```
[1]: import numpy as np
     import pandas as pd
     from pandas_datareader import data as pdr
     from datetime import datetime, date, timedelta

     from math import log, sqrt, pi, exp
     from scipy.stats import norm
     from pandas import DataFrame
     import statsmodels
     import statsmodels.api as sm
     from statsmodels.tsa.stattools import coint, adfuller

     import plotly.graph_objects as go
     from plotly.offline import iplot, init_notebook_mode
     import matplotlib.pyplot as plt
     import seaborn as sns

     import yfinance as yfin
     yfin.pdr_override()

     pd.set_option('display.float_format', lambda x: f'{x:,.2f}')
     plt.rc('figure',figsize=(7,5))
     import warnings
```

Assignment

- Select an asset in your portfolio and identify a closely correlated asset.
- Prepare a Candlestick chart for the past year that demonstrates the correlation of the asset in your portfolio and the closely correlated asset.

Setup

Variables

```
[2]: # Portfolio Sub Class U.S. Equities
     ticker = ['VOO',
               'EXAS',
               'FSMD',
               'BACB',
               'IVV',
               'NVTA',
               'PATH',
               'SCHD',
               'TWLO',
               'VBR',
               'VO',
               'VONG',
               'SPY']


     # pairs to trade
     sp_list = ['IVV','VALD']


     today = datetime.today()
     offset = max(1, (today.weekday() + 6) % 7 + 3)
     timed = timedelta(offset)
     recent_business_day = today - timed
     print("As of", today,business)

     today = today.business.strftime("%Y-%m-%d")
     start = '2022-01-01'
     end = today

     d1 = 2023-10-20 15:20:05.475845
```

Functions

```
[3]:


     def stationarity_test(X, cutoff=0.01):
         # H_0 in adfuller is unit root exists (non-stationary)
         # We must observe significant p-value to convince ourselves that the series is stationary
         pvalue = adfuller(X)[1]
         if pvalue < cutoff:
             print('p-value = ' + str(pvalue) + ' The series ' + X.name +' is likely stationary.')
         else:
             print('p-value = ' + str(pvalue) + ' The series ' + X.name +' is likely non-stationary.')


     def find_cointegrated_pairs(data):
         n = data.shape[1]
         score_matrix = np.zeros((n, n))
         pvalue_matrix = np.ones((n, n))
         keys = data.keys()
         pairs = []
         for i in range(n):
             for j in range(i+1, n):
                 S1 = data[keys[i]]
                 S2 = data[keys[j]]
                 result = coint(S1, S2)
                 score = result[0]
                 pvalue = result[1]
                 score_matrix[i, j] = score
                 pvalue_matrix[i, j] = pvalue
                 if pvalue < 0.05:
                     pairs.append((keys[i], keys[j]))
         return score_matrix, pvalue_matrix, pairs


     # Trade using a simple strategy
     def trade(S1, S2, window1, window2):

         # If window length is 0, algorithm doesn't make sense, so exit
         if (window1 == 0) or (window2 == 0):
             return 0

         # Compute rolling mean and rolling standard deviation
         ratios = S1/S2
         ma1 = ratios.rolling(window=window1,
                              center=False).mean()
         ma2 = ratios.rolling(window=window2,
                              center=False).mean()
         std = ratios.rolling(window=window2,
                              center=False).std()
         zscore = (ma1-ma2)/std

         # Simulate trading
         # Start with no money and no positions
         money = 0
         countS1 = 0
         countS2 = 0
         for i in range(len(ratios)):
             # Sell short if the z-score is > 1
             if zscore[i] > -1:
                 print('Selling ratios', S1[i] = ratios[i]
                 countS1 += 1
                 countS2 += ratios[i]
                 print('Buy %s %s %s %s'%(money, ratios[i], countS1,countS2))
             # Buy long if the z-score is < -1
             elif zscore[i] < 1:
                 print('Buying ratios', S1[i] = ratios[i]
                 countS1 += 1
                 countS2 += ratios[i]
                 print('Sell %s %s %s %s'%(money,ratios[i], countS1,countS2))
             # Close positions if the z-score between -1 and .5
             elif abs(zscore[i]) < 0.75:
                 print('Closing', countS1 = countS1 + countS2
                 countS1 = 0
                 countS2 = 0
                 print('Exit pos %s %s %s %s'%(money,ratios[i], countS1,countS2))


         return money
```

Load Data

```
[4]: df = pdr.get_data_yahoo(ticker, start=start, end=today)['Close']
     df.columns = ticker
     df1 = pdr.get_data_yahoo(sp_list[0], start=start, end=today)
     df2 = pdr.get_data_yahoo(sp_list[1], start=start, end=today)

     [*********************100%***********************]  13 of 13 completed
     [*********************100%***********************]  1 of 1 completed
     [*********************100%***********************]  1 of 1 completed
```

1.0 Asset Selection

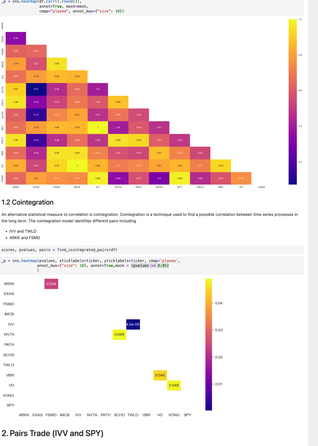
The Pairs Trading Strategy is applied to the U.S Equity portion of the portfolio. The first step is identifying paired assets to pair trade. I have included SPY in the list of assets for comparison purposes.

1.1 Correlation

The correlation heatmap identifies several options for the pairs trading strategy including:

- IVV and SPY
- VO and BACB

```
[5]: plt.figure(figsize=(24,12))
     corr = df.corr(method='pearson')
     mask=np.eye(corr.shape[0])
     sns.set_style('white')
     ax = sns.heatmap(corr, vmin=-1,vmax=1,
                      annot=True, mask=mask,
                      cmap='Pilaway', annot_kws={'size': 14})
```



1.2 Cointegration

An alternative statistical measure to correlation is cointegration. Cointegration is a technique used to find a possible correlation between time series processes in the long term. The cointegration model identifies different pairs including

- IVV and TWLO
- ARKK and FSMD

```
[7]: scores, pvalues, pairs = find_cointegrated_pairs(df)

     ax = sns.heatmap(pvalues, xticklabels=ticker, yticklabels=ticker, cmap='cicone',
                      annot_kws={"size": 16}, annot=True,mask = (pvalues >= 0.05))
```

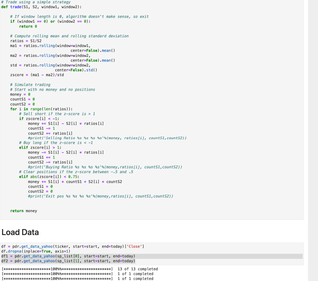
2. Pairs Trade (IVV and SPY)

2.1 Load Data

```
[8]: # pairs to trade
     sp_list = ['IVV','SPY']

     df1 = pdr.get_data_yahoo(sp_list[0], start=start, end=today)
     df2 = pdr.get_data_yahoo(sp_list[1], start=start, end=today)

     [*********************100%***********************]  1 of 1 completed
     [*********************100%***********************]  1 of 1 completed
```

2.2 Candle Stick Graph

```
[9]: trace1 = {
         'x': df1.index,
         'open': df1.Open,
         'close': df1.Close,
         'high': df1.High,
         'low': df1.Low,
         'type': 'candlestick',
         'name': sp_list[0],
         'showlegend': True
     }

[10]: trace2 = {
          'x': df2.index,
          'open': df2.Open,
          'close': df2.Close,
          'high': df2.High,
          'low': df2.Low,
          'type': 'candlestick',
          'name': sp_list[1],
          'showlegend': True
      }

[11]: data = [trace1, trace2]

      # Config graph layout
      layout = go.Layout({
          'title': {
              'text': 'Moving Averages',
              'font': {
                  'size': 15
              }
          }
      })

[12]: fig = go.Figure(data=data, layout=layout)
      fig.update_layout(width=1200, height=800)
      fig.show()
```




```
[13]: S1 = df1.Close
      S2 = df2.Close

      ratio = S1/S2

      score, pvalue, _ = coint(S1, S2)
      print(coint (IVV & SPY): ', pvalue)

      coint (IVV & SPY): 4.4086733368758076e-05
```

2.3 Spread

Plot the spread of two time series using linear regression to get the coefficient.

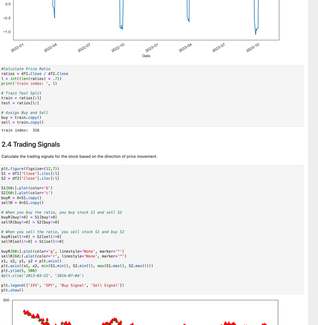
```
[14]: S1 = sm.add_constant(S1)
      results = sm.OLS(S2, S1).fit()
      S1 = df1.Close
      b = results.params['Close']

      spread = S2 - b * S1
      spread.plot(figsize=(12,6)
      plt.axhline(spread.mean(), color='black')

      plt.legend(['Spread (IVV & SPY)']);
```

```
[15]: #Calculate Price Ratio
      ratio = df1.Close / df2.Close
      l = int(len(ratio) * .7)
      print('train index: ', l)

      # Train Test Split
      train = ratio[:l]
      test = ratio[l:]

      # Assign Buy and Sell
      buy = train.copy()
      sell = train.copy()

      train index:  358
```

2.4 Trading Signals

Calculate the trading signals for the stock based on the direction of price movement.

```
[16]: plt.figure(figsize=(12,7))
      S1 = df1['Close'].iloc[:l]
      S2 = df2['Close'].iloc[:l]

      S1[buy.shape[0]:].plot(color='r')
      S2[buy.shape[0]:].plot(color='r')
      ratio[:l].plot(color='r')
      sell[0 = 0].copy()

      # When you buy the ratio, you buy stock S1 and sell S2
      buy[buy<0] = S1[buy<0]
      sell[S1[buy<0] = S2[buy<0]

      # When you sell the ratio, you sell stock S1 and buy S2
      buy[buy>0] = S1[buy>0]
      sell[S1[buy>0] = S2[buy>0]

      buy[S1[S1.pct_change(1) == 0] = nan
      sell[S1[S1.pct_change(1) == 0] = nan
      s1, s2, s3, s4 = plt.axvline(
      plt.axhline(s1, s2, xcr=[S1.shape[0], S1.shape[0]], ncc=[S1.min(), S1.max()])
      plt.clear
      plt.xlim('2022-01-27', '2022-07-0')

      plt.legend(['IVV', 'SPY', 'Buy Signal', 'Sell Signal'])
      plt.show()
```



2.5 Backtesting Pairs Trade Strategy

[69]:
```
profit_var = trade(df1.Close,iloc[l:], df2.Close.iloc[l:], 60, 5)
print('Backtested Profit', round(profit_var,2))
```

```
Backtested Profit -54.57
```

3. Pairs Trade (IVV and TWLO)

3.1 Load Data

[70]:
```
# pairs to trade
sp_list = ['IVV','TWLO']
```

[71]:
```
df1 = pdr.get_data_yahoo(sp_list[0], start=start, end=today)
df2 = pdr.get_data_yahoo(sp_list[1], start=start, end=today)
```

```
[*********************100%***********************]  1 of 1 completed
[*********************100%***********************]  1 of 1 completed
```

3.2 Candle Stick Graph

[72]:
```
trace1 = {
    'x': df1.index,
    'open': df1.Open,
    'close': df1.Close,
    'high': df1.High,
    'low': df1.Low,
    'type': 'candlestick',
    'name': sp_list[0],
    'showlegend': True
}
```

[73]:
```
trace2 = {
    'x': df2.index,
    'open': df2.Open,
    'close': df2.Close,
    'high': df2.High,
    'low': df2.Low,
    'type': 'candlestick',
    'name': sp_list[1],
    'showlegend': True
}
```

[74]:
```
data = [trace1, trace2]

# Config graph layout
layout = go.Layout({
    'title': {
        'text': 'Moving Averages',
        'font': {
            'size': 15
        }
    }
})
```

[75]:
```
fig = go.Figure(data=data, layout=layout)
fig.update_layout(width=1200, height=800)
fig.show()
```

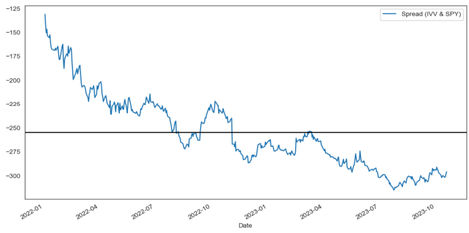
[76]:
```
S1 = df1.Close
S2 = df2.Close

ratio = S1/S2

score, pvalue, _ = coint(S1, S2)
print('coint (IVV & SPY): ' , pvalue)
```

```
coint (IVV & SPY):  0.49688570041928 25
```

3.3 Spread

Plot the spread of two time series using linear regression to get the coefficient.

[77]:
```
S1 = sm.add_constant(S1)
results = sm.OLS(S2, S1).fit()
S1 = df1.Close
b = results.params['Close']

spread = S2 - b * S1
spread.plot(figsize=(12,6))
plt.axhline(spread.mean(), color='black')

plt.legend(['Spread (IVV & SPY)']);
```



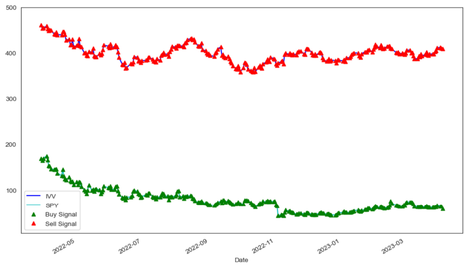
[78]:
```
#Calculate Price Ratio
ratios = df1.Close / df2.Close
l = int((len(ratios) * .7))
print('train index: ', l)

# Train Test Split
train = ratios[:l]
test = ratios[l:]

# Assign Buy and Sell
buy = train.copy()
sell = train.copy()
```

```
train index:  316
```

3.4 Trading Signals

Calculate the trading signals for the stock based on the direction of price movement.

[79]:
```
plt.figure(figsize=(12,7))
S1 = df1['Close'].iloc[:l]
S2 = df2['Close'].iloc[:l]

S1[60:].plot(color='b')
S2[60:].plot(color='c')
buyR = 0*S1.copy()
sellR = 0*S1.copy()

# When you buy the ratio, you buy stock S1 and sell S2
buyR[buy!=0] = S1[buy!=0]
sellR[buy!=0] = S2[buy!=0]

# When you sell the ratio, you sell stock S1 and buy S2
buyR[sell!=0] = S2[sell!=0]
sellR[sell!=0] = S1[sell!=0]

buyR[60:].plot(color='g', linestyle='None', marker='^')
sellR[60:].plot(color='r', linestyle='None', marker='^')
x1, x2, y1, y2 = plt.axis()
plt.axis((x1, x2, min(S1.min(), S2.min()), max(S1.max(), S2.max())))
plt.ylim(5, 500)
#plt.xlim('2013-03-22', '2016-07-04')

plt.legend(['IVV', 'SPY', 'Buy Signal', 'Sell Signal'])
plt.show()
```



3.5 Backtesting Pairs Trade Strategy

[80]:
```
profit_var = trade(df1.Close,iloc[l:], df2.Close.iloc[l:], 60, 5)
print('Backtested Profit', round(profit_var,2))
```

```
Backtested Profit 1340.81
```

Conclusion

The IVV and TWLO pairs trading strategy generates 1340.81 in profits when we backtest the portfolio.

[ ]: