-31	0.0	2016	12	31

79784650 rows × 9 columns

In [17]:
```
tr_group = tr_data.groupby(["month", "weekday"])['Visits'].mean().reset_inde
tr_group = tr_group.pivot('weekday','month','Visits')
tr_group.sort_index(inplace=True)
```

```
/var/folders/fx/1km2ndm10xxcmn5xy9fsdksm0000gn/T/ipykernel_72560/63364917.p
y:2: FutureWarning: In a future version of pandas all arguments of DataFram
e.pivot will be keyword-only.
  tr_group = tr_group.pivot('weekday','month','Visits')
```

In [18]:
```
sns.set(font_scale=3.5)
f, ax = plt.subplots(figsize=(60, 40))
sns.heatmap(tr_group, annot=False, ax=ax, fmt="d", linewidths=2)
plt.title('Web Traffic of various months across weekdays')
plt.show()
```



In [19]:
```
cols_to_drop = ['year','month','day','month_num','weekday','weekday','weekda
tr_data.drop(cols_to_drop,axis=1,inplace=True)
tr_data
```

Out[19]:

	Page	Date	Visits
0	2NE1_zh.wikipedia.org_all-access_spider	2015-07-01	18.0
1	2PM_zh.wikipedia.org_all-access_spider	2015-07-01	11.0
2	3C_zh.wikipedia.org_all-access_spider	2015-07-01	1.0
3	4minute_zh.wikipedia.org_all-access_spider	2015-07-01	35.0
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	2015-07-01	0.0
...	...	...	...
79784645	Underworld_(serie_de_películas)_es.wikipedia.o...	2016-12-31	10.0
79784646	Resident_Evil:_Capítulo_Final_es.wikipedia.org...	2016-12-31	0.0
79784647	Enamorándome_de_Ramón_es.wikipedia.org_all-acc...	2016-12-31	0.0
79784648	Hasta_el_último_hombre_es.wikipedia.org_all-ac...	2016-12-31	0.0
79784649	Francisco_el_matemático_(serie_de_televisión_d...	2016-12-31	0.0

79784650 rows × 3 columns

Top 5 Pages

In [20]:
```
top_pages = tr_data.groupby('Page')['Visits'].sum().reset_index()
top_pages_list = top_pages.nlargest(5,'Visits')['Page'].tolist()
```

In [21]:
```
top5_pages_df = tr_data[tr_data['Page'].isin(top_pages_list)]
top5_pages_df
```

Out[21]:

	Page	Date	Visits
9774	Main_Page_en.wikipedia.org_desktop_all-agents	2015-07-01	11952559.0
38573	Main_Page_en.wikipedia.org_all-access_all-agents	2015-07-01	20381245.0
39180	Special:Search_en.wikipedia.org_all-access_all...	2015-07-01	2034850.0
74114	Main_Page_en.wikipedia.org_mobile-web_all-agents	2015-07-01	8039732.0
139119	Wikipedia:Hauptseite_de.wikipedia.org_all-acce...	2015-07-01	2983623.0
...	...	...	...
79649361	Main_Page_en.wikipedia.org_desktop_all-agents	2016-12-31	19591761.0
79678160	Main_Page_en.wikipedia.org_all-access_all-agents	2016-12-31	26149541.0
79678767	Special:Search_en.wikipedia.org_all-access_all...	2016-12-31	1576945.0
79713701	Main_Page_en.wikipedia.org_mobile-web_all-agents	2016-12-31	3939419.0
79778706	Wikipedia:Hauptseite_de.wikipedia.org_all-acce...	2016-12-31	3286214.0

2750 rows × 3 columns

Language based EDA

In [22]:
```
def detect_language(page):
    text = page.split('.wikipedia')
    if re.search('[a-z][a-z]',text[0][-2:]):
        return text[0][-2:]
    else:
        return 'none'
```

In [23]:
```
temp1 = tr_data
temp1['Wikipedia_page'] = temp1.Page.apply(detect_language)
```

In [24]:
```
temp1.head()
```

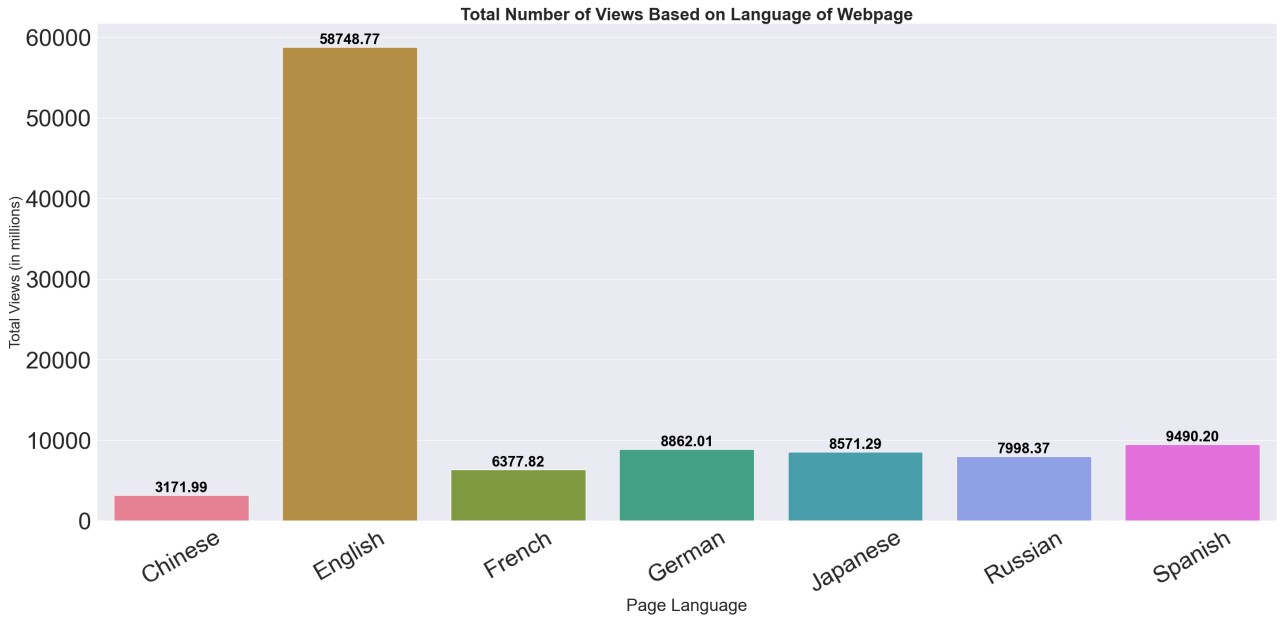
Out[24]:

	Page	Date	Visits	Wikipedia_page
0	2NE1_zh.wikipedia.org_all-access_spider	2015-07-01	18.0	zh
1	2PM_zh.wikipedia.org_all-access_spider	2015-07-01	11.0	zh
2	3C_zh.wikipedia.org_all-access_spider	2015-07-01	1.0	zh
3	4minute_zh.wikipedia.org_all-access_spider	2015-07-01	35.0	zh
4	52_Hz_I_Love_You_zh.wikipedia.org_all-access_s...	2015-07-01	0.0	zh

In [25]:
```
def lang_code(code):
    if code == 'zh':
        return 'Chinese'
    elif code == 'fr':
        return 'French'
    elif code == 'en':
        return 'English'
    elif code == 'ru':
        return 'Russian'
    elif code == 'de':
        return 'German'
    elif code == 'ja':
        return 'Japanese'
    elif code == 'es':
        return 'Spanish'
    else:
        return 'None'
```

In [26]:
```
temp1['Page_language'] = temp1.Wikipedia_page.apply(lang_code)
```

In [27]:
```
# Aggregate visits by language, excluding 'None'
lang_df = temp1.groupby('Page_language')['Visits'].sum().reset_index()
lang_df = lang_df[lang_df['Page_language'] != 'None']
lang_df['Visits'] = round(lang_df['Visits'] / 1000000, 2)  # rounded to 2 de

# Set a vibrant color palette
colors = sns.color_palette("husl", len(lang_df))

# Create the plot
fig, ax = plt.subplots(figsize=(30, 15))
bar_graph = sns.barplot(data=lang_df, x='Page_language', y='Visits', ax=ax,

# Add labels and title
ax.set_ylabel('Total Views (in millions)', fontsize=24)
ax.set_xlabel('Page Language', fontsize=28)
ax.set_title('Total Number of Views Based on Language of Webpage', fontsize=
ax.set_xticklabels(ax.get_xticklabels(), rotation=30)

# Annotate bars with values
for p in ax.patches:
    height = p.get_height()
    ax.annotate(f'{height:.2f}',
                (p.get_x() + p.get_width() / 2., height + 0.5),
                ha='center', va='bottom', fontsize=24, fontweight='bold', cc

# Remove top and right borders for a cleaner look
sns.despine()

plt.tight_layout()
plt.show()
```



In [28]:
```
top_pages = tr_data.groupby('Page')['Visits'].sum().reset_index()
top_pages_list = top_pages.nlargest(5,'Visits')['Page'].tolist()
print(top_pages_list)
```

```
['Main_Page_en.wikipedia.org_all-access_all-agents', 'Main_Page_en.wikipedi
a.org_desktop_all-agents', 'Main_Page_en.wikipedia.org_mobile-web_all-agent
s', 'Wikipedia:Hauptseite_de.wikipedia.org_all-access_all-agents', 'Special:
Search_en.wikipedia.org_all-access_all-agents']
```

In [29]:
```
top5_pages_df = tr_data[tr_data['Page'].isin(top_pages_list)]
top5_pages_df
```

Out[29]:

	Page	Date	Visits	Wikipedia_page	Page
9774	Main_Page_en.wikipedia.org_desktop_all-agents	2015-07-01	11952559.0	en	
38573	Main_Page_en.wikipedia.org_all-access_all-agents	2015-07-01	20381245.0	en	
39180	Special:Search_en.wikipedia.org_all-access_all...	2015-07-01	2034850.0	en	
74114	Main_Page_en.wikipedia.org_mobile-web_all-agents	2015-07-01	8039732.0	en	
139119	Wikipedia:Hauptseite_de.wikipedia.org_all-acce...	2015-07-01	2983623.0	de	
...	...	...	...	...	
79649361	Main_Page_en.wikipedia.org_desktop_all-agents	2016-12-31	19591761.0	en	
79678160	Main_Page_en.wikipedia.org_all-access_all-agents	2016-12-31	26149541.0	en	
79678767	Special:Search_en.wikipedia.org_all-access_all...	2016-12-31	1576945.0	en	
79713701	Main_Page_en.wikipedia.org_mobile-web_all-agents	2016-12-31	3939419.0	en	
79778706	Wikipedia:Hauptseite_de.wikipedia.org_all-acce...	2016-12-31	3286214.0	de	

2750 rows × 5 columns

In [30]:

```
# Time-series of page with maximum views
top_page_df = tr_data[tr_data.Page == top_pages_list[0]]
#top_page_df = top_page_df['Visits']
top_page_df['Visits'] = top_page_df['Visits'].div(1000000).round(2)
top_page_df.drop(['Page','Wikipedia_page','Page_language'],axis=1,inplace=Tr
top_page_df.head()
```

```
/var/folders/fx/1km2ndm10xxcmn5xy9fsdksm0000gn/T/ipykernel_72560/3371127952.
py:4: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/
stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  top_page_df['Visits'] = top_page_df['Visits'].div(1000000).round(2)
/var/folders/fx/1km2ndm10xxcmn5xy9fsdksm0000gn/T/ipykernel_72560/3371127952.
py:5: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/
stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  top_page_df.drop(['Page','Wikipedia_page','Page_language'],axis=1,inplace=
True)
```

Out[30]:

	Date	Visits
38573	2015-07-01	20.38
183636	2015-07-02	20.75
328699	2015-07-03	19.57
473762	2015-07-04	20.44
618825	2015-07-05	20.77

In [31]:
```
top_page_df.reset_index(inplace=True)

top_page_df.head()
```

Out[31]:

	index	Date	Visits
0	38573	2015-07-01	20.38
1	183636	2015-07-02	20.75
2	328699	2015-07-03	19.57
3	473762	2015-07-04	20.44
4	618825	2015-07-05	20.77

In [32]:
```
top_page_df.drop('index',axis=1,inplace=True)
top_page_df = top_page_df.set_index('Date')
top_page_df.head()
```

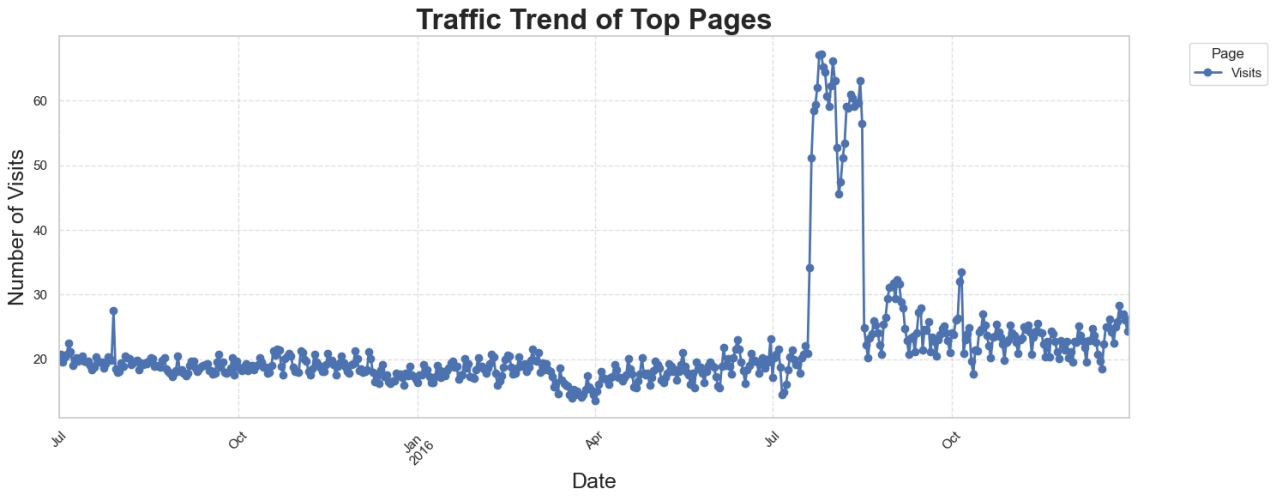
```
/var/folders/fx/1km2ndm10xxcmn5xy9fsdksm0000gn/T/ipykernel_72560/476779604.p
y:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/
stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  top_page_df.drop('index',axis=1,inplace=True)
```

Out[32]:

Date	Visits
2015-07-01	20.38
2015-07-02	20.75
2015-07-03	19.57
2015-07-04	20.44
2015-07-05	20.77

In [33]:

```
# Set the style
sns.set(style="whitegrid")

# Plotting with customization
fig, ax = plt.subplots(figsize=(15, 6))

top_page_df.plot(ax=ax, linewidth=2, marker='o')  # Optional: marker to high

# Titles and labels
ax.set_title("Traffic Trend of Top Pages", fontsize=24, fontweight='bold')
ax.set_xlabel("Date", fontsize=18)
ax.set_ylabel("Number of Visits", fontsize=18)

# Customize ticks and legend
ax.tick_params(axis='x', rotation=45)
ax.legend(title="Page", bbox_to_anchor=(1.05, 1), loc='upper left')

# Optional grid customization
ax.grid(True, linestyle='--', alpha=0.6)

plt.tight_layout()
plt.show()
```



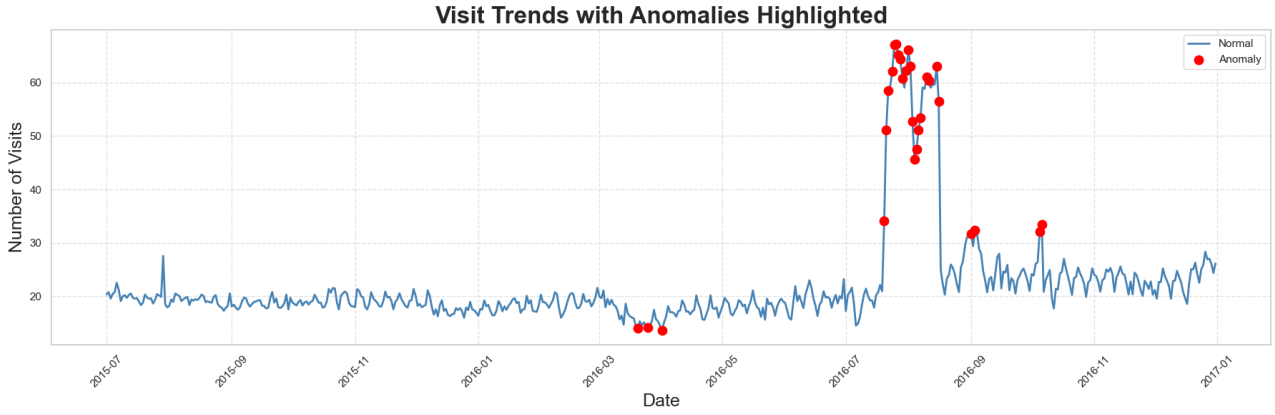
Anomaly Detection

Given the presence of anomalies in the dataset, as illustrated in the figure above, the Isolation Forest algorithm is applied to identify and eliminate these outliers. Retaining anomalous data can distort forecasting results, so removing them helps enhance the model's overall accuracy.

In [34]:
```
isolation_forest_model = IsolationForest(contamination=0.05)
isolation_forest_model.fit(top_page_df)
top_page_df['anomaly'] = isolation_forest_model.predict(top_page_df)
```

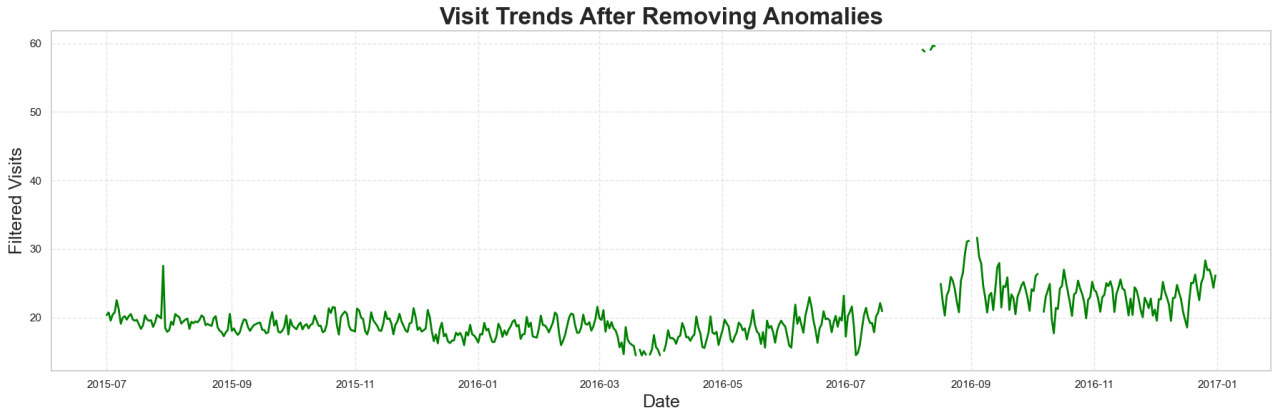
```
/Users/ramv/anaconda3/lib/python3.10/site-packages/sklearn/base.py:420: User
Warning: X does not have valid feature names, but IsolationForest was fitted
with feature names
  warnings.warn(
```

In [35]:
```
# Create a large, readable plot
fig, ax = plt.subplots(figsize=(18, 6))  # Adjusted to a more practical size

# Separate anomalies
anomaly_df = top_page_df[top_page_df['anomaly'] == -1]

# Plot normal data
ax.plot(top_page_df.index, top_page_df['Visits'], color='steelblue', linewid

# Highlight anomalies
ax.scatter(anomaly_df.index, anomaly_df['Visits'], color='red', s=80, label=

# Add title and labels
ax.set_title("Visit Trends with Anomalies Highlighted", fontsize=24, fontwei
ax.set_xlabel("Date", fontsize=18)
ax.set_ylabel("Number of Visits", fontsize=18)

# Improve tick appearance
ax.tick_params(axis='x', rotation=45)

# Add legend and grid
ax.legend()
ax.grid(True, linestyle='--', alpha=0.6)

# Tidy up layout
plt.tight_layout()
plt.show()
```



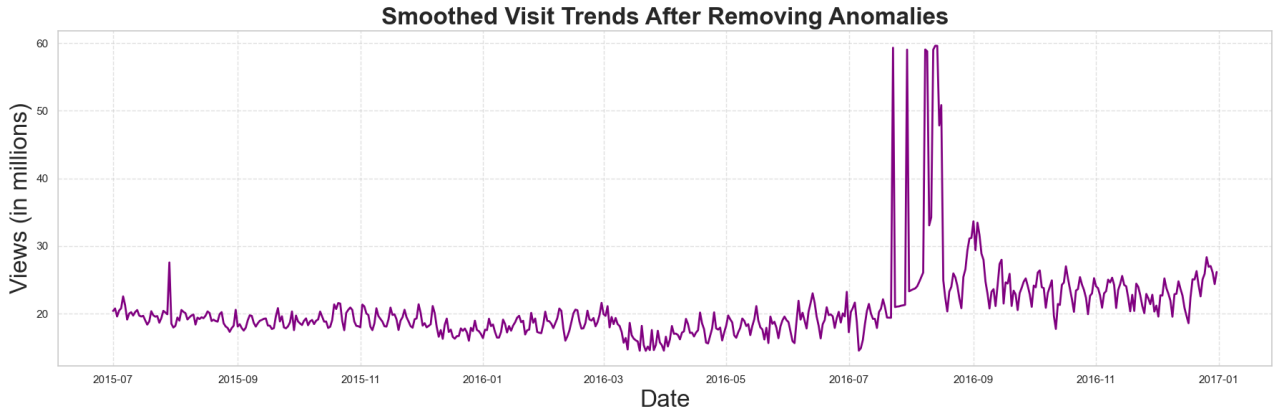
Remove anomalies: keep Visits only where anomaly == 1

In [36]:
```
top_page_df['new_visits'] = top_page_df['Visits'].where(top_page_df['anomaly

# Plot the cleaned data
plt.figure(figsize=(18, 6))  # More practical width
plt.plot(top_page_df.index, top_page_df['new_visits'], color='green', linewi

# Plot formatting
plt.title("Visit Trends After Removing Anomalies", fontsize=24, fontweight='
plt.xlabel("Date", fontsize=18)
plt.ylabel("Filtered Visits", fontsize=18)
plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()
```



Filling missing data with rolling mean

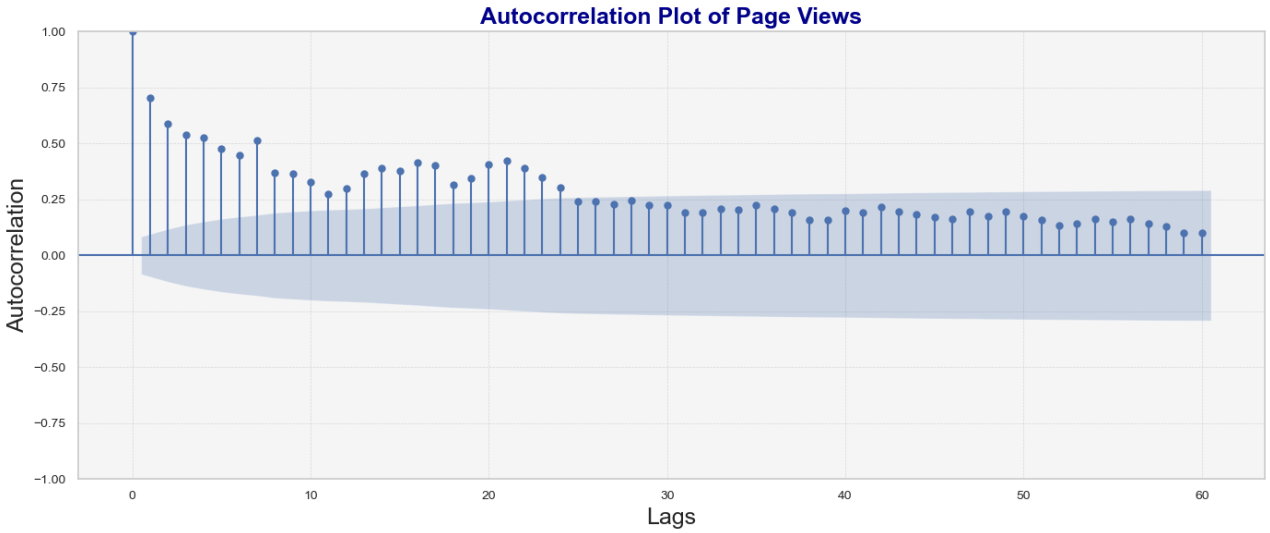
In [37]:
```
# Compute 30-day rolling mean for new_visits, using rolling average to fill
top_page_df['rolling_mean'] = top_page_df['new_visits'].fillna(
    top_page_df['new_visits'].rolling(window=30, min_periods=1).mean()
)

# Plotting the smoothed series
plt.figure(figsize=(18, 6))  # Adjusted for readability
plt.plot(top_page_df.index, top_page_df['rolling_mean'], color='purple', lin

# Add title and labels
plt.title('Smoothed Visit Trends After Removing Anomalies', fontsize=24, fon
plt.xlabel('Date', fontsize=24)
plt.ylabel('Views (in millions)', fontsize=24)

# Grid and layout
plt.grid(True, linestyle='--', alpha=0.6)
plt.tight_layout()
plt.show()
```



In [38]:
```
top_page_df = top_page_df.drop(columns=['Visits','anomaly','new_visits']).re
```

ACF Plot

In [39]:
```
import matplotlib.pyplot as plt
from statsmodels.graphics.tsaplots import plot_acf

# Set up the figure
fig, ax = plt.subplots(figsize=(14, 6))

# Plot ACF with enhancements
plot_acf(top_page_df['Views'], lags=60, ax=ax, alpha=0.05, title='Autocorrel

# Aesthetic improvements
ax.set_facecolor('#f5f5f5')  # Light background
ax.grid(True, linestyle='--', linewidth=0.5, alpha=0.7)
ax.set_xlabel("Lags", fontsize=18)
ax.set_ylabel("Autocorrelation", fontsize=18)
ax.set_title("Autocorrelation Plot of Page Views", fontsize=18, fontweight='

# Make the x-ticks more readable
plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.tight_layout()
plt.show()
```



Augmented Dickey-Fuller (ADF) Test:

The first element of the ADF test output is the test statistic, which indicates the likelihood that the time series is stationary. The second element is the p-value. If the p-value is greater than 0.05, we fail to reject the null hypothesis, suggesting that the data is non-stationary.

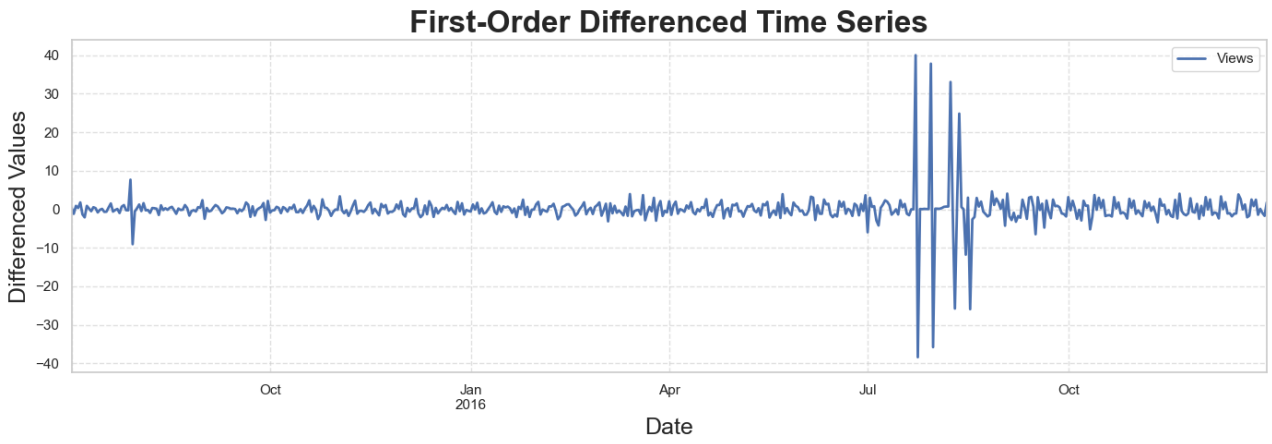
Conversely, a p-value less than or equal to 0.05 indicates that we reject the null hypothesis, implying the data is stationary.

In [40]:
```
from statsmodels.tsa.stattools import adfuller

# Perform Augmented Dickey-Fuller test
adf_result = adfuller(top_page_df['Views'])

# Display results with labels
print("Augmented Dickey-Fuller Test Results")
print(f"Test Statistic      : {adf_result[0]:.4f}")
print(f"p-value             : {adf_result[1]:.4f}")
print(f"# Lags Used         : {adf_result[2]}")
print(f"# Observations Used : {adf_result[3]}")

# Display critical values
print("\nCritical Values:")
for key, value in adf_result[4].items():
    print(f"   {key} : {value:.4f}")

# Optional interpretation
if adf_result[1] <= 0.05:
    print("\nConclusion: The data is likely stationary (reject null hypothes
else:
    print("\nConclusion: The data is likely non-stationary (fail to reject n
```

```
Augmented Dickey-Fuller Test Results
Test Statistic      : -2.2620
p-value             : 0.1845
# Lags Used         : 14
# Observations Used : 535

Critical Values:
   1% : -3.4426
   5% : -2.8670
   10% : -2.5697

Conclusion: The data is likely non-stationary (fail to reject null hypothesi
s).
```

Differencing the data to make it 'stationary'

In [41]:
```
# Calculate first-order difference to achieve stationarity
top_page_stationary_df = top_page_df.diff().dropna()

# Plotting the stationary series
fig, ax = plt.subplots(figsize=(14, 5))
top_page_stationary_df.plot(ax=ax, linewidth=2)

# Add labels and title
ax.set_title("First-Order Differenced Time Series", fontsize=24, fontweight=
ax.set_xlabel("Date", fontsize=18)
ax.set_ylabel("Differenced Values", fontsize=18)

# Improve grid and layout
ax.grid(True, linestyle='--', alpha=0.6)
plt.tight_layout()
plt.show()
```



In [42]:
```
# Perform ADF test on the differenced data
adf_result_2 = adfuller(top_page_stationary_df['Views'])

# Display results
print("Augmented Dickey-Fuller Test on Differenced Series")
print(f"Test Statistic      : {adf_result_2[0]:.4f}")
print(f"p-value             : {adf_result_2[1]:.4f}")
print(f"# Lags Used         : {adf_result_2[2]}")
print(f"# Observations Used : {adf_result_2[3]}")

# Critical values
print("\nCritical Values:")
for key, value in adf_result_2[4].items():
    print(f"   {key} : {value:.4f}")

# Interpretation
if adf_result_2[1] <= 0.05:
    print("\nConclusion: The differenced data is likely stationary (reject n
else:
    print("\nConclusion: The differenced data is still non-stationary (fail
```

```
Augmented Dickey-Fuller Test on Differenced Series
Test Statistic      : -8.6096
p-value             : 0.0000
# Lags Used         : 19
# Observations Used : 529

Critical Values:
   1% : -3.4428
   5% : -2.8670
   10% : -2.5697

Conclusion: The differenced data is likely stationary (reject null hypothesi
s).
```

In [43]:
```
top_page_df
```

Out[43]:

Date	Views
2015-07-01	20.38
2015-07-02	20.75
2015-07-03	19.57
2015-07-04	20.44
2015-07-05	20.77
...	...
2016-12-27	26.92
2016-12-28	27.03
2016-12-29	26.07
2016-12-30	24.36
2016-12-31	26.15

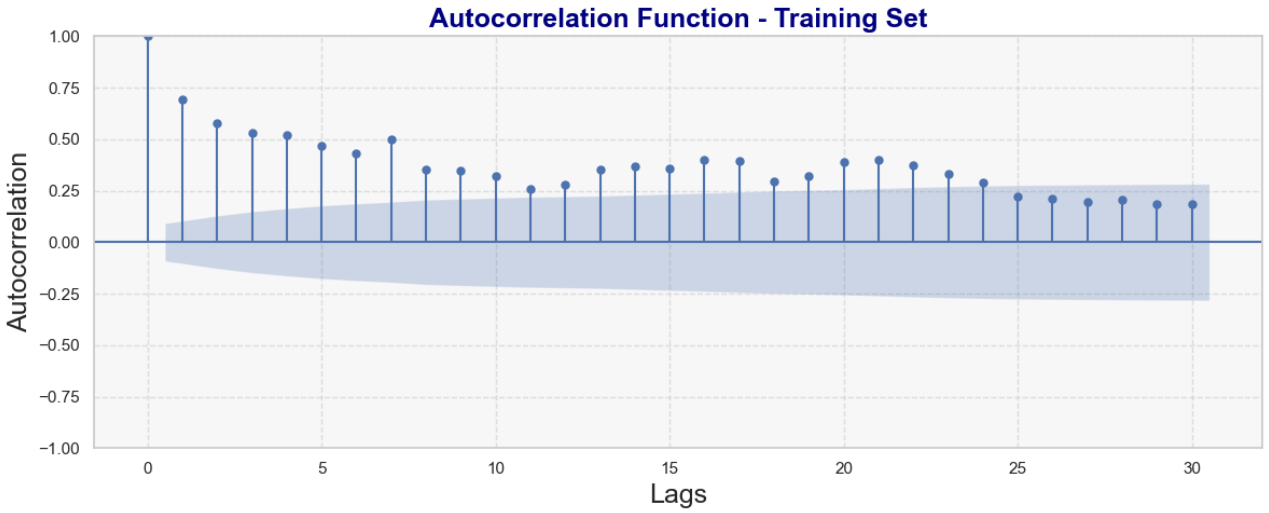
550 rows × 1 columns

Preparing dataset for modelling

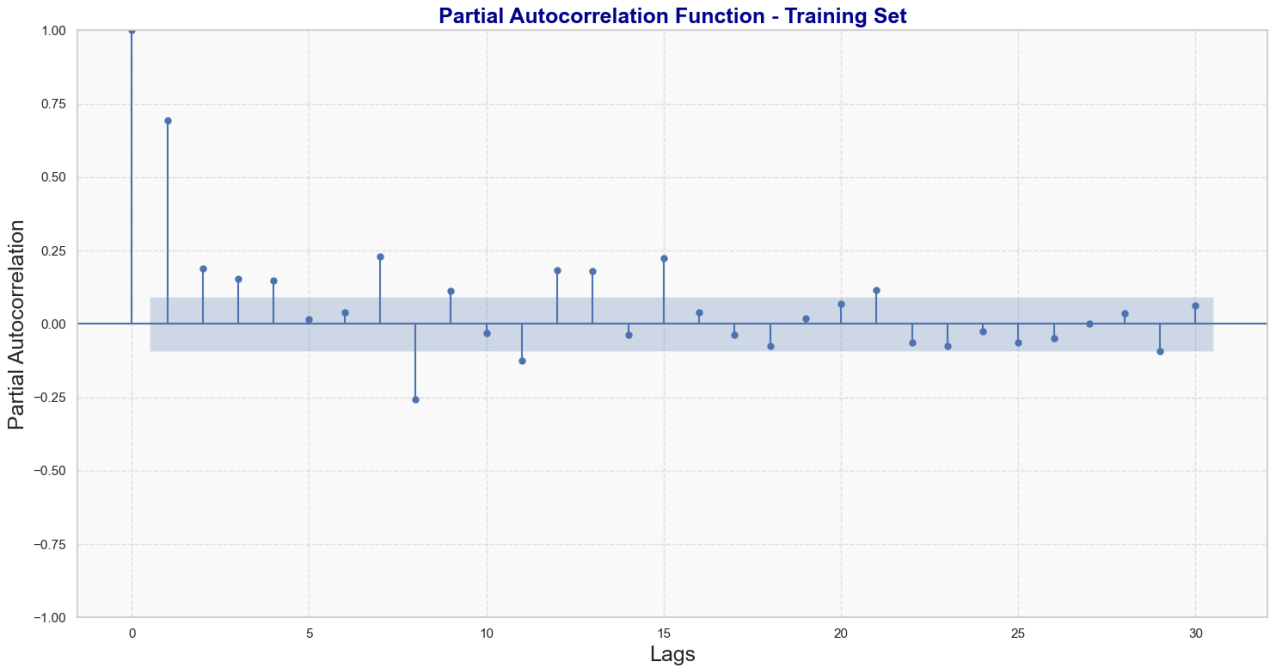
In [44]:
```
# Ensure the index is datetime (safety check)
top_page_df.index = pd.to_datetime(top_page_df.index)

# Perform time-based train-test split
train = top_page_df.loc[:'2016-09']
test = top_page_df.loc['2016-10':]

# Optional: Print shapes for confirmation
print(f"Training set: {train.shape}")
print(f"Testing set: {test.shape}")
```

```
Training set: (458, 1)
Testing set: (92, 1)
```

In [45]:
```
# Plot ACF for the training set
fig, ax = plt.subplots(figsize=(12, 5))
plot_acf(train['Views'], lags=30, ax=ax, alpha=0.05, title='ACF Plot - Train

# Beautify the plot
ax.set_facecolor('#f7f7f7')  # Soft background color
ax.grid(True, linestyle='--', alpha=0.6)
ax.set_xlabel("Lags", fontsize=18)
ax.set_ylabel("Autocorrelation", fontsize=18)
ax.set_title("Autocorrelation Function - Training Set", fontsize=18, fontwei

plt.tight_layout()
plt.show()
```



In [46]:
```
import matplotlib.pyplot as plt
from statsmodels.graphics.tsaplots import plot_pacf

# Create PACF plot for the training data
fig, ax = plt.subplots(figsize=(15, 8))
plot_pacf(train['Views'], lags=30, ax=ax, alpha=0.05, title='PACF Plot - Tra

# Beautify the plot
ax.set_facecolor('#f9f9f9')  # Light background
ax.grid(True, linestyle='--', alpha=0.6)
ax.set_xlabel("Lags", fontsize=18)
ax.set_ylabel("Partial Autocorrelation", fontsize=18)
ax.set_title("Partial Autocorrelation Function - Training Set", fontsize=18,

plt.tight_layout()
plt.show()
```



ARMA Model

In [47]:
```
from statsmodels.tsa.statespace.sarimax import SARIMAX

# Store AIC and BIC values for each (p, q) combination
aic_bic_values = []

# Grid search over p and q from 0 to 6
for p in range(7):
    for q in range(7):
        try:
            model = SARIMAX(train['Views'], order=(p, 0, q), enforce_station
            result = model.fit(disp=False)
            aic_bic_values.append({
                'p': p,
                'q': q,
                'AIC': result.aic,
                'BIC': result.bic
            })
        except Exception as e:
            print(f"Model failed for p={p}, q={q}: {e}")
            continue
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
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model.py:471: ValueWarning: No frequency information was provided, so inferr
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```

```
  self._init_dates(dates, freq)
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/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
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/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
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/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
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/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
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ed frequency D will be used.
  self._init_dates(dates, freq)
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
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  self._init_dates(dates, freq)
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/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
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  warnings.warn("Maximum Likelihood optimization failed to "
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e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
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model.py:471: ValueWarning: No frequency information was provided, so inferr
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  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
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/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
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```

In [48]:
```
result = model.fit()
print(result.mle_retvals)
```

```
 This problem is unconstrained.
```

```
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           13     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.80400D+00    |proj g|=  1.86728D-01

At iterate    5    f=  2.75177D+00    |proj g|=  1.54841D-01

At iterate   10    f=  2.73746D+00    |proj g|=  7.90971D-02

At iterate   15    f=  2.73048D+00    |proj g|=  2.40255D-02

At iterate   20    f=  2.72888D+00    |proj g|=  1.80167D-02

At iterate   25    f=  2.72721D+00    |proj g|=  2.00110D-02

At iterate   30    f=  2.72273D+00    |proj g|=  1.69810D-01

At iterate   35    f=  2.71884D+00    |proj g|=  2.08572D-01

At iterate   40    f=  2.71765D+00    |proj g|=  1.35025D-01

At iterate   45    f=  2.71733D+00    |proj g|=  2.04708D-01

At iterate   50    f=  2.71693D+00    |proj g|=  1.60828D-01

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   13     50     60      1     0     0   1.608D-01   2.717D+00
  F =   2.7169336441400000

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
{'fopt': 2.71693364414, 'gopt': array([-0.12852538, -0.12677518, -0.1605716
1, -0.13319736, -0.16082814,
       -0.12941889,  0.02035226,  0.00464005,  0.01847289,  0.01536162,
        0.00843908,  0.03659258, -0.03268268]), 'fcalls': 840, 'warnflag':
1, 'converged': False, 'iterations': 50}
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
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```

In [49]:
```
import pandas as pd
from statsmodels.tsa.statespace.sarimax import SARIMAX

# Store AIC and BIC values for each (p, q) combination
aic_bic_values = []

# Grid search over p and q
for p in range(7):
    for q in range(7):
        try:
            print(f"Trying SARIMAX({p}, 0, {q}) ...")
            model = SARIMAX(
                train['Views'],
                order=(p, 0, q),
                enforce_stationarity=False,
                enforce_invertibility=False
            )
            result = model.fit(maxiter=200, disp=True)  # More iterations +
            aic_bic_values.append({
                'p': p,
                'q': q,
                'AIC': result.aic,
                'BIC': result.bic,
                'Converged': result.mle_retvals.get('converged', False)
            })

        except Exception as e:
            print(f"Model failed for p={p}, q={q} using default optimizer. T

            try:
                # Retry with a more robust optimizer
                result = model.fit(method='powell', maxiter=200, disp=True)
                aic_bic_values.append({
                    'p': p,
                    'q': q,
                    'AIC': result.aic,
                    'BIC': result.bic,
                    'Converged': result.mle_retvals.get('converged', False)
                })
            except Exception as e2:
                print(f"Retry with 'powell' also failed for p={p}, q={q}: {e
                continue

# Convert results into DataFrame and sort by AIC
aic_bic_df = pd.DataFrame(aic_bic_values).sort_values(by='AIC')

# Show top results
print("\nTop SARIMAX models based on AIC:")
print(aic_bic_df.head())
```

```
Trying SARIMAX(0, 0, 0) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            1     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  4.45737D+00    |proj g|=  6.70344D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    1      0      1      0     0     0   6.703D-06   4.457D+00
  F =   4.4573728067549547

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
Trying SARIMAX(0, 0, 1) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            2     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  4.14899D+00    |proj g|=  2.08585D-01

At iterate    1    f=  4.12652D+00    |proj g|=  1.41669D-01
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
```

```
At iterate    2    f=  4.11468D+00    |proj g|=  7.95169D-02

At iterate    3    f=  4.11102D+00    |proj g|=  3.13015D-02

At iterate    4    f=  4.11003D+00    |proj g|=  7.11142D-02

At iterate    5    f=  4.07628D+00    |proj g|=  6.04917D-02
```

```
At iterate    6    f=  3.95782D+00    |proj g|=  2.97870D-01

At iterate    7    f=  3.94291D+00    |proj g|=  3.55936D-01

At iterate    8    f=  3.91281D+00    |proj g|=  1.94717D-01

At iterate    9    f=  3.90841D+00    |proj g|=  2.45698D-02

At iterate   10    f=  3.90778D+00    |proj g|=  7.82510D-03

At iterate   11    f=  3.90772D+00    |proj g|=  6.40940D-03

At iterate   12    f=  3.90772D+00    |proj g|=  2.25384D-03

At iterate   13    f=  3.90772D+00    |proj g|=  2.79584D-05

At iterate   14    f=  3.90772D+00    |proj g|=  5.63594D-07

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    2     14     25      1     0     0   5.636D-07   3.908D+00
  F =   3.9077170044848835

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
Trying SARIMAX(0, 0, 2) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            3     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  4.07596D+00    |proj g|=  1.27056D-01

At iterate    1    f=  4.06811D+00    |proj g|=  1.48848D-01

At iterate    2    f=  4.06783D+00    |proj g|=  1.55048D-01

At iterate    3    f=  4.05706D+00    |proj g|=  6.43273D-01
```

```
At iterate    4    f=  4.05223D+00    |proj g|=  7.01228D-01

At iterate    5    f=  4.04035D+00    |proj g|=  3.00896D-01

At iterate    6    f=  4.02896D+00    |proj g|=  3.08059D-01

At iterate    7    f=  4.01074D+00    |proj g|=  1.34769D-01

At iterate    8    f=  4.00273D+00    |proj g|=  4.00941D-02

At iterate    9    f=  3.99924D+00    |proj g|=  4.01299D-02

At iterate   10    f=  3.99581D+00    |proj g|=  4.71246D-02

At iterate   11    f=  3.98251D+00    |proj g|=  8.20105D-02

At iterate   12    f=  3.95223D+00    |proj g|=  1.46098D-01

At iterate   13    f=  3.93740D+00    |proj g|=  1.87229D-01

At iterate   14    f=  3.87104D+00    |proj g|=  2.68323D-01

At iterate   15    f=  3.76676D+00    |proj g|=  3.30845D-01

At iterate   16    f=  3.72065D+00    |proj g|=  5.24367D-01

At iterate   17    f=  3.65712D+00    |proj g|=  2.90004D-01

At iterate   18    f=  3.57963D+00    |proj g|=  2.68822D-01

At iterate   19    f=  3.55147D+00    |proj g|=  2.42636D-01

At iterate   20    f=  3.53965D+00    |proj g|=  8.86779D-02

At iterate   21    f=  3.53700D+00    |proj g|=  2.60197D-02

At iterate   22    f=  3.53679D+00    |proj g|=  1.02428D-03

At iterate   23    f=  3.53679D+00    |proj g|=  2.96423D-03

At iterate   24    f=  3.53679D+00    |proj g|=  1.33027D-03

At iterate   25    f=  3.53679D+00    |proj g|=  1.17134D-04

At iterate   26    f=  3.53679D+00    |proj g|=  1.06201D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
```

```
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    3     26     33      1     0     0   1.062D-05   3.537D+00
  F =   3.5367898641543269

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(0, 0, 3) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  4.03472D+00    |proj g|=  8.06112D-02

At iterate    1    f=  4.00054D+00    |proj g|=  3.98417D-02

At iterate    2    f=  3.98481D+00    |proj g|=  1.24962D-01

At iterate    3    f=  3.97219D+00    |proj g|=  4.14750D-02

At iterate    4    f=  3.92758D+00    |proj g|=  1.48300D-01

At iterate    5    f=  3.91360D+00    |proj g|=  4.93306D-02

At iterate    6    f=  3.91113D+00    |proj g|=  6.90113D-02

At iterate    7    f=  3.90737D+00    |proj g|=  2.63640D-01

At iterate    8    f=  3.82788D+00    |proj g|=  2.64382D-01

At iterate    9    f=  3.54099D+00    |proj g|=  9.36218D-01

At iterate   10    f=  3.52822D+00    |proj g|=  1.01553D+00

At iterate   11    f=  3.47340D+00    |proj g|=  1.73639D-01

At iterate   12    f=  3.45525D+00    |proj g|=  2.32358D-01

At iterate   13    f=  3.44897D+00    |proj g|=  1.30035D-01

At iterate   14    f=  3.44391D+00    |proj g|=  6.21814D-02

At iterate   15    f=  3.44286D+00    |proj g|=  1.26752D-02

At iterate   16    f=  3.44244D+00    |proj g|=  1.58724D-02
```

```
At iterate   17    f=  3.44236D+00    |proj g|=  2.65215D-02

At iterate   18    f=  3.44123D+00    |proj g|=  2.40018D-02

At iterate   19    f=  3.43765D+00    |proj g|=  1.54698D-02

At iterate   20    f=  3.43673D+00    |proj g|=  1.43344D-02

At iterate   21    f=  3.43665D+00    |proj g|=  1.06661D-02

At iterate   22    f=  3.43657D+00    |proj g|=  6.89820D-03

At iterate   23    f=  3.43655D+00    |proj g|=  3.82789D-03

At iterate   24    f=  3.43655D+00    |proj g|=  4.19110D-04

At iterate   25    f=  3.43655D+00    |proj g|=  1.43569D-04

At iterate   26    f=  3.43655D+00    |proj g|=  2.53202D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4     26     48      1     0     0   2.532D-06   3.437D+00
  F =   3.4365478954441153

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
Trying SARIMAX(0, 0, 4) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  3.99382D+00    |proj g|=  6.47564D-02

At iterate    1    f=  3.96502D+00    |proj g|=  4.18842D-02

At iterate    2    f=  3.94347D+00    |proj g|=  4.32435D-02
```

```
At iterate    3    f=  3.91537D+00    |proj g|=  1.09355D-01

At iterate    4    f=  3.89729D+00    |proj g|=  7.81192D-02

At iterate    5    f=  3.87917D+00    |proj g|=  1.34106D-01

At iterate    6    f=  3.86726D+00    |proj g|=  1.15833D-01

At iterate    7    f=  3.83146D+00    |proj g|=  3.20528D-01

At iterate    8    f=  3.81522D+00    |proj g|=  3.17229D-01

At iterate    9    f=  3.68799D+00    |proj g|=  1.68109D-01

At iterate   10    f=  3.60880D+00    |proj g|=  4.32994D-01

At iterate   11    f=  3.54234D+00    |proj g|=  1.46067D-01

At iterate   12    f=  3.51079D+00    |proj g|=  3.82039D-01

At iterate   13    f=  3.47890D+00    |proj g|=  5.80134D-01

At iterate   14    f=  3.44164D+00    |proj g|=  3.16284D-01

At iterate   15    f=  3.40445D+00    |proj g|=  1.45065D-01

At iterate   16    f=  3.39231D+00    |proj g|=  1.20973D-01

At iterate   17    f=  3.38878D+00    |proj g|=  1.26222D-01

At iterate   18    f=  3.38428D+00    |proj g|=  9.36108D-02

At iterate   19    f=  3.37687D+00    |proj g|=  6.98012D-02

At iterate   20    f=  3.37433D+00    |proj g|=  2.84787D-02

At iterate   21    f=  3.37335D+00    |proj g|=  2.64347D-02

At iterate   22    f=  3.37242D+00    |proj g|=  4.30584D-02

At iterate   23    f=  3.37183D+00    |proj g|=  1.80980D-02

At iterate   24    f=  3.37136D+00    |proj g|=  7.20523D-03

At iterate   25    f=  3.37128D+00    |proj g|=  7.60165D-03

At iterate   26    f=  3.37125D+00    |proj g|=  5.79487D-03

At iterate   27    f=  3.37124D+00    |proj g|=  1.64812D-04

At iterate   28    f=  3.37124D+00    |proj g|=  4.67561D-05
```

```
At iterate   29    f=  3.37124D+00    |proj g|=  1.56991D-05

At iterate   30    f=  3.37124D+00    |proj g|=  4.15041D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     30     47      1     0     0   4.150D-06   3.371D+00
  F =   3.3712427935229750

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
Trying SARIMAX(0, 0, 5) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  3.96834D+00    |proj g|=  4.10963D-02

At iterate    1    f=  3.92388D+00    |proj g|=  4.41507D-02

At iterate    2    f=  3.90402D+00    |proj g|=  4.53224D-02

At iterate    3    f=  3.89671D+00    |proj g|=  7.39078D-02

At iterate    4    f=  3.89578D+00    |proj g|=  5.41965D-01

At iterate    5    f=  3.83359D+00    |proj g|=  4.68682D-01

At iterate    6    f=  3.82639D+00    |proj g|=  2.12406D-01

At iterate    7    f=  3.82500D+00    |proj g|=  7.62170D-02

At iterate    8    f=  3.81746D+00    |proj g|=  1.34678D-01

At iterate    9    f=  3.80770D+00    |proj g|=  1.35892D-01

At iterate   10    f=  3.78778D+00    |proj g|=  1.52333D-01
```

```
At iterate   11    f=  3.75840D+00    |proj g|=  2.38892D-01

At iterate   12    f=  3.75624D+00    |proj g|=  2.28211D-01

At iterate   13    f=  3.74903D+00    |proj g|=  2.63994D-01

At iterate   14    f=  3.73958D+00    |proj g|=  1.69066D-01

At iterate   15    f=  3.72696D+00    |proj g|=  3.43095D-01

At iterate   16    f=  3.68958D+00    |proj g|=  1.63921D-01

At iterate   17    f=  3.61408D+00    |proj g|=  2.20964D-01

At iterate   18    f=  3.56963D+00    |proj g|=  5.20209D-01

At iterate   19    f=  3.52525D+00    |proj g|=  2.00244D+00

At iterate   20    f=  3.46201D+00    |proj g|=  1.51934D+00

At iterate   21    f=  3.43407D+00    |proj g|=  1.21964D+00

At iterate   22    f=  3.19608D+00    |proj g|=  1.16401D-01

At iterate   23    f=  3.19009D+00    |proj g|=  9.87381D-02

At iterate   24    f=  3.17202D+00    |proj g|=  1.05850D-01

At iterate   25    f=  3.15894D+00    |proj g|=  4.19202D-02

At iterate   26    f=  3.15311D+00    |proj g|=  1.03156D-01

At iterate   27    f=  3.14826D+00    |proj g|=  1.67024D-01

At iterate   28    f=  3.14477D+00    |proj g|=  7.46269D-02

At iterate   29    f=  3.14152D+00    |proj g|=  5.64419D-02

At iterate   30    f=  3.13964D+00    |proj g|=  4.67215D-02

At iterate   31    f=  3.13919D+00    |proj g|=  2.25585D-02

At iterate   32    f=  3.13869D+00    |proj g|=  1.79498D-02

At iterate   33    f=  3.13854D+00    |proj g|=  1.43110D-02

At iterate   34    f=  3.13847D+00    |proj g|=  4.30364D-03

At iterate   35    f=  3.13847D+00    |proj g|=  6.69581D-04

At iterate   36    f=  3.13847D+00    |proj g|=  1.56354D-04

At iterate   37    f=  3.13847D+00    |proj g|=  1.14870D-05
```

```
At iterate   38    f=  3.13847D+00    |proj g|=  2.85283D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     38     62      1     0     0   2.853D-06   3.138D+00
  F =   3.1384672417370649

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
Trying SARIMAX(0, 0, 6) ...
RUNNING THE L-BFGS-B CODE

           * * *

/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  3.95560D+00    |proj g|=  4.13655D-02

At iterate    1    f=  3.93845D+00    |proj g|=  4.24862D-02

At iterate    2    f=  3.90567D+00    |proj g|=  6.39344D-02
```

```
At iterate    3    f=  3.89353D+00    |proj g|=  6.10736D-02

At iterate    4    f=  3.87632D+00    |proj g|=  6.65102D-02

At iterate    5    f=  3.84349D+00    |proj g|=  1.33236D-01

At iterate    6    f=  3.80743D+00    |proj g|=  1.47699D-01

At iterate    7    f=  3.79355D+00    |proj g|=  4.75143D-01

At iterate    8    f=  3.77373D+00    |proj g|=  3.83948D-01

At iterate    9    f=  3.76061D+00    |proj g|=  4.08224D-01

At iterate   10    f=  3.75964D+00    |proj g|=  4.61754D-01

At iterate   11    f=  3.74330D+00    |proj g|=  1.32299D-01

At iterate   12    f=  3.73433D+00    |proj g|=  1.51186D-01

At iterate   13    f=  3.69682D+00    |proj g|=  7.88918D-01

At iterate   14    f=  3.68980D+00    |proj g|=  5.93460D-01

At iterate   15    f=  3.68265D+00    |proj g|=  3.71197D-01

At iterate   16    f=  3.67972D+00    |proj g|=  1.14975D-01

At iterate   17    f=  3.67858D+00    |proj g|=  6.35627D-02

At iterate   18    f=  3.67741D+00    |proj g|=  1.12590D-01

At iterate   19    f=  3.67514D+00    |proj g|=  1.83743D-01

At iterate   20    f=  3.67048D+00    |proj g|=  2.36353D-01

At iterate   21    f=  3.66443D+00    |proj g|=  2.81268D-01

At iterate   22    f=  3.65408D+00    |proj g|=  3.56580D-01

At iterate   23    f=  3.63949D+00    |proj g|=  3.74789D-01

At iterate   24    f=  3.59580D+00    |proj g|=  1.02365D+00

At iterate   25    f=  3.56798D+00    |proj g|=  1.48003D+00

At iterate   26    f=  3.48090D+00    |proj g|=  1.08790D+00

At iterate   27    f=  3.38864D+00    |proj g|=  3.23575D-01

At iterate   28    f=  3.35272D+00    |proj g|=  1.55395D-01
```

```
At iterate   29    f=  3.24087D+00    |proj g|=  1.96015D-01

At iterate   30    f=  3.20602D+00    |proj g|=  2.90452D-01

At iterate   31    f=  3.19061D+00    |proj g|=  2.50615D-01

At iterate   32    f=  3.17856D+00    |proj g|=  8.44459D-02

At iterate   33    f=  3.17347D+00    |proj g|=  1.44253D-01

At iterate   34    f=  3.15918D+00    |proj g|=  9.89685D-02

At iterate   35    f=  3.13937D+00    |proj g|=  1.11532D-01

At iterate   36    f=  3.13544D+00    |proj g|=  7.06867D-02

At iterate   37    f=  3.13225D+00    |proj g|=  5.53107D-02

At iterate   38    f=  3.12860D+00    |proj g|=  1.06564D-01

At iterate   39    f=  3.12567D+00    |proj g|=  3.92005D-02

At iterate   40    f=  3.12445D+00    |proj g|=  2.93998D-02

At iterate   41    f=  3.12384D+00    |proj g|=  2.40792D-02

At iterate   42    f=  3.12367D+00    |proj g|=  1.77097D-02

At iterate   43    f=  3.12355D+00    |proj g|=  8.26599D-03

At iterate   44    f=  3.12349D+00    |proj g|=  3.12771D-03

At iterate   45    f=  3.12348D+00    |proj g|=  1.50160D-03

At iterate   46    f=  3.12348D+00    |proj g|=  1.59200D-03

At iterate   47    f=  3.12348D+00    |proj g|=  1.29007D-03

At iterate   48    f=  3.12348D+00    |proj g|=  6.66210D-04

At iterate   49    f=  3.12348D+00    |proj g|=  4.12108D-04

At iterate   50    f=  3.12348D+00    |proj g|=  5.33059D-05

At iterate   51    f=  3.12348D+00    |proj g|=  7.83156D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
```

```
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     51     82      1     0     0   7.832D-06   3.123D+00
  F =   3.1234753049556208

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
Trying SARIMAX(1, 0, 0) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            2     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.95211D+00    |proj g|=  1.01926D-04

At iterate    1    f=  2.95211D+00    |proj g|=  1.01894D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    2      1     12      1     0     0   1.019D-04   2.952D+00
  F =   2.9521053964926889

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(1, 0, 1) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            3     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.86895D+00    |proj g|=  1.12776D-01
```

```
At iterate    1    f=  2.86749D+00    |proj g|=  4.13625D-01

At iterate    2    f=  2.86504D+00    |proj g|=  3.31123D-01

At iterate    3    f=  2.86029D+00    |proj g|=  6.53367D-01

At iterate    4    f=  2.85840D+00    |proj g|=  2.78207D-01

At iterate    5    f=  2.85796D+00    |proj g|=  3.64048D-02

At iterate    6    f=  2.85793D+00    |proj g|=  9.76828D-03

At iterate    7    f=  2.85792D+00    |proj g|=  9.72540D-03

At iterate    8    f=  2.85784D+00    |proj g|=  8.82968D-03

At iterate    9    f=  2.85749D+00    |proj g|=  5.85990D-03

At iterate   10    f=  2.85746D+00    |proj g|=  2.25745D-03

At iterate   11    f=  2.85746D+00    |proj g|=  7.89676D-04

At iterate   12    f=  2.85746D+00    |proj g|=  5.14448D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    3     12     16      1     0     0   5.144D-04   2.857D+00
  F =   2.8574554596365127

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(1, 0, 2) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83806D+00    |proj g|=  5.79569D-02
```

```
At iterate    1    f=  2.83793D+00    |proj g|=  1.54118D-01

At iterate    2    f=  2.83702D+00    |proj g|=  1.10927D-01

At iterate    3    f=  2.83529D+00    |proj g|=  4.52851D-02

At iterate    4    f=  2.83525D+00    |proj g|=  2.31139D-02

At iterate    5    f=  2.83525D+00    |proj g|=  7.23367D-03

At iterate    6    f=  2.83525D+00    |proj g|=  1.22030D-02

At iterate    7    f=  2.83521D+00    |proj g|=  7.23577D-02

At iterate    8    f=  2.83517D+00    |proj g|=  1.12515D-01

At iterate    9    f=  2.83510D+00    |proj g|=  1.15549D-01

At iterate   10    f=  2.83502D+00    |proj g|=  8.47159D-02

At iterate   11    f=  2.83501D+00    |proj g|=  3.74377D-02

At iterate   12    f=  2.83500D+00    |proj g|=  3.18384D-03

At iterate   13    f=  2.83500D+00    |proj g|=  6.42628D-05

At iterate   14    f=  2.83500D+00    |proj g|=  7.90676D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4     14     17      1     0     0   7.907D-05   2.835D+00
  F =   2.8350020899525750

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(1, 0, 3) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10
```

```
At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.82727D+00    |proj g|=  1.42974D-01

At iterate    1    f=  2.82724D+00    |proj g|=  8.58497D-02

At iterate    2    f=  2.82720D+00    |proj g|=  4.41530D-02

At iterate    3    f=  2.82718D+00    |proj g|=  6.16878D-02

At iterate    4    f=  2.82705D+00    |proj g|=  1.99664D-01

At iterate    5    f=  2.82683D+00    |proj g|=  3.25570D-01

At iterate    6    f=  2.82644D+00    |proj g|=  4.01727D-01

At iterate    7    f=  2.82612D+00    |proj g|=  1.65584D-01

At iterate    8    f=  2.82608D+00    |proj g|=  9.91220D-03

At iterate    9    f=  2.82608D+00    |proj g|=  7.71736D-03

At iterate   10    f=  2.82607D+00    |proj g|=  2.05587D-02

At iterate   11    f=  2.82600D+00    |proj g|=  8.84656D-02

At iterate   12    f=  2.82597D+00    |proj g|=  5.44853D-02

At iterate   13    f=  2.82597D+00    |proj g|=  8.89813D-03

At iterate   14    f=  2.82597D+00    |proj g|=  4.27364D-03

At iterate   15    f=  2.82597D+00    |proj g|=  7.91788D-03

At iterate   16    f=  2.82597D+00    |proj g|=  1.80546D-02

At iterate   17    f=  2.82597D+00    |proj g|=  3.23085D-02

At iterate   18    f=  2.82596D+00    |proj g|=  5.51098D-02

At iterate   19    f=  2.82595D+00    |proj g|=  8.53789D-02

At iterate   20    f=  2.82594D+00    |proj g|=  1.14293D-01

At iterate   21    f=  2.82591D+00    |proj g|=  1.12712D-01

At iterate   22    f=  2.82591D+00    |proj g|=  1.08759D-01

At iterate   23    f=  2.82589D+00    |proj g|=  5.77112D-02

At iterate   24    f=  2.82588D+00    |proj g|=  9.81523D-03

At iterate   25    f=  2.82588D+00    |proj g|=  3.79418D-03
```

```
At iterate   26    f=  2.82588D+00    |proj g|=  4.15959D-03

At iterate   27    f=  2.82588D+00    |proj g|=  2.00010D-03

At iterate   28    f=  2.82588D+00    |proj g|=  3.72314D-03

At iterate   29    f=  2.82588D+00    |proj g|=  7.95130D-03

At iterate   30    f=  2.82588D+00    |proj g|=  1.07400D-02

At iterate   31    f=  2.82588D+00    |proj g|=  7.88456D-03

At iterate   32    f=  2.82588D+00    |proj g|=  2.81791D-03

At iterate   33    f=  2.82588D+00    |proj g|=  3.30807D-04

At iterate   34    f=  2.82588D+00    |proj g|=  5.45526D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     34     39      1     0     0   5.455D-05   2.826D+00
  F =   2.8258796832550233

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(1, 0, 4) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83054D+00    |proj g|=  2.80642D-01

At iterate    1    f=  2.83024D+00    |proj g|=  2.36025D-01

At iterate    2    f=  2.82991D+00    |proj g|=  7.69266D-02

At iterate    3    f=  2.82975D+00    |proj g|=  7.46636D-02
```

```
At iterate    4    f=  2.82875D+00    |proj g|=  2.67831D-01

At iterate    5    f=  2.82746D+00    |proj g|=  4.38036D-01

At iterate    6    f=  2.82490D+00    |proj g|=  4.11471D-01

At iterate    7    f=  2.82392D+00    |proj g|=  1.77310D-01

At iterate    8    f=  2.82354D+00    |proj g|=  4.94621D-02

At iterate    9    f=  2.82337D+00    |proj g|=  1.47810D-01

At iterate   10    f=  2.82319D+00    |proj g|=  1.09505D-01

At iterate   11    f=  2.82307D+00    |proj g|=  2.28476D-02

At iterate   12    f=  2.82286D+00    |proj g|=  1.54255D-01
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
```

```
At iterate   13    f=  2.82260D+00    |proj g|=  2.72950D-01

At iterate   14    f=  2.82198D+00    |proj g|=  4.19164D-01
```

```
At iterate   15    f=  2.82137D+00    |proj g|=  3.49427D-01

At iterate   16    f=  2.82130D+00    |proj g|=  4.30532D-01

At iterate   17    f=  2.82098D+00    |proj g|=  1.52049D-02

At iterate   18    f=  2.82096D+00    |proj g|=  1.43691D-02

At iterate   19    f=  2.82094D+00    |proj g|=  5.19056D-02

At iterate   20    f=  2.82087D+00    |proj g|=  4.19190D-02

At iterate   21    f=  2.82080D+00    |proj g|=  3.57208D-03

At iterate   22    f=  2.82080D+00    |proj g|=  2.63728D-03

At iterate   23    f=  2.82078D+00    |proj g|=  2.43391D-02

At iterate   24    f=  2.82077D+00    |proj g|=  3.53700D-02

At iterate   25    f=  2.82075D+00    |proj g|=  3.01976D-02

At iterate   26    f=  2.82075D+00    |proj g|=  7.44977D-03

At iterate   27    f=  2.82075D+00    |proj g|=  6.10667D-04

At iterate   28    f=  2.82075D+00    |proj g|=  1.15723D-03

At iterate   29    f=  2.82075D+00    |proj g|=  1.15723D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     29     51      1     0     0   1.157D-03   2.821D+00
  F =   2.8207463004037301

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(1, 0, 5) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
```

```
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.82168D+00    |proj g|=  4.63082D-01

At iterate    1    f=  2.82118D+00    |proj g|=  3.76160D-01

At iterate    2    f=  2.82060D+00    |proj g|=  9.80376D-02

At iterate    3    f=  2.82042D+00    |proj g|=  9.65148D-02

At iterate    4    f=  2.81852D+00    |proj g|=  5.10589D-01

At iterate    5    f=  2.81611D+00    |proj g|=  9.53249D-01

At iterate    6    f=  2.81125D+00    |proj g|=  1.98198D+00

At iterate    7    f=  2.80900D+00    |proj g|=  9.04609D-02

At iterate    8    f=  2.80866D+00    |proj g|=  2.22201D-01

At iterate    9    f=  2.80849D+00    |proj g|=  6.06211D-02

At iterate   10    f=  2.80804D+00    |proj g|=  4.12663D-01

At iterate   11    f=  2.80761D+00    |proj g|=  6.52348D-01

At iterate   12    f=  2.80647D+00    |proj g|=  9.51979D-01

At iterate   13    f=  2.80508D+00    |proj g|=  1.06511D+00

At iterate   14    f=  2.80357D+00    |proj g|=  9.52822D-01

At iterate   15    f=  2.80169D+00    |proj g|=  4.49402D-01

At iterate   16    f=  2.80115D+00    |proj g|=  4.37482D-01

At iterate   17    f=  2.80103D+00    |proj g|=  1.28978D-01

At iterate   18    f=  2.80099D+00    |proj g|=  1.34917D-01

At iterate   19    f=  2.80033D+00    |proj g|=  3.95471D-01

At iterate   20    f=  2.79918D+00    |proj g|=  5.62764D-02

At iterate   21    f=  2.79267D+00    |proj g|=  1.59531D+00

At iterate   22    f=  2.79093D+00    |proj g|=  5.64480D-01

At iterate   23    f=  2.79063D+00    |proj g|=  3.16837D-01

At iterate   24    f=  2.79051D+00    |proj g|=  7.35793D-02
```

```
At iterate   25    f=  2.79049D+00    |proj g|=  1.11033D-02

At iterate   26    f=  2.79048D+00    |proj g|=  1.10640D-02

At iterate   27    f=  2.79047D+00    |proj g|=  1.09306D-02

At iterate   28    f=  2.79033D+00    |proj g|=  9.80920D-03

At iterate   29    f=  2.79024D+00    |proj g|=  2.64187D-01

At iterate   30    f=  2.79014D+00    |proj g|=  8.93582D-02

At iterate   31    f=  2.79012D+00    |proj g|=  6.60434D-02

At iterate   32    f=  2.79010D+00    |proj g|=  3.66101D-02

At iterate   33    f=  2.79003D+00    |proj g|=  1.00727D-02

At iterate   34    f=  2.78998D+00    |proj g|=  2.88578D-02

At iterate   35    f=  2.78995D+00    |proj g|=  1.13697D-02

At iterate   36    f=  2.78993D+00    |proj g|=  6.17029D-02

At iterate   37    f=  2.78992D+00    |proj g|=  1.77811D-02

At iterate   38    f=  2.78991D+00    |proj g|=  1.05441D-02

At iterate   39    f=  2.78991D+00    |proj g|=  2.18281D-02

At iterate   40    f=  2.78990D+00    |proj g|=  4.93109D-02

At iterate   41    f=  2.78988D+00    |proj g|=  5.11792D-02

At iterate   42    f=  2.78988D+00    |proj g|=  8.82682D-02

At iterate   43    f=  2.78986D+00    |proj g|=  5.92091D-02

At iterate   44    f=  2.78985D+00    |proj g|=  1.54235D-02

At iterate   45    f=  2.78985D+00    |proj g|=  3.71260D-03
```

```
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   46    f=  2.78985D+00    |proj g|=  5.97773D-03

At iterate   47    f=  2.78985D+00    |proj g|=  2.11009D-03

At iterate   48    f=  2.78985D+00    |proj g|=  2.11927D-03

At iterate   49    f=  2.78985D+00    |proj g|=  2.59302D-03

At iterate   50    f=  2.78985D+00    |proj g|=  9.06096D-03

At iterate   51    f=  2.78985D+00    |proj g|=  2.73596D-03

At iterate   52    f=  2.78985D+00    |proj g|=  4.07011D-04

At iterate   53    f=  2.78985D+00    |proj g|=  8.82204D-04

At iterate   54    f=  2.78985D+00    |proj g|=  3.17299D-03

At iterate   55    f=  2.78985D+00    |proj g|=  1.75002D-03

At iterate   56    f=  2.78985D+00    |proj g|=  3.75612D-04

At iterate   57    f=  2.78985D+00    |proj g|=  6.82837D-04

At iterate   58    f=  2.78985D+00    |proj g|=  1.18770D-04

At iterate   59    f=  2.78985D+00    |proj g|=  1.18770D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
```

```
    7     59     85      1     0     0   1.188D-04   2.790D+00
  F =   2.7898468793454758

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(1, 0, 6) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.80481D+00    |proj g|=  3.28634D+00

At iterate    1    f=  2.79875D+00    |proj g|=  5.96330D-02

At iterate    2    f=  2.79850D+00    |proj g|=  1.27678D-01

At iterate    3    f=  2.79593D+00    |proj g|=  9.41276D-01

At iterate    4    f=  2.79453D+00    |proj g|=  8.35904D-01

At iterate    5    f=  2.79374D+00    |proj g|=  3.08902D-01

At iterate    6    f=  2.79345D+00    |proj g|=  1.75668D-01

At iterate    7    f=  2.79330D+00    |proj g|=  3.86856D-01

At iterate    8    f=  2.79285D+00    |proj g|=  7.68962D-01

At iterate    9    f=  2.79197D+00    |proj g|=  1.12335D+00

At iterate   10    f=  2.79061D+00    |proj g|=  1.25005D+00

At iterate   11    f=  2.78949D+00    |proj g|=  1.06541D+00

At iterate   12    f=  2.78813D+00    |proj g|=  5.31531D-01

At iterate   13    f=  2.78731D+00    |proj g|=  2.54765D-01

At iterate   14    f=  2.78721D+00    |proj g|=  4.03626D-01

At iterate   15    f=  2.78702D+00    |proj g|=  5.19938D-01

At iterate   16    f=  2.78638D+00    |proj g|=  5.99681D-01

At iterate   17    f=  2.78533D+00    |proj g|=  4.82121D-01

At iterate   18    f=  2.78512D+00    |proj g|=  5.78394D-01

At iterate   19    f=  2.78474D+00    |proj g|=  2.42717D-01
```

```
At iterate   20    f=  2.78440D+00    |proj g|=  1.64409D-01

At iterate   21    f=  2.78399D+00    |proj g|=  5.22672D-02

At iterate   22    f=  2.78383D+00    |proj g|=  1.55304D-02

At iterate   23    f=  2.78378D+00    |proj g|=  2.68945D-02

At iterate   24    f=  2.78377D+00    |proj g|=  2.04782D-02

At iterate   25    f=  2.78373D+00    |proj g|=  1.02264D-02

At iterate   26    f=  2.78368D+00    |proj g|=  1.05648D-01

At iterate   27    f=  2.78362D+00    |proj g|=  6.14400D-02

At iterate   28    f=  2.78359D+00    |proj g|=  2.88595D-02

At iterate   29    f=  2.78358D+00    |proj g|=  5.07971D-02

At iterate   30    f=  2.78357D+00    |proj g|=  2.60071D-02

At iterate   31    f=  2.78356D+00    |proj g|=  1.38947D-02
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   32    f=  2.78350D+00    |proj g|=  5.71434D-02

At iterate   33    f=  2.78341D+00    |proj g|=  1.09754D-01

At iterate   34    f=  2.78328D+00    |proj g|=  1.37821D-01

At iterate   35    f=  2.78320D+00    |proj g|=  6.52040D-02

At iterate   36    f=  2.78316D+00    |proj g|=  2.80576D-02

At iterate   37    f=  2.78315D+00    |proj g|=  1.83106D-02

At iterate   38    f=  2.78315D+00    |proj g|=  2.53041D-02

At iterate   39    f=  2.78314D+00    |proj g|=  2.63152D-02

At iterate   40    f=  2.78314D+00    |proj g|=  4.58376D-02
```

```
At iterate   41    f=  2.78314D+00    |proj g|=  4.21182D-02

At iterate   42    f=  2.78312D+00    |proj g|=  4.03528D-03

At iterate   43    f=  2.78312D+00    |proj g|=  2.01363D-03

At iterate   44    f=  2.78312D+00    |proj g|=  4.27692D-03

At iterate   45    f=  2.78312D+00    |proj g|=  2.84618D-03

At iterate   46    f=  2.78312D+00    |proj g|=  8.13503D-03

At iterate   47    f=  2.78311D+00    |proj g|=  1.81132D-02

At iterate   48    f=  2.78311D+00    |proj g|=  8.99459D-03

At iterate   49    f=  2.78310D+00    |proj g|=  3.58514D-02

At iterate   50    f=  2.78310D+00    |proj g|=  7.64226D-03

At iterate   51    f=  2.78310D+00    |proj g|=  5.16001D-03

At iterate   52    f=  2.78310D+00    |proj g|=  6.82091D-04

At iterate   53    f=  2.78310D+00    |proj g|=  6.58865D-03

At iterate   54    f=  2.78310D+00    |proj g|=  1.60723D-03

At iterate   55    f=  2.78310D+00    |proj g|=  1.39754D-03

At iterate   56    f=  2.78310D+00    |proj g|=  1.33551D-03

At iterate   57    f=  2.78310D+00    |proj g|=  1.04768D-03

At iterate   58    f=  2.78310D+00    |proj g|=  9.06444D-04

At iterate   59    f=  2.78310D+00    |proj g|=  6.07039D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     59     69      1     0     0   6.070D-04   2.783D+00
```

```
  F =   2.7830975922331964

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(2, 0, 0) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            3     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.89847D+00    |proj g|=  1.11829D-04

At iterate    1    f=  2.89847D+00    |proj g|=  1.11037D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    3      1     10      1     0     0   1.110D-04   2.898D+00
  F =   2.8984672432891259

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(2, 0, 1) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84625D+00    |proj g|=  5.81335D-01

At iterate    1    f=  2.84583D+00    |proj g|=  1.43911D-01

At iterate    2    f=  2.84512D+00    |proj g|=  2.67723D-01

At iterate    3    f=  2.84124D+00    |proj g|=  1.15785D+00

At iterate    4    f=  2.83843D+00    |proj g|=  8.70656D-01
```

```
At iterate    5    f=  2.83795D+00    |proj g|=  6.56280D-01

At iterate    6    f=  2.83767D+00    |proj g|=  9.41345D-02

At iterate    7    f=  2.83766D+00    |proj g|=  1.92529D-02

At iterate    8    f=  2.83766D+00    |proj g|=  1.64925D-02

At iterate    9    f=  2.83765D+00    |proj g|=  4.31070D-02

At iterate   10    f=  2.83765D+00    |proj g|=  8.22445D-02

At iterate   11    f=  2.83763D+00    |proj g|=  1.50133D-01

At iterate   12    f=  2.83758D+00    |proj g|=  2.58293D-01

At iterate   13    f=  2.83746D+00    |proj g|=  4.32732D-01

At iterate   14    f=  2.83719D+00    |proj g|=  6.86645D-01

At iterate   15    f=  2.83662D+00    |proj g|=  9.26568D-01

At iterate   16    f=  2.83579D+00    |proj g|=  6.57663D-01

At iterate   17    f=  2.83572D+00    |proj g|=  6.15445D-01

At iterate   18    f=  2.83568D+00    |proj g|=  5.00633D-01

At iterate   19    f=  2.83550D+00    |proj g|=  5.29005D-02

At iterate   20    f=  2.83549D+00    |proj g|=  1.21146D-02

At iterate   21    f=  2.83549D+00    |proj g|=  4.13780D-03

At iterate   22    f=  2.83549D+00    |proj g|=  5.99413D-03

At iterate   23    f=  2.83549D+00    |proj g|=  1.47269D-02

At iterate   24    f=  2.83549D+00    |proj g|=  2.68201D-02

At iterate   25    f=  2.83549D+00    |proj g|=  4.75360D-02

At iterate   26    f=  2.83549D+00    |proj g|=  7.98774D-02

At iterate   27    f=  2.83549D+00    |proj g|=  1.30729D-01

At iterate   28    f=  2.83548D+00    |proj g|=  2.03093D-01

At iterate   29    f=  2.83546D+00    |proj g|=  2.84949D-01

At iterate   30    f=  2.83543D+00    |proj g|=  3.20518D-01
```

```
At iterate   31    f=  2.83540D+00    |proj g|=  2.36270D-01

At iterate   32    f=  2.83538D+00    |proj g|=  9.54959D-02

At iterate   33    f=  2.83538D+00    |proj g|=  1.04278D-02

At iterate   34    f=  2.83538D+00    |proj g|=  1.84735D-03

At iterate   35    f=  2.83538D+00    |proj g|=  1.98158D-03

At iterate   36    f=  2.83538D+00    |proj g|=  1.75601D-03

At iterate   37    f=  2.83538D+00    |proj g|=  9.54937D-03

At iterate   38    f=  2.83538D+00    |proj g|=  6.13502D-03

At iterate   39    f=  2.83538D+00    |proj g|=  1.92460D-04

At iterate   40    f=  2.83538D+00    |proj g|=  4.40176D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4     40     46      1     0     0   4.402D-04   2.835D+00
  F =   2.8353753047385211

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(2, 0, 2) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83941D+00    |proj g|=  5.44715D-02

At iterate    1    f=  2.83937D+00    |proj g|=  5.48438D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate    2    f=  2.83928D+00    |proj g|=  7.93899D-02

At iterate    3    f=  2.83904D+00    |proj g|=  1.88861D-01

At iterate    4    f=  2.83856D+00    |proj g|=  3.12620D-01

At iterate    5    f=  2.83774D+00    |proj g|=  3.78362D-01

At iterate    6    f=  2.83695D+00    |proj g|=  1.52338D-01

At iterate    7    f=  2.83688D+00    |proj g|=  1.37458D-02

At iterate    8    f=  2.83688D+00    |proj g|=  1.60301D-02
```

```
At iterate    9    f=  2.83683D+00    |proj g|=  1.69036D-02

At iterate   10    f=  2.83659D+00    |proj g|=  8.37586D-03

At iterate   11    f=  2.83644D+00    |proj g|=  1.04303D-02

At iterate   12    f=  2.83535D+00    |proj g|=  1.99386D-02

At iterate   13    f=  2.83466D+00    |proj g|=  1.68688D-02

At iterate   14    f=  2.83264D+00    |proj g|=  7.41805D-02

At iterate   15    f=  2.83144D+00    |proj g|=  3.79595D-01

At iterate   16    f=  2.83070D+00    |proj g|=  1.18177D+00

At iterate   17    f=  2.83017D+00    |proj g|=  1.80847D-01

At iterate   18    f=  2.82962D+00    |proj g|=  1.01312D+00

At iterate   19    f=  2.82949D+00    |proj g|=  4.33865D-01

At iterate   20    f=  2.82936D+00    |proj g|=  1.51697D-01

At iterate   21    f=  2.82935D+00    |proj g|=  4.95480D-02

At iterate   22    f=  2.82934D+00    |proj g|=  7.46078D-03

At iterate   23    f=  2.82934D+00    |proj g|=  2.14044D-02

At iterate   24    f=  2.82934D+00    |proj g|=  3.12108D-02

At iterate   25    f=  2.82934D+00    |proj g|=  1.25546D-02

At iterate   26    f=  2.82933D+00    |proj g|=  2.03885D-03

At iterate   27    f=  2.82933D+00    |proj g|=  2.03885D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     27     43      1     0     0   2.039D-03   2.829D+00
```

```
  F =   2.8293349606850993

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(2, 0, 3) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84914D+00    |proj g|=  4.68422D+01

At iterate    1    f=  2.82840D+00    |proj g|=  4.48992D-01

At iterate    2    f=  2.82801D+00    |proj g|=  1.46132D+00

At iterate    3    f=  2.82605D+00    |proj g|=  2.36762D+00

At iterate    4    f=  2.82487D+00    |proj g|=  1.40668D+00

At iterate    5    f=  2.82445D+00    |proj g|=  8.40183D-01

At iterate    6    f=  2.82439D+00    |proj g|=  5.61857D-01

At iterate    7    f=  2.82438D+00    |proj g|=  3.97966D-01

At iterate    8    f=  2.82437D+00    |proj g|=  1.53641D-01

At iterate    9    f=  2.82436D+00    |proj g|=  1.54502D-01

At iterate   10    f=  2.82436D+00    |proj g|=  3.01236D-01

At iterate   11    f=  2.82436D+00    |proj g|=  3.45340D-01

At iterate   12    f=  2.82434D+00    |proj g|=  6.71250D-01

At iterate   13    f=  2.82428D+00    |proj g|=  1.10026D+00

At iterate   14    f=  2.82409D+00    |proj g|=  1.92657D+00

At iterate   15    f=  2.82375D+00    |proj g|=  2.54960D+00

At iterate   16    f=  2.82333D+00    |proj g|=  2.35775D+00

At iterate   17    f=  2.82321D+00    |proj g|=  1.22440D+00

At iterate   18    f=  2.82302D+00    |proj g|=  7.41895D-01

At iterate   19    f=  2.82299D+00    |proj g|=  1.70931D-01
```

```
At iterate   20    f=  2.82299D+00    |proj g|=  6.86694D-03

At iterate   21    f=  2.82299D+00    |proj g|=  6.86694D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     21     64      2     0     0   6.867D-03   2.823D+00
  F =   2.8229870446829768

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(2, 0, 4) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10
 Bad direction in the line search;
   refresh the lbfgs memory and restart the iteration.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At X0         0 variables are exactly at the bounds
```

```
 At iterate    0    f=  2.86854D+00    |proj g|=  4.04321D-01

 At iterate    1    f=  2.85382D+00    |proj g|=  3.15952D-01

 At iterate    2    f=  2.84626D+00    |proj g|=  6.07734D-01

 At iterate    3    f=  2.82578D+00    |proj g|=  1.30163D-01

 At iterate    4    f=  2.82016D+00    |proj g|=  9.62984D-02

 At iterate    5    f=  2.81673D+00    |proj g|=  7.87167D-02

 At iterate    6    f=  2.81590D+00    |proj g|=  8.38063D-02

 At iterate    7    f=  2.81503D+00    |proj g|=  3.42287D-02

 At iterate    8    f=  2.81474D+00    |proj g|=  2.51176D-02

 At iterate    9    f=  2.81399D+00    |proj g|=  1.82639D-02

 At iterate   10    f=  2.81343D+00    |proj g|=  6.48948D-02

 At iterate   11    f=  2.81324D+00    |proj g|=  8.69863D-02

 At iterate   12    f=  2.81296D+00    |proj g|=  1.92676D-02

 At iterate   13    f=  2.81260D+00    |proj g|=  2.18650D-02

 At iterate   14    f=  2.81250D+00    |proj g|=  3.29089D-02

 At iterate   15    f=  2.81249D+00    |proj g|=  1.26836D-03

 At iterate   16    f=  2.81249D+00    |proj g|=  1.34196D-03

 At iterate   17    f=  2.81249D+00    |proj g|=  6.76112D-04

 At iterate   18    f=  2.81249D+00    |proj g|=  7.67791D-04

 At iterate   19    f=  2.81249D+00    |proj g|=  1.66761D-03

 At iterate   20    f=  2.81249D+00    |proj g|=  3.08617D-03

 At iterate   21    f=  2.81249D+00    |proj g|=  4.05728D-03

 At iterate   22    f=  2.81249D+00    |proj g|=  1.13867D-03

 At iterate   23    f=  2.81249D+00    |proj g|=  1.74097D-03

 At iterate   24    f=  2.81249D+00    |proj g|=  4.71742D-04

 At iterate   25    f=  2.81249D+00    |proj g|=  7.63638D-04
```

```
At iterate   26    f=  2.81249D+00    |proj g|=  8.63347D-04

At iterate   27    f=  2.81249D+00    |proj g|=  2.18011D-03

At iterate   28    f=  2.81249D+00    |proj g|=  1.82561D-03

At iterate   29    f=  2.81249D+00    |proj g|=  4.00489D-04

At iterate   30    f=  2.81249D+00    |proj g|=  1.15329D-03

At iterate   31    f=  2.81249D+00    |proj g|=  1.65987D-03

At iterate   32    f=  2.81249D+00    |proj g|=  1.59791D-03

At iterate   33    f=  2.81249D+00    |proj g|=  1.08908D-03

At iterate   34    f=  2.81249D+00    |proj g|=  4.51782D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     34     39      1     0     0   4.518D-04   2.812D+00
  F =   2.8124886945107197

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(2, 0, 5) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84330D+00    |proj g|=  3.08747D-01

At iterate    1    f=  2.82225D+00    |proj g|=  4.09768D-01

At iterate    2    f=  2.82103D+00    |proj g|=  1.23130D-01

At iterate    3    f=  2.81774D+00    |proj g|=  9.35620D-02
```

```
At iterate    4    f=  2.81309D+00    |proj g|=  5.75392D-02

At iterate    5    f=  2.81142D+00    |proj g|=  3.50486D-02

At iterate    6    f=  2.81055D+00    |proj g|=  3.45470D-02

At iterate    7    f=  2.80884D+00    |proj g|=  5.31701D-02

At iterate    8    f=  2.80789D+00    |proj g|=  6.02899D-02

At iterate    9    f=  2.80755D+00    |proj g|=  4.65095D-02

At iterate   10    f=  2.80698D+00    |proj g|=  2.68870D-02

At iterate   11    f=  2.80666D+00    |proj g|=  1.78564D-02

At iterate   12    f=  2.80636D+00    |proj g|=  1.44240D-02

At iterate   13    f=  2.80635D+00    |proj g|=  2.41481D-02

At iterate   14    f=  2.80627D+00    |proj g|=  8.77354D-03

At iterate   15    f=  2.80624D+00    |proj g|=  5.60839D-03

At iterate   16    f=  2.80621D+00    |proj g|=  8.00235D-03

At iterate   17    f=  2.80614D+00    |proj g|=  9.62566D-03

At iterate   18    f=  2.80606D+00    |proj g|=  8.80818D-03

At iterate   19    f=  2.80602D+00    |proj g|=  5.08668D-03

At iterate   20    f=  2.80601D+00    |proj g|=  2.14788D-03

At iterate   21    f=  2.80600D+00    |proj g|=  1.72498D-03

At iterate   22    f=  2.80600D+00    |proj g|=  2.93833D-03

At iterate   23    f=  2.80600D+00    |proj g|=  8.03858D-04

At iterate   24    f=  2.80600D+00    |proj g|=  2.75486D-03

At iterate   25    f=  2.80600D+00    |proj g|=  1.52432D-04

At iterate   26    f=  2.80600D+00    |proj g|=  1.51259D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
```

```
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     26     32      1     0     0   1.513D-04   2.806D+00
  F =   2.8059950335991206

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(2, 0, 6) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.76166D+00    |proj g|=  1.94416D-01

At iterate    1    f=  2.76161D+00    |proj g|=  1.52834D-01

At iterate    2    f=  2.76143D+00    |proj g|=  1.21486D-01

At iterate    3    f=  2.76132D+00    |proj g|=  1.55552D-01

At iterate    4    f=  2.76068D+00    |proj g|=  4.27370D-01

At iterate    5    f=  2.75952D+00    |proj g|=  7.41794D-01

At iterate    6    f=  2.75688D+00    |proj g|=  1.20656D+00

At iterate    7    f=  2.75252D+00    |proj g|=  1.38794D+00

At iterate    8    f=  2.75049D+00    |proj g|=  5.22164D-01

At iterate    9    f=  2.74974D+00    |proj g|=  1.80855D-01

At iterate   10    f=  2.74964D+00    |proj g|=  3.47014D-02

At iterate   11    f=  2.74962D+00    |proj g|=  7.34460D-02

At iterate   12    f=  2.74958D+00    |proj g|=  1.22873D-01

At iterate   13    f=  2.74945D+00    |proj g|=  2.46151D-01

At iterate   14    f=  2.74918D+00    |proj g|=  3.76421D-01

At iterate   15    f=  2.74866D+00    |proj g|=  4.56745D-01

At iterate   16    f=  2.74813D+00    |proj g|=  3.57039D-01
```

```
At iterate   17    f=  2.74778D+00    |proj g|=  1.36505D-01

At iterate   18    f=  2.74768D+00    |proj g|=  2.29956D-02

At iterate   19    f=  2.74767D+00    |proj g|=  6.98569D-02

At iterate   20    f=  2.74765D+00    |proj g|=  1.17636D-01

At iterate   21    f=  2.74759D+00    |proj g|=  1.90809D-01

At iterate   22    f=  2.74746D+00    |proj g|=  2.78907D-01

At iterate   23    f=  2.74719D+00    |proj g|=  3.64785D-01

At iterate   24    f=  2.74679D+00    |proj g|=  3.78733D-01

At iterate   25    f=  2.74671D+00    |proj g|=  4.82067D-01

At iterate   26    f=  2.74614D+00    |proj g|=  3.14101D-01

At iterate   27    f=  2.74573D+00    |proj g|=  1.06605D-01

At iterate   28    f=  2.74538D+00    |proj g|=  2.02738D-01

At iterate   29    f=  2.74525D+00    |proj g|=  2.62074D-01

At iterate   30    f=  2.74488D+00    |proj g|=  2.77677D-01

At iterate   31    f=  2.74481D+00    |proj g|=  2.71341D-01

At iterate   32    f=  2.74449D+00    |proj g|=  7.89857D-02

At iterate   33    f=  2.74438D+00    |proj g|=  8.88672D-02

At iterate   34    f=  2.74432D+00    |proj g|=  1.38620D-01

At iterate   35    f=  2.74424D+00    |proj g|=  1.51332D-01

At iterate   36    f=  2.74423D+00    |proj g|=  1.33021D-01

At iterate   37    f=  2.74418D+00    |proj g|=  9.88390D-02

At iterate   38    f=  2.74415D+00    |proj g|=  6.73173D-03

At iterate   39    f=  2.74415D+00    |proj g|=  1.62217D-02

At iterate   40    f=  2.74414D+00    |proj g|=  2.23233D-02

At iterate   41    f=  2.74413D+00    |proj g|=  2.05161D-02

At iterate   42    f=  2.74413D+00    |proj g|=  2.27768D-02
```

```
At iterate   43    f=  2.74409D+00    |proj g|=  3.52540D-02

At iterate   44    f=  2.74406D+00    |proj g|=  1.65169D-02
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   45    f=  2.74405D+00    |proj g|=  8.11329D-03

At iterate   46    f=  2.74403D+00    |proj g|=  1.34075D-02

At iterate   47    f=  2.74401D+00    |proj g|=  1.83687D-02

At iterate   48    f=  2.74398D+00    |proj g|=  2.38762D-02

At iterate   49    f=  2.74398D+00    |proj g|=  1.02702D-02

At iterate   50    f=  2.74398D+00    |proj g|=  8.09788D-03

At iterate   51    f=  2.74398D+00    |proj g|=  3.48708D-03

At iterate   52    f=  2.74397D+00    |proj g|=  6.50442D-04

At iterate   53    f=  2.74397D+00    |proj g|=  2.13155D-04

At iterate   54    f=  2.74397D+00    |proj g|=  8.75308D-04

At iterate   55    f=  2.74397D+00    |proj g|=  1.07830D-03

At iterate   56    f=  2.74397D+00    |proj g|=  3.19378D-04

At iterate   57    f=  2.74397D+00    |proj g|=  5.26880D-04

At iterate   58    f=  2.74397D+00    |proj g|=  1.09065D-03

At iterate   59    f=  2.74397D+00    |proj g|=  1.45271D-03

At iterate   60    f=  2.74397D+00    |proj g|=  1.04107D-03

At iterate   61    f=  2.74397D+00    |proj g|=  3.22738D-04

At iterate   62    f=  2.74397D+00    |proj g|=  1.13409D-03

At iterate   63    f=  2.74397D+00    |proj g|=  1.58240D-04

           * * *

Tit   = total number of iterations
```

```
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     63     72      1     0     0   1.582D-04   2.744D+00
  F =   2.7439694813310203

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(3, 0, 0) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.86655D+00    |proj g|=  1.17483D-04

At iterate    1    f=  2.86655D+00    |proj g|=  1.17308D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4      1     11      1     0     0   1.173D-04   2.867D+00
  F =   2.8665543344615183

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(3, 0, 1) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10
```

```
 At X0         0 variables are exactly at the bounds

 At iterate    0    f=  2.87493D+00    |proj g|=  3.79525D-02

 At iterate    1    f=  2.87462D+00    |proj g|=  9.71707D-02

 At iterate    2    f=  2.87412D+00    |proj g|=  9.01646D-02

 At iterate    3    f=  2.87257D+00    |proj g|=  2.81965D-02

 At iterate    4    f=  2.87225D+00    |proj g|=  4.31712D-02

 At iterate    5    f=  2.87116D+00    |proj g|=  5.24278D-02

 At iterate    6    f=  2.86551D+00    |proj g|=  1.16792D-01

 At iterate    7    f=  2.84618D+00    |proj g|=  1.18680D+00

 At iterate    8    f=  2.84555D+00    |proj g|=  1.41989D+00

 At iterate    9    f=  2.84117D+00    |proj g|=  3.08442D+00

 At iterate   10    f=  2.83989D+00    |proj g|=  3.51200D+00

 At iterate   11    f=  2.83727D+00    |proj g|=  2.79312D+00

 At iterate   12    f=  2.83604D+00    |proj g|=  7.88666D-01

 At iterate   13    f=  2.83518D+00    |proj g|=  2.35607D-01

 At iterate   14    f=  2.83465D+00    |proj g|=  3.84057D-01

 At iterate   15    f=  2.83428D+00    |proj g|=  5.26282D-01

 At iterate   16    f=  2.83415D+00    |proj g|=  5.30760D-01

 At iterate   17    f=  2.83310D+00    |proj g|=  7.12992D-01

 At iterate   18    f=  2.83255D+00    |proj g|=  6.01958D-01

 At iterate   19    f=  2.83238D+00    |proj g|=  3.18916D-01

 At iterate   20    f=  2.83228D+00    |proj g|=  2.41152D-01

 At iterate   21    f=  2.83226D+00    |proj g|=  1.13510D-01

 At iterate   22    f=  2.83226D+00    |proj g|=  8.57104D-02

 At iterate   23    f=  2.83225D+00    |proj g|=  2.70071D-01

 At iterate   24    f=  2.83222D+00    |proj g|=  8.19594D-02

 At iterate   25    f=  2.83219D+00    |proj g|=  2.22806D-02
```

```
At iterate   26    f=  2.83205D+00    |proj g|=  2.79995D-01

At iterate   27    f=  2.83179D+00    |proj g|=  5.36671D-01

At iterate   28    f=  2.83128D+00    |proj g|=  8.13262D-01

At iterate   29    f=  2.83066D+00    |proj g|=  9.62452D-01

At iterate   30    f=  2.83006D+00    |proj g|=  5.82951D-01

At iterate   31    f=  2.82960D+00    |proj g|=  1.20898D-01

At iterate   32    f=  2.82953D+00    |proj g|=  3.35344D-02

At iterate   33    f=  2.82953D+00    |proj g|=  1.78830D-01

At iterate   34    f=  2.82946D+00    |proj g|=  8.75486D-03

At iterate   35    f=  2.82946D+00    |proj g|=  1.23475D-02

At iterate   36    f=  2.82946D+00    |proj g|=  4.89455D-03

At iterate   37    f=  2.82945D+00    |proj g|=  2.15673D-03

At iterate   38    f=  2.82945D+00    |proj g|=  3.68712D-03

At iterate   39    f=  2.82945D+00    |proj g|=  1.14368D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     39     63      1     0     0   1.144D-03   2.829D+00
  F =   2.8294486743052265

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(3, 0, 2) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10
```

```
At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83588D+00    |proj g|=  5.67665D-02

At iterate    1    f=  2.83586D+00    |proj g|=  5.13923D-02

At iterate    2    f=  2.83581D+00    |proj g|=  6.77056D-02

At iterate    3    f=  2.83572D+00    |proj g|=  1.38058D-01

At iterate    4    f=  2.83547D+00    |proj g|=  2.47667D-01
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate    5    f=  2.83498D+00    |proj g|=  3.59888D-01

At iterate    6    f=  2.83421D+00    |proj g|=  3.86305D-01

At iterate    7    f=  2.83346D+00    |proj g|=  2.89445D-02

At iterate    8    f=  2.83343D+00    |proj g|=  6.80473D-02

At iterate    9    f=  2.83338D+00    |proj g|=  1.16424D-01

At iterate   10    f=  2.83329D+00    |proj g|=  1.76242D-01

At iterate   11    f=  2.83304D+00    |proj g|=  2.73644D-01
```

```
At iterate   12    f=  2.83252D+00    |proj g|=  4.06350D-01

At iterate   13    f=  2.83151D+00    |proj g|=  5.21698D-01

At iterate   14    f=  2.83071D+00    |proj g|=  4.11661D-02

At iterate   15    f=  2.83051D+00    |proj g|=  1.39626D-01

At iterate   16    f=  2.83045D+00    |proj g|=  8.27961D-02

At iterate   17    f=  2.83044D+00    |proj g|=  1.50652D-01

At iterate   18    f=  2.83043D+00    |proj g|=  8.11427D-02

At iterate   19    f=  2.83040D+00    |proj g|=  1.99979D-02

At iterate   20    f=  2.83034D+00    |proj g|=  1.34848D-01

At iterate   21    f=  2.83021D+00    |proj g|=  2.64839D-01

At iterate   22    f=  2.83002D+00    |proj g|=  3.19847D-01

At iterate   23    f=  2.82986D+00    |proj g|=  1.66705D-01

At iterate   24    f=  2.82984D+00    |proj g|=  3.18107D-02

At iterate   25    f=  2.82984D+00    |proj g|=  3.67716D-03

At iterate   26    f=  2.82983D+00    |proj g|=  3.34436D-03

At iterate   27    f=  2.82983D+00    |proj g|=  3.34336D-03

At iterate   28    f=  2.82983D+00    |proj g|=  7.30288D-03

At iterate   29    f=  2.82983D+00    |proj g|=  1.27864D-02

At iterate   30    f=  2.82982D+00    |proj g|=  1.81467D-02

At iterate   31    f=  2.82981D+00    |proj g|=  5.07385D-02

At iterate   32    f=  2.82980D+00    |proj g|=  3.39351D-02

At iterate   33    f=  2.82978D+00    |proj g|=  8.01981D-03

At iterate   34    f=  2.82978D+00    |proj g|=  9.59386D-03

At iterate   35    f=  2.82978D+00    |proj g|=  2.45293D-03

At iterate   36    f=  2.82978D+00    |proj g|=  1.84604D-03

At iterate   37    f=  2.82978D+00    |proj g|=  3.33712D-03

At iterate   38    f=  2.82978D+00    |proj g|=  1.05903D-03
```

```
At iterate   39    f=  2.82978D+00    |proj g|=  1.03441D-03

At iterate   40    f=  2.82978D+00    |proj g|=  3.18643D-03

At iterate   41    f=  2.82978D+00    |proj g|=  5.62768D-03

At iterate   42    f=  2.82977D+00    |proj g|=  1.27605D-02

At iterate   43    f=  2.82977D+00    |proj g|=  1.80518D-02

At iterate   44    f=  2.82977D+00    |proj g|=  5.14004D-02

At iterate   45    f=  2.82975D+00    |proj g|=  5.47388D-02

At iterate   46    f=  2.82975D+00    |proj g|=  8.41073D-02

At iterate   47    f=  2.82971D+00    |proj g|=  9.02321D-02

At iterate   48    f=  2.82969D+00    |proj g|=  6.68671D-02

At iterate   49    f=  2.82959D+00    |proj g|=  5.52471D-02

At iterate   50    f=  2.82941D+00    |proj g|=  2.18975D-02

At iterate   51    f=  2.82936D+00    |proj g|=  4.42158D-03

At iterate   52    f=  2.82935D+00    |proj g|=  8.82293D-03

At iterate   53    f=  2.82934D+00    |proj g|=  8.44106D-03

At iterate   54    f=  2.82934D+00    |proj g|=  2.48858D-03

At iterate   55    f=  2.82934D+00    |proj g|=  8.16503D-03

At iterate   56    f=  2.82934D+00    |proj g|=  3.15690D-03

At iterate   57    f=  2.82934D+00    |proj g|=  3.15690D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     57     84      1     0     0   3.157D-03   2.829D+00
```

```
  F =   2.8293432941707453

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(3, 0, 3) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.87991D+00    |proj g|=  2.51949D-01

At iterate    1    f=  2.87865D+00    |proj g|=  1.06268D+00

At iterate    2    f=  2.87331D+00    |proj g|=  6.43578D-01

At iterate    3    f=  2.86379D+00    |proj g|=  1.98766D-01

At iterate    4    f=  2.85646D+00    |proj g|=  3.11900D-01

At iterate    5    f=  2.85373D+00    |proj g|=  7.14987D-02

At iterate    6    f=  2.85339D+00    |proj g|=  7.10132D-02

At iterate    7    f=  2.85296D+00    |proj g|=  8.11217D-02

At iterate    8    f=  2.84888D+00    |proj g|=  2.34495D-01

At iterate    9    f=  2.84682D+00    |proj g|=  1.43821D-01

At iterate   10    f=  2.84571D+00    |proj g|=  1.11032D-01

At iterate   11    f=  2.84553D+00    |proj g|=  2.04532D-01

At iterate   12    f=  2.84535D+00    |proj g|=  2.46761D-02

At iterate   13    f=  2.84535D+00    |proj g|=  1.44341D-02

At iterate   14    f=  2.84533D+00    |proj g|=  1.47553D-02

At iterate   15    f=  2.84527D+00    |proj g|=  2.32681D-02

At iterate   16    f=  2.84503D+00    |proj g|=  6.25232D-02

At iterate   17    f=  2.84447D+00    |proj g|=  9.56024D-02

At iterate   18    f=  2.84091D+00    |proj g|=  3.99611D-01

At iterate   19    f=  2.84002D+00    |proj g|=  4.37962D-01
```

```
At iterate   20    f=  2.83927D+00    |proj g|=  1.02090D-01

At iterate   21    f=  2.83782D+00    |proj g|=  3.51401D-01

At iterate   22    f=  2.83707D+00    |proj g|=  1.04387D-01

At iterate   23    f=  2.83683D+00    |proj g|=  1.78945D-02
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
At iterate   24    f=  2.83679D+00    |proj g|=  1.79754D-02

At iterate   25    f=  2.83672D+00    |proj g|=  1.79696D-02

At iterate   26    f=  2.83654D+00    |proj g|=  2.84284D-02

At iterate   27    f=  2.83642D+00    |proj g|=  2.50320D-02

At iterate   28    f=  2.83615D+00    |proj g|=  1.71857D-02

At iterate   29    f=  2.83559D+00    |proj g|=  1.01095D-01

At iterate   30    f=  2.83541D+00    |proj g|=  2.61216D-01

At iterate   31    f=  2.83499D+00    |proj g|=  2.06324D-02

At iterate   32    f=  2.83483D+00    |proj g|=  3.73160D-02

At iterate   33    f=  2.83481D+00    |proj g|=  1.24622D-02

At iterate   34    f=  2.83481D+00    |proj g|=  1.22304D-02
```

```
At iterate   35    f=  2.82882D+00    |proj g|=  1.90177D+00

At iterate   36    f=  2.82882D+00    |proj g|=  1.91837D+00

At iterate   37    f=  2.82806D+00    |proj g|=  2.72780D+00

At iterate   38    f=  2.82574D+00    |proj g|=  3.80836D+00

At iterate   39    f=  2.82513D+00    |proj g|=  2.33868D+00

At iterate   40    f=  2.82486D+00    |proj g|=  1.90346D+00

At iterate   41    f=  2.82441D+00    |proj g|=  8.16533D+00

At iterate   42    f=  2.82434D+00    |proj g|=  2.59334D+00

At iterate   43    f=  2.82430D+00    |proj g|=  4.63959D-02

At iterate   44    f=  2.82429D+00    |proj g|=  4.52377D-01

At iterate   45    f=  2.82429D+00    |proj g|=  4.52377D-01

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     45     79      1     0     0   4.524D-01   2.824D+00
  F =   2.8242933430800234

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(3, 0, 4) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83053D+00    |proj g|=  3.30881D-01

At iterate    1    f=  2.81008D+00    |proj g|=  3.16873D-01
```

```
At iterate    2    f=  2.80847D+00    |proj g|=  1.15027D-01

At iterate    3    f=  2.80824D+00    |proj g|=  1.15337D-01

At iterate    4    f=  2.80510D+00    |proj g|=  1.54709D-01

At iterate    5    f=  2.80013D+00    |proj g|=  2.82498D-01

At iterate    6    f=  2.79764D+00    |proj g|=  3.31244D-01

At iterate    7    f=  2.79097D+00    |proj g|=  1.80637D-01

At iterate    8    f=  2.78682D+00    |proj g|=  1.63991D-01

At iterate    9    f=  2.78504D+00    |proj g|=  1.60760D-01

At iterate   10    f=  2.77917D+00    |proj g|=  1.11681D-01

At iterate   11    f=  2.77361D+00    |proj g|=  6.46913D-02

At iterate   12    f=  2.77182D+00    |proj g|=  4.74707D-02

At iterate   13    f=  2.77166D+00    |proj g|=  2.47789D-01

At iterate   14    f=  2.77013D+00    |proj g|=  1.53034D-01
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   15    f=  2.76877D+00    |proj g|=  8.08418D-02

At iterate   16    f=  2.76670D+00    |proj g|=  6.09565D-02

At iterate   17    f=  2.76573D+00    |proj g|=  6.18872D-02

At iterate   18    f=  2.76364D+00    |proj g|=  5.62626D-02

At iterate   19    f=  2.76316D+00    |proj g|=  4.02725D-02

At iterate   20    f=  2.76258D+00    |proj g|=  2.13250D-02

At iterate   21    f=  2.76227D+00    |proj g|=  1.36631D-02

At iterate   22    f=  2.76189D+00    |proj g|=  3.34579D-02

At iterate   23    f=  2.76168D+00    |proj g|=  2.82366D-02
```

```
At iterate   24    f=  2.76166D+00    |proj g|=  2.61507D-02

At iterate   25    f=  2.76159D+00    |proj g|=  1.00800D-02

At iterate   26    f=  2.76158D+00    |proj g|=  1.59628D-03

At iterate   27    f=  2.76158D+00    |proj g|=  4.53052D-04

At iterate   28    f=  2.76158D+00    |proj g|=  3.10040D-04

At iterate   29    f=  2.76158D+00    |proj g|=  3.05768D-04

At iterate   30    f=  2.76158D+00    |proj g|=  7.57011D-04

At iterate   31    f=  2.76158D+00    |proj g|=  1.04689D-03

At iterate   32    f=  2.76158D+00    |proj g|=  9.06376D-04

At iterate   33    f=  2.76158D+00    |proj g|=  8.78548D-04

At iterate   34    f=  2.76158D+00    |proj g|=  2.02520D-04

At iterate   35    f=  2.76158D+00    |proj g|=  2.83988D-04

At iterate   36    f=  2.76158D+00    |proj g|=  2.97917D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     36     48      1     0     0   2.979D-05   2.762D+00
  F =   2.7615792788489664

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(3, 0, 5) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds
```

```
At iterate    0    f=  2.80930D+00    |proj g|=  7.18918D-01

At iterate    1    f=  2.79876D+00    |proj g|=  2.29923D-01

At iterate    2    f=  2.79379D+00    |proj g|=  2.61192D-01

At iterate    3    f=  2.79193D+00    |proj g|=  1.69223D-01

At iterate    4    f=  2.79024D+00    |proj g|=  1.62762D-01

At iterate    5    f=  2.78601D+00    |proj g|=  9.10830D-02

At iterate    6    f=  2.78346D+00    |proj g|=  1.12951D-01

At iterate    7    f=  2.77847D+00    |proj g|=  1.96114D-01

At iterate    8    f=  2.77485D+00    |proj g|=  8.02002D-02

At iterate    9    f=  2.77427D+00    |proj g|=  5.88352D-02

At iterate   10    f=  2.77322D+00    |proj g|=  4.91632D-02

At iterate   11    f=  2.77263D+00    |proj g|=  6.77866D-02

At iterate   12    f=  2.77126D+00    |proj g|=  8.55300D-02

At iterate   13    f=  2.76999D+00    |proj g|=  9.51968D-02

At iterate   14    f=  2.76964D+00    |proj g|=  9.30191D-02

At iterate   15    f=  2.76890D+00    |proj g|=  5.01526D-02

At iterate   16    f=  2.76870D+00    |proj g|=  1.82452D-02

At iterate   17    f=  2.76867D+00    |proj g|=  6.05907D-03

At iterate   18    f=  2.76865D+00    |proj g|=  6.23806D-03

At iterate   19    f=  2.76859D+00    |proj g|=  1.24930D-02

At iterate   20    f=  2.76850D+00    |proj g|=  1.82400D-02

At iterate   21    f=  2.76846D+00    |proj g|=  3.54301D-02

At iterate   22    f=  2.76835D+00    |proj g|=  1.97361D-02

At iterate   23    f=  2.76827D+00    |proj g|=  1.30203D-02

At iterate   24    f=  2.76821D+00    |proj g|=  1.36957D-02

At iterate   25    f=  2.76811D+00    |proj g|=  2.53703D-02

At iterate   26    f=  2.76794D+00    |proj g|=  3.73695D-02
```

```
At iterate   27    f=  2.76764D+00    |proj g|=  4.59209D-02

At iterate   28    f=  2.76743D+00    |proj g|=  3.24302D-02

At iterate   29    f=  2.76680D+00    |proj g|=  2.99886D-02

At iterate   30    f=  2.76467D+00    |proj g|=  7.02875D-02

At iterate   31    f=  2.76336D+00    |proj g|=  1.13573D-01

At iterate   32    f=  2.76251D+00    |proj g|=  5.51147D-02

At iterate   33    f=  2.76145D+00    |proj g|=  6.52111D-02

At iterate   34    f=  2.76084D+00    |proj g|=  4.75549D-02

At iterate   35    f=  2.76020D+00    |proj g|=  2.84841D-02

At iterate   36    f=  2.75995D+00    |proj g|=  5.14876D-02

At iterate   37    f=  2.75969D+00    |proj g|=  1.13260D-02

At iterate   38    f=  2.75958D+00    |proj g|=  1.16627D-02

At iterate   39    f=  2.75949D+00    |proj g|=  1.44556D-02

At iterate   40    f=  2.75938D+00    |proj g|=  4.09892D-02

At iterate   41    f=  2.75916D+00    |proj g|=  2.38972D-02

At iterate   42    f=  2.75885D+00    |proj g|=  1.07682D-02

At iterate   43    f=  2.75873D+00    |proj g|=  1.38572D-02

At iterate   44    f=  2.75864D+00    |proj g|=  1.48892D-02

At iterate   45    f=  2.75861D+00    |proj g|=  1.04650D-02

At iterate   46    f=  2.75854D+00    |proj g|=  1.69237D-02

At iterate   47    f=  2.75846D+00    |proj g|=  7.91484D-03

At iterate   48    f=  2.75841D+00    |proj g|=  1.60867D-02

At iterate   49    f=  2.75840D+00    |proj g|=  1.15832D-02

At iterate   50    f=  2.75839D+00    |proj g|=  5.07194D-03

At iterate   51    f=  2.75839D+00    |proj g|=  3.38833D-03

At iterate   52    f=  2.75838D+00    |proj g|=  5.06151D-03
```

```
At iterate   53    f=  2.75836D+00    |proj g|=  3.44480D-03

At iterate   54    f=  2.75836D+00    |proj g|=  7.10342D-03

At iterate   55    f=  2.75836D+00    |proj g|=  1.80621D-03

At iterate   56    f=  2.75836D+00    |proj g|=  1.29989D-03

At iterate   57    f=  2.75836D+00    |proj g|=  5.46110D-03

At iterate   58    f=  2.75836D+00    |proj g|=  4.44170D-03

At iterate   59    f=  2.75835D+00    |proj g|=  1.15501D-03

At iterate   60    f=  2.75835D+00    |proj g|=  9.74385D-04

At iterate   61    f=  2.75835D+00    |proj g|=  1.24772D-03

At iterate   62    f=  2.75835D+00    |proj g|=  9.89543D-04

At iterate   63    f=  2.75835D+00    |proj g|=  6.94518D-04

At iterate   64    f=  2.75835D+00    |proj g|=  5.99394D-04

At iterate   65    f=  2.75835D+00    |proj g|=  2.32379D-04

At iterate   66    f=  2.75835D+00    |proj g|=  1.63867D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     66     75      1     0     0   1.639D-04   2.758D+00
  F =   2.7583541221957288

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(3, 0, 6) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10
```

```
At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.76865D+00    |proj g|=  1.40996D+00

At iterate    1    f=  2.76358D+00    |proj g|=  2.19110D-01

At iterate    2    f=  2.75733D+00    |proj g|=  1.97256D-01

At iterate    3    f=  2.75141D+00    |proj g|=  5.01276D-01

At iterate    4    f=  2.74409D+00    |proj g|=  2.74142D-01

At iterate    5    f=  2.74305D+00    |proj g|=  7.78977D-02

At iterate    6    f=  2.74285D+00    |proj g|=  9.38305D-02

At iterate    7    f=  2.74249D+00    |proj g|=  6.18436D-02

At iterate    8    f=  2.74140D+00    |proj g|=  4.64962D-02

At iterate    9    f=  2.74064D+00    |proj g|=  6.70000D-02

At iterate   10    f=  2.73825D+00    |proj g|=  1.77895D-01

At iterate   11    f=  2.73732D+00    |proj g|=  7.49355D-02

At iterate   12    f=  2.73701D+00    |proj g|=  5.20644D-02

At iterate   13    f=  2.73693D+00    |proj g|=  3.73843D-02

At iterate   14    f=  2.73688D+00    |proj g|=  3.99466D-02

At iterate   15    f=  2.73657D+00    |proj g|=  5.63145D-02

At iterate   16    f=  2.73586D+00    |proj g|=  4.68793D-02

At iterate   17    f=  2.73536D+00    |proj g|=  1.76127D-01

At iterate   18    f=  2.73500D+00    |proj g|=  4.52590D-02

At iterate   19    f=  2.73486D+00    |proj g|=  3.21774D-02

At iterate   20    f=  2.73469D+00    |proj g|=  3.66667D-02

At iterate   21    f=  2.73440D+00    |proj g|=  4.99928D-02

At iterate   22    f=  2.73438D+00    |proj g|=  1.01719D-01
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   23    f=  2.73431D+00    |proj g|=  4.11866D-02

At iterate   24    f=  2.73429D+00    |proj g|=  1.40495D-02

At iterate   25    f=  2.73428D+00    |proj g|=  1.47473D-02

At iterate   26    f=  2.73427D+00    |proj g|=  1.49465D-02

At iterate   27    f=  2.73422D+00    |proj g|=  2.25021D-02

At iterate   28    f=  2.73413D+00    |proj g|=  1.88812D-02

At iterate   29    f=  2.73411D+00    |proj g|=  5.72516D-02

At iterate   30    f=  2.73404D+00    |proj g|=  3.28022D-02

At iterate   31    f=  2.73400D+00    |proj g|=  1.20499D-02

At iterate   32    f=  2.73399D+00    |proj g|=  8.80892D-03

At iterate   33    f=  2.73398D+00    |proj g|=  1.91451D-02

At iterate   34    f=  2.73395D+00    |proj g|=  2.02512D-02

At iterate   35    f=  2.73393D+00    |proj g|=  4.41218D-02

At iterate   36    f=  2.73390D+00    |proj g|=  2.15410D-02

At iterate   37    f=  2.73388D+00    |proj g|=  1.20039D-02

At iterate   38    f=  2.73388D+00    |proj g|=  1.12514D-02

At iterate   39    f=  2.73383D+00    |proj g|=  4.73435D-03

At iterate   40    f=  2.73381D+00    |proj g|=  5.38269D-03

At iterate   41    f=  2.73381D+00    |proj g|=  7.78041D-03

At iterate   42    f=  2.73381D+00    |proj g|=  6.59399D-03

At iterate   43    f=  2.73381D+00    |proj g|=  3.51339D-03

At iterate   44    f=  2.73381D+00    |proj g|=  6.83203D-03
```

```
At iterate   45    f=  2.73380D+00    |proj g|=  1.05168D-02

At iterate   46    f=  2.73380D+00    |proj g|=  8.92119D-03

At iterate   47    f=  2.73379D+00    |proj g|=  4.75354D-03

At iterate   48    f=  2.73377D+00    |proj g|=  1.69372D-02

At iterate   49    f=  2.73373D+00    |proj g|=  3.17711D-02

At iterate   50    f=  2.73368D+00    |proj g|=  3.33340D-02

At iterate   51    f=  2.73366D+00    |proj g|=  5.89961D-02

At iterate   52    f=  2.73356D+00    |proj g|=  1.22780D-02

At iterate   53    f=  2.73345D+00    |proj g|=  1.07150D-02

At iterate   54    f=  2.73343D+00    |proj g|=  5.64707D-02

At iterate   55    f=  2.73342D+00    |proj g|=  4.32141D-02

At iterate   56    f=  2.73335D+00    |proj g|=  1.72848D-02

At iterate   57    f=  2.73335D+00    |proj g|=  7.81508D-03

At iterate   58    f=  2.73334D+00    |proj g|=  4.34768D-03

At iterate   59    f=  2.73332D+00    |proj g|=  6.26476D-03

At iterate   60    f=  2.73331D+00    |proj g|=  2.77745D-03

At iterate   61    f=  2.73331D+00    |proj g|=  5.89445D-04

At iterate   62    f=  2.73331D+00    |proj g|=  2.52338D-03

At iterate   63    f=  2.73331D+00    |proj g|=  1.14661D-03

At iterate   64    f=  2.73331D+00    |proj g|=  3.13991D-04

At iterate   65    f=  2.73331D+00    |proj g|=  5.44972D-04

At iterate   66    f=  2.73331D+00    |proj g|=  5.85363D-04

At iterate   67    f=  2.73331D+00    |proj g|=  1.24063D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
```

```
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10     67     83      1     0     0   1.241D-03   2.733D+00
  F =   2.7333069439962583

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(4, 0, 0) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84118D+00    |proj g|=  1.21861D-04

At iterate    1    f=  2.84118D+00    |proj g|=  1.21853D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5      1     13      1     0     0   1.219D-04   2.841D+00
  F =   2.8411802505988266

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(4, 0, 1) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84404D+00    |proj g|=  2.62927D-02
```

```
At iterate    1    f=  2.84402D+00    |proj g|=  2.84141D-02

At iterate    2    f=  2.84389D+00    |proj g|=  3.47626D-02

At iterate    3    f=  2.84350D+00    |proj g|=  1.82551D-02

At iterate    4    f=  2.84337D+00    |proj g|=  1.20481D-02

At iterate    5    f=  2.84271D+00    |proj g|=  4.90816D-02

At iterate    6    f=  2.84242D+00    |proj g|=  4.29306D-02

At iterate    7    f=  2.84152D+00    |proj g|=  2.42246D-02

At iterate    8    f=  2.83660D+00    |proj g|=  1.97547D-01

At iterate    9    f=  2.83449D+00    |proj g|=  1.48240D+00

At iterate   10    f=  2.83441D+00    |proj g|=  1.67674D+00

At iterate   11    f=  2.83319D+00    |proj g|=  1.62599D+00

At iterate   12    f=  2.83119D+00    |proj g|=  1.11494D+00

At iterate   13    f=  2.82994D+00    |proj g|=  9.91741D-01

At iterate   14    f=  2.82934D+00    |proj g|=  4.78336D-01

At iterate   15    f=  2.82926D+00    |proj g|=  6.05853D-01

At iterate   16    f=  2.82896D+00    |proj g|=  1.63296D-01

At iterate   17    f=  2.82856D+00    |proj g|=  2.35582D-01

At iterate   18    f=  2.82817D+00    |proj g|=  3.34038D-01

At iterate   19    f=  2.82798D+00    |proj g|=  2.24210D-01

At iterate   20    f=  2.82788D+00    |proj g|=  1.08015D-01

At iterate   21    f=  2.82784D+00    |proj g|=  2.72234D-01

At iterate   22    f=  2.82776D+00    |proj g|=  3.01242D-01

At iterate   23    f=  2.82730D+00    |proj g|=  1.06979D-01

At iterate   24    f=  2.82639D+00    |proj g|=  9.95848D-02

At iterate   25    f=  2.82638D+00    |proj g|=  2.71037D-01

At iterate   26    f=  2.82494D+00    |proj g|=  3.80250D-01

At iterate   27    f=  2.82477D+00    |proj g|=  2.14318D-01
```

```
At iterate   28    f=  2.82371D+00    |proj g|=  1.50410D-01

At iterate   29    f=  2.82352D+00    |proj g|=  4.20020D-02

At iterate   30    f=  2.82350D+00    |proj g|=  2.80682D-02

At iterate   31    f=  2.82349D+00    |proj g|=  1.24453D-02

At iterate   32    f=  2.82342D+00    |proj g|=  1.15844D-01

At iterate   33    f=  2.82333D+00    |proj g|=  3.31638D-01

At iterate   34    f=  2.82315D+00    |proj g|=  3.88974D-01

At iterate   35    f=  2.82313D+00    |proj g|=  6.53882D-01

At iterate   36    f=  2.82292D+00    |proj g|=  4.56169D-01

At iterate   37    f=  2.82277D+00    |proj g|=  2.60643D-01

At iterate   38    f=  2.82276D+00    |proj g|=  5.03787D-02

At iterate   39    f=  2.82274D+00    |proj g|=  5.44092D-03

At iterate   40    f=  2.82274D+00    |proj g|=  6.87610D-03

At iterate   41    f=  2.82274D+00    |proj g|=  8.11828D-03

At iterate   42    f=  2.82274D+00    |proj g|=  7.15403D-03

At iterate   43    f=  2.82274D+00    |proj g|=  1.66990D-03

At iterate   44    f=  2.82274D+00    |proj g|=  1.76004D-03

At iterate   45    f=  2.82274D+00    |proj g|=  5.86491D-04

At iterate   46    f=  2.82274D+00    |proj g|=  5.86491D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     46     73      1     0     0   5.865D-04   2.823D+00
```

```
  F =   2.8227397291921386

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(4, 0, 2) ...
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83888D+00    |proj g|=  5.96110D-02

At iterate    1    f=  2.83815D+00    |proj g|=  3.22842D-01

At iterate    2    f=  2.83679D+00    |proj g|=  2.09151D-01
```

```
At iterate    3    f=  2.83476D+00    |proj g|=  8.18647D-02

At iterate    4    f=  2.83469D+00    |proj g|=  2.88390D-02

At iterate    5    f=  2.83465D+00    |proj g|=  4.69203D-02

At iterate    6    f=  2.83456D+00    |proj g|=  8.80822D-02

At iterate    7    f=  2.83435D+00    |proj g|=  1.48492D-01

At iterate    8    f=  2.83396D+00    |proj g|=  2.05731D-01

At iterate    9    f=  2.83340D+00    |proj g|=  1.92530D-01

At iterate   10    f=  2.83278D+00    |proj g|=  9.70737D-02

At iterate   11    f=  2.83229D+00    |proj g|=  1.42310D-01

At iterate   12    f=  2.83196D+00    |proj g|=  1.96688D-01

At iterate   13    f=  2.83055D+00    |proj g|=  3.45609D-01

At iterate   14    f=  2.82951D+00    |proj g|=  2.59770D-01

At iterate   15    f=  2.82888D+00    |proj g|=  1.69736D-01

At iterate   16    f=  2.82865D+00    |proj g|=  1.87388D-01

At iterate   17    f=  2.82774D+00    |proj g|=  1.79568D-01

At iterate   18    f=  2.82689D+00    |proj g|=  1.98369D-01

At iterate   19    f=  2.82522D+00    |proj g|=  4.20584D-01

At iterate   20    f=  2.82323D+00    |proj g|=  1.17439D+00

At iterate   21    f=  2.82252D+00    |proj g|=  7.44153D-02

At iterate   22    f=  2.82065D+00    |proj g|=  3.76024D-01

At iterate   23    f=  2.81923D+00    |proj g|=  3.06558D-01

At iterate   24    f=  2.81806D+00    |proj g|=  2.02272D-01

At iterate   25    f=  2.81783D+00    |proj g|=  1.36890D-01

At iterate   26    f=  2.81782D+00    |proj g|=  7.77010D-02

At iterate   27    f=  2.81781D+00    |proj g|=  2.14641D-02

At iterate   28    f=  2.81781D+00    |proj g|=  1.40923D-02
```

```
At iterate   29    f=  2.81780D+00    |proj g|=  3.39067D-02

At iterate   30    f=  2.81780D+00    |proj g|=  6.00115D-02

At iterate   31    f=  2.81777D+00    |proj g|=  1.01217D-01

At iterate   32    f=  2.81771D+00    |proj g|=  1.58140D-01

At iterate   33    f=  2.81757D+00    |proj g|=  2.56748D-01

At iterate   34    f=  2.81736D+00    |proj g|=  8.39414D-02

At iterate   35    f=  2.81717D+00    |proj g|=  3.96438D-01

At iterate   36    f=  2.81676D+00    |proj g|=  2.05301D-01

At iterate   37    f=  2.81632D+00    |proj g|=  3.19815D-01

At iterate   38    f=  2.81628D+00    |proj g|=  5.16063D-02

At iterate   39    f=  2.81619D+00    |proj g|=  6.67908D-02

At iterate   40    f=  2.81604D+00    |proj g|=  4.65595D-02

At iterate   41    f=  2.81585D+00    |proj g|=  3.44600D-02

At iterate   42    f=  2.81567D+00    |proj g|=  3.50518D-02

At iterate   43    f=  2.81564D+00    |proj g|=  1.36583D-02

At iterate   44    f=  2.81561D+00    |proj g|=  9.52264D-03

At iterate   45    f=  2.81560D+00    |proj g|=  5.01406D-03

At iterate   46    f=  2.81560D+00    |proj g|=  4.08639D-03

At iterate   47    f=  2.81560D+00    |proj g|=  1.80670D-03

At iterate   48    f=  2.81560D+00    |proj g|=  3.09193D-03

At iterate   49    f=  2.81560D+00    |proj g|=  5.02090D-03

At iterate   50    f=  2.81560D+00    |proj g|=  1.58662D-02

At iterate   51    f=  2.81560D+00    |proj g|=  1.58457D-02

At iterate   52    f=  2.81560D+00    |proj g|=  2.26649D-02

At iterate   53    f=  2.81559D+00    |proj g|=  1.77355D-02

At iterate   54    f=  2.81559D+00    |proj g|=  7.27063D-03

At iterate   55    f=  2.81559D+00    |proj g|=  9.43245D-04
```

```
At iterate   56    f=  2.81559D+00    |proj g|=  2.74512D-04

At iterate   57    f=  2.81559D+00    |proj g|=  2.74512D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     57    104      2     0     0   2.745D-04   2.816D+00
  F =   2.8155885208438791

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(4, 0, 3) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  3.76547D+00    |proj g|=  3.24027D-01

At iterate    1    f=  3.75854D+00    |proj g|=  7.47049D-01

At iterate    2    f=  3.70212D+00    |proj g|=  7.66616D-01

At iterate    3    f=  3.37762D+00    |proj g|=  2.72561D-01

At iterate    4    f=  3.30867D+00    |proj g|=  7.62181D-01

At iterate    5    f=  3.20400D+00    |proj g|=  1.39258D+00

At iterate    6    f=  3.07072D+00    |proj g|=  1.34519D+00

At iterate    7    f=  3.05364D+00    |proj g|=  1.15707D+00

At iterate    8    f=  3.03732D+00    |proj g|=  9.31843D-01

At iterate    9    f=  3.01007D+00    |proj g|=  4.00351D-01

At iterate   10    f=  2.97790D+00    |proj g|=  7.79639D-01
```

```
At iterate   11    f=  2.97484D+00    |proj g|=  7.80114D-01

At iterate   12    f=  2.96503D+00    |proj g|=  8.54827D-01

At iterate   13    f=  2.94914D+00    |proj g|=  8.25265D-01

At iterate   14    f=  2.92124D+00    |proj g|=  1.04492D+00

At iterate   15    f=  2.90737D+00    |proj g|=  7.60334D-01

At iterate   16    f=  2.87534D+00    |proj g|=  9.92402D-01
 Bad direction in the line search;
   refresh the lbfgs memory and restart the iteration.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   17    f=  2.86170D+00    |proj g|=  1.27141D+00

At iterate   18    f=  2.84953D+00    |proj g|=  1.75256D-01

At iterate   19    f=  2.84337D+00    |proj g|=  5.03599D-01

At iterate   20    f=  2.83549D+00    |proj g|=  2.17409D-01

At iterate   21    f=  2.83319D+00    |proj g|=  1.34312D-01

At iterate   22    f=  2.83309D+00    |proj g|=  3.53680D-02

At iterate   23    f=  2.83307D+00    |proj g|=  2.30341D-02

At iterate   24    f=  2.83304D+00    |proj g|=  1.44693D-02

At iterate   25    f=  2.83302D+00    |proj g|=  1.46206D-02

At iterate   26    f=  2.83293D+00    |proj g|=  3.17432D-02

At iterate   27    f=  2.83277D+00    |proj g|=  5.70280D-02

At iterate   28    f=  2.83245D+00    |proj g|=  7.99754D-02

At iterate   29    f=  2.83200D+00    |proj g|=  7.58093D-02
```

```
At iterate   30    f=  2.83172D+00    |proj g|=  5.01397D-02

At iterate   31    f=  2.83142D+00    |proj g|=  1.21368D-01

At iterate   32    f=  2.83106D+00    |proj g|=  8.56890D-02

At iterate   33    f=  2.83102D+00    |proj g|=  6.30529D-02

At iterate   34    f=  2.83052D+00    |proj g|=  2.61738D-02

At iterate   35    f=  2.82943D+00    |proj g|=  7.87782D-02

At iterate   36    f=  2.82753D+00    |proj g|=  1.72998D-01

At iterate   37    f=  2.82533D+00    |proj g|=  2.79485D-01

At iterate   38    f=  2.82476D+00    |proj g|=  2.50160D-01

At iterate   39    f=  2.82393D+00    |proj g|=  8.00274D-01

At iterate   40    f=  2.82367D+00    |proj g|=  1.11692D-01

At iterate   41    f=  2.82348D+00    |proj g|=  3.08853D-01

At iterate   42    f=  2.82312D+00    |proj g|=  1.41287D-01

At iterate   43    f=  2.82266D+00    |proj g|=  3.95184D-01

At iterate   44    f=  2.82224D+00    |proj g|=  3.01261D-01

At iterate   45    f=  2.82180D+00    |proj g|=  1.73124D-01

At iterate   46    f=  2.82176D+00    |proj g|=  7.35701D-02

At iterate   47    f=  2.82170D+00    |proj g|=  1.45992D-01

At iterate   48    f=  2.82165D+00    |proj g|=  2.45919D-01

At iterate   49    f=  2.82152D+00    |proj g|=  3.47048D-01

At iterate   50    f=  2.82140D+00    |proj g|=  2.90863D-01

At iterate   51    f=  2.82138D+00    |proj g|=  1.90296D-01

At iterate   52    f=  2.82133D+00    |proj g|=  3.75646D-02

At iterate   53    f=  2.82133D+00    |proj g|=  9.94644D-03

At iterate   54    f=  2.82133D+00    |proj g|=  5.92003D-03

At iterate   55    f=  2.82133D+00    |proj g|=  6.26615D-03

At iterate   56    f=  2.82133D+00    |proj g|=  9.04261D-03
```

```
At iterate   57    f=  2.82133D+00    |proj g|=  3.93861D-03

At iterate   58    f=  2.82133D+00    |proj g|=  1.35403D-02

At iterate   59    f=  2.82132D+00    |proj g|=  1.04351D-03

At iterate   60    f=  2.82132D+00    |proj g|=  2.44871D-03

At iterate   61    f=  2.82132D+00    |proj g|=  1.43412D-03

At iterate   62    f=  2.82132D+00    |proj g|=  2.30162D-03

At iterate   63    f=  2.82132D+00    |proj g|=  7.37332D-04

At iterate   64    f=  2.82132D+00    |proj g|=  1.29179D-03

At iterate   65    f=  2.82132D+00    |proj g|=  2.78955D-03

At iterate   66    f=  2.82132D+00    |proj g|=  1.66970D-03

At iterate   67    f=  2.82132D+00    |proj g|=  1.53220D-02

At iterate   68    f=  2.82132D+00    |proj g|=  5.55552D-03

At iterate   69    f=  2.82132D+00    |proj g|=  1.32585D-02

At iterate   70    f=  2.82132D+00    |proj g|=  2.28329D-02

At iterate   71    f=  2.82132D+00    |proj g|=  1.95616D-02

At iterate   72    f=  2.82132D+00    |proj g|=  1.51752D-02

At iterate   73    f=  2.82132D+00    |proj g|=  3.72478D-03

At iterate   74    f=  2.82132D+00    |proj g|=  1.29111D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updatesTrying SARIMAX(4, 0, 4) ...
 skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     74     94      1     0     0   1.291D-03   2.821D+00
  F =   2.8213205365232938
```

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.82358D+00    |proj g|=  4.08285D-01

At iterate    1    f=  2.79616D+00    |proj g|=  4.06885D-01

At iterate    2    f=  2.79465D+00    |proj g|=  1.04309D-01

At iterate    3    f=  2.79453D+00    |proj g|=  1.05258D-01

At iterate    4    f=  2.79400D+00    |proj g|=  1.02947D-01

At iterate    5    f=  2.79284D+00    |proj g|=  1.18865D-01

At iterate    6    f=  2.79108D+00    |proj g|=  1.35847D-01

At iterate    7    f=  2.78868D+00    |proj g|=  1.18593D-01

At iterate    8    f=  2.78318D+00    |proj g|=  1.12949D-01

At iterate    9    f=  2.78196D+00    |proj g|=  4.70268D-02

At iterate   10    f=  2.78183D+00    |proj g|=  1.11925D-01

At iterate   11    f=  2.78177D+00    |proj g|=  5.72298D-02

At iterate   12    f=  2.78175D+00    |proj g|=  2.54114D-02

At iterate   13    f=  2.78173D+00    |proj g|=  2.59480D-02

At iterate   14    f=  2.78167D+00    |proj g|=  3.43117D-02

At iterate   15    f=  2.78153D+00    |proj g|=  5.09478D-02

At iterate   16    f=  2.78117D+00    |proj g|=  5.87784D-02

At iterate   17    f=  2.78012D+00    |proj g|=  9.15481D-02

At iterate   18    f=  2.77006D+00    |proj g|=  2.79886D-01

At iterate   19    f=  2.76995D+00    |proj g|=  2.76427D-01

At iterate   20    f=  2.76780D+00    |proj g|=  1.12683D-01
```

```
At iterate   21    f=  2.76540D+00    |proj g|=  1.46642D-01

At iterate   22    f=  2.76466D+00    |proj g|=  9.67097D-02

At iterate   23    f=  2.76359D+00    |proj g|=  1.96153D-01

At iterate   24    f=  2.76261D+00    |proj g|=  2.15750D-01

At iterate   25    f=  2.76208D+00    |proj g|=  7.05841D-02

At iterate   26    f=  2.76177D+00    |proj g|=  2.17210D-02

At iterate   27    f=  2.76161D+00    |proj g|=  1.62444D-02

At iterate   28    f=  2.76142D+00    |proj g|=  4.54073D-02

At iterate   29    f=  2.76123D+00    |proj g|=  3.38666D-02

At iterate   30    f=  2.76102D+00    |proj g|=  1.25954D-02
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   31    f=  2.76089D+00    |proj g|=  1.05766D-02

At iterate   32    f=  2.76086D+00    |proj g|=  9.98158D-03

At iterate   33    f=  2.76084D+00    |proj g|=  3.90465D-03

At iterate   34    f=  2.76083D+00    |proj g|=  1.35986D-02

At iterate   35    f=  2.76081D+00    |proj g|=  6.88771D-03

At iterate   36    f=  2.76075D+00    |proj g|=  1.70605D-02

At iterate   37    f=  2.76073D+00    |proj g|=  5.93286D-02

At iterate   38    f=  2.76059D+00    |proj g|=  6.79845D-02

At iterate   39    f=  2.76013D+00    |proj g|=  1.18515D-01

At iterate   40    f=  2.75922D+00    |proj g|=  1.30667D-01

At iterate   41    f=  2.75807D+00    |proj g|=  4.16099D-01

At iterate   42    f=  2.75713D+00    |proj g|=  1.70523D-01

At iterate   43    f=  2.75671D+00    |proj g|=  5.61624D-01
```

```
At iterate   44    f=  2.75630D+00    |proj g|=  7.05153D-02

At iterate   45    f=  2.75600D+00    |proj g|=  5.59062D-01

At iterate   46    f=  2.75513D+00    |proj g|=  6.87002D-02

At iterate   47    f=  2.75420D+00    |proj g|=  1.12020D+00

At iterate   48    f=  2.75396D+00    |proj g|=  1.42628D-01

At iterate   49    f=  2.75391D+00    |proj g|=  4.02407D-01

At iterate   50    f=  2.75389D+00    |proj g|=  1.87601D-01

At iterate   51    f=  2.75388D+00    |proj g|=  7.01544D-02

At iterate   52    f=  2.75387D+00    |proj g|=  9.20226D-02

At iterate   53    f=  2.75383D+00    |proj g|=  3.71862D-01

At iterate   54    f=  2.75376D+00    |proj g|=  5.80973D-01

At iterate   55    f=  2.75367D+00    |proj g|=  5.09337D-01

At iterate   56    f=  2.75364D+00    |proj g|=  1.35182D-01

At iterate   57    f=  2.75362D+00    |proj g|=  7.43168D-02

At iterate   58    f=  2.75362D+00    |proj g|=  5.15533D-02

At iterate   59    f=  2.75362D+00    |proj g|=  9.59523D-02

At iterate   60    f=  2.75362D+00    |proj g|=  9.42297D-02

At iterate   61    f=  2.75361D+00    |proj g|=  1.92608D-01

At iterate   62    f=  2.75360D+00    |proj g|=  1.03746D-01

At iterate   63    f=  2.75359D+00    |proj g|=  8.08358D-02

At iterate   64    f=  2.75358D+00    |proj g|=  2.33665D-01

At iterate   65    f=  2.75356D+00    |proj g|=  3.99504D-01

At iterate   66    f=  2.75351D+00    |proj g|=  5.56241D-01

At iterate   67    f=  2.75343D+00    |proj g|=  4.66159D-01

At iterate   68    f=  2.75341D+00    |proj g|=  4.59154D-01

At iterate   69    f=  2.75341D+00    |proj g|=  3.78002D-01
```

```
At iterate   70    f=  2.75337D+00    |proj g|=  3.43592D-01

At iterate   71    f=  2.75333D+00    |proj g|=  1.10057D-01

At iterate   72    f=  2.75332D+00    |proj g|=  7.79846D-02

At iterate   73    f=  2.75332D+00    |proj g|=  1.17007D-01

At iterate   74    f=  2.75331D+00    |proj g|=  5.43986D-02

At iterate   75    f=  2.75330D+00    |proj g|=  1.85180D-02

At iterate   76    f=  2.75330D+00    |proj g|=  1.85026D-02

At iterate   77    f=  2.75330D+00    |proj g|=  1.84919D-02

At iterate   78    f=  2.75329D+00    |proj g|=  1.02518D-01

At iterate   79    f=  2.75328D+00    |proj g|=  7.03181D-02

At iterate   80    f=  2.75327D+00    |proj g|=  7.80060D-01

At iterate   81    f=  2.75314D+00    |proj g|=  2.34949D-01

At iterate   82    f=  2.75295D+00    |proj g|=  2.72919D-01

At iterate   83    f=  2.75256D+00    |proj g|=  7.18537D-01

At iterate   84    f=  2.75223D+00    |proj g|=  9.59771D-01

At iterate   85    f=  2.75219D+00    |proj g|=  6.54553D-01

At iterate   86    f=  2.75209D+00    |proj g|=  5.29497D-01

At iterate   87    f=  2.75202D+00    |proj g|=  2.20635D-01

At iterate   88    f=  2.75201D+00    |proj g|=  6.03965D-02

At iterate   89    f=  2.75201D+00    |proj g|=  1.05310D-01

At iterate   90    f=  2.75200D+00    |proj g|=  1.26122D-01

At iterate   91    f=  2.75199D+00    |proj g|=  2.42371D-01

At iterate   92    f=  2.75198D+00    |proj g|=  1.42204D-01

At iterate   93    f=  2.75197D+00    |proj g|=  5.30910D-02

At iterate   94    f=  2.75197D+00    |proj g|=  7.11545D-02

At iterate   95    f=  2.75195D+00    |proj g|=  2.11674D-01

At iterate   96    f=  2.75191D+00    |proj g|=  3.35224D-01
```

```
At iterate   97    f=  2.75183D+00    |proj g|=  3.91691D-01

At iterate   98    f=  2.75180D+00    |proj g|=  5.28956D-01

At iterate   99    f=  2.75166D+00    |proj g|=  6.83759D-01

At iterate  100    f=  2.75157D+00    |proj g|=  3.32689D-01

At iterate  101    f=  2.75142D+00    |proj g|=  9.86492D-02

At iterate  102    f=  2.75137D+00    |proj g|=  2.12463D-01

At iterate  103    f=  2.75135D+00    |proj g|=  3.05599D-01

At iterate  104    f=  2.75135D+00    |proj g|=  1.15252D-01

At iterate  105    f=  2.75134D+00    |proj g|=  2.39950D-02

At iterate  106    f=  2.75134D+00    |proj g|=  1.49080D-02

At iterate  107    f=  2.75134D+00    |proj g|=  2.51468D-02

At iterate  108    f=  2.75134D+00    |proj g|=  3.62336D-02

At iterate  109    f=  2.75133D+00    |proj g|=  6.73120D-02

At iterate  110    f=  2.75133D+00    |proj g|=  8.32488D-02

At iterate  111    f=  2.75133D+00    |proj g|=  3.67756D-02

At iterate  112    f=  2.75132D+00    |proj g|=  2.61207D-02

At iterate  113    f=  2.75132D+00    |proj g|=  8.60840D-02

At iterate  114    f=  2.75132D+00    |proj g|=  1.68176D-02

At iterate  115    f=  2.75132D+00    |proj g|=  5.13819D-02

At iterate  116    f=  2.75132D+00    |proj g|=  3.10881D-02

At iterate  117    f=  2.75132D+00    |proj g|=  1.47933D-02

At iterate  118    f=  2.75132D+00    |proj g|=  1.69260D-02

At iterate  119    f=  2.75132D+00    |proj g|=  2.63674D-02

At iterate  120    f=  2.75132D+00    |proj g|=  2.72973D-02

At iterate  121    f=  2.75132D+00    |proj g|=  4.82158D-02

At iterate  122    f=  2.75131D+00    |proj g|=  2.16723D-02
```

```
At iterate  123    f=  2.75131D+00    |proj g|=  5.05363D-02

At iterate  124    f=  2.75131D+00    |proj g|=  2.45644D-01

At iterate  125    f=  2.75131D+00    |proj g|=  2.07737D-01

At iterate  126    f=  2.75130D+00    |proj g|=  7.82258D-02

At iterate  127    f=  2.75129D+00    |proj g|=  8.50367D-03

At iterate  128    f=  2.75129D+00    |proj g|=  2.39294D-01

At iterate  129    f=  2.75128D+00    |proj g|=  6.33866D-02

At iterate  130    f=  2.75128D+00    |proj g|=  3.31014D-02

At iterate  131    f=  2.75128D+00    |proj g|=  1.54830D-02

At iterate  132    f=  2.75128D+00    |proj g|=  3.67512D-02

At iterate  133    f=  2.75128D+00    |proj g|=  3.18299D-02

At iterate  134    f=  2.75128D+00    |proj g|=  5.74490D-02

At iterate  135    f=  2.75128D+00    |proj g|=  5.74490D-02

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9    135    191      1     0     0   5.745D-02   2.751D+00
  F =   2.7512750995121218

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(4, 0, 5) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10

At X0         0 variables are exactly at the bounds
```

```
At iterate    0    f=  2.81297D+00    |proj g|=  8.89035D-01

At iterate    1    f=  2.80355D+00    |proj g|=  3.66383D-01

At iterate    2    f=  2.80089D+00    |proj g|=  3.69488D-01

At iterate    3    f=  2.79731D+00    |proj g|=  1.08961D-01

At iterate    4    f=  2.79519D+00    |proj g|=  1.23531D-01

At iterate    5    f=  2.79372D+00    |proj g|=  1.17611D-01

At iterate    6    f=  2.79261D+00    |proj g|=  6.99341D-02

At iterate    7    f=  2.79102D+00    |proj g|=  1.40125D-01

At iterate    8    f=  2.79002D+00    |proj g|=  1.31621D-01

At iterate    9    f=  2.78860D+00    |proj g|=  1.45718D-01

At iterate   10    f=  2.78739D+00    |proj g|=  8.66813D-02

At iterate   11    f=  2.78615D+00    |proj g|=  6.12065D-02

At iterate   12    f=  2.78159D+00    |proj g|=  9.39432D-02

At iterate   13    f=  2.77914D+00    |proj g|=  1.39687D-01

At iterate   14    f=  2.77522D+00    |proj g|=  1.40131D-01

At iterate   15    f=  2.77283D+00    |proj g|=  8.31705D-02

At iterate   16    f=  2.77013D+00    |proj g|=  2.03871D-01

At iterate   17    f=  2.76808D+00    |proj g|=  1.01172D-01

At iterate   18    f=  2.76689D+00    |proj g|=  4.72626D-02

At iterate   19    f=  2.76645D+00    |proj g|=  5.16477D-02

At iterate   20    f=  2.76589D+00    |proj g|=  1.14702D-01

At iterate   21    f=  2.76422D+00    |proj g|=  4.78118D-02

At iterate   22    f=  2.76380D+00    |proj g|=  3.61732D-02

At iterate   23    f=  2.76316D+00    |proj g|=  6.13119D-02

At iterate   24    f=  2.76250D+00    |proj g|=  3.61190D-02

At iterate   25    f=  2.76090D+00    |proj g|=  9.32061D-02

At iterate   26    f=  2.75853D+00    |proj g|=  1.06137D-01
```

```
At iterate   27    f=  2.75789D+00    |proj g|=  9.05368D-02

At iterate   28    f=  2.75738D+00    |proj g|=  9.42566D-02

At iterate   29    f=  2.75688D+00    |proj g|=  5.69463D-02

At iterate   30    f=  2.75622D+00    |proj g|=  4.25206D-02

At iterate   31    f=  2.75583D+00    |proj g|=  3.86859D-02

At iterate   32    f=  2.75527D+00    |proj g|=  1.12935D-01

At iterate   33    f=  2.75449D+00    |proj g|=  9.38539D-02

At iterate   34    f=  2.75279D+00    |proj g|=  6.47674D-02

At iterate   35    f=  2.75169D+00    |proj g|=  4.56076D-02

At iterate   36    f=  2.75088D+00    |proj g|=  2.78359D-02
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   37    f=  2.75055D+00    |proj g|=  3.48993D-02

At iterate   38    f=  2.74985D+00    |proj g|=  3.06923D-02

At iterate   39    f=  2.74852D+00    |proj g|=  9.90531D-02

At iterate   40    f=  2.74719D+00    |proj g|=  1.00760D-01

At iterate   41    f=  2.74653D+00    |proj g|=  8.83618D-02

At iterate   42    f=  2.74605D+00    |proj g|=  4.57895D-02

At iterate   43    f=  2.74593D+00    |proj g|=  2.26520D-02

At iterate   44    f=  2.74587D+00    |proj g|=  1.04961D-02

At iterate   45    f=  2.74585D+00    |proj g|=  1.08752D-02

At iterate   46    f=  2.74578D+00    |proj g|=  1.59189D-02

At iterate   47    f=  2.74553D+00    |proj g|=  2.92739D-02
```

```
At iterate   48    f=  2.74533D+00    |proj g|=  5.33556D-02

At iterate   49    f=  2.74507D+00    |proj g|=  2.88179D-02

At iterate   50    f=  2.74494D+00    |proj g|=  1.12555D-02

At iterate   51    f=  2.74488D+00    |proj g|=  9.83757D-03

At iterate   52    f=  2.74486D+00    |proj g|=  5.04870D-03

At iterate   53    f=  2.74485D+00    |proj g|=  6.24955D-03

At iterate   54    f=  2.74485D+00    |proj g|=  3.34530D-03

At iterate   55    f=  2.74485D+00    |proj g|=  2.67582D-03

At iterate   56    f=  2.74485D+00    |proj g|=  2.16032D-03

At iterate   57    f=  2.74485D+00    |proj g|=  1.26216D-03

At iterate   58    f=  2.74485D+00    |proj g|=  1.61278D-03

At iterate   59    f=  2.74485D+00    |proj g|=  1.19901D-03

At iterate   60    f=  2.74485D+00    |proj g|=  2.98766D-04

At iterate   61    f=  2.74485D+00    |proj g|=  3.93657D-04

At iterate   62    f=  2.74485D+00    |proj g|=  3.70961D-04

At iterate   63    f=  2.74485D+00    |proj g|=  2.22831D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10     63     76      1     0     0   2.228D-04   2.745D+00
  F =   2.7448461474015380

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(4, 0, 6) ...
RUNNING THE L-BFGS-B CODE
```

```
           * * *

Machine precision = 2.220D-16
 N =           11     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.78895D+00    |proj g|=  2.13976D+00

At iterate    1    f=  2.77698D+00    |proj g|=  1.15685D+00

At iterate    2    f=  2.76779D+00    |proj g|=  1.93486D-01

At iterate    3    f=  2.76736D+00    |proj g|=  1.40423D-01

At iterate    4    f=  2.76706D+00    |proj g|=  1.23146D-01

At iterate    5    f=  2.76025D+00    |proj g|=  8.04964D-02

At iterate    6    f=  2.76018D+00    |proj g|=  1.24999D-01

At iterate    7    f=  2.76014D+00    |proj g|=  1.11154D-01

At iterate    8    f=  2.75823D+00    |proj g|=  1.08095D-01

At iterate    9    f=  2.75219D+00    |proj g|=  1.86005D-01

At iterate   10    f=  2.75188D+00    |proj g|=  2.39221D-01

At iterate   11    f=  2.75158D+00    |proj g|=  9.03728D-02

At iterate   12    f=  2.75126D+00    |proj g|=  8.32331D-02

At iterate   13    f=  2.74999D+00    |proj g|=  2.20400D-01
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   14    f=  2.74790D+00    |proj g|=  3.91295D-01

At iterate   15    f=  2.74538D+00    |proj g|=  3.75787D-01

At iterate   16    f=  2.74212D+00    |proj g|=  3.50035D-01

At iterate   17    f=  2.73995D+00    |proj g|=  1.08235D-01

At iterate   18    f=  2.73848D+00    |proj g|=  2.49646D-01
```

```
At iterate   19    f=  2.73762D+00    |proj g|=  3.99824D-01

At iterate   20    f=  2.73665D+00    |proj g|=  3.50786D-01

At iterate   21    f=  2.73647D+00    |proj g|=  2.05624D-01

At iterate   22    f=  2.73589D+00    |proj g|=  4.57704D-02

At iterate   23    f=  2.73559D+00    |proj g|=  1.17157D-01

At iterate   24    f=  2.73514D+00    |proj g|=  1.63458D-01

At iterate   25    f=  2.73505D+00    |proj g|=  1.87441D-01

At iterate   26    f=  2.73447D+00    |proj g|=  6.93614D-02

At iterate   27    f=  2.73409D+00    |proj g|=  1.15140D-01

At iterate   28    f=  2.73383D+00    |proj g|=  1.77145D-01

At iterate   29    f=  2.73345D+00    |proj g|=  1.57142D-01

At iterate   30    f=  2.73340D+00    |proj g|=  2.08877D-01

At iterate   31    f=  2.73309D+00    |proj g|=  1.25639D-01

At iterate   32    f=  2.73287D+00    |proj g|=  2.37710D-02

At iterate   33    f=  2.73282D+00    |proj g|=  2.57795D-02

At iterate   34    f=  2.73278D+00    |proj g|=  3.79568D-02

At iterate   35    f=  2.73271D+00    |proj g|=  7.37767D-02

At iterate   36    f=  2.73261D+00    |proj g|=  2.63476D-02

At iterate   37    f=  2.73256D+00    |proj g|=  1.76608D-02

At iterate   38    f=  2.73248D+00    |proj g|=  2.30758D-02

At iterate   39    f=  2.73233D+00    |proj g|=  3.14451D-02

At iterate   40    f=  2.73208D+00    |proj g|=  4.33635D-02

At iterate   41    f=  2.73148D+00    |proj g|=  8.75362D-02

At iterate   42    f=  2.73117D+00    |proj g|=  4.43067D-02

At iterate   43    f=  2.73034D+00    |proj g|=  6.60544D-02

At iterate   44    f=  2.72998D+00    |proj g|=  1.51177D-01

At iterate   45    f=  2.72909D+00    |proj g|=  9.12115D-02
```

```
At iterate   46    f=  2.72867D+00    |proj g|=  3.98801D-02

At iterate   47    f=  2.72814D+00    |proj g|=  6.24437D-02

At iterate   48    f=  2.72789D+00    |proj g|=  2.65714D-01

At iterate   49    f=  2.72750D+00    |proj g|=  1.39246D-01

At iterate   50    f=  2.72723D+00    |proj g|=  4.27363D-02

At iterate   51    f=  2.72718D+00    |proj g|=  3.60497D-02

At iterate   52    f=  2.72705D+00    |proj g|=  2.97618D-02

At iterate   53    f=  2.72670D+00    |proj g|=  6.74754D-02

At iterate   54    f=  2.72651D+00    |proj g|=  2.38867D-02

At iterate   55    f=  2.72637D+00    |proj g|=  2.19488D-02

At iterate   56    f=  2.72626D+00    |proj g|=  5.59722D-02

At iterate   57    f=  2.72604D+00    |proj g|=  3.90254D-02

At iterate   58    f=  2.72588D+00    |proj g|=  5.09224D-02

At iterate   59    f=  2.72561D+00    |proj g|=  1.30420D-01

At iterate   60    f=  2.72497D+00    |proj g|=  3.59198D-02

At iterate   61    f=  2.72446D+00    |proj g|=  5.91390D-02

At iterate   62    f=  2.72408D+00    |proj g|=  1.18185D-01

At iterate   63    f=  2.72375D+00    |proj g|=  6.65018D-02

At iterate   64    f=  2.72360D+00    |proj g|=  3.68201D-02

At iterate   65    f=  2.72336D+00    |proj g|=  3.79365D-02

At iterate   66    f=  2.72297D+00    |proj g|=  9.34886D-02

At iterate   67    f=  2.72248D+00    |proj g|=  1.43426D-01

At iterate   68    f=  2.72197D+00    |proj g|=  1.42485D-01

At iterate   69    f=  2.72188D+00    |proj g|=  1.45713D-01

At iterate   70    f=  2.72173D+00    |proj g|=  1.05797D-01

At iterate   71    f=  2.72152D+00    |proj g|=  2.41023D-02
```

```
At iterate   72    f=  2.72145D+00    |proj g|=  4.18423D-02

At iterate   73    f=  2.72139D+00    |proj g|=  5.47006D-02

At iterate   74    f=  2.72127D+00    |proj g|=  1.05965D-01

At iterate   75    f=  2.72096D+00    |proj g|=  1.16721D-01

At iterate   76    f=  2.71926D+00    |proj g|=  1.14315D-01

At iterate   77    f=  2.71899D+00    |proj g|=  1.19276D-01

At iterate   78    f=  2.71829D+00    |proj g|=  1.32769D-01

At iterate   79    f=  2.71772D+00    |proj g|=  1.55013D-02

At iterate   80    f=  2.71766D+00    |proj g|=  1.44519D-02

At iterate   81    f=  2.71763D+00    |proj g|=  9.31543D-03

At iterate   82    f=  2.71762D+00    |proj g|=  1.51109D-02

At iterate   83    f=  2.71761D+00    |proj g|=  5.93834D-03

At iterate   84    f=  2.71761D+00    |proj g|=  5.25243D-03

At iterate   85    f=  2.71760D+00    |proj g|=  6.79520D-03

At iterate   86    f=  2.71760D+00    |proj g|=  4.21930D-03

At iterate   87    f=  2.71759D+00    |proj g|=  4.65701D-03

At iterate   88    f=  2.71756D+00    |proj g|=  6.35823D-03

At iterate   89    f=  2.71755D+00    |proj g|=  1.53444D-03

At iterate   90    f=  2.71755D+00    |proj g|=  2.37733D-03

At iterate   91    f=  2.71755D+00    |proj g|=  1.82768D-03

At iterate   92    f=  2.71755D+00    |proj g|=  7.07834D-04

At iterate   93    f=  2.71755D+00    |proj g|=  9.85625D-04

At iterate   94    f=  2.71755D+00    |proj g|=  1.69111D-03

At iterate   95    f=  2.71755D+00    |proj g|=  2.29943D-03

At iterate   96    f=  2.71755D+00    |proj g|=  6.38712D-04

At iterate   97    f=  2.71755D+00    |proj g|=  4.75953D-04

At iterate   98    f=  2.71755D+00    |proj g|=  6.71384D-04
```

```
At iterate   99    f=  2.71755D+00    |proj g|=  3.10697D-04

At iterate  100    f=  2.71755D+00    |proj g|=  1.49128D-04

At iterate  101    f=  2.71755D+00    |proj g|=  1.90503D-04

At iterate  102    f=  2.71755D+00    |proj g|=  1.01374D-04

At iterate  103    f=  2.71755D+00    |proj g|=  9.09290D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   11    103    124      1     0     0   9.093D-05   2.718D+00
  F =   2.7175506366898325

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(5, 0, 0) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83431D+00    |proj g|=  1.21760D-04

At iterate    1    f=  2.83431D+00    |proj g|=  1.21718D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *
```

```
   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6      1     14      1     0     0   1.217D-04   2.834D+00
  F =   2.8343091334428996

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(5, 0, 1) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83581D+00    |proj g|=  4.44794D-02

At iterate    1    f=  2.83576D+00    |proj g|=  4.49151D-02

At iterate    2    f=  2.83552D+00    |proj g|=  3.76526D-02

At iterate    3    f=  2.83467D+00    |proj g|=  2.71487D-03

At iterate    4    f=  2.83467D+00    |proj g|=  1.82265D-03

At iterate    5    f=  2.83466D+00    |proj g|=  9.93297D-04

At iterate    6    f=  2.83466D+00    |proj g|=  1.17415D-03

At iterate    7    f=  2.83466D+00    |proj g|=  7.83400D-04

At iterate    8    f=  2.83466D+00    |proj g|=  9.07207D-04

At iterate    9    f=  2.83465D+00    |proj g|=  2.22046D-03

At iterate   10    f=  2.83463D+00    |proj g|=  6.25131D-03

At iterate   11    f=  2.82236D+00    |proj g|=  9.43382D-02

At iterate   12    f=  2.82211D+00    |proj g|=  1.04806D-01

At iterate   13    f=  2.82156D+00    |proj g|=  4.05413D-02

At iterate   14    f=  2.82080D+00    |proj g|=  7.79729D-02

At iterate   15    f=  2.82013D+00    |proj g|=  4.00592D-02

At iterate   16    f=  2.81983D+00    |proj g|=  3.02909D-02

At iterate   17    f=  2.81965D+00    |proj g|=  2.03801D-02

At iterate   18    f=  2.81931D+00    |proj g|=  3.92611D-02
```

```
At iterate   19    f=  2.81903D+00    |proj g|=  3.43133D-02

At iterate   20    f=  2.81853D+00    |proj g|=  1.96810D-02

At iterate   21    f=  2.81780D+00    |proj g|=  1.74837D-02
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   22    f=  2.81732D+00    |proj g|=  2.53498D-02

At iterate   23    f=  2.81691D+00    |proj g|=  1.79411D-02

At iterate   24    f=  2.81685D+00    |proj g|=  2.75453D-02

At iterate   25    f=  2.81676D+00    |proj g|=  4.15454D-03

At iterate   26    f=  2.81676D+00    |proj g|=  3.00318D-03

At iterate   27    f=  2.81675D+00    |proj g|=  2.48251D-03

At iterate   28    f=  2.81675D+00    |proj g|=  1.90388D-03

At iterate   29    f=  2.81675D+00    |proj g|=  8.04612D-04
```

```
At iterate   30    f=  2.81675D+00    |proj g|=  8.53870D-04

At iterate   31    f=  2.81675D+00    |proj g|=  1.01724D-04

At iterate   32    f=  2.81675D+00    |proj g|=  9.95104D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     32     49      1     0     0   9.951D-05   2.817D+00
  F =   2.8167524883553581

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(5, 0, 2) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83333D+00    |proj g|=  1.25773D-01

At iterate    1    f=  2.83307D+00    |proj g|=  1.71140D-01

At iterate    2    f=  2.83109D+00    |proj g|=  2.15363D-01

At iterate    3    f=  2.82584D+00    |proj g|=  8.73263D-02

At iterate    4    f=  2.82547D+00    |proj g|=  3.10884D-02

At iterate    5    f=  2.82452D+00    |proj g|=  1.09702D-01

At iterate    6    f=  2.82434D+00    |proj g|=  6.99597D-02

At iterate    7    f=  2.82427D+00    |proj g|=  1.93028D-02

At iterate    8    f=  2.82425D+00    |proj g|=  3.30826D-02

At iterate    9    f=  2.82423D+00    |proj g|=  5.30542D-02
```

```
At iterate   10    f=  2.82417D+00    |proj g|=  8.34544D-02

At iterate   11    f=  2.82406D+00    |proj g|=  1.13674D-01

At iterate   12    f=  2.82387D+00    |proj g|=  1.21863D-01

At iterate   13    f=  2.82356D+00    |proj g|=  8.95462D-02

At iterate   14    f=  2.82305D+00    |proj g|=  4.01572D-02

At iterate   15    f=  2.82259D+00    |proj g|=  1.55064D-01

At iterate   16    f=  2.82150D+00    |proj g|=  3.79114D-01

At iterate   17    f=  2.81970D+00    |proj g|=  7.32727D-01

At iterate   18    f=  2.81790D+00    |proj g|=  6.32372D-01

At iterate   19    f=  2.81660D+00    |proj g|=  2.92995D-01

At iterate   20    f=  2.81541D+00    |proj g|=  5.18933D-02

At iterate   21    f=  2.81540D+00    |proj g|=  4.11647D-02

At iterate   22    f=  2.81539D+00    |proj g|=  2.33499D-02

At iterate   23    f=  2.81538D+00    |proj g|=  1.34659D-02

At iterate   24    f=  2.81535D+00    |proj g|=  4.12226D-02

At iterate   25    f=  2.81531D+00    |proj g|=  6.08235D-02

At iterate   26    f=  2.81527D+00    |proj g|=  5.38031D-02

At iterate   27    f=  2.81523D+00    |proj g|=  3.12998D-02

At iterate   28    f=  2.81517D+00    |proj g|=  4.70255D-02

At iterate   29    f=  2.81511D+00    |proj g|=  8.33485D-02

At iterate   30    f=  2.81499D+00    |proj g|=  1.26910D-01

At iterate   31    f=  2.81485D+00    |proj g|=  1.21191D-01

At iterate   32    f=  2.81485D+00    |proj g|=  1.06134D-01

At iterate   33    f=  2.81475D+00    |proj g|=  4.74011D-02

At iterate   34    f=  2.81473D+00    |proj g|=  1.63393D-02

At iterate   35    f=  2.81473D+00    |proj g|=  3.35227D-02

At iterate   36    f=  2.81471D+00    |proj g|=  5.35975D-02
```

```
At iterate   37    f=  2.81469D+00    |proj g|=  7.57916D-02

At iterate   38    f=  2.81464D+00    |proj g|=  9.87160D-02

At iterate   39    f=  2.81455D+00    |proj g|=  1.02074D-01

At iterate   40    f=  2.81450D+00    |proj g|=  1.06316D-01

At iterate   41    f=  2.81425D+00    |proj g|=  2.38610D-01

At iterate   42    f=  2.81404D+00    |proj g|=  1.41209D-01

At iterate   43    f=  2.81393D+00    |proj g|=  7.90968D-02

At iterate   44    f=  2.81392D+00    |proj g|=  2.40028D-02

At iterate   45    f=  2.81391D+00    |proj g|=  2.46438D-02

At iterate   46    f=  2.81388D+00    |proj g|=  4.38102D-02

At iterate   47    f=  2.81383D+00    |proj g|=  3.87609D-02

At iterate   48    f=  2.81374D+00    |proj g|=  7.52321D-02

At iterate   49    f=  2.81345D+00    |proj g|=  6.56784D-02

At iterate   50    f=  2.81303D+00    |proj g|=  3.17953D-01

At iterate   51    f=  2.81263D+00    |proj g|=  1.67622D-01

At iterate   52    f=  2.81248D+00    |proj g|=  1.03921D-01

At iterate   53    f=  2.81243D+00    |proj g|=  5.75799D-02

At iterate   54    f=  2.81240D+00    |proj g|=  3.25356D-02

At iterate   55    f=  2.81238D+00    |proj g|=  5.64249D-02

At iterate   56    f=  2.81222D+00    |proj g|=  1.24806D-01

At iterate   57    f=  2.81199D+00    |proj g|=  1.54029D-01

At iterate   58    f=  2.81141D+00    |proj g|=  1.30963D-01

At iterate   59    f=  2.81138D+00    |proj g|=  2.84162D-01

At iterate   60    f=  2.81083D+00    |proj g|=  8.13866D-02

At iterate   61    f=  2.81057D+00    |proj g|=  6.77505D-02

At iterate   62    f=  2.81048D+00    |proj g|=  4.95346D-02
```

```
At iterate   63    f=  2.81048D+00    |proj g|=  7.47186D-02

At iterate   64    f=  2.81047D+00    |proj g|=  3.13375D-02

At iterate   65    f=  2.81046D+00    |proj g|=  9.85191D-03

At iterate   66    f=  2.81046D+00    |proj g|=  9.39221D-03

At iterate   67    f=  2.81046D+00    |proj g|=  1.11718D-02

At iterate   68    f=  2.81045D+00    |proj g|=  2.20047D-02

At iterate   69    f=  2.81045D+00    |proj g|=  1.90922D-02

At iterate   70    f=  2.81045D+00    |proj g|=  1.00249D-02

At iterate   71    f=  2.81044D+00    |proj g|=  2.91105D-03

At iterate   72    f=  2.81044D+00    |proj g|=  6.22800D-03

At iterate   73    f=  2.81044D+00    |proj g|=  7.23407D-03

At iterate   74    f=  2.81044D+00    |proj g|=  6.86773D-03

At iterate   75    f=  2.81044D+00    |proj g|=  7.09516D-03

At iterate   76    f=  2.81044D+00    |proj g|=  3.05690D-03

At iterate   77    f=  2.81044D+00    |proj g|=  3.11519D-03

At iterate   78    f=  2.81044D+00    |proj g|=  5.36625D-03

At iterate   79    f=  2.81044D+00    |proj g|=  6.67786D-03

At iterate   80    f=  2.81044D+00    |proj g|=  9.66764D-03

At iterate   81    f=  2.81044D+00    |proj g|=  1.62206D-02

At iterate   82    f=  2.81044D+00    |proj g|=  1.60608D-02

At iterate   83    f=  2.81044D+00    |proj g|=  2.08993D-02

At iterate   84    f=  2.81043D+00    |proj g|=  1.34248D-02

At iterate   85    f=  2.81043D+00    |proj g|=  1.01322D-02

At iterate   86    f=  2.81043D+00    |proj g|=  8.15522D-04

At iterate   87    f=  2.81043D+00    |proj g|=  2.14249D-03

At iterate   88    f=  2.81043D+00    |proj g|=  6.89098D-04

At iterate   89    f=  2.81043D+00    |proj g|=  6.31176D-04
```

```
At iterate   90    f=  2.81043D+00    |proj g|=  6.29589D-04

At iterate   91    f=  2.81043D+00    |proj g|=  1.53612D-03

At iterate   92    f=  2.81043D+00    |proj g|=  2.81732D-03

At iterate   93    f=  2.81043D+00    |proj g|=  1.74862D-03

At iterate   94    f=  2.81043D+00    |proj g|=  4.99599D-03

At iterate   95    f=  2.81043D+00    |proj g|=  1.93501D-03

At iterate   96    f=  2.81043D+00    |proj g|=  8.66352D-04

At iterate   97    f=  2.81043D+00    |proj g|=  6.52869D-04

At iterate   98    f=  2.81043D+00    |proj g|=  1.12885D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     98    115      1     0     0   1.129D-03   2.810D+00
  F =   2.8104330240470694

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(5, 0, 3) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  3.42889D+00    |proj g|=  1.33544D+00

At iterate    1    f=  3.41991D+00    |proj g|=  1.03032D+00

At iterate    2    f=  3.38688D+00    |proj g|=  8.13358D-01

At iterate    3    f=  3.29712D+00    |proj g|=  1.22630D+00
```

```
At iterate    4    f=  3.24804D+00    |proj g|=  8.50070D-01

At iterate    5    f=  3.17850D+00    |proj g|=  1.08431D+00

At iterate    6    f=  3.12169D+00    |proj g|=  1.16530D+00

At iterate    7    f=  3.06701D+00    |proj g|=  9.00108D-01

At iterate    8    f=  3.06341D+00    |proj g|=  6.28945D+00

At iterate    9    f=  3.04932D+00    |proj g|=  4.54685D+00

At iterate   10    f=  3.03663D+00    |proj g|=  2.31370D+00

At iterate   11    f=  3.02577D+00    |proj g|=  2.18610D+00

At iterate   12    f=  2.96666D+00    |proj g|=  1.37785D+00

At iterate   13    f=  2.94032D+00    |proj g|=  1.30019D+00

At iterate   14    f=  2.88678D+00    |proj g|=  2.21868D+00

At iterate   15    f=  2.86755D+00    |proj g|=  8.08325D-01

At iterate   16    f=  2.84696D+00    |proj g|=  1.28791D+00

At iterate   17    f=  2.83729D+00    |proj g|=  1.37604D+00
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   18    f=  2.82508D+00    |proj g|=  7.22783D-01

At iterate   19    f=  2.82428D+00    |proj g|=  2.21714D-01

At iterate   20    f=  2.82407D+00    |proj g|=  1.58623D-01

At iterate   21    f=  2.82406D+00    |proj g|=  4.41980D-02

At iterate   22    f=  2.82406D+00    |proj g|=  4.40093D-02

At iterate   23    f=  2.82400D+00    |proj g|=  6.39504D-02

At iterate   24    f=  2.82359D+00    |proj g|=  1.93346D-01

At iterate   25    f=  2.82205D+00    |proj g|=  1.06620D+00
```

```
At iterate   26    f=  2.82125D+00    |proj g|=  2.55135D-01

At iterate   27    f=  2.82071D+00    |proj g|=  3.51162D-01

At iterate   28    f=  2.81966D+00    |proj g|=  1.04048D+00

At iterate   29    f=  2.81864D+00    |proj g|=  8.45517D-01

At iterate   30    f=  2.81847D+00    |proj g|=  7.43174D-02

At iterate   31    f=  2.81841D+00    |proj g|=  2.05655D-01

At iterate   32    f=  2.81839D+00    |proj g|=  6.96625D-02

At iterate   33    f=  2.81839D+00    |proj g|=  4.18015D-02

At iterate   34    f=  2.81838D+00    |proj g|=  4.81319D-02

At iterate   35    f=  2.81838D+00    |proj g|=  4.58336D-02

At iterate   36    f=  2.81835D+00    |proj g|=  3.17846D-01

At iterate   37    f=  2.81828D+00    |proj g|=  1.30380D-01

At iterate   38    f=  2.81808D+00    |proj g|=  5.18239D-01

At iterate   39    f=  2.81788D+00    |proj g|=  7.25951D-01

At iterate   40    f=  2.81723D+00    |proj g|=  7.55475D-01

At iterate   41    f=  2.81710D+00    |proj g|=  1.63428D+00

At iterate   42    f=  2.81623D+00    |proj g|=  1.45465D+00

At iterate   43    f=  2.81562D+00    |proj g|=  1.22152D+00

At iterate   44    f=  2.81518D+00    |proj g|=  1.22228D+00

At iterate   45    f=  2.81482D+00    |proj g|=  1.22712D+00

At iterate   46    f=  2.81437D+00    |proj g|=  4.80700D-01

At iterate   47    f=  2.81436D+00    |proj g|=  3.49220D-01

At iterate   48    f=  2.81430D+00    |proj g|=  2.56586D-01

At iterate   49    f=  2.81427D+00    |proj g|=  2.17095D-01

At iterate   50    f=  2.81425D+00    |proj g|=  7.93229D-02

At iterate   51    f=  2.81425D+00    |proj g|=  4.81745D-02

At iterate   52    f=  2.81424D+00    |proj g|=  3.44208D-02
```

```
At iterate   53    f=  2.81424D+00    |proj g|=  1.42827D-02

At iterate   54    f=  2.81424D+00    |proj g|=  1.42835D-02

At iterate   55    f=  2.81424D+00    |proj g|=  6.21654D-02

At iterate   56    f=  2.81423D+00    |proj g|=  1.15924D-01

At iterate   57    f=  2.81420D+00    |proj g|=  2.12798D-01

At iterate   58    f=  2.81414D+00    |proj g|=  3.57556D-01

At iterate   59    f=  2.81399D+00    |proj g|=  6.29026D-01

At iterate   60    f=  2.81369D+00    |proj g|=  5.68974D-01

At iterate   61    f=  2.81361D+00    |proj g|=  1.19516D+00

At iterate   62    f=  2.81322D+00    |proj g|=  9.34534D-01

At iterate   63    f=  2.81275D+00    |proj g|=  1.71869D-01

At iterate   64    f=  2.81261D+00    |proj g|=  1.12219D-01

At iterate   65    f=  2.81259D+00    |proj g|=  2.22060D-01

At iterate   66    f=  2.81254D+00    |proj g|=  1.11668D-01

At iterate   67    f=  2.81246D+00    |proj g|=  6.17015D-02

At iterate   68    f=  2.81242D+00    |proj g|=  3.96087D-02

At iterate   69    f=  2.81241D+00    |proj g|=  3.98177D-02

At iterate   70    f=  2.81241D+00    |proj g|=  2.04283D-02

At iterate   71    f=  2.81241D+00    |proj g|=  6.31852D-03

At iterate   72    f=  2.81241D+00    |proj g|=  3.34237D-02

At iterate   73    f=  2.81241D+00    |proj g|=  2.84360D-02

At iterate   74    f=  2.81241D+00    |proj g|=  8.10270D-02

At iterate   75    f=  2.81241D+00    |proj g|=  9.88350D-02

At iterate   76    f=  2.81240D+00    |proj g|=  1.16949D-01

At iterate   77    f=  2.81239D+00    |proj g|=  2.27988D-01

At iterate   78    f=  2.81236D+00    |proj g|=  1.62223D-01
```

```
At iterate   79    f=  2.81231D+00    |proj g|=  2.12348D-01

At iterate   80    f=  2.81223D+00    |proj g|=  3.17742D-01

At iterate   81    f=  2.81210D+00    |proj g|=  3.55226D-01

At iterate   82    f=  2.81188D+00    |proj g|=  2.65176D-01

At iterate   83    f=  2.81166D+00    |proj g|=  2.77799D-01

At iterate   84    f=  2.81154D+00    |proj g|=  7.93200D-02

At iterate   85    f=  2.81151D+00    |proj g|=  2.64507D-01

At iterate   86    f=  2.81148D+00    |proj g|=  1.47752D-01

At iterate   87    f=  2.81146D+00    |proj g|=  8.98386D-02

At iterate   88    f=  2.81142D+00    |proj g|=  1.79744D-01

At iterate   89    f=  2.81138D+00    |proj g|=  1.75765D-01

At iterate   90    f=  2.81137D+00    |proj g|=  4.74951D-02

At iterate   91    f=  2.81136D+00    |proj g|=  3.03867D-02

At iterate   92    f=  2.81135D+00    |proj g|=  6.52302D-02

At iterate   93    f=  2.81134D+00    |proj g|=  1.19043D-01

At iterate   94    f=  2.81133D+00    |proj g|=  1.05691D-01

At iterate   95    f=  2.81133D+00    |proj g|=  3.32852D-02

At iterate   96    f=  2.81133D+00    |proj g|=  1.91345D-02

At iterate   97    f=  2.81133D+00    |proj g|=  1.24075D-02

At iterate   98    f=  2.81133D+00    |proj g|=  5.43530D-03

At iterate   99    f=  2.81133D+00    |proj g|=  9.10620D-03

At iterate  100    f=  2.81133D+00    |proj g|=  1.35171D-02

At iterate  101    f=  2.81133D+00    |proj g|=  1.16980D-02

At iterate  102    f=  2.81133D+00    |proj g|=  1.76514D-02

At iterate  103    f=  2.81133D+00    |proj g|=  1.00154D-02

At iterate  104    f=  2.81133D+00    |proj g|=  2.36463D-03

At iterate  105    f=  2.81133D+00    |proj g|=  4.16128D-03
```

```
At iterate  106    f=  2.81133D+00    |proj g|=  6.46669D-03

At iterate  107    f=  2.81133D+00    |proj g|=  1.08088D-02

At iterate  108    f=  2.81133D+00    |proj g|=  1.23829D-02

At iterate  109    f=  2.81133D+00    |proj g|=  3.04234D-02

At iterate  110    f=  2.81133D+00    |proj g|=  2.70531D-02

At iterate  111    f=  2.81132D+00    |proj g|=  1.60687D-02

At iterate  112    f=  2.81132D+00    |proj g|=  3.44023D-02

At iterate  113    f=  2.81132D+00    |proj g|=  4.15760D-02

At iterate  114    f=  2.81132D+00    |proj g|=  2.19196D-02

At iterate  115    f=  2.81132D+00    |proj g|=  4.75353D-02

At iterate  116    f=  2.81132D+00    |proj g|=  1.48912D-02

At iterate  117    f=  2.81132D+00    |proj g|=  6.65640D-03

At iterate  118    f=  2.81132D+00    |proj g|=  1.90309D-02

At iterate  119    f=  2.81132D+00    |proj g|=  3.19884D-02

At iterate  120    f=  2.81132D+00    |proj g|=  4.96045D-02

At iterate  121    f=  2.81131D+00    |proj g|=  2.28286D-02

At iterate  122    f=  2.81131D+00    |proj g|=  1.50551D-02

At iterate  123    f=  2.81131D+00    |proj g|=  3.12588D-02

At iterate  124    f=  2.81131D+00    |proj g|=  5.12325D-02

At iterate  125    f=  2.81131D+00    |proj g|=  7.35204D-02

At iterate  126    f=  2.81131D+00    |proj g|=  8.04990D-02

At iterate  127    f=  2.81131D+00    |proj g|=  7.69126D-02

At iterate  128    f=  2.81131D+00    |proj g|=  5.64701D-02

At iterate  129    f=  2.81130D+00    |proj g|=  3.77525D-02

At iterate  130    f=  2.81130D+00    |proj g|=  1.45331D-02

At iterate  131    f=  2.81130D+00    |proj g|=  3.05749D-02
```

```
At iterate  132    f=  2.81130D+00    |proj g|=  1.00941D-01

At iterate  133    f=  2.81130D+00    |proj g|=  7.28957D-02

At iterate  134    f=  2.81130D+00    |proj g|=  2.56103D-02

At iterate  135    f=  2.81130D+00    |proj g|=  3.28948D-02

At iterate  136    f=  2.81129D+00    |proj g|=  5.22177D-02

At iterate  137    f=  2.81129D+00    |proj g|=  7.65305D-02

At iterate  138    f=  2.81128D+00    |proj g|=  1.21098D-01

At iterate  139    f=  2.81128D+00    |proj g|=  1.58665D-01

At iterate  140    f=  2.81127D+00    |proj g|=  1.00107D-01

At iterate  141    f=  2.81127D+00    |proj g|=  2.46124D-02

At iterate  142    f=  2.81127D+00    |proj g|=  2.56148D-02

At iterate  143    f=  2.81127D+00    |proj g|=  4.43853D-02

At iterate  144    f=  2.81126D+00    |proj g|=  3.69229D-02

At iterate  145    f=  2.81126D+00    |proj g|=  5.45076D-02

At iterate  146    f=  2.81126D+00    |proj g|=  2.80700D-02

At iterate  147    f=  2.81126D+00    |proj g|=  1.61497D-02

At iterate  148    f=  2.81126D+00    |proj g|=  4.61755D-02

At iterate  149    f=  2.81125D+00    |proj g|=  8.12042D-02

At iterate  150    f=  2.81125D+00    |proj g|=  1.00935D-01

At iterate  151    f=  2.81124D+00    |proj g|=  1.72554D-01

At iterate  152    f=  2.81124D+00    |proj g|=  5.18845D-02

At iterate  153    f=  2.81123D+00    |proj g|=  3.88428D-02

At iterate  154    f=  2.81123D+00    |proj g|=  8.88646D-02

At iterate  155    f=  2.81122D+00    |proj g|=  1.92687D-02

At iterate  156    f=  2.81122D+00    |proj g|=  1.92122D-02

At iterate  157    f=  2.81122D+00    |proj g|=  1.14822D-01

At iterate  158    f=  2.81122D+00    |proj g|=  2.77336D-02
```

```
At iterate  159    f=  2.81122D+00    |proj g|=  1.87269D-02

At iterate  160    f=  2.81121D+00    |proj g|=  5.13178D-02

At iterate  161    f=  2.81121D+00    |proj g|=  4.52967D-02

At iterate  162    f=  2.81121D+00    |proj g|=  3.55639D-02

At iterate  163    f=  2.81121D+00    |proj g|=  1.15858D-02

At iterate  164    f=  2.81121D+00    |proj g|=  4.52566D-03

At iterate  165    f=  2.81121D+00    |proj g|=  3.82764D-03

At iterate  166    f=  2.81121D+00    |proj g|=  4.75306D-03

At iterate  167    f=  2.81121D+00    |proj g|=  6.63530D-03

At iterate  168    f=  2.81121D+00    |proj g|=  8.71538D-03

At iterate  169    f=  2.81121D+00    |proj g|=  8.71538D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9    169    231      1     0     0   8.715D-03   2.811D+00
  F =   2.8112119101884496

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(5, 0, 4) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.81587D+00    |proj g|=  3.91817D-01

At iterate    1    f=  2.79732D+00    |proj g|=  3.69131D-01
```

```
At iterate    2    f=  2.79542D+00    |proj g|=  9.15188D-02

At iterate    3    f=  2.79530D+00    |proj g|=  8.79233D-02

At iterate    4    f=  2.79486D+00    |proj g|=  6.20366D-02

At iterate    5    f=  2.79421D+00    |proj g|=  4.84567D-02

At iterate    6    f=  2.79298D+00    |proj g|=  6.11423D-02

At iterate    7    f=  2.79122D+00    |proj g|=  5.81315D-02

At iterate    8    f=  2.78985D+00    |proj g|=  1.06905D-01

At iterate    9    f=  2.78890D+00    |proj g|=  5.83167D-02

At iterate   10    f=  2.78667D+00    |proj g|=  1.08628D-01

At iterate   11    f=  2.78537D+00    |proj g|=  2.03675D-01

At iterate   12    f=  2.77549D+00    |proj g|=  2.07608D+00

At iterate   13    f=  2.77430D+00    |proj g|=  2.17058D+00

At iterate   14    f=  2.76979D+00    |proj g|=  6.04962D-01

At iterate   15    f=  2.76850D+00    |proj g|=  4.52740D-01

At iterate   16    f=  2.76810D+00    |proj g|=  1.75636D-01

At iterate   17    f=  2.76740D+00    |proj g|=  5.35835D-01

At iterate   18    f=  2.76718D+00    |proj g|=  3.80654D-01

At iterate   19    f=  2.76703D+00    |proj g|=  1.35421D-01

At iterate   20    f=  2.76697D+00    |proj g|=  1.61889D-01

At iterate   21    f=  2.76688D+00    |proj g|=  3.17625D-01
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   22    f=  2.76676D+00    |proj g|=  4.40745D-01
```

```
At iterate   23    f=  2.76660D+00    |proj g|=  4.03211D-01

At iterate   24    f=  2.76628D+00    |proj g|=  3.33061D-01

At iterate   25    f=  2.76570D+00    |proj g|=  5.04629D-01

At iterate   26    f=  2.76551D+00    |proj g|=  1.66907D-01

At iterate   27    f=  2.76426D+00    |proj g|=  1.44338D-01

At iterate   28    f=  2.76196D+00    |proj g|=  1.13906D-01

At iterate   29    f=  2.76137D+00    |proj g|=  7.46253D-01

At iterate   30    f=  2.75992D+00    |proj g|=  5.12215D-01

At iterate   31    f=  2.75929D+00    |proj g|=  2.28849D-01

At iterate   32    f=  2.75889D+00    |proj g|=  5.86048D-01

At iterate   33    f=  2.75838D+00    |proj g|=  1.42972D-01

At iterate   34    f=  2.75783D+00    |proj g|=  1.56021D-01

At iterate   35    f=  2.75591D+00    |proj g|=  4.92536D-01

At iterate   36    f=  2.75434D+00    |proj g|=  5.74079D-01

At iterate   37    f=  2.75427D+00    |proj g|=  4.65838D-01

At iterate   38    f=  2.75359D+00    |proj g|=  4.11121D-01

At iterate   39    f=  2.75293D+00    |proj g|=  2.61682D-01

At iterate   40    f=  2.75253D+00    |proj g|=  1.08525D-01

At iterate   41    f=  2.75246D+00    |proj g|=  2.57930D-02

At iterate   42    f=  2.75244D+00    |proj g|=  2.04534D-02

At iterate   43    f=  2.75243D+00    |proj g|=  6.23263D-02

At iterate   44    f=  2.75242D+00    |proj g|=  4.71002D-02

At iterate   45    f=  2.75240D+00    |proj g|=  2.31087D-02

At iterate   46    f=  2.75237D+00    |proj g|=  4.60729D-02

At iterate   47    f=  2.75230D+00    |proj g|=  9.50156D-02

At iterate   48    f=  2.75218D+00    |proj g|=  9.09359D-02
```

```
At iterate   49    f=  2.75212D+00    |proj g|=  1.79061D-01

At iterate   50    f=  2.75195D+00    |proj g|=  1.46366D-01

At iterate   51    f=  2.75147D+00    |proj g|=  5.53564D-02

At iterate   52    f=  2.75138D+00    |proj g|=  7.26820D-02

At iterate   53    f=  2.75126D+00    |proj g|=  6.25833D-02

At iterate   54    f=  2.75125D+00    |proj g|=  1.04665D-01

At iterate   55    f=  2.75116D+00    |proj g|=  6.44038D-02

At iterate   56    f=  2.75103D+00    |proj g|=  5.26776D-02

At iterate   57    f=  2.75101D+00    |proj g|=  4.31599D-02

At iterate   58    f=  2.75097D+00    |proj g|=  2.38345D-02

At iterate   59    f=  2.75095D+00    |proj g|=  1.19585D-02

At iterate   60    f=  2.75095D+00    |proj g|=  2.67232D-02

At iterate   61    f=  2.75094D+00    |proj g|=  2.32723D-02

At iterate   62    f=  2.75091D+00    |proj g|=  9.70143D-03

At iterate   63    f=  2.75088D+00    |proj g|=  1.43992D-02

At iterate   64    f=  2.75087D+00    |proj g|=  4.19006D-02

At iterate   65    f=  2.75084D+00    |proj g|=  2.73569D-02

At iterate   66    f=  2.75083D+00    |proj g|=  8.20692D-02

At iterate   67    f=  2.75080D+00    |proj g|=  1.73956D-02

At iterate   68    f=  2.75079D+00    |proj g|=  1.72748D-02

At iterate   69    f=  2.75077D+00    |proj g|=  2.36906D-02

At iterate   70    f=  2.75068D+00    |proj g|=  2.16748D-02

At iterate   71    f=  2.75067D+00    |proj g|=  5.93531D-02

At iterate   72    f=  2.75058D+00    |proj g|=  4.85467D-02

At iterate   73    f=  2.75040D+00    |proj g|=  2.39616D-02

At iterate   74    f=  2.75023D+00    |proj g|=  2.40596D-02

At iterate   75    f=  2.74999D+00    |proj g|=  2.87633D-02
```

```
At iterate   76    f=  2.74998D+00    |proj g|=  2.74979D-02

At iterate   77    f=  2.74979D+00    |proj g|=  4.69260D-02

At iterate   78    f=  2.74975D+00    |proj g|=  7.79436D-02

At iterate   79    f=  2.74966D+00    |proj g|=  1.40120D-02

At iterate   80    f=  2.74961D+00    |proj g|=  1.02860D-02

At iterate   81    f=  2.74955D+00    |proj g|=  4.17662D-02

At iterate   82    f=  2.74953D+00    |proj g|=  3.63701D-02

At iterate   83    f=  2.74949D+00    |proj g|=  1.44583D-02

At iterate   84    f=  2.74946D+00    |proj g|=  1.56106D-02

At iterate   85    f=  2.74944D+00    |proj g|=  1.89097D-02

At iterate   86    f=  2.74939D+00    |proj g|=  3.14959D-02

At iterate   87    f=  2.74928D+00    |proj g|=  2.03054D-02

At iterate   88    f=  2.74924D+00    |proj g|=  1.32037D-01

At iterate   89    f=  2.74915D+00    |proj g|=  6.66563D-02

At iterate   90    f=  2.74880D+00    |proj g|=  9.93871D-02

At iterate   91    f=  2.74870D+00    |proj g|=  6.06965D-02

At iterate   92    f=  2.74867D+00    |proj g|=  3.95452D-02

At iterate   93    f=  2.74866D+00    |proj g|=  3.69203D-02

At iterate   94    f=  2.74858D+00    |proj g|=  9.46133D-02

At iterate   95    f=  2.74835D+00    |proj g|=  1.33867D-01

At iterate   96    f=  2.74805D+00    |proj g|=  1.74507D-01

At iterate   97    f=  2.74788D+00    |proj g|=  1.19005D-01

At iterate   98    f=  2.74785D+00    |proj g|=  8.15356D-02

At iterate   99    f=  2.74785D+00    |proj g|=  9.01165D-03

At iterate  100    f=  2.74785D+00    |proj g|=  1.27838D-02

At iterate  101    f=  2.74785D+00    |proj g|=  4.65223D-02
```

```
At iterate  102    f=  2.74784D+00    |proj g|=  7.03006D-02

At iterate  103    f=  2.74783D+00    |proj g|=  8.93091D-02

At iterate  104    f=  2.74781D+00    |proj g|=  9.34963D-02

At iterate  105    f=  2.74780D+00    |proj g|=  7.47125D-02

At iterate  106    f=  2.74778D+00    |proj g|=  9.38956D-02

At iterate  107    f=  2.74776D+00    |proj g|=  8.25062D-02

At iterate  108    f=  2.74776D+00    |proj g|=  1.06667D-01

At iterate  109    f=  2.74774D+00    |proj g|=  5.28538D-02

At iterate  110    f=  2.74773D+00    |proj g|=  3.45724D-02

At iterate  111    f=  2.74773D+00    |proj g|=  9.59237D-02

At iterate  112    f=  2.74772D+00    |proj g|=  6.22972D-03

At iterate  113    f=  2.74772D+00    |proj g|=  2.56979D-02

At iterate  114    f=  2.74772D+00    |proj g|=  4.59954D-02

At iterate  115    f=  2.74771D+00    |proj g|=  3.81955D-02

At iterate  116    f=  2.74771D+00    |proj g|=  5.60400D-02

At iterate  117    f=  2.74771D+00    |proj g|=  1.34741D-02

At iterate  118    f=  2.74771D+00    |proj g|=  1.68262D-02

At iterate  119    f=  2.74771D+00    |proj g|=  8.86511D-03

At iterate  120    f=  2.74771D+00    |proj g|=  1.10862D-02

At iterate  121    f=  2.74771D+00    |proj g|=  2.63937D-03

At iterate  122    f=  2.74770D+00    |proj g|=  1.55006D-02

At iterate  123    f=  2.74770D+00    |proj g|=  1.07073D-02

At iterate  124    f=  2.74770D+00    |proj g|=  2.68388D-03

At iterate  125    f=  2.74770D+00    |proj g|=  2.49004D-03

At iterate  126    f=  2.74770D+00    |proj g|=  5.07831D-03

At iterate  127    f=  2.74770D+00    |proj g|=  8.73291D-03

At iterate  128    f=  2.74770D+00    |proj g|=  1.58888D-02
```

```
At iterate  129    f=  2.74770D+00    |proj g|=  1.00932D-02

At iterate  130    f=  2.74770D+00    |proj g|=  1.41137D-02

At iterate  131    f=  2.74770D+00    |proj g|=  2.96912D-02

At iterate  132    f=  2.74770D+00    |proj g|=  4.68136D-02

At iterate  133    f=  2.74770D+00    |proj g|=  3.73269D-02

At iterate  134    f=  2.74770D+00    |proj g|=  2.96623D-02

At iterate  135    f=  2.74770D+00    |proj g|=  3.79060D-03

At iterate  136    f=  2.74770D+00    |proj g|=  2.98364D-03

At iterate  137    f=  2.74770D+00    |proj g|=  2.46251D-03

At iterate  138    f=  2.74770D+00    |proj g|=  2.19655D-03

At iterate  139    f=  2.74770D+00    |proj g|=  2.38827D-03

At iterate  140    f=  2.74770D+00    |proj g|=  2.29523D-03

At iterate  141    f=  2.74769D+00    |proj g|=  1.27149D-02

At iterate  142    f=  2.74769D+00    |proj g|=  8.61064D-03

At iterate  143    f=  2.74769D+00    |proj g|=  3.11404D-03

At iterate  144    f=  2.74769D+00    |proj g|=  1.60145D-03

At iterate  145    f=  2.74769D+00    |proj g|=  2.65283D-03

At iterate  146    f=  2.74769D+00    |proj g|=  3.00186D-03

At iterate  147    f=  2.74769D+00    |proj g|=  3.92813D-03

At iterate  148    f=  2.74769D+00    |proj g|=  4.93960D-03

At iterate  149    f=  2.74769D+00    |proj g|=  5.41426D-03

At iterate  150    f=  2.74769D+00    |proj g|=  1.08357D-02

At iterate  151    f=  2.74769D+00    |proj g|=  7.07352D-03

At iterate  152    f=  2.74769D+00    |proj g|=  2.19331D-02

At iterate  153    f=  2.74769D+00    |proj g|=  4.02807D-03

At iterate  154    f=  2.74769D+00    |proj g|=  3.55318D-03
```

```
At iterate  155    f=  2.74769D+00    |proj g|=  2.11859D-03

At iterate  156    f=  2.74769D+00    |proj g|=  4.88675D-03

At iterate  157    f=  2.74769D+00    |proj g|=  4.53397D-03

At iterate  158    f=  2.74769D+00    |proj g|=  1.58424D-03

At iterate  159    f=  2.74769D+00    |proj g|=  1.38980D-03

At iterate  160    f=  2.74769D+00    |proj g|=  1.69449D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10    160    203      1     0     0   1.694D-03   2.748D+00
  F =   2.7476924247375800

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(5, 0, 5) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           11     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83143D+00    |proj g|=  1.66970D+00

At iterate    1    f=  2.80601D+00    |proj g|=  2.58461D-01

At iterate    2    f=  2.80358D+00    |proj g|=  6.14297D-01

At iterate    3    f=  2.79705D+00    |proj g|=  3.86876D-01

At iterate    4    f=  2.79361D+00    |proj g|=  2.25935D-01

At iterate    5    f=  2.79261D+00    |proj g|=  6.01949D-02

At iterate    6    f=  2.79154D+00    |proj g|=  1.77348D-01
```

```
At iterate    7    f=  2.78838D+00    |proj g|=  4.29272D-01

At iterate    8    f=  2.78639D+00    |proj g|=  6.00926D-01

At iterate    9    f=  2.78376D+00    |proj g|=  5.22798D-01

At iterate   10    f=  2.78010D+00    |proj g|=  1.51669D-01

At iterate   11    f=  2.77975D+00    |proj g|=  1.69857D-01

At iterate   12    f=  2.77709D+00    |proj g|=  2.39240D-01

At iterate   13    f=  2.77258D+00    |proj g|=  1.40170D-01

At iterate   14    f=  2.77049D+00    |proj g|=  9.67588D-02

At iterate   15    f=  2.76797D+00    |proj g|=  1.48233D-01
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   16    f=  2.76522D+00    |proj g|=  1.99647D-01

At iterate   17    f=  2.76296D+00    |proj g|=  6.94027D-01

At iterate   18    f=  2.75870D+00    |proj g|=  2.10871D-01

At iterate   19    f=  2.75451D+00    |proj g|=  2.35413D-01

At iterate   20    f=  2.75361D+00    |proj g|=  1.72720D-01

At iterate   21    f=  2.75297D+00    |proj g|=  8.70508D-02

At iterate   22    f=  2.75279D+00    |proj g|=  1.26422D-01

At iterate   23    f=  2.75246D+00    |proj g|=  9.67144D-02

At iterate   24    f=  2.75197D+00    |proj g|=  5.51320D-02

At iterate   25    f=  2.75097D+00    |proj g|=  8.39278D-02

At iterate   26    f=  2.74971D+00    |proj g|=  1.51720D-01

At iterate   27    f=  2.74849D+00    |proj g|=  1.07106D-01

At iterate   28    f=  2.74751D+00    |proj g|=  7.75030D-02

At iterate   29    f=  2.74716D+00    |proj g|=  7.26879D-02
```

```
At iterate   30    f=  2.74706D+00    |proj g|=  1.70222D-01

At iterate   31    f=  2.74679D+00    |proj g|=  8.98423D-02

At iterate   32    f=  2.74661D+00    |proj g|=  4.88639D-02

At iterate   33    f=  2.74650D+00    |proj g|=  5.14794D-02

At iterate   34    f=  2.74622D+00    |proj g|=  1.16280D-01

At iterate   35    f=  2.74573D+00    |proj g|=  1.76184D-01

At iterate   36    f=  2.74486D+00    |proj g|=  2.07210D-01

At iterate   37    f=  2.74353D+00    |proj g|=  2.28764D-01

At iterate   38    f=  2.74212D+00    |proj g|=  7.23696D-02

At iterate   39    f=  2.74184D+00    |proj g|=  3.94186D-02

At iterate   40    f=  2.74159D+00    |proj g|=  7.61374D-02

At iterate   41    f=  2.74088D+00    |proj g|=  6.80004D-02

At iterate   42    f=  2.74080D+00    |proj g|=  9.90195D-02

At iterate   43    f=  2.74072D+00    |proj g|=  6.54947D-02

At iterate   44    f=  2.74064D+00    |proj g|=  3.91317D-02

At iterate   45    f=  2.74055D+00    |proj g|=  2.64864D-02

At iterate   46    f=  2.74051D+00    |proj g|=  2.97170D-02

At iterate   47    f=  2.74047D+00    |proj g|=  1.66084D-02

At iterate   48    f=  2.74036D+00    |proj g|=  1.82780D-02

At iterate   49    f=  2.74030D+00    |proj g|=  1.46993D-01

At iterate   50    f=  2.73995D+00    |proj g|=  5.03562D-02

At iterate   51    f=  2.73990D+00    |proj g|=  7.87436D-03

At iterate   52    f=  2.73989D+00    |proj g|=  6.55445D-03

At iterate   53    f=  2.73989D+00    |proj g|=  2.22741D-02

At iterate   54    f=  2.73989D+00    |proj g|=  1.69151D-02

At iterate   55    f=  2.73988D+00    |proj g|=  1.05107D-02
```

```
At iterate   56    f=  2.73987D+00    |proj g|=  1.69319D-02

At iterate   57    f=  2.73986D+00    |proj g|=  2.26444D-02

At iterate   58    f=  2.73983D+00    |proj g|=  2.00073D-02

At iterate   59    f=  2.73982D+00    |proj g|=  6.27439D-02

At iterate   60    f=  2.73977D+00    |proj g|=  1.12659D-02

At iterate   61    f=  2.73975D+00    |proj g|=  8.11125D-03

At iterate   62    f=  2.73975D+00    |proj g|=  3.14471D-02

At iterate   63    f=  2.73974D+00    |proj g|=  2.56648D-02

At iterate   64    f=  2.73973D+00    |proj g|=  1.38791D-02

At iterate   65    f=  2.73972D+00    |proj g|=  1.46376D-02

At iterate   66    f=  2.73969D+00    |proj g|=  1.93619D-02

At iterate   67    f=  2.73964D+00    |proj g|=  3.34651D-02

At iterate   68    f=  2.73958D+00    |proj g|=  1.87874D-02

At iterate   69    f=  2.73953D+00    |proj g|=  1.67963D-02

At iterate   70    f=  2.73949D+00    |proj g|=  1.92789D-02

At iterate   71    f=  2.73935D+00    |proj g|=  3.19022D-02

At iterate   72    f=  2.73932D+00    |proj g|=  4.13019D-02

At iterate   73    f=  2.73928D+00    |proj g|=  2.39533D-02

At iterate   74    f=  2.73922D+00    |proj g|=  5.57397D-02

At iterate   75    f=  2.73917D+00    |proj g|=  5.00259D-02

At iterate   76    f=  2.73910D+00    |proj g|=  6.22551D-02

At iterate   77    f=  2.73903D+00    |proj g|=  3.27340D-02

At iterate   78    f=  2.73897D+00    |proj g|=  3.07837D-02

At iterate   79    f=  2.73892D+00    |proj g|=  4.74898D-02

At iterate   80    f=  2.73879D+00    |proj g|=  7.57765D-02

At iterate   81    f=  2.73845D+00    |proj g|=  8.88435D-02

At iterate   82    f=  2.73833D+00    |proj g|=  3.73102D-01
```

```
 At iterate   83    f=  2.73788D+00    |proj g|=  1.05917D-01

 At iterate   84    f=  2.73751D+00    |proj g|=  4.88284D-01

 At iterate   85    f=  2.73741D+00    |proj g|=  8.57513D-01

 At iterate   86    f=  2.73725D+00    |proj g|=  4.07894D-02

 At iterate   87    f=  2.73721D+00    |proj g|=  7.90425D-02

 At iterate   88    f=  2.73721D+00    |proj g|=  3.26265D-02

 At iterate   89    f=  2.73718D+00    |proj g|=  6.34028D-02

 At iterate   90    f=  2.73715D+00    |proj g|=  5.62279D-02

 At iterate   91    f=  2.73705D+00    |proj g|=  7.99781D-02

 At iterate   92    f=  2.73700D+00    |proj g|=  6.47953D-02

 At iterate   93    f=  2.73700D+00    |proj g|=  1.20162D-01

 At iterate   94    f=  2.73698D+00    |proj g|=  1.12993D-01

 At iterate   95    f=  2.73698D+00    |proj g|=  4.07583D-02

 At iterate   96    f=  2.73696D+00    |proj g|=  1.67970D-02

 At iterate   97    f=  2.73696D+00    |proj g|=  7.58639D-02

 At iterate   98    f=  2.73695D+00    |proj g|=  3.60670D-02

 At iterate   99    f=  2.73695D+00    |proj g|=  1.91625D-02

 At iterate  100    f=  2.73694D+00    |proj g|=  1.89191D-02

 At iterate  101    f=  2.73693D+00    |proj g|=  2.73994D-02

 At iterate  102    f=  2.73690D+00    |proj g|=  6.80104D-02

 At iterate  103    f=  2.73688D+00    |proj g|=  5.34065D-02

 At iterate  104    f=  2.73688D+00    |proj g|=  1.49004D-02

 At iterate  105    f=  2.73688D+00    |proj g|=  3.37558D-02

 At iterate  106    f=  2.73687D+00    |proj g|=  3.90296D-02

 At iterate  107    f=  2.73687D+00    |proj g|=  2.35707D-02

 At iterate  108    f=  2.73686D+00    |proj g|=  1.74173D-02
```

```
At iterate  109    f=  2.73686D+00    |proj g|=  1.40365D-01

At iterate  110    f=  2.73685D+00    |proj g|=  8.81086D-02

At iterate  111    f=  2.73683D+00    |proj g|=  1.88295D-02

At iterate  112    f=  2.73682D+00    |proj g|=  4.18700D-02

At iterate  113    f=  2.73681D+00    |proj g|=  3.05680D-02

At iterate  114    f=  2.73679D+00    |proj g|=  2.19569D-02

At iterate  115    f=  2.73679D+00    |proj g|=  9.27260D-02

At iterate  116    f=  2.73677D+00    |proj g|=  2.97000D-02

At iterate  117    f=  2.73676D+00    |proj g|=  5.85053D-02

At iterate  118    f=  2.73676D+00    |proj g|=  5.45591D-02

At iterate  119    f=  2.73669D+00    |proj g|=  5.89162D-02

At iterate  120    f=  2.73669D+00    |proj g|=  9.17519D-02

At iterate  121    f=  2.73655D+00    |proj g|=  2.20110D-02

At iterate  122    f=  2.73654D+00    |proj g|=  4.88584D-02

At iterate  123    f=  2.73653D+00    |proj g|=  2.27961D-02

At iterate  124    f=  2.73652D+00    |proj g|=  2.60622D-02

At iterate  125    f=  2.73650D+00    |proj g|=  8.29589D-02

At iterate  126    f=  2.73645D+00    |proj g|=  1.63622D-01

At iterate  127    f=  2.73636D+00    |proj g|=  2.71852D-01

At iterate  128    f=  2.73625D+00    |proj g|=  2.97743D-02

At iterate  129    f=  2.73620D+00    |proj g|=  1.87321D-01

At iterate  130    f=  2.73617D+00    |proj g|=  1.35646D-01

At iterate  131    f=  2.73617D+00    |proj g|=  4.81989D-02

At iterate  132    f=  2.73617D+00    |proj g|=  2.79049D-02

At iterate  133    f=  2.73616D+00    |proj g|=  1.24135D-01

At iterate  134    f=  2.73616D+00    |proj g|=  1.01722D-01

At iterate  135    f=  2.73615D+00    |proj g|=  2.22576D-02
```

```
At iterate  136    f=  2.73614D+00    |proj g|=  1.70254D-02

At iterate  137    f=  2.73612D+00    |proj g|=  8.03571D-02

At iterate  138    f=  2.73610D+00    |proj g|=  5.85819D-02

At iterate  139    f=  2.73609D+00    |proj g|=  2.38545D-02

At iterate  140    f=  2.73605D+00    |proj g|=  7.22418D-02

At iterate  141    f=  2.73605D+00    |proj g|=  2.08059D-01

At iterate  142    f=  2.73602D+00    |proj g|=  2.09321D-01

At iterate  143    f=  2.73601D+00    |proj g|=  1.67625D-01

At iterate  144    f=  2.73600D+00    |proj g|=  1.11789D-01

At iterate  145    f=  2.73596D+00    |proj g|=  5.27567D-02

At iterate  146    f=  2.73596D+00    |proj g|=  3.98749D-02

At iterate  147    f=  2.73595D+00    |proj g|=  8.16496D-03

At iterate  148    f=  2.73595D+00    |proj g|=  1.02922D-02

At iterate  149    f=  2.73595D+00    |proj g|=  3.07022D-02

At iterate  150    f=  2.73595D+00    |proj g|=  3.52699D-02

At iterate  151    f=  2.73595D+00    |proj g|=  1.03881D-02

At iterate  152    f=  2.73595D+00    |proj g|=  4.06380D-02

At iterate  153    f=  2.73595D+00    |proj g|=  2.31900D-02

At iterate  154    f=  2.73594D+00    |proj g|=  9.72961D-03

At iterate  155    f=  2.73594D+00    |proj g|=  9.72960D-03
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
```

* * *

```
Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   11    155    200      1     0     0   9.730D-03   2.736D+00
  F =   2.7359449632079733

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(5, 0, 6) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           12     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.74540D+00    |proj g|=  1.48989D-01

At iterate    1    f=  2.74539D+00    |proj g|=  1.33285D-01

At iterate    2    f=  2.74533D+00    |proj g|=  1.09426D-01

At iterate    3    f=  2.74528D+00    |proj g|=  1.66264D-01

At iterate    4    f=  2.74505D+00    |proj g|=  3.40000D-01

At iterate    5    f=  2.74469D+00    |proj g|=  4.79421D-01

At iterate    6    f=  2.74426D+00    |proj g|=  4.57170D-01

At iterate    7    f=  2.74362D+00    |proj g|=  1.91922D-01

At iterate    8    f=  2.74293D+00    |proj g|=  5.07719D-01

At iterate    9    f=  2.74154D+00    |proj g|=  6.15828D-01

At iterate   10    f=  2.73898D+00    |proj g|=  1.11474D+00

At iterate   11    f=  2.73868D+00    |proj g|=  7.17000D-01

At iterate   12    f=  2.73841D+00    |proj g|=  9.82913D-02

At iterate   13    f=  2.73837D+00    |proj g|=  7.95921D-02
```

```
At iterate   14    f=  2.73836D+00    |proj g|=  7.23531D-02

At iterate   15    f=  2.73831D+00    |proj g|=  1.16039D-01

At iterate   16    f=  2.73820D+00    |proj g|=  2.38545D-01

At iterate   17    f=  2.73797D+00    |proj g|=  3.83146D-01

At iterate   18    f=  2.73759D+00    |proj g|=  4.95925D-01

At iterate   19    f=  2.73702D+00    |proj g|=  4.93893D-01

At iterate   20    f=  2.73538D+00    |proj g|=  8.46985D-01

At iterate   21    f=  2.73387D+00    |proj g|=  5.99217D-01

At iterate   22    f=  2.73326D+00    |proj g|=  3.26512D-01

At iterate   23    f=  2.73303D+00    |proj g|=  3.52800D-02

At iterate   24    f=  2.73302D+00    |proj g|=  4.42474D-02

At iterate   25    f=  2.73300D+00    |proj g|=  1.63139D-01

At iterate   26    f=  2.73297D+00    |proj g|=  1.52042D-01

At iterate   27    f=  2.73253D+00    |proj g|=  1.75994D-01

At iterate   28    f=  2.73168D+00    |proj g|=  9.39841D-02

At iterate   29    f=  2.73057D+00    |proj g|=  1.25451D-01

At iterate   30    f=  2.73000D+00    |proj g|=  6.05601D-02

At iterate   31    f=  2.72964D+00    |proj g|=  6.67382D-02

At iterate   32    f=  2.72759D+00    |proj g|=  1.36679D-01

At iterate   33    f=  2.72737D+00    |proj g|=  7.57374D-02

At iterate   34    f=  2.72693D+00    |proj g|=  3.44052D-02

At iterate   35    f=  2.72667D+00    |proj g|=  3.04688D-02

At iterate   36    f=  2.72662D+00    |proj g|=  2.49921D-01

At iterate   37    f=  2.72642D+00    |proj g|=  1.87713D-01

At iterate   38    f=  2.72589D+00    |proj g|=  5.29748D-02

At iterate   39    f=  2.72570D+00    |proj g|=  1.74189D-02
```

```
At iterate   40    f=  2.72567D+00    |proj g|=  1.81166D-02

At iterate   41    f=  2.72550D+00    |proj g|=  4.31081D-02

At iterate   42    f=  2.72497D+00    |proj g|=  3.55664D-02

At iterate   43    f=  2.72443D+00    |proj g|=  3.67073D-02

At iterate   44    f=  2.72438D+00    |proj g|=  4.65814D-02

At iterate   45    f=  2.72423D+00    |proj g|=  2.46426D-02

At iterate   46    f=  2.72410D+00    |proj g|=  3.20870D-02

At iterate   47    f=  2.72408D+00    |proj g|=  1.60214D-01

At iterate   48    f=  2.72402D+00    |proj g|=  7.32390D-02

At iterate   49    f=  2.72400D+00    |proj g|=  1.76496D-02

At iterate   50    f=  2.72399D+00    |proj g|=  1.76874D-02

At iterate   51    f=  2.72397D+00    |proj g|=  4.31688D-02

At iterate   52    f=  2.72394D+00    |proj g|=  6.01846D-02

At iterate   53    f=  2.72392D+00    |proj g|=  4.97705D-02

At iterate   54    f=  2.72389D+00    |proj g|=  1.75877D-02

At iterate   55    f=  2.72387D+00    |proj g|=  3.93929D-02

At iterate   56    f=  2.72386D+00    |proj g|=  5.34575D-02

At iterate   57    f=  2.72383D+00    |proj g|=  6.05971D-02

At iterate   58    f=  2.72382D+00    |proj g|=  1.22601D-01

At iterate   59    f=  2.72378D+00    |proj g|=  6.48303D-02

At iterate   60    f=  2.72375D+00    |proj g|=  1.63496D-02

At iterate   61    f=  2.72372D+00    |proj g|=  3.79395D-02

At iterate   62    f=  2.72371D+00    |proj g|=  2.22923D-02

At iterate   63    f=  2.72370D+00    |proj g|=  3.92646D-02

At iterate   64    f=  2.72370D+00    |proj g|=  1.34747D-02

At iterate   65    f=  2.72369D+00    |proj g|=  2.95744D-02

At iterate   66    f=  2.72368D+00    |proj g|=  4.57882D-02
```

```
At iterate   67    f=  2.72367D+00    |proj g|=  6.23222D-02

At iterate   68    f=  2.72365D+00    |proj g|=  5.96203D-02

At iterate   69    f=  2.72365D+00    |proj g|=  7.13088D-02

At iterate   70    f=  2.72365D+00    |proj g|=  3.92866D-02

At iterate   71    f=  2.72364D+00    |proj g|=  1.30317D-02

At iterate   72    f=  2.72364D+00    |proj g|=  7.89949D-03

At iterate   73    f=  2.72364D+00    |proj g|=  9.71005D-03

At iterate   74    f=  2.72364D+00    |proj g|=  1.73898D-02

At iterate   75    f=  2.72364D+00    |proj g|=  2.43232D-02

At iterate   76    f=  2.72364D+00    |proj g|=  2.42141D-02

At iterate   77    f=  2.72364D+00    |proj g|=  2.25438D-02

At iterate   78    f=  2.72363D+00    |proj g|=  8.34792D-03

At iterate   79    f=  2.72363D+00    |proj g|=  1.91515D-02

At iterate   80    f=  2.72362D+00    |proj g|=  2.36736D-02

At iterate   81    f=  2.72362D+00    |proj g|=  5.47184D-02

At iterate   82    f=  2.72362D+00    |proj g|=  4.51187D-02

At iterate   83    f=  2.72361D+00    |proj g|=  1.30474D-02

At iterate   84    f=  2.72361D+00    |proj g|=  7.59597D-03

At iterate   85    f=  2.72361D+00    |proj g|=  7.27152D-03

At iterate   86    f=  2.72361D+00    |proj g|=  8.66543D-03

At iterate   87    f=  2.72360D+00    |proj g|=  8.02136D-03

At iterate   88    f=  2.72358D+00    |proj g|=  5.96657D-03

At iterate   89    f=  2.72357D+00    |proj g|=  7.25337D-03

At iterate   90    f=  2.72356D+00    |proj g|=  2.74771D-02

At iterate   91    f=  2.72354D+00    |proj g|=  1.91103D-02

At iterate   92    f=  2.72353D+00    |proj g|=  2.48485D-02
```

```
At iterate   93    f=  2.72352D+00    |proj g|=  2.43671D-02

At iterate   94    f=  2.72351D+00    |proj g|=  1.37105D-02

At iterate   95    f=  2.72351D+00    |proj g|=  9.53359D-03

At iterate   96    f=  2.72350D+00    |proj g|=  6.29879D-03

At iterate   97    f=  2.72349D+00    |proj g|=  6.74442D-03

At iterate   98    f=  2.72348D+00    |proj g|=  3.33259D-02

At iterate   99    f=  2.72347D+00    |proj g|=  1.52518D-02

At iterate  100    f=  2.72346D+00    |proj g|=  4.80193D-03

At iterate  101    f=  2.72346D+00    |proj g|=  5.04701D-03

At iterate  102    f=  2.72346D+00    |proj g|=  4.39716D-03

At iterate  103    f=  2.72345D+00    |proj g|=  5.29458D-02

At iterate  104    f=  2.72344D+00    |proj g|=  1.50815D-02

At iterate  105    f=  2.72343D+00    |proj g|=  8.58982D-03

At iterate  106    f=  2.72342D+00    |proj g|=  8.27440D-03

At iterate  107    f=  2.72342D+00    |proj g|=  1.78563D-02

At iterate  108    f=  2.72342D+00    |proj g|=  1.17867D-02

At iterate  109    f=  2.72341D+00    |proj g|=  5.72334D-03

At iterate  110    f=  2.72341D+00    |proj g|=  1.06746D-02

At iterate  111    f=  2.72341D+00    |proj g|=  9.00411D-03

At iterate  112    f=  2.72341D+00    |proj g|=  1.41614D-02

At iterate  113    f=  2.72341D+00    |proj g|=  6.51852D-03

At iterate  114    f=  2.72341D+00    |proj g|=  2.57987D-02

At iterate  115    f=  2.72340D+00    |proj g|=  2.29222D-02

At iterate  116    f=  2.72340D+00    |proj g|=  5.29266D-02

At iterate  117    f=  2.72340D+00    |proj g|=  2.90220D-02

At iterate  118    f=  2.72339D+00    |proj g|=  4.85291D-03

At iterate  119    f=  2.72339D+00    |proj g|=  3.63022D-03
```

```
At iterate  120    f=  2.72339D+00    |proj g|=  2.86041D-03

At iterate  121    f=  2.72339D+00    |proj g|=  4.50236D-03

At iterate  122    f=  2.72339D+00    |proj g|=  3.01943D-03

At iterate  123    f=  2.72339D+00    |proj g|=  1.30903D-02

At iterate  124    f=  2.72339D+00    |proj g|=  1.39241D-02

At iterate  125    f=  2.72339D+00    |proj g|=  1.16999D-02

At iterate  126    f=  2.72339D+00    |proj g|=  5.64372D-03

At iterate  127    f=  2.72339D+00    |proj g|=  4.82177D-03

At iterate  128    f=  2.72339D+00    |proj g|=  3.75283D-03

At iterate  129    f=  2.72339D+00    |proj g|=  4.63779D-03

At iterate  130    f=  2.72339D+00    |proj g|=  6.58776D-03

At iterate  131    f=  2.72338D+00    |proj g|=  1.27707D-02

At iterate  132    f=  2.72338D+00    |proj g|=  1.06630D-02

At iterate  133    f=  2.72337D+00    |proj g|=  4.16133D-03

At iterate  134    f=  2.72337D+00    |proj g|=  5.20388D-03

At iterate  135    f=  2.72336D+00    |proj g|=  1.22950D-02

At iterate  136    f=  2.72336D+00    |proj g|=  2.25095D-02

At iterate  137    f=  2.72335D+00    |proj g|=  3.61489D-03

At iterate  138    f=  2.72335D+00    |proj g|=  5.39389D-03

At iterate  139    f=  2.72334D+00    |proj g|=  1.36331D-02

At iterate  140    f=  2.72334D+00    |proj g|=  1.76517D-02

At iterate  141    f=  2.72334D+00    |proj g|=  4.21447D-03

At iterate  142    f=  2.72334D+00    |proj g|=  6.66022D-03

At iterate  143    f=  2.72334D+00    |proj g|=  1.07997D-02

At iterate  144    f=  2.72333D+00    |proj g|=  7.21046D-03

At iterate  145    f=  2.72332D+00    |proj g|=  5.31312D-03
```

```
At iterate  146    f=  2.72331D+00    |proj g|=  1.45458D-02

At iterate  147    f=  2.72330D+00    |proj g|=  7.67757D-03

At iterate  148    f=  2.72330D+00    |proj g|=  2.72595D-02

At iterate  149    f=  2.72329D+00    |proj g|=  9.86489D-03

At iterate  150    f=  2.72328D+00    |proj g|=  7.85762D-03

At iterate  151    f=  2.72328D+00    |proj g|=  1.31489D-02

At iterate  152    f=  2.72328D+00    |proj g|=  5.39422D-02

At iterate  153    f=  2.72327D+00    |proj g|=  1.24120D-02

At iterate  154    f=  2.72326D+00    |proj g|=  6.50678D-03

At iterate  155    f=  2.72326D+00    |proj g|=  6.73177D-03

At iterate  156    f=  2.72326D+00    |proj g|=  7.88902D-03

At iterate  157    f=  2.72325D+00    |proj g|=  1.92501D-02

At iterate  158    f=  2.72324D+00    |proj g|=  7.56767D-03

At iterate  159    f=  2.72323D+00    |proj g|=  1.00590D-02

At iterate  160    f=  2.72322D+00    |proj g|=  1.24721D-02

At iterate  161    f=  2.72321D+00    |proj g|=  4.05567D-02

At iterate  162    f=  2.72319D+00    |proj g|=  4.05586D-02

At iterate  163    f=  2.72318D+00    |proj g|=  1.38300D-02

At iterate  164    f=  2.72310D+00    |proj g|=  4.13712D-02

At iterate  165    f=  2.72306D+00    |proj g|=  7.29178D-02

At iterate  166    f=  2.72297D+00    |proj g|=  3.11555D-02

At iterate  167    f=  2.72291D+00    |proj g|=  1.73997D-02

At iterate  168    f=  2.72287D+00    |proj g|=  2.59258D-02

At iterate  169    f=  2.72276D+00    |proj g|=  3.19863D-02

At iterate  170    f=  2.72267D+00    |proj g|=  5.53668D-02

At iterate  171    f=  2.72220D+00    |proj g|=  5.13928D-02

At iterate  172    f=  2.72215D+00    |proj g|=  4.35650D-02
```

```
At iterate  173    f=  2.72173D+00    |proj g|=  5.64611D-02

At iterate  174    f=  2.72169D+00    |proj g|=  2.17190D-02

At iterate  175    f=  2.72131D+00    |proj g|=  2.53803D-02

At iterate  176    f=  2.72110D+00    |proj g|=  1.29698D-01

At iterate  177    f=  2.72044D+00    |proj g|=  1.00688D-01

At iterate  178    f=  2.71979D+00    |proj g|=  4.43997D-02

At iterate  179    f=  2.71896D+00    |proj g|=  3.47024D-02

At iterate  180    f=  2.71766D+00    |proj g|=  2.50324D-02

At iterate  181    f=  2.71679D+00    |proj g|=  2.69441D-02

At iterate  182    f=  2.71571D+00    |proj g|=  6.06652D-02

At iterate  183    f=  2.71554D+00    |proj g|=  6.85056D-02

At iterate  184    f=  2.71520D+00    |proj g|=  5.44035D-02

At iterate  185    f=  2.71479D+00    |proj g|=  7.00841D-02

At iterate  186    f=  2.71459D+00    |proj g|=  5.35411D-02

At iterate  187    f=  2.71390D+00    |proj g|=  5.20473D-02

At iterate  188    f=  2.71371D+00    |proj g|=  6.03655D-02

At iterate  189    f=  2.71339D+00    |proj g|=  1.95635D-02

At iterate  190    f=  2.71335D+00    |proj g|=  1.41282D-02

At iterate  191    f=  2.71331D+00    |proj g|=  1.15227D-02

At iterate  192    f=  2.71325D+00    |proj g|=  1.12149D-02

At iterate  193    f=  2.71320D+00    |proj g|=  1.01049D-02

At iterate  194    f=  2.71318D+00    |proj g|=  1.12895D-02

At iterate  195    f=  2.71313D+00    |proj g|=  9.60482D-03

At iterate  196    f=  2.71309D+00    |proj g|=  1.30914D-02

At iterate  197    f=  2.71303D+00    |proj g|=  1.37025D-02

At iterate  198    f=  2.71299D+00    |proj g|=  2.46142D-02
```

```
At iterate  199    f=  2.71293D+00    |proj g|=  1.06797D-02

At iterate  200    f=  2.71289D+00    |proj g|=  1.45840D-02

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   12    200    242      1     0     0   1.458D-02   2.713D+00
  F =   2.7128923773363458

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
Trying SARIMAX(6, 0, 0) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.82578D+00    |proj g|=  1.22059D-04

At iterate    1    f=  2.82578D+00    |proj g|=  1.22051D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7      1     13      1     0     0   1.221D-04   2.826D+00
  F =   2.8257831480155655

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(6, 0, 1) ...
```

```
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83111D+00    |proj g|=  5.75382D-02

At iterate    1    f=  2.83099D+00    |proj g|=  8.12184D-02
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.

 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate    2    f=  2.83020D+00    |proj g|=  3.57998D-02

At iterate    3    f=  2.82871D+00    |proj g|=  4.70679D-02

At iterate    4    f=  2.82855D+00    |proj g|=  2.08656D-02

At iterate    5    f=  2.82844D+00    |proj g|=  1.94464D-02

At iterate    6    f=  2.82841D+00    |proj g|=  1.40065D-02

At iterate    7    f=  2.82839D+00    |proj g|=  7.01641D-03

At iterate    8    f=  2.82838D+00    |proj g|=  8.27088D-03

At iterate    9    f=  2.82837D+00    |proj g|=  1.45183D-02
```

```
At iterate   10    f=  2.82834D+00    |proj g|=  2.69289D-02

At iterate   11    f=  2.82827D+00    |proj g|=  4.22873D-02

At iterate   12    f=  2.82815D+00    |proj g|=  5.35267D-02

At iterate   13    f=  2.82794D+00    |proj g|=  9.12016D-02

At iterate   14    f=  2.82743D+00    |proj g|=  7.19841D-02

At iterate   15    f=  2.82630D+00    |proj g|=  6.27890D-02

At iterate   16    f=  2.82527D+00    |proj g|=  1.89664D-01

At iterate   17    f=  2.82469D+00    |proj g|=  1.04431D-01

At iterate   18    f=  2.82357D+00    |proj g|=  8.78050D-02

At iterate   19    f=  2.82236D+00    |proj g|=  2.54729D-01

At iterate   20    f=  2.82134D+00    |proj g|=  3.62690D-02

At iterate   21    f=  2.82080D+00    |proj g|=  5.44835D-02

At iterate   22    f=  2.81937D+00    |proj g|=  1.48929D-01

At iterate   23    f=  2.81914D+00    |proj g|=  4.00287D-02

At iterate   24    f=  2.81909D+00    |proj g|=  1.30256D-02

At iterate   25    f=  2.81901D+00    |proj g|=  2.80165D-02

At iterate   26    f=  2.81861D+00    |proj g|=  9.21245D-02

At iterate   27    f=  2.81385D+00    |proj g|=  1.87480D+00
  ys=-9.172E-04  -gs= 1.375E-03 BFGS update SKIPPED

At iterate   28    f=  2.81373D+00    |proj g|=  2.25957D+00

At iterate   29    f=  2.81187D+00    |proj g|=  1.63146D+00

At iterate   30    f=  2.81075D+00    |proj g|=  5.04709D-01

At iterate   31    f=  2.81001D+00    |proj g|=  9.49399D-02

At iterate   32    f=  2.80919D+00    |proj g|=  2.85610D-01

At iterate   33    f=  2.80892D+00    |proj g|=  6.83163D-01

At iterate   34    f=  2.80891D+00    |proj g|=  6.48756D-01

At iterate   35    f=  2.80888D+00    |proj g|=  2.00283D-02
```

```
At iterate   36    f=  2.80888D+00    |proj g|=  5.97039D-02

At iterate   37    f=  2.80887D+00    |proj g|=  3.76441D-02

At iterate   38    f=  2.80887D+00    |proj g|=  1.19014D-02

At iterate   39    f=  2.80887D+00    |proj g|=  2.12322D-02

At iterate   40    f=  2.80887D+00    |proj g|=  3.41476D-02

At iterate   41    f=  2.80887D+00    |proj g|=  6.33789D-02

At iterate   42    f=  2.80887D+00    |proj g|=  1.01508D-01

At iterate   43    f=  2.80885D+00    |proj g|=  1.61873D-01

At iterate   44    f=  2.80883D+00    |proj g|=  2.39584D-01

At iterate   45    f=  2.80877D+00    |proj g|=  3.15144D-01

At iterate   46    f=  2.80875D+00    |proj g|=  7.55564D-01

At iterate   47    f=  2.80865D+00    |proj g|=  5.76921D-01

At iterate   48    f=  2.80851D+00    |proj g|=  3.20938D-01

At iterate   49    f=  2.80840D+00    |proj g|=  2.12138D-01

At iterate   50    f=  2.80837D+00    |proj g|=  8.12288D-02

At iterate   51    f=  2.80834D+00    |proj g|=  7.36860D-02

At iterate   52    f=  2.80831D+00    |proj g|=  1.17569D-01

At iterate   53    f=  2.80827D+00    |proj g|=  1.72780D-01

At iterate   54    f=  2.80826D+00    |proj g|=  1.14393D-01

At iterate   55    f=  2.80825D+00    |proj g|=  5.60135D-02

At iterate   56    f=  2.80824D+00    |proj g|=  2.70643D-02

At iterate   57    f=  2.80824D+00    |proj g|=  3.14066D-02

At iterate   58    f=  2.80824D+00    |proj g|=  3.64031D-02

At iterate   59    f=  2.80824D+00    |proj g|=  2.25039D-01

At iterate   60    f=  2.80824D+00    |proj g|=  1.62841D-01

At iterate   61    f=  2.80822D+00    |proj g|=  4.96883D-02
```

```
At iterate   62    f=  2.80821D+00    |proj g|=  1.26023D-01

At iterate   63    f=  2.80821D+00    |proj g|=  1.38241D-01

At iterate   64    f=  2.80820D+00    |proj g|=  1.32821D-01

At iterate   65    f=  2.80820D+00    |proj g|=  7.86666D-02

At iterate   66    f=  2.80820D+00    |proj g|=  4.18296D-02

At iterate   67    f=  2.80820D+00    |proj g|=  9.25585D-03

At iterate   68    f=  2.80820D+00    |proj g|=  7.56372D-03

At iterate   69    f=  2.80820D+00    |proj g|=  7.25590D-02

At iterate   70    f=  2.80820D+00    |proj g|=  4.94049D-02

At iterate   71    f=  2.80819D+00    |proj g|=  2.96870D-01

At iterate   72    f=  2.80818D+00    |proj g|=  1.95879D-01

At iterate   73    f=  2.80812D+00    |proj g|=  1.40158D-01

At iterate   74    f=  2.80806D+00    |proj g|=  3.46384D-01

At iterate   75    f=  2.80802D+00    |proj g|=  3.47784D-01

At iterate   76    f=  2.80802D+00    |proj g|=  2.51427D-01

At iterate   77    f=  2.80800D+00    |proj g|=  1.72674D-02

At iterate   78    f=  2.80800D+00    |proj g|=  4.61980D-02

At iterate   79    f=  2.80799D+00    |proj g|=  1.03095D-01

At iterate   80    f=  2.80799D+00    |proj g|=  9.90463D-02

At iterate   81    f=  2.80799D+00    |proj g|=  1.07767D-01

At iterate   82    f=  2.80799D+00    |proj g|=  3.40209D-02

At iterate   83    f=  2.80799D+00    |proj g|=  8.54078D-03

At iterate   84    f=  2.80799D+00    |proj g|=  1.10475D-02

At iterate   85    f=  2.80799D+00    |proj g|=  1.10475D-02

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
```

```
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     85    135      1     1     0   1.105D-02   2.808D+00
  F =   2.8079867596007828

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(6, 0, 2) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83009D+00    |proj g|=  4.27112D-02

At iterate    1    f=  2.83000D+00    |proj g|=  5.03390D-02

At iterate    2    f=  2.82943D+00    |proj g|=  4.23222D-02

At iterate    3    f=  2.82907D+00    |proj g|=  9.63490D-03

At iterate    4    f=  2.82903D+00    |proj g|=  9.69623D-03

At iterate    5    f=  2.82898D+00    |proj g|=  1.12552D-02

At iterate    6    f=  2.82890D+00    |proj g|=  1.10603D-02

At iterate    7    f=  2.82850D+00    |proj g|=  1.67095D-02

At iterate    8    f=  2.82746D+00    |proj g|=  3.51500D-02

At iterate    9    f=  2.82689D+00    |proj g|=  1.23178D-01

At iterate   10    f=  2.81947D+00    |proj g|=  5.87302D-01
```

```
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   11    f=  2.81933D+00    |proj g|=  5.62730D-01

At iterate   12    f=  2.81827D+00    |proj g|=  1.36053D+00

At iterate   13    f=  2.81489D+00    |proj g|=  1.96419D+00

At iterate   14    f=  2.81417D+00    |proj g|=  8.66597D-01

At iterate   15    f=  2.81330D+00    |proj g|=  7.53607D-01

At iterate   16    f=  2.81196D+00    |proj g|=  5.09897D-01

At iterate   17    f=  2.81147D+00    |proj g|=  3.71620D-01

At iterate   18    f=  2.81129D+00    |proj g|=  2.51603D-01

At iterate   19    f=  2.81124D+00    |proj g|=  8.38113D-02

At iterate   20    f=  2.81115D+00    |proj g|=  3.28891D-01

At iterate   21    f=  2.81099D+00    |proj g|=  5.91776D-01

At iterate   22    f=  2.81070D+00    |proj g|=  8.58699D-01

At iterate   23    f=  2.81031D+00    |proj g|=  1.12854D+00

At iterate   24    f=  2.80986D+00    |proj g|=  1.17835D+00

At iterate   25    f=  2.80978D+00    |proj g|=  6.40588D-01

At iterate   26    f=  2.80942D+00    |proj g|=  3.91110D-01

At iterate   27    f=  2.80938D+00    |proj g|=  1.99601D-01

At iterate   28    f=  2.80937D+00    |proj g|=  3.04159D-02

At iterate   29    f=  2.80937D+00    |proj g|=  3.43977D-02

At iterate   30    f=  2.80937D+00    |proj g|=  4.64853D-02

At iterate   31    f=  2.80936D+00    |proj g|=  2.10881D-02
```

```
At iterate   32    f=  2.80936D+00    |proj g|=  3.12181D-02

At iterate   33    f=  2.80936D+00    |proj g|=  5.81999D-02

At iterate   34    f=  2.80936D+00    |proj g|=  9.52522D-02

At iterate   35    f=  2.80935D+00    |proj g|=  1.59379D-01

At iterate   36    f=  2.80933D+00    |proj g|=  2.53503D-01

At iterate   37    f=  2.80927D+00    |proj g|=  4.00170D-01

At iterate   38    f=  2.80913D+00    |proj g|=  6.64050D-01

At iterate   39    f=  2.80891D+00    |proj g|=  3.55763D-01

At iterate   40    f=  2.80870D+00    |proj g|=  1.97358D+00

At iterate   41    f=  2.80844D+00    |proj g|=  5.66573D-01

At iterate   42    f=  2.80837D+00    |proj g|=  3.27023D-01

At iterate   43    f=  2.80836D+00    |proj g|=  1.35268D-01

At iterate   44    f=  2.80835D+00    |proj g|=  4.29919D-02

At iterate   45    f=  2.80835D+00    |proj g|=  3.22353D-02

At iterate   46    f=  2.80834D+00    |proj g|=  6.26126D-02

At iterate   47    f=  2.80834D+00    |proj g|=  8.16793D-02

At iterate   48    f=  2.80834D+00    |proj g|=  2.66066D-02

At iterate   49    f=  2.80834D+00    |proj g|=  1.28363D-02

At iterate   50    f=  2.80834D+00    |proj g|=  1.10195D-02

At iterate   51    f=  2.80834D+00    |proj g|=  2.55981D-02

At iterate   52    f=  2.80834D+00    |proj g|=  1.10788D-02

At iterate   53    f=  2.80834D+00    |proj g|=  1.68519D-02

At iterate   54    f=  2.80833D+00    |proj g|=  3.82906D-02

At iterate   55    f=  2.80833D+00    |proj g|=  6.16978D-02

At iterate   56    f=  2.80833D+00    |proj g|=  4.39121D-02

At iterate   57    f=  2.80833D+00    |proj g|=  1.09733D-02
```

```
 At iterate   58    f=  2.80833D+00    |proj g|=  1.09579D-02

 At iterate   59    f=  2.80833D+00    |proj g|=  1.40936D-02

 At iterate   60    f=  2.80833D+00    |proj g|=  3.65527D-02

 At iterate   61    f=  2.80833D+00    |proj g|=  2.67978D-02

 At iterate   62    f=  2.80833D+00    |proj g|=  3.69709D-02

 At iterate   63    f=  2.80833D+00    |proj g|=  1.37205D-02

 At iterate   64    f=  2.80833D+00    |proj g|=  1.09634D-02

 At iterate   65    f=  2.80833D+00    |proj g|=  3.32310D-02

 At iterate   66    f=  2.80832D+00    |proj g|=  7.35987D-02

 At iterate   67    f=  2.80832D+00    |proj g|=  1.43965D-01

 At iterate   68    f=  2.80831D+00    |proj g|=  2.36781D-01

 At iterate   69    f=  2.80828D+00    |proj g|=  3.58169D-01

 At iterate   70    f=  2.80824D+00    |proj g|=  1.63624D-01

 At iterate   71    f=  2.80823D+00    |proj g|=  4.99554D-01

 At iterate   72    f=  2.80820D+00    |proj g|=  2.56534D-01

 At iterate   73    f=  2.80819D+00    |proj g|=  4.36662D-02

 At iterate   74    f=  2.80819D+00    |proj g|=  1.95707D-02

 At iterate   75    f=  2.80819D+00    |proj g|=  7.33614D-02

 At iterate   76    f=  2.80819D+00    |proj g|=  1.04272D-01

 At iterate   77    f=  2.80818D+00    |proj g|=  7.84435D-02

 At iterate   78    f=  2.80818D+00    |proj g|=  8.01367D-02

 At iterate   79    f=  2.80817D+00    |proj g|=  1.55988D-01

 At iterate   80    f=  2.80807D+00    |proj g|=  2.57015D-02

 At iterate   81    f=  2.80802D+00    |proj g|=  8.71517D-02

 At iterate   82    f=  2.80802D+00    |proj g|=  8.71517D-02

           * * *

 Tit   = total number of iterations
```

```
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     82    116      1     0     0   8.715D-02   2.808D+00
  F =   2.8080215334891045

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(6, 0, 3) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  4.11008D+00    |proj g|=  3.52022D-01

At iterate    1    f=  4.10164D+00    |proj g|=  4.69046D-01

At iterate    2    f=  4.04450D+00    |proj g|=  3.92461D-01

At iterate    3    f=  3.81445D+00    |proj g|=  2.13348D-01

At iterate    4    f=  3.75665D+00    |proj g|=  2.22165D-01

At iterate    5    f=  3.64409D+00    |proj g|=  6.21044D-01

At iterate    6    f=  3.53606D+00    |proj g|=  3.83944D+00
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate    7    f=  3.52659D+00    |proj g|=  9.24765D-01

At iterate    8    f=  3.41495D+00    |proj g|=  2.83856D+00
```

```
At iterate    9    f=  3.28857D+00    |proj g|=  2.96018D+00

At iterate   10    f=  3.28827D+00    |proj g|=  7.24012D-01

At iterate   11    f=  3.28467D+00    |proj g|=  3.10232D+00

At iterate   12    f=  3.28361D+00    |proj g|=  6.88170D-01

At iterate   13    f=  3.28290D+00    |proj g|=  2.66315D+00

At iterate   14    f=  3.28278D+00    |proj g|=  2.68377D+00

At iterate   15    f=  3.28272D+00    |proj g|=  6.02758D-01

At iterate   16    f=  3.28259D+00    |proj g|=  4.30409D-01

At iterate   17    f=  3.28217D+00    |proj g|=  2.65818D-01

At iterate   18    f=  3.28132D+00    |proj g|=  2.90471D-01

At iterate   19    f=  3.27624D+00    |proj g|=  8.59722D-01

At iterate   20    f=  3.25861D+00    |proj g|=  7.19234D-01

At iterate   21    f=  3.22206D+00    |proj g|=  4.81850D-01

At iterate   22    f=  3.20955D+00    |proj g|=  4.16222D-01

At iterate   23    f=  3.17167D+00    |proj g|=  5.03049D-01

At iterate   24    f=  3.16338D+00    |proj g|=  6.46648D-01

At iterate   25    f=  3.14511D+00    |proj g|=  5.79808D-01

At iterate   26    f=  3.13668D+00    |proj g|=  6.87011D-01

At iterate   27    f=  3.11316D+00    |proj g|=  9.45932D-01

At iterate   28    f=  3.10228D+00    |proj g|=  9.94305D-01

At iterate   29    f=  3.09799D+00    |proj g|=  1.11526D+00

At iterate   30    f=  3.08635D+00    |proj g|=  4.11090D-01

At iterate   31    f=  3.07823D+00    |proj g|=  5.49618D-01

At iterate   32    f=  3.06753D+00    |proj g|=  1.95490D+00

At iterate   33    f=  3.04603D+00    |proj g|=  2.06824D+00

At iterate   34    f=  3.02433D+00    |proj g|=  2.67340D+00

At iterate   35    f=  3.02032D+00    |proj g|=  2.16157D+00
```

```
At iterate   36    f=  3.01257D+00    |proj g|=  7.10093D-01

At iterate   37    f=  3.00337D+00    |proj g|=  6.74510D-01

At iterate   38    f=  2.99550D+00    |proj g|=  9.99882D-01

At iterate   39    f=  2.98812D+00    |proj g|=  3.68332D-01

At iterate   40    f=  2.98609D+00    |proj g|=  6.63020D-01

At iterate   41    f=  2.97478D+00    |proj g|=  1.05851D+00

At iterate   42    f=  2.96676D+00    |proj g|=  9.08238D-01

At iterate   43    f=  2.95938D+00    |proj g|=  4.39977D-01

At iterate   44    f=  2.95388D+00    |proj g|=  3.77604D-01

At iterate   45    f=  2.94640D+00    |proj g|=  5.56240D-01

At iterate   46    f=  2.93980D+00    |proj g|=  5.94549D-01

At iterate   47    f=  2.92925D+00    |proj g|=  1.91875D+00

At iterate   48    f=  2.92042D+00    |proj g|=  1.66639D+00

At iterate   49    f=  2.91530D+00    |proj g|=  2.27460D+00

At iterate   50    f=  2.90734D+00    |proj g|=  7.11811D-01

At iterate   51    f=  2.89443D+00    |proj g|=  9.08269D+00

At iterate   52    f=  2.89099D+00    |proj g|=  1.31416D+01

At iterate   53    f=  2.87282D+00    |proj g|=  4.51934D+00

At iterate   54    f=  2.86793D+00    |proj g|=  2.67726D+00

At iterate   55    f=  2.86222D+00    |proj g|=  1.32369D+01

At iterate   56    f=  2.85859D+00    |proj g|=  7.58221D+00

At iterate   57    f=  2.85633D+00    |proj g|=  1.41002D+01

At iterate   58    f=  2.85466D+00    |proj g|=  6.96632D+00

At iterate   59    f=  2.84944D+00    |proj g|=  5.05758D+00

At iterate   60    f=  2.84797D+00    |proj g|=  2.62536D+00

At iterate   61    f=  2.84787D+00    |proj g|=  5.14619D-01
```

```
At iterate   62    f=  2.84785D+00    |proj g|=  3.79678D-01

At iterate   63    f=  2.84784D+00    |proj g|=  1.18633D-01

At iterate   64    f=  2.84783D+00    |proj g|=  3.63317D-01

At iterate   65    f=  2.84780D+00    |proj g|=  1.11731D+00

At iterate   66    f=  2.84777D+00    |proj g|=  1.30610D+00

At iterate   67    f=  2.84774D+00    |proj g|=  9.19605D-01

At iterate   68    f=  2.84773D+00    |proj g|=  3.28910D-01

At iterate   69    f=  2.84772D+00    |proj g|=  7.40128D-01

At iterate   70    f=  2.84770D+00    |proj g|=  1.35907D+00

At iterate   71    f=  2.84766D+00    |proj g|=  2.00580D+00

At iterate   72    f=  2.84757D+00    |proj g|=  2.54576D+00

At iterate   73    f=  2.84743D+00    |proj g|=  3.39852D+00

At iterate   74    f=  2.84724D+00    |proj g|=  2.06567D+00

At iterate   75    f=  2.84713D+00    |proj g|=  1.04519D+00

At iterate   76    f=  2.84703D+00    |proj g|=  1.49712D+00

At iterate   77    f=  2.84696D+00    |proj g|=  1.29340D+00

At iterate   78    f=  2.84682D+00    |proj g|=  2.70350D-01

At iterate   79    f=  2.84657D+00    |proj g|=  3.47190D+00

At iterate   80    f=  2.84628D+00    |proj g|=  9.66253D-01

At iterate   81    f=  2.84607D+00    |proj g|=  1.37053D+00

At iterate   82    f=  2.84594D+00    |proj g|=  2.01198D+00

At iterate   83    f=  2.84558D+00    |proj g|=  3.12926D+00

At iterate   84    f=  2.84527D+00    |proj g|=  3.10747D+00

At iterate   85    f=  2.84514D+00    |proj g|=  3.76348D+00

At iterate   86    f=  2.84493D+00    |proj g|=  1.24982D+00

At iterate   87    f=  2.84486D+00    |proj g|=  2.27137D-01

At iterate   88    f=  2.84485D+00    |proj g|=  6.31147D-02
```

```
At iterate   89    f=  2.84485D+00    |proj g|=  6.72260D-02

At iterate   90    f=  2.84485D+00    |proj g|=  1.15031D-01

At iterate   91    f=  2.84485D+00    |proj g|=  1.17649D-01

At iterate   92    f=  2.84485D+00    |proj g|=  2.84620D-01

At iterate   93    f=  2.84484D+00    |proj g|=  2.73030D-01

At iterate   94    f=  2.84484D+00    |proj g|=  4.38198D-01

At iterate   95    f=  2.84482D+00    |proj g|=  4.14233D-01

At iterate   96    f=  2.84471D+00    |proj g|=  5.15294D-01

At iterate   97    f=  2.84470D+00    |proj g|=  1.97272D-01

At iterate   98    f=  2.84446D+00    |proj g|=  3.68011D-01

At iterate   99    f=  2.84429D+00    |proj g|=  1.66168D+00

At iterate  100    f=  2.84351D+00    |proj g|=  6.18705D-01

At iterate  101    f=  2.84194D+00    |proj g|=  1.14370D+00

At iterate  102    f=  2.83833D+00    |proj g|=  2.02425D+00

At iterate  103    f=  2.83820D+00    |proj g|=  1.34234D+00

At iterate  104    f=  2.83574D+00    |proj g|=  6.91616D-01

At iterate  105    f=  2.83483D+00    |proj g|=  9.65025D-01

At iterate  106    f=  2.83471D+00    |proj g|=  1.71078D+00

At iterate  107    f=  2.83339D+00    |proj g|=  4.48629D-01

At iterate  108    f=  2.83185D+00    |proj g|=  3.31549D-01

At iterate  109    f=  2.83180D+00    |proj g|=  1.23276D+00

At iterate  110    f=  2.83113D+00    |proj g|=  3.93261D-01

At iterate  111    f=  2.83069D+00    |proj g|=  3.83388D+00

At iterate  112    f=  2.83028D+00    |proj g|=  2.50011D+00

At iterate  113    f=  2.82992D+00    |proj g|=  2.28653D+00

At iterate  114    f=  2.82950D+00    |proj g|=  1.47843D+00
```

```
At iterate  115    f=  2.82916D+00    |proj g|=  9.63181D-01

At iterate  116    f=  2.82905D+00    |proj g|=  6.70892D-01

At iterate  117    f=  2.82903D+00    |proj g|=  1.12324D-01

At iterate  118    f=  2.82903D+00    |proj g|=  2.44770D-02

At iterate  119    f=  2.82903D+00    |proj g|=  1.83120D-02

At iterate  120    f=  2.82903D+00    |proj g|=  6.65811D-02

At iterate  121    f=  2.82903D+00    |proj g|=  1.06299D-01

At iterate  122    f=  2.82903D+00    |proj g|=  3.52019D-01

At iterate  123    f=  2.82902D+00    |proj g|=  4.23409D-01

At iterate  124    f=  2.82902D+00    |proj g|=  1.00913D+00

At iterate  125    f=  2.82900D+00    |proj g|=  1.11588D+00

At iterate  126    f=  2.82894D+00    |proj g|=  3.43265D-01

At iterate  127    f=  2.82883D+00    |proj g|=  1.93995D+00

At iterate  128    f=  2.82865D+00    |proj g|=  2.59376D+00

At iterate  129    f=  2.82747D+00    |proj g|=  5.68288D+00

At iterate  130    f=  2.82599D+00    |proj g|=  7.52522D+00

At iterate  131    f=  2.82264D+00    |proj g|=  8.43405D+00

At iterate  132    f=  2.82095D+00    |proj g|=  1.79587D+00

At iterate  133    f=  2.81890D+00    |proj g|=  3.86103D+00

At iterate  134    f=  2.81835D+00    |proj g|=  4.44225D+00

At iterate  135    f=  2.81821D+00    |proj g|=  9.24228D+00

At iterate  136    f=  2.81708D+00    |proj g|=  5.25768D+00

At iterate  137    f=  2.81382D+00    |proj g|=  8.71002D-01

At iterate  138    f=  2.81308D+00    |proj g|=  9.55631D-01

At iterate  139    f=  2.81301D+00    |proj g|=  1.53685D+00

At iterate  140    f=  2.81276D+00    |proj g|=  1.22677D+00

At iterate  141    f=  2.81266D+00    |proj g|=  7.45414D-01
```

```
At iterate  142    f=  2.81262D+00    |proj g|=  6.09472D-02

At iterate  143    f=  2.81262D+00    |proj g|=  5.39068D-02

At iterate  144    f=  2.81261D+00    |proj g|=  2.42025D-01

At iterate  145    f=  2.81261D+00    |proj g|=  1.72284D-01
 Warning:  more than 10 function and gradient
   evaluations in the last line search.  Termination
   may possibly be caused by a bad search direction.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate  146    f=  2.81261D+00    |proj g|=  1.72284D-01

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10    146    240      1     0     0   1.723D-01   2.813D+00
  F =   2.8126141657324779

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(6, 0, 4) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           11     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.81174D+00    |proj g|=  3.97790D-01

At iterate    1    f=  2.79339D+00    |proj g|=  5.30032D-01
```

```
At iterate    2    f=  2.78925D+00    |proj g|=  1.04820D-01

At iterate    3    f=  2.78877D+00    |proj g|=  9.07329D-02

At iterate    4    f=  2.78783D+00    |proj g|=  1.22478D-01

At iterate    5    f=  2.78650D+00    |proj g|=  1.24659D-01

At iterate    6    f=  2.78138D+00    |proj g|=  1.71333D-01

At iterate    7    f=  2.77656D+00    |proj g|=  1.06852D-01

At iterate    8    f=  2.77467D+00    |proj g|=  1.05696D-01

At iterate    9    f=  2.77205D+00    |proj g|=  1.18838D-01

At iterate   10    f=  2.77090D+00    |proj g|=  2.54367D-01

At iterate   11    f=  2.77058D+00    |proj g|=  2.00790D-01

At iterate   12    f=  2.77035D+00    |proj g|=  9.57184D-02

At iterate   13    f=  2.77007D+00    |proj g|=  7.88084D-02

At iterate   14    f=  2.76946D+00    |proj g|=  2.19354D-01

At iterate   15    f=  2.76885D+00    |proj g|=  2.67032D-01

At iterate   16    f=  2.76763D+00    |proj g|=  3.16890D-01

At iterate   17    f=  2.76609D+00    |proj g|=  3.91809D-01

At iterate   18    f=  2.76491D+00    |proj g|=  8.39708D-02

At iterate   19    f=  2.76285D+00    |proj g|=  6.28397D-02

At iterate   20    f=  2.76268D+00    |proj g|=  1.36019D-01

At iterate   21    f=  2.76226D+00    |proj g|=  1.26671D-01

At iterate   22    f=  2.76199D+00    |proj g|=  1.07572D-01

At iterate   23    f=  2.76033D+00    |proj g|=  7.93201D-01

At iterate   24    f=  2.75836D+00    |proj g|=  7.81463D-02

At iterate   25    f=  2.75587D+00    |proj g|=  2.44050D-01

At iterate   26    f=  2.75525D+00    |proj g|=  4.86596D-01

At iterate   27    f=  2.75487D+00    |proj g|=  4.10295D-01

At iterate   28    f=  2.75482D+00    |proj g|=  3.55851D-02
```

```
 At iterate   29    f=  2.75482D+00    |proj g|=  3.82722D-02

 At iterate   30    f=  2.75403D+00    |proj g|=  1.76843D-01

 At iterate   31    f=  2.75204D+00    |proj g|=  1.23061D-01

 At iterate   32    f=  2.75168D+00    |proj g|=  2.85154D-01

 At iterate   33    f=  2.75160D+00    |proj g|=  2.82153D-02

 At iterate   34    f=  2.75147D+00    |proj g|=  3.36477D-01

 At iterate   35    f=  2.75141D+00    |proj g|=  2.57848D-01

 At iterate   36    f=  2.75139D+00    |proj g|=  7.42599D-02

 At iterate   37    f=  2.75138D+00    |proj g|=  3.00615D-02

 At iterate   38    f=  2.75138D+00    |proj g|=  7.16298D-02

 At iterate   39    f=  2.75138D+00    |proj g|=  1.42598D-01

 At iterate   40    f=  2.75137D+00    |proj g|=  2.15686D-01

 At iterate   41    f=  2.75136D+00    |proj g|=  2.98172D-01

 At iterate   42    f=  2.75133D+00    |proj g|=  2.97679D-01

 At iterate   43    f=  2.75133D+00    |proj g|=  3.20713D-01

 At iterate   44    f=  2.75130D+00    |proj g|=  1.68579D-01

 At iterate   45    f=  2.75128D+00    |proj g|=  3.05040D-02

 At iterate   46    f=  2.75127D+00    |proj g|=  9.83257D-02

 At iterate   47    f=  2.75127D+00    |proj g|=  8.90306D-02

 At iterate   48    f=  2.75127D+00    |proj g|=  2.46360D-02

 At iterate   49    f=  2.75127D+00    |proj g|=  4.85801D-02

 At iterate   50    f=  2.75126D+00    |proj g|=  5.69788D-02

 At iterate   51    f=  2.75125D+00    |proj g|=  5.34133D-02

 At iterate   52    f=  2.75124D+00    |proj g|=  6.96703D-02

 At iterate   53    f=  2.75119D+00    |proj g|=  5.13037D-02

 At iterate   54    f=  2.75100D+00    |proj g|=  1.60636D-01
```

```
At iterate   55    f=  2.75098D+00    |proj g|=  5.00451D-01

At iterate   56    f=  2.75088D+00    |proj g|=  3.54230D-02

At iterate   57    f=  2.75084D+00    |proj g|=  1.06123D-01

At iterate   58    f=  2.75075D+00    |proj g|=  3.96829D-01

At iterate   59    f=  2.75066D+00    |proj g|=  1.07280D-01

At iterate   60    f=  2.75052D+00    |proj g|=  1.48930D-01

At iterate   61    f=  2.75020D+00    |proj g|=  1.29223D+00

At iterate   62    f=  2.74985D+00    |proj g|=  7.93021D-02

At iterate   63    f=  2.74937D+00    |proj g|=  2.53357D+00

At iterate   64    f=  2.74880D+00    |proj g|=  1.26804D+00

At iterate   65    f=  2.74838D+00    |proj g|=  8.55551D-01

At iterate   66    f=  2.74811D+00    |proj g|=  2.78383D-01

At iterate   67    f=  2.74797D+00    |proj g|=  1.00729D+00

At iterate   68    f=  2.74778D+00    |proj g|=  1.41798D+00

At iterate   69    f=  2.74760D+00    |proj g|=  1.12595D+00

At iterate   70    f=  2.74743D+00    |proj g|=  5.48789D-01

At iterate   71    f=  2.74732D+00    |proj g|=  2.99644D-01

At iterate   72    f=  2.74715D+00    |proj g|=  1.01710D-01

At iterate   73    f=  2.74684D+00    |proj g|=  6.06832D-01

At iterate   74    f=  2.74659D+00    |proj g|=  4.36245D-01

At iterate   75    f=  2.74652D+00    |proj g|=  8.50091D-02

At iterate   76    f=  2.74594D+00    |proj g|=  1.59889D-01

At iterate   77    f=  2.74471D+00    |proj g|=  9.04828D-01

At iterate   78    f=  2.74415D+00    |proj g|=  5.27344D-01

At iterate   79    f=  2.74300D+00    |proj g|=  8.33344D-01

At iterate   80    f=  2.74188D+00    |proj g|=  1.02078D+00

At iterate   81    f=  2.74135D+00    |proj g|=  4.65371D-01
```

```
At iterate   82    f=  2.73925D+00    |proj g|=  2.45446D-01

At iterate   83    f=  2.73654D+00    |proj g|=  1.87738D-01

At iterate   84    f=  2.73651D+00    |proj g|=  1.84817D-01

At iterate   85    f=  2.73543D+00    |proj g|=  1.96788D-01

At iterate   86    f=  2.73538D+00    |proj g|=  2.15874D-01

At iterate   87    f=  2.73344D+00    |proj g|=  1.25512D-01

At iterate   88    f=  2.73081D+00    |proj g|=  4.90171D-01

At iterate   89    f=  2.72844D+00    |proj g|=  5.19057D-01

At iterate   90    f=  2.72406D+00    |proj g|=  6.84871D-02

At iterate   91    f=  2.72251D+00    |proj g|=  9.62263D-02

At iterate   92    f=  2.72174D+00    |proj g|=  3.81101D-01

At iterate   93    f=  2.72131D+00    |proj g|=  2.24489D-01

At iterate   94    f=  2.72086D+00    |proj g|=  1.48136D-01

At iterate   95    f=  2.72032D+00    |proj g|=  1.82145D-01

At iterate   96    f=  2.71933D+00    |proj g|=  1.25673D-01

At iterate   97    f=  2.71862D+00    |proj g|=  5.23124D-02

At iterate   98    f=  2.71831D+00    |proj g|=  3.22741D-02

At iterate   99    f=  2.71815D+00    |proj g|=  6.58913D-02

At iterate  100    f=  2.71803D+00    |proj g|=  7.12575D-02

At iterate  101    f=  2.71767D+00    |proj g|=  1.98139D-01

At iterate  102    f=  2.71731D+00    |proj g|=  2.36320D-01

At iterate  103    f=  2.71712D+00    |proj g|=  1.20110D-01

At iterate  104    f=  2.71680D+00    |proj g|=  4.39046D-02

At iterate  105    f=  2.71675D+00    |proj g|=  1.69700D-01

At iterate  106    f=  2.71653D+00    |proj g|=  9.21139D-02

At iterate  107    f=  2.71625D+00    |proj g|=  1.93355D-02
```

```
At iterate  108    f=  2.71614D+00    |proj g|=  3.82887D-02

At iterate  109    f=  2.71609D+00    |proj g|=  3.69500D-02

At iterate  110    f=  2.71609D+00    |proj g|=  1.47465D-02

At iterate  111    f=  2.71608D+00    |proj g|=  1.36539D-02

At iterate  112    f=  2.71606D+00    |proj g|=  3.09126D-02

At iterate  113    f=  2.71605D+00    |proj g|=  3.69990D-02

At iterate  114    f=  2.71604D+00    |proj g|=  1.18818D-02

At iterate  115    f=  2.71604D+00    |proj g|=  9.81762D-03

At iterate  116    f=  2.71604D+00    |proj g|=  2.04522D-02

At iterate  117    f=  2.71603D+00    |proj g|=  1.81017D-02

At iterate  118    f=  2.71603D+00    |proj g|=  6.97470D-03

At iterate  119    f=  2.71602D+00    |proj g|=  4.88498D-03

At iterate  120    f=  2.71601D+00    |proj g|=  4.18870D-03

At iterate  121    f=  2.71601D+00    |proj g|=  2.23521D-02

At iterate  122    f=  2.71600D+00    |proj g|=  8.62416D-03

At iterate  123    f=  2.71599D+00    |proj g|=  7.19066D-03

At iterate  124    f=  2.71598D+00    |proj g|=  5.28594D-03

At iterate  125    f=  2.71598D+00    |proj g|=  1.20335D-02

At iterate  126    f=  2.71598D+00    |proj g|=  4.26833D-03

At iterate  127    f=  2.71598D+00    |proj g|=  1.38593D-02

At iterate  128    f=  2.71598D+00    |proj g|=  5.96386D-03

At iterate  129    f=  2.71598D+00    |proj g|=  2.99568D-03

At iterate  130    f=  2.71598D+00    |proj g|=  5.30072D-03

At iterate  131    f=  2.71598D+00    |proj g|=  6.13802D-03

At iterate  132    f=  2.71598D+00    |proj g|=  3.57842D-03

At iterate  133    f=  2.71597D+00    |proj g|=  3.96346D-03

At iterate  134    f=  2.71597D+00    |proj g|=  8.57396D-03
```

```
At iterate  135    f=  2.71597D+00    |proj g|=  9.17593D-03

At iterate  136    f=  2.71597D+00    |proj g|=  2.36074D-03

At iterate  137    f=  2.71597D+00    |proj g|=  5.15469D-03

At iterate  138    f=  2.71597D+00    |proj g|=  1.12048D-02

At iterate  139    f=  2.71597D+00    |proj g|=  6.37653D-03

At iterate  140    f=  2.71597D+00    |proj g|=  5.57302D-03

At iterate  141    f=  2.71597D+00    |proj g|=  5.39679D-03

At iterate  142    f=  2.71597D+00    |proj g|=  1.34837D-02

At iterate  143    f=  2.71597D+00    |proj g|=  6.34142D-03

At iterate  144    f=  2.71596D+00    |proj g|=  3.42811D-03

At iterate  145    f=  2.71596D+00    |proj g|=  4.79239D-03

At iterate  146    f=  2.71596D+00    |proj g|=  7.18101D-03

At iterate  147    f=  2.71596D+00    |proj g|=  8.50720D-03

At iterate  148    f=  2.71596D+00    |proj g|=  1.07723D-02

At iterate  149    f=  2.71596D+00    |proj g|=  4.05482D-03

At iterate  150    f=  2.71596D+00    |proj g|=  3.46982D-03

At iterate  151    f=  2.71596D+00    |proj g|=  4.95620D-03

At iterate  152    f=  2.71596D+00    |proj g|=  2.03919D-03

At iterate  153    f=  2.71596D+00    |proj g|=  5.69311D-03

At iterate  154    f=  2.71596D+00    |proj g|=  3.40380D-03

At iterate  155    f=  2.71596D+00    |proj g|=  1.35968D-02

At iterate  156    f=  2.71596D+00    |proj g|=  9.72418D-03

At iterate  157    f=  2.71595D+00    |proj g|=  2.44372D-03

At iterate  158    f=  2.71595D+00    |proj g|=  2.99703D-03

At iterate  159    f=  2.71595D+00    |proj g|=  3.41164D-03

At iterate  160    f=  2.71595D+00    |proj g|=  3.25879D-03
```

```
At iterate  161    f=  2.71595D+00    |proj g|=  3.81439D-03

At iterate  162    f=  2.71595D+00    |proj g|=  6.28600D-03

At iterate  163    f=  2.71595D+00    |proj g|=  2.79373D-03

At iterate  164    f=  2.71595D+00    |proj g|=  3.53203D-03

At iterate  165    f=  2.71595D+00    |proj g|=  4.93012D-03

At iterate  166    f=  2.71595D+00    |proj g|=  9.52811D-03

At iterate  167    f=  2.71595D+00    |proj g|=  1.59652D-03

At iterate  168    f=  2.71595D+00    |proj g|=  1.65877D-03

At iterate  169    f=  2.71595D+00    |proj g|=  2.48311D-03

At iterate  170    f=  2.71595D+00    |proj g|=  5.29160D-03

At iterate  171    f=  2.71595D+00    |proj g|=  6.20264D-03

At iterate  172    f=  2.71595D+00    |proj g|=  3.44923D-03

At iterate  173    f=  2.71595D+00    |proj g|=  2.33464D-03

At iterate  174    f=  2.71595D+00    |proj g|=  1.94098D-03

At iterate  175    f=  2.71595D+00    |proj g|=  1.00573D-03

At iterate  176    f=  2.71595D+00    |proj g|=  9.99975D-04

At iterate  177    f=  2.71595D+00    |proj g|=  1.09534D-03

At iterate  178    f=  2.71595D+00    |proj g|=  3.54485D-04

At iterate  179    f=  2.71595D+00    |proj g|=  1.07961D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   11    179    222      1     0     0   1.080D-03   2.716D+00
  F =   2.7159466648089219
```

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Trying SARIMAX(6, 0, 5) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           12     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.86857D+00    |proj g|=  2.48829D+00

At iterate    1    f=  2.80815D+00    |proj g|=  2.79993D-01

At iterate    2    f=  2.80529D+00    |proj g|=  5.34846D-01

At iterate    3    f=  2.79794D+00    |proj g|=  3.82337D-01
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate    4    f=  2.79178D+00    |proj g|=  2.49255D-01

At iterate    5    f=  2.79047D+00    |proj g|=  1.18366D-01

At iterate    6    f=  2.78999D+00    |proj g|=  1.51117D-01

At iterate    7    f=  2.78894D+00    |proj g|=  1.99342D-01

At iterate    8    f=  2.78335D+00    |proj g|=  3.98198D-01

At iterate    9    f=  2.78045D+00    |proj g|=  2.54501D-01

At iterate   10    f=  2.77281D+00    |proj g|=  3.55273D-01

At iterate   11    f=  2.77107D+00    |proj g|=  2.09200D-01

At iterate   12    f=  2.77015D+00    |proj g|=  1.14757D-01

At iterate   13    f=  2.76912D+00    |proj g|=  2.05788D-01

At iterate   14    f=  2.76597D+00    |proj g|=  4.13533D-01

At iterate   15    f=  2.76090D+00    |proj g|=  4.13507D-01

At iterate   16    f=  2.75827D+00    |proj g|=  7.50434D-01
```

```
At iterate   17    f=  2.74916D+00    |proj g|=  4.32851D-01

At iterate   18    f=  2.74591D+00    |proj g|=  6.91378D-02

At iterate   19    f=  2.74535D+00    |proj g|=  1.05366D-01

At iterate   20    f=  2.74470D+00    |proj g|=  2.80002D-01

At iterate   21    f=  2.74406D+00    |proj g|=  6.67855D-02

At iterate   22    f=  2.74371D+00    |proj g|=  1.02244D-01

At iterate   23    f=  2.74345D+00    |proj g|=  1.31288D-01

At iterate   24    f=  2.74302D+00    |proj g|=  9.49068D-02

At iterate   25    f=  2.74162D+00    |proj g|=  1.51643D-01

At iterate   26    f=  2.73981D+00    |proj g|=  1.45149D-01

At iterate   27    f=  2.73892D+00    |proj g|=  2.36051D-01

At iterate   28    f=  2.73865D+00    |proj g|=  6.89804D-02

At iterate   29    f=  2.73848D+00    |proj g|=  7.30912D-02

At iterate   30    f=  2.73815D+00    |proj g|=  2.00454D-01

At iterate   31    f=  2.73744D+00    |proj g|=  8.60394D-02

At iterate   32    f=  2.73629D+00    |proj g|=  1.01363D-01

At iterate   33    f=  2.73533D+00    |proj g|=  5.07015D-01

At iterate   34    f=  2.73264D+00    |proj g|=  3.16419D-01

At iterate   35    f=  2.72962D+00    |proj g|=  1.69270D+00

At iterate   36    f=  2.72857D+00    |proj g|=  2.93441D-01

At iterate   37    f=  2.72795D+00    |proj g|=  4.65092D-02

At iterate   38    f=  2.72782D+00    |proj g|=  3.38259D-01

At iterate   39    f=  2.72769D+00    |proj g|=  4.98371D-02

At iterate   40    f=  2.72742D+00    |proj g|=  3.76637D-01

At iterate   41    f=  2.72722D+00    |proj g|=  3.59653D-01

At iterate   42    f=  2.72712D+00    |proj g|=  3.24946D-01
```

```
At iterate   43    f=  2.72677D+00    |proj g|=  2.46631D-01

At iterate   44    f=  2.72649D+00    |proj g|=  6.58680D-01

At iterate   45    f=  2.72556D+00    |proj g|=  1.48014D+00

At iterate   46    f=  2.72407D+00    |proj g|=  1.71681D+00

At iterate   47    f=  2.72359D+00    |proj g|=  1.48801D+00

At iterate   48    f=  2.72308D+00    |proj g|=  1.10413D+00

At iterate   49    f=  2.72282D+00    |proj g|=  2.22108D-01

At iterate   50    f=  2.72269D+00    |proj g|=  7.04349D-02

At iterate   51    f=  2.72256D+00    |proj g|=  7.13631D-02

At iterate   52    f=  2.72247D+00    |proj g|=  2.63152D-01

At iterate   53    f=  2.72237D+00    |proj g|=  2.38260D-01

At iterate   54    f=  2.72200D+00    |proj g|=  2.89942D-01

At iterate   55    f=  2.72177D+00    |proj g|=  5.06661D-02

At iterate   56    f=  2.72173D+00    |proj g|=  6.87324D-02

At iterate   57    f=  2.72170D+00    |proj g|=  1.40259D-01

At iterate   58    f=  2.72168D+00    |proj g|=  9.73202D-02

At iterate   59    f=  2.72162D+00    |proj g|=  1.72489D-02

At iterate   60    f=  2.72158D+00    |proj g|=  1.41875D-01

At iterate   61    f=  2.72154D+00    |proj g|=  1.19189D-01

At iterate   62    f=  2.72152D+00    |proj g|=  1.03661D-01

At iterate   63    f=  2.72151D+00    |proj g|=  3.55823D-02

At iterate   64    f=  2.72150D+00    |proj g|=  1.37564D-02

At iterate   65    f=  2.72150D+00    |proj g|=  1.38817D-02

At iterate   66    f=  2.72150D+00    |proj g|=  1.55653D-02

At iterate   67    f=  2.72150D+00    |proj g|=  3.66396D-02

At iterate   68    f=  2.72150D+00    |proj g|=  1.14471D-02

At iterate   69    f=  2.72150D+00    |proj g|=  1.01001D-02
```

```
 At iterate   70    f=  2.72150D+00    |proj g|=  1.77896D-02

 At iterate   71    f=  2.72150D+00    |proj g|=  3.24247D-02

 At iterate   72    f=  2.72149D+00    |proj g|=  4.68988D-02

 At iterate   73    f=  2.72149D+00    |proj g|=  1.47955D-01

 At iterate   74    f=  2.72148D+00    |proj g|=  1.00900D-01

 At iterate   75    f=  2.72145D+00    |proj g|=  1.91396D-02

 At iterate   76    f=  2.72142D+00    |proj g|=  1.16721D-01

 At iterate   77    f=  2.72139D+00    |proj g|=  1.20285D-01

 At iterate   78    f=  2.72139D+00    |proj g|=  1.64993D-01

 At iterate   79    f=  2.72136D+00    |proj g|=  1.05858D-01

 At iterate   80    f=  2.72132D+00    |proj g|=  3.43772D-02

 At iterate   81    f=  2.72132D+00    |proj g|=  1.77446D-02

 At iterate   82    f=  2.72131D+00    |proj g|=  3.40035D-02

 At iterate   83    f=  2.72131D+00    |proj g|=  5.08224D-02

 At iterate   84    f=  2.72130D+00    |proj g|=  2.42033D-02

 At iterate   85    f=  2.72129D+00    |proj g|=  9.74063D-02

 At iterate   86    f=  2.72128D+00    |proj g|=  4.49471D-02

 At iterate   87    f=  2.72128D+00    |proj g|=  3.15269D-02

 At iterate   88    f=  2.72127D+00    |proj g|=  4.85650D-02

 At iterate   89    f=  2.72127D+00    |proj g|=  1.60826D-02

 At iterate   90    f=  2.72127D+00    |proj g|=  4.92839D-02

 At iterate   91    f=  2.72126D+00    |proj g|=  2.90656D-02

 At iterate   92    f=  2.72125D+00    |proj g|=  1.62205D-02

 At iterate   93    f=  2.72125D+00    |proj g|=  1.78315D-02

 At iterate   94    f=  2.72125D+00    |proj g|=  1.69740D-02

 At iterate   95    f=  2.72125D+00    |proj g|=  4.87661D-02
```

```
At iterate   96    f=  2.72124D+00    |proj g|=  3.70931D-02

At iterate   97    f=  2.72124D+00    |proj g|=  7.92127D-02

At iterate   98    f=  2.72124D+00    |proj g|=  1.86873D-02

At iterate   99    f=  2.72123D+00    |proj g|=  1.40835D-02

At iterate  100    f=  2.72123D+00    |proj g|=  2.59837D-02

At iterate  101    f=  2.72123D+00    |proj g|=  1.22673D-02

At iterate  102    f=  2.72123D+00    |proj g|=  9.07191D-03

At iterate  103    f=  2.72122D+00    |proj g|=  2.12063D-02

At iterate  104    f=  2.72119D+00    |proj g|=  1.24538D-01

At iterate  105    f=  2.72116D+00    |proj g|=  1.61403D-01

At iterate  106    f=  2.72112D+00    |proj g|=  1.15832D-01

At iterate  107    f=  2.72111D+00    |proj g|=  1.72876D-01

At iterate  108    f=  2.72110D+00    |proj g|=  4.14310D-02

At iterate  109    f=  2.72109D+00    |proj g|=  1.65088D-02

At iterate  110    f=  2.72109D+00    |proj g|=  3.32579D-02

At iterate  111    f=  2.72108D+00    |proj g|=  5.77273D-02

At iterate  112    f=  2.72107D+00    |proj g|=  1.37038D-01

At iterate  113    f=  2.72103D+00    |proj g|=  1.94557D-01

At iterate  114    f=  2.72095D+00    |proj g|=  2.52116D-01

At iterate  115    f=  2.72087D+00    |proj g|=  1.29698D-01

At iterate  116    f=  2.72082D+00    |proj g|=  1.78558D-01

At iterate  117    f=  2.72078D+00    |proj g|=  3.76609D-02

At iterate  118    f=  2.72076D+00    |proj g|=  9.12645D-02

At iterate  119    f=  2.72076D+00    |proj g|=  3.77289D-02

At iterate  120    f=  2.72075D+00    |proj g|=  3.67239D-02

At iterate  121    f=  2.72073D+00    |proj g|=  1.11198D-01

At iterate  122    f=  2.72070D+00    |proj g|=  1.53330D-01
```

```
At iterate  123    f=  2.72066D+00    |proj g|=  1.29844D-01

At iterate  124    f=  2.72061D+00    |proj g|=  6.40686D-02

At iterate  125    f=  2.72054D+00    |proj g|=  6.35898D-02

At iterate  126    f=  2.72046D+00    |proj g|=  9.26171D-02

At iterate  127    f=  2.72040D+00    |proj g|=  1.28809D-01

At iterate  128    f=  2.72035D+00    |proj g|=  1.42224D-01

At iterate  129    f=  2.72032D+00    |proj g|=  1.31148D-01

At iterate  130    f=  2.72029D+00    |proj g|=  6.46317D-02

At iterate  131    f=  2.72026D+00    |proj g|=  3.70846D-02

At iterate  132    f=  2.72021D+00    |proj g|=  4.17294D-02

At iterate  133    f=  2.71997D+00    |proj g|=  8.21743D-02

At iterate  134    f=  2.71970D+00    |proj g|=  5.62845D-02

At iterate  135    f=  2.71956D+00    |proj g|=  2.64089D-02

At iterate  136    f=  2.71949D+00    |proj g|=  1.24096D-01

At iterate  137    f=  2.71918D+00    |proj g|=  4.88457D-02

At iterate  138    f=  2.71901D+00    |proj g|=  3.33926D-02

At iterate  139    f=  2.71899D+00    |proj g|=  1.33096D-01

At iterate  140    f=  2.71885D+00    |proj g|=  1.19009D-01

At iterate  141    f=  2.71884D+00    |proj g|=  7.21011D-02

At iterate  142    f=  2.71873D+00    |proj g|=  5.25903D-02

At iterate  143    f=  2.71849D+00    |proj g|=  2.00137D-02

At iterate  144    f=  2.71823D+00    |proj g|=  5.49223D-02

At iterate  145    f=  2.71805D+00    |proj g|=  3.01256D-02

At iterate  146    f=  2.71792D+00    |proj g|=  5.42136D-02

At iterate  147    f=  2.71781D+00    |proj g|=  9.19141D-02

At iterate  148    f=  2.71769D+00    |proj g|=  5.97863D-02
```

```
At iterate  149    f=  2.71686D+00    |proj g|=  4.97070D-02

At iterate  150    f=  2.71681D+00    |proj g|=  1.10306D-01

At iterate  151    f=  2.71656D+00    |proj g|=  2.75285D-02

At iterate  152    f=  2.71655D+00    |proj g|=  9.80794D-02

At iterate  153    f=  2.71653D+00    |proj g|=  4.71823D-02

At iterate  154    f=  2.71648D+00    |proj g|=  2.64197D-02

At iterate  155    f=  2.71638D+00    |proj g|=  2.02568D-02

At iterate  156    f=  2.71621D+00    |proj g|=  2.24280D-02

At iterate  157    f=  2.71613D+00    |proj g|=  3.07725D-02

At iterate  158    f=  2.71609D+00    |proj g|=  9.18381D-02

At iterate  159    f=  2.71601D+00    |proj g|=  6.18057D-02

At iterate  160    f=  2.71589D+00    |proj g|=  2.40105D-02

At iterate  161    f=  2.71588D+00    |proj g|=  8.52212D-02

At iterate  162    f=  2.71583D+00    |proj g|=  8.39455D-02

At iterate  163    f=  2.71576D+00    |proj g|=  6.22862D-02

At iterate  164    f=  2.71551D+00    |proj g|=  6.80687D-02

At iterate  165    f=  2.71538D+00    |proj g|=  4.26170D-02

At iterate  166    f=  2.71529D+00    |proj g|=  2.60816D-02

At iterate  167    f=  2.71522D+00    |proj g|=  1.67809D-02

At iterate  168    f=  2.71513D+00    |proj g|=  3.72082D-02

At iterate  169    f=  2.71502D+00    |proj g|=  4.28444D-02

At iterate  170    f=  2.71491D+00    |proj g|=  7.28348D-02

At iterate  171    f=  2.71480D+00    |proj g|=  5.67650D-02

At iterate  172    f=  2.71479D+00    |proj g|=  3.70399D-02

At iterate  173    f=  2.71473D+00    |proj g|=  2.91051D-02

At iterate  174    f=  2.71464D+00    |proj g|=  2.71161D-02

At iterate  175    f=  2.71453D+00    |proj g|=  3.24447D-02
```

```
At iterate  176    f=  2.71415D+00    |proj g|=  2.76392D-02

At iterate  177    f=  2.71404D+00    |proj g|=  1.95838D-02

At iterate  178    f=  2.71401D+00    |proj g|=  1.91047D-02

At iterate  179    f=  2.71397D+00    |proj g|=  8.70605D-03

At iterate  180    f=  2.71390D+00    |proj g|=  3.16487D-02

At iterate  181    f=  2.71388D+00    |proj g|=  1.90969D-02

At iterate  182    f=  2.71387D+00    |proj g|=  2.34897D-02

At iterate  183    f=  2.71387D+00    |proj g|=  1.01794D-02

At iterate  184    f=  2.71387D+00    |proj g|=  7.67641D-03

At iterate  185    f=  2.71386D+00    |proj g|=  1.05892D-02

At iterate  186    f=  2.71385D+00    |proj g|=  1.30255D-02

At iterate  187    f=  2.71383D+00    |proj g|=  1.09137D-02

At iterate  188    f=  2.71382D+00    |proj g|=  7.82474D-03

At iterate  189    f=  2.71380D+00    |proj g|=  9.77575D-03

At iterate  190    f=  2.71379D+00    |proj g|=  1.08358D-02

At iterate  191    f=  2.71377D+00    |proj g|=  1.26568D-02

At iterate  192    f=  2.71376D+00    |proj g|=  1.05189D-02

At iterate  193    f=  2.71375D+00    |proj g|=  5.20969D-03

At iterate  194    f=  2.71375D+00    |proj g|=  2.20585D-02

At iterate  195    f=  2.71375D+00    |proj g|=  7.73974D-03

At iterate  196    f=  2.71375D+00    |proj g|=  5.09281D-03

At iterate  197    f=  2.71374D+00    |proj g|=  4.35511D-03

At iterate  198    f=  2.71374D+00    |proj g|=  5.76257D-03

At iterate  199    f=  2.71373D+00    |proj g|=  7.10148D-03

At iterate  200    f=  2.71372D+00    |proj g|=  9.09525D-03
```

* * *

```
Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   12    200    242      1     0     0   9.095D-03   2.714D+00
  F =   2.7137213378497309

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
Trying SARIMAX(6, 0, 6) ...
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           13     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.80400D+00    |proj g|=  1.86728D-01

At iterate    1    f=  2.77533D+00    |proj g|=  4.79844D-01
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate    2    f=  2.76960D+00    |proj g|=  3.63809D-01

At iterate    3    f=  2.76650D+00    |proj g|=  3.16825D-01

At iterate    4    f=  2.76053D+00    |proj g|=  3.30606D-01

At iterate    5    f=  2.75177D+00    |proj g|=  1.54841D-01

At iterate    6    f=  2.74832D+00    |proj g|=  1.07996D-01

At iterate    7    f=  2.74594D+00    |proj g|=  9.77831D-02
```

```
At iterate    8    f=  2.74413D+00    |proj g|=  9.76173D-02

At iterate    9    f=  2.74217D+00    |proj g|=  7.46403D-02

At iterate   10    f=  2.73746D+00    |proj g|=  7.90971D-02

At iterate   11    f=  2.73569D+00    |proj g|=  6.55461D-02

At iterate   12    f=  2.73256D+00    |proj g|=  6.24331D-02

At iterate   13    f=  2.73255D+00    |proj g|=  5.22886D-02

At iterate   14    f=  2.73164D+00    |proj g|=  4.92569D-02

At iterate   15    f=  2.73048D+00    |proj g|=  2.40255D-02

At iterate   16    f=  2.73003D+00    |proj g|=  2.12533D-02

At iterate   17    f=  2.72979D+00    |proj g|=  1.65706D-02

At iterate   18    f=  2.72937D+00    |proj g|=  1.58537D-02

At iterate   19    f=  2.72911D+00    |proj g|=  2.13398D-02

At iterate   20    f=  2.72888D+00    |proj g|=  1.80167D-02

At iterate   21    f=  2.72854D+00    |proj g|=  1.68331D-02

At iterate   22    f=  2.72824D+00    |proj g|=  1.73412D-02

At iterate   23    f=  2.72777D+00    |proj g|=  2.36735D-02

At iterate   24    f=  2.72777D+00    |proj g|=  8.13423D-02

At iterate   25    f=  2.72721D+00    |proj g|=  2.00110D-02

At iterate   26    f=  2.72699D+00    |proj g|=  2.32444D-02

At iterate   27    f=  2.72678D+00    |proj g|=  2.49082D-02

At iterate   28    f=  2.72635D+00    |proj g|=  2.37366D-02

At iterate   29    f=  2.72498D+00    |proj g|=  4.63435D-02

At iterate   30    f=  2.72273D+00    |proj g|=  1.69810D-01

At iterate   31    f=  2.72178D+00    |proj g|=  6.92288D-01

At iterate   32    f=  2.72163D+00    |proj g|=  4.76034D-01

At iterate   33    f=  2.72090D+00    |proj g|=  4.93517D-01

At iterate   34    f=  2.71953D+00    |proj g|=  2.12867D-01
```

```
At iterate   35    f=  2.71884D+00    |proj g|=  2.08572D-01

At iterate   36    f=  2.71864D+00    |proj g|=  6.08264D-02

At iterate   37    f=  2.71854D+00    |proj g|=  5.67600D-02

At iterate   38    f=  2.71828D+00    |proj g|=  1.61150D-01

At iterate   39    f=  2.71800D+00    |proj g|=  2.14885D-01

At iterate   40    f=  2.71765D+00    |proj g|=  1.35025D-01

At iterate   41    f=  2.71751D+00    |proj g|=  6.88016D-02

At iterate   42    f=  2.71744D+00    |proj g|=  1.72664D-01

At iterate   43    f=  2.71743D+00    |proj g|=  1.57918D-01

At iterate   44    f=  2.71739D+00    |proj g|=  6.59996D-02

At iterate   45    f=  2.71733D+00    |proj g|=  2.04708D-01

At iterate   46    f=  2.71727D+00    |proj g|=  2.73723D-01

At iterate   47    f=  2.71718D+00    |proj g|=  2.27117D-01

At iterate   48    f=  2.71708D+00    |proj g|=  2.02241D-01

At iterate   49    f=  2.71704D+00    |proj g|=  8.94043D-02

At iterate   50    f=  2.71693D+00    |proj g|=  1.60828D-01

At iterate   51    f=  2.71676D+00    |proj g|=  2.03784D-01

At iterate   52    f=  2.71660D+00    |proj g|=  6.59128D-02

At iterate   53    f=  2.71654D+00    |proj g|=  1.90206D-01

At iterate   54    f=  2.71644D+00    |proj g|=  1.43277D-01

At iterate   55    f=  2.71635D+00    |proj g|=  4.05288D-01

At iterate   56    f=  2.71627D+00    |proj g|=  2.06242D-01

At iterate   57    f=  2.71622D+00    |proj g|=  8.47054D-02

At iterate   58    f=  2.71615D+00    |proj g|=  3.05522D-02

At iterate   59    f=  2.71609D+00    |proj g|=  1.09839D-01

At iterate   60    f=  2.71605D+00    |proj g|=  4.23047D-02
```

```
At iterate   61    f=  2.71602D+00    |proj g|=  1.04861D-01

At iterate   62    f=  2.71601D+00    |proj g|=  5.72104D-02

At iterate   63    f=  2.71599D+00    |proj g|=  2.83753D-02

At iterate   64    f=  2.71597D+00    |proj g|=  9.84045D-02

At iterate   65    f=  2.71593D+00    |proj g|=  1.46634D-01

At iterate   66    f=  2.71588D+00    |proj g|=  1.57812D-01

At iterate   67    f=  2.71588D+00    |proj g|=  2.47918D-01

At iterate   68    f=  2.71582D+00    |proj g|=  1.34766D-01

At iterate   69    f=  2.71580D+00    |proj g|=  2.71546D-02

At iterate   70    f=  2.71579D+00    |proj g|=  2.71419D-02

At iterate   71    f=  2.71574D+00    |proj g|=  7.71717D-02

At iterate   72    f=  2.71561D+00    |proj g|=  1.78524D-01

At iterate   73    f=  2.71526D+00    |proj g|=  1.91093D-01

At iterate   74    f=  2.71502D+00    |proj g|=  5.07302D-01

At iterate   75    f=  2.71451D+00    |proj g|=  4.48593D-01

At iterate   76    f=  2.71362D+00    |proj g|=  1.52038D-01

At iterate   77    f=  2.71353D+00    |proj g|=  9.02798D-02

At iterate   78    f=  2.71353D+00    |proj g|=  8.92379D-02

At iterate   79    f=  2.71349D+00    |proj g|=  3.02774D-02

At iterate   80    f=  2.71338D+00    |proj g|=  8.29074D-02

At iterate   81    f=  2.71321D+00    |proj g|=  1.81426D-01

At iterate   82    f=  2.71311D+00    |proj g|=  2.22900D-02

At iterate   83    f=  2.71306D+00    |proj g|=  2.06806D-02

At iterate   84    f=  2.71275D+00    |proj g|=  2.64967D-01

At iterate   85    f=  2.71264D+00    |proj g|=  1.58292D-01

At iterate   86    f=  2.71260D+00    |proj g|=  4.29583D-02

At iterate   87    f=  2.71259D+00    |proj g|=  2.27773D-02
```

```
 At iterate   88    f=  2.71259D+00    |proj g|=  3.10774D-02

 At iterate   89    f=  2.71259D+00    |proj g|=  4.90401D-02

 At iterate   90    f=  2.71259D+00    |proj g|=  5.69386D-02

 At iterate   91    f=  2.71259D+00    |proj g|=  4.84706D-02

 At iterate   92    f=  2.71258D+00    |proj g|=  2.20253D-02

 At iterate   93    f=  2.71257D+00    |proj g|=  3.80359D-02

 At iterate   94    f=  2.71256D+00    |proj g|=  8.99026D-02

 At iterate   95    f=  2.71254D+00    |proj g|=  1.53962D-01

 At iterate   96    f=  2.71248D+00    |proj g|=  2.23260D-01

 At iterate   97    f=  2.71240D+00    |proj g|=  2.35146D-01

 At iterate   98    f=  2.71240D+00    |proj g|=  1.86132D-01

 At iterate   99    f=  2.71234D+00    |proj g|=  1.05759D-01

 At iterate  100    f=  2.71232D+00    |proj g|=  1.37912D-01

 At iterate  101    f=  2.71232D+00    |proj g|=  5.32667D-02

 At iterate  102    f=  2.71232D+00    |proj g|=  1.83603D-02

 At iterate  103    f=  2.71231D+00    |proj g|=  3.26371D-02

 At iterate  104    f=  2.71231D+00    |proj g|=  3.91464D-02

 At iterate  105    f=  2.71230D+00    |proj g|=  3.55275D-02

 At iterate  106    f=  2.71228D+00    |proj g|=  7.17674D-02

 At iterate  107    f=  2.71223D+00    |proj g|=  5.13014D-02

 At iterate  108    f=  2.71213D+00    |proj g|=  1.90770D-02

 At iterate  109    f=  2.71212D+00    |proj g|=  6.36164D-02

 At iterate  110    f=  2.71209D+00    |proj g|=  1.43150D-02

 At iterate  111    f=  2.71207D+00    |proj g|=  1.73186D-02

 At iterate  112    f=  2.71205D+00    |proj g|=  1.40399D-01

 At iterate  113    f=  2.71204D+00    |proj g|=  1.62728D-02
```

```
At iterate  114    f=  2.71204D+00    |proj g|=  2.65425D-02

At iterate  115    f=  2.71204D+00    |proj g|=  1.36924D-02

At iterate  116    f=  2.71203D+00    |proj g|=  8.71409D-03

At iterate  117    f=  2.71202D+00    |proj g|=  4.17905D-02

At iterate  118    f=  2.71200D+00    |proj g|=  5.62584D-02

At iterate  119    f=  2.71198D+00    |proj g|=  1.72237D-01

At iterate  120    f=  2.71197D+00    |proj g|=  4.26438D-02

At iterate  121    f=  2.71196D+00    |proj g|=  1.76624D-02

At iterate  122    f=  2.71196D+00    |proj g|=  1.17014D-02

At iterate  123    f=  2.71196D+00    |proj g|=  3.38584D-02

At iterate  124    f=  2.71196D+00    |proj g|=  1.11158D-02

At iterate  125    f=  2.71196D+00    |proj g|=  1.03937D-02

At iterate  126    f=  2.71195D+00    |proj g|=  3.41156D-02

At iterate  127    f=  2.71194D+00    |proj g|=  1.07176D-02

At iterate  128    f=  2.71191D+00    |proj g|=  5.99250D-02

At iterate  129    f=  2.71189D+00    |proj g|=  7.10153D-02

At iterate  130    f=  2.71188D+00    |proj g|=  3.66819D-02

At iterate  131    f=  2.71187D+00    |proj g|=  5.78126D-02

At iterate  132    f=  2.71187D+00    |proj g|=  9.75933D-03

At iterate  133    f=  2.71187D+00    |proj g|=  7.88089D-03

At iterate  134    f=  2.71187D+00    |proj g|=  3.96279D-02

At iterate  135    f=  2.71187D+00    |proj g|=  2.81389D-02

At iterate  136    f=  2.71187D+00    |proj g|=  1.09040D-02

At iterate  137    f=  2.71187D+00    |proj g|=  7.91171D-03

At iterate  138    f=  2.71186D+00    |proj g|=  6.84314D-02

At iterate  139    f=  2.71185D+00    |proj g|=  4.97674D-02

At iterate  140    f=  2.71183D+00    |proj g|=  9.39699D-03
```

```
At iterate  141    f=  2.71182D+00    |proj g|=  9.28671D-03

At iterate  142    f=  2.71182D+00    |proj g|=  3.26813D-02

At iterate  143    f=  2.71181D+00    |proj g|=  1.59975D-02

At iterate  144    f=  2.71181D+00    |proj g|=  4.26360D-02

At iterate  145    f=  2.71181D+00    |proj g|=  1.18004D-02

At iterate  146    f=  2.71181D+00    |proj g|=  1.33942D-02

At iterate  147    f=  2.71181D+00    |proj g|=  3.27372D-02

At iterate  148    f=  2.71181D+00    |proj g|=  3.57886D-02

At iterate  149    f=  2.71180D+00    |proj g|=  2.49635D-02

At iterate  150    f=  2.71178D+00    |proj g|=  6.94568D-02

At iterate  151    f=  2.71174D+00    |proj g|=  1.28300D-01

At iterate  152    f=  2.71169D+00    |proj g|=  1.56620D-01

At iterate  153    f=  2.71167D+00    |proj g|=  6.23825D-02

At iterate  154    f=  2.71160D+00    |proj g|=  7.99481D-02

At iterate  155    f=  2.71157D+00    |proj g|=  1.80333D-02

At iterate  156    f=  2.71153D+00    |proj g|=  1.85649D-01

At iterate  157    f=  2.71148D+00    |proj g|=  5.14252D-02

At iterate  158    f=  2.71146D+00    |proj g|=  7.19595D-02

At iterate  159    f=  2.71144D+00    |proj g|=  6.36619D-02

At iterate  160    f=  2.71144D+00    |proj g|=  1.04792D-01

At iterate  161    f=  2.71141D+00    |proj g|=  5.76901D-02

At iterate  162    f=  2.71134D+00    |proj g|=  7.44792D-02

At iterate  163    f=  2.71132D+00    |proj g|=  1.04832D-01

At iterate  164    f=  2.71130D+00    |proj g|=  3.53357D-02

At iterate  165    f=  2.71129D+00    |proj g|=  9.02021D-02

At iterate  166    f=  2.71126D+00    |proj g|=  5.91145D-02
```

```
At iterate  167    f=  2.71124D+00    |proj g|=  6.17358D-02

At iterate  168    f=  2.71121D+00    |proj g|=  2.38470D-01

At iterate  169    f=  2.71116D+00    |proj g|=  9.21987D-02

At iterate  170    f=  2.71114D+00    |proj g|=  5.29409D-02

At iterate  171    f=  2.71110D+00    |proj g|=  5.24591D-02

At iterate  172    f=  2.71110D+00    |proj g|=  4.41459D-02

At iterate  173    f=  2.71105D+00    |proj g|=  3.15446D-02

At iterate  174    f=  2.71097D+00    |proj g|=  1.98335D-02

At iterate  175    f=  2.71081D+00    |proj g|=  3.75105D-02

At iterate  176    f=  2.71066D+00    |proj g|=  5.22402D-02

At iterate  177    f=  2.71065D+00    |proj g|=  9.59066D-02

At iterate  178    f=  2.71055D+00    |proj g|=  7.90610D-02

At iterate  179    f=  2.71055D+00    |proj g|=  2.75942D-02

At iterate  180    f=  2.71054D+00    |proj g|=  3.07235D-02

At iterate  181    f=  2.71046D+00    |proj g|=  2.66834D-02

At iterate  182    f=  2.71029D+00    |proj g|=  2.72449D-02

At iterate  183    f=  2.70928D+00    |proj g|=  2.98027D-02

At iterate  184    f=  2.70912D+00    |proj g|=  3.92130D-02

At iterate  185    f=  2.70896D+00    |proj g|=  3.60498D-02

At iterate  186    f=  2.70867D+00    |proj g|=  1.93356D-02

At iterate  187    f=  2.70826D+00    |proj g|=  1.10777D-02

At iterate  188    f=  2.70825D+00    |proj g|=  9.14499D-03

At iterate  189    f=  2.70812D+00    |proj g|=  7.36944D-03

At iterate  190    f=  2.70812D+00    |proj g|=  2.14786D-02

At iterate  191    f=  2.70812D+00    |proj g|=  1.96761D-02

At iterate  192    f=  2.70806D+00    |proj g|=  2.20568D-02

At iterate  193    f=  2.70799D+00    |proj g|=  5.77783D-03
```

```
At iterate  194    f=  2.70798D+00    |proj g|=  3.21783D-03

At iterate  195    f=  2.70797D+00    |proj g|=  1.89301D-03

At iterate  196    f=  2.70797D+00    |proj g|=  1.42357D-03

At iterate  197    f=  2.70797D+00    |proj g|=  9.19173D-04

At iterate  198    f=  2.70797D+00    |proj g|=  8.88837D-04

At iterate  199    f=  2.70797D+00    |proj g|=  5.77012D-04

At iterate  200    f=  2.70797D+00    |proj g|=  1.08671D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   13    200    243      1     0     0   1.087D-03   2.708D+00
  F =   2.7079711611956911

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT

Top SARIMAX models based on AIC:
    p  q          AIC          BIC  Converged
48  6  6  2506.501584  2559.950659      False
41  5  6  2509.009418  2558.347026      False
47  6  5  2509.768745  2559.132932      False
46  6  4  2509.807145  2555.057649       True
34  4  6  2511.276383  2556.502524       True
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
```

The best model (lowest AIC) is SARIMAX(6, 0, 5) with AIC ≈ 2512.67, and it successfully converged.

best_model = SARIMAX(train['Views'], order=(6, 0, 5)).fit()

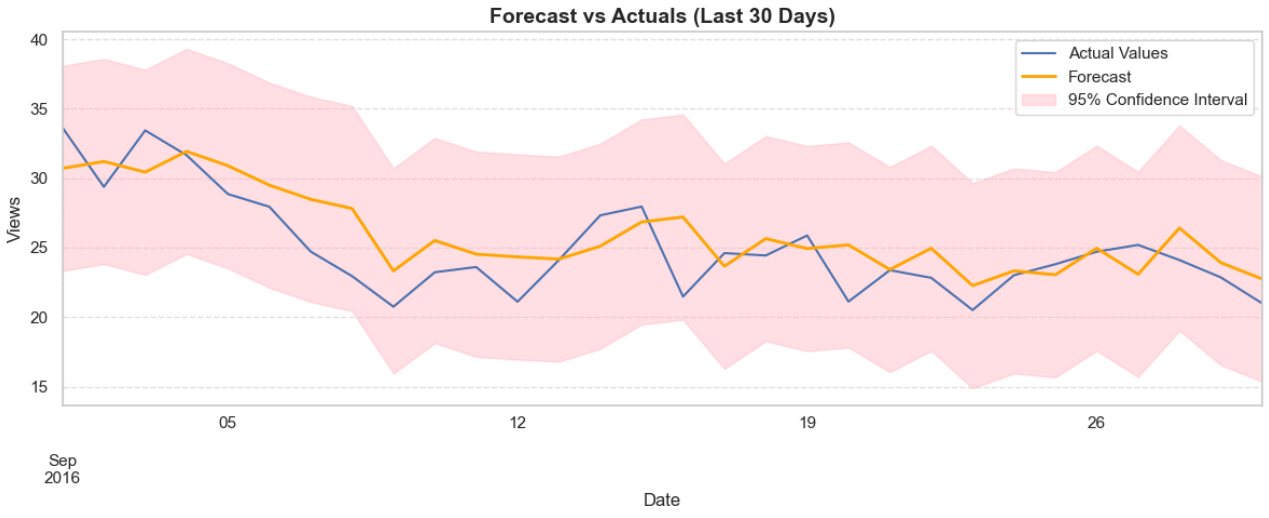
In [50]:
```
import pickle

# Save the trained model to a file
model_filename = 'arma_model.pkl'

try:
    with open(model_filename, 'wb') as f:
        pickle.dump(model, f)
    print(f"✅ Model successfully saved to '{model_filename}'")
except Exception as e:
    print(f"❌ Error saving model: {e}")
```

```
✅ Model successfully saved to 'arma_model.pkl'
```

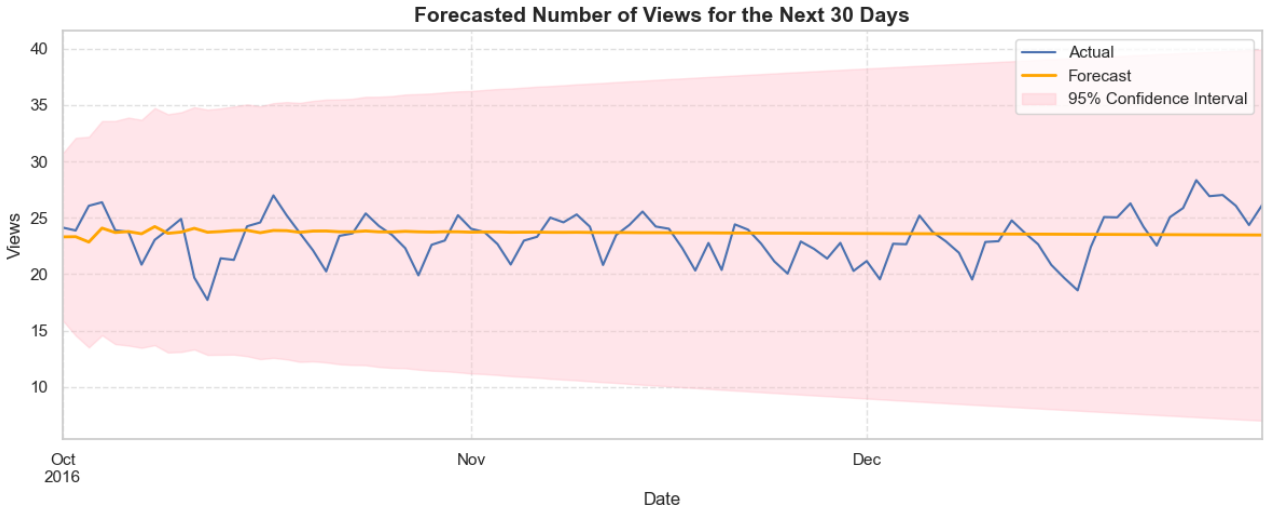
In [51]:
```
# Generate forecast for the last 30 observations
n_periods = 30
forecast = result.get_prediction(start=len(result.data.endog) - n_periods)

# Extract forecast mean and confidence intervals
forecast_mean = forecast.predicted_mean
conf_int = forecast.conf_int()

# Preview results (optional)
print("Forecast Summary:")
print(forecast_mean.head())
print("\nConfidence Intervals:")
print(conf_int.head())
```

```
Forecast Summary:
2016-09-01    30.711581
2016-09-02    31.209310
2016-09-03    30.436964
2016-09-04    31.933502
2016-09-05    30.900152
Freq: D, Name: predicted_mean, dtype: float64

Confidence Intervals:
            lower Views  upper Views
2016-09-01    23.330395    38.092766
2016-09-02    23.828125    38.590495
2016-09-03    23.055779    37.818149
2016-09-04    24.552317    39.314687
2016-09-05    23.518966    38.281337
```

In [52]:
```
import matplotlib.pyplot as plt

# Create the plot
fig, ax = plt.subplots(figsize=(12, 5))

# Plot actual values from the training set (last 30 days)
train[-30:].rename(columns={'Views': 'Actual Values'}).plot(ax=ax, legend=Tr

# Plot forecasted mean
forecast_mean.plot(ax=ax, label='Forecast', color='orange', linewidth=2)

# Add confidence interval shading
ax.fill_between(
    conf_int.index,
    conf_int.iloc[:, 0],  # Lower bound
    conf_int.iloc[:, 1],  # Upper bound
    color='pink',
    alpha=0.5,
    label='95% Confidence Interval'
)

# Final touches
ax.set_title('Forecast vs Actuals (Last 30 Days)', fontsize=14, fontweight='
ax.set_xlabel('Date')
ax.set_ylabel('Views')
ax.grid(True, linestyle='--', alpha=0.6)
ax.legend()
plt.tight_layout()
plt.show()
```



In [53]:
```
# Forecasting using ARMA model
forecast_values = result.get_forecast(steps=test.shape[0])
forecast_mean = forecast_values.predicted_mean
conf_int = forecast_values.conf_int()

# Prepare forecast DataFrame
arma_forecast_df = pd.DataFrame({
    'Date': test.index,
    'Forecast': forecast_mean.values,
    'Lower Bound': conf_int.iloc[:, 0].values,
    'Upper Bound': conf_int.iloc[:, 1].values
}).set_index('Date')

# Plotting actual vs forecast
fig, ax = plt.subplots(figsize=(12, 5))

# Actual values
test.rename(columns={'Views': 'Actual'}).plot(ax=ax, legend=True)

# Forecasted values
arma_forecast_df[['Forecast']].plot(ax=ax, legend=True, color='orange', line

# Confidence interval shading
ax.fill_between(
    arma_forecast_df.index,
    arma_forecast_df['Lower Bound'],
    arma_forecast_df['Upper Bound'],
    color='pink',
    alpha=0.4,
    label='95% Confidence Interval'
)

# Final plot formatting
ax.set_title('Forecasted Number of Views for the Next 30 Days', fontsize=14,
ax.set_xlabel('Date')
ax.set_ylabel('Views')
ax.grid(True, linestyle='--', alpha=0.6)
ax.legend()
plt.tight_layout()
plt.show()
```



In [54]:
```
import numpy as np

# Initialize RMSE list
rmse_values = []

# Compute RMSE between forecasted values and actual test values
arma_rmse = np.sqrt(np.mean((forecast_mean.values - test['Views'].values) **
rmse_values.append(('ARMA', arma_rmse))

# Optional: print the result
print(f"✅ RMSE for ARMA model: {arma_rmse:.2f}")
```

```
✅ RMSE for ARMA model: 2.14
```

In [55]:
```
print("Mean of actual test values:", test['Views'].mean())
```

```
Mean of actual test values: 23.24856701113729
```

In [56]:
```
relative_error = (3.77 / 23.25) * 100
relative_error
```

Out[56]:
```
16.21505376344086
```

ARIMA Model

In [57]:
```
arima_aic_bic = []
for p in range(7):
    for q in range(7):
        try:
            arima_model = SARIMAX(train, order=(p,1,q))
            arima_result = arima_model.fit()
            arima_aic_bic.append((p,q,arima_result.aic,arima_result.bic))
        except:
            continue

arima_aic_bic_df = pd.DataFrame(arima_aic_bic,columns=['p','q','aic','bic'])
arima_aic_bic_df = arima_aic_bic_df.sort_values(by=['aic','bic'])
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
```

```
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            1     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.95830D+00    |proj g|=  4.65414D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    1      2      4      1     0     0   8.464D-08   2.958D+00
  F =   2.9582939820883070

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE
```

```
           * * *

Machine precision = 2.220D-16
 N =            2     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.87051D+00    |proj g|=  6.89867D-02

At iterate    5    f=  2.86351D+00    |proj g|=  1.60902D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    2      5      7      1     0     0   1.609D-06   2.864D+00
  F =   2.8635091819513367

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            3     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84820D+00    |proj g|=  2.81191D-02

At iterate    5    f=  2.84565D+00    |proj g|=  8.21293D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *
```

```
   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    3      7      9      1     0     0   4.046D-06   2.846D+00
  F =   2.8456468654314060

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84852D+00    |proj g|=  4.33532D-02

At iterate    5    f=  2.84152D+00    |proj g|=  2.05687D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4      8     11      1     0     0   5.763D-06   2.841D+00
  F =   2.8414960594881493

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85032D+00    |proj g|=  4.45747D-02

At iterate    5    f=  2.84197D+00    |proj g|=  1.88637D-02

At iterate   10    f=  2.84150D+00    |proj g|=  3.01968D-04

           * * *
```

```
Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     13     15      1     0     0   3.363D-06   2.841D+00
  F =   2.8414957690595690

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84991D+00    |proj g|=  7.06576D-02

At iterate    5    f=  2.81725D+00    |proj g|=  1.78288D-02

At iterate   10    f=  2.81544D+00    |proj g|=  1.69029D-03

At iterate   15    f=  2.81542D+00    |proj g|=  3.80551D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     17     20      1     0     0   3.806D-06   2.815D+00
  F =   2.8154243203362039

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *
```

```
Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83247D+00    |proj g|=  9.20558D-02

At iterate    5    f=  2.81688D+00    |proj g|=  2.47141D-02

At iterate   10    f=  2.81400D+00    |proj g|=  2.53061D-03

At iterate   15    f=  2.81396D+00    |proj g|=  1.27253D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     18     21      1     0     0   6.047D-05   2.814D+00
  F =   2.8139587989296371

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            2     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.90711D+00    |proj g|=  6.48454D-04

At iterate    5    f=  2.90710D+00    |proj g|=  2.11440D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value
```

```
           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    2      5      7      1     0     0   2.114D-06   2.907D+00
  F =   2.9071046970210674

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            3     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84336D+00    |proj g|=  4.31024D-02

At iterate    5    f=  2.84011D+00    |proj g|=  3.90232D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    3      9     11      1     0     0   1.920D-06   2.840D+00
  F =   2.8398147703693022

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85170D+00    |proj g|=  3.35649D-02

At iterate    5    f=  2.84884D+00    |proj g|=  2.84274D-02

At iterate   10    f=  2.83935D+00    |proj g|=  1.17670D-02

At iterate   15    f=  2.83807D+00    |proj g|=  2.03716D-04
```

```
           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4     19     21      1     0     0   8.270D-07   2.838D+00
  F =   2.8380642115121777

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.97500D+00    |proj g|=  3.99678D-01

At iterate    5    f=  2.84128D+00    |proj g|=  9.76278D-03

At iterate   10    f=  2.84073D+00    |proj g|=  7.13532D-04

At iterate   15    f=  2.84072D+00    |proj g|=  5.87552D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     15     17      1     0     0   5.876D-06   2.841D+00
  F =   2.8407173042974092

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE
```

```
           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.87586D+00    |proj g|=  2.03397D-01

At iterate    5    f=  2.83706D+00    |proj g|=  1.47971D-02

At iterate   10    f=  2.83259D+00    |proj g|=  1.46653D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so infer
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:966: UserWarning: Non-stationary starting autoregressive parame
ters found. Using zeros as starting parameters.
  warn('Non-stationary starting autoregressive parameters'
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
```

```
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
At iterate   15    f=  2.83211D+00    |proj g|=  1.29639D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     19     22      1     0     0   2.306D-06   2.832D+00
  F =   2.8321061425388088

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.87429D+00    |proj g|=  1.96162D-01

At iterate    5    f=  2.83722D+00    |proj g|=  1.80029D-02
```

```
At iterate   10    f=  2.83127D+00    |proj g|=  5.72435D-03

At iterate   15    f=  2.83090D+00    |proj g|=  1.91858D-03

At iterate   20    f=  2.83087D+00    |proj g|=  4.13691D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     20     22      1     0     0   4.137D-06   2.831D+00
  F =   2.8308695572231963

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.79215D+00    |proj g|=  1.01459D-01

At iterate    5    f=  2.77581D+00    |proj g|=  1.66672D-02

At iterate   10    f=  2.77406D+00    |proj g|=  2.10092D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     14     16      1     0     0   4.443D-05   2.774D+00
  F =   2.7740281017062589
```

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            3     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.87924D+00    |proj g|=  9.74424D-04
```

```
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:966: UserWarning: Non-stationary starting autoregressive parame
ters found. Using zeros as starting parameters.
  warn('Non-stationary starting autoregressive parameters'
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
```

```
At iterate    5    f=  2.87923D+00    |proj g|=  4.70705D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
```

```
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    3      6      8      1     0     0   9.675D-06   2.879D+00
  F =   2.8792328677768420

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84160D+00    |proj g|=  4.14095D-02

At iterate    5    f=  2.83922D+00    |proj g|=  3.30425D-03

At iterate   10    f=  2.83882D+00    |proj g|=  1.26283D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4     12     14      1     0     0   1.171D-05   2.839D+00
  F =   2.8388141242722584

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.97005D+00    |proj g|=  3.84560D-01
```

```
At iterate    5    f=  2.84069D+00    |proj g|=  2.00571D-02

At iterate   10    f=  2.83972D+00    |proj g|=  9.88906D-04

At iterate   15    f=  2.83956D+00    |proj g|=  8.65149D-03

At iterate   20    f=  2.83873D+00    |proj g|=  2.43543D-02

At iterate   25    f=  2.83579D+00    |proj g|=  1.79894D-02

At iterate   30    f=  2.83499D+00    |proj g|=  2.34878D-03

At iterate   35    f=  2.83496D+00    |proj g|=  8.70517D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     35     46      1     0     0   8.705D-06   2.835D+00
  F =   2.8349610203951232

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.90082D+00    |proj g|=  2.67473D-01

At iterate    5    f=  2.85068D+00    |proj g|=  6.16048D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   10    f=  2.83958D+00    |proj g|=  1.95811D-02

At iterate   15    f=  2.83571D+00    |proj g|=  1.90524D-03

At iterate   20    f=  2.83555D+00    |proj g|=  7.11853D-04

At iterate   25    f=  2.83554D+00    |proj g|=  2.44275D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     26     31      1     0     0   4.182D-06   2.836D+00
  F =   2.8355365675585356

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83371D+00    |proj g|=  7.58101D-01
```

```
At iterate    5    f=  2.82557D+00    |proj g|=  6.99541D-02

At iterate   10    f=  2.81802D+00    |proj g|=  5.54080D-02

At iterate   15    f=  2.81751D+00    |proj g|=  1.83475D-02

At iterate   20    f=  2.81721D+00    |proj g|=  1.10433D-02

At iterate   25    f=  2.81716D+00    |proj g|=  8.25816D-03

At iterate   30    f=  2.81708D+00    |proj g|=  6.21129D-03

At iterate   35    f=  2.81235D+00    |proj g|=  3.41020D-02

At iterate   40    f=  2.79832D+00    |proj g|=  2.88242D-02

At iterate   45    f=  2.79203D+00    |proj g|=  1.86832D-02

At iterate   50    f=  2.79062D+00    |proj g|=  2.20833D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     50     74      1     0     0   2.208D-03   2.791D+00
  F =   2.7906233066227499

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  3.44309D+00    |proj g|=  9.85733D-01

At iterate    5    f=  2.79422D+00    |proj g|=  7.38389D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   10    f=  2.76944D+00    |proj g|=  8.45751D-02

At iterate   15    f=  2.76806D+00    |proj g|=  2.48814D-02

At iterate   20    f=  2.76780D+00    |proj g|=  5.67349D-03

At iterate   25    f=  2.76771D+00    |proj g|=  2.42642D-04

At iterate   30    f=  2.76771D+00    |proj g|=  1.32132D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     32     38      1     0     0   1.658D-05   2.768D+00
  F =   2.7677054321789707

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
```

```
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.78185D+00    |proj g|=  1.03712D-01

At iterate    5    f=  2.76596D+00    |proj g|=  2.40888D-02

At iterate   10    f=  2.76395D+00    |proj g|=  3.72302D-03

At iterate   15    f=  2.76386D+00    |proj g|=  1.38310D-03

At iterate   20    f=  2.76386D+00    |proj g|=  1.45793D-03

At iterate   25    f=  2.76385D+00    |proj g|=  3.06435D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     29     34      1     0     0   3.143D-05   2.764D+00
  F =   2.7638531287191785

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            4     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85840D+00    |proj g|=  1.50022D-03

At iterate    5    f=  2.85839D+00    |proj g|=  4.22329D-06

           * * *
```

```
Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    4      5      7      1     0     0   4.223D-06   2.858D+00
  F =   2.8583898359879312

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85481D+00    |proj g|=  2.81040D-02

At iterate    5    f=  2.85043D+00    |proj g|=  6.51349D-02

At iterate   10    f=  2.84085D+00    |proj g|=  3.80389D-02

At iterate   15    f=  2.83707D+00    |proj g|=  3.74425D-03

At iterate   20    f=  2.83698D+00    |proj g|=  1.07390D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5     20     24      1     0     0   1.074D-06   2.837D+00
  F =   2.8369777789543003

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE
```

```
           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.97112D+00    |proj g|=  3.88010D-01

At iterate    5    f=  2.84912D+00    |proj g|=  1.88774D-02

At iterate   10    f=  2.83782D+00    |proj g|=  3.41701D-03

At iterate   15    f=  2.83623D+00    |proj g|=  1.21545D-02

At iterate   20    f=  2.83024D+00    |proj g|=  1.76052D-02

At iterate   25    f=  2.82935D+00    |proj g|=  7.43291D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     28     31      1     0     0   1.957D-05   2.829D+00
  F =   2.8293506513125957

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:966: UserWarning: Non-stationary starting autoregressive parame
ters found. Using zeros as starting parameters.
  warn('Non-stationary starting autoregressive parameters'
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.90185D+00    |proj g|=  2.95677D-01

At iterate    5    f=  2.82899D+00    |proj g|=  3.14380D-02
```

```
At iterate   10    f=  2.82047D+00    |proj g|=  6.25122D-03

At iterate   15    f=  2.82008D+00    |proj g|=  2.50770D-03

At iterate   20    f=  2.81851D+00    |proj g|=  7.64443D-03

At iterate   25    f=  2.81364D+00    |proj g|=  8.98833D-03

At iterate   30    f=  2.81018D+00    |proj g|=  1.02506D-02

At iterate   35    f=  2.80853D+00    |proj g|=  3.41550D-03

At iterate   40    f=  2.80816D+00    |proj g|=  2.71157D-03

At iterate   45    f=  2.80808D+00    |proj g|=  1.63532D-03

At iterate   50    f=  2.80806D+00    |proj g|=  4.92591D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     50     57      1     0     0   4.926D-04   2.808D+00
  F =   2.8080629047157974

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84262D+00    |proj g|=  8.52358D-01
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate    5    f=  2.82681D+00    |proj g|=  3.95433D-02

At iterate   10    f=  2.81739D+00    |proj g|=  1.14411D-02

At iterate   15    f=  2.81733D+00    |proj g|=  5.02568D-03

At iterate   20    f=  2.81728D+00    |proj g|=  2.60075D-03

At iterate   25    f=  2.81701D+00    |proj g|=  2.66291D-02

At iterate   30    f=  2.81566D+00    |proj g|=  2.28690D-02

At iterate   35    f=  2.81503D+00    |proj g|=  8.23471D-02

At iterate   40    f=  2.81425D+00    |proj g|=  6.65278D-02

At iterate   45    f=  2.81388D+00    |proj g|=  7.60524D-03

At iterate   50    f=  2.81387D+00    |proj g|=  3.01667D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     50     65      1     0     0   3.017D-04   2.814D+00
  F =   2.8138719684189724

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85379D+00    |proj g|=  2.03163D-01

At iterate    5    f=  2.84034D+00    |proj g|=  1.03100D-01

At iterate   10    f=  2.82547D+00    |proj g|=  2.66774D-02

At iterate   15    f=  2.82492D+00    |proj g|=  9.01901D-03

At iterate   20    f=  2.82447D+00    |proj g|=  1.36755D-02

At iterate   25    f=  2.81365D+00    |proj g|=  8.53099D-02

At iterate   30    f=  2.80658D+00    |proj g|=  4.20888D-02

At iterate   35    f=  2.80642D+00    |proj g|=  2.84993D-03

At iterate   40    f=  2.80574D+00    |proj g|=  2.56651D-02

At iterate   45    f=  2.78958D+00    |proj g|=  6.43591D-02

At iterate   50    f=  2.77755D+00    |proj g|=  2.86019D-02

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value
```

```
           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     50     72      1     0     0   2.860D-02   2.778D+00
  F =   2.7775474381960530

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.78017D+00    |proj g|=  3.80120D-02

At iterate    5    f=  2.77303D+00    |proj g|=  2.41526D-02
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   10    f=  2.76794D+00    |proj g|=  3.11841D-02

At iterate   15    f=  2.75048D+00    |proj g|=  3.59947D-02

At iterate   20    f=  2.74844D+00    |proj g|=  1.23424D-02

At iterate   25    f=  2.74728D+00    |proj g|=  5.58373D-03

At iterate   30    f=  2.74715D+00    |proj g|=  5.36254D-04

At iterate   35    f=  2.74714D+00    |proj g|=  1.00583D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
```

```
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10     38     42      1     0     0   6.098D-05   2.747D+00
  F =   2.7471444851824138

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            5     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85657D+00    |proj g|=  2.00992D-03

At iterate    5    f=  2.85655D+00    |proj g|=  1.54206D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    5      6      8      1     0     0   8.248D-07   2.857D+00
  F =   2.8565491479981944

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85428D+00    |proj g|=  2.57014D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:966: UserWarning: Non-stationary starting autoregressive parame
ters found. Using zeros as starting parameters.
  warn('Non-stationary starting autoregressive parameters'
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
At iterate    5    f=  2.85174D+00    |proj g|=  3.69856D-02

At iterate   10    f=  2.83816D+00    |proj g|=  2.64550D-02

At iterate   15    f=  2.83289D+00    |proj g|=  7.99483D-03

At iterate   20    f=  2.83242D+00    |proj g|=  1.68311D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value
```

```
           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6     23     25      1     0     0   1.296D-05   2.832D+00
  F =   2.8324166020619566

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.97732D+00    |proj g|=  4.06096D-01

At iterate    5    f=  2.84907D+00    |proj g|=  1.29662D-02

At iterate   10    f=  2.83964D+00    |proj g|=  3.00456D-02

At iterate   15    f=  2.83599D+00    |proj g|=  4.98072D-03

At iterate   20    f=  2.83129D+00    |proj g|=  1.47706D-02

At iterate   25    f=  2.82935D+00    |proj g|=  1.89273D-03

At iterate   30    f=  2.82934D+00    |proj g|=  1.13469D-06

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     30     36      1     0     0   1.135D-06   2.829D+00
  F =   2.8293406221100628

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10
```

```
At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.88106D+00    |proj g|=  2.34004D-01

At iterate    5    f=  2.82467D+00    |proj g|=  7.63618D-03
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   10    f=  2.82094D+00    |proj g|=  1.80276D-02

At iterate   15    f=  2.81964D+00    |proj g|=  2.61098D-03

At iterate   20    f=  2.81958D+00    |proj g|=  2.51048D-03

At iterate   25    f=  2.81870D+00    |proj g|=  2.20454D-02

At iterate   30    f=  2.81567D+00    |proj g|=  1.62183D-02

At iterate   35    f=  2.80710D+00    |proj g|=  9.08355D-03

At iterate   40    f=  2.80601D+00    |proj g|=  1.06329D-02

At iterate   45    f=  2.80511D+00    |proj g|=  1.52748D-03

At iterate   50    f=  2.80494D+00    |proj g|=  4.08852D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     50     64      1     0     0   4.089D-04   2.805D+00
  F =   2.8049382214714678

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83543D+00    |proj g|=  2.24261D-01

At iterate    5    f=  2.82030D+00    |proj g|=  3.51698D-02

At iterate   10    f=  2.81441D+00    |proj g|=  1.58908D-02

At iterate   15    f=  2.81273D+00    |proj g|=  9.27418D-03

At iterate   20    f=  2.80874D+00    |proj g|=  2.88681D-01

At iterate   25    f=  2.79945D+00    |proj g|=  2.20708D-02

At iterate   30    f=  2.78777D+00    |proj g|=  3.51407D-02

At iterate   35    f=  2.77499D+00    |proj g|=  2.79516D-02

At iterate   40    f=  2.77071D+00    |proj g|=  1.98582D-02

At iterate   45    f=  2.76789D+00    |proj g|=  6.57974D-03
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   50    f=  2.76750D+00    |proj g|=  1.62214D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     50     66      1     0     0   1.622D-03   2.768D+00
  F =   2.7675006919463874

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85405D+00    |proj g|=  1.78628D-01

At iterate    5    f=  2.84281D+00    |proj g|=  1.39743D-01

At iterate   10    f=  2.82657D+00    |proj g|=  5.60655D-02

At iterate   15    f=  2.82471D+00    |proj g|=  1.21221D-02

At iterate   20    f=  2.82383D+00    |proj g|=  1.67984D-02

At iterate   25    f=  2.82213D+00    |proj g|=  1.19789D-01
```

```
At iterate   30    f=  2.81639D+00    |proj g|=  3.51654D-02

At iterate   35    f=  2.81046D+00    |proj g|=  2.18923D-02

At iterate   40    f=  2.80943D+00    |proj g|=  2.55186D-02

At iterate   45    f=  2.80890D+00    |proj g|=  3.15740D-03

At iterate   50    f=  2.80887D+00    |proj g|=  2.44435D-02

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10     50     58      1     0     0   2.444D-02   2.809D+00
  F =   2.8088746283520951

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           11     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.77645D+00    |proj g|=  3.67135D-02

At iterate    5    f=  2.76586D+00    |proj g|=  3.12035D-02

At iterate   10    f=  2.75451D+00    |proj g|=  1.31841D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   15    f=  2.75306D+00    |proj g|=  4.38063D-03

At iterate   20    f=  2.75264D+00    |proj g|=  4.50969D-03

At iterate   25    f=  2.75254D+00    |proj g|=  1.77176D-03

At iterate   30    f=  2.75253D+00    |proj g|=  3.32567D-04

At iterate   35    f=  2.75252D+00    |proj g|=  1.41315D-03

At iterate   40    f=  2.75249D+00    |proj g|=  4.52347D-03

At iterate   45    f=  2.75246D+00    |proj g|=  4.87611D-03

At iterate   50    f=  2.75237D+00    |proj g|=  3.73633D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   11     50     59      1     0     0   3.736D-03   2.752D+00
  F =   2.7523730580324575

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            6     M =           10
```

```
At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.85331D+00    |proj g|=  2.42073D-03

At iterate    5    f=  2.85328D+00    |proj g|=  1.42630D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    6      6      8      1     0     0   1.079D-06   2.853D+00
  F =   2.8532789661379105

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84948D+00    |proj g|=  4.83564D-02

At iterate    5    f=  2.84577D+00    |proj g|=  1.22315D-02

At iterate   10    f=  2.83996D+00    |proj g|=  4.34353D-02

At iterate   15    f=  2.83291D+00    |proj g|=  1.18800D-02

At iterate   20    f=  2.83218D+00    |proj g|=  4.15944D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *
```

```
   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7     24     28      1     0     0   7.033D-07   2.832D+00
  F =   2.8321787733004280

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.97732D+00    |proj g|=  4.06096D-01

At iterate    5    f=  2.84890D+00    |proj g|=  9.69095D-03
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:966: UserWarning: Non-stationary starting autoregressive parame
ters found. Using zeros as starting parameters.
  warn('Non-stationary starting autoregressive parameters'
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
```

```
At iterate   10    f=  2.83938D+00    |proj g|=  2.51039D-02

At iterate   15    f=  2.83269D+00    |proj g|=  6.61413D-03

At iterate   20    f=  2.83241D+00    |proj g|=  1.62579D-04

At iterate   25    f=  2.83239D+00    |proj g|=  5.26042D-03

At iterate   30    f=  2.83221D+00    |proj g|=  2.34898D-03

At iterate   35    f=  2.83218D+00    |proj g|=  1.18887D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     37     47      1     0     0   2.173D-05   2.832D+00
  F =   2.8321786571806773

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84195D+00    |proj g|=  1.25691D-01

At iterate    5    f=  2.81831D+00    |proj g|=  2.52822D-02

At iterate   10    f=  2.81338D+00    |proj g|=  1.17831D-02

At iterate   15    f=  2.81169D+00    |proj g|=  4.96709D-03

At iterate   20    f=  2.80403D+00    |proj g|=  2.06617D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   25    f=  2.80245D+00    |proj g|=  3.00397D-03

At iterate   30    f=  2.79596D+00    |proj g|=  8.04029D-02

At iterate   35    f=  2.78009D+00    |proj g|=  9.39055D-03

At iterate   40    f=  2.77895D+00    |proj g|=  2.63936D-03

At iterate   45    f=  2.77890D+00    |proj g|=  1.17284D-04

At iterate   50    f=  2.77890D+00    |proj g|=  1.92372D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     50     61      1     0     0   1.924D-04   2.779D+00
  F =   2.7788974526603840

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.82401D+00    |proj g|=  1.09908D-01

At iterate    5    f=  2.81267D+00    |proj g|=  2.09967D-02

At iterate   10    f=  2.80743D+00    |proj g|=  1.64124D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
```

```
At iterate   15    f=  2.80546D+00    |proj g|=  9.44596D-03

At iterate   20    f=  2.80056D+00    |proj g|=  2.06964D-02

At iterate   25    f=  2.79437D+00    |proj g|=  3.00345D-02

At iterate   30    f=  2.78504D+00    |proj g|=  2.31732D-02

At iterate   35    f=  2.76733D+00    |proj g|=  6.25388D-02

At iterate   40    f=  2.75351D+00    |proj g|=  4.94955D-02

At iterate   45    f=  2.74533D+00    |proj g|=  5.69126D-02

At iterate   50    f=  2.73958D+00    |proj g|=  1.29528D-02

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10     50     72      1     0     0   1.295D-02   2.740D+00
  F =   2.7395835082247308

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           11     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83367D+00    |proj g|=  2.16948D-01

At iterate    5    f=  2.82036D+00    |proj g|=  3.82697D-02

At iterate   10    f=  2.80829D+00    |proj g|=  3.39046D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
```

```
At iterate   15    f=  2.80624D+00    |proj g|=  4.32774D-02

At iterate   20    f=  2.78825D+00    |proj g|=  1.40332D-01

At iterate   25    f=  2.75256D+00    |proj g|=  4.58791D-02

At iterate   30    f=  2.75063D+00    |proj g|=  1.25859D-02

At iterate   35    f=  2.74846D+00    |proj g|=  6.91761D-02

At iterate   40    f=  2.74629D+00    |proj g|=  1.35848D-02

At iterate   45    f=  2.73894D+00    |proj g|=  1.63644D-02

At iterate   50    f=  2.73708D+00    |proj g|=  9.74498D-03

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   11     50     65      1     0     0   9.745D-03   2.737D+00
  F =   2.7370790101270712

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           12     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  3.07755D+00    |proj g|=  7.28162D-01

At iterate    5    f=  2.77852D+00    |proj g|=  1.03475D-01

At iterate   10    f=  2.76933D+00    |proj g|=  5.61026D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
At iterate   15    f=  2.76145D+00    |proj g|=  1.82641D-02

At iterate   20    f=  2.75990D+00    |proj g|=  2.04878D-02

At iterate   25    f=  2.75940D+00    |proj g|=  4.35267D-03

At iterate   30    f=  2.75843D+00    |proj g|=  1.30462D-02

At iterate   35    f=  2.75656D+00    |proj g|=  4.58034D-02

At iterate   40    f=  2.75348D+00    |proj g|=  1.87912D-02

At iterate   45    f=  2.75159D+00    |proj g|=  2.52790D-02

At iterate   50    f=  2.74891D+00    |proj g|=  3.24031D-02

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   12     50     57      1     0     0   3.240D-02   2.749D+00
  F =   2.7489065746104600

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *
```

```
Machine precision = 2.220D-16
 N =            7     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.81925D+00    |proj g|=  3.11359D-03

At iterate    5    f=  2.81921D+00    |proj g|=  1.71681D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    7      7     11      1     0     0   1.665D-05   2.819D+00
  F =   2.8192078455841942

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =            8     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.84486D+00    |proj g|=  9.30786D-02

At iterate    5    f=  2.82314D+00    |proj g|=  5.33719D-02

At iterate   10    f=  2.79680D+00    |proj g|=  5.92224D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   15    f=  2.79257D+00    |proj g|=  1.79590D-02

At iterate   20    f=  2.79230D+00    |proj g|=  4.01940D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    8     23     28      1     0     0   7.944D-06   2.792D+00
  F =   2.7923006882456076

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
RUNNING THE L-BFGS-B CODE
```

```
           * * *

Machine precision = 2.220D-16
 N =            9     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83549D+00    |proj g|=  6.20844D-02

At iterate    5    f=  2.81908D+00    |proj g|=  5.98354D-02

At iterate   10    f=  2.80887D+00    |proj g|=  1.29200D-02

At iterate   15    f=  2.80610D+00    |proj g|=  1.51752D-02

At iterate   20    f=  2.80518D+00    |proj g|=  3.34968D-04

At iterate   25    f=  2.80518D+00    |proj g|=  7.46586D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    9     25     27      1     0     0   7.466D-05   2.805D+00
  F =   2.8051844182214332

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           10     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.98878D+00    |proj g|=  4.33935D-01

At iterate    5    f=  2.81597D+00    |proj g|=  8.12286D-02
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:966: UserWarning: Non-stationary starting autoregressive parame
ters found. Using zeros as starting parameters.
  warn('Non-stationary starting autoregressive parameters'
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/statespac
e/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found.
Using zeros as starting parameters.
  warn('Non-invertible starting MA parameters found.'
 This problem is unconstrained.
At iterate   10    f=  2.77459D+00    |proj g|=  3.92626D-02

At iterate   15    f=  2.76638D+00    |proj g|=  1.90148D-02

At iterate   20    f=  2.76495D+00    |proj g|=  1.89336D-02

At iterate   25    f=  2.76107D+00    |proj g|=  1.68336D-02

At iterate   30    f=  2.75987D+00    |proj g|=  2.40240D-03

At iterate   35    f=  2.75981D+00    |proj g|=  7.33157D-03

At iterate   40    f=  2.75978D+00    |proj g|=  1.04075D-03
 Bad direction in the line search;
   refresh the lbfgs memory and restart the iteration.
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
At iterate   45    f=  2.75978D+00    |proj g|=  1.93601D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value
```

```
           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   10     45     74      2     0     0   1.936D-05   2.760D+00
  F =   2.7597791827769140

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           11     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83874D+00    |proj g|=  1.87191D-01

At iterate    5    f=  2.78693D+00    |proj g|=  6.18948D-02

At iterate   10    f=  2.75312D+00    |proj g|=  3.66722D-02

At iterate   15    f=  2.74081D+00    |proj g|=  1.75346D-02

At iterate   20    f=  2.73832D+00    |proj g|=  8.71403D-03

At iterate   25    f=  2.73714D+00    |proj g|=  2.48194D-02

At iterate   30    f=  2.73694D+00    |proj g|=  6.12514D-04

At iterate   35    f=  2.73694D+00    |proj g|=  3.22933D-04

At iterate   40    f=  2.73693D+00    |proj g|=  2.44214D-05

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   11     40     47      1     0     0   2.442D-05   2.737D+00
  F =   2.7369347774999664

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE
```

```
           * * *

Machine precision = 2.220D-16
 N =           12     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.83037D+00    |proj g|=  1.60681D-01

At iterate    5    f=  2.75998D+00    |proj g|=  8.98653D-02

At iterate   10    f=  2.74829D+00    |proj g|=  1.55656D-02

At iterate   15    f=  2.74152D+00    |proj g|=  2.24588D-02

At iterate   20    f=  2.73824D+00    |proj g|=  9.09869D-03
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
```

```
At iterate   25    f=  2.73701D+00    |proj g|=  7.49529D-03

At iterate   30    f=  2.73674D+00    |proj g|=  4.11544D-03

At iterate   35    f=  2.73667D+00    |proj g|=  1.78527D-03

At iterate   40    f=  2.73664D+00    |proj g|=  8.30416D-04

At iterate   45    f=  2.73657D+00    |proj g|=  3.92078D-03

At iterate   50    f=  2.73653D+00    |proj g|=  8.63492D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   12     50     56      1     0     0   8.635D-04   2.737D+00
  F =   2.7365324539720985

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           13     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  2.77171D+00    |proj g|=  6.55163D-02
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
 This problem is unconstrained.
```

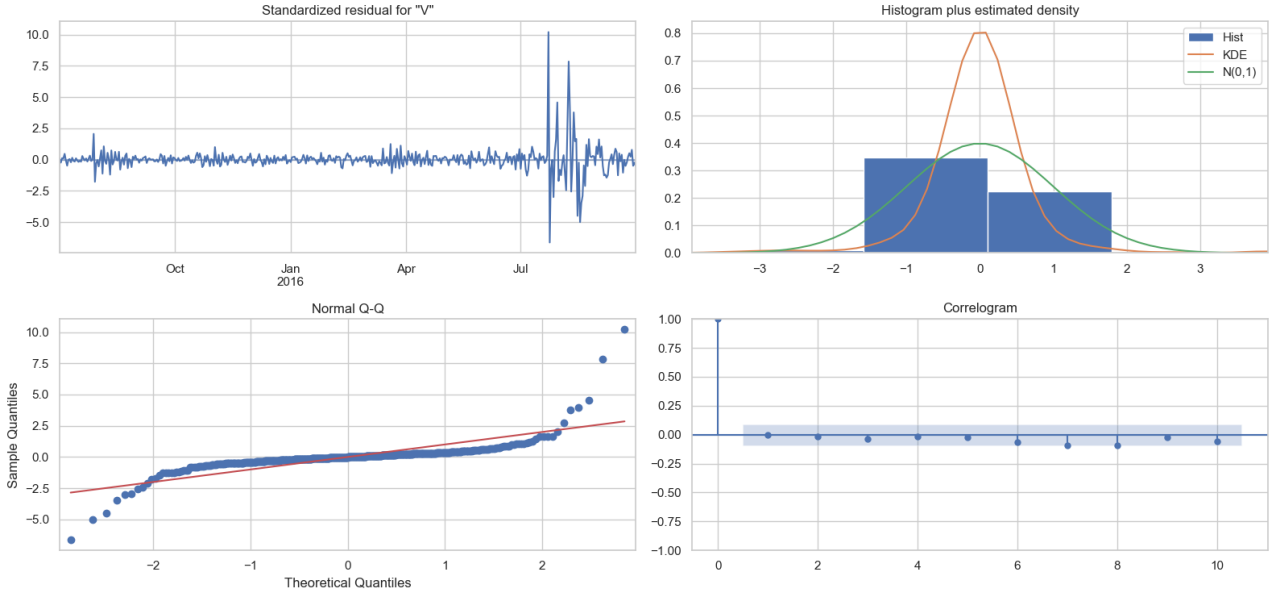
```
At iterate    5    f=  2.76653D+00    |proj g|=  2.10352D-02

At iterate   10    f=  2.74986D+00    |proj g|=  5.34851D-02

At iterate   15    f=  2.74202D+00    |proj g|=  1.75572D-02

At iterate   20    f=  2.73985D+00    |proj g|=  1.14531D-02

At iterate   25    f=  2.73902D+00    |proj g|=  1.07163D-02

At iterate   30    f=  2.73833D+00    |proj g|=  9.16601D-03

At iterate   35    f=  2.73787D+00    |proj g|=  2.06456D-03

At iterate   40    f=  2.73784D+00    |proj g|=  9.17662D-04

At iterate   45    f=  2.73783D+00    |proj g|=  3.64567D-04

At iterate   50    f=  2.73783D+00    |proj g|=  3.74885D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   13     50     56      1     0     0   3.749D-04   2.738D+00
  F =   2.7378309063215980

STOP: TOTAL NO. of ITERATIONS REACHED LIMIT
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/base/model.p
y:604: ConvergenceWarning: Maximum Likelihood optimization failed to converg
e. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
```

In [58]:
```
import pickle

# Define file name
model_filename = 'arima_model.pkl'

# Save the fitted ARIMA model to file
try:
    with open(model_filename, 'wb') as file:
        pickle.dump(arima_result, file)  # Save the fitted model (not just t
    print(f"✅ ARIMA model successfully saved to '{model_filename}'")
except Exception as e:
    print(f"❌ Error saving model: {e}")
```

✅ ARIMA model successfully saved to 'arima_model.pkl'

In [59]:
```
import matplotlib.pyplot as plt

# Set up a clean diagnostic plot for the ARIMA model
fig = plt.figure(figsize=(16, 8))  # Adjusted for clarity and balance
ax = arima_result.plot_diagnostics(figsize=(16, 8))

# Optional: Add a main title
fig.suptitle('ARIMA Model Diagnostics', fontsize=16, fontweight='bold')

plt.tight_layout(rect=[0, 0, 1, 0.95])  # Prevent title overlap
plt.show()
```

<Figure size 1600x800 with 0 Axes>



In [60]:
```
arima_result.summary()
```

Out[60]:

SARIMAX Results

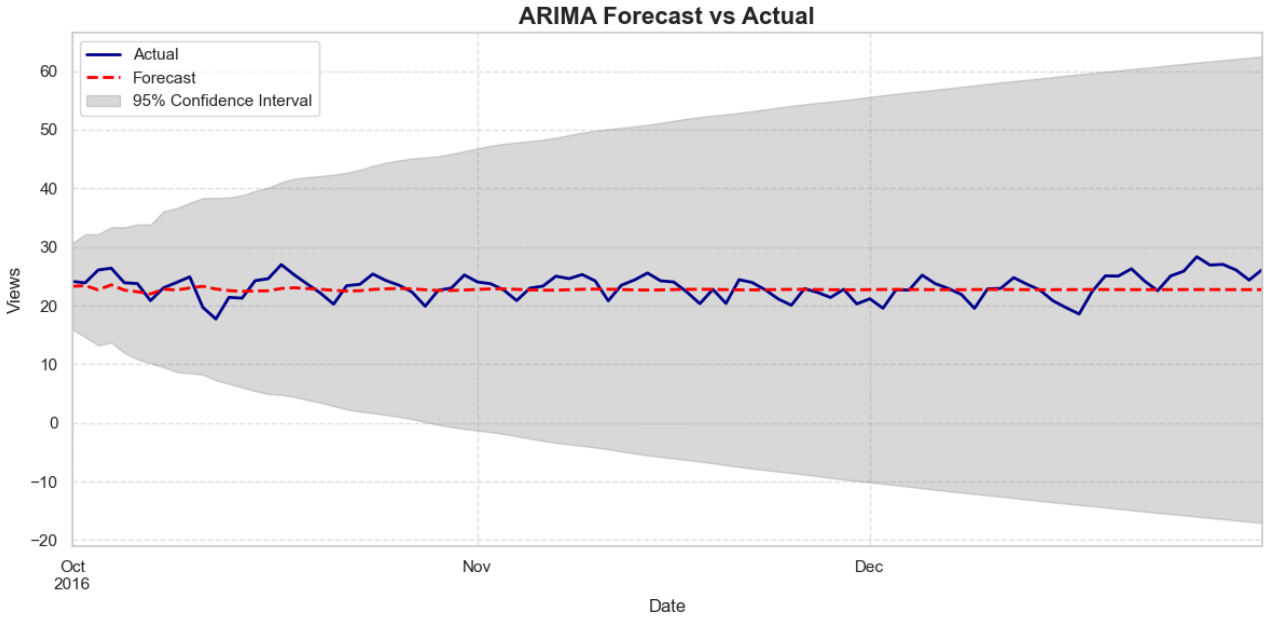
Dep. Variable:	Views	**No. Observations:**	458
Model:	SARIMAX(6, 1, 6)	**Log Likelihood**	-1253.927
Date:	Thu, 24 Apr 2025	**AIC**	2533.853
Time:	15:21:39	**BIC**	2587.474
Sample:	07-01-2015	**HQIC**	2554.974
	- 09-30-2016		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	-0.8692	0.067	-12.924	0.000	-1.001	-0.737
ar.L2	-0.5240	0.080	-6.521	0.000	-0.681	-0.366
ar.L3	-0.4291	0.071	-6.070	0.000	-0.568	-0.291
ar.L4	-0.6312	0.050	-12.547	0.000	-0.730	-0.533
ar.L5	-0.7834	0.049	-16.056	0.000	-0.879	-0.688
ar.L6	-0.4682	0.031	-15.121	0.000	-0.529	-0.408
ma.L1	0.5183	0.070	7.419	0.000	0.381	0.655
ma.L2	0.0625	0.076	0.819	0.413	-0.087	0.212
ma.L3	-0.0233	0.065	-0.357	0.721	-0.151	0.104
ma.L4	0.4987	0.059	8.474	0.000	0.383	0.614
ma.L5	0.6013	0.052	11.460	0.000	0.498	0.704
ma.L6	-0.0382	0.061	-0.629	0.529	-0.157	0.081
sigma2	14.0667	0.249	56.511	0.000	13.579	14.555

Ljung-Box (L1) (Q):	0.00	**Jarque-Bera (JB):**	29204.89
Prob(Q):	0.99	**Prob(JB):**	0.00
Heteroskedasticity (H):	17.05	**Skew:**	2.50
Prob(H) (two-sided):	0.00	**Kurtosis:**	41.84

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

In [67]:
```
# 1. Generate forecast for the test period
n_steps = len(test)
forecast_obj = arima_result.get_forecast(steps=n_steps)
forecast_mean = forecast_obj.predicted_mean
conf_int = forecast_obj.conf_int()

# 2. Build a tidy DataFrame of results
arima_forecast_df = pd.DataFrame({
    'Forecast':    forecast_mean.values,
    'Lower Bound': conf_int.iloc[:, 0].values,
    'Upper Bound': conf_int.iloc[:, 1].values
}, index=test.index)

# 3. Plot actual vs. forecasted with confidence intervals
fig, ax = plt.subplots(figsize=(12, 6))

# Actual values
test['Views'].plot(
    ax=ax,
    label='Actual',
    color='darkblue',
    linewidth=2
)

# Forecasted values
arima_forecast_df['Forecast'].plot(
    ax=ax,
    label='Forecast',
    color='red',
    linestyle='--',
    linewidth=2
)

# Confidence interval shading
ax.fill_between(
    arima_forecast_df.index,
    arima_forecast_df['Lower Bound'],
    arima_forecast_df['Upper Bound'],
    color='gray',
    alpha=0.3,
    label='95% Confidence Interval'
)

# 4. Formatting
ax.set_title('ARIMA Forecast vs Actual', fontsize=16, fontweight='bold')
ax.set_xlabel('Date')
ax.set_ylabel('Views')
ax.grid(True, linestyle='--', alpha=0.6)
ax.legend(loc='upper left')

plt.tight_layout()
plt.show()
```



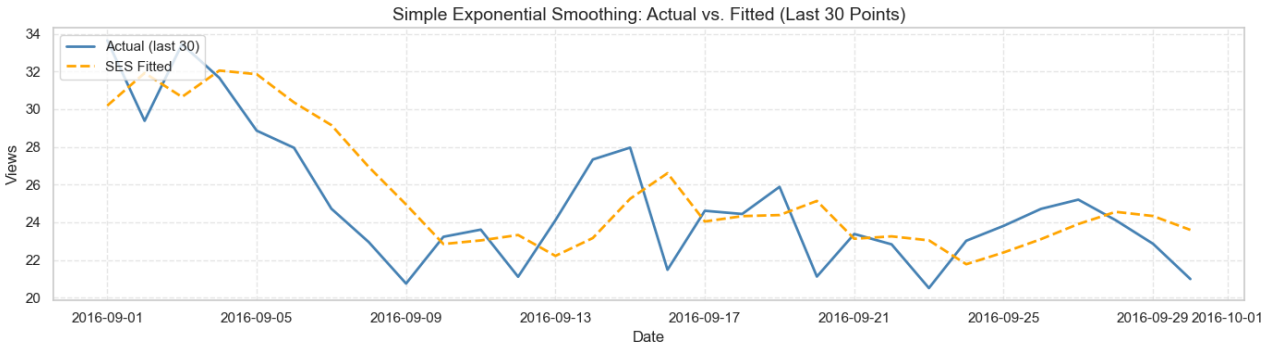
In [68]:
```
# 1. Align actual and predicted series
actual    = test['Views']
predicted = arima_forecast_df['Forecast']

# 2. Compute RMSE
errors     = predicted - actual
rmse_arima = np.sqrt((errors**2).mean())

# 3. Store and (optionally) display
rmse_values.append(('ARIMA', rmse_arima))
print(f"✅ ARIMA RMSE: {rmse_arima:.2f}")
```

```
✅ ARIMA RMSE: 2.12
```

Exponential Smoothing Model

In [70]:
```
import matplotlib.pyplot as plt
from statsmodels.tsa.holtwinters import SimpleExpSmoothing

# 1. Fit the Simple Exponential Smoothing model on the training series
ses_model = SimpleExpSmoothing(train['Views']).fit(
    smoothing_level=0.5,
    optimized=True
)

# 2. Define the in-sample window you want to compare (last 30 points)
n_window = 30
start_idx = train.index[-n_window]
end_idx   = train.index[-1]

# 3. Generate in-sample "predictions" (fitted values) over that window
ses_pred = ses_model.predict(start=start_idx, end=end_idx)

# 4. Plot actual vs. SES fitted values
plt.figure(figsize=(14, 4))
plt.plot(
    train['Views'].iloc[-n_window:],
    label='Actual (last 30)',
    color='steelblue',
    linewidth=2
)
plt.plot(
    ses_pred,
    label='SES Fitted',
    color='orange',
    linestyle='--',
    linewidth=2
)

# 5. Formatting
plt.title('Simple Exponential Smoothing: Actual vs. Fitted (Last 30 Points)'
plt.xlabel('Date')
plt.ylabel('Views')
plt.legend(loc='upper left')
plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
```



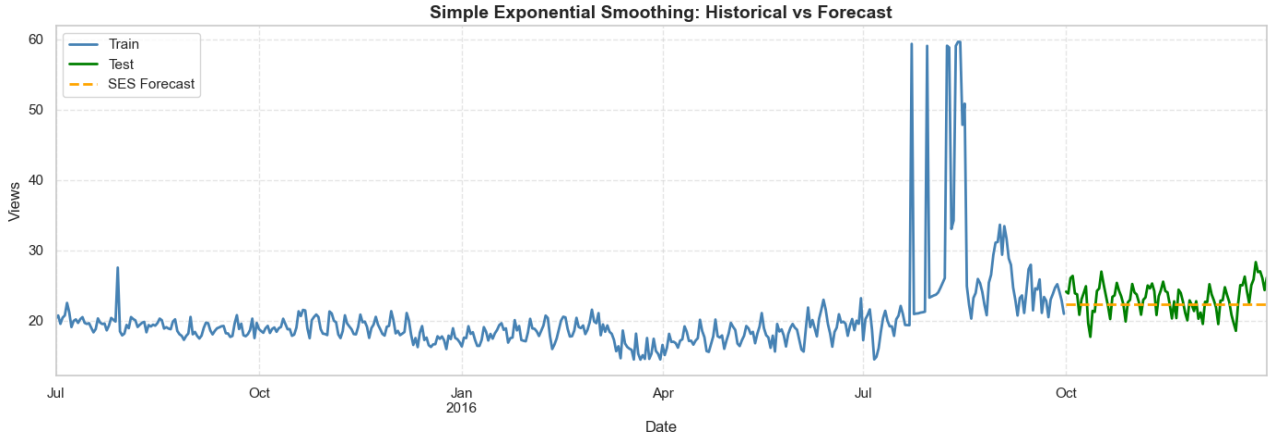
In [74]:
```
import pickle

# Define the filename for clarity
model_filename = 'ses_model.pkl'

try:
    # Save the fitted SimpleExpSmoothing result (not the class)
    with open(model_filename, 'wb') as f:
        pickle.dump(ses_pred, f)
    print(f"✅ Simple smoothing model saved to '{model_filename}'")
except Exception as e:
    print(f"❌ Failed to save model: {e}")
```

```
✅ Simple smoothing model saved to 'ses_model.pkl'
```

In [79]:
```
import matplotlib.pyplot as plt
from statsmodels.tsa.holtwinters import SimpleExpSmoothing

# 1. Fit SES on the 'Views' series
ses_model = SimpleExpSmoothing(
    train['Views'],
    initialization_method='estimated'
).fit(
    smoothing_level=0.5,
    optimized=True
)

# 2. Forecast the next N points matching the test set length
n_steps = len(test)
ses_forecast = ses_model.forecast(steps=n_steps)
ses_forecast.index = test.index  # align forecast index with test dates

# 3. Plot historical train/test and the SES forecast
fig, ax = plt.subplots(figsize=(14, 5))

# — Training data
train['Views'].plot(
    ax=ax,
    label='Train',
    color='steelblue',
    linewidth=2
)
```

```
# — Test data
test['Views'].plot(
    ax=ax,
    label='Test',
    color='green',
    linewidth=2
)

# — SES forecast
ses_forecast.plot(
    ax=ax,
    label='SES Forecast',
    color='orange',
    linestyle='--',
    linewidth=2
)

# 4. Format the plot
ax.set_title('Simple Exponential Smoothing: Historical vs Forecast', fontsiz
ax.set_xlabel('Date')
ax.set_ylabel('Views')
ax.grid(True, linestyle='--', alpha=0.5)
ax.legend(loc='upper left')

plt.tight_layout()
plt.show()
```

```
/Users/ramv/anaconda3/lib/python3.10/site-packages/statsmodels/tsa/base/tsa_
model.py:471: ValueWarning: No frequency information was provided, so inferr
ed frequency D will be used.
  self._init_dates(dates, freq)
```



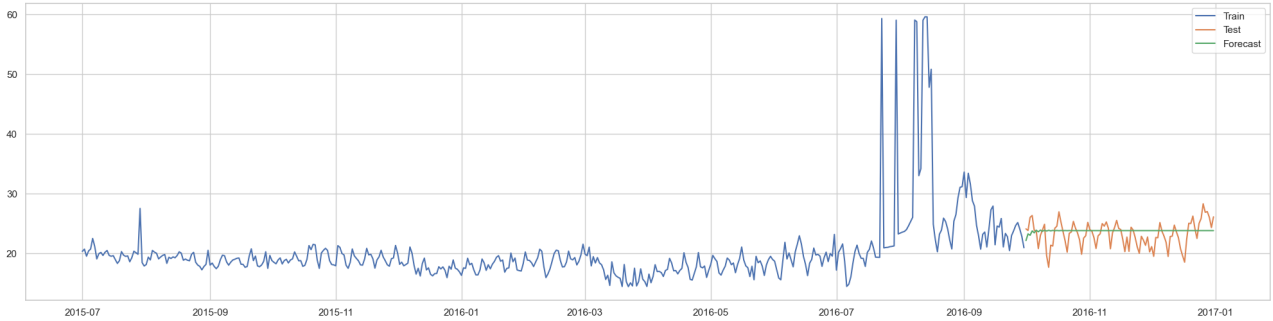
In [80]:
```
import numpy as np

# 1. Align actual and forecasted series
actual    = test['Views']
predicted = ses_forecast
predicted.index = actual.index  # ensure the same index

# 2. Compute RMSE
errors    = predicted - actual
rmse_ses = np.sqrt((errors ** 2).mean())

# 3. Store and/or print
rmse_values.append(('SES', rmse_ses))
print(f"✅ Simple Exp Smoothing RMSE: {rmse_ses:.2f}")
```

```
✅ Simple Exp Smoothing RMSE: 2.28
```

Auto Arima

In [81]:
```
auto_arima_model = auto_arima(train,start_p=2,max_p=7,start_q=2,max_q=7, m=1
auto_arima_model.fit(train)

auto_arima_forecast = auto_arima_model.predict(n_periods=test.shape[0])
auto_arima_forecast = pd.DataFrame(auto_arima_forecast,index = test.index,cc

plt.figure(figsize=(25,6))
plt.plot(train, label='Train')
plt.plot(test, label='Test')
plt.plot(auto_arima_forecast, label='Forecast')
plt.legend()
plt.show()
```

```
Performing stepwise search to minimize aic
 ARIMA(2,1,2)(0,0,0)[0] intercept   : AIC=2608.339, Time=0.19 sec
 ARIMA(0,1,0)(0,0,0)[0] intercept   : AIC=2713.797, Time=0.01 sec
 ARIMA(1,1,0)(0,0,0)[0] intercept   : AIC=2668.908, Time=0.02 sec
 ARIMA(0,1,1)(0,0,0)[0] intercept   : AIC=2628.972, Time=0.02 sec
 ARIMA(0,1,0)(0,0,0)[0]             : AIC=2711.797, Time=0.01 sec
 ARIMA(1,1,2)(0,0,0)[0] intercept   : AIC=2609.583, Time=0.06 sec
 ARIMA(2,1,1)(0,0,0)[0] intercept   : AIC=2610.306, Time=0.05 sec
 ARIMA(3,1,2)(0,0,0)[0] intercept   : AIC=2605.622, Time=0.13 sec
 ARIMA(3,1,1)(0,0,0)[0] intercept   : AIC=2610.574, Time=0.09 sec
 ARIMA(4,1,2)(0,0,0)[0] intercept   : AIC=2607.609, Time=0.19 sec
 ARIMA(3,1,3)(0,0,0)[0] intercept   : AIC=inf, Time=0.23 sec
 ARIMA(2,1,3)(0,0,0)[0] intercept   : AIC=inf, Time=0.12 sec
 ARIMA(4,1,1)(0,0,0)[0] intercept   : AIC=2608.158, Time=0.12 sec
 ARIMA(4,1,3)(0,0,0)[0] intercept   : AIC=inf, Time=0.29 sec
 ARIMA(3,1,2)(0,0,0)[0]             : AIC=2603.685, Time=0.07 sec
 ARIMA(2,1,2)(0,0,0)[0]             : AIC=2606.824, Time=0.08 sec
 ARIMA(3,1,1)(0,0,0)[0]             : AIC=2608.672, Time=0.04 sec
 ARIMA(4,1,2)(0,0,0)[0]             : AIC=2605.676, Time=0.10 sec
 ARIMA(3,1,3)(0,0,0)[0]             : AIC=inf, Time=0.19 sec
 ARIMA(2,1,1)(0,0,0)[0]             : AIC=2608.354, Time=0.03 sec
 ARIMA(2,1,3)(0,0,0)[0]             : AIC=inf, Time=0.10 sec
 ARIMA(4,1,1)(0,0,0)[0]             : AIC=2606.494, Time=0.06 sec
 ARIMA(4,1,3)(0,0,0)[0]             : AIC=inf, Time=0.22 sec

Best model:  ARIMA(3,1,2)(0,0,0)[0]
Total fit time: 2.423 seconds
```



In [82]:
```
with open('auto_arima_model.pkl', 'wb') as f:
    pickle.dump(auto_arima_model, f)
```

In [83]:
```
rmse_values.append(('Auto-arima',np.sqrt(np.mean(np.square(auto_arima_foreca
```

In [84]:
```
# RMSE
rmse_df = pd.DataFrame(rmse_values,columns=['Model','RMSE_values']).sort_val
rmse_df
```

Out[84]:

	Model	RMSE_values
1	ARIMA	2.116424
0	ARMA	2.140259
3	Auto-arima	2.153403
2	SES	2.278368

Ranking the models:

ARIMA (2.12) performed best, yielding the smallest average error.

ARMA (2.14) was a close second—its errors are only ~0.024 higher.

Auto-ARIMA (2.15) comes next, with marginally larger errors.

Simple Exponential Smoothing (SES, 2.28) had the highest errors, indicating it's the least accurate of the four.

Summary & Key Take Aways:

Data Ingestion & Wrangling

The raw Wikipedia-page-view data (~145K pages × 550 daily columns) is loaded, NaNs filled with zeroes, and then “unpivoted” into a long form with columns Page, Date, and Visits

Date strings are cast to datetime, enabling time-series operations.

Exploratory Data Analysis (EDA)

Overall Trends: Plotting daily mean and median visits over time reveals the aggregate traffic patterns and seasonal dips/rises

Heatmap by Month & Weekday: A pivoted heatmap shows which weekdays in which months see the most/least activity

Top Pages: Summing visits by page identifies the five most-viewed pages (e.g., “Main_Page” in various languages). Language Breakdown: A helper function parses the language code from each page’s URL (e.g. “en”→English, “zh”→Chinese, etc.), then a bar chart compares total views (in millions) by language, showing English pages dominating overall traffic .

Focusing on the Single Top Page:

The page with the highest total views (English desktop Main_Page) is isolated. Its daily visits are scaled to millions and plotted to visualize the raw time series .

Anomaly Detection & Smoothing

Isolation Forest (5% contamination) flags outliers in the top-page series; these are highlighted in red on the time-series plot . Outliers are removed (set to NaN) and then filled via a 30-day rolling mean, producing a smoothed “clean” series for modeling .

Stationarity Analysis

Autocorrelation (ACF): The cleaned series’ ACF (up to 60 lags) displays significant correlations, indicating persistence .

Augmented Dickey-Fuller (ADF) Test: On raw smoothed data: p-value≈0.1845 ⇒ non-stationary . On first difference: p-value≈0.000 ⇒ stationary after differencing .

Train/Test Split

The series is split at September 30, 2016: Train: 2015-07-01 to 2016-09-30 (458 days) Test: 2016-10-01 to 2016-12-31 (92 days) ACF and PACF of the training portion guide model choice .

Model Building & Comparison Four models are fit and evaluated via RMSE on the test set:

Model RMSE ARIMA (via SARIMAX(p,d,q)) 2.116 ARMA (via SARIMAX(p,0,q)) 2.140 Auto-ARIMA 2.153 Simple Exp. Smoothing (SES) 2.278 Auto-ARIMA uses pmdarima.auto_arima(...) with a stepwise AIC search, finding e.g. ARIMA(3,1,2) as the best; its forecast overlay on train/test is plotted . Ranking: ARIMA < ARMA < Auto-ARIMA < SES in terms of RMSE (lower is better) .

Diagnostic Plots & Model Persistence

Diagnostic plots (result.plot_diagnostics()) check residuals, QQ-plots, and forecast errors for the chosen ARIMA . Final models (ARIMA, ARMA, Auto-ARIMA) are serialized to .pkl files for future use . Key Takeaways:

Cleaning & smoothing is crucial: removing anomalies and applying rolling means produced a stationary series amenable to ARIMA modeling.

Differencing (first order) was necessary to achieve stationarity.

ARIMA outperformed simpler approaches (ARMA, SES) and even automated selection.

Model diagnostics confirm residuals are roughly white noise, validating model assumptions.

This end-to-end pipeline—from raw page-view ingestion through EDA, anomaly handling, stationarity checks, and multiple forecasting approaches—yields ARIMA as the most accurate for predicting daily views on Wikipedia's main page.

In [ ]: