w8_pairs_trading

November 26, 2020

[28]:
```
#install pandas-datareader package with pip
#!pip install pandas-datareader
```

```
Requirement already satisfied: pandas-datareader in /usr/local/lib/python3.6
/dist-packages (0.9.0)
Requirement already satisfied: requests>=2.19.0 in /usr/local/lib/python3.6
/dist-packages (from pandas-datareader) (2.23.0)
Requirement already satisfied: lxml in /usr/local/lib/python3.6/dist-packages
(from pandas-datareader) (4.2.6)
Requirement already satisfied: pandas>=0.23 in /usr/local/lib/python3.6/dist-
packages (from pandas-datareader) (1.1.4)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.6
/dist-packages (from requests>=2.19.0->pandas-datareader) (2020.11.8)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.6
/dist-packages (from requests>=2.19.0->pandas-datareader) (3.0.4)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in
/usr/local/lib/python3.6/dist-packages (from requests>=2.19.0->pandas-
datareader) (1.24.3)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.6/dist-
packages (from requests>=2.19.0->pandas-datareader) (2.10)
Requirement already satisfied: numpy>=1.15.4 in /usr/local/lib/python3.6/dist-
packages (from pandas>=0.23->pandas-datareader) (1.18.5)
Requirement already satisfied: python-dateutil>=2.7.3 in
/usr/local/lib/python3.6/dist-packages (from pandas>=0.23->pandas-datareader)
(2.8.1)
Requirement already satisfied: pytz>=2017.2 in /usr/local/lib/python3.6/dist-
packages (from pandas>=0.23->pandas-datareader) (2018.9)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.6/dist-
packages (from python-dateutil>=2.7.3->pandas>=0.23->pandas-datareader) (1.15.0)
```

[29]:
```
#import libraries
import datetime as dt
import math

import matplotlib.pyplot as plt
from matplotlib import style
```

```
import seaborn as sn

import pandas as pd
import pandas_datareader as web

import numpy as np
import statsmodels
from statsmodels.tsa.stattools import coint

np.random.seed(107)
```

[30]:
```
start = dt.date(2019,1,1)
end = dt.date.today()
```

[31]:
```
#symbol_list = ['IG', 'NVS', 'PBH', 'GNC', 'JNJ', 'PFE', 'MRTX','SPX', 'CPHD']

symbol_list = ['NVS', 'PBH']

df_stock_prices = pd.DataFrame()
```

[32]:
```
for symbol in symbol_list:
  try:
    df = web.DataReader(symbol, 'yahoo', start, end)
    df_stock_prices[symbol] = df['Adj Close']
  except:
    pass
```

[33]:
```
df_stock_prices.head()
```

[33]:

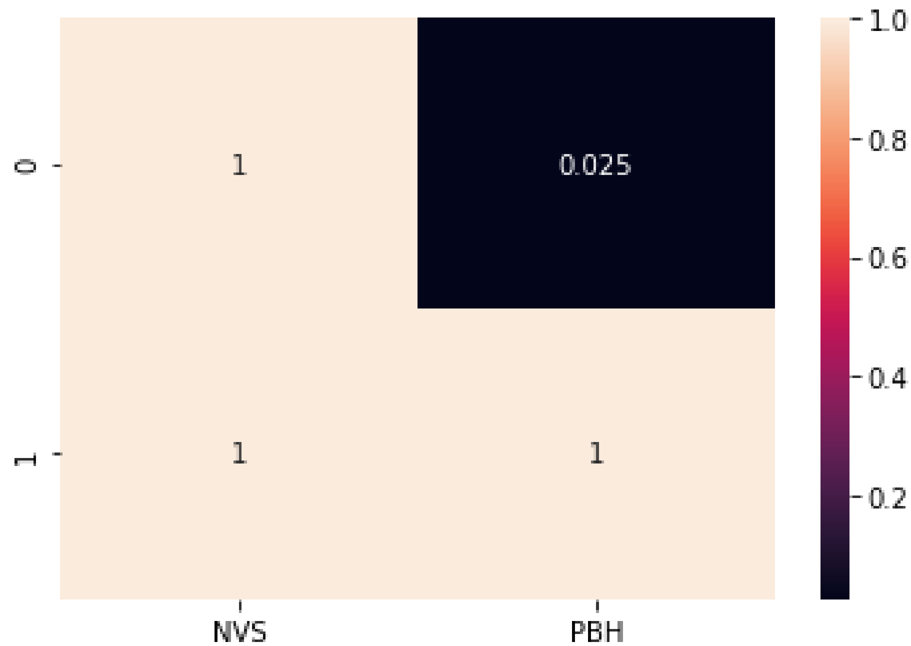
	NVS	PBH
Date		
2019-01-02	70.406586	30.709999
2019-01-03	70.976135	30.209999
2019-01-04	71.939354	31.379999
2019-01-07	71.093399	31.440001
2019-01-08	72.634537	31.719999

[34]:
```
def find_cointegrated_pairs(stockprice_data):
  symb = list(df_stock_prices.columns)
  n = len(symb)
  score_matrix = np.zeros((n,n))
  pvalue_matrix = np.ones((n,n))
  pairs = []

  for i in range(n):
    for j in range(i+1, n):
      S1 = stockprice_data[symb[i]]
      S2 = stockprice_data[symb[j]]
      S1 = S1.fillna(S1.mean())
      S2 = S2.fillna(S2.mean())
```

```
        result = coint(S1,S2)
        score = result[0]
        pvalue = result[1]
        score_matrix[i,j] = score
        pvalue_matrix[i,j] = pvalue

        if(pvalue < 0.01):
          pairs.append((S1,S2,symb[i], symb[j]))
    return score_matrix, pvalue_matrix, pairs
```

[35]:
```
score, pvalue, _ = find_cointegrated_pairs(df_stock_prices)
```

[36]:
```
df_pvalue = pd.DataFrame(pvalue, columns=list(df_stock_prices.columns))
sn.heatmap(df_pvalue, annot=True)
plt.show()
```



[36]:
```
```

1 Week 8

1.1 Visualize the Time Series in Graph

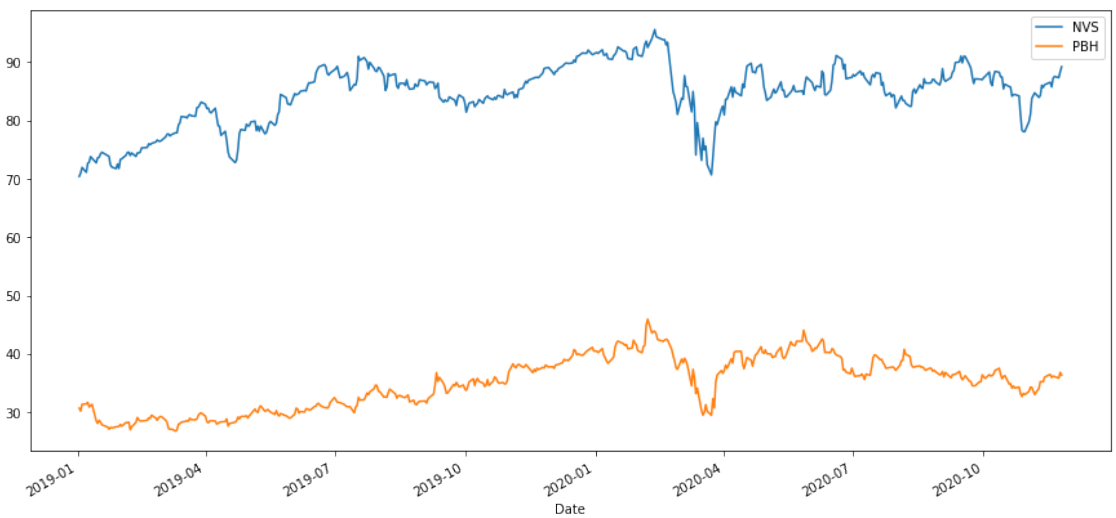
[37]:
```
X = df_stock_prices['NVS']
Y = df_stock_prices['PBH']
```

[38]:
```
print("Correlation : " , X.corr(Y))
print("Cointegration test p-value : ", pvalue[0][1])
```

```
Correlation :  0.708861839412714
Cointegration test p-value :  0.025479193494852313
```

We see that these two stock prices are both cointegrated and correlated.

[39]:
```
s1 = X
s2 = Y

pd.concat([s1, s2], axis=1 ).plot(figsize=(15,7))
plt.show()
```



1.2 How to make a pairs trade ?

Because two cointegrated time series (such as X and Y above) drift towards and apart from each other, there will be times when the spread is high and times when the spread is low.

We make a pairs trade by buying one security and selling another. This way, if both securities go down together or go up together, we neither make nor lose money — we are market neutral.

1.3 Getting Ratio of time series

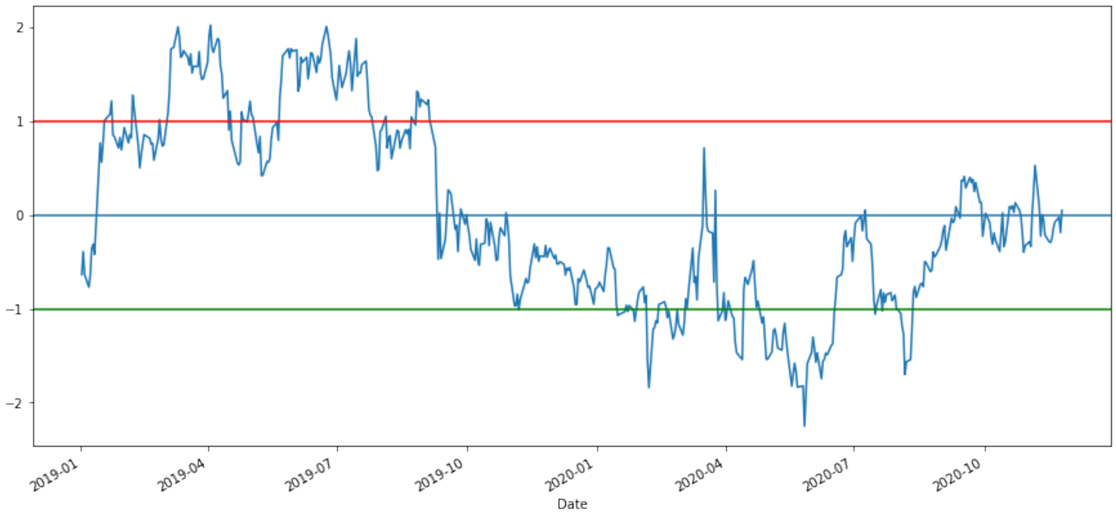
[40]:
```
ratios = s1 / s2
```

1.4 Z-Score

$ZScore(Value) = (Value - Mean)/StandardDeviation$

[41]:
```python
def zscore(series):
    return (series - series.mean()) / np.std(series)
```

[42]:
```python
zscore(ratios).plot(figsize=(15,7))
plt.axhline(zscore(ratios).mean())
plt.axhline(1.0, color='red')
plt.axhline(-1.0, color='green')
plt.show()
```



It's easier to now observe the ratio now moves around the mean, but sometimes is prone to large divergences from the mean, which we can take advantages of.

By setting two other lines placed at the z-score of 1 and -1, we can clearly see that for the most part, any big divergences from the mean eventually converge back. This is precisely what we want for a pairs trading strategy.

1.5 Trading Signals

When conducting any type of trading strategy, it's always important to clearly define and delineate at what point you will actually make a trade. As in, what is the best indicator that I need to buy or sell a particular stock?

1.5.1 Setup rules

We're going to use the **ratio** time series that we've created to see if it tells us whether to buy or sell a particular moment in time.

We'll start off by creating a prediction variable Y

. If the ratio is positive, it will signal a "buy," otherwise, it will signal a sell. The prediction model is as follows:

$Y_t = sign(Ratio_{t+1} - Ratio_t)$

What's great about pair trading signals is that we don't need to know absolutes about where the prices will go, all we need to know is where it's heading: up or down.

[60]:
```
#signal of sell
ratios[0] - ratios[1]
```

[60]: -0.05679785892271472

[59]:
```
#signal of buy
ratios[1] - ratios[2]
```

[59]: 0.056902775776478176

1.6 Train Test Split

[61]:
```
print(len(ratios) * .70 )
```

```
336.7
```

[62]:
```
train = ratios[:336]
test = ratios[336:]
```

[63]:
```
train.head()
```

[63]:
```
Date
2019-01-02    2.292627
2019-01-03    2.349425
2019-01-04    2.292522
2019-01-07    2.261240
2019-01-08    2.289866
dtype: float64
```

[64]:
```
test.head()
```

[64]:
```
Date
2020-05-04    2.101051
2020-05-05    2.152654
2020-05-06    2.158028
2020-05-07    2.140834
2020-05-08    2.110586
dtype: float64
```

1.7 Feature Engineering

We need to find out what features are actually important in determining the direction of the ratio moves. Knowing that the ratios always eventually revert back to the mean, maybe the moving averages and metrics related to the mean will be important.

- 60 day Moving Average of Ratio
- 5 day Moving Average of Ratio
- 60 day Standard Deviation
- z score

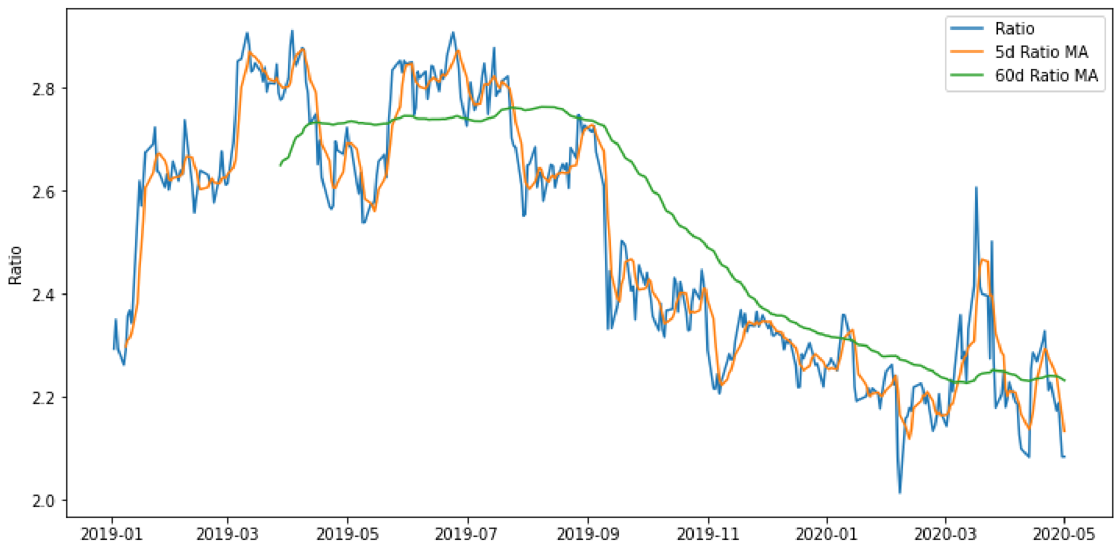
[65]:
```
ratios_mavg60 = train.rolling(window=60, center=False).mean()
ratios_mavg5 = train.rolling(window=5, center=False).mean()

std_60 = train.rolling(window=60, center=False).std()

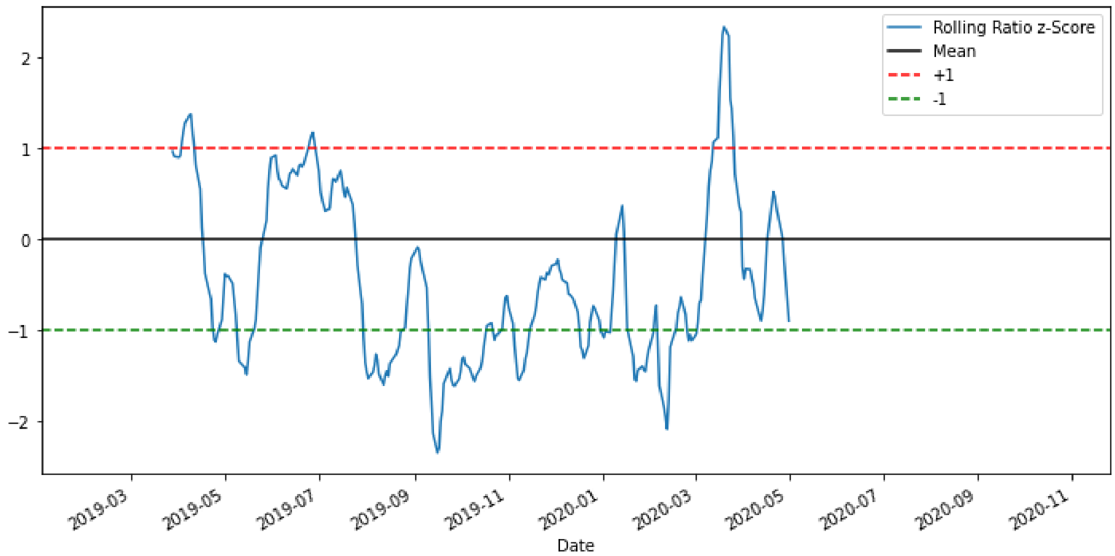
zscore_60_5 = (ratios_mavg5 - ratios_mavg60)/std_60

plt.figure(figsize=(12, 6))
plt.plot(train.index, train.values)
plt.plot(ratios_mavg5.index, ratios_mavg5.values)
plt.plot(ratios_mavg60.index, ratios_mavg60.values)
plt.legend(['Ratio', '5d Ratio MA', '60d Ratio MA'])

plt.ylabel('Ratio')
plt.show()
```



[70]:
```
plt.figure(figsize=(12,6))
zscore_60_5.plot()
plt.xlim('2019-01-02', '2020-11-25')
plt.axhline(0, color='black')
plt.axhline(1.0, color='red', linestyle='--')
plt.axhline(-1.0, color='green', linestyle='--')
plt.legend(['Rolling Ratio z-Score', 'Mean', '+1', '-1'])
plt.show()
```



1.8 Creating a Model

A standard normal distribution has a mean of 0 and a standard deviation 1. Looking at the plot, it's pretty clear that if the time series moves 1 standard deviation beyond the mean, it tends to revert back towards the mean. Using these models, we can create the following trading signals:

```
Buy(1) whenever the z-score is below -1, meaning we expect the ratio to increase.
Sell(-1) whenever the z-score is above 1, meaning we expect the ratio to decrease.
```

We can use our model on actual data

[77]:
```
plt.figure(figsize=(12,6))

train[100:].plot()

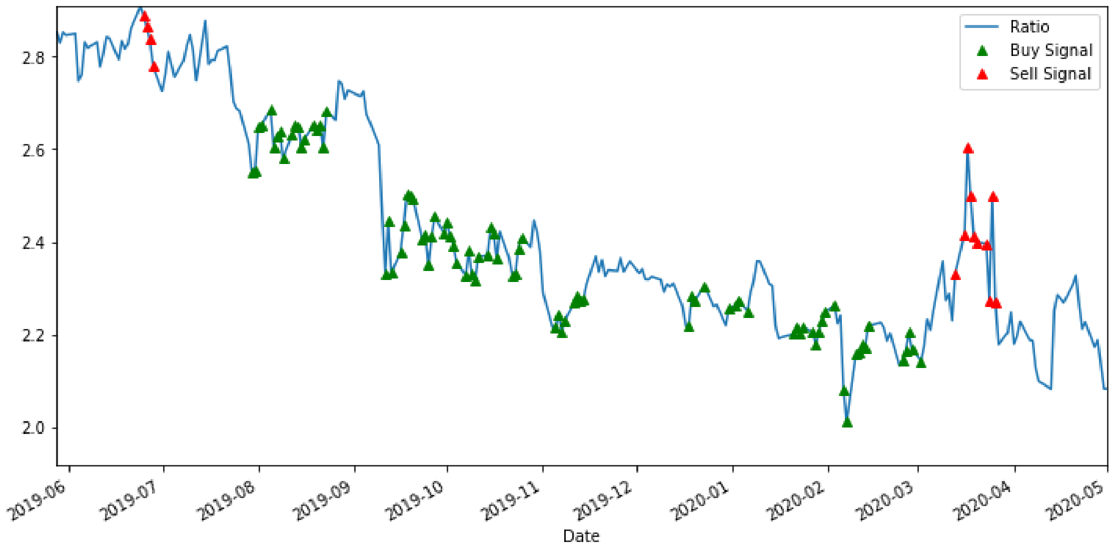
buy = train.copy()
sell = train.copy()

#Buy signal (1) whenever the z-score is below -1, meaning we expect the ratio␣
↪to increase.
buy[zscore_60_5>-1] = 0

#Sell signal (-1) whenever the z-score is above 1, meaning we expect the ratio␣
↪to decrease.
sell[zscore_60_5<1] = 0

buy[100:].plot(color='g', linestyle='None', marker='^')
sell[100:].plot(color='r', linestyle='None', marker='^')
```

```
x1, x2, y1, y2 = plt.axis()
plt.axis((x1, x2, ratios.min(), ratios.max()))
plt.xlim('2019-05-28','2020-05-01')
plt.legend(['Ratio', 'Buy Signal', 'Sell Signal'])
plt.show()
```



[96]:
```
plt.figure(figsize=(20,9))

S1 = df_stock_prices['NVS'].iloc[:336]
S2 = df_stock_prices['PBH'].iloc[:336]

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]

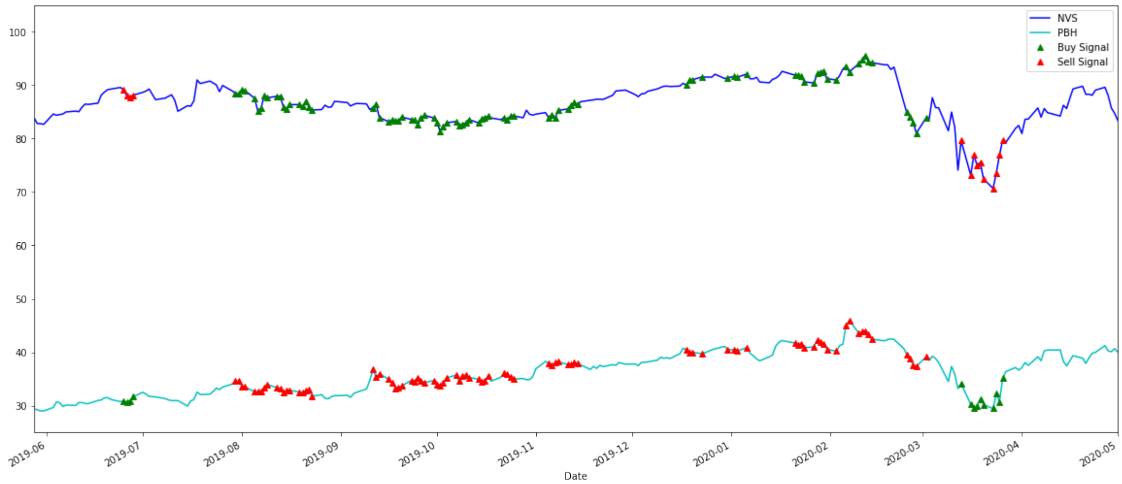
# When you sell the ratio, you sell stock S1 and buy S2
buyR[sell!=0] = S2[sell!=0]
sellR[sell!=0] = S1[sell!=0]

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(25, 105)
plt.xlim('2019-05-28', '2020-05-01')

plt.legend(['NVS', 'PBH', 'Buy Signal', 'Sell Signal'])
plt.show()
```



Now we can clearly see when we should buy or sell on the respective stocks.

1.9 how much can we expect to make of this strategy?

[131]:
```
# 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

    #get moving average of first window
    ma1 = ratios.rolling(window=window1, center=False).mean()

    #get moving average of second window
    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:
            money += S1[i] - S2[i] * ratios[i]
            countS1 -= 1
            countS2 += ratios[i]
            print('Selling Ratio %s %s %s %s'%(money, ratios[i],␣
↪countS1,countS2))
        # Buy long if the z-score is < -1
        elif zscore[i] > 1:
            money -= S1[i] - S2[i] * ratios[i]
            countS1 += 1
            countS2 -= ratios[i]
            print('Buying Ratio %s %s %s %s'%(money,ratios[i], countS1,countS2))
        # Clear positions if the z-score between -.5 and .5
        elif abs(zscore[i]) < 0.75:
            money += S1[i] * countS1 + S2[i] * countS2
            countS1 = 0
            countS2 = 0
            print('Exit pos %s %s %s %s'%(money,ratios[i], countS1,countS2))


    return money
```

[132]:
```
S1 = df_stock_prices['NVS'].iloc[:336]
S2 = df_stock_prices['PBH'].iloc[:336]

trade(S1,S2,60,5)
```

```
Selling Ratio 0.0 2.776671704893592 -1 2.776671704893592
Selling Ratio 0.0 2.779347119214838 -2 5.556018824108429
Selling Ratio 0.0 2.8197090263339533 -3 8.375727850442383
Selling Ratio 0.0 2.883682844066577 -4 11.25941069450896
Selling Ratio 0.0 2.9117004472529513 -5 14.17111114176191
Selling Ratio 0.0 2.8565948049227785 -6 17.02770594668469
Selling Ratio 0.0 2.8436392559044554 -7 19.871345202589147
Selling Ratio 0.0 2.8781208255850084 -8 22.749466028174155
Selling Ratio 0.0 2.8746130807059154 -9 25.62407910888007
Selling Ratio 0.0 2.8115571486603894 -10 28.43563625754046
Selling Ratio 0.0 2.790642578422786 -11 31.226278835963246
Selling Ratio 0.0 2.7302597491338916 -12 33.956538585097135
Selling Ratio 0.0 2.748942787259153 -13 36.70548137235629
Exit pos 64.75238371697674 2.6510279044188474 0 0
Exit pos 64.75238371697674 2.6977622212934196 0 0
Buying Ratio 64.75238371697674 2.5701045632660007 1 -2.5701045632660007
```

```
Buying Ratio 64.75238371697674 2.5645010757219424 2 -5.134605638987943
Buying Ratio 64.75238371697674 2.5717434145850766 3 -7.706349053573019
Buying Ratio 64.75238371697674 2.695929162725529 4 -10.402278216298548
Buying Ratio 64.75238371697674 2.678163027314482 5 -13.08044124361303
Buying Ratio 64.75238371697674 2.6710679935635606 6 -15.751509237176592
Buying Ratio 64.75238371697674 2.697161337511693 7 -18.448670574688286
Buying Ratio 64.75238371697674 2.7227589656060305 8 -21.171429540294316
Buying Ratio 64.75238371697674 2.6882349469593647 9 -23.85966448725368
Buying Ratio 64.75238371697674 2.684080009997846 10 -26.543744497251527
Buying Ratio 64.75238371697674 2.61359843482569 11 -29.157342932077217
Buying Ratio 64.75238371697674 2.594729783733232 12 -31.75207271581045
Buying Ratio 64.75238371697674 2.6351931658132375 13 -34.387265881623684
Buying Ratio 64.75238371697674 2.537975130503775 14 -36.92524101212746
Buying Ratio 64.75238371697674 2.538969515703234 15 -39.464210527830694
Buying Ratio 64.75238371697674 2.5733922027412373 16 -42.03760273057193
Buying Ratio 64.75238371697674 2.5710566699102086 17 -44.60865940048214
Buying Ratio 64.75238371697674 2.5809871558303845 18 -47.189646556312525
Buying Ratio 64.75238371697674 2.630174368866219 19 -49.819820925178746
Buying Ratio 64.75238371697674 2.657476587343704 20 -52.47729751252245
Buying Ratio 64.75238371697674 2.6699795159504287 21 -55.14727702847288
Buying Ratio 64.75238371697674 2.6256563203504077 22 -57.77293334882329
Buying Ratio 64.75238371697674 2.730915947422535 23 -60.503849296245825
Exit pos 161.86542412891708 2.774364689594118 0 0
Exit pos 161.86542412891708 2.8350196625292763 0 0
Exit pos 161.86542412891708 2.852933492503958 0 0
Selling Ratio 161.86542412891708 2.8299765583856296 -1 2.8299765583856296
Selling Ratio 161.86542412891708 2.853048583231711 -2 5.683025141617341
Selling Ratio 161.86542412891708 2.8467470048286865 -3 8.529772146446028
Selling Ratio 161.86542412891708 2.8500788002314525 -4 11.37985094667748
Selling Ratio 161.86542412891708 2.747841682860491 -5 14.127692629537972
Selling Ratio 161.86542412891708 2.7615083455075675 -6 16.88920097504554
Selling Ratio 161.86542412891708 2.831949691462262 -7 19.721150666507803
Selling Ratio 161.86542412891708 2.819387117106399 -8 22.5405377836142
Selling Ratio 161.86542412891708 2.8320269856207103 -9 25.372564769234913
Selling Ratio 161.86542412891708 2.7782654260091166 -10 28.15083019524403
Selling Ratio 161.86542412891708 2.806016724954035 -11 30.956846920198064
Selling Ratio 161.86542412891708 2.8429053467103222 -12 33.799752266908385
Selling Ratio 161.86542412891708 2.840684016242758 -13 36.640436283151146
Selling Ratio 161.86542412891708 2.7940902709960938 -14 39.43452655414724
Selling Ratio 161.86542412891708 2.8347128369411454 -15 42.269239391088384
Selling Ratio 161.86542412891708 2.81739245080125 -16 45.086631841889634
Selling Ratio 161.86542412891708 2.8278999111557988 -17 47.91453175304543
Selling Ratio 161.86542412891708 2.862450190551345 -18 50.77698194359677
Selling Ratio 161.86542412891708 2.9084229851176016 -19 53.68540492871438
Selling Ratio 161.86542412891708 2.889316220160582 -20 56.57472114887496
Selling Ratio 161.86542412891708 2.864790771859678 -21 59.43951192073464
Selling Ratio 161.86542412891708 2.8381461089501965 -22 62.27765802968484
Selling Ratio 161.86542412891708 2.781329465333096 -23 65.05898749501793
```

```
Selling Ratio 161.86542412891708 2.7258076114001266 -24 67.78479510641806
Selling Ratio 161.86542412891708 2.811365322803888 -25 70.59616042922195
Selling Ratio 161.86542412891708 2.7565694183936125 -26 73.35272984761556
Selling Ratio 161.86542412891708 2.7930614368851043 -27 76.14579128450067
Selling Ratio 161.86542412891708 2.825442705731619 -28 78.97123399023229
Selling Ratio 161.86542412891708 2.847585473331946 -29 81.81881946356424
Selling Ratio 161.86542412891708 2.8148687467586004 -30 84.63368821032284
Selling Ratio 161.86542412891708 2.7487654599359437 -31 87.38245367025878
Selling Ratio 161.86542412891708 2.8781807730592903 -32 90.26063444331807
Selling Ratio 161.86542412891708 2.784395221406452 -33 93.04502966472452
Selling Ratio 161.86542412891708 2.793402079065077 -34 95.8384317437896
Selling Ratio 161.86542412891708 2.8134536966009254 -35 98.65188544039053
Selling Ratio 161.86542412891708 2.822610296953107 -36 101.47449573734363
Selling Ratio 161.86542412891708 2.7678973951551007 -37 104.24239313249873
Exit pos 303.29306033673606 2.702645032341352 0 0
Exit pos 303.29306033673606 2.688331497418841 0 0
Exit pos 303.29306033673606 2.6835778469783804 0 0
Buying Ratio 303.29306033673606 2.610978060392765 1 -2.610978060392765
Buying Ratio 303.29306033673606 2.5506480034399397 2 -5.1616260638327045
Buying Ratio 303.29306033673606 2.5541350768926137 3 -7.715761140725318
Buying Ratio 303.29306033673606 2.6487510128003904 4 -10.364512153525709
Buying Ratio 303.29306033673606 2.652118499006518 5 -13.016630652532227
Buying Ratio 303.29306033673606 2.6853738181166302 6 -15.702004470648857
Buying Ratio 303.29306033673606 2.6065747113602176 7 -18.308579182009076
Buying Ratio 303.29306033673606 2.6293468557074084 8 -20.937926037716483
Buying Ratio 303.29306033673606 2.637367324136233 9 -23.575293361852715
Buying Ratio 303.29306033673606 2.5799139183329154 10 -26.155207280185632
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