Time series analysis with ARIMA

Import libraries and get sample data

In [1]:

```
# Import libraries
import warnings
import itertools
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import statsmodels.api as sm

# Defaults
plt.rcParams['figure.figsize'] = (20.0, 10.0)
plt.rcParams.update({'font.size': 12})
plt.style.use('ggplot')
```

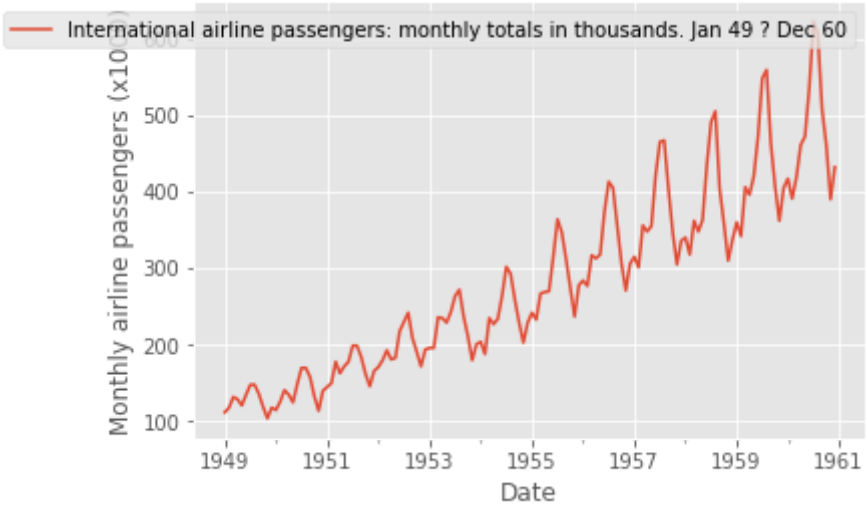
```
C:\Users\gmonaci\AppData\Local\Continuum\anaconda3\lib\site-packages\stat
smodels\compat\pandas.py:56: FutureWarning: The pandas.core.datetools mod
ule is deprecated and will be removed in a future version. Please use the
pandas.tseries module instead.
  from pandas.core import datetools
```

Get the classic international airline passengers data, downloadable from the DataMarket webpage (https://datamarket.com/data/set/22u3/international-airline-passengers-monthly-totals-in-thousands-jan-49-dec-60#!ds=22u3&display=line (https://datamarket.com/data/set/22u3/international-airline-passengers-monthly-totals-in-thousands-jan-49-dec-60#!ds=22u3&display=line)) as a CSV with filename "international-airline-passengers.csv".

In [2]:

```
# Load the data
data = pd.read_csv('international-airline-passengers.csv', engine='python', skipfooter=3
# A bit of pre-processing to make it nicer
data['Month']=pd.to_datetime(data['Month'], format='%Y-%m-%d')
data.set_index(['Month'], inplace=True)

# Plot the data
data.plot()
plt.ylabel('Monthly airline passengers (x1000)')
plt.xlabel('Date')
plt.show()
```



Two obvious patterns appear in the data, an overall increase in the number of passengers over time, and a 12 months seasonality with peaks corresponding to the northern emisphere summer period.

In [3]:

```
# Define the d and q parameters to take any value between 0 and 1
q = d = range(0, 2)
# Define the p parameters to take any value between 0 and 3
p = range(0, 4)

# Generate all different combinations of p, q and q triplets
pdq = list(itertools.product(p, d, q))

# Generate all different combinations of seasonal p, q and q triplets
seasonal_pdq = [(x[0], x[1], x[2], 12) for x in list(itertools.product(p, d, q))]

print('Examples of parameter combinations for Seasonal ARIMA...')
print('SARIMAX: {} x {}'.format(pdq[1], seasonal_pdq[1]))
print('SARIMAX: {} x {}'.format(pdq[1], seasonal_pdq[2]))
print('SARIMAX: {} x {}'.format(pdq[2], seasonal_pdq[3]))
print('SARIMAX: {} x {}'.format(pdq[2], seasonal_pdq[4]))
```

```
Examples of parameter combinations for Seasonal ARIMA...
SARIMAX: (0, 0, 1) x (0, 0, 1, 12)
SARIMAX: (0, 0, 1) x (0, 1, 0, 12)
SARIMAX: (0, 1, 0) x (0, 1, 1, 12)
SARIMAX: (0, 1, 0) x (1, 0, 0, 12)
```

We select a subset of the data series as training data, say the first 11 years. Our goal is to predict the last year of the series based on this input.

In [13]:

```
train_data = data['1949-01-01':'1959-12-01']
test_data = data['1960-01-01':'1960-12-01']
```

In [5]:

```
warnings.filterwarnings("ignore") # specify to ignore warning messages

AIC = []
SARIMAX_model = []
for param in pdq:
    for param_seasonal in seasonal_pdq:
        try:
            mod = sm.tsa.statespace.SARIMAX(train_data,
                                            order=param,
                                            seasonal_order=param_seasonal,
                                            enforce_stationarity=False,
                                            enforce_invertibility=False)

            results = mod.fit()

            print('SARIMAX{}x{} - AIC:{}'.format(param, param_seasonal, results.aic), er
            AIC.append(results.aic)
            SARIMAX_model.append([param, param_seasonal])
        except:
            continue
```

```
SARIMAX(3, 1, 1)x(3, 1, 1, 12) - AIC:619.77849554151587
```

In [6]:

```
print('The smallest AIC is {} for model SARIMAX{}x{}'.format(min(AIC), SARIMAX_model[AIC
```

```
The smallest AIC is 618.2055110262379 for model SARIMAX(3, 1, 0)x(3, 1,
1, 12)
```

In [7]:

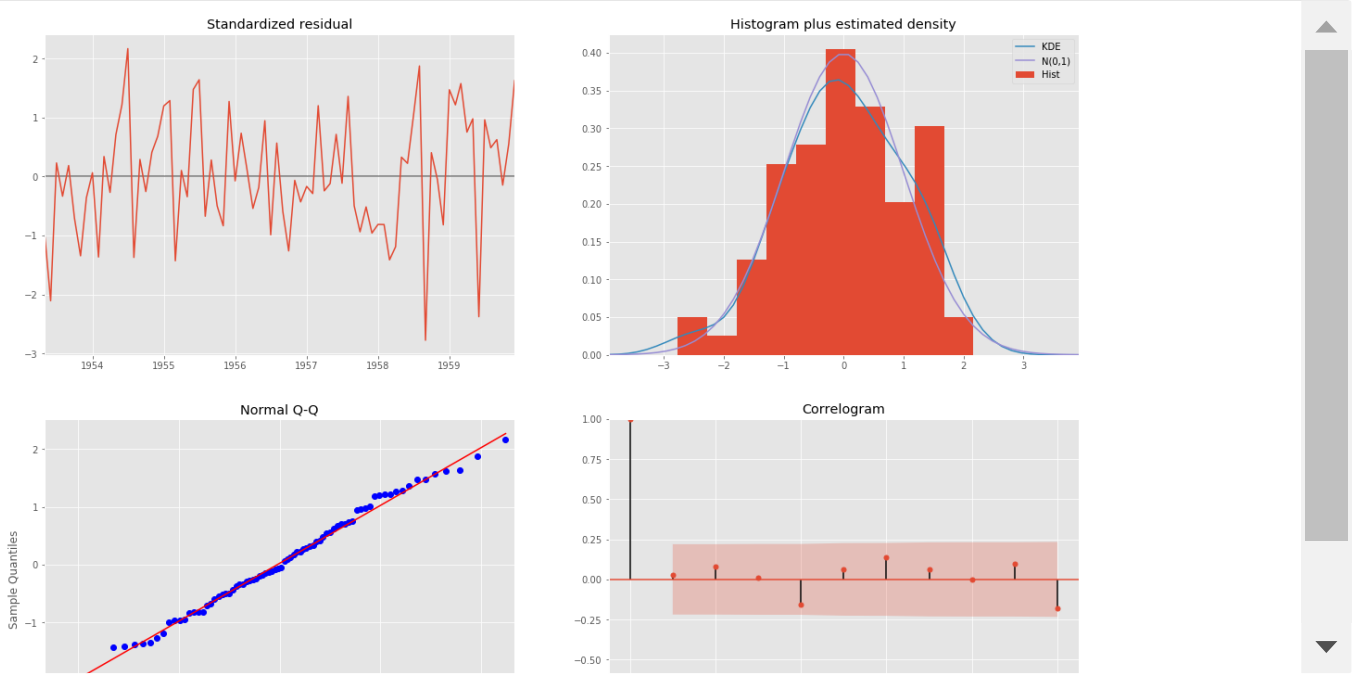
```
# Let's fit this model
mod = sm.tsa.statespace.SARIMAX(train_data,
                                order=SARIMAX_model[AIC.index(min(AIC))][0],
                                seasonal_order=SARIMAX_model[AIC.index(min(AIC))][1],
                                enforce_stationarity=False,
                                enforce_invertibility=False)

results = mod.fit()
```

Once the model has been fitted, we can check if does what we expect and if the assumptions we made are violated. To do this, we can use the $plot\_diagnostics$ method.

In [8]:

```
results.plot_diagnostics(figsize=(20, 14))
plt.show()
```



Results

Now let's create some predictions. We will use three methods:

1) In sample prediction with 1-step ahead forecasting of the last year (1959). In this case the model is used to predict data that the model was built on. 1-step ahead forecasting implies that each forecasted point is used to predict the following one.

In [9]:

```
pred0 = results.get_prediction(start='1958-01-01', dynamic=False)
pred0_ci = pred0.conf_int()
```

2) In sample prediction with dynamic forecasting of the last year (1959). Again, the model is used to predict data that the model was built on.

In [10]:

```
pred1 = results.get_prediction(start='1958-01-01', dynamic=True)
pred1_ci = pred1.conf_int()
```

3) "True" forecasting of out of sample data. In this case the model is asked to predict data it has not seen before.

In [16]:

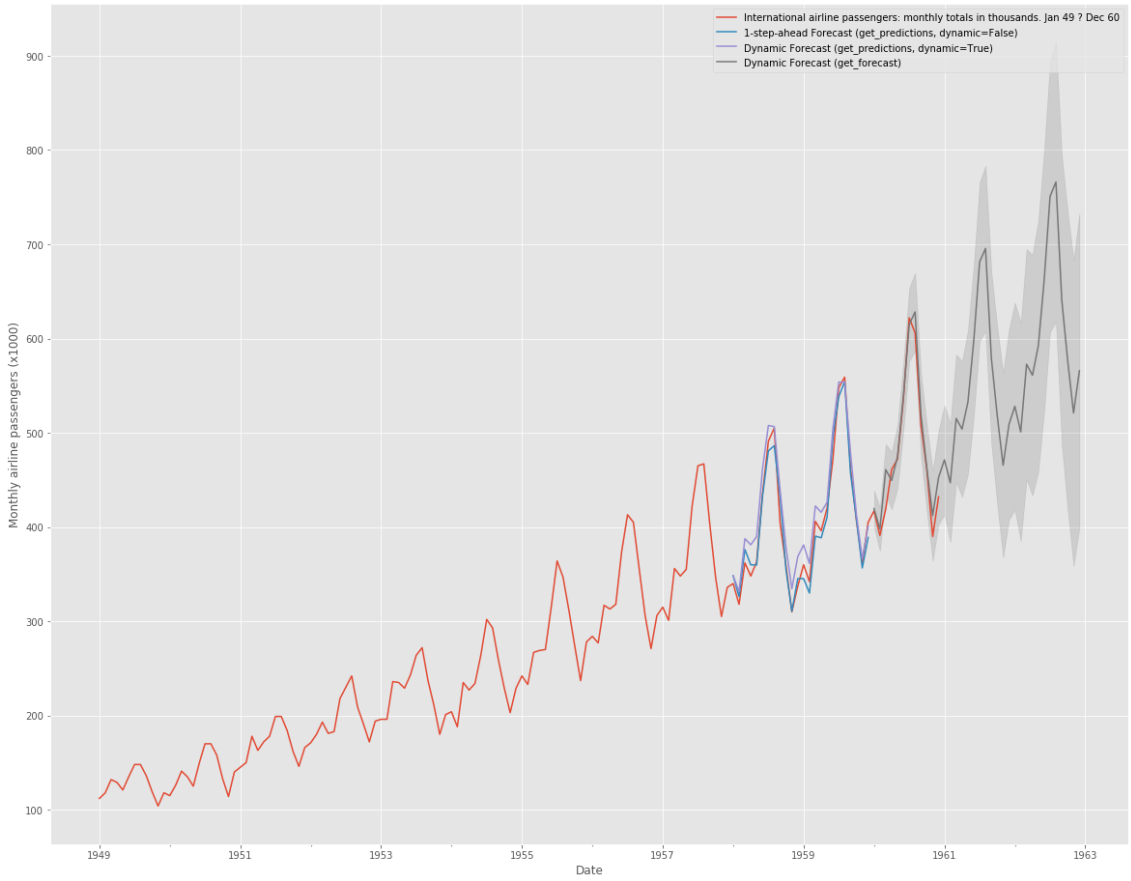
```
pred2 = results.get_forecast('1962-12-01')
pred2_ci = pred2.conf_int()
print(pred2.predicted_mean['1960-01-01':'1960-12-01'])
```

```
1960-01-01    419.495085
1960-02-01    397.834142
1960-03-01    460.859052
1960-04-01    449.451900
1960-05-01    474.555739
1960-06-01    537.848954
1960-07-01    614.884907
1960-08-01    628.209240
1960-09-01    519.336551
1960-10-01    462.254691
1960-11-01    412.164222
1960-12-01    452.664872
Freq: MS, dtype: float64
```

Let's plot all this

In [12]:

```
ax = data.plot(figsize=(20, 16))
pred0.predicted_mean.plot(ax=ax, label='1-step-ahead Forecast (get_predictions, dynamic=
pred1.predicted_mean.plot(ax=ax, label='Dynamic Forecast (get_predictions, dynamic=True)
pred2.predicted_mean.plot(ax=ax, label='Dynamic Forecast (get_forecast)')
ax.fill_between(pred2_ci.index, pred2_ci.iloc[:, 0], pred2_ci.iloc[:, 1], color='k', alp
plt.ylabel('Monthly airline passengers (x1000)')
plt.xlabel('Date')
plt.legend()
plt.show()
```



In [33]:

```
prediction = pred2.predicted_mean['1960-01-01':'1960-12-01'].values
# flatten nested list
truth = list(itertools.chain.from_iterable(test_data.values))
# Mean Absolute Percentage Error
MAPE = np.mean(np.abs((truth - prediction) / truth)) * 100

print('The Mean Absolute Percentage Error for the forecast of year 1960 is {:.2f}%'.form
```

```
The Mean Absolute Percentage Error for the forecast of year 1960 is 2.81%
```