

In [206...]

```

import datetime
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn import linear_model
from sklearn.model_selection import train_test_split, KFold
from sklearn.metrics import mean_squared_error
from sklearn.ensemble import RandomForestClassifier
from sklearn.ensemble import RandomForestRegressor
from sklearn.datasets import make_regression
from sklearn.svm import SVC
# from sklearn.neural_network import MLPRegressor
from sklearn.metrics import r2_score
from itertools import combinations

from statsmodels.graphics.tsaplots import plot_acf
from statsmodels.graphics.tsaplots import plot_pacf
from matplotlib import pyplot

import warnings
warnings.filterwarnings("ignore")

```

In [207...]

```

#Import Libraries

import warnings
warnings.filterwarnings("ignore")
from pandas_datareader import data as wb
import os
import pandas as pd
import numpy as np
import talib
import matplotlib.pyplot as plt
%matplotlib inline
import datetime
from sklearn import linear_model
from sklearn.metrics import accuracy_score, log_loss, precision_score, recall_score
from sklearn.preprocessing import MinMaxScaler, StandardScaler
from sklearn.ensemble import RandomForestClassifier
from sklearn.ensemble import RandomForestRegressor
from sklearn.datasets import make_regression
from sklearn.model_selection import train_test_split

```

In [208...]

```

# General syntax to import specific functions in a library:
##from (library) import (specific library function)
from pandas import DataFrame, read_csv # those functions can be used
import numpy as np # a package useful for numerical computations
import scipy.stats as st
# General syntax to import a library but no functions:
##import (library) as (give the library a nickname/alias)
import matplotlib.pyplot as plt # all functions func in the package
import pandas as pd #this is how I usually import pandas
import sys #only needed to determine Python version number
import os # some terminal commands
import matplotlib #only needed to determine Matplotlib version number
import sklearn # sklearn is a popular statistical learning package; we

```

```
from sklearn import datasets

from statsmodels.stats.outliers_influence import variance_inflation_factor

# Enable inline plotting
%matplotlib inline
```

In [381...]

```
# set display options
pd.options.display.max_rows, pd.options.display.max_columns = 10, 25
factor = pd.read_csv('5_factors.csv')
factor.index = factor['Time'].values
del factor['Time']
factor.dropna(inplace = True)
# factor = factor[-409:]
factor = factor.loc[198701:, :]
factor
```

Out[381...]

	Mkt-RF	SMB	HML	RMW	CMA	RF
198701	12.47	-1.51	-3.18	0.20	-1.09	0.42
198702	4.39	3.41	-5.99	-0.90	-2.76	0.43
198703	1.64	0.21	1.66	1.36	4.03	0.47
198704	-2.11	-1.55	-0.33	-0.46	1.22	0.44
198705	0.11	-0.59	0.13	0.52	1.32	0.38
...
202006	2.46	1.94	-2.22	0.04	0.34	0.01
202007	5.77	-3.03	-1.31	0.55	1.06	0.01
202008	7.63	-0.94	-2.95	4.27	-1.44	0.01
202009	-3.63	0.07	-2.56	-1.15	-1.77	0.01
202010	-2.10	4.76	3.88	-0.60	-0.53	0.01

406 rows × 6 columns

In [382...]

```
# # set display options
# pd.options.display.max_rows, pd.options.display.max_columns = 10, 25
# BTC_price_origin = pd.read_csv('HSI_Monthly.csv')
# BTC_price_origin.dropna(inplace = True)
# BTC_price_origin = BTC_price_origin[:-1]
# BTC_price_origin

BTC_price_origin = wb.get_data_yahoo('^HSI', start='1987-2-1', end='2020-1-1')
BTC_price_origin
```

Out[382...]

Date	High	Low	Open	Close	Volume
1987-01-31	2879.000000	2585.199951	2585.199951	2877.899902	0 2

	High	Low	Open	Close	Volume	
Date						
1987-02-28	2939.100098	2629.300049	2894.300049	2713.800049	0	2
1987-03-31	2785.500000	2589.500000	2695.899902	2659.899902	0	2
1987-04-30	2950.800049	2685.399902	2685.399902	2950.800049	0	2
1987-05-31	3179.000000	2934.100098	2934.100098	3178.199951	0	
...
2020-06-30	26782.619141	24526.910156	24563.570312	24595.349609	48701717400	24
2020-07-31	25847.109375	24167.789062	24566.810547	25177.050781	35256937100	2
2020-08-31	25254.140625	23124.250000	25085.669922	23459.050781	38637026300	23
2020-09-30	24970.589844	23674.519531	24039.390625	24107.419922	37826792700	2
2020-10-31	27040.410156	24232.660156	24274.830078	26341.490234	56229675200	26

406 rows × 6 columns

In [383...]

```
BTC_price_origin = BTC_price_origin[['Open', 'High', 'Low', 'Close', 'Volume']]

BTC_price_origin['Mkt-RF'] = factor['Mkt-RF'].values
BTC_price_origin['SMB'] = factor['SMB'].values
BTC_price_origin['HML'] = factor['HML'].values
BTC_price_origin['RMW'] = factor['RMW'].values
BTC_price_origin['CMA'] = factor['CMA'].values
BTC_price_origin['RF'] = factor['RF'].values
BTC_price_origin['Return-RF'] = (BTC_price_origin['Close'] - BTC_price_origin['Open']) / BTC_price_origin['Open']

# BTC_price_origin.index = BTC_price_origin['Time'].values
# del BTC_price_origin['Time']
BTC_price_origin
```

Out[383...]

	Open	High	Low	Close	Volume	M
Date						
1987-01-31	2585.199951	2879.000000	2585.199951	2877.899902	0	12
1987-02-28	2894.300049	2939.100098	2629.300049	2713.800049	0	4

	Open	High	Low	Close	Volume	M
Date						
1987-03-31	2695.899902	2785.500000	2589.500000	2659.899902	0	1
1987-04-30	2685.399902	2950.800049	2685.399902	2950.800049	0	-2
1987-05-31	2934.100098	3179.000000	2934.100098	3178.199951	0	0
...
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	48701717400	2
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	35256937100	5
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	38637026300	7
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	37826792700	-3
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	56229675200	-2

406 rows × 12 columns

CAPM

In [384...]

```
features = ['Mkt-RF']
target = ['Return-RF']

X = BTC_price_origin[features]
Y = BTC_price_origin[target]

model = linear_model.LinearRegression()
model.fit(X, Y)
Y_Pred = model.predict(X)
```

In [385...]

```
r2_score(Y, Y_Pred)
```

Out[385...]

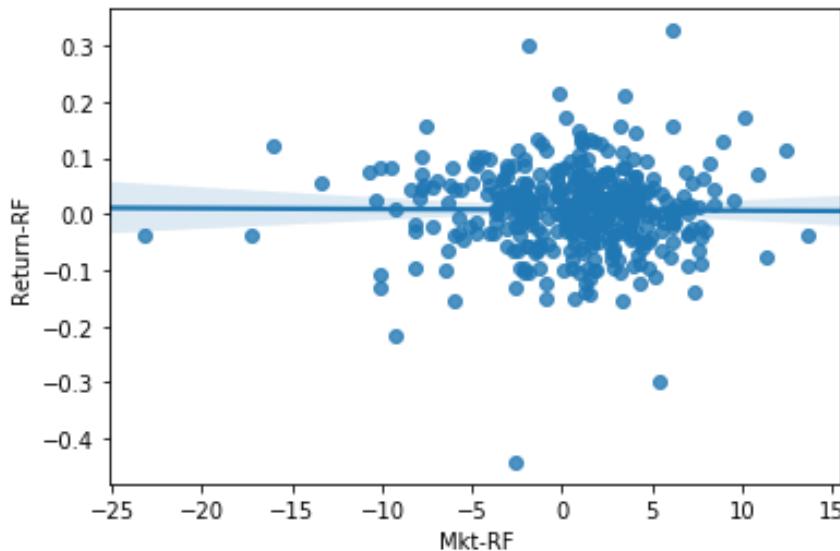
6.862940618579394e-05

Statistical Analysis

In [386...]

```
# Seaborn is a statistical data visualization package
```

```
import seaborn as sns
# Use seaborn to visualize the trend
sns.regplot(x="Mkt-RF", y = "Return-RF", data=BTC_price_origin)
plt.show()
```



In [387...]

```
# Import the object from linear_model
from sklearn.linear_model import LinearRegression
# Create an object
lm = LinearRegression()
# Fit 'Return-RF' and 'Mkt-RF'
# Here is another trick here. np.array(bos['CRIM']) returns a 1D array
lm.fit(X=np.array(BTC_price_origin['Mkt-RF']).reshape(-1,1), y=BTC_price_origin['Return-RF'])
# Report result
print('Intercept: ', lm.intercept_)
print('Coefficient: ', lm.coef_)
```

Intercept: 0.007599360664226076

Coefficient: [-0.00013567]

In [388...]

```
# Import statsmodels to do the linear regression
import statsmodels.api as sm
# We need the intercept, so add a constant column
X = sm.add_constant(np.array(BTC_price_origin['Mkt-RF']))
y = BTC_price_origin['Return-RF']
# Fit the model using OLS (ordinary least square, as opposed to general linear model)
lm1 = sm.OLS(y,X).fit()
print(lm1.summary())
```

OLS Regression Results

```
=====
Dep. Variable:          Return-RF    R-squared:     0.000
Model:                 OLS         Adj. R-squared:  -0.002
Method:                Least Squares   F-statistic:   0.02773
Date:      Thu, 22 Apr 2021   Prob (F-statistic): 0.868
Time:      00:24:20             Log-Likelihood: 485.48
```

```

No. Observations: 406 AIC:
-967.0
Df Residuals: 404 BIC:
-958.9
Df Model: 1
Covariance Type: nonrobust
=====
=====

            coef      std err          t      P>|t|      [ 0.025
0.975]
-----
const      0.0076      0.004      2.063      0.040      0.000
0.015
x1        -0.0001      0.001     -0.167      0.868     -0.002
0.001
=====
=====

Omnibus: 62.532 Durbin-Watson:
1.930
Prob(Omnibus): 0.000 Jarque-Bera (JB):
415.768
Skew: -0.412 Prob(JB):
5.21e-91
Kurtosis: 7.889 Cond. No.
4.58
=====
=====

=====
```

Notes :

[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

In [389...]

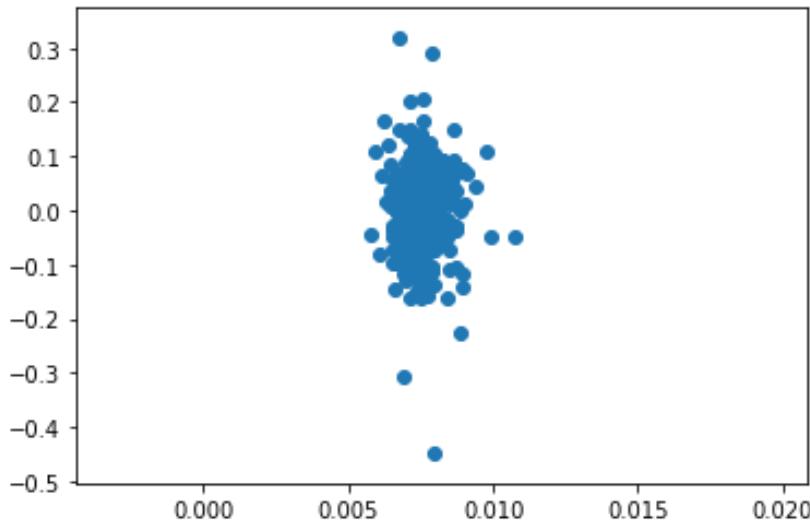
```
# Consider two observation of 'Mkt-RF'
test = np.array([0.005, 0.006])
test = sm.add_constant(test)
# Use the estimated lml object to predict 'Return-RF' for the new 'Mkt'
lml.predict(test)
```

```
Out[389]: array([0.00759868, 0.00759855])
```

Regression diagnostics

In [390...]

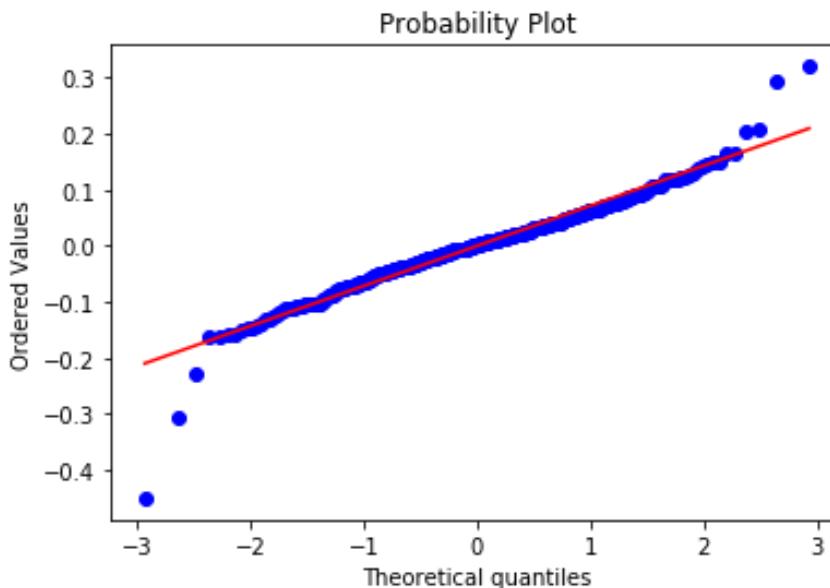
```
# The results object has an attribute resid, representing the residual
residual = lm1.resid
fitted = lm1.fittedvalues
# Next we plot it
plt.scatter(fitted, residual)
plt.show()
```



The residuals seem to be i.i.d.; there is no trend in the fitted value. Next we check the QQ-plot (normal probability plot) for normality. Scipy has a function for that.

In [391...]

```
# We first create an axis handle to plot
fig=plt.figure()
ax = fig.add_subplot(111)
# Use the scipy package
st.probplot(residual, dist='norm', plot=ax)
plt.show()
```

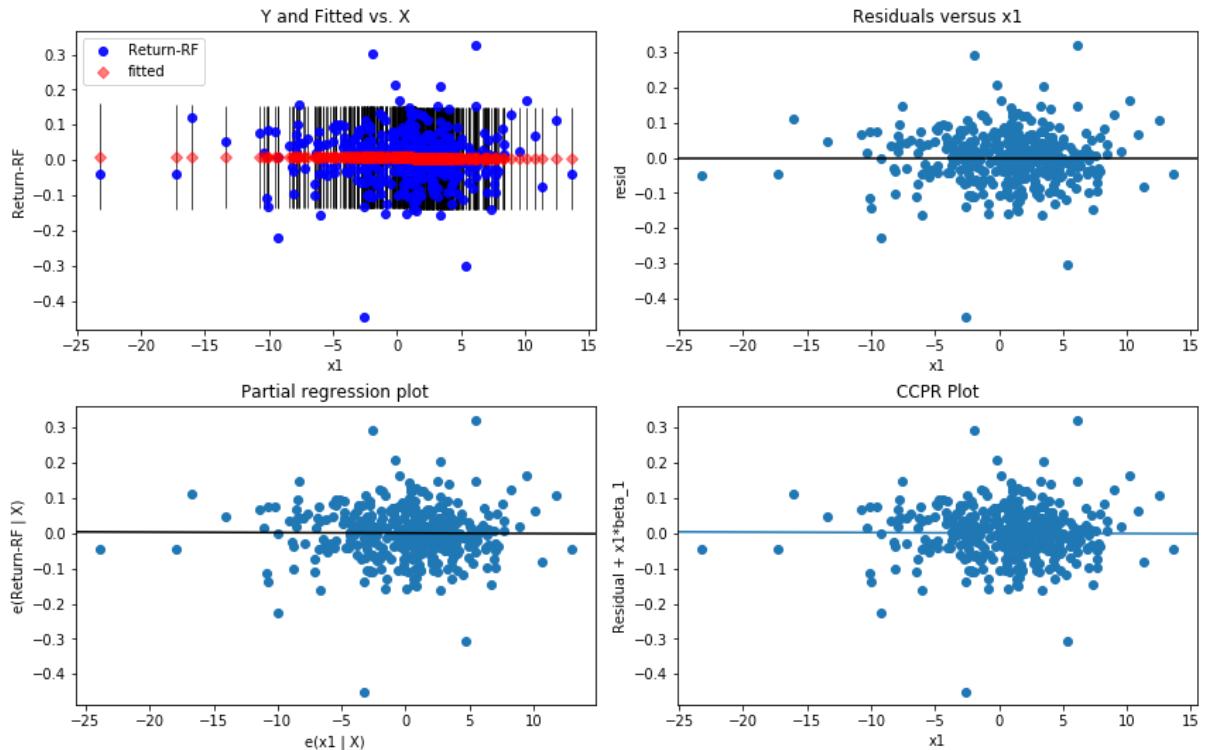


The normality assumption seem to be satisfied, with a heavy tail

In [392...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm1, 'x1', fig=fig)
plt.show()
```

Regression Plots for x1



In []:

Fama–French three-factor model

In [393...]

```

features = ['Mkt-RF', 'SMB', 'HML']
target = ['Return-RF']

X = BTC_price_origin[features]
Y = BTC_price_origin[target]

model = linear_model.LinearRegression()
model.fit(X, Y)
Y_Pred = model.predict(X)

```

In [394...]

```
r2_score(Y, Y_Pred)
```

Out[394...]

```
0.002061541863011329
```

Statistical Analysis

In [395...]

```

# Specify the matrices
X = sm.add_constant(BTC_price_origin[features])
y = BTC_price_origin[target]
lm2 = sm.OLS(y,X).fit()
# Show results
print(lm2.summary())

```

OLS Regression Results

```
=====
Dep. Variable:           Return-RF      R-squared:
0.002                   OLS             Adj. R-squared:
Model:                  -0.005          Least Squares   F-statistic:
-0.005                   OLS             485.88         Prob (F-statistic):
Method:                 0.2768          Thu, 22 Apr 2021  0.842
Time:                   00:24:22        Log-Likelihood:
485.88                  No. Observations: 406            AIC:
-963.8                  Df Residuals:    402            BIC:
-947.7                  Df Model:       3
Covariance Type:        nonrobust
=====
```

```
=====
          coef    std err      t      P>|t|      [ 0.025
0.975 ]
-----
```

	coef	std err	t	P> t	[0.025
const	0.0077	0.004	2.098	0.037	0.000
Mkt-RF	-0.0003	0.001	-0.306	0.760	-0.002
SMB	4.527e-05	0.001	0.036	0.971	-0.002
HML	-0.0011	0.001	-0.894	0.372	-0.004

```
=====
Omnibus:                62.083     Durbin-Watson:
1.930                   Prob(Omnibus): 0.000     Jarque-Bera (JB):
408.926                 Skew:        -0.409     Prob(JB):
1.59e-89                 Kurtosis:    7.848     Cond. No.
4.72
=====
```

Notes:

[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Hypothesis testing on factors

In [396...]

```
print(lm2.f_test('SMB = 0'))
```

```
<F test: F=array([[0.00129867]]), p=0.9712707209177422, df_denom=402,
df_num=1>
```

In [397...]

```
print(lm2.f_test('HML = 0'))
```

```
<F test: F=array([[0.79987097]]), p=0.37166708809759863, df_denom=402,
df_num=1>
```

In [398...]

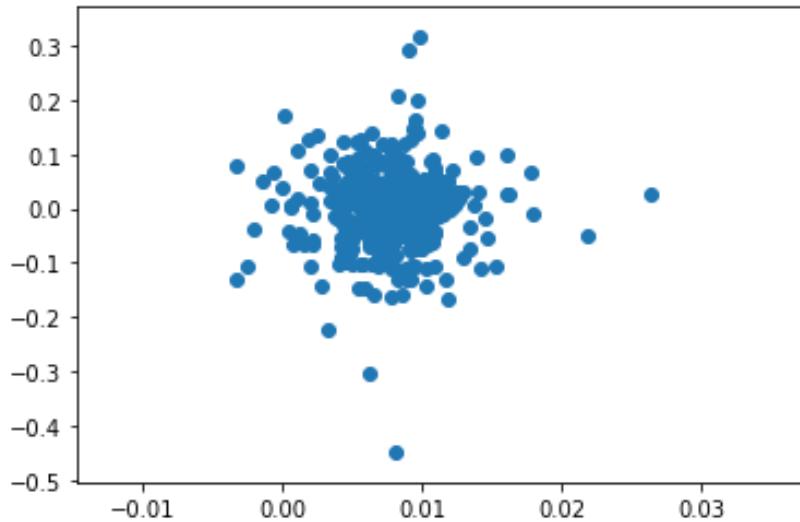
```
print(lm2.f_test('SMB = HML = 0'))
```

```
<F test: F=array([[0.40140291]]), p=0.6696482939439542, df_denom=402,
df_num=2>
```

Regression diagnostics

In [399...]

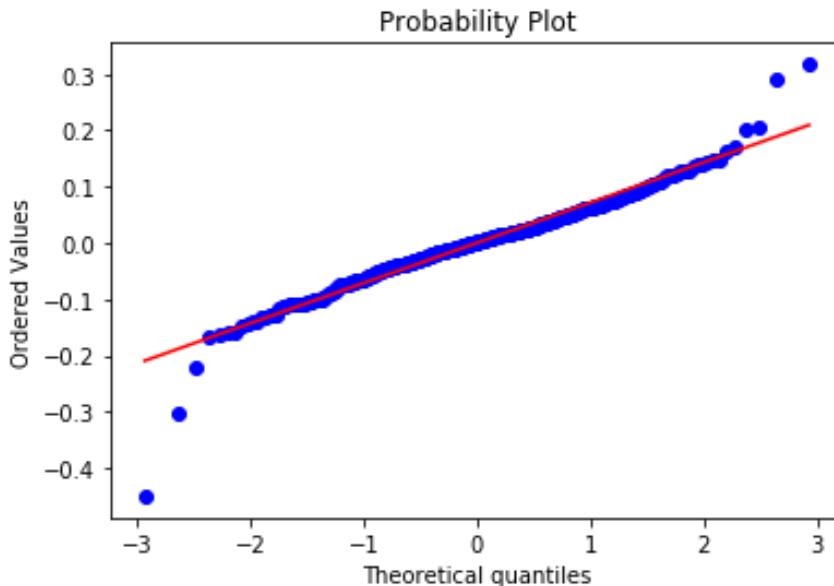
```
# The results object has an attribute resid, representing the residual
residual = lm2.resid
fitted = lm2.fittedvalues
# Next we plot it
plt.scatter(fitted, residual)
plt.show()
```



The residuals seem to be i.i.d.; there is no trend in the fitted value. Next we check the QQ-plot (normal probability plot) for normality. Scipy has a function for that.

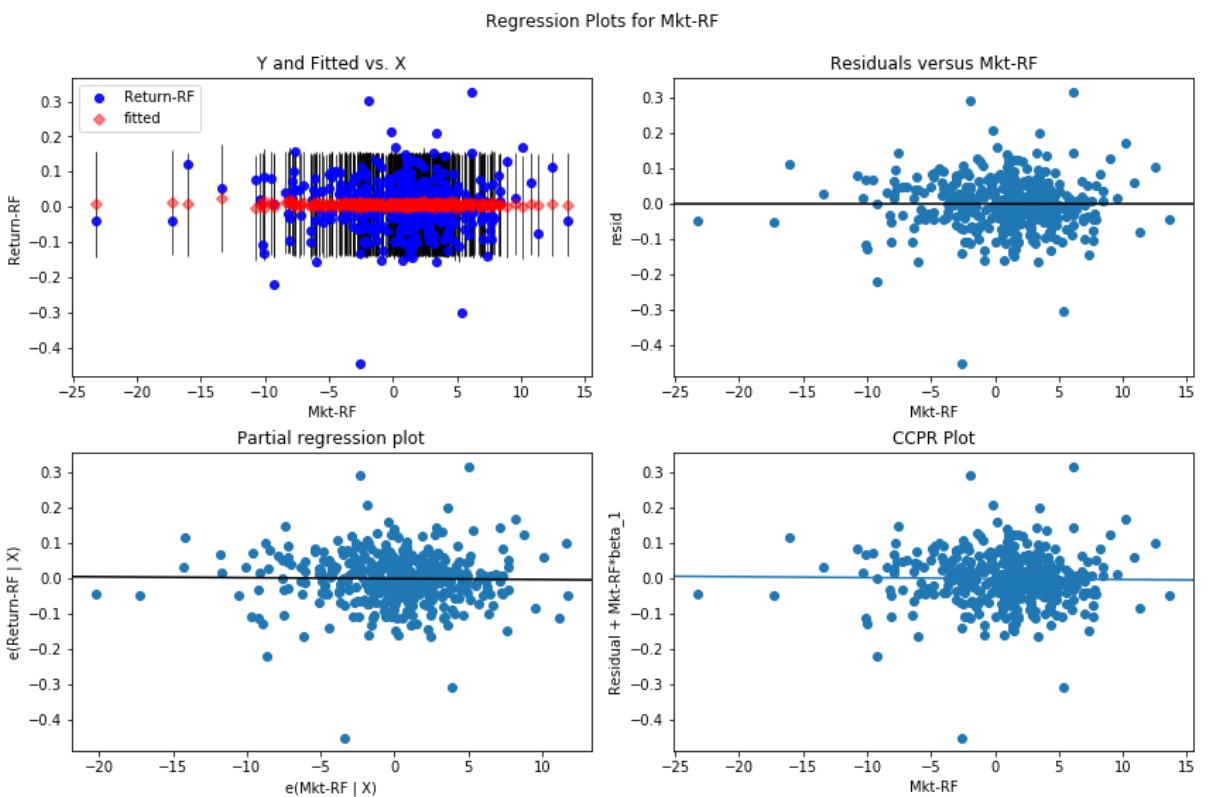
In [400...]

```
# We first create an axis handle to plot
fig=plt.figure()
ax = fig.add_subplot(111)
# Use the scipy package
st.probplot(residual, dist='norm', plot=ax)
plt.show()
```



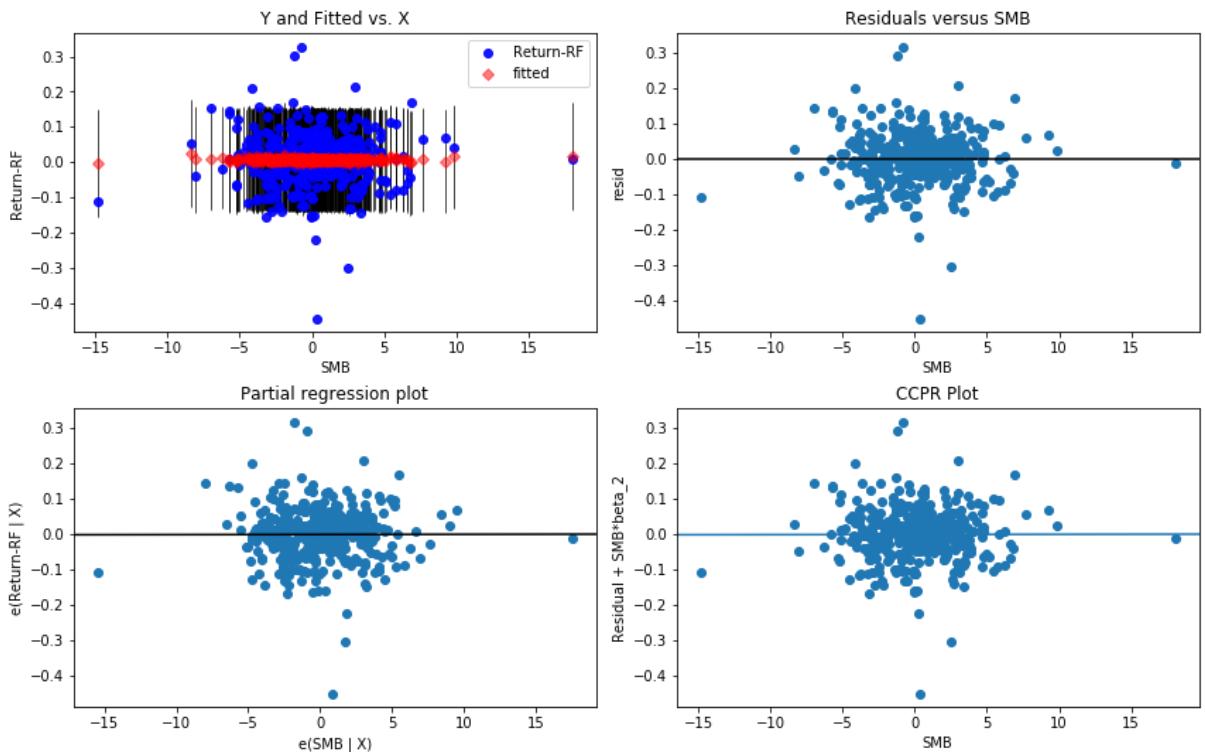
The normality assumption seem to be satisfied, with a heavy tail

```
In [401...]: fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm2, 'Mkt-RF', fig=fig)
plt.show()
```



```
In [402...]: fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm2, 'SMB', fig=fig)
plt.show()
```

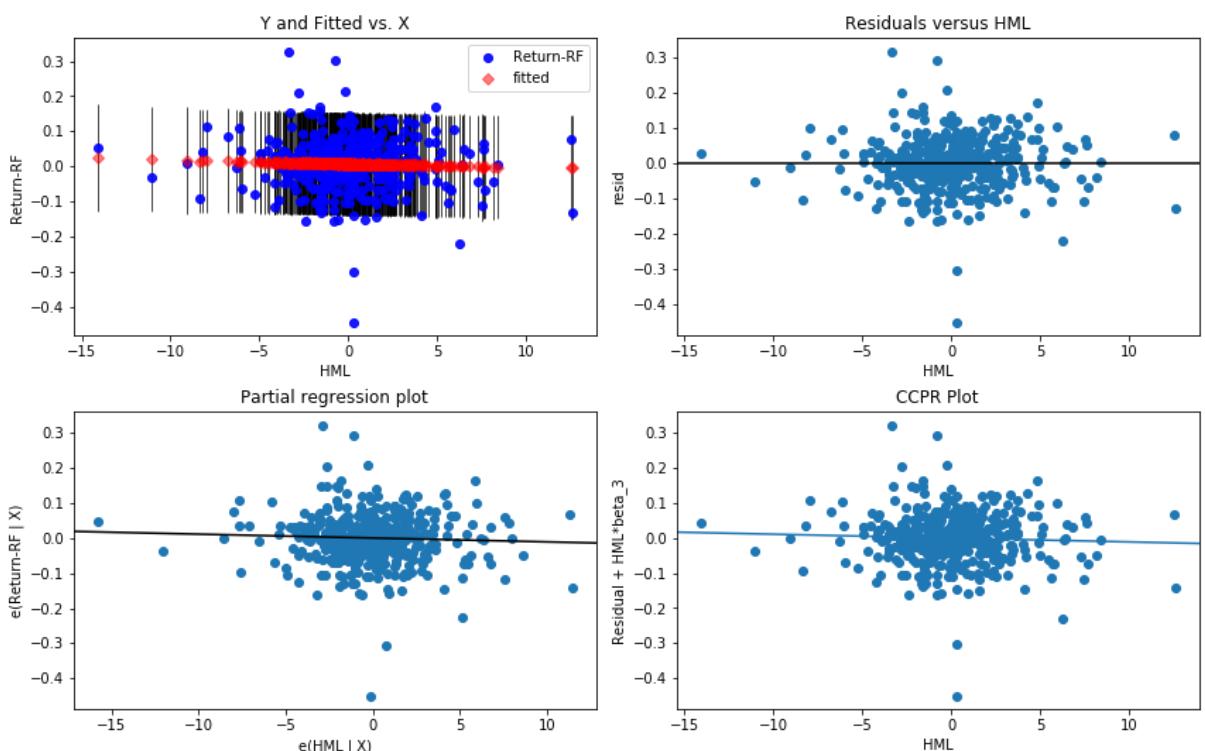
Regression Plots for SMB



In [403...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm2, 'HML', fig=fig)
plt.show()
```

Regression Plots for HML



Detecting Multicollinearity with VIF

In [404...]

```
# VIF dataframe
vif_data = pd.DataFrame()
vif_data["feature"] = BTC_price_origin[features].columns
```

```
# calculating VIF for each feature
vif_data["VIF"] = [variance_inflation_factor(BTC_price_origin[features],
                                              for i in range(len(BTC_price_origin[features])))

vif_data
```

Out[404...]

	feature	VIF
0	Mkt-RF	1.081405
1	SMB	1.059271
2	HML	1.024584

In []:

In []:

In []:

Fama–French five-factor model

In [405...]

```
features = ['Mkt-RF', 'SMB', 'HML', 'RMW', 'CMA']
target = ['Return-RF']

X = BTC_price_origin[features]
Y = BTC_price_origin[target]

model = linear_model.LinearRegression()
model.fit(X, Y)
Y_Pred = model.predict(X)
```

In [406...]

```
r2_score(Y, Y_Pred)
```

Out[406...]

```
0.006713100343744838
```

In []:

Statistical Analysis

In [407...]

```
# Specify the matrices
X = sm.add_constant(BTC_price_origin[features])
y = BTC_price_origin[target]
lm3 = sm.OLS(y,X).fit()
# Show results
print(lm3.summary())
```

```
OLS Regression Results
=====
Dep. Variable: Return-RF   R-squared: 0.007
Model: OLS   Adj. R-squared: -0.006
Method: Least Squares   F-statistic: 0.5407
Date: Thu, 22 Apr 2021   Prob (F-statistic): 0.745
Time: 00:24:27   Log-Likelihood: 486.83
No. Observations: 406   AIC: -961.7
Df Residuals: 400   BIC: -937.6
Df Model: 5
Covariance Type: nonrobust
=====
```

	coef	std err	t	P> t	[0.025
0.975]					
const	0.0087	0.004	2.267	0.024	0.001
0.016					
Mkt-RF	-0.0005	0.001	-0.520	0.603	-0.002
0.001					
SMB	-0.0007	0.001	-0.513	0.608	-0.003
0.002					
HML	-0.0006	0.002	-0.353	0.724	-0.004
0.003					
RMW	-0.0024	0.002	-1.350	0.178	-0.006
0.001					
CMA	0.0002	0.003	0.076	0.940	-0.005
0.005					

```
=====
Omnibus: 64.815   Durbin-Watson: 1.938
Prob(Omnibus): 0.000   Jarque-Bera (JB): 442.317
Skew: -0.432   Prob(JB): 8.95e-97
Kurtosis: 8.040   Cond. No. 5.28
=====
```

Notes:

[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Hypothesis testing on factors

In [408...]

```
print(lm3.f_test('Mkt-RF = 0'))
```

```
<F test: F=array([[0.2707863]]), p=0.6030926957398871, df_denom=400, df_num=1>
```

```
In [409...]: print(lm3.f_test('SMB = 0'))

<F test: F=array([[0.26358836]]), p=0.60794900463773, df_denom=400, df_num=1>

In [410...]: print(lm3.f_test('HML = 0'))

<F test: F=array([[0.12477303]]), p=0.7241004099876814, df_denom=400, df_num=1>

In [411...]: print(lm3.f_test('RMW = 0'))

<F test: F=array([[1.82238703]]), p=0.1777928090190581, df_denom=400, df_num=1>

In [412...]: print(lm3.f_test('CMA = 0'))

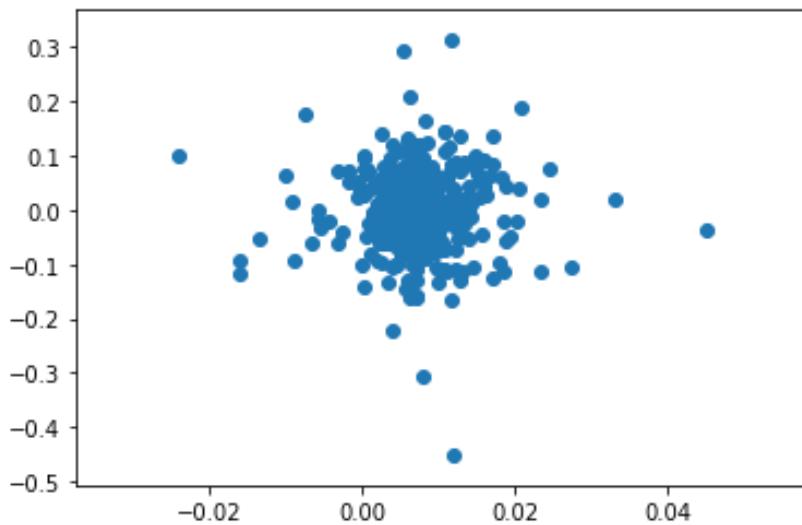
<F test: F=array([[0.00570547]]), p=0.9398271513089791, df_denom=400, df_num=1>

In [413...]: print(lm3.f_test('SMB = HML = RMW = CMA = 0'))

<F test: F=array([[0.66893774]]), p=0.6138603381697852, df_denom=400, df_num=4>
```

Regression diagnostics

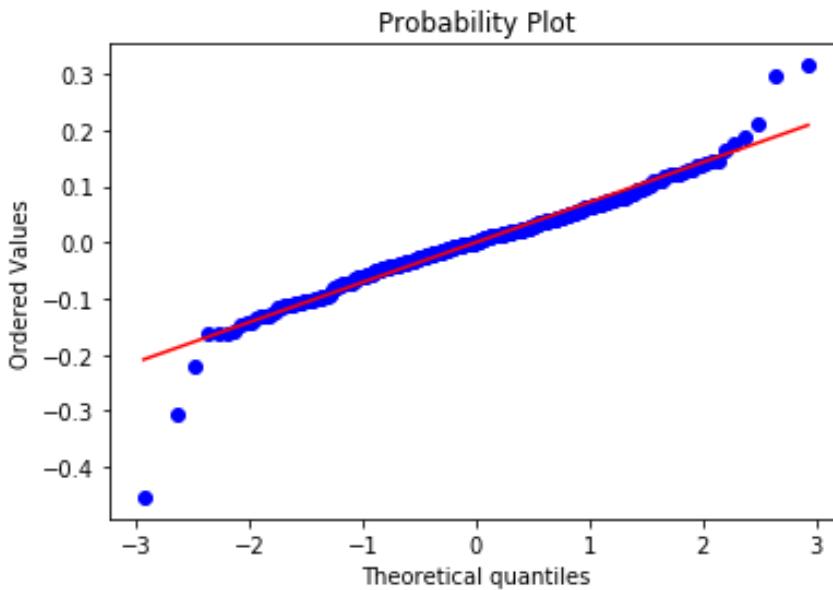
```
In [414...]: # The results object has an attribute resid, representing the residuals
residual = lm3.resid
fitted = lm3.fittedvalues
# Next we plot it
plt.scatter(fitted, residual)
plt.show()
```



The residuals seem to be i.i.d.; there is no trend in the fitted value. Next we check the QQ-plot (normal probability plot) for normality. Scipy has a function for that.

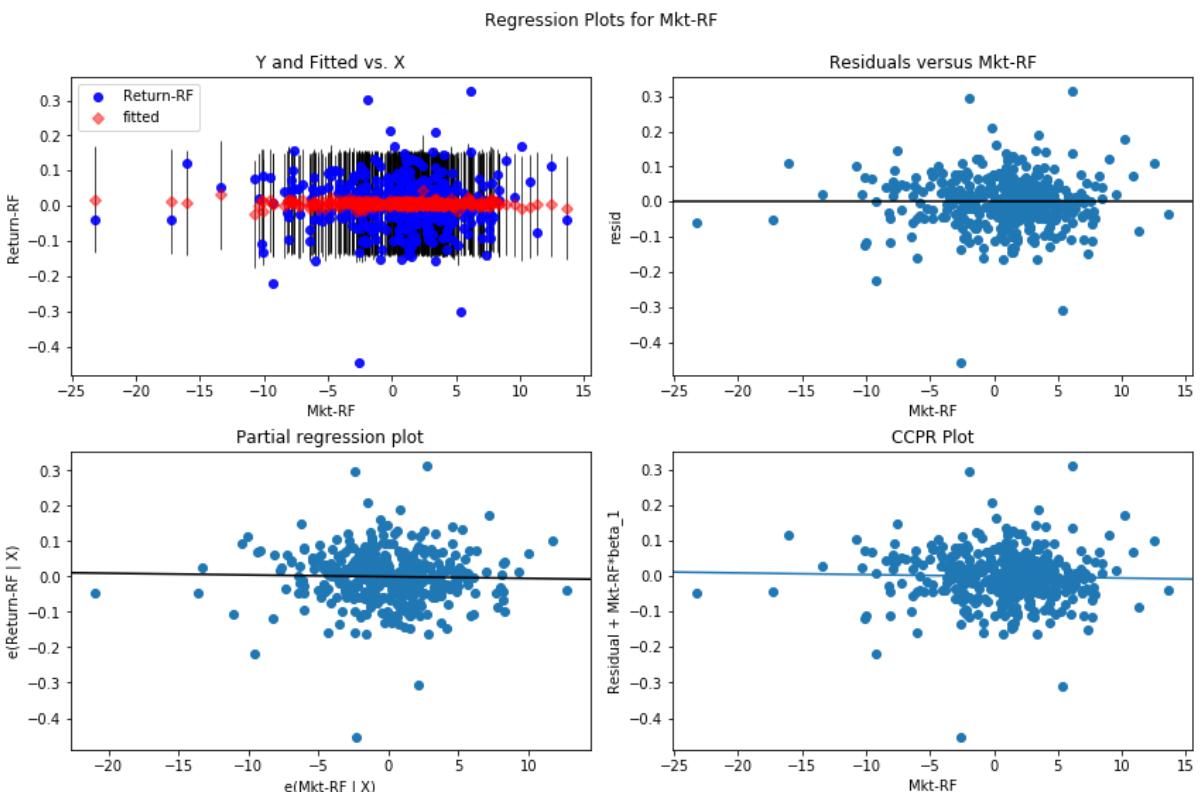
```
In [415...]: # We first create an axis handle to plot
fig=plt.figure()
```

```
ax = fig.add_subplot(111)
# Use the scipy package
st.probplot(residual, dist='norm', plot=ax)
plt.show()
```



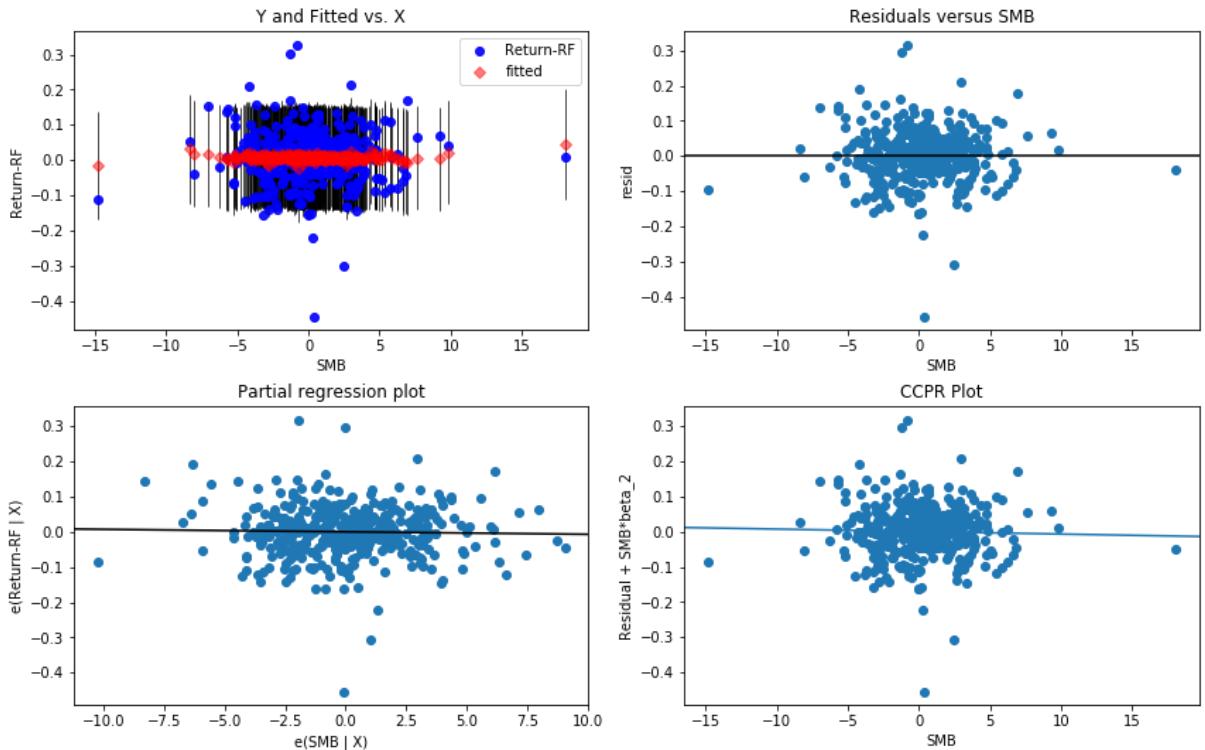
The normality assumption seem to be satisfied, with a heavy tail

```
In [416...]
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm3, 'Mkt-RF', fig=fig)
plt.show()
```



```
In [417...]
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm3, 'SMB', fig=fig)
plt.show()
```

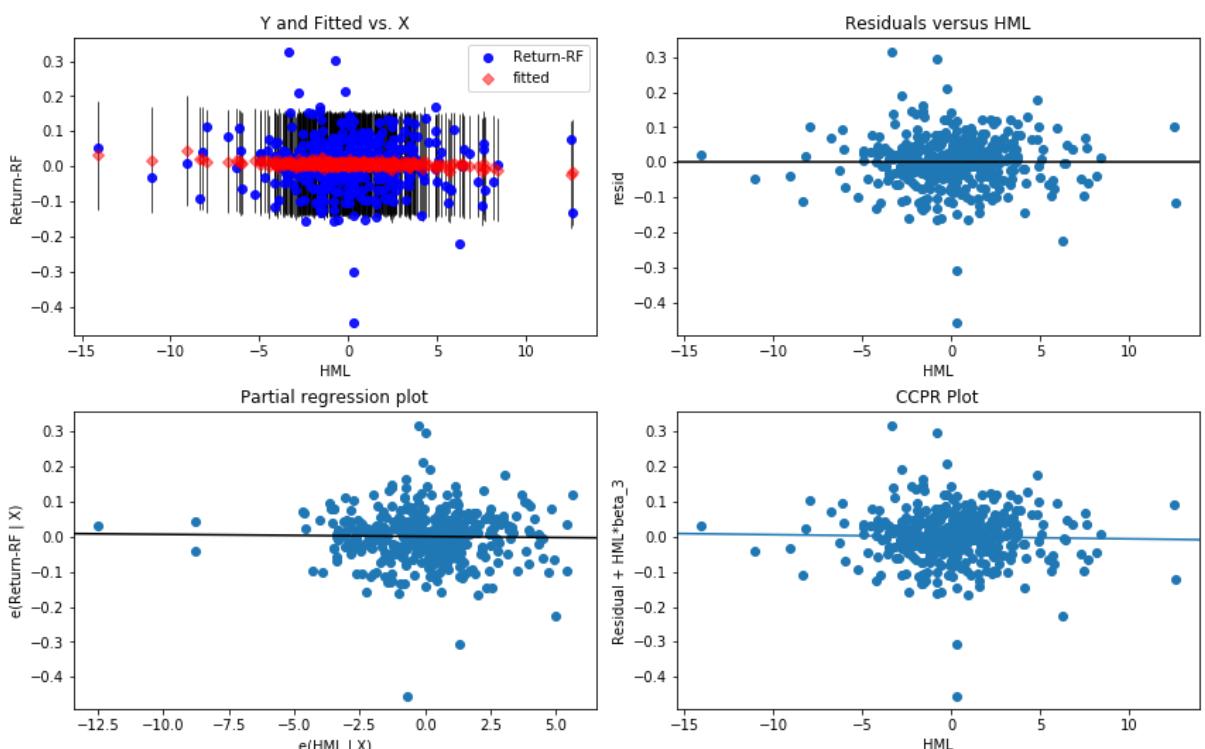
Regression Plots for SMB



In [418]:

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm3, 'HML', fig=fig)
plt.show()
```

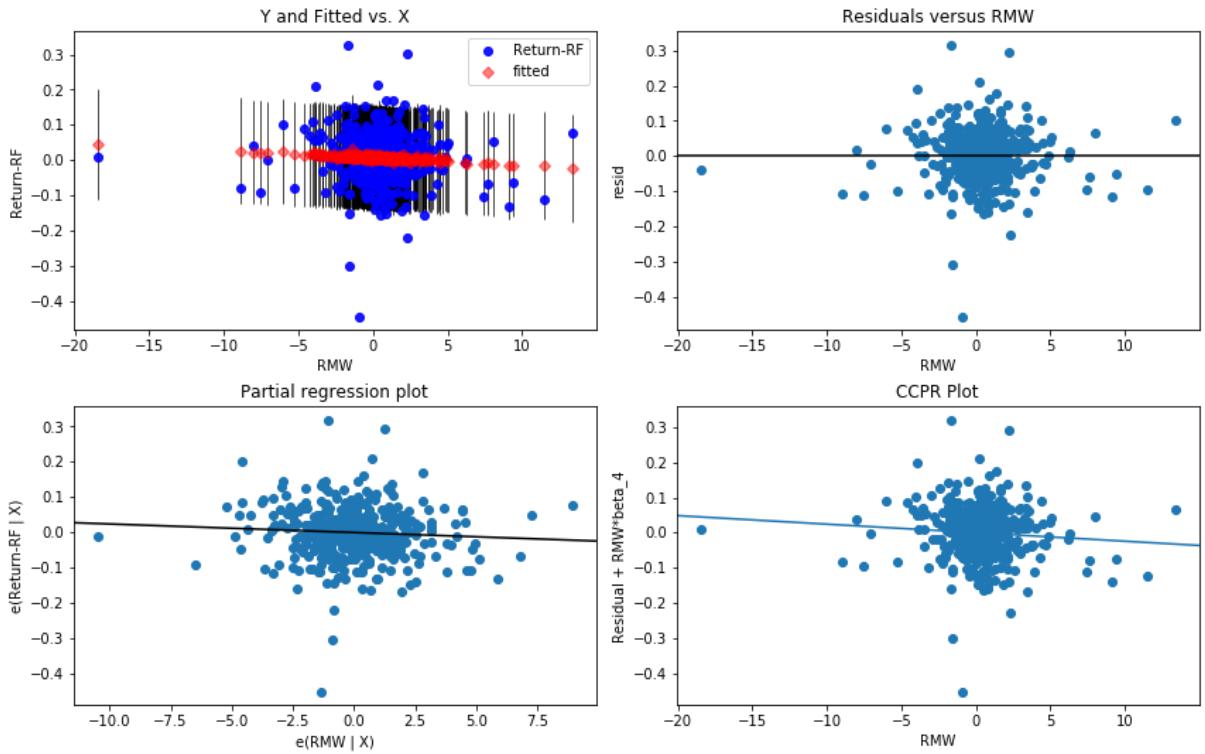
Regression Plots for HML



In [419]:

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm3, 'RMW', fig=fig)
plt.show()
```

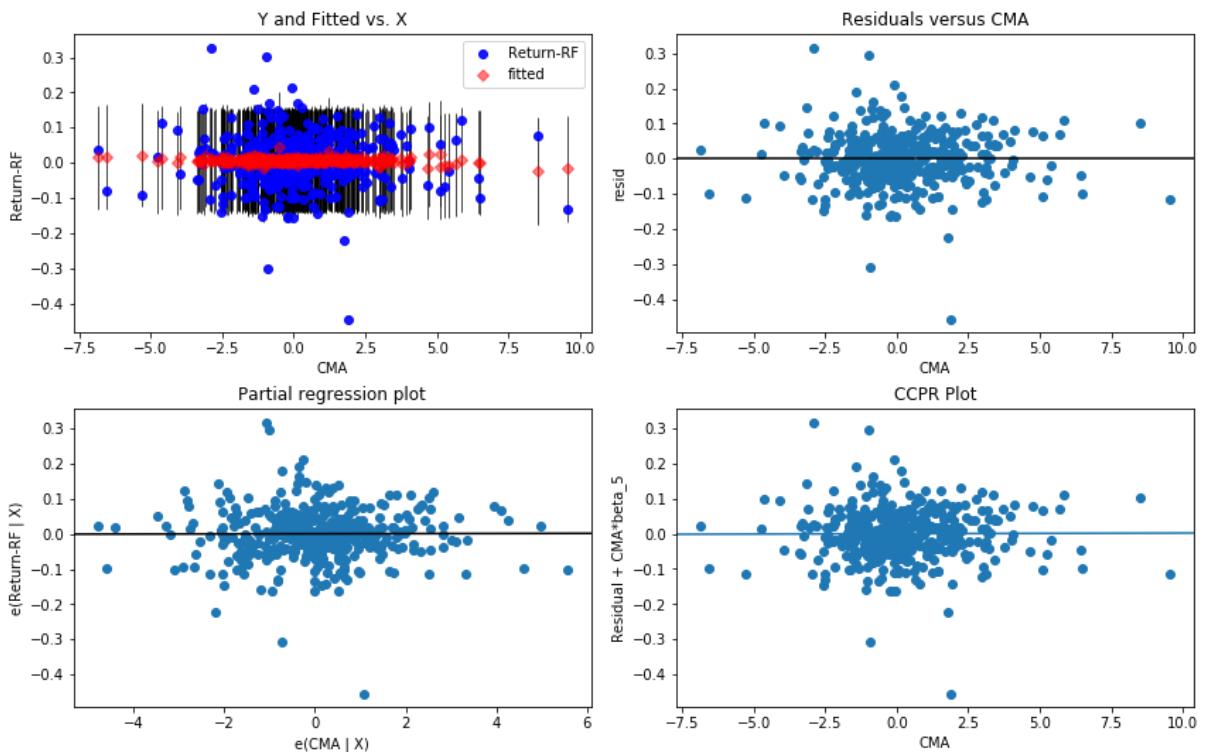
Regression Plots for RMW



In [420...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm3, 'CMA', fig=fig)
plt.show()
```

Regression Plots for CMA



Detecting Multicollinearity with VIF

In [421...]

```
# VIF dataframe
vif_data = pd.DataFrame()
vif_data["feature"] = BTC_price_origin[features].columns
```

```
# calculating VIF for each feature
vif_data["VIF"] = [variance_inflation_factor(BTC_price_origin[features],
                                              i) for i in range(len(BTC_price_origin[features]))]
vif_data
```

Out[421...]

	feature	VIF
0	Mkt-RF	1.260869
1	SMB	1.255893
2	HML	1.905279
3	RMW	1.444893
4	CMA	1.933027

In []:

In []:

Technical Indicators

In [422...]

```
stock_high = BTC_price_origin['High']
stock_low = BTC_price_origin['Low']
stock_open = BTC_price_origin['Open']
stock_close = BTC_price_origin['Close']
stock_volume = BTC_price_origin['Volume']
```

Oscillators and Trend Following Indicators

1. MACD and MACD HISTOGRAM

In [423...]

```
#Compute MACD and MACD Histogram
macd, macdsignal, macdhist = talib.MACD(stock_close, fastperiod=26, slowperiod=13, signalperiod=9)

dict = {'MACD': macd, 'MSIG': macdsignal}
macdata = []
macdata = pd.DataFrame(data=dict)
macdata.dropna(inplace=True)

macdata['MACD_Signal1'] = macdata.apply(lambda x : 1 if x['MACD'] > x['MSIG'] else 0, axis=1)

n_days = len(macdata['MACD'])
Signal = macdata['MACD_Signal1'].values

psy = []
```

```

for d in range(0, n_days):

    if Signal[d] == 1:
        psychology = 1
        psy.append(psychology)

    elif Signal[d] == 0:
        psychology = 0
        psy.append(psychology)

macdata['MACD_Signal'] = psy

del macdata['MACD_Signal1']

dict = {'MHIST': macdhist, 'PrevMHIST': macdhist.shift(1)}
machdata = []
machdata = pd.DataFrame(data=dict)
machdata.dropna(inplace=True)

machdata['MHIST_Signal1'] = machdata['MHIST'] - machdata['PrevMHIST']

machdata.loc[machdata[machdata['MHIST']] > machdata['PrevMHIST']].index
machdata.loc[machdata[machdata['MHIST']] < machdata['PrevMHIST']].index

n_days = len(machdata['MHIST'])
Signal = machdata['MHIST_Signal1'].values
psy = []

for d in range(0, n_days):

    if Signal[d] == 1:
        psychology = 1
        psy.append(psychology)

    elif Signal[d] == 0:
        psychology = 0
        psy.append(psychology)

    elif Signal[d] == -1:
        psychology = -1
        psy.append(psychology)

machdata['MHIST_Signal'] = psy

del machdata['MHIST_Signal1']

```

In [424...]

macdata

Out[424...]

MACD MSIG MACD_Signal

Date

1989-10-31	-40.151346	-51.603627	1
1989-11-30	-24.928536	-46.268609	1
1989-12-31	-19.498374	-40.914562	1

	MACD	MSIG	MACD_Signal
Date			
1990-01-31	0.964548	-32.538740	1
1990-02-28	20.575503	-21.915891	1
...
2020-06-30	-788.972039	-407.208321	0
2020-07-31	-746.577139	-475.082084	0
2020-08-31	-841.902193	-548.446106	0
2020-09-30	-855.270982	-609.811081	0
2020-10-31	-677.781992	-623.405264	0

373 rows × 3 columns

In [425...]

```
macdata[macdata['MACD_Signal'] == 1]
```

Out[425...]

	MACD	MSIG	MACD_Signal
Date			
1989-10-31	-40.151346	-51.603627	1
1989-11-30	-24.928536	-46.268609	1
1989-12-31	-19.498374	-40.914562	1
1990-01-31	0.964548	-32.538740	1
1990-02-28	20.575503	-21.915891	1
...
2018-01-31	2129.136522	1423.115558	1
2018-02-28	2117.643740	1562.021195	1
2018-03-31	2141.549221	1677.926800	1
2018-04-30	2108.759842	1764.093408	1
2018-05-31	1938.307558	1798.936238	1

228 rows × 3 columns

In [426...]

```
machdata
```

Out[426...]

	MHIST	PrevMHIST	MHIST_Signal
Date			
1989-11-30	21.340073	11.452281	1
1989-12-31	21.416188	21.340073	1

	MHIST	PrevMHIST	MHIST_Signal
--	-------	-----------	--------------

Date			
------	--	--	--

1990-01-31	33.503288	21.416188	1
1990-02-28	42.491394	33.503288	1
1990-03-31	43.161686	42.491394	1
...
2020-06-30	-381.763719	-460.612245	1
2020-07-31	-271.495055	-381.763719	1
2020-08-31	-293.456087	-271.495055	-1
2020-09-30	-245.459901	-293.456087	1
2020-10-31	-54.376729	-245.459901	1

372 rows × 3 columns

In [427...]

```
machdata[machdata['MHIST_Signal'] == -1]
```

Out[427...]

MHIST	PrevMHIST	MHIST_Signal
-------	-----------	--------------

Date			
------	--	--	--

1990-07-31	62.343341	80.183650	-1
1990-08-31	26.531101	62.343341	-1
1990-09-30	16.817709	26.531101	-1
1990-10-31	7.659927	16.817709	-1
1990-11-30	4.673681	7.659927	-1
...
2020-01-31	-263.305332	-246.036480	-1
2020-02-29	-422.920141	-263.305332	-1
2020-03-31	-434.814009	-422.920141	-1
2020-04-30	-526.230991	-434.814009	-1
2020-08-31	-293.456087	-271.495055	-1

180 rows × 3 columns

In [428...]

```
machdata['MACDH'] = machdata['MHIST'] - machdata['PrevMHIST']
machdata
```

Out[428...]

MHIST	PrevMHIST	MHIST_Signal	MACDH
-------	-----------	--------------	-------

Date			
------	--	--	--

1989-11-30	21.340073	11.452281	1	9.887792
-------------------	-----------	-----------	---	----------

	MHIST	PrevMHIST	MHIST_Signal	MACDH
Date				
1989-12-31	21.416188	21.340073	1	0.076115
1990-01-31	33.503288	21.416188	1	12.087099
1990-02-28	42.491394	33.503288	1	8.988106
1990-03-31	43.161686	42.491394	1	0.670292
...
2020-06-30	-381.763719	-460.612245	1	78.848526
2020-07-31	-271.495055	-381.763719	1	110.268664
2020-08-31	-293.456087	-271.495055	-1	-21.961032
2020-09-30	-245.459901	-293.456087	1	47.996186
2020-10-31	-54.376729	-245.459901	1	191.083172

372 rows × 4 columns

2. Average Directional Index (ADX)

In [429...]

```
#Compute Average Directional Index (ADX)
adx = talib.ADX(stock_high, stock_low, stock_close, timeperiod=14)

dict = {'Close': stock_close, 'ADX': adx }

adxdata = []
adxdata = pd.DataFrame(data=dict)
adxdata.dropna(inplace=True)

adxdata['adx1'] = adxdata.apply(lambda x : 1 if x['ADX'] > 25 else 0,
adxdata['adx2'] = adxdata.apply(lambda x : -1 if x['ADX'] < 20 else 0,

adxdata['Signw'] = adxdata.apply(lambda x : x['adx1'] + x['adx2'] , axis=1)

n_days = len(adxdata['ADX'])
Signal = adxdata['Signw'].values
psy = []

for d in range(0, n_days):
    if Signal[d] == 1:
        psycology = 1
        psy.append(psycology)

    elif Signal[d] == -1:
        psycology = -1
        psy.append(psycology)

    elif Signal[d] == 0:
        psycology = 0
        psy.append(psycology)
```

```
adxdata['Trend'] = psy

del adxdata['Signw']
del adxdata['adx1']
del adxdata['adx2']
```

In [430...]

adxdata

Out[430...]

	Close	ADX	Trend
Date			
1989-04-30	2743.899902	7.853138	-1
1989-05-31	2273.899902	8.734179	-1
1989-06-30	2571.100098	9.552288	-1
1989-07-31	2508.600098	10.060231	-1
1989-08-31	2758.199951	10.107371	-1
...
2020-06-30	24595.349609	19.588596	-1
2020-07-31	25177.050781	19.470573	-1
2020-08-31	23459.050781	19.842403	-1
2020-09-30	24107.419922	20.187674	0
2020-10-31	26341.490234	19.093151	-1

379 rows × 3 columns

3. Relative Strength Index (RSI)

In [431...]

```
#Compute Bollinger Bands
rsi = talib.RSI(stock_close, timeperiod=14)

dict = {'Close': stock_close, 'RSI': rsi}

rsidata = []
rsidata = pd.DataFrame(data=dict)
rsidata.dropna(inplace=True)
rsidata['Psychology'] = 0

#Generate the Long and Short Signals
n_days = len(rsidata['RSI'])
cash = 1
stock = 0

position = []

RSI = rsidata['RSI'].values
```

```

for d in range(0, n_days):

    # Long if spread < lower band & if not bought yet
    if RSI[d] < 30 and cash == 1:
        signal = 1
        cash = 0
        stock = 1
        position.append(signal)

    # Take Profit if spread > moving average & if already bought
    elif RSI[d] > 50 and stock == 1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    # Short if spread > upper band and no current position
    elif RSI[d] > 70 and cash == 1:
        signal = -1
        cash = 0
        stock = -1
        position.append(signal)

    # Take Profit if spread < moving average & if already short
    elif RSI[d] < 50 and stock == -1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    else:
        signal = 0
        position.append(signal)

rsidata['Position1'] = position
rsidata['Position1'] = rsidata['Position1'].replace(to_replace=0, method='ffill')
rsidata['Position1'] = rsidata['Position1'].replace(3,0)
rsidata['Position'] = rsidata['Position1']

del rsidata['Position1']

t_days = len(rsidata['RSI'])
Signal = rsidata['Position'].values
pos = []

for d in range(0, t_days):
    if Signal[d] == 0:
        strategy = 0
        pos.append(strategy)

    elif Signal[d] == 1:
        strategy = 1
        pos.append(strategy)

    elif Signal[d] == -1:
        strategy = -1
        pos.append(strategy)

```

```
pos.append(strategy)
```

```
rsidata['Psychology'] = pos
```

In [432...]

```
rsidata
```

Out[432...]

		Close	RSI	Psychology	Position
	Date				
1988-03-31	2602.899902	46.354139	0	0	
1988-04-30	2496.699951	44.989806	0	0	
1988-05-31	2671.500000	47.717468	0	0	
1988-06-30	2678.899902	47.835389	0	0	
1988-07-31	2443.800049	44.408405	0	0	
...
2020-06-30	24595.349609	44.773509	0	0	
2020-07-31	25177.050781	46.809067	0	0	
2020-08-31	23459.050781	41.897378	0	0	
2020-09-30	24107.419922	44.273908	0	0	
2020-10-31	26341.490234	51.617303	0	0	

392 rows × 4 columns

Volatility Indicators

4. Bollinger Bands

In [433...]

```
#Compute Bollinger Bands
upper, middle, lower = talib.BBANDS(stock_close, timeperiod=26)

dict = {'Close': stock_close, 'Middle': middle, 'Upper': upper, 'Lower': lower}
bbdata = []
bbdata = pd.DataFrame(data=dict)
bbdata.dropna(inplace=True)

#Generate the Long and Short Signals
n_days = len(bbdata['Middle'])
cash = 1
stock = 0

position = []

spread = bbdata['Close'].values
ma = bbdata['Middle'].values
```

```

upper_band = bbd़ata[ 'Upper' ].values
lower_band = bbd़ata[ 'Lower' ].values

for d in range(0, n_days):

    # Long if spread < lower band & if not bought yet
    if spread[d] < lower_band[d] and cash == 1:
        signal = 1
        cash = 0
        stock = 1
        position.append(signal)

    # Take Profit if spread > moving average & if already bought
    elif spread[d] > ma[d] and stock == 1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    # Short if spread > upper band and no current position
    elif spread[d] > upper_band[d] and cash == 1:
        signal = -1
        cash = 0
        stock = -1
        position.append(signal)

    # Take Profit if spread < moving average & if already short
    elif spread[d] < ma[d] and stock == -1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    else:
        signal = 0
        position.append(signal)

bbdata[ 'Position1' ] = position
bbdata[ 'Position1' ] = bbd़ata[ 'Position1' ].replace(to_replace=0, method='ffill')
bbdata[ 'Position1' ] = bbd़ata[ 'Position1' ].replace(3,0)
bbdata[ 'Position' ] = bbd़ata[ 'Position1' ]

del bbd़ata[ 'Position1' ]

t_days = len(bbd़ata[ 'Middle' ])
Signal = bbd़ata[ 'Position' ].values
pos = []

for d in range(0, t_days):
    if Signal[d] == 0:
        strategy = 0
        pos.append(strategy)

    elif Signal[d] == 1:
        strategy = 1
        pos.append(strategy)

    elif Signal[d] == -1:
        strategy = -1
        pos.append(strategy)

```

```
strategy = -1
pos.append(strategy)
```

```
bbdata['Strategy'] = pos
```

In [434...]

bbdata

Out[434...]

	Close	Middle	Upper	Lower	Position	Strategy
Date						
1989-02-28	3005.000000	2762.773053	3607.294276	1918.251829	0	
1989-03-31	3116.000000	2771.930749	3626.352665	1917.508833	0	
1989-04-30	2743.899902	2773.088435	3627.273695	1918.903176	0	
1989-05-31	2273.899902	2758.242281	3632.951719	1883.532844	0	
1989-06-30	2571.100098	2743.638437	3617.679145	1869.597730	0	
...
2020-06-30	24595.349609	26731.865685	30259.827946	23203.903424	1	
2020-07-31	25177.050781	26586.555739	30046.836131	23126.275348	1	
2020-08-31	23459.050781	26389.480394	29954.560285	22824.400502	1	
2020-09-30	24107.419922	26244.052284	29860.773501	22627.331066	1	
2020-10-31	26341.490234	26188.397311	29752.490702	22624.303919	0	

381 rows × 6 columns

In [435...]

bbdata[bbdata['Strategy'] == -1]

Out[435...]

	Close	Middle	Upper	Lower	Position	Strategy
Date						
1990-05-31	3278.000000	2774.623066	3261.430308	2287.815823	-1	-1
1990-06-30	3438.000000	2810.826914	3347.071320	2274.582508	-1	-1

Date	Close	Middle	Upper	Lower	Position	Strategy
1990-07-31	3087.000000	2826.807683	3370.208227	2283.407139	-1	-1
1991-01-31	3552.000000	2942.046152	3490.833683	2393.258621	-1	-1
1991-02-28	3745.000000	2967.896156	3596.426651	2339.365661	-1	-1
...
2018-04-30	30468.560547	25812.048152	32974.393786	18649.702518	-1	-1
2018-05-31	28955.109375	26115.435021	33114.506034	19116.364008	-1	-1
2018-06-30	28583.009766	26414.201172	33140.612289	19687.790054	-1	-1
2018-07-31	27888.550781	26687.054312	33044.913983	20329.194641	-1	-1
2018-08-31	27788.519531	26913.867788	32985.523798	20842.211779	-1	-1

154 rows × 6 columns

In [436...]

```
bbdata['BB'] = (bbdata['Close'] - bbdata['Middle'])/(bbdata['Upper'] - bbdata['Lower'])
```

Out[436...]

Date	Close	Middle	Upper	Lower	Position	Strateg
1989-02-28	3005.000000	2762.773053	3607.294276	1918.251829	0	
1989-03-31	3116.000000	2771.930749	3626.352665	1917.508833	0	
1989-04-30	2743.899902	2773.088435	3627.273695	1918.903176	0	
1989-05-31	2273.899902	2758.242281	3632.951719	1883.532844	0	
1989-06-30	2571.100098	2743.638437	3617.679145	1869.597730	0	
...	

	Close	Middle	Upper	Lower	Position	Strateg
Date						
2020-06-30	24595.349609	26731.865685	30259.827946	23203.903424	1	
2020-07-31	25177.050781	26586.555739	30046.836131	23126.275348	1	
2020-08-31	23459.050781	26389.480394	29954.560285	22824.400502	1	
2020-09-30	24107.419922	26244.052284	29860.773501	22627.331066	1	
2020-10-31	26341.490234	26188.397311	29752.490702	22624.303919	0	

381 rows × 7 columns

5. ATR

```
In [437...]: ATR = talib.ATR(stock_high, stock_low, stock_close, timeperiod=20)

dict = {'ATR': ATR}

atrdata = pd.DataFrame(data=dict)
atrdata.dropna(inplace=True)
```

```
In [438...]: atrdata
```

```
Out[438...]: ATR
```

	Date
1988-09-30	321.180005
1988-10-31	311.521005
1988-11-30	300.364950
1988-12-31	304.621702
1989-01-31	299.255619
...	...
2020-06-30	2208.189556
2020-07-31	2181.746094
2020-08-31	2179.153321
2020-09-30	2145.772608
2020-10-31	2185.133489

386 rows × 1 columns

Volume Indicators

6. Force Index

In [439...]

```
#Force Index Function

def ForceIndex(Volume, Close):
    dict = {'Volume': Volume, 'Close': Close}
    df = pd.DataFrame(data=dict)
    df.dropna(inplace=True)

    FI = df['Volume']*(df['Close'] - df['Close'].shift(1))

    return FI

#Compute Force Index
fi = ForceIndex(stock_volume,stock_close)

efi = talib.EMA(fi, timeperiod=13)

dict = {'Close': stock_close, 'EFI': efi }

efidata = []
efidata = pd.DataFrame(data=dict)
efidata.dropna(inplace=True)

efidata['efi_sign'] = efidata.apply(lambda x : 1 if x['EFI'] > 0 else
n_days = len(efidata['EFI'])
Signal = efidata['efi_sign'].values
psy = []

for d in range(0, n_days):
    if Signal[d] == 1:
        psycology = 1
        psy.append(psycology)

    elif Signal[d] == -1:
        psycology = -1
        psy.append(psycology)

efidata['Psycology'] = psy

del efidata['efi_sign']
```

In [440...]

efidata

Out[440...]

	Close	EFI	Psycology
--	-------	-----	-----------

Date	Close	EFI	Psychology
Date			
1988-02-29	2544.000000	0.000000e+00	-1
1988-03-31	2602.899902	0.000000e+00	-1
1988-04-30	2496.699951	0.000000e+00	-1
1988-05-31	2671.500000	0.000000e+00	-1
1988-06-30	2678.899902	0.000000e+00	-1
...
2020-06-30	24595.349609	-1.240001e+13	-1
2020-07-31	25177.050781	-7.698725e+12	-1
2020-08-31	23459.050781	-1.608154e+13	-1
2020-09-30	24107.419922	-1.028050e+13	-1
2020-10-31	26341.490234	9.134007e+12	1

393 rows × 3 columns

7. Volume

In [441...]

```
voldata = pd.DataFrame()
voldata['Volume'] = stock_volume

voldata.dropna(inplace=True)
voldata
```

Out[441...]

Date	Volume
1987-01-31	0
1987-02-28	0
1987-03-31	0
1987-04-30	0
1987-05-31	0
...	...
2020-06-30	48701717400
2020-07-31	35256937100
2020-08-31	38637026300
2020-09-30	37826792700
2020-10-31	56229675200

406 rows × 1 columns

8. Volume_Change (Deleted due to insignificant in Statistical testing)

```
In [442...]: # voldata['Volume_Diff'] = talib.SMA(stock_volume, timeperiod=6) - talib.SMA(stock_volume, timeperiod=12)

# voldata.dropna(inplace=True)
# voldata
```

In []:

```
In [443...]: len(macdata), len(machdata), len(adxdata), len(rsidata), len(bbd़ata),
```

Out[443...]: (373, 372, 379, 392, 381, 386, 393, 406)

```
In [444...]: BTC_price_origin.iloc[-min(len(macdata), len(machdata), len(adxdata),
```

	Open	High	Low	Close	Volume	M
Date						
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0	1
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0	1
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0	-7
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0	-
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0	1
...

	Open	High	Low	Close	Volume	M
Date						
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	48701717400	2
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	35256937100	5
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	38637026300	7
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	37826792700	-3
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	56229675200	-2

372 rows × 12 columns

End of Technical indicators

```
In [446...]: BTC = BTC_price_origin.copy()

# compute Return
BTC['Return'] = BTC.Close.diff(periods=1)/BTC.Close.shift(periods=1)
BTC['Close_1M'] = BTC.Close.shift(periods=1)

# change index into date format
BTC.index
```



```
Out[446...]: DatetimeIndex(['1987-01-31', '1987-02-28', '1987-03-31', '1987-04-30',
                           '1987-05-31', '1987-06-30', '1987-07-31', '1987-08-31',
                           '1987-09-30', '1987-10-31',
                           ...,
                           '2020-01-31', '2020-02-29', '2020-03-31', '2020-04-30',
                           '2020-05-31', '2020-06-30', '2020-07-31', '2020-08-31',
                           '2020-09-30', '2020-10-31'],
                          dtype='datetime64[ns]', name='Date', length=406, freq=None)
```



```
In [447...]: # feature list
predictor_variables = ['6M']

# create all features
def ShiftNum(var):

    if var[1]=='M':
        return int(var[0])*1
    elif var[1]=='Y':
        return int(var[0])*12
    else:
        return("Please give a str whose format is xD, xW, xM, xY.")
```

```
# shift Return by the value of each feature
for var in predictor_variables:
    name = 'Return_' + var
    BTC[name] = BTC.Close_1M.diff(periods = ShiftNum(var))/BTC.Close_1M

BTC['Gain'] = BTC['Close'] - BTC['Open']
# drop the first 250 rows (cuz they do not have feature '1Y')
BTC = BTC.dropna()
BTC
```

Out[447...]

	Open	High	Low	Close	Volume
Date					
1987-08-31	3644.300049	3943.600098	3571.399902	3943.600098	0
1987-09-30	3949.699951	3949.699951	2202.800049	2204.500000	0 -
1987-10-31	2224.800049	2317.500000	1960.900024	2138.399902	0 -2
1987-11-30	2086.699951	2379.100098	1894.900024	2302.800049	0 -
1987-12-31	2238.100098	2512.199951	2238.100098	2409.699951	0
...
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	48701717400
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	35256937100
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	38637026300
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	37826792700 -
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	56229675200 -

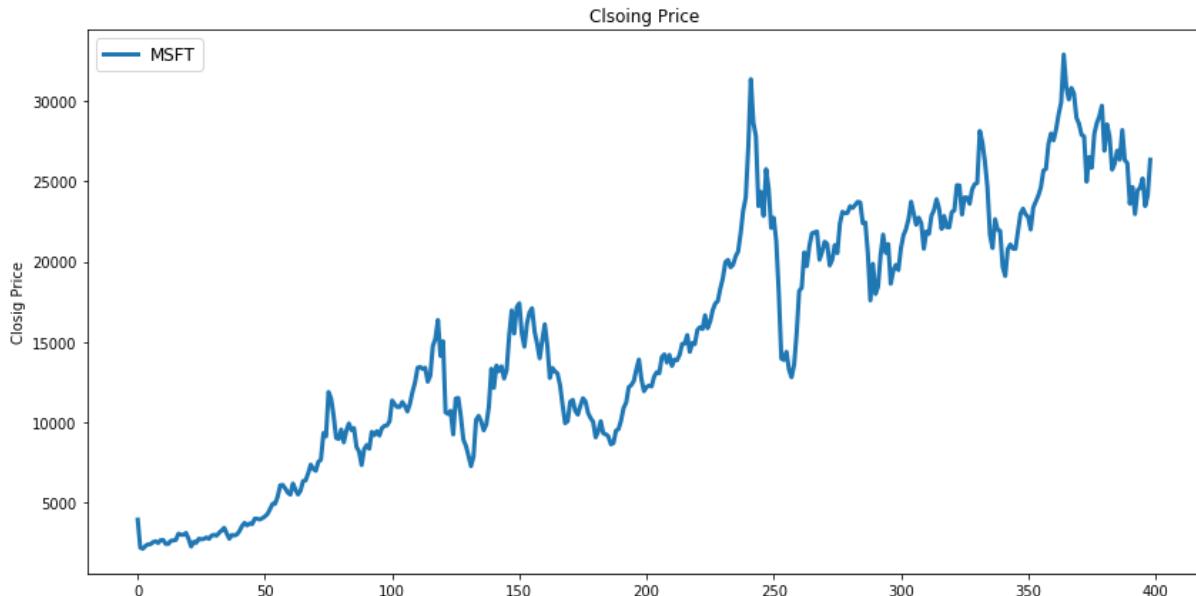
399 rows × 16 columns

In [448...]

```
plt.figure(figsize=(14, 7))
plt.plot(range(len(BTC)), BTC['Close'], label='MSFT', lw=3)
plt.title('Closing Price')
plt.ylabel('Closing Price')
plt.legend(loc='upper left', fontsize=12)
```

Out[448...]

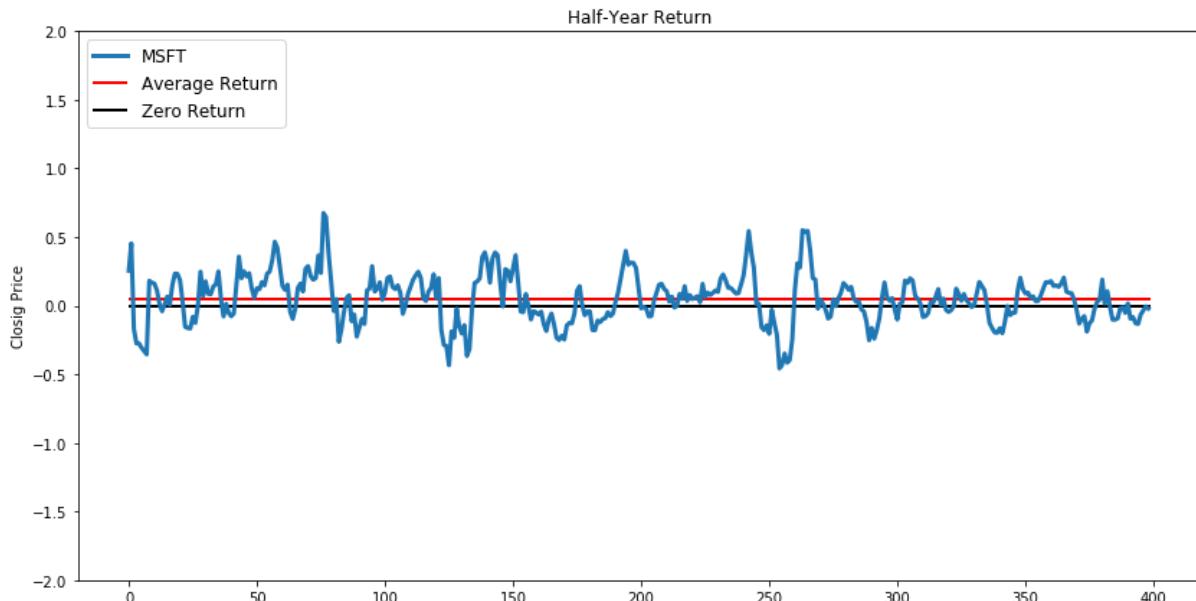
<matplotlib.legend.Legend at 0x12e208d30>



In [449...]

```
plt.figure(figsize=(14, 7))
plt.plot(range(len(BTC)), BTC['Return_6M'], label='MSFT', lw=3)
plt.hlines(BTC['Return_6M'].mean(), 0, len(BTC), label='Average Return')
plt.hlines(0, 0, len(BTC), label='Zero Return', color='k', lw=2)
plt.title('Half-Year Return')
plt.ylabel('Closig Price')
plt.ylim(-2, 2)
plt.legend(loc='upper left', fontsize=12)
print('Average Half-Year Return: ', BTC['Return_6M'].mean())
print('Average Half-year Std: ', BTC['Return_6M'].std())
```

Average Half-Year Return: 0.0475168747279544
 Average Half-year Std: 0.17764540885167268



In [450...]

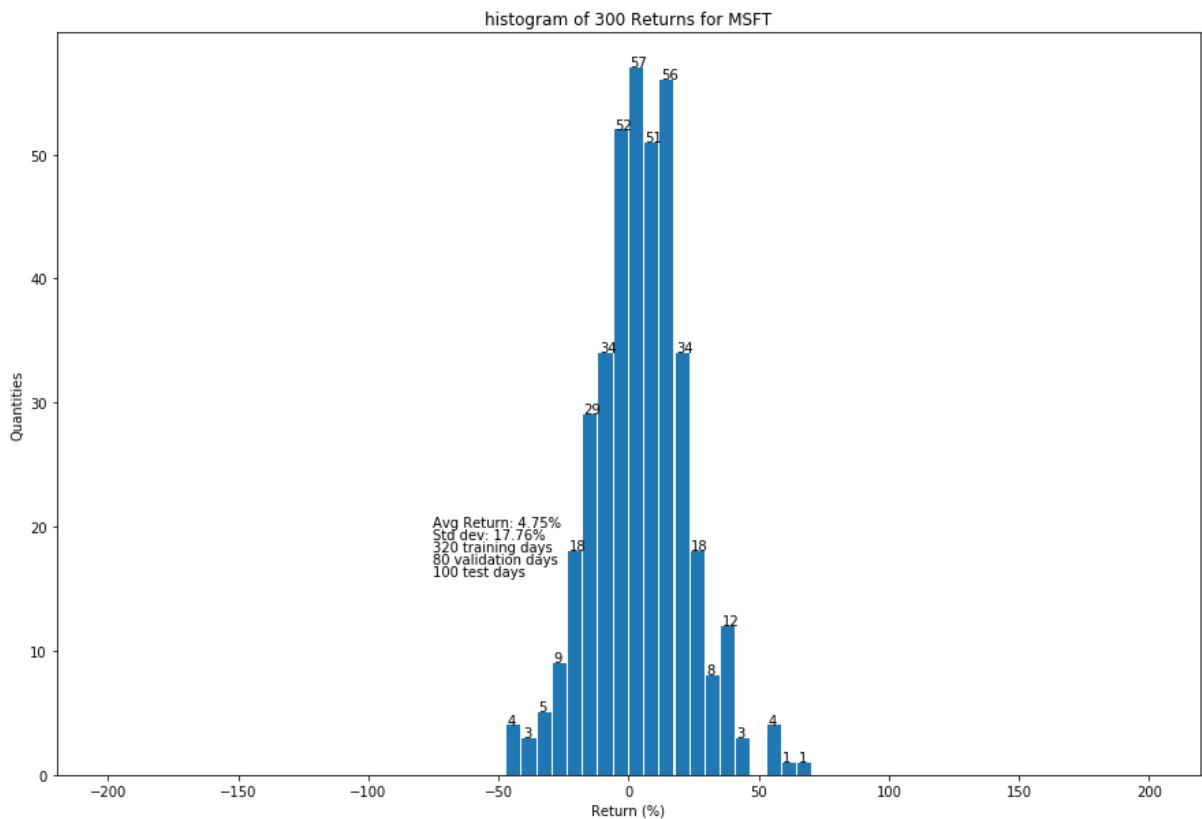
```
fig = plt.figure(figsize=(15,10))
bins = np.linspace(-200, 200, 69)
a = plt.hist(BTC['Return_6M']*100, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 300 Returns for MSFT")
plt.xlabel('Return (%)')
```

```

plt.ylabel('Quantities')
# you should change the coordinates of the plot to make it look nice
plt.text(-75, 20, ("Avg Return: {0:.2f}%".format(BTC['Return_6M'].mean)))
plt.text(-75, 19, ("Std dev: {0:.2f}%".format(BTC['Return_6M'].std())))
plt.text(-75, 18, "320 training days")
plt.text(-75, 17, "80 validation days")
plt.text(-75, 16, "100 test days")

```

Out[450... Text(-75, 16, '100 test days')



In [451... BTC.drop(['Close'], axis=1, inplace=True)
BTC

Date	Open	High	Low	Volume	Mkt-RF	SMB	HI
1987-08-31	3644.300049	3943.600098	3571.399902	0	3.52	-0.90	-0.
1987-09-30	3949.699951	3949.699951	2202.800049	0	-2.59	0.37	0.
1987-10-31	2224.800049	2317.500000	1960.900024	0	-23.24	-8.09	4.
1987-11-30	2086.699951	2379.100098	1894.900024	0	-7.77	2.83	3.
1987-12-31	2238.100098	2512.199951	2238.100098	0	6.81	0.09	-4.
...

	Open	High	Low	Volume	Mkt-RF	SMB	HI
Date							
2020-06-30	24563.570312	26782.619141	24526.910156	48701717400	2.46	1.94	-2.
2020-07-31	24566.810547	25847.109375	24167.789062	35256937100	5.77	-3.03	-1.
2020-08-31	25085.669922	25254.140625	23124.250000	38637026300	7.63	-0.94	-2.
2020-09-30	24039.390625	24970.589844	23674.519531	37826792700	-3.63	0.07	-2.
2020-10-31	24274.830078	27040.410156	24232.660156	56229675200	-2.10	4.76	3.

399 rows × 15 columns

Technical indicators (Signal)

In [452...]

```
# BTC = BTC_price_origin.copy()

# # compute Return
# BTC[ 'Return' ] = (BTC[ 'Close' ] - BTC[ 'Open' ]) / BTC[ 'Open' ]

# length = min(len(macdata), len(machdata), len(adxdata), len(rsidata))

# BTC = BTC.iloc[-length::]
# BTC[ 'MACD' ] = macdata[ 'MACD_Signal' ].iloc[-length::].values
# BTC[ 'MACDH' ] = machdata[ 'MHIST_Signal' ].iloc[-length::].values
# BTC[ 'ADX' ] = adxdata[ 'Trend' ].iloc[-length::].values
# BTC[ 'RSI' ] = rsidata[ 'Psychology' ].iloc[-length::].values
# BTC[ 'BB' ] = bbdta[ 'Strategy' ].iloc[-length::].values
# BTC[ 'ATR' ] = atrdata[ 'ATR' ].iloc[-length::].values
# BTC[ 'EFI' ] = efidata[ 'Psychology' ].iloc[-length::].values
# BTC[ 'Volume' ] = voldata[ 'Volume' ].iloc[-length::].values
# BTC[ 'Volume_Diff' ] = voldata[ 'Volume_Diff' ].iloc[-length::].values

# BTC
```

Technical indicators (Value)

In [453...]

```
BTC = BTC_price_origin.copy()

# compute Return
BTC[ 'Return' ] = (BTC[ 'Close' ] - BTC[ 'Open' ]) / BTC[ 'Open' ]

length = min(len(macdata), len(machdata), len(adxdata), len(rsidata))

BTC = BTC.iloc[-length::]
```

```

BTC[ 'MACD' ] = macdata[ 'MACD' ].iloc[ -length:: ].values
BTC[ 'MACDH' ] = machdata[ 'MACDH' ].iloc[ -length:: ].values
BTC[ 'ADX' ] = adxdata[ 'ADX' ].iloc[ -length:: ].values
BTC[ 'RSI' ] = rsidata[ 'RSI' ].iloc[ -length:: ].values
BTC[ 'BB' ] = bbdelta[ 'BB' ].iloc[ -length:: ].values
BTC[ 'ATR' ] = atrdata[ 'ATR' ].iloc[ -length:: ].values
BTC[ 'EFI' ] = efidata[ 'EFI' ].iloc[ -length:: ].values
BTC[ 'Volume' ] = voldata[ 'Volume' ].iloc[ -length:: ].values
# BTC[ 'Volume_Diff' ] = voldata[ 'Volume_Diff' ].iloc[ -length:: ].values

```

BTC

Out[453...]

	Open	High	Low	Close	Volume	M
Date						

1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0	1
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0	1
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0	-7
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0	-
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0	1
...
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	48701717400	2
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	35256937100	5
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	38637026300	7
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	37826792700	-3
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	56229675200	-2

372 rows × 20 columns

In [454...]

```

BTC_Gain = pd.DataFrame()
BTC_Gain[ 'Gain' ] = BTC[ 'Close' ] - BTC[ 'Open' ]
BTC_Gain.index = BTC.index
BTC_Gain

```

Out[454...]

Gain

Date	Gain
Date	
1989-11-30	88.600098
1989-12-31	-84.399902
1990-01-31	201.000000
1990-02-28	46.000000
1990-03-31	-46.000000
...	...
2020-06-30	31.779297
2020-07-31	610.240234
2020-08-31	-1626.619141
2020-09-30	68.029297
2020-10-31	2066.660156

372 rows × 1 columns

In [455...]

```
# BTC.drop(['Open'], axis=1, inplace=True)
# BTC.drop(['High'], axis=1, inplace=True)
# BTC.drop(['Low'], axis=1, inplace=True)
# BTC.drop(['Close'], axis=1, inplace=True)
# BTC.drop(['Volume'], axis=1, inplace=True)
# BTC
```

In [456...]

```
# Expected value of the factor is assume to be t-1.

# BTC['MACD'] = BTC.MACD.shift(periods=1)
# BTC['MACDH'] = BTC.MACDH.shift(periods=1)
# BTC['ADX'] = BTC.ADX.shift(periods=1)
# BTC['RSI'] = BTC.RSI.shift(periods=1)
# BTC['BB'] = BTC.BB.shift(periods=1)
# BTC['ATR'] = BTC.ATR.shift(periods=1)
# BTC['EFI'] = BTC.EFI.shift(periods=1)

# BTC['Volume'] = BTC.Volume.shift(periods=1)
# BTC['Volume_Diff'] = BTC.Volume_Diff.shift(periods=1)
```

```
BTC = BTC.dropna()
```

In [457...]

```
BTC
```

Out[457...]

Open	High	Low	Close	Volume	M
------	------	-----	-------	--------	---

Date	Open	High	Low	Close	Volume	M
Date						
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0	1
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0	1
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0	-7
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0	-
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0	1
...
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	48701717400	2
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	35256937100	5
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	38637026300	7
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	37826792700	-3
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	56229675200	-2

372 rows × 20 columns

In [458]:

```
features = ['Mkt-RF', 'SMB', 'HML', 'RMW', 'CMA', 'MACD', 'MACDH', 'ADX', 'RSI']
target = ['Return-RF']
```

In [459]:

```
fix_history_length = 250 # one year and a half
fix_test_length = 100 # five months
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[459]: 22

In []:

Extended-Factors Model (Linearly Regression)

In [460...]

```

features = ['Mkt-RF', 'SMB', 'HML', 'RMW', 'CMA', 'MACD', 'MACDH', 'ADX', 'RSI']
target = ['Return-RF']

X = BTC[features]
Y = BTC[target]

model = linear_model.LinearRegression()
model.fit(X, Y)
Y_Pred = model.predict(X)

```

In [461...]

```
r2_score(Y, Y_Pred)
```

Out[461...]

Statistical Analysis

In [462...]

```

# Specify the matrices
X = sm.add_constant(BTC[features])
y = BTC[target]
lm4 = sm.OLS(y,X).fit()
# Show results
print(lm4.summary())

```

OLS Regression Results

Dep. Variable:	Return-RF	R-squared:			
0.592					
Model:	OLS	Adj. R-squared:			
0.577					
Method:	Least Squares	F-statistic:			
39.99					
Date:	Thu, 22 Apr 2021	Prob (F-statistic):			
1.01e-61					
Time:	00:24:46	Log-Likelihood:			
630.32					
No. Observations:	372	AIC:			
-1233.					
Df Residuals:	358	BIC:			
-1178.					
Df Model:	13				
Covariance Type:	nonrobust				
coef	std err	t	P> t	[0.025	
0.975]					

const	0.0321	0.042	0.767	0.443	-0.050
0.114					
Mkt-RF	-0.0036	0.001	-5.474	0.000	-0.005

```

-0.002
SMB           -0.0007      0.001     -0.825      0.410     -0.002
0.001
HML           -0.0002      0.001     -0.171      0.865     -0.002
0.002
RMW           0.0001      0.001      0.086      0.931     -0.002
0.002
CMA           -0.0003      0.002     -0.173      0.863     -0.004
0.003
MACD          2.928e-05   7.78e-06    3.766      0.000     1.4e-05
4.46e-05
MACDH          0.0006      4.78e-05   13.334      0.000     0.001
0.001
ADX           -0.0004      0.000     -1.235      0.218     -0.001
0.000
RSI            -0.0005      0.001     -0.600      0.549     -0.002
0.001
BB             0.0437      0.025      1.721      0.086     -0.006
0.094
ATR            4.279e-07   7.65e-06    0.056      0.955     -1.46e-05
1.55e-05
EFI            -1.523e-15   2.96e-16    -5.140      0.000     -2.11e-15
-9.4e-16
Volume         -3.413e-13   2.02e-13    -1.689      0.092     -7.39e-13
5.6e-14
=====
=====
Omnibus:                  46.242   Durbin-Watson:
1.680
Prob(Omnibus):           0.000   Jarque-Bera (JB):
122.213
Skew:                      0.591   Prob(JB):
2.90e-27
Kurtosis:                 5.547   Cond. No.
2.36e+14
=====
=====
```

Notes:

- [1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
- [2] The condition number is large, 2.36e+14. This might indicate that there are strong multicollinearity or other numerical problems.

Hypothesis testing on factors

In [463...]

```
print(lm4.f_test('MACD = 0'))
```

```
<F test: F=array([[14.18549203]]), p=0.00019358952467807974, df_denom=358, df_num=1>
```

In [464...]

```
print(lm4.f_test('MACDH = 0'))
```

```
<F test: F=array([[177.7904556]]), p=3.287031308714528e-33, df_denom=358, df_num=1>
```

In [465...]

```
print(lm4.f_test('ADX = 0'))
```

```
<F test: F=array([[1.5251383]]), p=0.21765346894897306, df_denom=358,
```

df_num=1>

In [466...]

print(lm4.f_test('RSI = 0'))

<F test: F=array([[0.36023042]]), p=0.5487580217606759, df_denom=358, df_num=1>

In [467...]

print(lm4.f_test('BB = 0'))

<F test: F=array([[2.9610713]]), p=0.08615543924118597, df_denom=358, df_num=1>

In [468...]

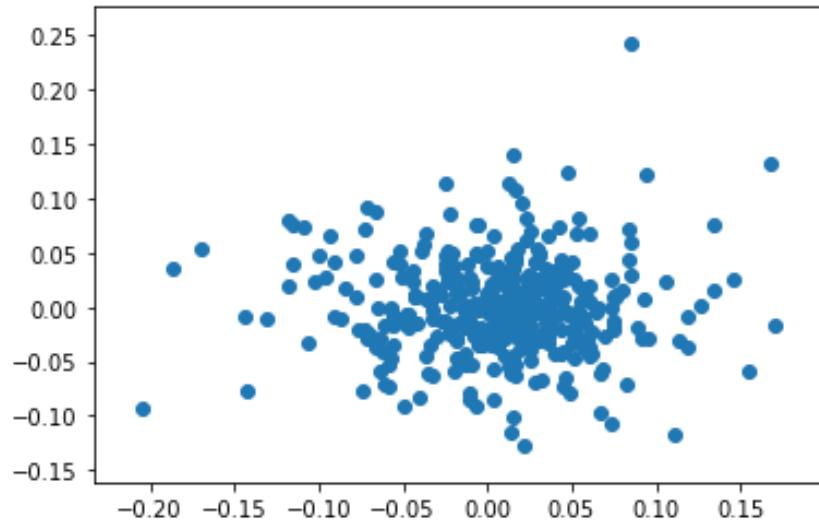
print(lm4.f_test('MACD = MACDH = ADX = RSI = BB = ATR = EFI = Volume = # print(lm4.f_test('MACD = MACDH = ADX = RSI = BB = ATR = 0'))

<F test: F=array([[71.37632617]]), p=3.366299271563608e-58, df_denom=358, df_num=6>

Regression diagnostics

In [469...]

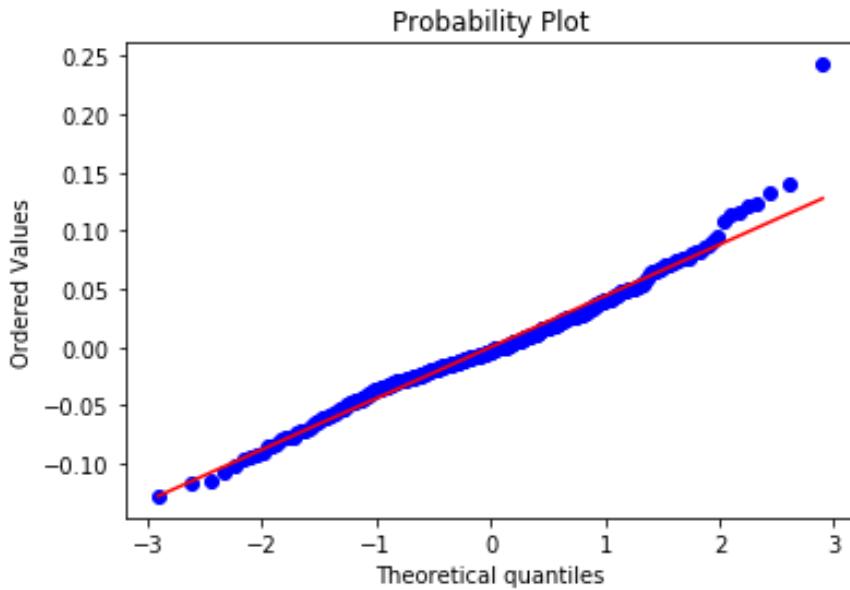
```
# The results object has an attribute resid, representing the residual
residual = lm4.resid
fitted = lm4.fittedvalues
# Next we plot it
plt.scatter(fitted, residual)
plt.show()
```



The residuals seem to be i.i.d.; there is no trend in the fitted value. Next we check the QQ-plot (normal probability plot) for normality. Scipy has a function for that.

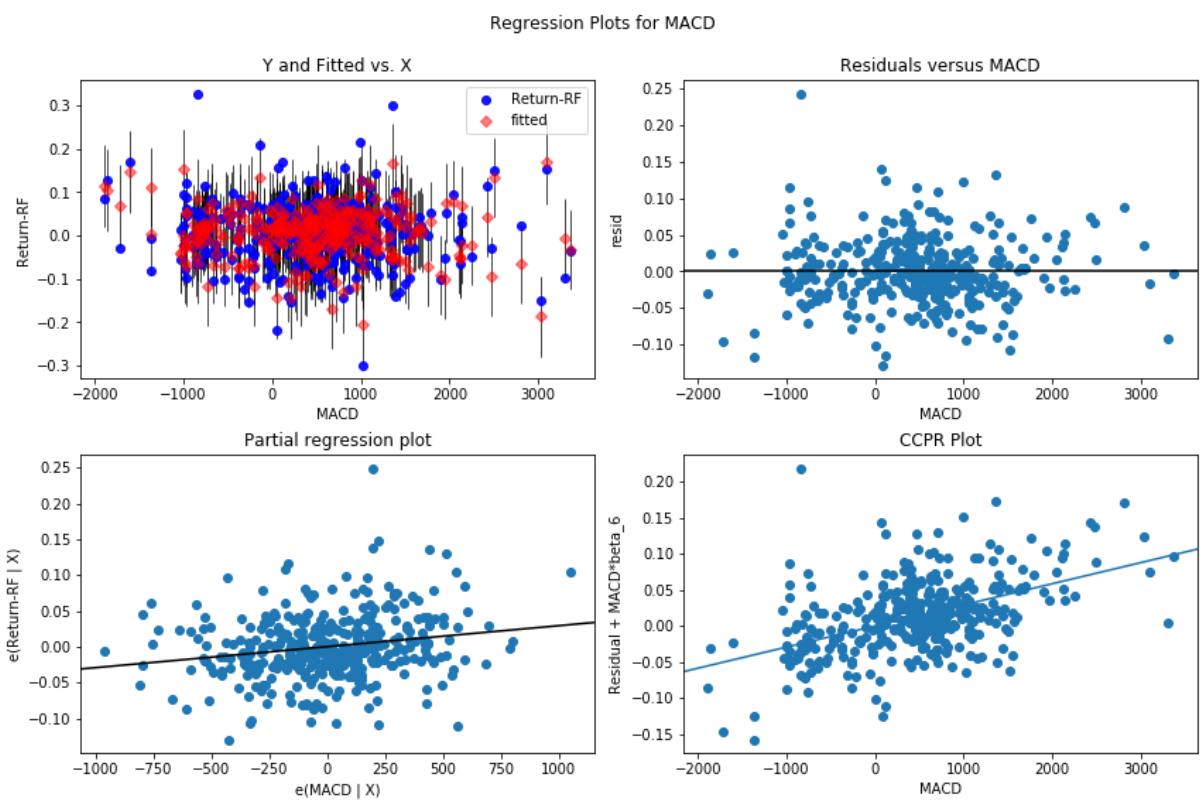
In [470...]

```
# We first create an axis handle to plot
fig=plt.figure()
ax = fig.add_subplot(111)
# Use the scipy package
st.probplot(residual, dist='norm', plot=ax)
plt.show()
```



In [471...]

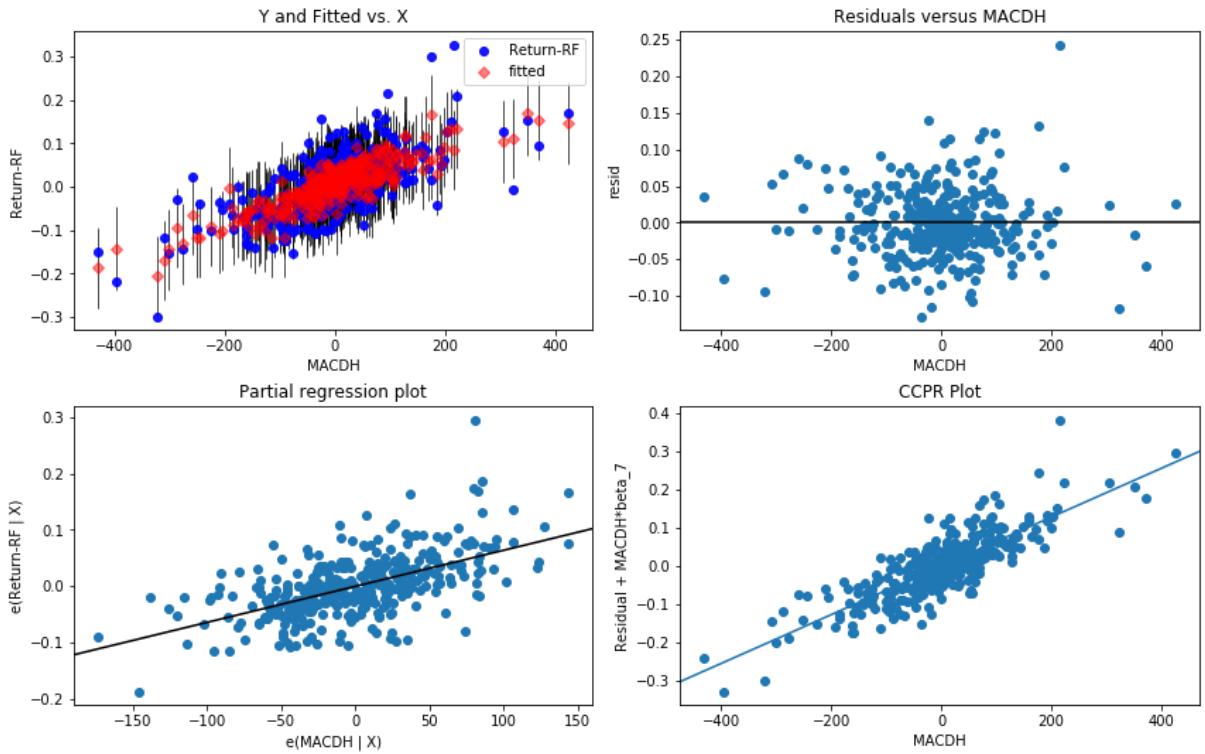
```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'MACD', fig=fig)
plt.show()
```



In [472...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'MACDH', fig=fig)
plt.show()
```

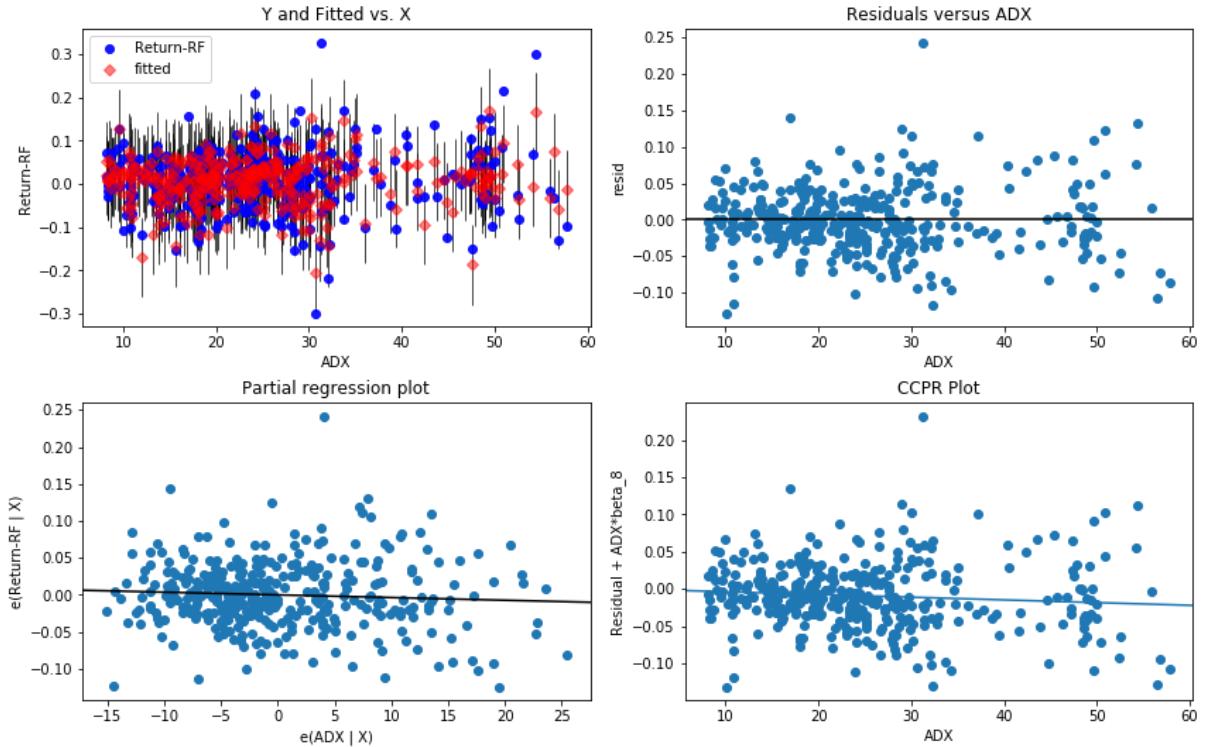
Regression Plots for MACDH



In [473...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'ADX', fig=fig)
plt.show()
```

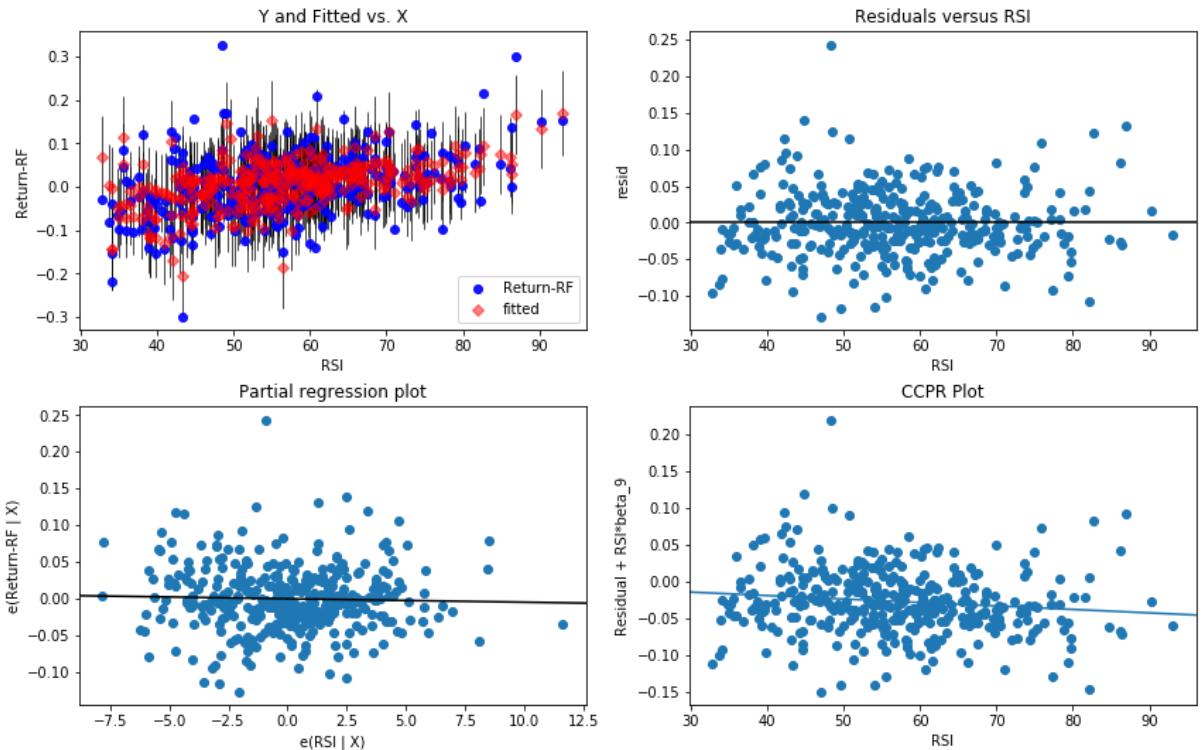
Regression Plots for ADX



In [474...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'RSI', fig=fig)
plt.show()
```

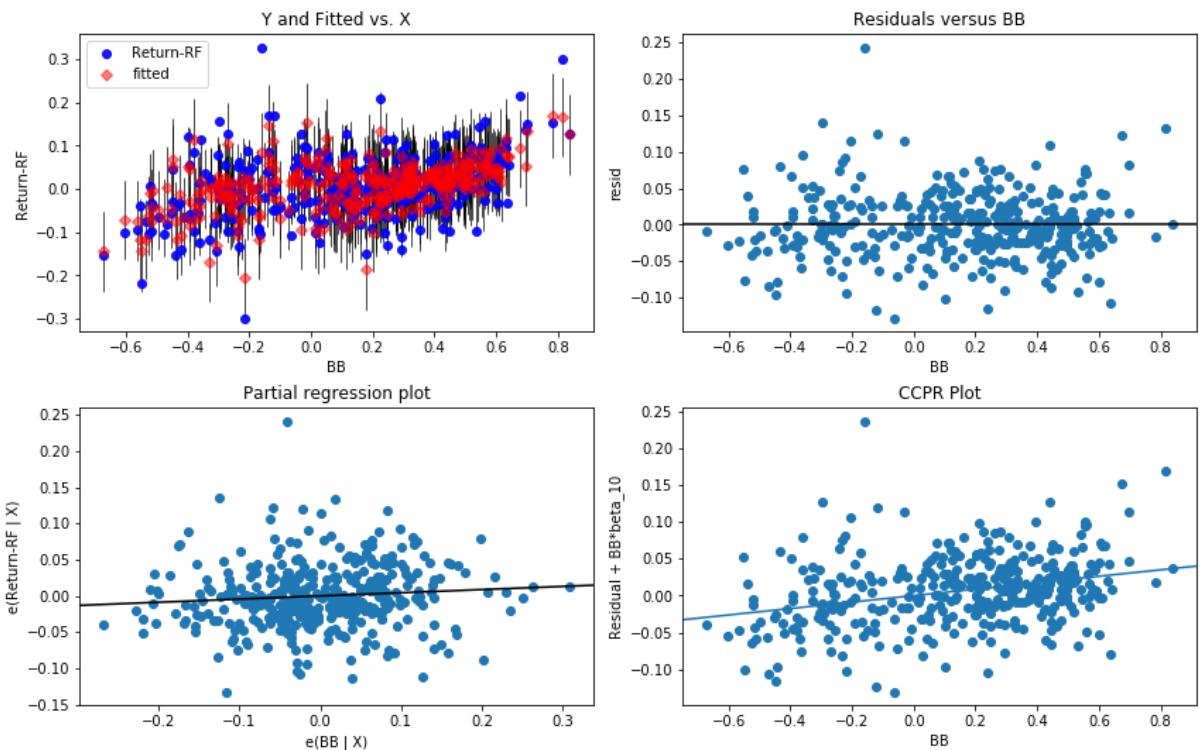
Regression Plots for RSI



In [475...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'BB', fig=fig)
plt.show()
```

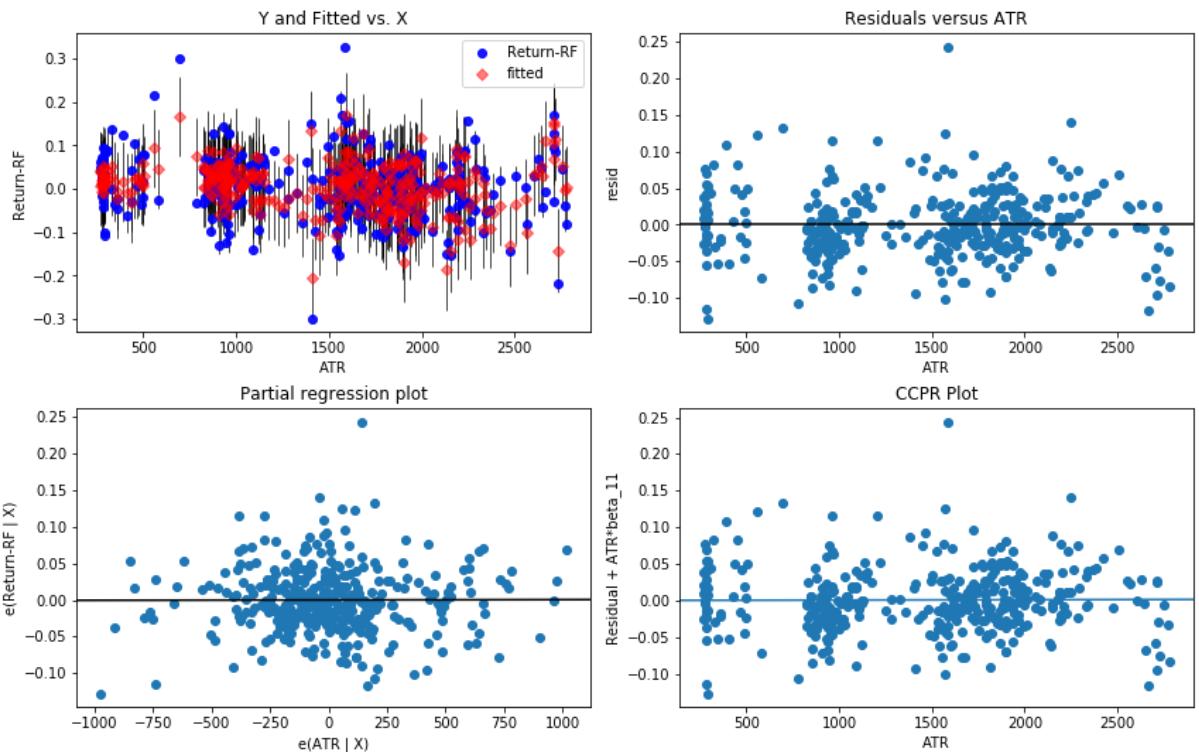
Regression Plots for BB



In [476...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'ATR', fig=fig)
plt.show()
```

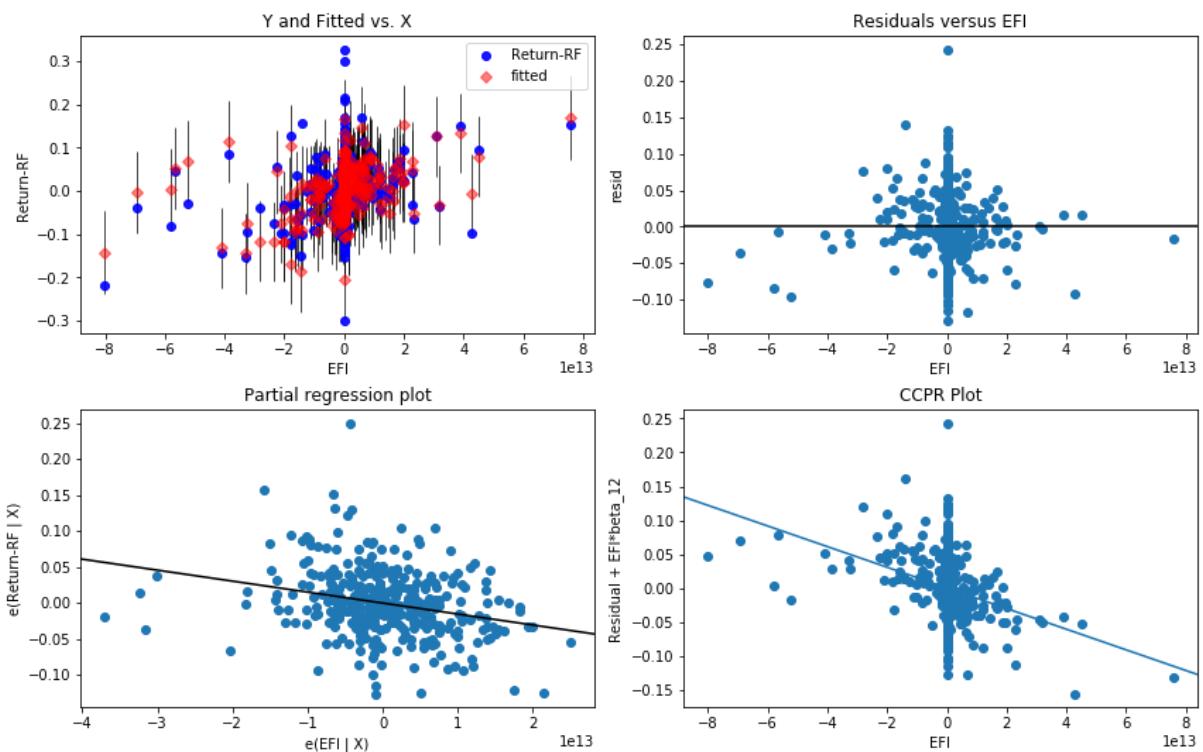
Regression Plots for ATR



In [477...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'EFI', fig=fig)
plt.show()
```

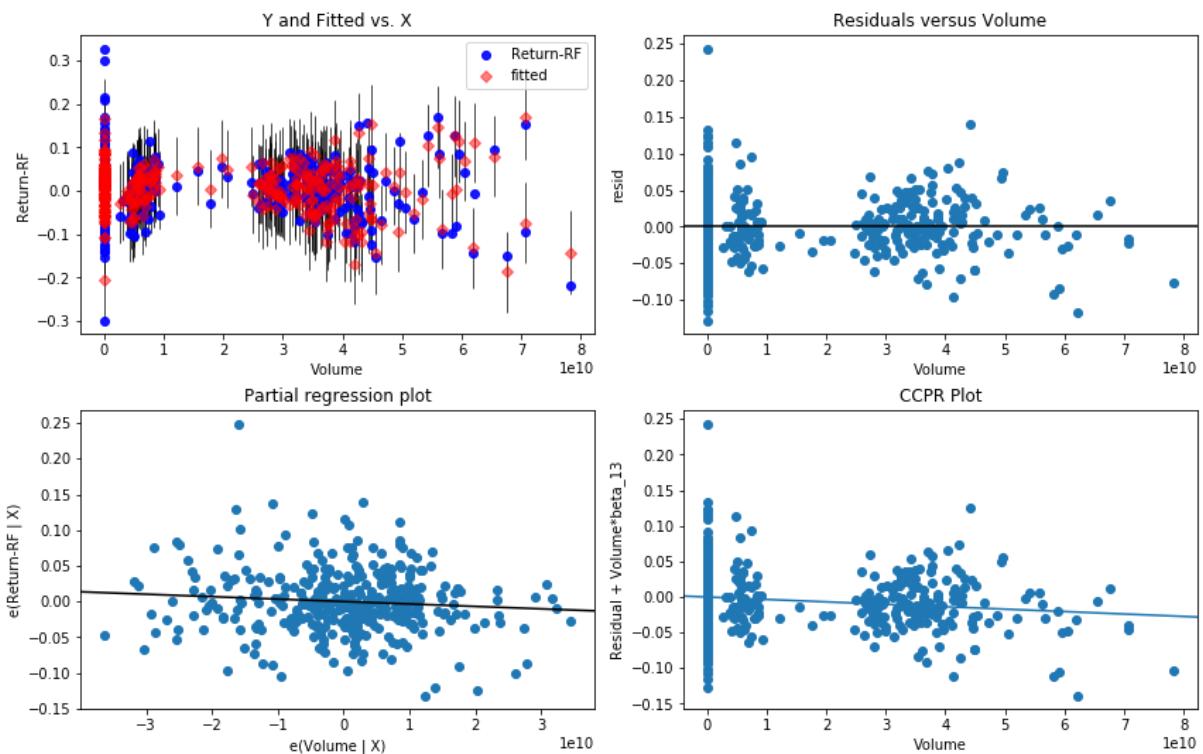
Regression Plots for EFI



In [478...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm4, 'Volume', fig=fig)
plt.show()
```

Regression Plots for Volume



Detecting Multicollinearity with VIF

```
In [479...]: pd.options.display.max_rows, pd.options.display.max_columns = len(features)

# VIF dataframe
vif_data = pd.DataFrame()
vif_data["feature"] = BTC[features].columns

# calculating VIF for each feature
vif_data["VIF"] = [variance_inflation_factor(BTC[features].values, i)
                  for i in range(len(BTC[features].columns))]

vif_data
```

	feature	VIF
0	Mkt-RF	1.447438
1	SMB	1.304794
2	HML	2.083541
3	RMW	1.625082
4	CMA	2.094293
5	MACD	6.102685
6	MACDH	3.391623
7	ADX	1.879673
8	RSI	1.383521
9	BB	8.310330
10	ATR	3.048147

	feature	VIF
11	EFI	2.416027
12	Volume	2.409627

Principle Component Analysis on Feature

In [480...]

```
from sklearn.decomposition import PCA
X = BTC[features]
pca_number = 13
pca = PCA(n_components=pca_number)
pca.fit(X)
print(pca.explained_variance_ratio_)
print(pca.singular_values_)
```

```
[9.99997571e-01 2.42859620e-06 3.94026041e-21 1.09232602e-21
 3.37064278e-23 6.35077449e-25 1.41944519e-25 1.24297493e-25
 6.56689658e-26 5.85340723e-26 2.30427574e-26 1.00392095e-26
 5.58233308e-29]
[2.38771048e+14 3.72100152e+11 1.49880335e+04 7.89147768e+03
 1.38624042e+03 1.90281050e+02 8.99583550e+01 8.41808638e+01
 6.11874397e+01 5.77678976e+01 3.62451095e+01 2.39238985e+01
 1.78398035e+00]
```

In [481...]

```
features = ['Mkt-RF', 'SMB', 'HML', 'RMW', 'CMA', 'MACD', 'MACDH', 'ADX', 'RSI']
target = ['Return-RF']

X = BTC[features]
X_transform = pca.transform(X)
Y = BTC[target]

model = linear_model.LinearRegression()
model.fit(X_transform, Y)
Y_Pred = model.predict(X_transform)
```

In [482...]

```
r2_score(Y, Y_Pred)
```

Out[482...]

```
0.5921918251994969
```

In [483...]

```
# Specify the matrices
X = sm.add_constant(X_transform)
y = BTC[target]
lm5 = sm.OLS(y,X).fit()
# Show results
print(lm5.summary())
```

OLS Regression Results

Dep. Variable: Return-RF
0.592
Model:

R-squared:
Adj. R-squared:

```

0.577
Method: Least Squares F-statistic:
39.99
Date: Thu, 22 Apr 2021 Prob (F-statistic):
1.01e-61 00:24:59 Log-Likelihood:
630.32
No. Observations: 372 AIC:
-1233. BIC:
Df Residuals: 358
Df Model: 13
Covariance Type: nonrobust
=====
=====

          coef    std err      t    P>|t|   [ 0.025
0.975]
-----
const      0.0073    0.002    3.118    0.002    0.003
0.012
x1      -1.539e-15  1.9e-16   -8.111    0.000   -1.91e-15  -
1.17e-15
x2      -2.444e-13  1.22e-13   -2.007    0.045   -4.84e-13  -
4.93e-15
x3      -1.363e-05  3.02e-06   -4.508    0.000   -1.96e-05  -
7.68e-06
x4      -2.075e-05  5.74e-06   -3.614    0.000   -3.2e-05  -
9.46e-06
x5      -0.0006    3.27e-05  -19.127    0.000   -0.001
-0.001
x6      -0.0005    0.000    -2.291    0.023   -0.001  -
7.73e-05
x7      0.0024     0.001     4.723    0.000    0.001
0.003
x8      0.0019     0.001     3.515    0.000    0.001
0.003
x9      0.0021     0.001     2.774    0.006    0.001
0.004
x10     -9.629e-05  0.001    -0.123    0.902   -0.002
0.001
x11     0.0002     0.001     0.131    0.895   -0.002
0.003
x12     -0.0009    0.002    -0.453    0.651   -0.005
0.003
x13     0.0437     0.025     1.720    0.086   -0.006
0.094
=====
=====

Omnibus: 46.241 Durbin-Watson:
1.679
Prob(Omnibus): 0.000 Jarque-Bera (JB):
122.213
Skew: 0.591 Prob(JB):
2.90e-27
Kurtosis: 5.547 Cond. No.
1.34e+14
=====
=====

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is
correctly specified.
[2] The condition number is large, 1.34e+14. This might indicate that

```

there are
strong multicollinearity or other numerical problems.

In [484...]

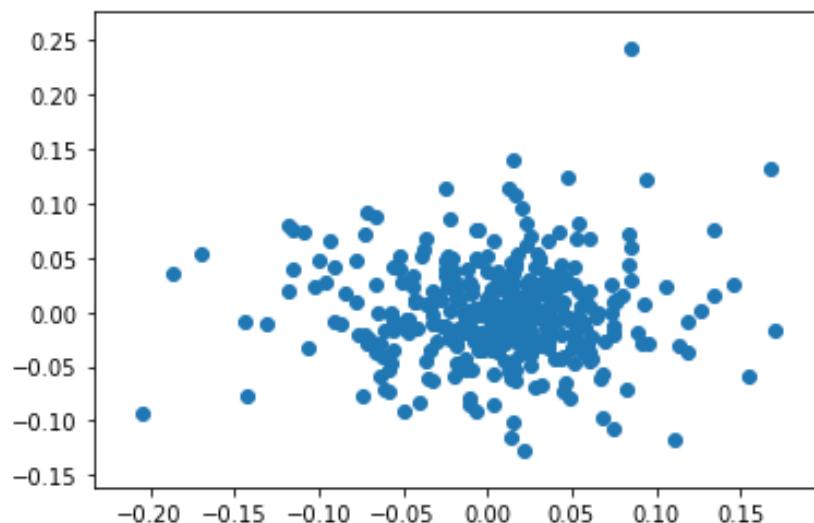
```
print(lm5.f_test('x1 = x2 = x3 = x4 = x5 = x6 = x7 = x8 = x9 = x10 = x11'))
```

<F test: F=array([[40.91280444]]), p=1.0668328803307408e-56, df_denom=358, df_num=11>

Regression diagnostics

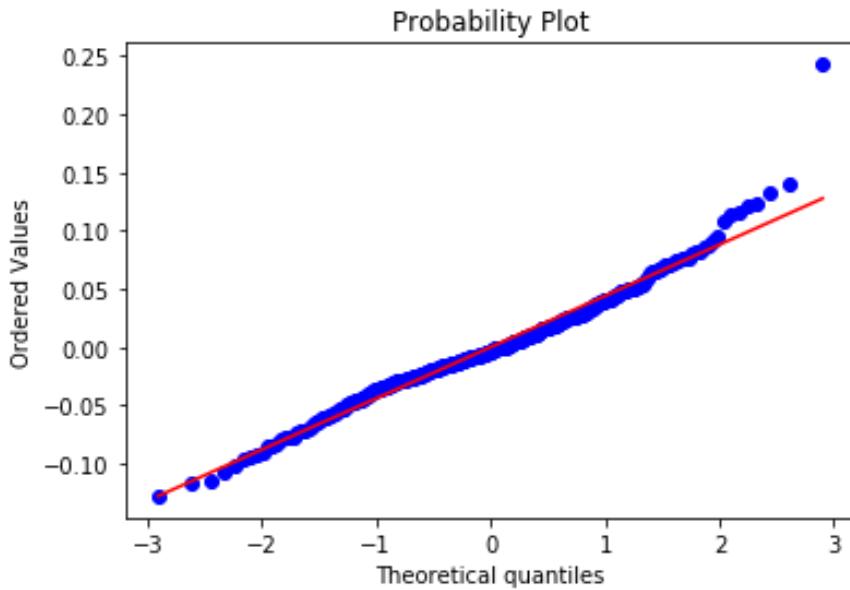
In [485...]

```
# The results object has an attribute resid, representing the residual
residual = lm5.resid
fitted = lm5.fittedvalues
# Next we plot it
plt.scatter(fitted, residual)
plt.show()
```



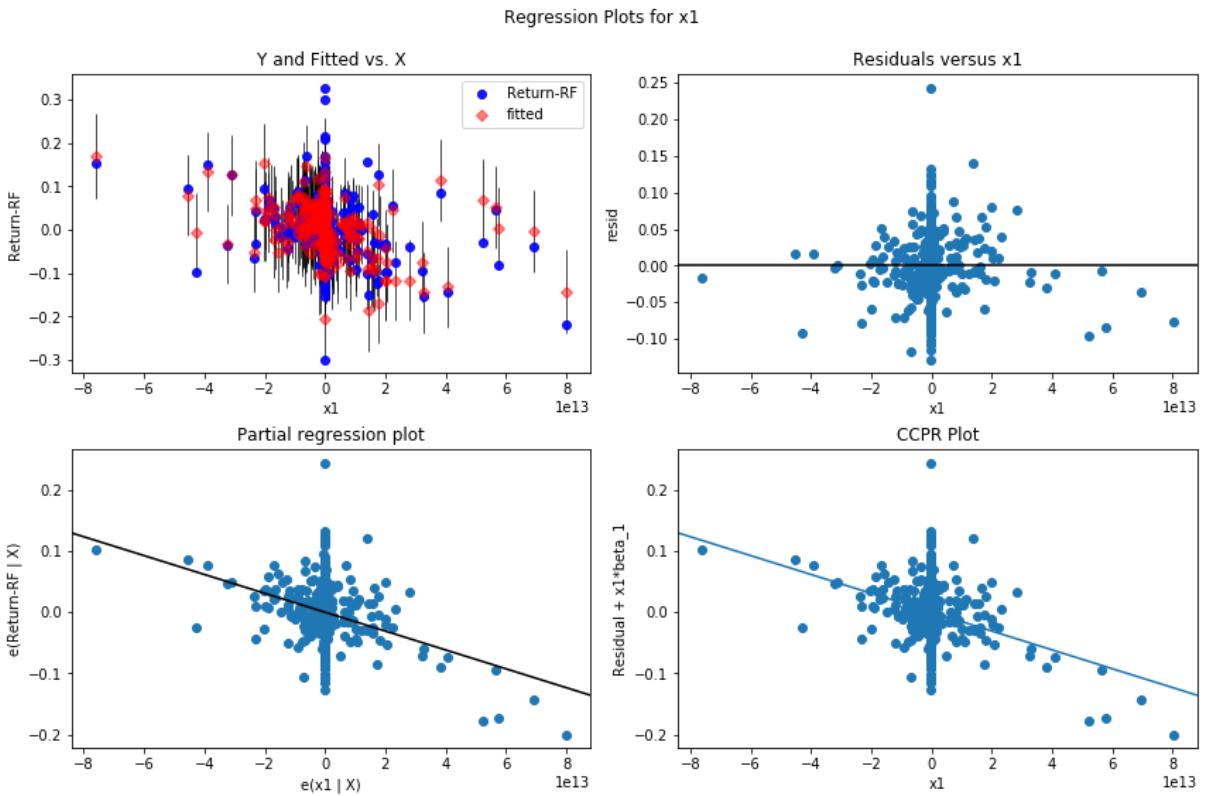
In [486...]

```
# We first create an axis handle to plot
fig=plt.figure()
ax = fig.add_subplot(111)
# Use the scipy package
st.probplot(residual, dist='norm', plot=ax)
plt.show()
```



In [487...]

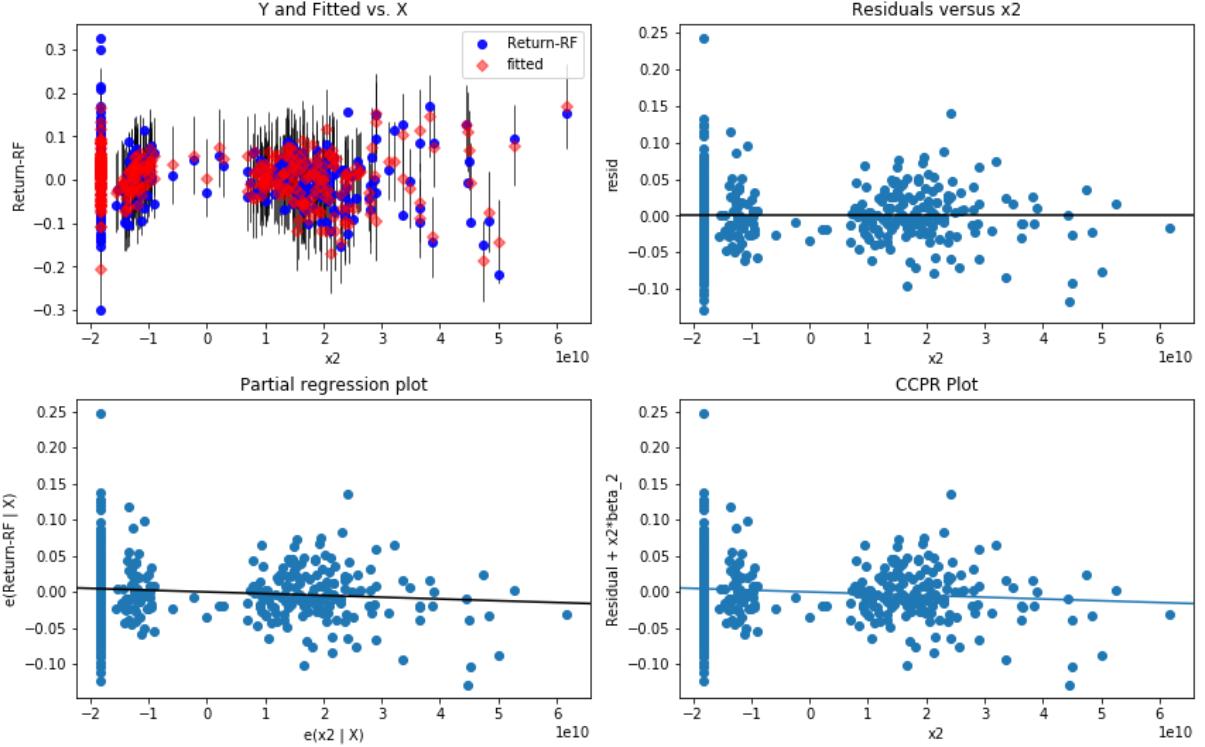
```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x1', fig=fig)
plt.show()
```



In [488...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x2', fig=fig)
plt.show()
```

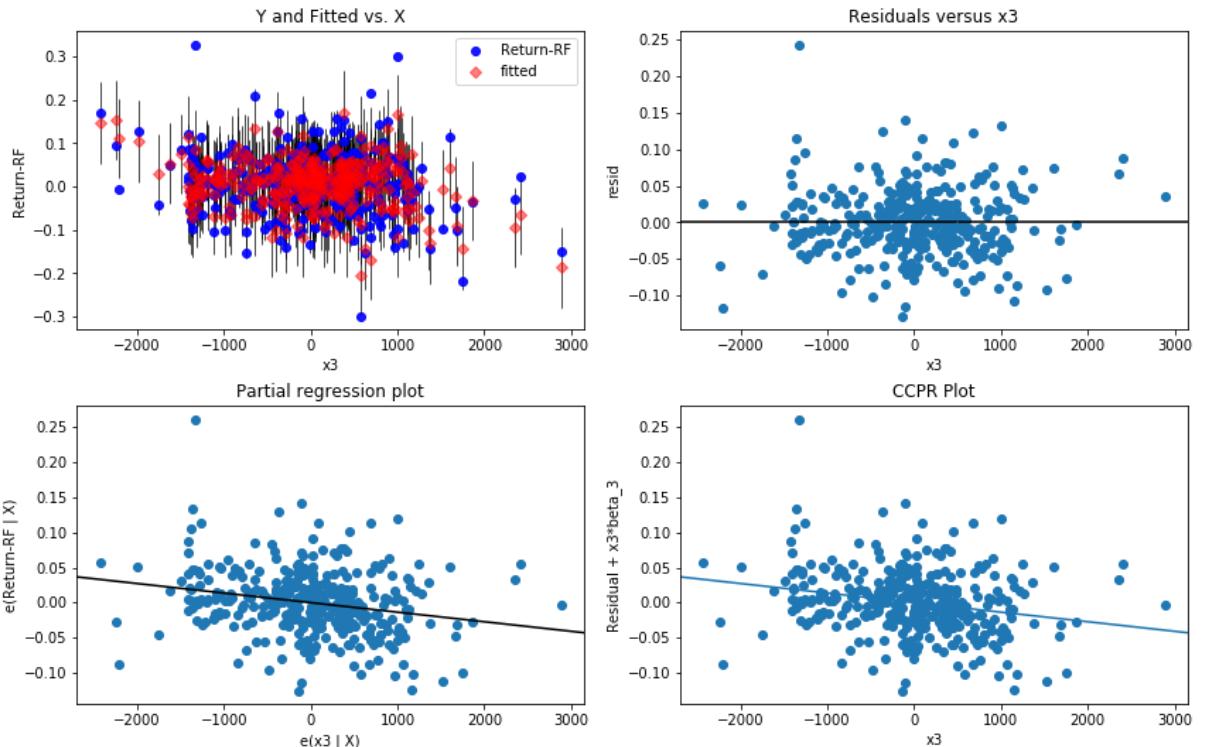
Regression Plots for x2



In [489]...

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x3', fig=fig)
plt.show()
```

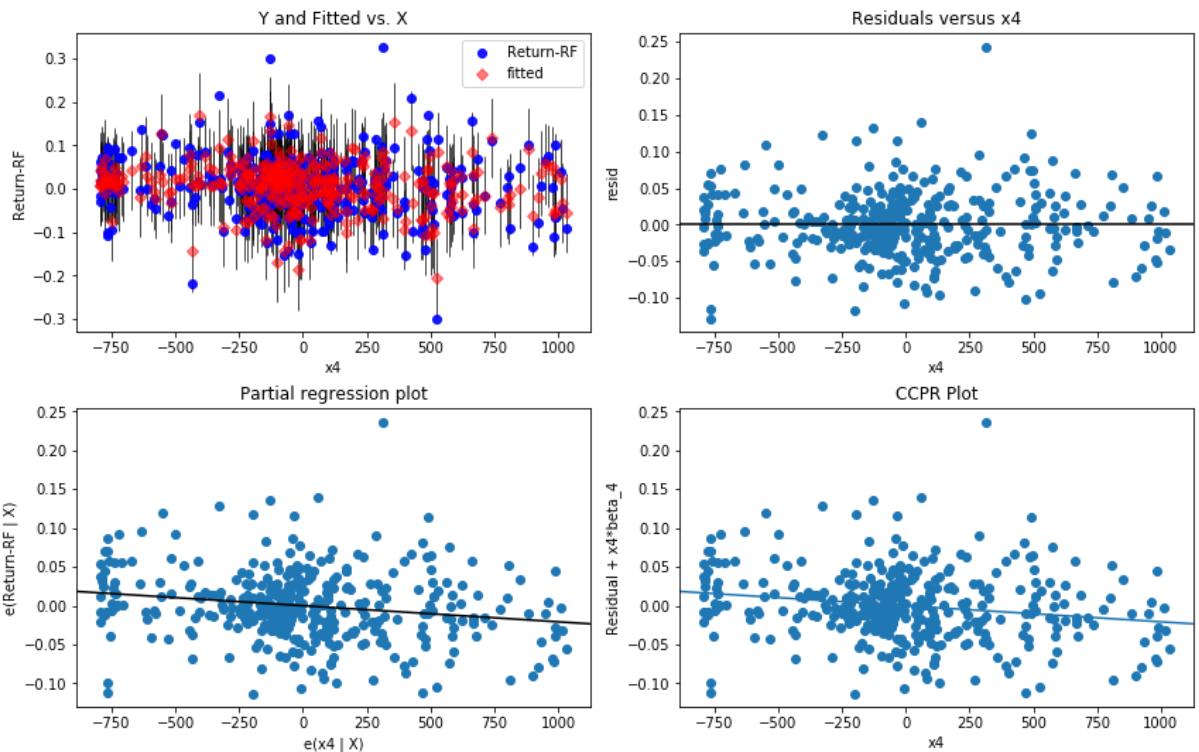
Regression Plots for x3



In [490]...

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x4', fig=fig)
plt.show()
```

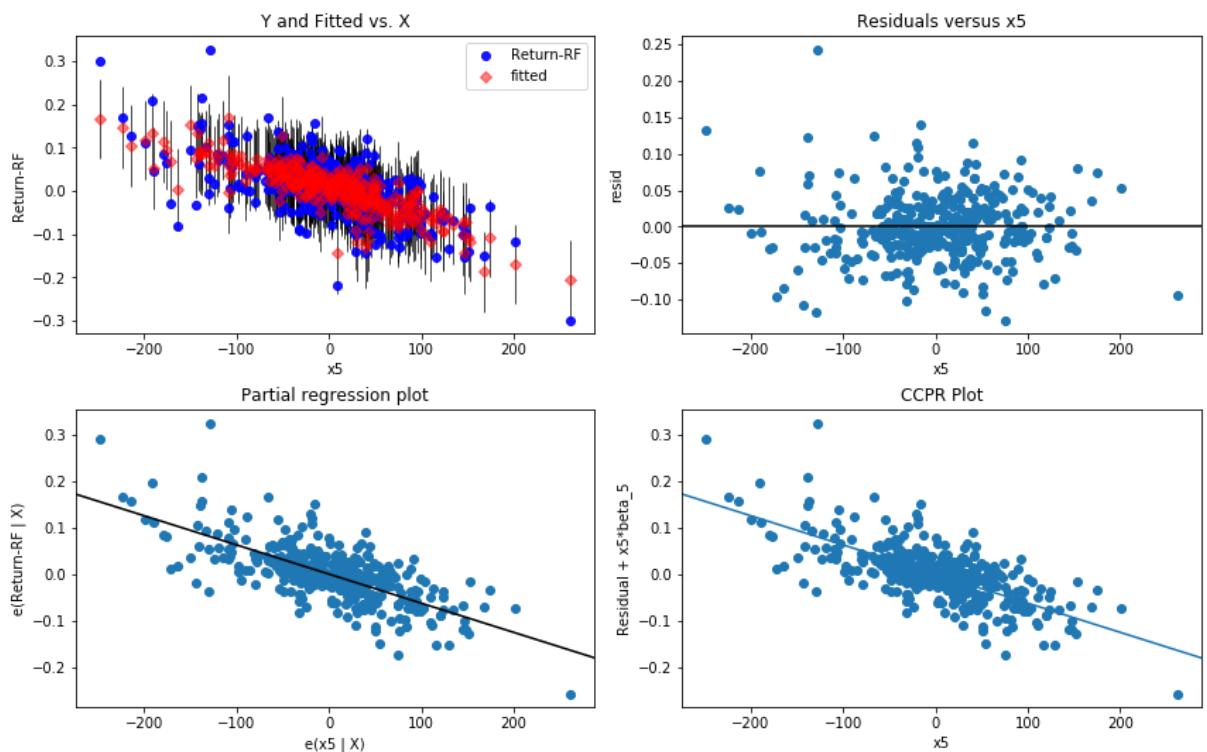
Regression Plots for x4



In [491...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x5', fig=fig)
plt.show()
```

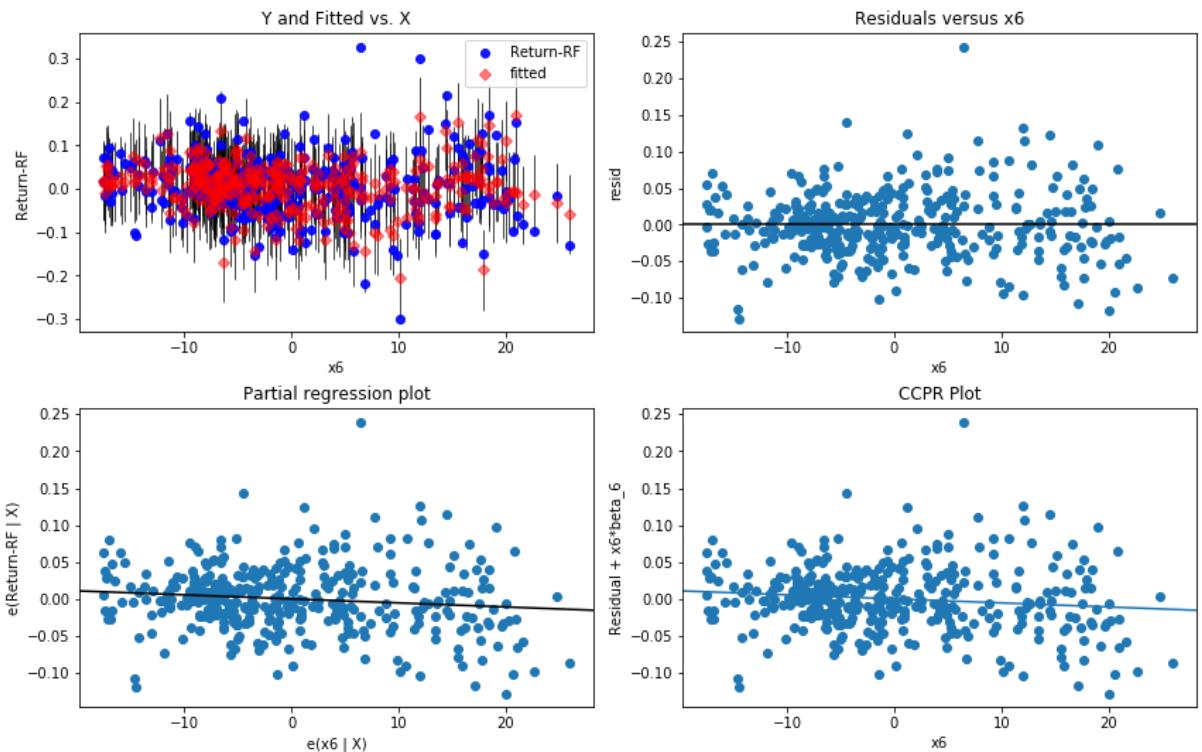
Regression Plots for x5



In [492...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x6', fig=fig)
plt.show()
```

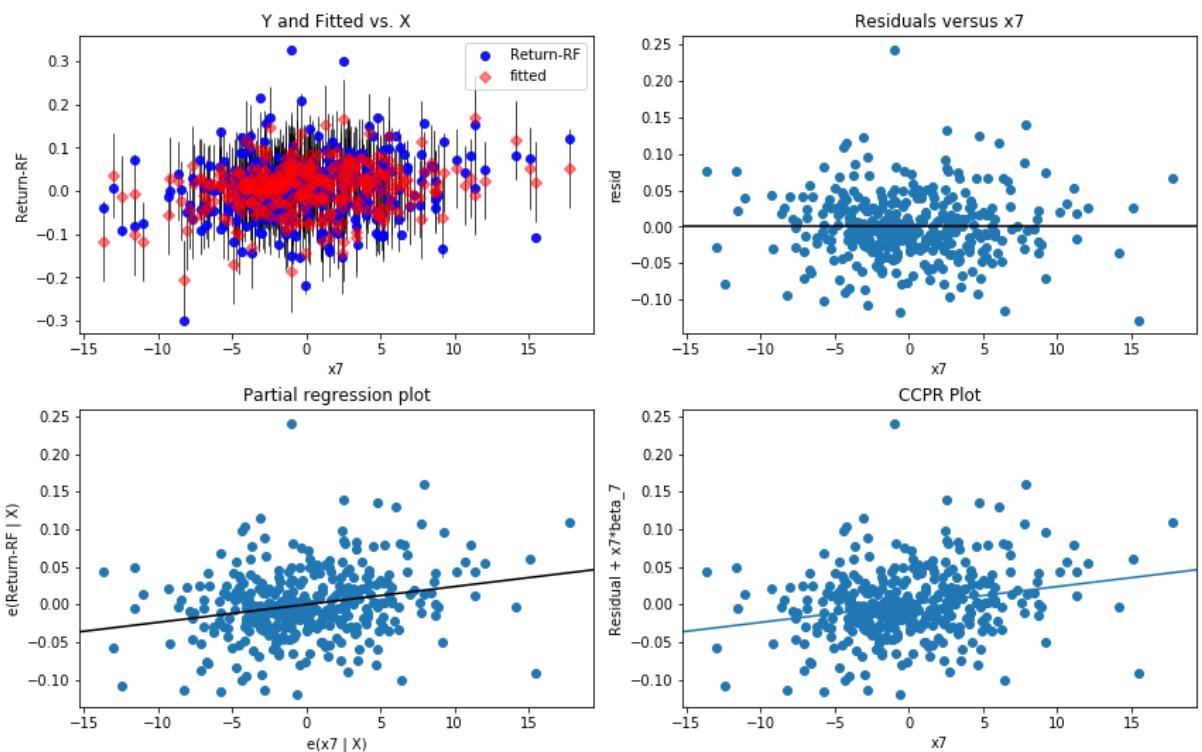
Regression Plots for x6



In [493...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x7', fig=fig)
plt.show()
```

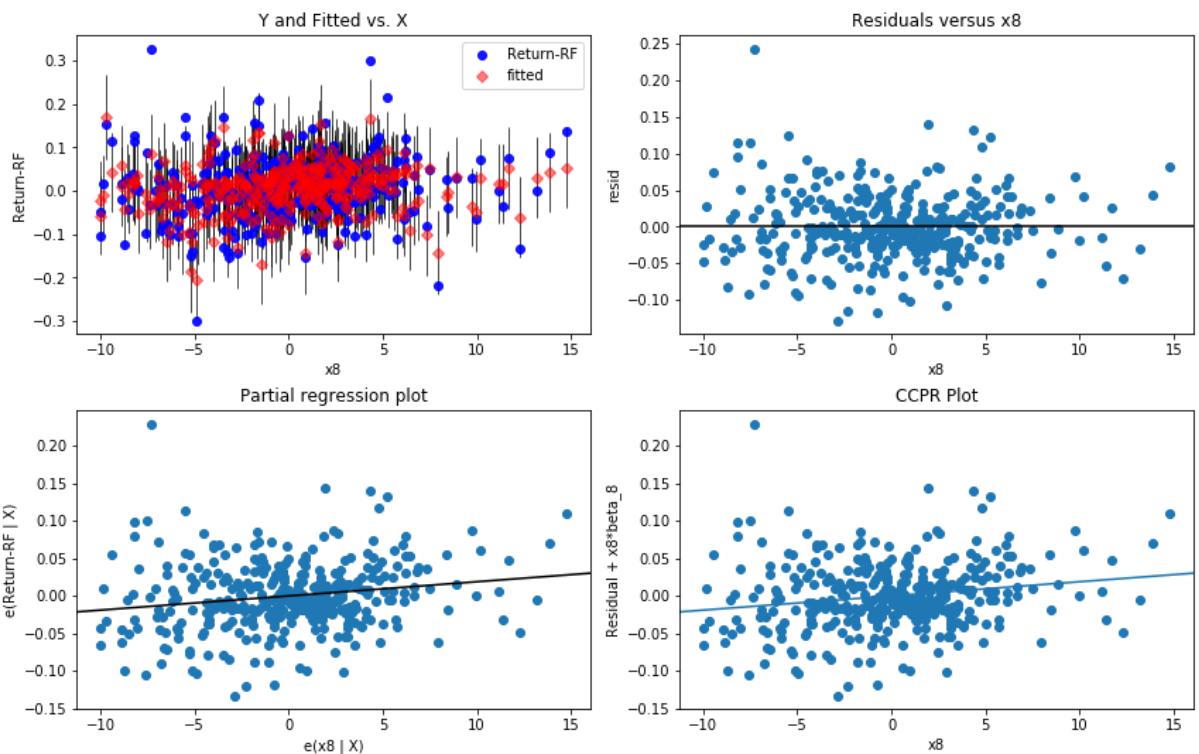
Regression Plots for x7



In [494...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x8', fig=fig)
plt.show()
```

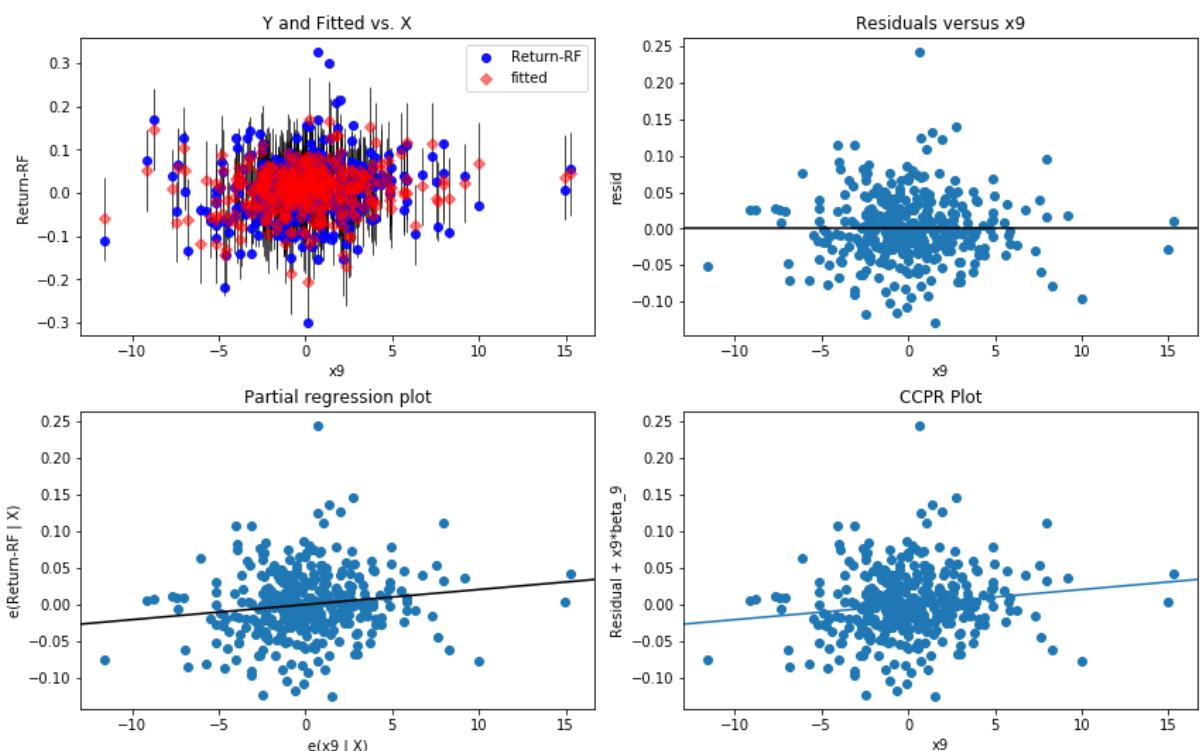
Regression Plots for x8



In [495...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x9', fig=fig)
plt.show()
```

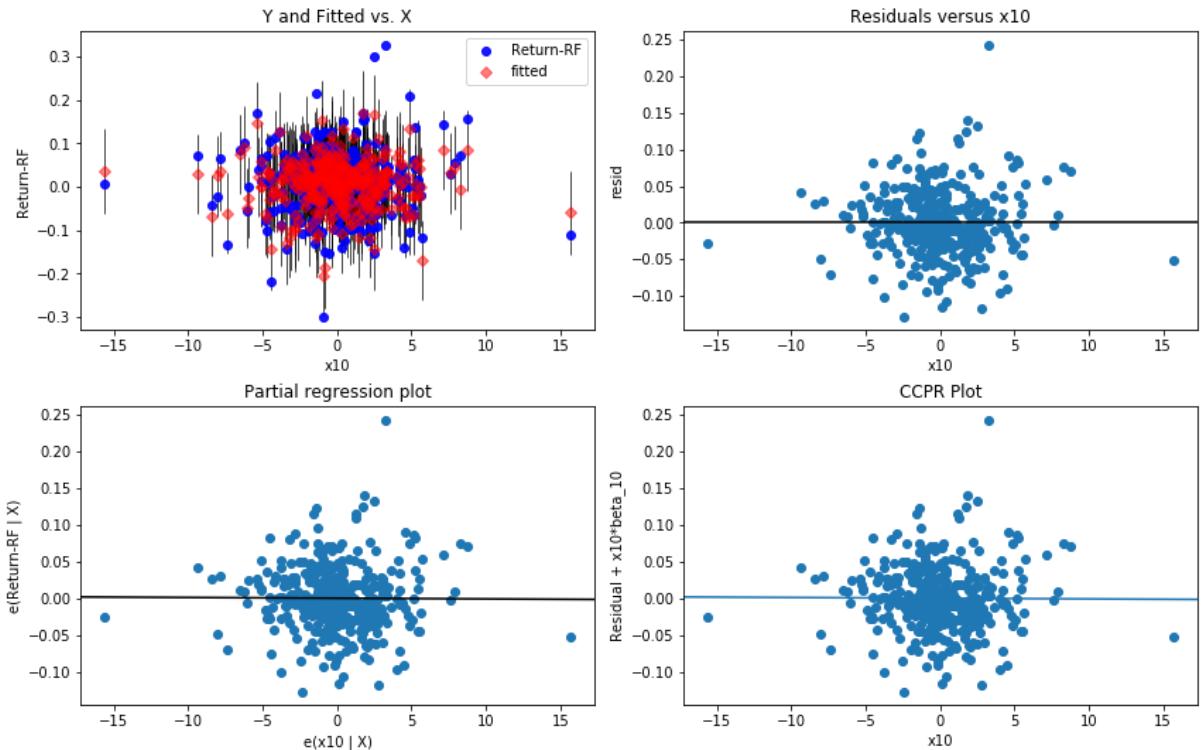
Regression Plots for x9



In [496...]

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x10', fig=fig)
plt.show()
```

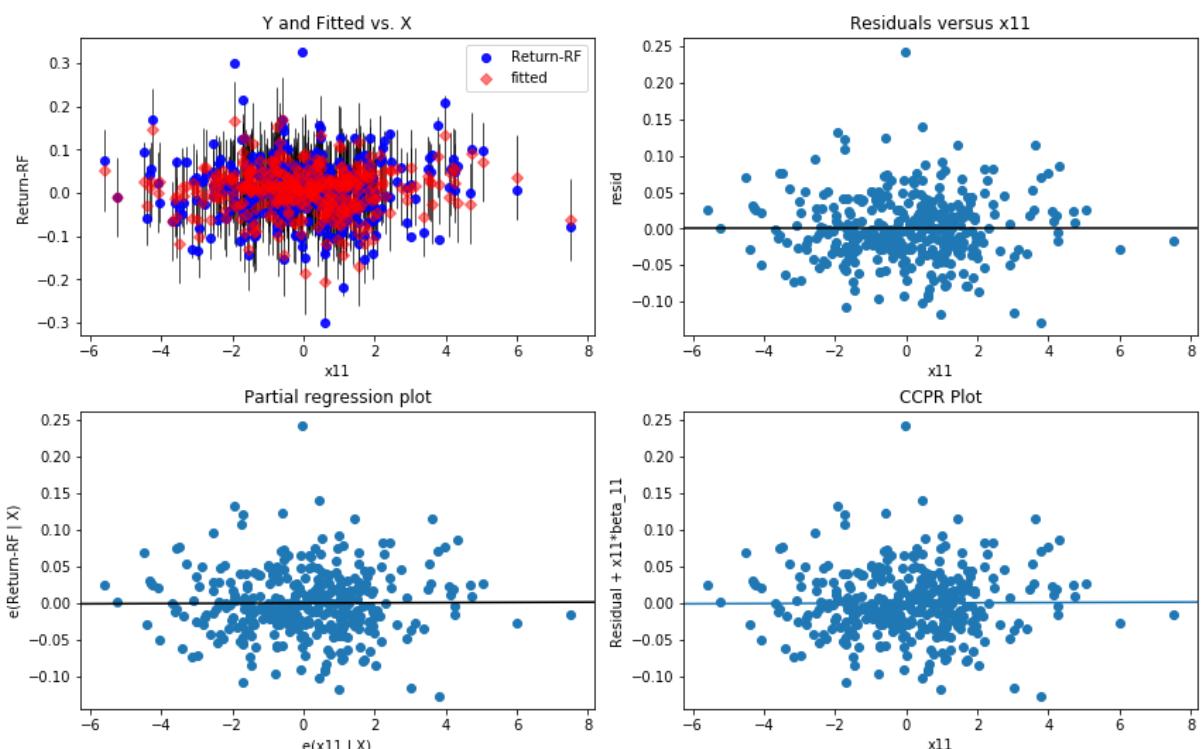
Regression Plots for x10



In [497]:

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x11', fig=fig)
plt.show()
```

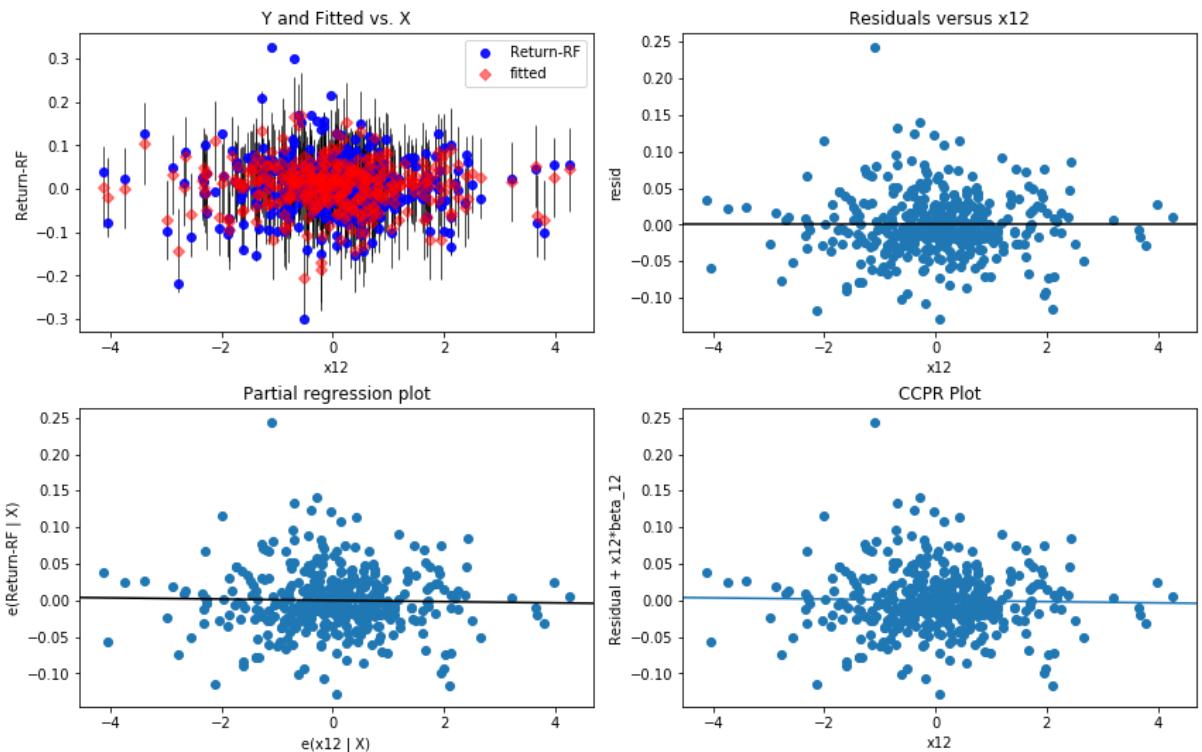
Regression Plots for x11



In [498]:

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x12', fig=fig)
plt.show()
```

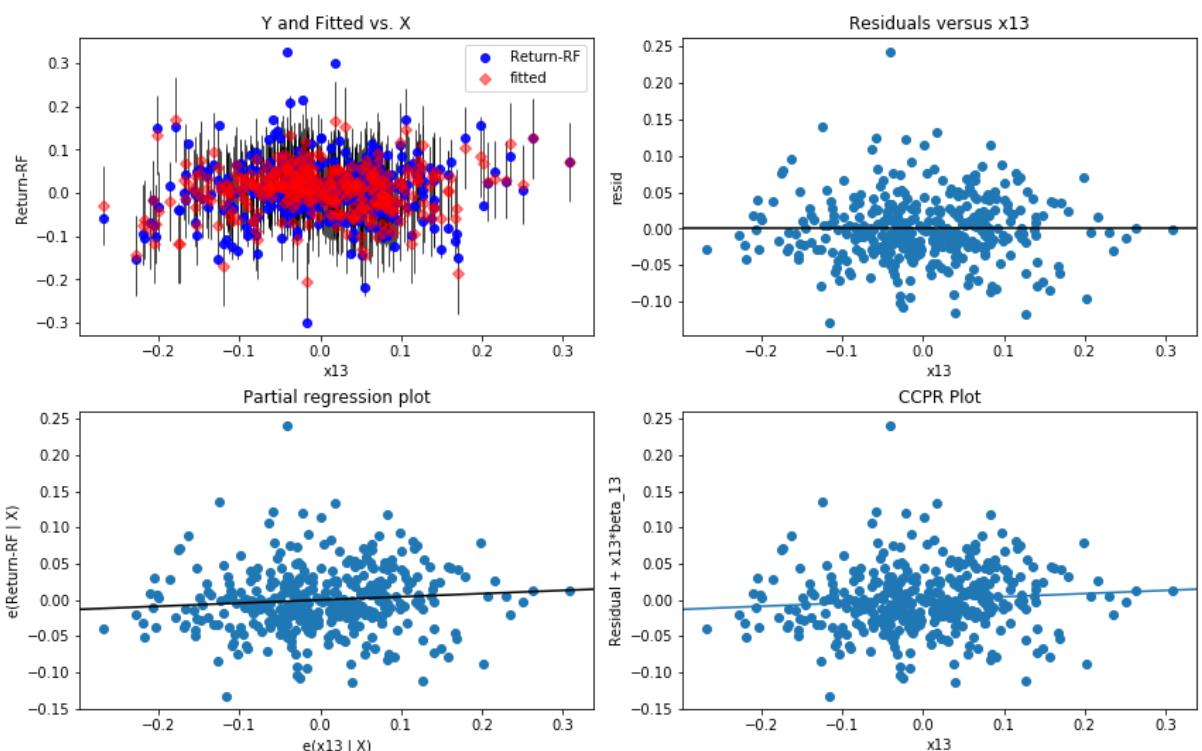
Regression Plots for x12



In [499]:

```
fig = plt.figure(figsize = (12, 8))
fig = sm.graphics.plot_regress_exog(lm5, 'x13', fig=fig)
plt.show()
```

Regression Plots for x13



In []:

In []:

In []:

In [500...]

```
features = ['Mkt-RF', 'SMB', 'HML', 'RMW', 'CMA', 'MACD', 'MACDH', 'ADX', 'RS']
BTC.drop(columns = features, inplace=True)
BTC
```

Out[500...]

	Open	High	Low	Close	RF	Return-RF
Date						
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349
1990-04-30	2948.000000	3137.000000	2906.000000	3132.000000	0.69	0.062415
...
2020-05-31	23539.910156	25303.779297	23539.910156	24427.189453	0.01	0.037693
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	0.01	0.001294
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	0.01	0.024840
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	0.01	-0.064843
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	0.01	0.002830
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	0.01	0.085136

372 rows × 7 columns

In [501...]

```
features = []
for i in range(X_transform.shape[1]):
    name = 'x' + str(i)
    features.append(name)
features
```

Out[501...]

['x0',
 'x1',

```
'x2',
'x3',
'x4',
'x5',
'x6',
'x7',
'x8',
'x9',
'x10',
'x11',
'x12']
```

In [502...]

```
for idx, i in enumerate(features):
    BTC[i] = X_transform[:,idx]
BTC
```

Out[502...]

	Open	High	Low	Close	RF	Return-RF
Date						
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349
1990-04-30	2948.000000	3137.000000	2906.000000	3132.000000	0.69	0.062415
...
2020-05-31	23539.910156	25303.779297	23539.910156	24427.189453	0.01	0.037693
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	0.01	0.001294
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	0.01	0.024840
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	0.01	-0.064843
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	0.01	0.002830
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	0.01	0.085136

372 rows × 20 columns

In [503...]

```
pd.options.display.max_rows, pd.options.display.max_columns = len(features)

# VIF dataframe
vif_data = pd.DataFrame()
vif_data["feature"] = BTC[features].columns

# calculating VIF for each feature
vif_data["VIF"] = [variance_inflation_factor(BTC[features].values, i)
                  for i in range(len(BTC[features].columns))]

vif_data
```

Out[503...]

	feature	VIF
0	x0	1.0
1	x1	1.0
2	x2	1.0
3	x3	1.0
4	x4	1.0
5	x5	1.0
6	x6	1.0
7	x7	1.0
8	x8	1.0
9	x9	1.0
10	x10	1.0
11	x11	1.0
12	x12	1.0

Time Series Modeling, ARIMA (p,d,q) parameter analysis and estimation

In [504...]

```
X = BTC[features]
# X = pca.transform(X)
X
```

Out[504...]

Date	x0	x1	x2	x3	x4	
1989-11-30	-2.122386e+11	-1.833889e+10	-253.193132	-788.023534	38.176064	-16.51
1989-12-31	-2.122386e+11	-1.833889e+10	-245.825102	-793.259264	47.789784	-16.88
1990-01-31	-2.122386e+11	-1.833889e+10	-226.675412	-789.750181	34.041898	-17.26

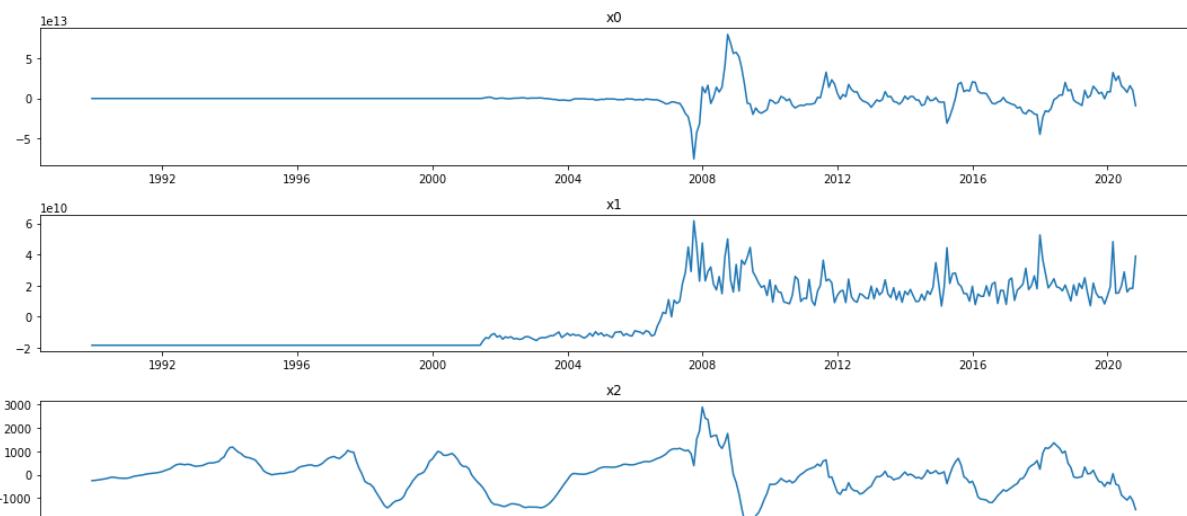
Date	x0	x1	x2	x3	x4	
1990-02-28	-2.122386e+11	-1.833889e+10	-206.076407	-791.738408	35.551938	-17.59
1990-03-31	-2.122386e+11	-1.833889e+10	-192.896097	-795.954085	43.105057	-17.39
1990-04-30	-2.122386e+11	-1.833889e+10	-170.595850	-793.844831	32.029658	-17.16
...
2020-05-31	1.561940e+13	1.982293e+10	-871.345485	-61.632578	-51.394104	0.74
2020-06-30	1.218778e+13	2.883502e+10	-980.949170	-253.493153	-38.011775	2.56
2020-07-31	7.486491e+12	1.596949e+10	-1084.939509	59.525367	-56.987926	0.81
2020-08-31	1.586930e+13	1.831673e+10	-922.731351	-58.583742	39.256792	4.53
2020-09-30	1.006827e+13	1.822124e+10	-1102.483572	-62.500751	2.332556	4.46
2020-10-31	-9.346239e+12	3.901618e+10	-1490.112650	-383.183314	-35.092974	5.59

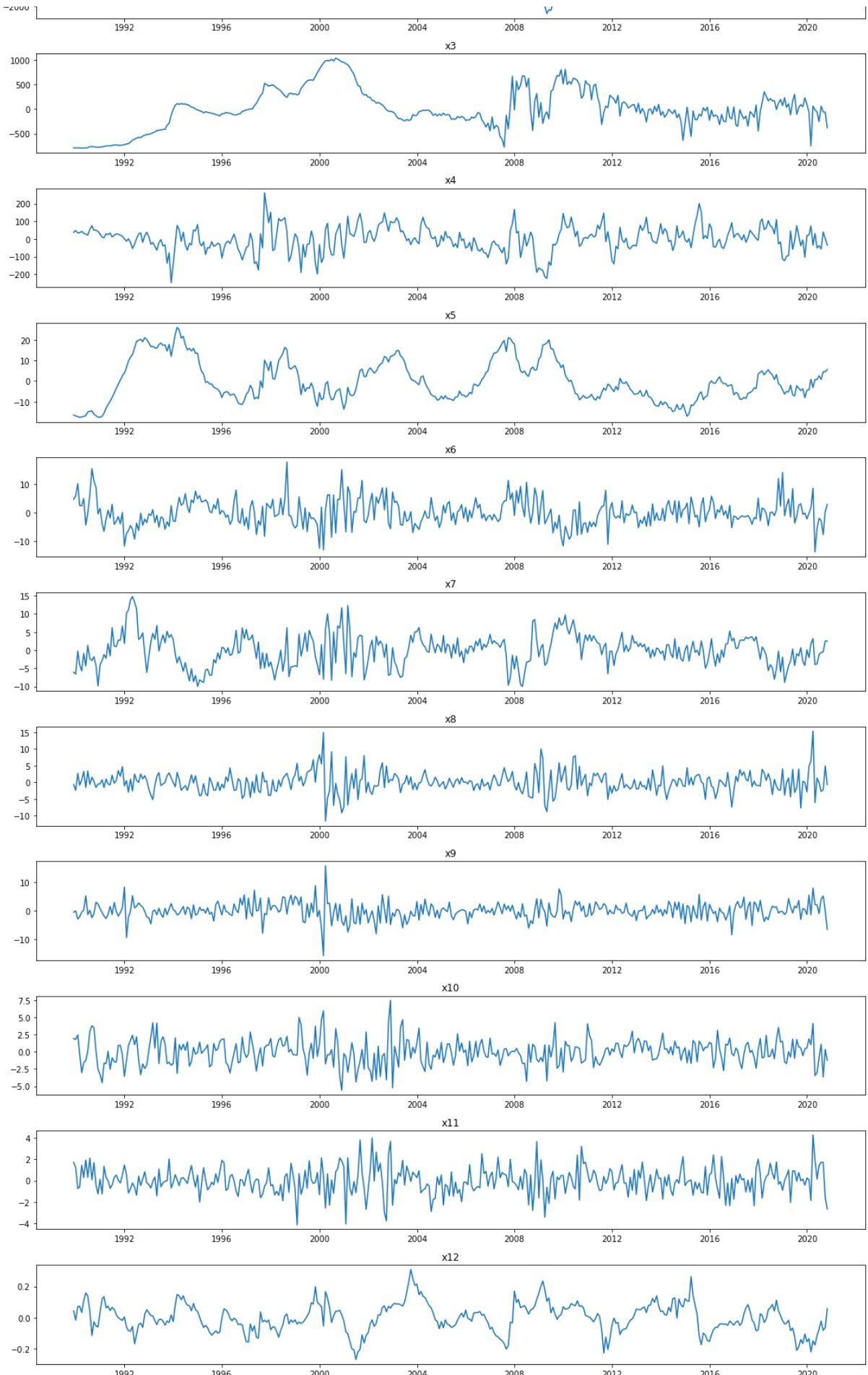
372 rows × 13 columns

In [505]:

```
fig, axs = plt.subplots(len(features), figsize=(15,30))
for idx, i in enumerate(features):
    axs[idx].plot(X[i])
    axs[idx].set_title(i)
    figsize=(15,10)

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





In [506]:

```
from statsmodels.graphics.tsaplots import plot_acf
from statsmodels.graphics.tsaplots import plot_pacf
from matplotlib import pyplot
```

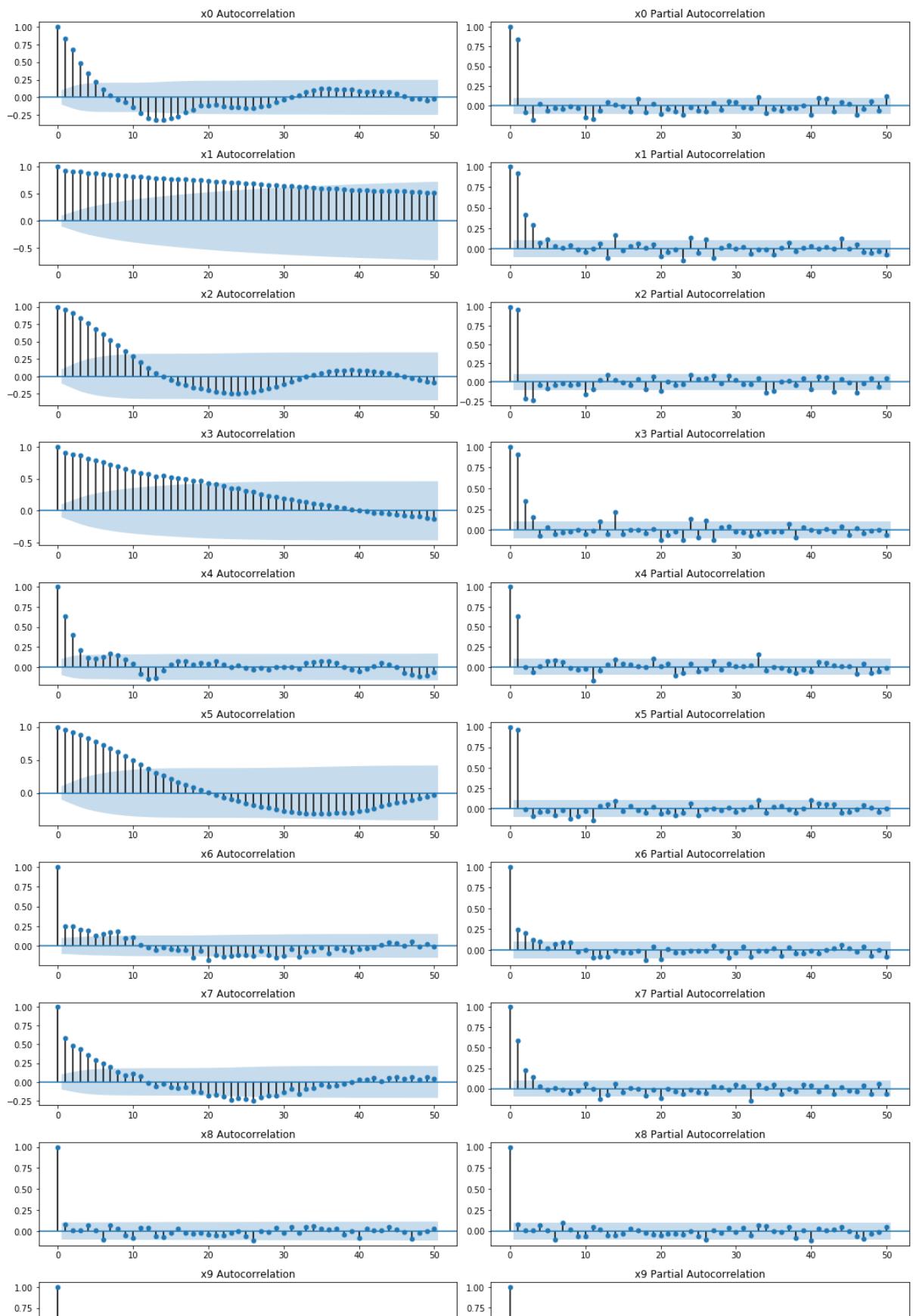
```

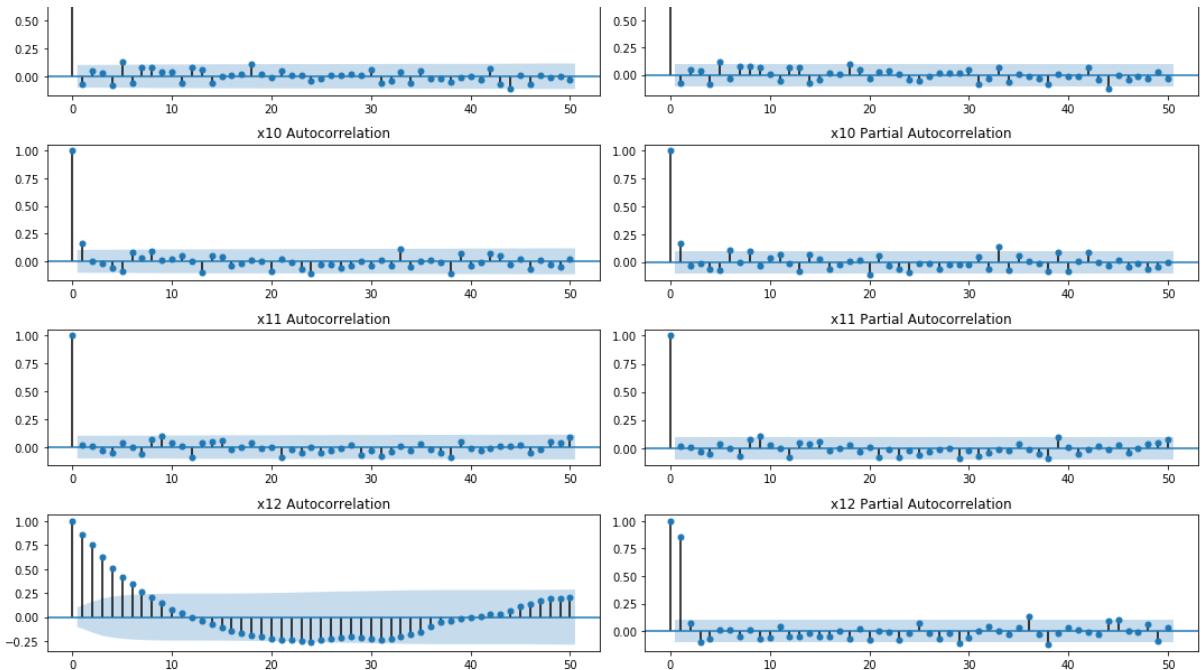
fig, axes = plt.subplots(len(features), 2, figsize=(15,30))

for idx, i in enumerate(features):
    plot_acf(X[i], lags=50, title = i + ' Autocorrelation', ax=axes[idx][0])
    plot_pacf(X[i], lags=50, title = i + ' Partial Autocorrelation', ax=axes[idx][1])

fig.tight_layout()
pyplot.show()

```





Workflow Demonstration on feature-x5

ARIMA(p, d, q) parameter analysis and estimation

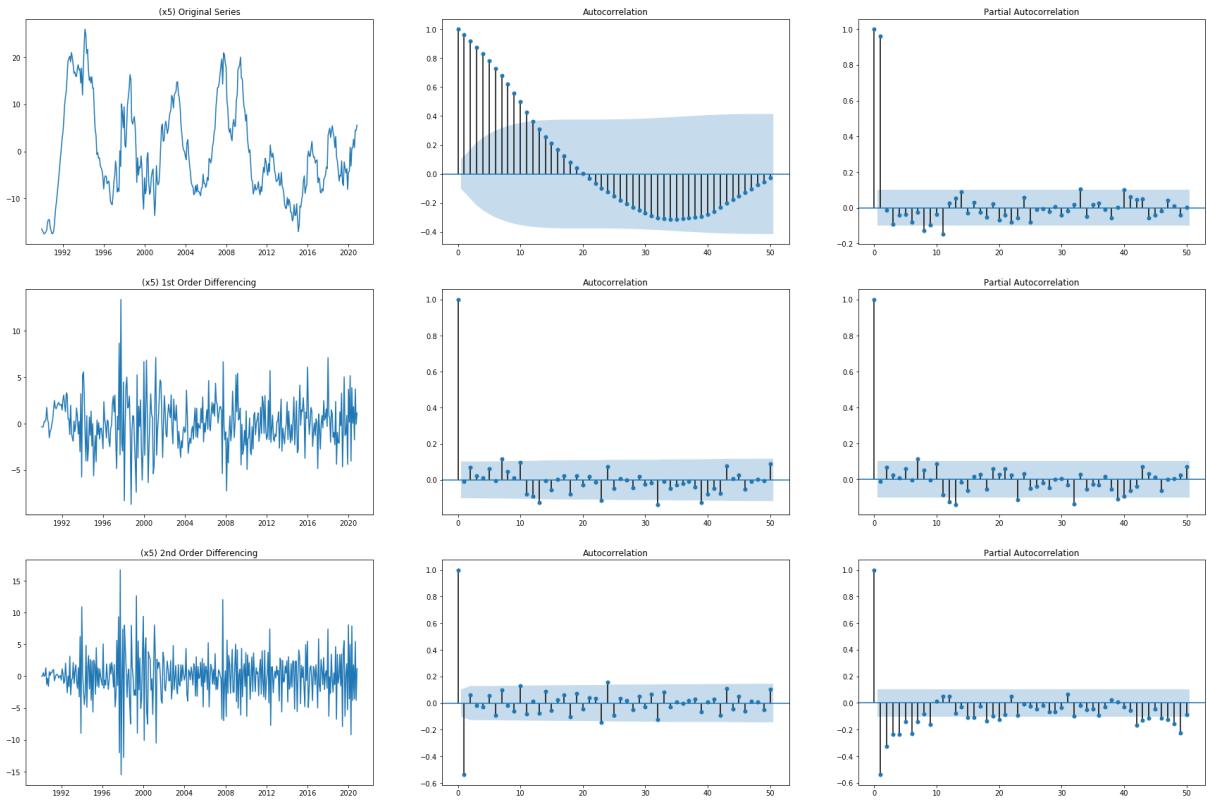
In [507...]

```
# Analysis on the d-term of ARIMA(p,d,q)
fig, axes = plt.subplots(3, 3, figsize=(30,20))
axes[0, 0].plot(X['x5']); axes[0, 0].set_title('(x5) Original Series')
plot_acf(X['x5'], lags=50, ax=axes[0, 1])
plot_pacf(X['x5'], lags=50, ax=axes[0, 2])

# 1st Differencing
axes[1, 0].plot(X['x5'].diff()); axes[1, 0].set_title('(x5) 1st Order')
plot_acf(X['x5'].diff().dropna(), lags=50, ax=axes[1, 1])
plot_pacf(X['x5'].diff().dropna(), lags=50, ax=axes[1, 2])

# 2nd Differencing
axes[2, 0].plot(X['x5'].diff().diff()); axes[2, 0].set_title('(x5) 2nd Order')
plot_acf(X['x5'].diff().diff().dropna(), lags=50, ax=axes[2, 1])
plot_pacf(X['x5'].diff().diff().dropna(), lags=50, ax=axes[2, 2])

plt.show()
```



In [508...]

```
# estimate the d-term of ARIMA(p,d,q)
import pmdarima
from pmdarima.arima.utils import ndiffs

## Adf Test
print('ADF: ', ndiffs(X['x5'], test='adf'))

# KPSS test
print('KPSS: ', ndiffs(X['x5'], test='kpss') )

# PP test:
print('PP: ', ndiffs(X['x5'], test='pp'))
```

ADF: 0
 KPSS: 0
 PP: 1

In [509...]

```
# estimate the p,d,q-term of ARIMA(p,d,q)
arima_order = pmdarima.arima.auto_arima(X['x5'])
arima_order
```

Out[509...]: ARIMA(order=(3, 0, 1), scoring_args={}, suppress_warnings=True, with_intercept=False)

In [510...]

```
model = pmdarima.arima.AutoARIMA()
model_fit = model.fit(X['x5'])
model_predict = model_fit.predict_in_sample(X['x5'])
model_fit.summary()
```

Out[510...]

SARIMAX Results

Dep. Variable:

y No. Observations:

372

Model: SARIMAX(3, 0, 1) **Log Likelihood** -883.345

Date: Thu, 22 Apr 2021 **AIC** 1776.690

Time: 00:25:35 **BIC** 1796.284

Sample: 0
- 372

Covariance Type: opg

	coef	std err	z	P> z	[0.025	0.975]
ar.L1	1.8633	0.059	31.465	0.000	1.747	1.979
ar.L2	-0.8000	0.098	-8.166	0.000	-0.992	-0.608
ar.L3	-0.0703	0.045	-1.549	0.121	-0.159	0.019
ma.L1	-0.9224	0.042	-21.770	0.000	-1.005	-0.839
sigma2	6.7086	0.359	18.705	0.000	6.006	7.412

Ljung-Box (L1) (Q): 0.00 Jarque-Bera (JB): 78.17

Prob(Q): 0.95 Prob(JB): 0.00

Heteroskedasticity (H): 0.55 Skew: 0.35

Prob(H) (two-sided): 0.00 Kurtosis: 5.13

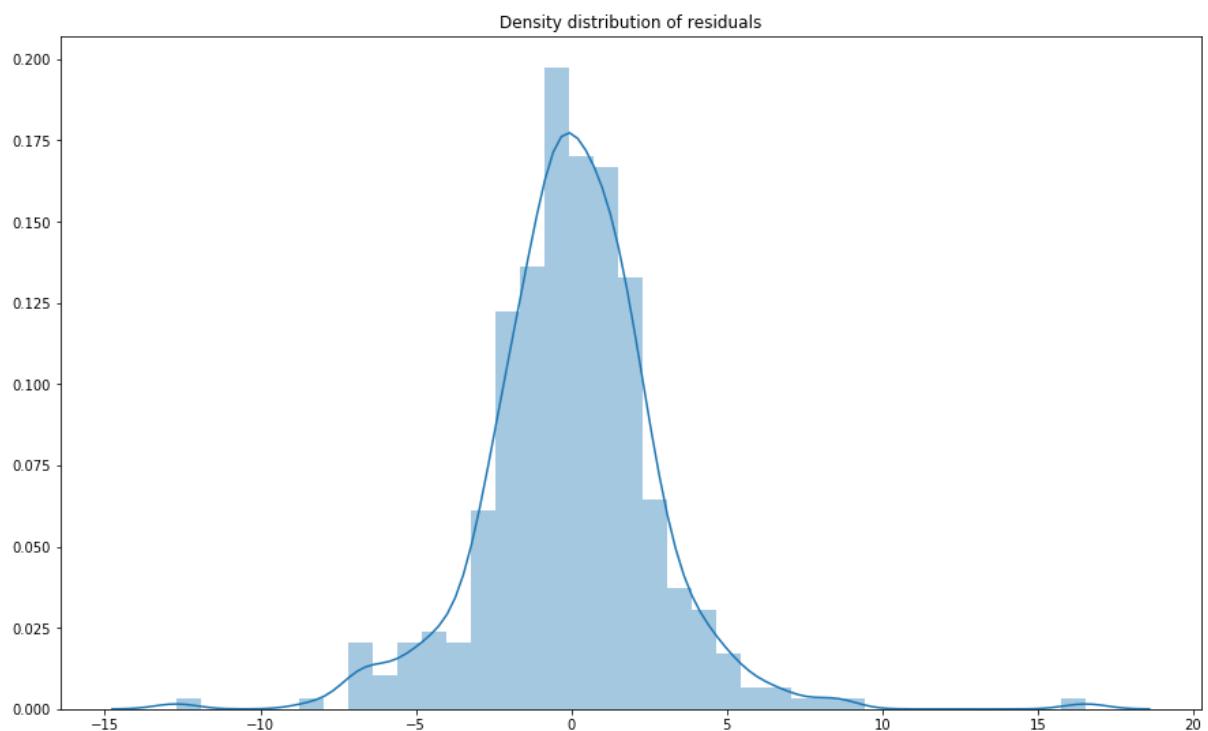
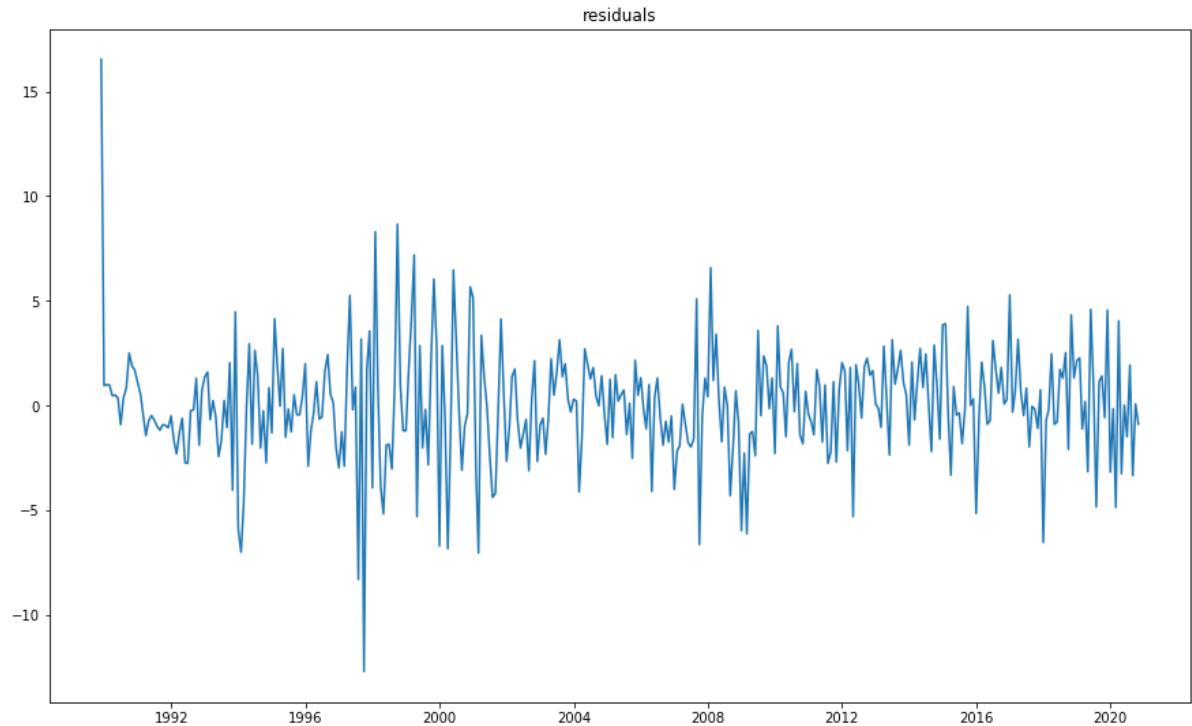
Warnings:

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

In [511...]

```
# Plot residual errors of the ARIMA model
residuals = pd.DataFrame(model_predict - x['x5'])
fig, ax = plt.subplots(2, 1, figsize=(15,20))
ax[0].set_title('residuals')
ax[0].plot(residuals)
ax[1].set_title('Density distribution of residuals')
sns.distplot(residuals, ax=ax[1])
```

Out[511...]: <matplotlib.axes._subplots.AxesSubplot at 0x12e227c18>

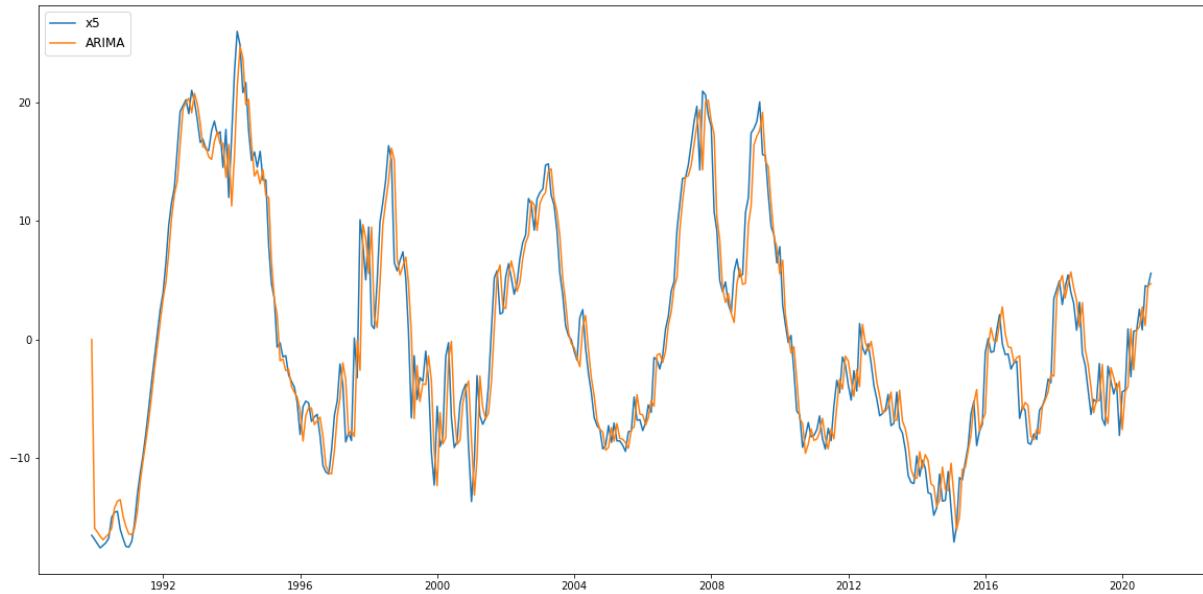


The residual errors seem fine with near zero mean and normal distributed. Let's plot the actuals against the fitted values using `plot_predict()`.

In [512...]

```
# Actual vs Fitted
plt.figure(figsize=(20,10))
plt.plot(X['x5'].index, X['x5'], label='x5')
plt.plot(X['x5'].index, model_predict, label='ARIMA')
plt.legend(loc='upper left', fontsize=12)
```

Out[512...]: <matplotlib.legend.Legend at 0x131cac860>



The code below use a different library - statsmodels

In [513]:

```
# from statsmodels.tsa.arima_model import ARIMA
# model = ARIMA(X['x6'], order=(1,0,1))
# model_fit = model.fit(disp=0)
# print(model_fit.summary())
```

In [514]:

```
# # Plot residual errors of the ARIMA model
# residuals = pd.DataFrame(model_fit.resid)
# fig, ax = plt.subplots(2, 1, figsize=(15,20))
# ax[0].set_title('residuals')
# ax[0].plot(residuals)
# ax[1].set_title('Density distribution of residuals')
# sns.distplot(residuals, ax=ax[1])
```

In [515]:

```
# # Actual vs Fitted
# plt.figure(figsize=(20,10))
# plt.plot(X['x6'], label='x6')
# plt.plot(model_fit.predict(), label='ARIMA')
# plt.legend(loc='upper left', fontsize=12)
```

In []:

ARIMA modeling on all features

In [516]:

```
X = BTC[features]
# X = pca.transform(X)
X
```

Out[516]:

Date

x0

x1

x2

x3

x4

Date	x0	x1	x2	x3	x4	
1989-11-30	-2.122386e+11	-1.833889e+10	-253.193132	-788.023534	38.176064	-16.53
1989-12-31	-2.122386e+11	-1.833889e+10	-245.825102	-793.259264	47.789784	-16.88
1990-01-31	-2.122386e+11	-1.833889e+10	-226.675412	-789.750181	34.041898	-17.26
1990-02-28	-2.122386e+11	-1.833889e+10	-206.076407	-791.738408	35.551938	-17.59
1990-03-31	-2.122386e+11	-1.833889e+10	-192.896097	-795.954085	43.105057	-17.31
1990-04-30	-2.122386e+11	-1.833889e+10	-170.595850	-793.844831	32.029658	-17.16
...
2020-05-31	1.561940e+13	1.982293e+10	-871.345485	-61.632578	-51.394104	0.74
2020-06-30	1.218778e+13	2.883502e+10	-980.949170	-253.493153	-38.011775	2.58
2020-07-31	7.486491e+12	1.596949e+10	-1084.939509	59.525367	-56.987926	0.81
2020-08-31	1.586930e+13	1.831673e+10	-922.731351	-58.583742	39.256792	4.53
2020-09-30	1.006827e+13	1.822124e+10	-1102.483572	-62.500751	2.332556	4.46
2020-10-31	-9.346239e+12	3.901618e+10	-1490.112650	-383.183314	-35.092974	5.59

372 rows × 13 columns

In [517...]

```

for i in features:
    model = pmдарима.арима.AutoARIMA()
    model_fit = model.fit(X[i])
    model_predict = model_fit.predict_in_sample(X[i])
    X[i] = model_predict

```

X

Out[517...]

Date	x0	x1	x2	x3	x4
1989-11-30	-7.536924e+11	0.000000e+00	0.000000	0.000000	0.000000

Date	x0	x1	x2	x3	x4	
1989-12-31	-3.012409e+11	-1.026783e+10	-245.044238	-779.499525	24.112443	-15.934
1990-01-31	-3.091808e+11	-1.393347e+10	-233.764803	-787.736644	30.184579	-16.274
1990-02-28	-3.274205e+11	-1.578702e+10	-209.058209	-790.379537	21.501255	-16.611
1990-03-31	-3.256557e+11	-1.683151e+10	-186.184164	-791.481732	22.455014	-16.910
1990-04-30	-3.368477e+11	-1.744244e+10	-174.884168	-793.673510	27.225651	-16.666
...
2020-05-31	1.926961e+13	1.996844e+10	-556.196885	-130.176877	19.666785	0.751
2020-06-30	1.308078e+13	1.990979e+10	-927.310820	-26.558050	-32.461109	1.051
2020-07-31	5.441472e+12	2.350734e+10	-1061.029931	-157.626304	-24.008676	2.736
2020-08-31	4.695536e+12	2.046901e+10	-1079.366662	-47.290660	-35.994232	1.189
2020-09-30	1.014213e+13	1.960148e+10	-867.555417	-62.592288	24.795043	4.53
2020-10-31	6.772577e+12	1.904514e+10	-1042.255916	-38.971382	1.473269	4.70

372 rows × 13 columns

In [518...]

```

new_features = []
for i in features:
    if np.all(X[i] == 0):
        pass
    else:
        new_features.append(i)

features = new_features.copy()
features

```

Out[518...]: ['x0', 'x1', 'x2', 'x3', 'x4', 'x5', 'x6', 'x7', 'x9', 'x10', 'x12']

In [519...]

```

for i in features:
    BTC[i] = X[i]

BTC

```

Out[519...]

	Open	High	Low	Close	RF	Return-RF
Date						
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349
1990-04-30	2948.000000	3137.000000	2906.000000	3132.000000	0.69	0.062415
...
2020-05-31	23539.910156	25303.779297	23539.910156	24427.189453	0.01	0.037693
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	0.01	0.001294
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	0.01	0.024840
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	0.01	-0.064843
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	0.01	0.002830
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	0.01	0.085136

372 rows × 20 columns

In []:

In [520...]

```
target = ['Return-RF']

X = BTC[features]
Y = BTC[target]

model = linear_model.LinearRegression()
model.fit(X, Y)
Y_Pred = model.predict(X)
```

In [521...]

```
r2_score(Y, Y_Pred)
```

Out[521... 0.08567319602093315

In [522...]

```
# Specify the matrices
X = sm.add_constant(BTC[features])
y = BTC[target]
lm4 = sm.OLS(y,X).fit()
# Show results
print(lm4.summary())
```

OLS Regression Results

```
=====
=====
Dep. Variable: Return-RF   R-squared: 0.086
Model: OLS                 Adj. R-squared: 0.058
Method: Least Squares     F-statistic: 3.067
Date: Thu, 22 Apr 2021    Prob (F-statistic): 0.000601
Time: 00:26:00              Log-Likelihood: -936.3
No. Observations: 372      AIC: 360
Df Residuals:             BIC: -889.3
Df Model: 11
Covariance Type: nonrobust
=====
```

	coef	std err	t	P> t	[0.025
0.975]					
const	0.0074	0.004	2.103	0.036	0.000
0.014					
x0	2.122e-16	3.41e-16	0.623	0.534	-4.58e-16
8.82e-16					
x1	-2.289e-13	1.9e-13	-1.205	0.229	-6.02e-13
1.45e-13					
x2	-1.1e-05	4.71e-06	-2.337	0.020	-2.03e-05
1.74e-06					
x3	-3.244e-05	8.85e-06	-3.667	0.000	-4.98e-05
-1.5e-05					
x4	6.249e-05	7.77e-05	0.804	0.422	-9.04e-05
0.000					
x5	0.0007	0.000	1.855	0.064	-4.14e-05
0.001					
x6	0.0017	0.003	0.665	0.507	-0.003
0.007					
x7	0.0036	0.002	2.296	0.022	0.001
0.007					
x9	-0.0100	0.007	-1.436	0.152	-0.024
0.004					
x10	0.0015	0.011	0.135	0.893	-0.020
0.023					
x12	0.0426	0.045	0.956	0.340	-0.045
0.130					

=====

```
Omnibus:           24.192    Durbin-Watson:
1.972
Prob(Omnibus):   0.000    Jarque-Bera (JB):
62.491
Skew:             0.259    Prob(JB):
2.69e-14
Kurtosis:         4.940    Cond. No.
1.33e+14
=====
=====
```

Notes:

- [1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
- [2] The condition number is large, 1.33e+14. This might indicate that there are strong multicollinearity or other numerical problems.

In []:

In []:

Investment Analysis with Extended Factor Modeling (long short strategy with market timing)

In [523...]

```
...
1) Greedy Algorithm + PnL Validation
2) Lasso Regression Algorithm + K-Fold Cross-Validation on PnL
3) Ridge Regression Algorithm + K-Fold Cross-Validation on PnL
4) Elastic Net Regression Algorithm + K-Fold Cross-Validation on PnL
5) Logistic Regression Algorithm (L2 Regularization) + K-Fold Cross-Validation on PnL
6) Support Vector Machine + K-Fold Cross-Validation on PnL
7) Random Forest + K-Fold Cross-Validation on PnL
'''
```

```
Out[523...]: '\n1) Greedy Algorithm + PnL Validation\n2) Lasso Regression Algorithm + K-Fold Cross-Validation on PnL\n3) Ridge Regression Algorithm + K-Fold Cross-Validation on PnL\n4) Elastic Net Regression Algorithm + K-Fold Cross-Validation on PnL\n5) Logistic Regression Algorithm (L2 Regularization) + K-Fold Cross-Validation on PnL\n6) Support Vector Machine + K-Fold Cross-Validation on PnL\n7) Random Forest + K-Fold Cross-Validation on PnL\n'
```

Greedy Algorithm + PnL Validation

In [524...]

```
target = ['Return-RF']
```

In [562...]

```
# compute Capital
def computation(df):
    for i in range(1, len(df)):
```

```

if i == 1:
    df.loc[df.index[i], 'Capital'] = 1
elif df.loc[df.index[i], 'Predicted_Return'] >= 0:
    df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
else:
    df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
return df

```

In [563...]

```

def PnL(data, target, proportion):

    train_sub, valid_sub = train_test_split(data, test_size = proportion)

    # create a linear model
    X_train = train_sub.drop(target, axis = 1)
    Y_train = train_sub[target]
    X_valid = valid_sub.drop(target, axis = 1)
    Y_valid = valid_sub[target]

    model = linear_model.LinearRegression()
    model.fit(X_train, Y_train)
    Y_valid_fit = model.predict(X_valid)

    # a data frame for computing and saving long_short value
    long_short_df = pd.DataFrame({'Return': Y_valid.iloc[:,0].values,
                                  'Predicted_Return': Y_valid_fit.reshape(-1,1),
                                  'Capital': np.zeros(len(valid_sub))},
                                 index = valid_sub.index)

    cols = ['Return', 'Predicted_Return', 'Capital']
    long_short_df = long_short_df[cols]

    # give an initial point
    initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                           columns = long_short_df.columns)

    # combine df and initial point
    long_short_df = pd.concat([initial, long_short_df])

    # compute long_short value
    long_short_df_final = computation(long_short_df)

# return final long_short value of this period
return long_short_df_final.iloc[-1,2]

```

In [564...]

```

def greedy_algo(train_valid, target, proportion):

    # initialize a list to save features
    greedy_select = []

    profit_greedy_algo = np.array([])
    for i in range(len(features)):
        profit = np.array([])
        features_left = list(set(features) - set(greedy_select))

```

```

for new in features_left:
    features_new = greedy_select + [new]
    train_valid_sub = train_valid[features_new + target]

    # CrossValidation, compute the profit and save it into profit
    profit_sub = PnL(train_valid_sub, target, proportion)
    profit = np.append(profit, profit_sub)

    # pick the features that gives the largest profit
    # and add it into our features list
    # meanwhile, save the corresponding profit
    greedy_select += [features_left[profit.argmax()]]
    profit_greedy_algo = np.append(profit_greedy_algo, profit.max())

return greedy_select[: (profit_greedy_algo.argmax() + 1)]

```

In [565...]: randomRange

Out[565...]: 116

6 month investment

```

In [566...]: fix_history_length = 250 # ~21 year
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC) - fix_history_length - fix_test_length
randomRange

```

Out[566...]: 116

```

In [567...]: %%time
# an array for saving 50 final best profit
profit_final = np.array([])

for i in range(sample_size):

    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    features_cv = greedy_algo(train_valid, target, 0.2)

    print('Selected Features: ', features_cv)

    X_cv = train_valid[features_cv]
    Y_cv = train_valid[target]

```

```

X_test_cv = test[features_cv]
Y_test_cv = test[target]

model_cv = linear_model.LinearRegression()
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(-1, 1),
                               'Predicted_Return': Y_test_cv_fit.reshape(-1, 1),
                               'Capital': np.zeros(len(Y_test_cv))})
index = Y_test_cv.index

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0, 0, 1]).reshape(-1, 3),
                        columns=long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1, :])

profit_final = (profit_final - 1) * 100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

```

Selected Features: ['x5', 'x3', 'x10', 'x12']
Selected Features: ['x0', 'x3', 'x2', 'x10']
Selected Features: ['x4', 'x12', 'x10', 'x9', 'x5', 'x1', 'x7', 'x3',
                    'x2', 'x0', 'x6']
Selected Features: ['x5', 'x3', 'x1', 'x6', 'x0']
Selected Features: ['x3', 'x9', 'x10', 'x12', 'x4', 'x0', 'x7', 'x5']
Selected Features: ['x2']
Selected Features: ['x2', 'x3', 'x0', 'x10']
Selected Features: ['x4', 'x7', 'x10', 'x1', 'x2', 'x6', 'x9', 'x3',
                    'x12', 'x5']
Selected Features: ['x4', 'x5', 'x7']
Selected Features: ['x3', 'x7', 'x12', 'x9', 'x4', 'x10', 'x2', 'x1',
                    'x5']
Selected Features: ['x2', 'x5', 'x4', 'x7', 'x3', 'x10', 'x1', 'x12',
                    'x6', 'x0']
Selected Features: ['x6', 'x7', 'x2', 'x3', 'x4', 'x1', 'x10', 'x9',
                    'x12']
Selected Features: ['x10', 'x7', 'x12', 'x3', 'x1', 'x0', 'x6', 'x5']
Selected Features: ['x3', 'x0', 'x5', 'x6', 'x2', 'x7', 'x1']
Selected Features: ['x5', 'x4', 'x6', 'x3', 'x2']
Selected Features: ['x2', 'x4', 'x3', 'x5']
Selected Features: ['x7', 'x10', 'x5', 'x0', 'x2', 'x3', 'x6', 'x12'],

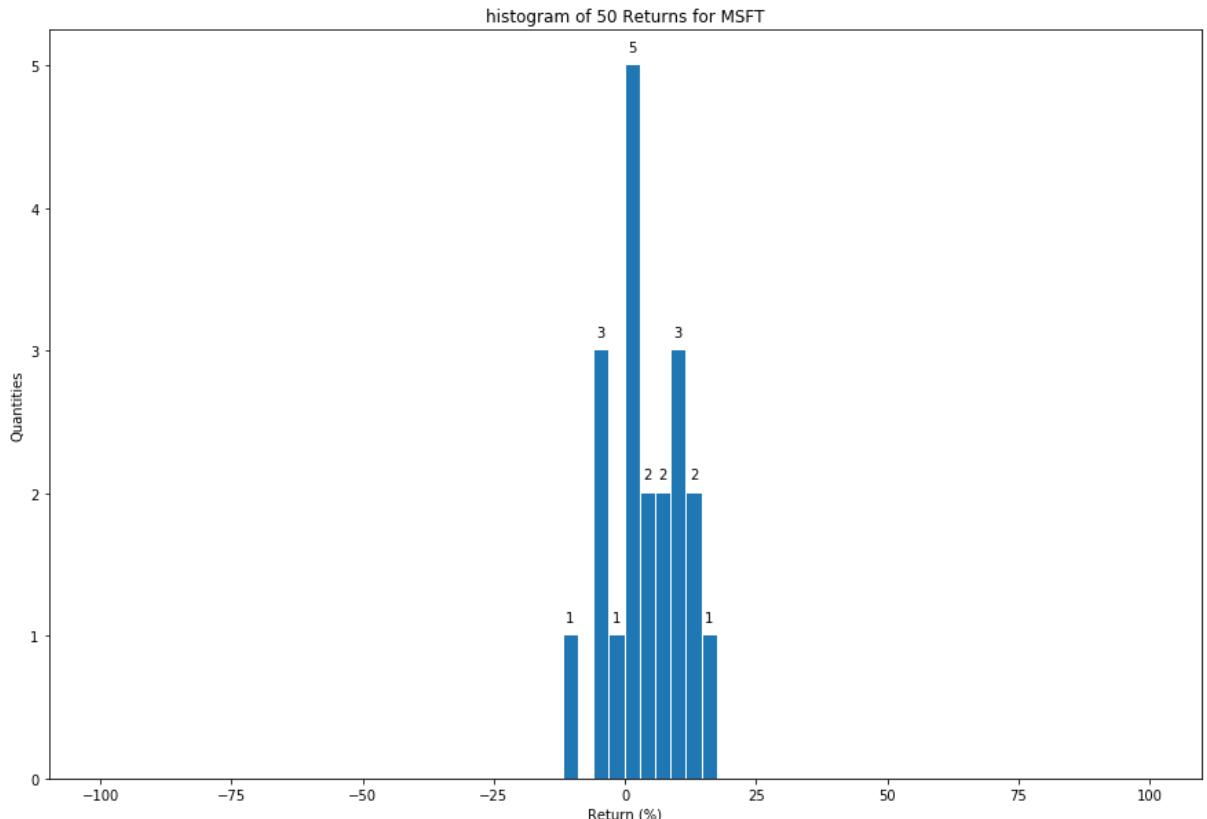
```

```
'x9']
Selected Features: ['x7', 'x5', 'x4', 'x6', 'x10', 'x1', 'x3', 'x2']
Selected Features: ['x1', 'x7', 'x3', 'x12', 'x2', 'x6', 'x4']
Selected Features: ['x7', 'x4', 'x10', 'x5', 'x12', 'x3', 'x1', 'x0',
'x9']
Returns :
4%, -6%, 8%, -1%, 1%, -11%, -5%, 10%, -5%, 8%, 2%, 3%, 1%, 15%, 11%,
4%, 10%, 15%, 2%, 13%, Maximum Return: 15.0
Minimum Return: -11.0
Average Return: 4.0
Standard Deviation: 7.0
320 training days
80 validation days
100 test days
CPU times: user 40.5 s, sys: 346 ms, total: 40.9 s
Wall time: 44.7 s
```

In [568]:

```
fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')
```

Out[568]: Text(0, 0.5, 'Quantities')



In []:

In []:

10 Year Investment

In [569...]

```
fix_history_length = 250 # 21 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[569...]

2

In [570...]

```
%%time
# an array for saving 50 final best profit
profit_final = np.array([])

for i in range(sample_size):

    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    features_cv = greedy_algo(train_valid, target, 0.2)

    print('Selected Features: ', features_cv)

    X_cv = train_valid[features_cv]
    Y_cv = train_valid[target]

    X_test_cv = test[features_cv]
    Y_test_cv = test[target]

    model_cv = linear_model.LinearRegression()
    model_cv.fit(X_cv, Y_cv)

    Y_test_cv_fit = model_cv.predict(X_test_cv)

    long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(1),
                                   'Predicted_Return': Y_test_cv_fit.reshape(1),
                                   'Capital': np.zeros(len(Y_test_cv))})
    index = Y_test_cv.index

    cols = ['Return', 'Predicted_Return', 'Capital']
    long_short_df = long_short_df[cols]

    initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                           columns = long_short_df.columns)
    long_short_df = pd.concat([initial, long_short_df])
    long_short_df_final = computation(long_short_df)
```

```

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%', ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

Selected Features: ['x12', 'x7', 'x2', 'x9', 'x1', 'x5', 'x0', 'x3', 'x4', 'x10']
 Returns :
 96%, Maximum Return: 96.0
 Minimum Return: 96.0
 Average Return: 96.0
 Standard Deviation: 0.0
 320 training days
 80 validation days
 100 test days
 CPU times: user 2.05 s, sys: 17.6 ms, total: 2.07 s
 Wall time: 2.17 s

In [571...]

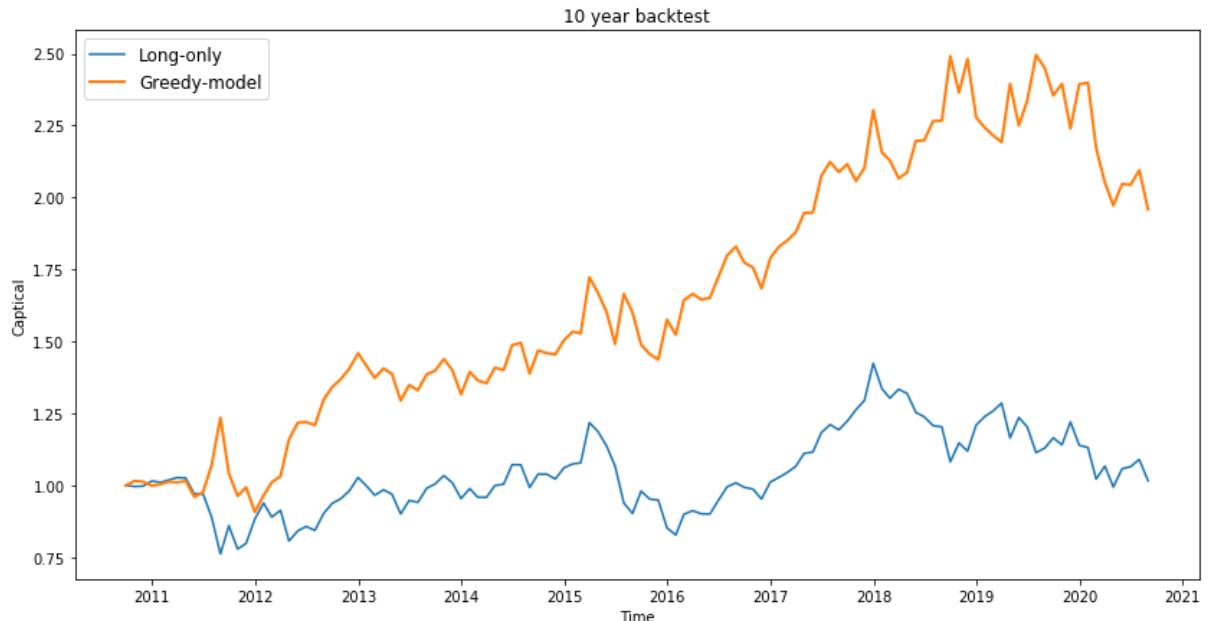
```

# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], label='BTC')
plt.plot(long_short_df_final.Capital[1:], lw=2, label='Greedy-model')
plt.xlabel('Time')
plt.ylabel('Capital')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)

```

Out[571... <matplotlib.legend.Legend at 0x13089e160>



Lasso Regression Algorithm + K-Fold Cross-Validation on PnL

In [583...]

```
target = ['Return-RF']
```

In [604...]

```
# compute Capital
def computation(df):
    for i in range(1, len(df)):
        if i == 1:
            df.loc[df.index[i], 'Capital'] = 1
        elif df.loc[df.index[i], 'Predicted_Return'] >= 0:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        else:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
    return df
```

In [585...]

```
def PnL_Lasso(x_train, y_train, x_valid, y_valid, lamb):

    # create a linear model
    X_train = x_train
    Y_train = y_train
    X_valid = x_valid
    Y_valid = y_valid

    model = linear_model.Lasso(alpha = lamb)
    model.fit(X_train, Y_train)
    Y_valid_fit = model.predict(X_valid)

    # a data frame for computing and saving long_short value
    long_short_df = pd.DataFrame({'Return': Y_valid.iloc[:, 0].values,
                                   'Predicted_Return': Y_valid_fit.reshape(-1),
                                   'Capital': np.zeros(len(Y_valid))},
                                  index = Y_valid.index)
```

```

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

# give an initial point
initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                        columns = long_short_df.columns)

# combine df and initial point
long_short_df = pd.concat([initial, long_short_df])

# compute long_short value
long_short_df_final = computation(long_short_df)

# return final long_short value of this period
return long_short_df_final.iloc[-1,2]

```

In [586...]

```

# Build a general function that can perform k-fold Cross Validation or
# Data: a subset of feature columns plus the target column
# Target: the name of the target column
# n: cut data into n pieces

def kfold_Lasso(data, target, n, lamb):
    # We need a vector to record mse from k-fold
    profit = np.array([])

    # KFold is a build-in function in Scikit-learn
    # it can help us cut data into n pieces
    # (compare with simple cross validation)
    kf = KFold(n_splits = n)

    for train_index, validation_index in kf.split(data):

        # obtain the train and validation part
        train, valid = data.iloc[train_index,:], data.iloc[validation_index,:]

        # extract X and Y to be fit in a model
        X_train = train[features]
        Y_train = train[target]
        X_valid = valid[features]
        Y_valid = valid[target]

        # Calculate PnL
        profit_temp = PnL_Lasso(X_train, Y_train, X_valid, Y_valid, lamb)
        profit = np.append(profit, profit_temp)

    return profit.mean()

```

6 Month Investment

In [587...]

```

fix_history_length = 250 # ~21 year
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange

```

Out[587... 116

In [588...]

```

%%time
# an array for saving 50 final best profit
# an array for saving 50 final best profit
lambda_list = np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1],sample_size))

for i in range(sample_size):

    PnL_lasso = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    for lamb in lambda_list:
        PnL_lasso = np.append(PnL_lasso, kfold_Lasso(train_valid, target, lamb))

    lambda_selected_lasso = lambda_list[PnL_lasso.argmax()]

    print('lambda_selected',lambda_selected_lasso)

    X_cv = train_valid[features]
    Y_cv = train_valid[target]

    X_test_cv = test[features]
    Y_test_cv = test[target]

    model_cv = linear_model.Lasso(alpha = lambda_selected_lasso)
    model_cv.fit(X_cv, Y_cv)

    Y_test_cv_fit = model_cv.predict(X_test_cv)

    long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(1,-1),
                                  'Predicted_Return': Y_test_cv_fit.reshape(1,-1),
                                  'Capital': np.zeros(len(Y_test_cv))})
    long_short_df.index = Y_test_cv.index

    cols = ['Return', 'Predicted_Return', 'Capital']
    long_short_df = long_short_df[cols]

    initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                           columns=cols)

```

```

columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(len(model_cv.coef_)):
    model_coef[j][i] = model_cv.coef_[j]

for i in range(len(model_cv.coef_)):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

lambda_selected 1e-08
lambda_selected 1e-08
lambda_selected 0.0001
lambda_selected 0.0001
lambda_selected 1e-05
lambda_selected 0.0001
lambda_selected 0.0001
lambda_selected 0.0001
lambda_selected 0.0001
lambda_selected 1e-05
lambda_selected 0.0001
lambda_selected 1e-08
lambda_selected 1e-06
lambda_selected 1e-08
lambda_selected 0.0001
lambda_selected 1e-08
lambda_selected 0.0001
lambda_selected 0.0001
lambda_selected 0.0001
lambda_selected 1e-08
0  feature coef =  9.27696748241314e-17
1  feature coef =  -3.4207265385478e-13
2  feature coef =  -9.32939831899784e-06
3  feature coef =  -4.1098641802330674e-05
4  feature coef =  2.0586647940144493e-05
5  feature coef =  0.0009937116523100194
6  feature coef =  0.0011062583448124452
7  feature coef =  0.0057852137803246365
8  feature coef =  -0.007324776240310371
9  feature coef =  0.014152793565385513
10 feature coef =  0.05851477735119968
Returns :

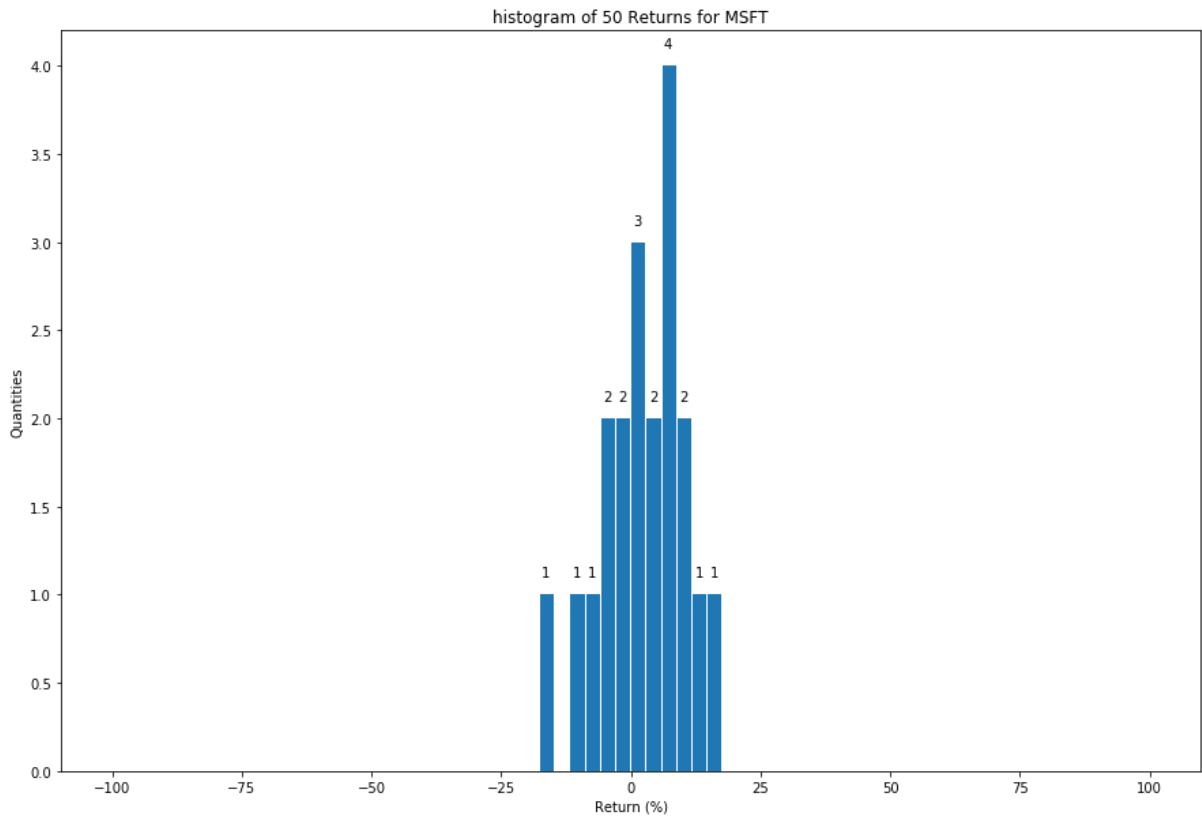
```

```
-8%, 8%, -4%, -10%, -1%, -15%, 10%, 4%, 8%, 2%, 3%, 9%, -5%, -2%,
4%, 10%, 15%, 1%, 13%, Maximum Return: 15.0
Minimum Return: -15.0
Average Return: 2.0
Standard Deviation: 8.0
320 training days
80 validation days
100 test days
CPU times: user 25.3 s, sys: 291 ms, total: 25.6 s
Wall time: 29.2 s
```

In [589...]

```
fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')
```

Out[589...]: Text(0, 0.5, 'Quantities')



In [590...]

```
fig, axs = plt.subplots(4,5, figsize=(10, 5), facecolor='w', edgecolor='k')
axs = axs.ravel()

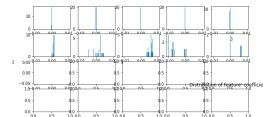
bins = np.linspace(-0.01, 0.01, 69)

for i in range(len(model_cv.coef_)):
    axs[i].hist(model_coef[i], bins, histtype='bar', rwidth=0.9)

for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
```

```
plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("Distribution of feature' coefficients")
```

Out[590... Text(0.5, 1.0, "Distribution of feature' coefficients")



10 Year Investment

In [591...]

```
fix_history_length = 250 # 2~1 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[591... 2

In [592...]

```
%%time
# an array for saving 50 final best profit
lambda_list = np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1],sample_size))

for i in range(sample_size):

    PnL_lasso = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    for lamb in lambda_list:
        PnL_lasso = np.append(PnL_lasso, kfold_Lasso(train_valid, target, lamb))

    lambda_selected_lasso = lambda_list[PnL_lasso.argmax()]

    print('lambda_selected',lambda_selected_lasso)

    X_cv = train_valid[features]
    Y_cv = train_valid[target]

    X_test_cv = test[features]
    Y_test_cv = test[target]

    model_cv = linear_model.Lasso(alpha = lambda_selected_lasso)
    model_cv.fit(X_cv, Y_cv)
```

```

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(-1, 1),
                               'Predicted_Return': Y_test_cv_fit.reshape(-1, 1),
                               'Capital': np.zeros(len(Y_test_cv))})
index = Y_test_cv.index

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0, 0, 1]).reshape(-1, 3),
                        columns=long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(len(model_cv.coef_)):
    model_coef[j][i] = model_cv.coef_[j]

for i in range(len(model_cv.coef_)):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1) * 100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

lambda_selected 0.0001
0  feature coef = -2.3510669781487353e-16
1  feature coef = -1.7712808195895884e-13
2  feature coef = -1.0640581944621301e-05
3  feature coef = -3.231016788879028e-05
4  feature coef = 3.486761466178813e-05
5  feature coef = 0.0005533270534737358
6  feature coef = 0.0032258873313605503
7  feature coef = 0.004106785258960432
8  feature coef = -0.013099780340023919
9  feature coef = 0.008200066636116062
10 feature coef = 0.07270985220012936
Returns :
85%, Maximum Return: 85.0
Minimum Return: 85.0
Average Return: 85.0
Standard Deviation: 0.0
320 training days
80 validation days
100 test days

```

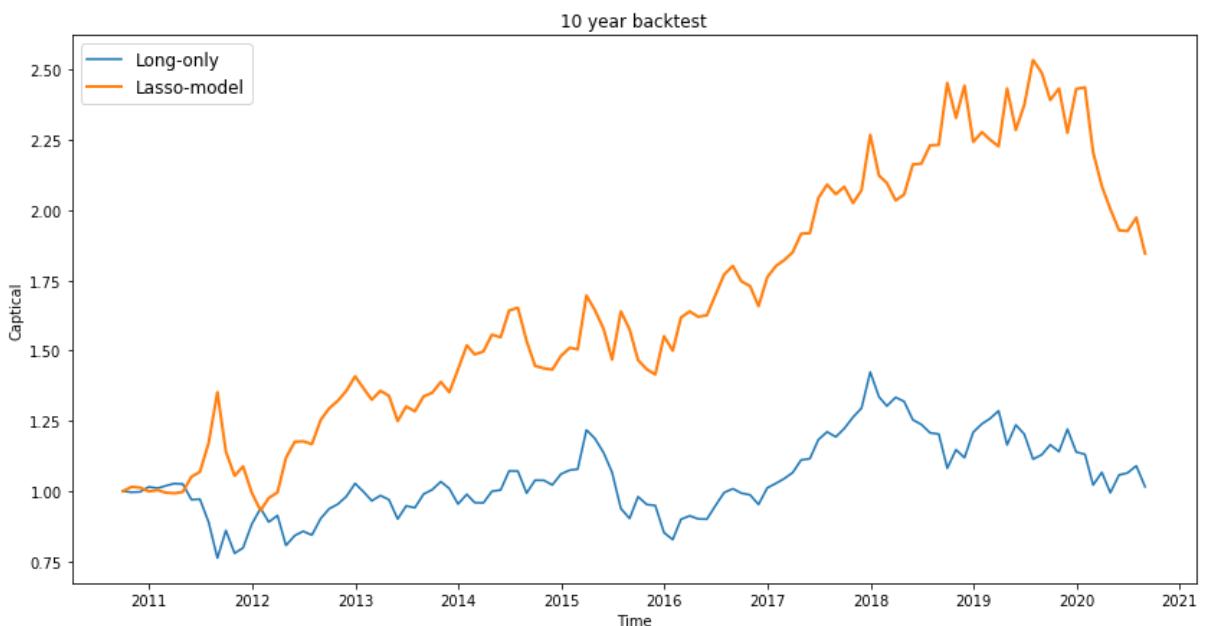
CPU times: user 1.43 s, sys: 23.2 ms, total: 1.45 s
Wall time: 1.61 s

In [593...]

```
# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], label='Long-only')
plt.plot(long_short_df_final.Capital[1:], lw=2, label='Lasso-model')
plt.xlabel('Time')
plt.ylabel('Capital')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)
```

Out[593...]



Ridge Regression Algorithm + K-Fold Cross-Validation on PnL

In [596...]

```
target = ['Return-RF']
```

In [605...]

```
# compute Capital
def computation(df):
    for i in range(1, len(df)):
        if i == 1:
            df.loc[df.index[i], 'Capital'] = 1
        elif df.loc[df.index[i], 'Predicted_Return'] >= 0:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        else:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital'] * (1 + df.loc[df.index[i], 'Predicted_Return'])
    return df
```

In [606...]

```
def PnL_Ridge(x_train, y_train, x_valid, y_valid, lamb):

    # create a linear model
    X_train = x_train
    Y_train = y_train
    X_valid = x_valid
    Y_valid = y_valid

    model = linear_model.Ridge(alpha = lamb)
    model.fit(X_train, Y_train)
    Y_valid_fit = model.predict(X_valid)

    # a data frame for computing and saving long_short value
    long_short_df = pd.DataFrame({'Return': Y_valid.iloc[:,0].values,
                                   'Predicted_Return': Y_valid_fit.reshape(len(Y_valid), 1),
                                   'Capital': np.zeros(len(Y_valid))},
                                  index = Y_valid.index)

    cols = ['Return', 'Predicted_Return', 'Capital']
    long_short_df = long_short_df[cols]

    # give an initial point
    initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                           columns = long_short_df.columns)

    # combine df and initial point
    long_short_df = pd.concat([initial, long_short_df])

    # compute long_short value
    long_short_df_final = computation(long_short_df)

    # return final long_short value of this period
    return long_short_df_final.iloc[-1,2]
```

In [607...]

```
# Build a general function that can perform k-fold Cross Validation or
# Data: a subset of feature columns plus the target column
# Target: the name of the target column
# n: cut data into n pieces

def kfold_Ridge(data, target, n, lamb):
    # We need a vector to record mse from k-fold
    profit = np.array([])

    # KFold is a build-in function in Scikit-learn
    # it can help us cut data into n pieces
    # (compare with simple cross validation)
    kf = KFold(n_splits = n)

    for train_index, validation_index in kf.split(data):

        # obtain the train and validation part
        train, valid = data.iloc[train_index,:], data.iloc[validation_
```

```

# extract X and Y to be fit in a model
X_train = train[features]
Y_train = train[target]
X_valid = valid[features]
Y_valid = valid[target]

# Calculate PnL
profit_temp = PnL_Ridge(X_train, Y_train, X_valid, Y_valid, lambda_list)
profit = np.append(profit, profit_temp)

return profit.mean()

```

6 Month investment

In [608...]

```

fix_history_length = 250 # ~21 year
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange

```

Out[608...]: 116

In [609...]

```

%%time
# an array for saving 50 final best profit
lambda_list = lambda_list = np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1], sample_size))

for i in range(sample_size):

    PnL_ridge = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    for lamb in lambda_list:
        PnL_ridge = np.append(PnL_ridge, kfold_Ridge(train_valid, target, lamb))

    lambda_selected_ridge = lambda_list[PnL_ridge.argmax()]

    X_cv = train_valid[features]
    Y_cv = train_valid[target]

    X_test_cv = test[features]

```

```

Y_test_cv = test[target]

model_cv = linear_model.Ridge(alpha = lambda_selected_ridge)
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(1, -1),
                               'Predicted_Return': Y_test_cv_fit.reshape(1, -1),
                               'Capital': np.zeros(len(Y_test_cv))},
                               index = Y_test_cv.index)

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                        columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1, :])

for j in range(model_cv.coef_.shape[1]):
    model_coef[j][i] = model_cv.coef_[0][j]

for i in range(model_cv.coef_.shape[1]):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

```

0  feature coef =  7.929736405410486e-17
1  feature coef = -3.458942040430193e-13
2  feature coef = -9.25473094055881e-06
3  feature coef = -4.110604170442289e-05
4  feature coef =  2.124128055909049e-05
5  feature coef =  0.0009888052509988128
6  feature coef =  0.001240951197141216
7  feature coef =  0.005819981245148263
8  feature coef = -0.007382746240511681
9  feature coef =  0.0146252933953498
10 feature coef =  0.06797253721025882
Returns :
-8%, 8%, 8%, -4%, -10%, -1%, -15%, 10%, 4%, 8%, 2%, 3%, 9%, -5%, -2%,
4%, 10%, 15%, 1%, 13%, Maximum Return: 15.0
Minimum Return: -15.0
Average Return: 2.0

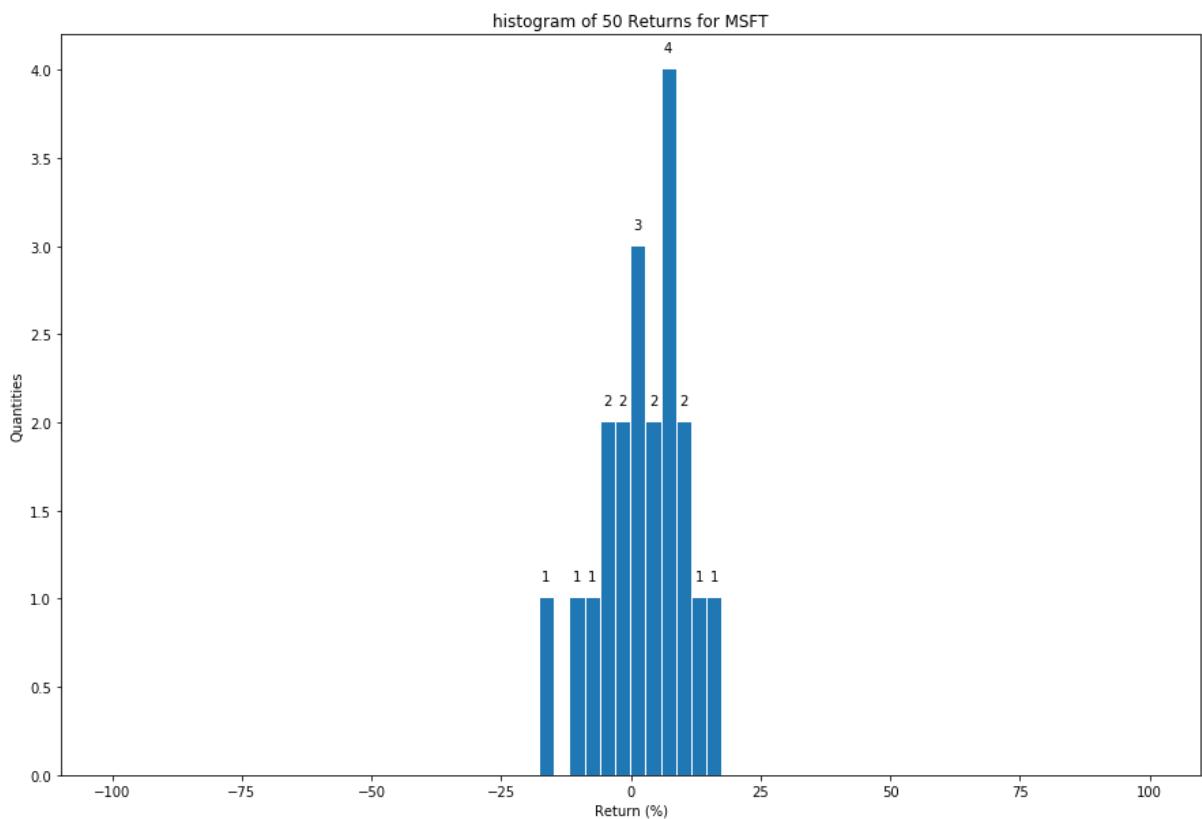
```

```
Standard Deviation: 8.0
320 training days
80 validation days
100 test days
CPU times: user 36.7 s, sys: 2.56 s, total: 39.2 s
Wall time: 23.4 s
```

In [610...]

```
fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')
```

Out[610...]: Text(0, 0.5, 'Quantities')



In [611...]

```
fig, axs = plt.subplots(4,5, figsize=(10, 5), facecolor='w', edgecolor='k')
axs = axs.ravel()

bins = np.linspace(-0.01, 0.01, 69)

for i in range(len(model_cv.coef_)):
    axs[i].hist(model_coef[i], bins, histtype='bar', rwidth=0.9)

for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("Distribution of feature' coefficients")
```

Out[611...]: Text(0.5, 1.0, "Distribution of feature' coefficients")



10 Year Investment

In [612...]

```
fix_history_length = 250 # 2~1 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[612...]

2

In [613...]

```
%time
# an array for saving 50 final best profit
lamddaa_list = np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1], sample_size))

for i in range(sample_size):

    PnL_ridge = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    for lamb in lambda_list:
        PnL_ridge = np.append(PnL_ridge, kfold_Ridge(train_valid, target))

    lambda_selected_ridge = lambda_list[PnL_ridge.argmax()]

    print('lambda_selected', lambda_selected_ridge)

    X_cv = train_valid[features]
    Y_cv = train_valid[target]

    X_test_cv = test[features]
    Y_test_cv = test[target]

    model_cv = linear_model.Ridge(alpha = lambda_selected_ridge)
    model_cv.fit(X_cv, Y_cv)

    Y_test_cv_fit = model_cv.predict(X_test_cv)

    long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(1),
                                  'Predicted_Return': Y_test_cv_fit.reshape(1)})
```

```

'Capital': np.zeros(len(Y_test_cv))]
index = Y_test_cv.index

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                       columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(model_cv.coef_.shape[1]):
    model_coef[j][i] = model_cv.coef_[0][j]

for i in range(model_cv.coef_.shape[1]):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

lambda_selected 1e-08
0  feature coef = -2.8114607542673535e-16
1  feature coef = -1.982490232622266e-13
2  feature coef = -1.0351696195251554e-05
3  feature coef = -3.210527973038548e-05
4  feature coef = 3.244537066398784e-05
5  feature coef = 0.0005622840137289524
6  feature coef = 0.0035114295629780556
7  feature coef = 0.004245827690220624
8  feature coef = -0.013340744736078556
9  feature coef = 0.009017231954306728
10 feature coef = 0.09187221293993196
Returns :
35%, Maximum Return: 35.0
Minimum Return: 35.0
Average Return: 35.0
Standard Deviation: 0.0
320 training days
80 validation days
100 test days
CPU times: user 2.06 s, sys: 144 ms, total: 2.2 s
Wall time: 1.39 s

```

In [616...]

```
# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
```

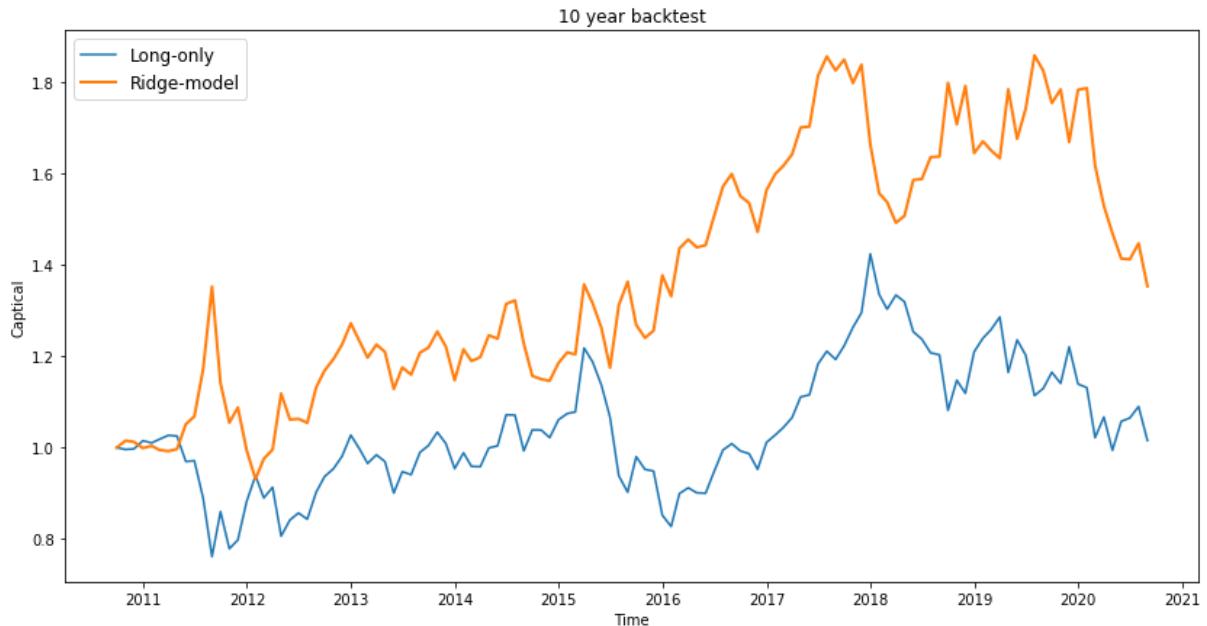
```

BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], la
plt.plot(long_short_df_final.Capital[1:], lw=2, label='Ridge-model')
plt.xlabel('Time')
plt.ylabel('Capital')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)

```

Out[616... <matplotlib.legend.Legend at 0x13919d588>



Elastic Net Regression Algorithm + K-Fold Cross-Validation on PnL

In [617...]

```
target = ['Return-RF']
```

In [618...]

```

# compute Capital
def computation(df):
    for i in range(1, len(df)):
        if i == 1:
            df.loc[df.index[i], 'Capital'] = 1
        elif df.loc[df.index[i], 'Predicted_Return'] >= 0:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        else:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
    return df

```

In [619...]

```

def PnL_ElasticNet(x_train, y_train, x_valid, y_valid, lamb):
    # create a linear model

```

```

X_train = x_train
Y_train = y_train
X_valid = x_valid
Y_valid = y_valid

model = linear_model.ElasticNet(alpha = lamb)
model.fit(X_train, Y_train)
Y_valid_fit = model.predict(X_valid)

# a data frame for computing and saving long_short value
long_short_df = pd.DataFrame({'Return': Y_valid.iloc[:,0].values,
                             'Predicted_Return': Y_valid_fit.reshape(-1,1),
                             'Capital': np.zeros(len(Y_valid))},
                             index = Y_valid.index)

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

# give an initial point
initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                        columns = long_short_df.columns)

# combine df and initial point
long_short_df = pd.concat([initial, long_short_df])

# compute long_short value
long_short_df_final = computation(long_short_df)

# return final long_short value of this period
return long_short_df_final.iloc[-1,2]

```

In [620...]

```

# Build a general function that can perform k-fold Cross Validation or
# Data: a subset of feature columns plus the target column
# Target: the name of the target column
# n: cut data into n pieces

def kfold_ElasticNet(data, target, n, lamb):
    # We need a vector to record mse from k-fold
    profit = np.array([])

    # KFold is a build-in function in Scikit-learn
    # it can help us cut data into n pieces
    # (compare with simple cross validation)
    kf = KFold(n_splits = n)

    for train_index, validation_index in kf.split(data):

        # obtain the train and validation part
        train, valid = data.iloc[train_index,:], data.iloc[validation_index,:]

        # extract X and Y to be fit in a model
        X_train = train[features]
        Y_train = train[target]
        X_valid = valid[features]

```

```

Y_valid = valid[target]

# Calculate PnL
profit_temp = PnL_ElasticNet(X_train, Y_train, X_valid, Y_valid)
profit = np.append(profit, profit_temp)

return profit.mean()

```

6 Month Investment

In [621...]

```

fix_history_length = 250 # ~21 year
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange

```

Out[621... 116

In [622...]

```

%%time
# an array for saving 50 final best profit
lambda_list = np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1], sample_size))

for i in range(sample_size):

    PnL_elasticNet = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    for lamb in lambda_list:
        PnL_elasticNet = np.append(PnL_elasticNet, kfold_ElasticNet(timestamp, EndTime, X_cv, Y_cv, lamb))

    lambda_selected_elasticNet = lambda_list[PnL_elasticNet.argmax()]

    X_cv = train_valid[features]
    Y_cv = train_valid[target]

    X_test_cv = test[features]
    Y_test_cv = test[target]

    model_cv = linear_model.ElasticNet(alpha = lambda_selected_elasticNet)
    model_cv.fit(X_cv, Y_cv)

```

```

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(-1, 1),
                               'Predicted_Return': Y_test_cv_fit.reshape(-1, 1),
                               'Capital': np.zeros(len(Y_test_cv))})
index = Y_test_cv.index

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0, 0, 1]).reshape(-1, 3),
                        columns=long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(len(model_cv.coef_)):
    model_coef[j][i] = model_cv.coef_[j]

for i in range(len(model_cv.coef_)):
    print(i, ' feature coef = ', model_coef[i].mean())

```

```
profit_final = (profit_final - 1) * 100
```

```

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

```

```

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

```

0  feature coef =  8.41542478329847e-17
1  feature coef = -3.4478849538136004e-13
2  feature coef = -9.277508290143674e-06
3  feature coef = -4.110580938997046e-05
4  feature coef =  2.092614072061587e-05
5  feature coef =  0.0009907864822193203
6  feature coef =  0.001191639911071189
7  feature coef =  0.0058078941516266774
8  feature coef = -0.007371894999518271
9  feature coef =  0.014442038662606918
10 feature coef =  0.06436940112617064
Returns :
-8%, 8%, 8%, -4%, -10%, -1%, -15%, 10%, 4%, 8%, 2%, 3%, 9%, -5%, -2%,
4%, 10%, 15%, 1%, 13%, Maximum Return: 15.0
Minimum Return: -15.0
Average Return: 2.0
Standard Deviation: 8.0
320 training days
80 validation days
100 test days

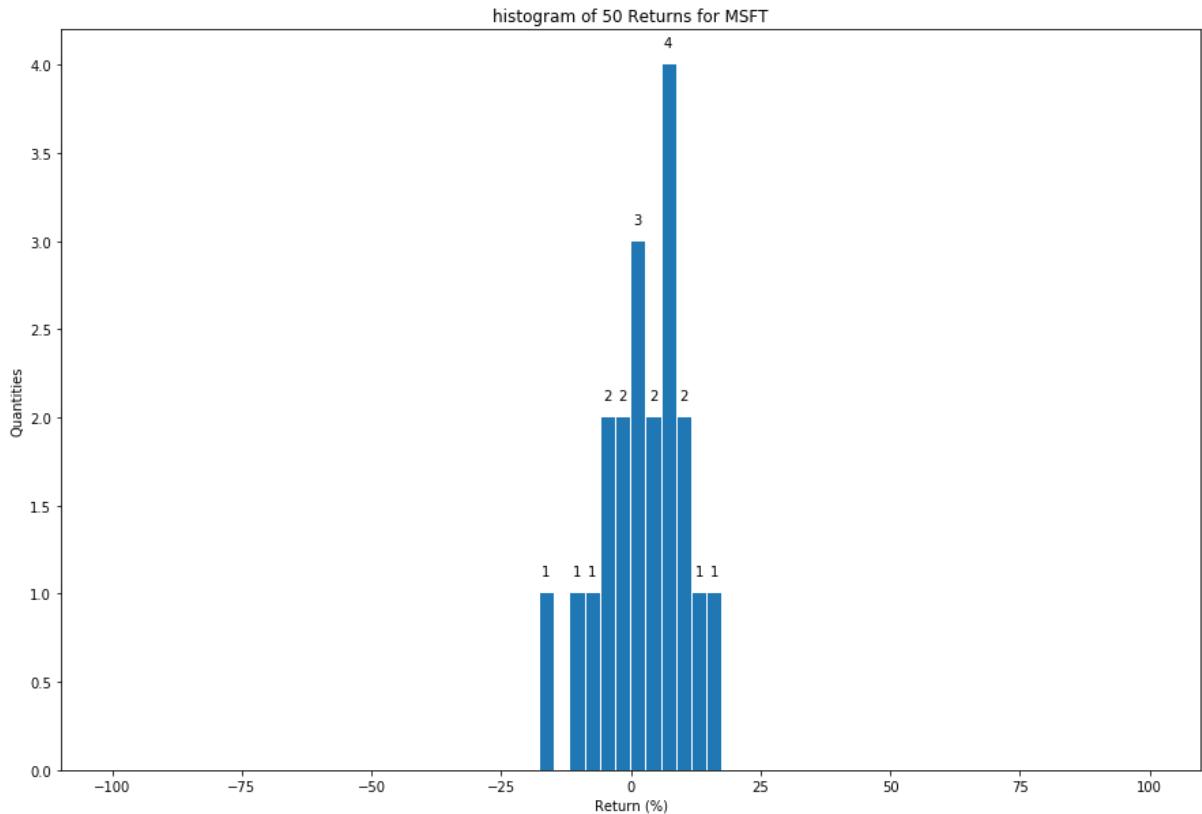
```

CPU times: user 19.4 s, sys: 170 ms, total: 19.6 s
Wall time: 20.2 s

In [623...]

```
fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')
```

Out[623...]: Text(0, 0.5, 'Quantities')



In [624...]

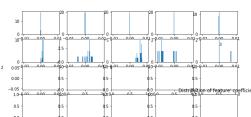
```
fig, axs = plt.subplots(4,5, figsize=(10, 5), facecolor='w', edgecolor='k')
axs = axs.ravel()

bins = np.linspace(-0.01, 0.01, 69)

for i in range(len(model_cv.coef_)):
    axs[i].hist(model_coef[i], bins, histtype='bar', rwidth=0.9)

for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("Distribution of feature' coefficients")
```

Out[624...]: Text(0.5, 1.0, "Distribution of feature' coefficients")



10 Year investment

In [625...]

```
fix_history_length = 250 # 2~1 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[625...]

2

In [626...]

```
%%time
# an array for saving 50 final best profit
lambda_list = np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1],sample_size))

for i in range(sample_size):

    PnL_elasticNet = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    for lamb in lambda_list:
        PnL_elasticNet = np.append(PnL_elasticNet, kfold_ElasticNet(ti

lambda_selected_elasticNet = lambda_list[PnL_elasticNet.argmax()]

X_cv = train_valid[features]
Y_cv = train_valid[target]

X_test_cv = test[features]
Y_test_cv = test[target]

model_cv = linear_model.ElasticNet(alpha = lambda_selected_elastic
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(1
                           'Predicted_Return': Y_test_cv_fit.re
                           'Capital': np.zeros(len(Y_test_cv))})
                           index = Y_test_cv.index)

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
```

```

columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1, :])

for j in range(len(model_cv.coef_)):
    model_coef[j][i] = model_cv.coef_[j]

for i in range(len(model_cv.coef_)):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

0 feature coef = -2.5632290985887866e-16
1 feature coef = -1.868506601819594e-13
2 feature coef = -1.0507130773818738e-05
3 feature coef = -3.221517656892354e-05
4 feature coef = 3.375792391404429e-05
5 feature coef = 0.0005574906343983132
6 feature coef = 0.0033604468789578284
7 feature coef = 0.0041722995693735734
8 feature coef = -0.013222642752298414
9 feature coef = 0.008607405403846581
10 feature coef = 0.08151541396719326
Returns :
89%, Maximum Return: 89.0
Minimum Return: 89.0
Average Return: 89.0
Standard Deviation: 0.0
320 training days
80 validation days
100 test days
CPU times: user 1.45 s, sys: 18.5 ms, total: 1.47 s
Wall time: 1.88 s

In [627...]

```

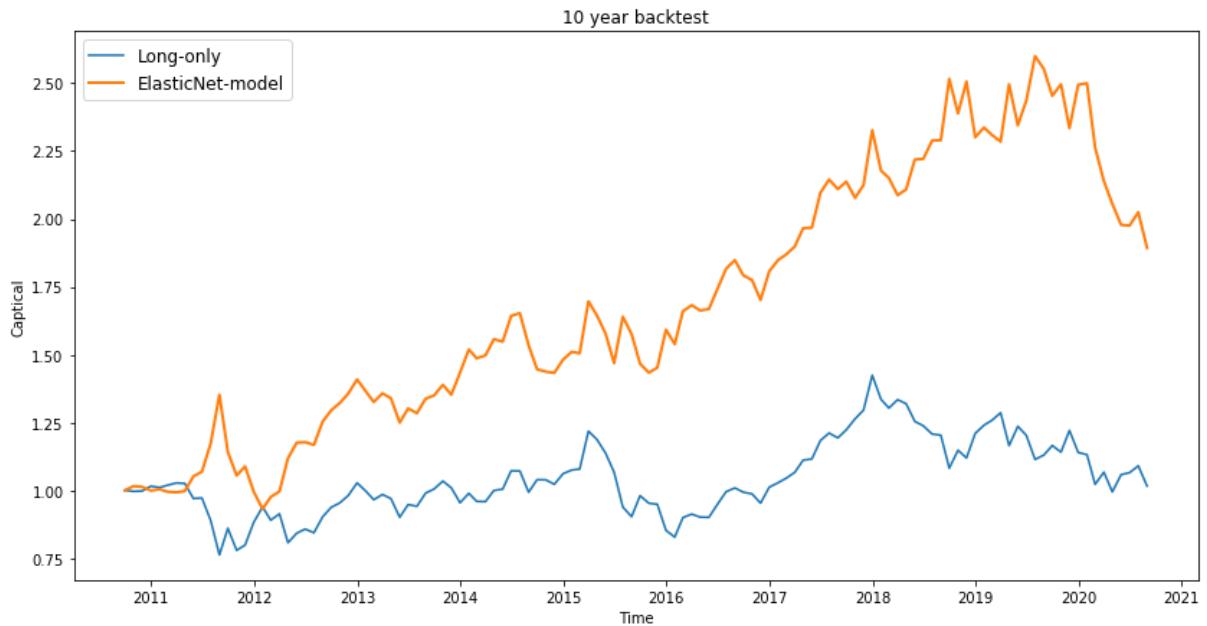
# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], la

```

```
plt.plot(long_short_df_final.Capital[1:], lw=2, label='ElasticNet-model')
plt.xlabel('Time')
plt.ylabel('Capital')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)
```

Out[627... <matplotlib.legend.Legend at 0x139c48080>



Logistic Regression Algorithm (L2 Regularization) + K-Fold Cross-Validation on PnL

In [643...]

```
BTC['Binary_Return'] = BTC.Return.shape[0]
BTC.Binary_Return[BTC.Return > 0] = 1
BTC.Binary_Return[BTC.Return <= 0] = 0
target = 'Binary_Return'
BTC
```

Out[643...]

	Open	High	Low	Close	RF	Return-RF
--	------	------	-----	-------	----	-----------

Date	Open	High	Low	Close	RF	Return-RF
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349

Date	Open	High	Low	Close	RF	Return-RF
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349

	Open	High	Low	Close	RF	Return-RF
Date						
1990-04-30	2948.000000	3137.000000	2906.000000	3132.000000	0.69	0.062415
...
2020-05-31	23539.910156	25303.779297	23539.910156	24427.189453	0.01	0.037693
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	0.01	0.001294
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	0.01	0.024840
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	0.01	-0.064843
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	0.01	0.002830
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	0.01	0.085136

372 rows × 21 columns

In [644...]

```
# Long & Short
def computation(df):
    for i in range(1, len(df)):
        if i == 1:
            df.loc[df.index[i], 'Capital'] = 1
        elif df.loc[df.index[i], 'Predicted_Binary_Return'] == 1:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        elif df.loc[df.index[i], 'Predicted_Binary_Return'] == -1:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        else:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
    return df
```

In [645...]

```
def PnL_Logistic(Y_valid_Return, x_train, y_train, x_valid, y_valid, lamb):

    # create a linear model
    X_train = x_train
    Y_train = y_train
    X_valid = x_valid
    Y_valid = y_valid

    model = linear_model.LogisticRegression(C = lamb)
    model.fit(X_train, Y_train)
    Y_valid_fit = model.predict(X_valid)

    # a data frame for computing and saving long_short value
```

```

long_short_df = pd.DataFrame({'Return': Y_valid_Return.iloc[:,].values,
                             'Binary_Return': Y_valid.iloc[:,].values,
                             'Predicted_Binary_Return': Y_valid_pred,
                             'Capital': np.zeros(len(Y_valid))},
                             index = Y_valid.index)

cols = ['Return', 'Binary_Return', 'Predicted_Binary_Return', 'Capital']
long_short_df = long_short_df[cols]

# give an initial point
initial = pd.DataFrame(np.array([0,0,0,1]).reshape(-1,4),
                        columns = long_short_df.columns)

# combine df and initial point
long_short_df = pd.concat([initial, long_short_df])

# compute long_short value
long_short_df_final = computation(long_short_df)

# return final long_short value of this period
return long_short_df_final.iloc[-1,3]

```

In [646]:

```

# Build a general function that can perform k-fold Cross Validation or not
# Data: a subset of feature columns plus the target column
# Target: the name of the target column
# n: cut data into n pieces

def kfolds_Logistic(data, target, n, lamb):
    # We need a vector to record mse from k-fold
    profit = np.array([])

    # KFold is a build-in function in Scikit-learn
    # it can help us cut data into n pieces
    # (compare with simple cross validation)
    kf = KFold(n_splits = n)

    for train_index, validation_index in kf.split(data):

        # obtain the train and validation ,opart
        train, valid = data.iloc[train_index,:], data.iloc[validation_index,:]

        ## Balance the data for binary prediction
        up_raw = train[train[target] == 1]
        down_raw = train[train[target] == 0]

        print('up_raw = ', up_raw.shape[0])
        print('down_raw = ', down_raw.shape[0])

        if up_raw.shape[0] / down_raw.shape[0] < 1:

            percentage = up_raw.shape[0] / down_raw.shape[0]
            down = down_raw.sample(frac=percentage, random_state = 1)
            up = up_raw

```

```

        train = up.append(down)

    elif up_raw.shape[0] / down_raw.shape[0] >= 1:

        percentage = down_raw.shape[0] / up_raw.shape[0]
        up = up_raw.sample(frac=percentage, random_state = 1)
        down = down_raw

        train = down.append(up)

    print('up = ', train[train[target] == 1].shape[0])
    print('down = ', train[train[target] == 1].shape[0])

    # extract X and Y to be fit in a model
    X_train = train[features]
    Y_train = train[target]
    X_valid = valid[features]
    Y_valid = valid[target]
    Y_valid_Return = valid['Return']

    # Calculate PnL
    profit_temp = PnL_Logistic(Y_valid_Return, X_train, Y_train, )
    profit = np.append(profit, profit_temp)

return profit.mean()

```

6 Month Investment

In [647...]

```

fix_history_length = 250 # ~21 year
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange

```

Out[647...]: 116

In [648...]

```

%%time
# an array for saving 50 final best profit
lambda_list = 1/np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1],sample_size))

for i in range(sample_size):

    PnL_logistic = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

```

```

# use BeginTime and EndTime to filter test and train_valid
train_valid = BTC.iloc[BeginTime:timestamp, :]
test = BTC.iloc[timestamp:EndTime, :]

for lamb in lambda_list:
    PnL_logistic = np.append(PnL_logistic, kfold_Logistic(train_vali
    lambda_selected_logistic = lambda_list[PnL_logistic.argmax()]


## Balance the data for binary prediction
up_raw = train_valid[train_valid[target] == 1]
down_raw = train_valid[train_valid[target] == 0]

print('up_raw = ', up_raw.shape[0])
print('down_raw = ', down_raw.shape[0])

if up_raw.shape[0] / down_raw.shape[0] < 1:

    percentage = up_raw.shape[0] / down_raw.shape[0]
    down = down_raw.sample(frac=percentage, random_state = 1)
    up = up_raw

    train_valid = up.append(down)

elif up_raw.shape[0] / down_raw.shape[0] >= 1:

    percentage = down_raw.shape[0] / up_raw.shape[0]
    up = up_raw.sample(frac=percentage, random_state = 1)
    down = down_raw

    train_valid = down.append(up)

print('up = ', train_valid[train_valid[target] == 1].shape[0])
print('down = ', train_valid[train_valid[target] == 1].shape[0])


X_cv = train_valid[features]
Y_cv = train_valid[target]

X_test_cv = test[features]
Y_test_cv = test[target]

model_cv = linear_model.LogisticRegression(C = lambda_selected_logistic)
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': test['Return'].iloc[:,val
    'Binary_Return': Y_test_cv.values.reshape(-1, 1),
    'Predicted_Binary_Return': Y_test_cv_fit,
    'Capital': np.zeros(len(Y_test_cv))})
index = Y_test_cv.index

cols = ['Return', 'Binary_Return', 'Predicted_Binary_Return', 'Capit
long_short_df = long_short_df[cols]

```

```

initial = pd.DataFrame(np.array([0,0,0,1]).reshape(-1,4),
                      columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(model_cv.coef_.shape[1]):
    model_coef[j][i] = model_cv.coef_[0][j]

for i in range(model_cv.coef_.shape[1]):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

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down = 96
up_raw = 124
down_raw = 101
up = 101
down = 101
up_raw = 122
down_raw = 103
up = 103
down = 103
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 129
down_raw = 96
up = 96
down = 96
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 142
down_raw = 108
```

```
up = 108
down = 108
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 120
down_raw = 105
up = 105
down = 105
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 126
down_raw = 99
up = 99
down = 99
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 120
down_raw = 105
up = 105
down = 105
up_raw = 127
down_raw = 98
```

```
up = 98
down = 98
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 126
down_raw = 99
up = 99
down = 99
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 120
down_raw = 105
up = 105
down = 105
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 126
down_raw = 99
up = 99
down = 99
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 128
down_raw = 97
```

```
up = 97
down = 97
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 120
down_raw = 105
up = 105
down = 105
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 126
down_raw = 99
up = 99
down = 99
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 120
down_raw = 105
up = 105
down = 105
up_raw = 127
down_raw = 98
up = 98
down = 98
up_raw = 128
down_raw = 97
up = 97
down = 97
up_raw = 126
down_raw = 99
```

```

up = 99
down = 99
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 140
down_raw = 110
up = 110
down = 110
0 feature coef = -2.5991538275327584e-15
1 feature coef = -5.00491734622438e-12
2 feature coef = -1.2599049160251173e-19
3 feature coef = -2.9284073173372995e-19
4 feature coef = 1.853146142683824e-21
5 feature coef = 1.8745029745130273e-21
6 feature coef = -6.674609435455322e-22
7 feature coef = 1.867654114965865e-21
8 feature coef = -3.3711120351869226e-23
9 feature coef = -6.622082115071062e-23
10 feature coef = 3.321190568793294e-23
Returns :
-7%, 0%, 0%, 0%, -7%, 0%, 0%, 1%, 0%, 0%, 0%, 1%, 0%, 0%, 0%, 0%, 0%, 6%,
0%, -1%, 0%, Maximum Return: 6.0
Minimum Return: -7.0
Average Return: -0.0
Standard Deviation: 3.0
320 training days
80 validation days
100 test days
CPU times: user 32.9 s, sys: 781 ms, total: 33.6 s
Wall time: 34.3 s

```

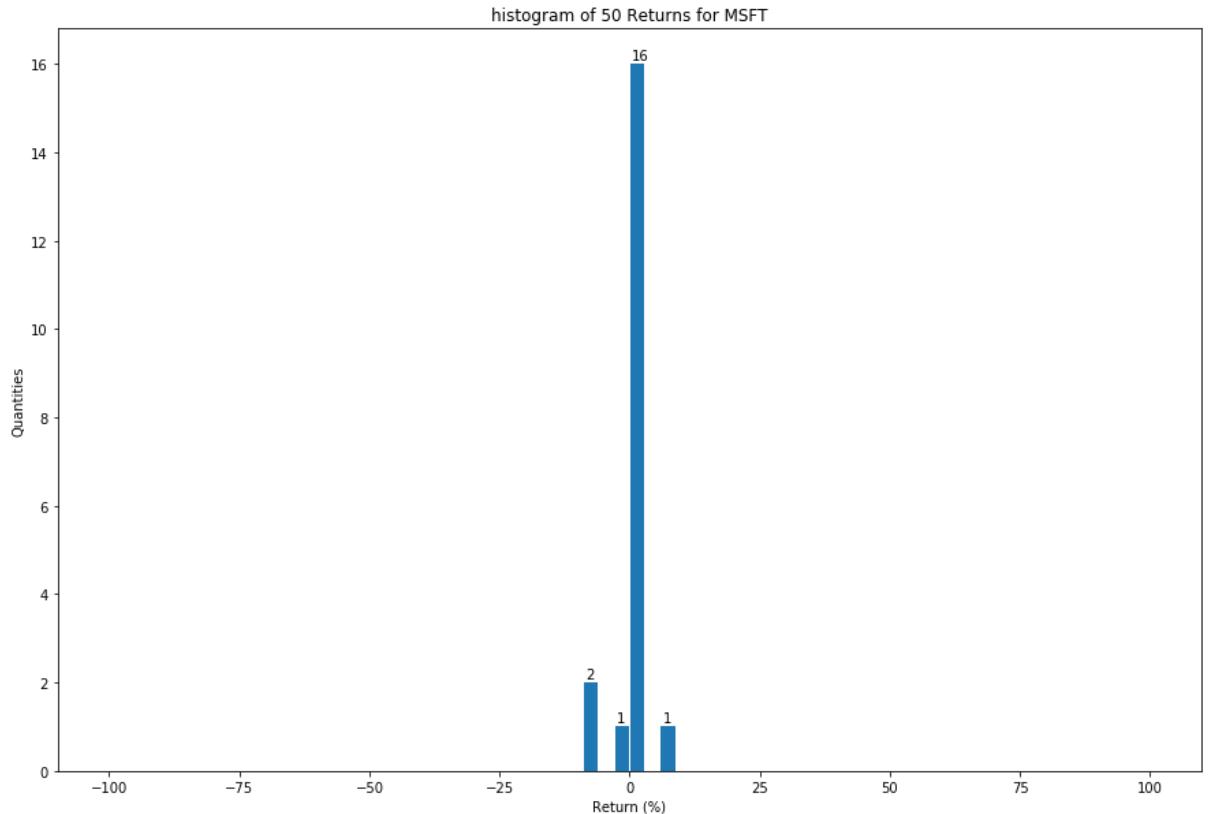
In [649...]

```

fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')

```

Out[649...]: Text(0, 0.5, 'Quantities')



In [650...]

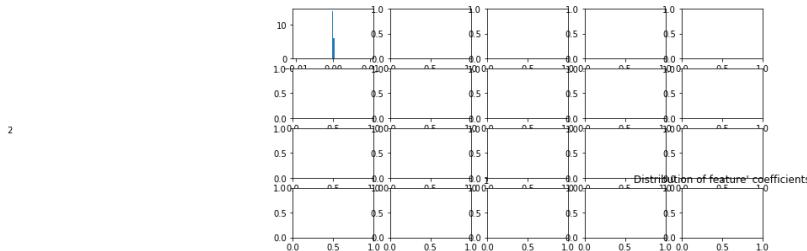
```
fig, axs = plt.subplots(4,5, figsize=(10, 5), facecolor='w', edgecolor='k')
axs = axs.ravel()

bins = np.linspace(-0.01, 0.01, 69)

for i in range(len(model_cv.coef_)):
    axs[i].hist(model_coef[i], bins, histtype='bar', rwidth=0.9)

for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("Distribution of feature' coefficients")
```

Out[650...]: Text(0.5, 1.0, "Distribution of feature' coefficients")



10 Year Investment

```
In [651...]: fix_history_length = 250 # 2~1 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[651...]: 2

```
In [672...]: %%time
# an array for saving 50 final best profit
lambda_list = 1/np.array([1e-8, 1e-7, 1e-6, 1e-5, 1e-4])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1], sample_size))

for i in range(sample_size):

    PnL_logistic = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]
```

```

for lamb in lambda_list:
    PnL_logistic = np.append(PnL_logistic, kfold_Logistic(train_va

lambda_selected_logistic = lambda_list[PnL_logistic.argmax()])

## Balance the data for binary prediction
up_raw = train_valid[train_valid[target] == 1]
down_raw = train_valid[train_valid[target] == 0]

print('up_raw = ', up_raw.shape[0])
print('down_raw = ', down_raw.shape[0])

if up_raw.shape[0] / down_raw.shape[0] < 1:

    percentage = up_raw.shape[0] / down_raw.shape[0]
    down = down_raw.sample(frac=percentage, random_state = 1)
    up = up_raw

    train_valid = up.append(down)

elif up_raw.shape[0] / down_raw.shape[0] >= 1:

    percentage = down_raw.shape[0] / up_raw.shape[0]
    up = up_raw.sample(frac=percentage, random_state = 1)
    down = down_raw

    train_valid = down.append(up)

print('up = ', train_valid[train_valid[target] == 1].shape[0])
print('down = ', train_valid[train_valid[target] == 1].shape[0])

X_cv = train_valid[features]
Y_cv = train_valid[target]

X_test_cv = test[features]
Y_test_cv = test[target]

model_cv = linear_model.LogisticRegression(C = lambda_selected_log
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': test['Return'].iloc[:,val
                                'Binary_Return': Y_test_cv.values.re
                                'Predicted_Binary_Return': Y_test_cv
                                'Capital': np.zeros(len(Y_test_cv))]
                                index = Y_test_cv.index)

cols = ['Return', 'Binary_Return', 'Predicted_Binary_Return', 'Cap
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0,0,0,1]).reshape(-1,4),
                        columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

```

```

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(model_cv.coef_.shape[1]):
    model_coef[j][i] = model_cv.coef_[0][j]

for i in range(model_cv.coef_.shape[1]):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

```

up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 137
down_raw = 88
up = 88
down = 88
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 131
down_raw = 94
up = 94
down = 94
up_raw = 134
down_raw = 91
up = 91

```

```
down = 91
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 137
down_raw = 88
up = 88
down = 88
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 131
down_raw = 94
up = 94
down = 94
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 137
down_raw = 88
up = 88
```

```
down = 88
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 131
down_raw = 94
up = 94
down = 94
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 137
down_raw = 88
up = 88
down = 88
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 131
down_raw = 94
up = 94
down = 94
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 132
down_raw = 93
up = 93
```

```

down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 132
down_raw = 93
up = 93
down = 93
up_raw = 135
down_raw = 90
up = 90
down = 90
up_raw = 137
down_raw = 88
up = 88
down = 88
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 130
down_raw = 95
up = 95
down = 95
up_raw = 131
down_raw = 94
up = 94
down = 94
up_raw = 134
down_raw = 91
up = 91
down = 91
up_raw = 148
down_raw = 102
up = 102
down = 102
0 feature coef = -8.839643082499417e-15
1 feature coef = -3.1543078204602745e-12
2 feature coef = 4.231919629818148e-20
3 feature coef = -4.860764477279054e-19
4 feature coef = 1.9736225744849877e-20
5 feature coef = -2.348838736209368e-21
6 feature coef = -5.434666554138803e-22
7 feature coef = 1.5418285796505285e-21
8 feature coef = -1.053438705139261e-23
9 feature coef = -6.7927236737487e-23
10 feature coef = 5.666383586260258e-23
Returns :
-6%, Maximum Return: -6.0
Minimum Return: -6.0
Average Return: -6.0
Standard Deviation: 0.0
320 training days
80 validation days
100 test days
CPU times: user 2.03 s, sys: 51.7 ms, total: 2.08 s
Wall time: 2.19 s

```

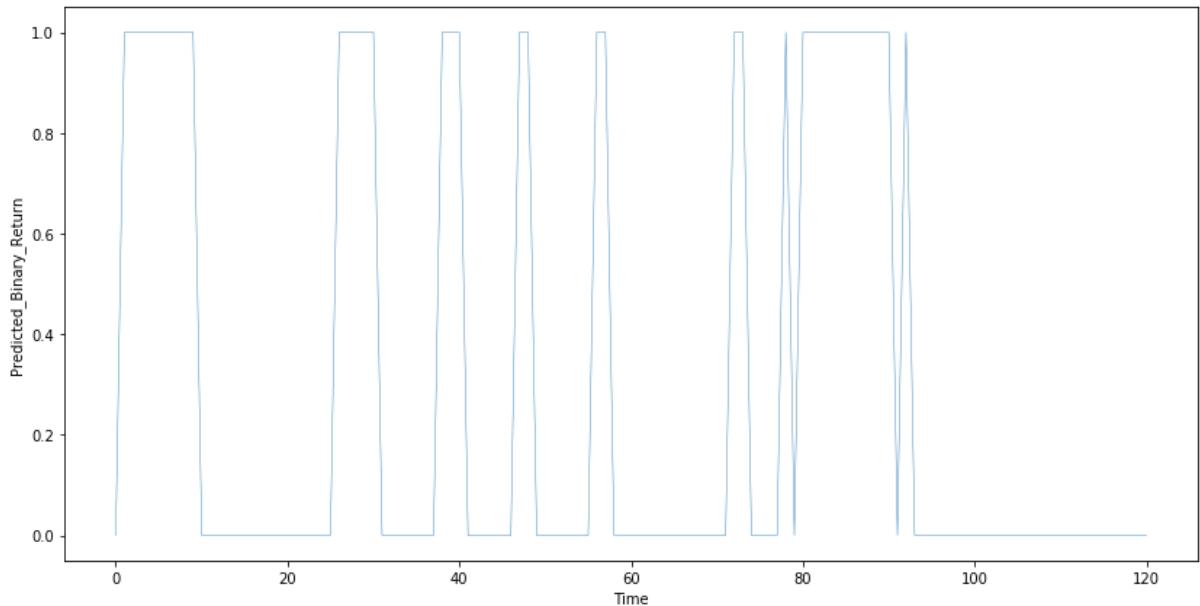
In [673...]

```

plt.figure(figsize=(14, 7))
plt.plot(range(long_short_df_final.shape[0]), long_short_df_final.Pred)
plt.xlabel('Time')
plt.ylabel('Predicted_Binary_Return')

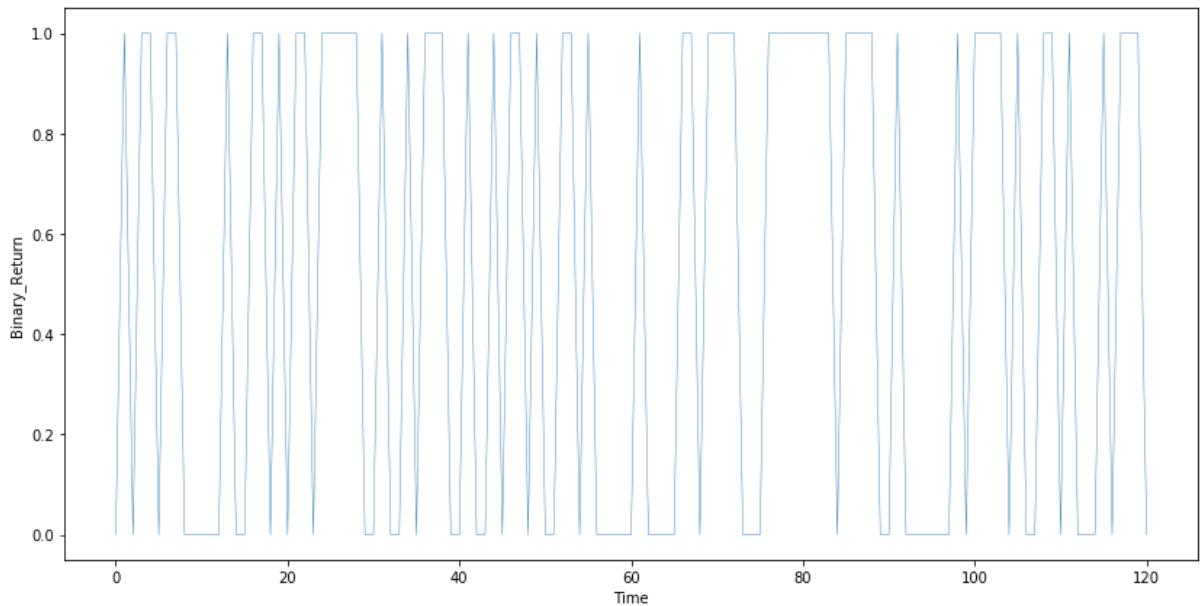
```

```
Out[673... Text(0, 0.5, 'Predicted_Binary_Return')
```



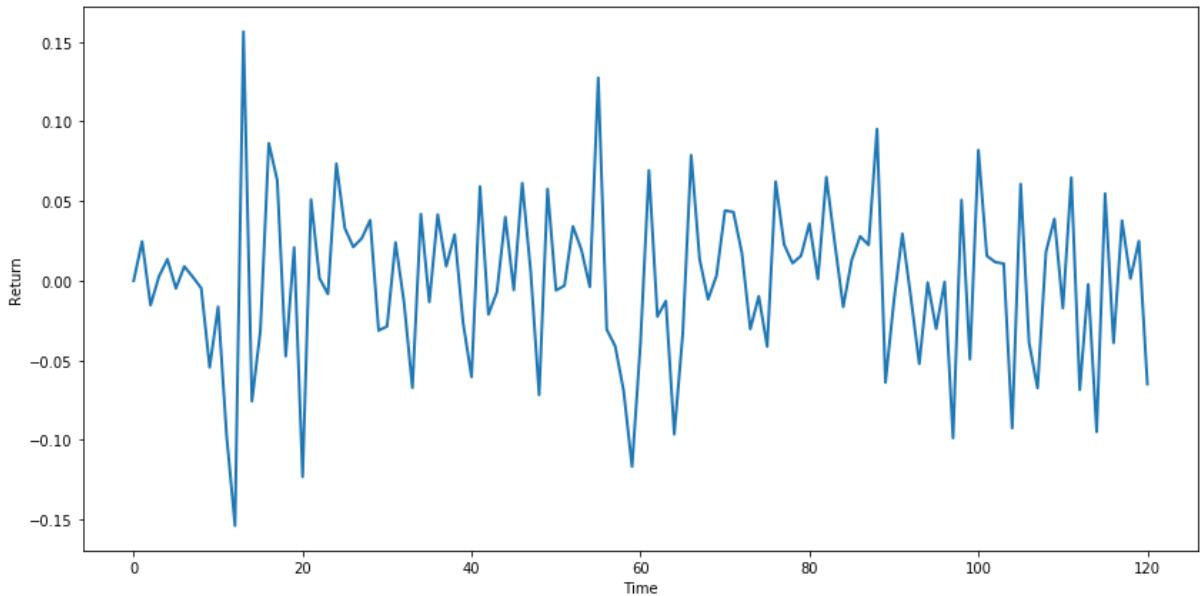
```
In [674... plt.figure(figsize=(14, 7))
plt.plot(range(long_short_df_final.shape[0]), long_short_df_final.Bina
plt.xlabel('Time')
plt.ylabel('Binary_Return')
```

```
Out[674... Text(0, 0.5, 'Binary_Return')
```



```
In [675... plt.figure(figsize=(14, 7))
plt.plot(range(long_short_df_final.shape[0]), long_short_df_final.Return)
plt.xlabel('Time')
plt.ylabel('Return')
```

```
Out[675... Text(0, 0.5, 'Return')
```

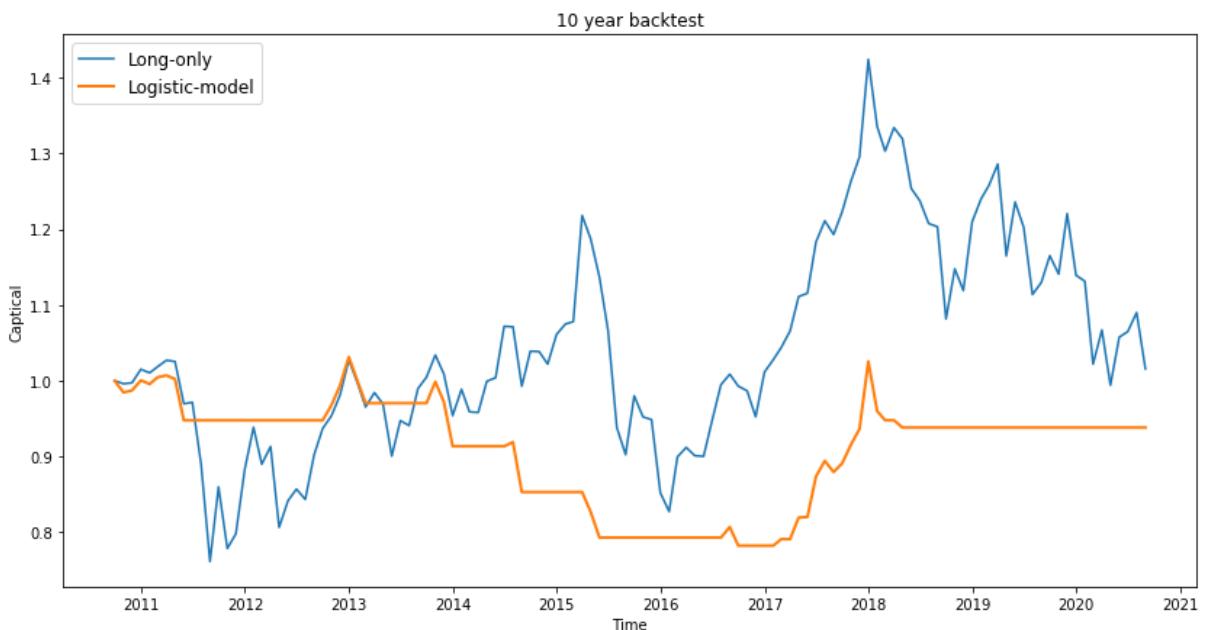


In [676...]

```
# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], label='Long-only')
plt.plot(long_short_df_final.Capital[1:], lw=2, label='Logistic-model')
plt.xlabel('Time')
plt.ylabel('Capital')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)
```

Out[676... <matplotlib.legend.Legend at 0x139096240>



Support Vector Machine + K-Fold Cross-Validation on PnL

```
In [657...]: target = ['Return-RF']
```

```
In [658...]: BTC['Binary_Return'] = BTC.Return.shape[0]
BTC.Binary_Return[BTC.Return > 0] = 1
BTC.Binary_Return[BTC.Return <= 0] = 0
target = 'Binary_Return'
BTC
```

	Open	High	Low	Close	RF	Return-RF
Date						
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349
1990-04-30	2948.000000	3137.000000	2906.000000	3132.000000	0.69	0.062415
...
2020-05-31	23539.910156	25303.779297	23539.910156	24427.189453	0.01	0.037693
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	0.01	0.001294
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	0.01	0.024840
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	0.01	-0.064843
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	0.01	0.002830
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	0.01	0.085136

372 rows × 21 columns

```
In [659...]: BTC
```

	Open	High	Low	Close	RF	Return-RF
--	------	------	-----	-------	----	-----------

Date	Open	High	Low	Close	RF	Return-RF
Date						
1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349
1990-04-30	2948.000000	3137.000000	2906.000000	3132.000000	0.69	0.062415
...
2020-05-31	23539.910156	25303.779297	23539.910156	24427.189453	0.01	0.037693
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	0.01	0.001294
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	0.01	0.024840
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	0.01	-0.064843
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	0.01	0.002830
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	0.01	0.085136

372 rows × 21 columns

In [660...]

```
# Long & Short
def computation(df):
    for i in range(1, len(df)):
        if i == 1:
            df.loc[df.index[i], 'Capital'] = 1
        elif df.loc[df.index[i], 'Predicted_Binary_Return'] == 1:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        elif df.loc[df.index[i], 'Predicted_Binary_Return'] == -1:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        else:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
    return df
```

In [661...]

```

def PnL_SVM(Y_valid_Return, x_train, y_train, x_valid, y_valid, lamb,

    # create a linear model
    X_train = x_train
    Y_train = y_train
    X_valid = x_valid
    Y_valid = y_valid

    svc_rbf = SVC(kernel='rbf', C=c, gamma=lamb)
    Y_valid_fit = svc_rbf.fit(X_train, Y_train).predict(X_valid)

    # a data frame for computing and saving long_short value
    long_short_df = pd.DataFrame({'Return': Y_valid_Return.iloc[:,val],
                                   'Binary_Return': Y_valid.iloc[:,val],
                                   'Predicted_Binary_Return': Y_valid_i,
                                   'Capital': np.zeros(len(Y_valid))},
                                  index = Y_valid.index)

    cols = ['Return', 'Binary_Return', 'Predicted_Binary_Return', 'Cap']
    long_short_df = long_short_df[cols]

    # give an initial point
    initial = pd.DataFrame(np.array([0,0,0,1]).reshape(-1,4),
                           columns = long_short_df.columns)

    # combine df and initial point
    long_short_df = pd.concat([initial, long_short_df])

    # compute long_short value
    long_short_df_final = computation(long_short_df)

    # return final long_short value of this period
    return long_short_df_final.iloc[-1,3]

```

In [662...]

```

def kfold_SVM(data, target, n, lamb,c ):
    # We need a vector to record mse from k-fold
    profit = np.array([])

    # KFold is a build-in function in Scikit-learn
    # it can help us cut data into n pieces
    # (compare with simple cross validation)
    kf = KFold(n_splits = n)

    for train_index, validation_index in kf.split(data):

        # obtain the train and validation ,opart
        train, valid = data.iloc[train_index,:], data.iloc[validation_]

        ## Balance the data for binary prediction
        up_raw = train[train[target] == 1]
        down_raw = train[train[target] == 0]

```

```

print('up_raw = ', up_raw.shape[0])
print('down_raw = ', down_raw.shape[0])

if up_raw.shape[0] / down_raw.shape[0] < 1:

    percentage = up_raw.shape[0] / down_raw.shape[0]
    down = down_raw.sample(frac=percentage, random_state = 1)
    up = up_raw

    train = up.append(down)

elif up_raw.shape[0] / down_raw.shape[0] >= 1:

    percentage = down_raw.shape[0] / up_raw.shape[0]
    up = up_raw.sample(frac=percentage, random_state = 1)
    down = down_raw

    train = down.append(up)

print('up = ', train[train[target] == 1].shape[0])
print('down = ', train[train[target] == 1].shape[0])

# extract X and Y to be fit in a model
X_train = train.drop(target, axis = 1).drop('Return', axis = 1)
Y_train = train[target]
X_valid = valid.drop(target, axis = 1).drop('Return', axis = 1)
Y_valid = valid[target]
Y_valid_Return = valid['Return']

# Calculate PnL
profit_temp = PnL_SVM(Y_valid_Return, X_train, Y_train, X_valid)
profit = np.append(profit, profit_temp)

return profit.mean()

```

6 Month Investment

In [663...]

```

fix_history_length = 250 # ~21 year
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange

```

Out[663...]: 116

In [664...]

```

# an array for saving 50 final best profit
lambda_list = np.array([ 2**(-11), 2**(-7), 2**(-3), 2**(-1), 2**(1),
C_list = np.array([ 2**(-3), 2**(-1), 2**(1), 2**(3), 2**(5), 2**(9),
profit_final = np.array([]) 
```

```

for i in range(sample_size):

    PnL_logistic = np.array([ ])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, : ]
    test = BTC.iloc[timestamp:EndTime, : ]
    Best_Inner_SVM_Profit = np.array([ ])
    Best_C = np.array([ ])
    for lamb in lambda_list:
        Inner_SVM_Profit= np.array([ ])
        for c in C_list:
            Inner_SVM_Profit = np.append(Inner_SVM_Profit, kfold_SVM(t))
        Best_Inner_SVM_Profit = np.append(Best_Inner_SVM_Profit, Inner_SVM_Profit)
        Best_C = np.append(Best_C,np.argmax(Inner_SVM_Profit))

    lamb_selected = lambda_list[Best_Inner_SVM_Profit.argmax()]
    C_Selected = Best_C[np.argmax(Best_Inner_SVM_Profit)]
    C_Selected = C_Selected.astype(int)
    C_Selected_1 = C_list[C_Selected]

    ## Balance the data for binary prediction
    up_raw = train_valid[train_valid[target] == 1]
    down_raw = train_valid[train_valid[target] == 0]

    print('up_raw = ', up_raw.shape[0])
    print('down_raw = ', down_raw.shape[0])

    if up_raw.shape[0] / down_raw.shape[0] < 1:

        percentage = up_raw.shape[0] / down_raw.shape[0]
        down = down_raw.sample(frac=percentage, random_state = 1)
        up = up_raw

        train_valid = up.append(down)

    elif up_raw.shape[0] / down_raw.shape[0] >= 1:

        percentage = down_raw.shape[0] / up_raw.shape[0]
        up = up_raw.sample(frac=percentage, random_state = 1)
        down = down_raw

        train_valid = down.append(up)

    print('up = ', train_valid[train_valid[target] == 1].shape[0])
    print('down = ', train_valid[train_valid[target] == 1].shape[0])

X_cv = train_valid.drop(target, axis = 1).drop('Return', axis = 1)
Y_cv = train_valid[target]

X_test_cv = test.drop(target, axis = 1).drop('Return', axis = 1)
Y_test_cv = test[target]

```

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svc_rbf = SVC(kernel='rbf', C=C_selected_1, gamma =lamb_selected)
svc_rbf.fit(X_cv, Y_cv)
Y_test_cv_fit = svc_rbf.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': test['Return'].iloc[:].values,
                               'Binary_Return': Y_test_cv.values.reshape(-1,1),
                               'Predicted_Binary_Return': Y_test_cv_fit,
                               'Capital': np.zeros(len(Y_test_cv))},
                               index = Y_test_cv.index)

cols = ['Return', 'Binary_Return', 'Predicted_Binary_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0,0,0,1]).reshape(-1,4),
                        columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='% , ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

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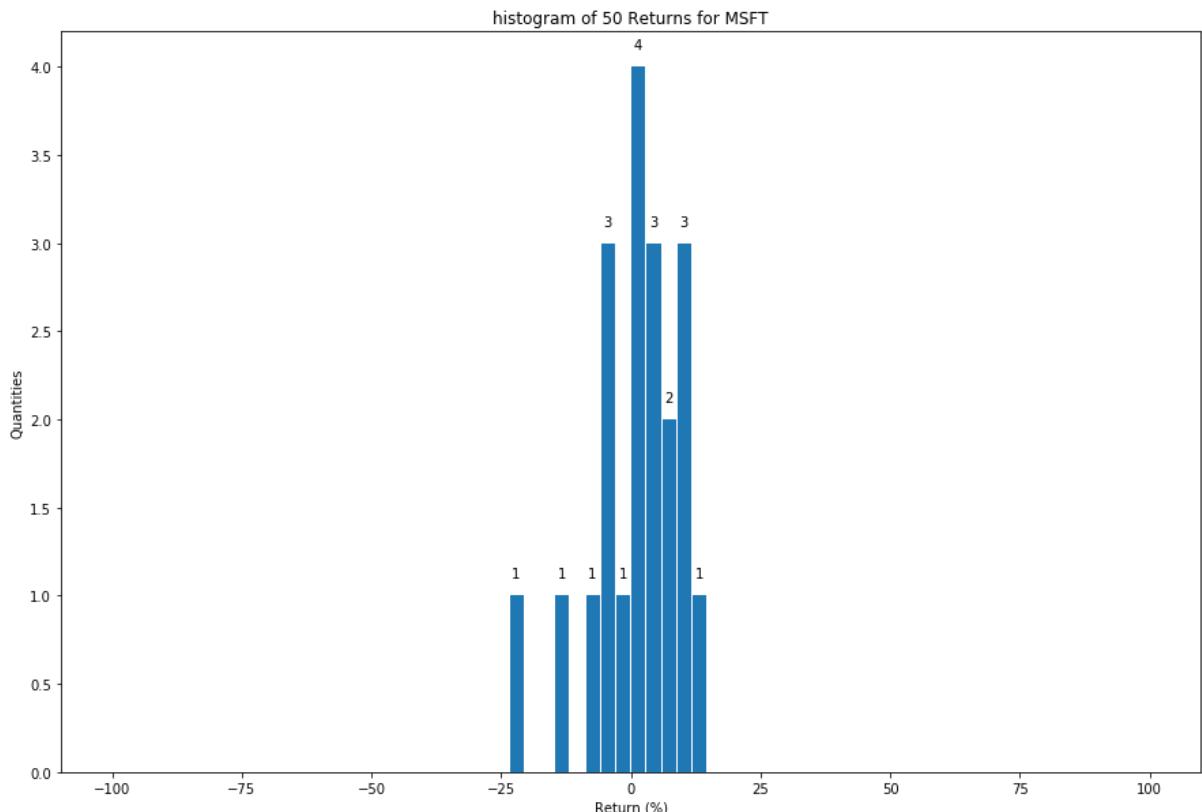
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down_raw = 97
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up = 95
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up_raw = 123
down_raw = 102
up = 102
down = 102
up_raw = 140
down_raw = 110
up = 110
down = 110
Returns :
4%, -6%, 7%, 3%, 1%, 0%, -5%, 10%, 8%, -8%, -21%, 3%, 9%, 15%, 1%, 4%,
10%, -5%, 2%, -13%, Maximum Return: 15.0
Minimum Return: -21.0
Average Return: 1.0
Standard Deviation: 8.0
320 training days
80 validation days
100 test days
```

In [665...]

```
fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')
```

Out[665...]: Text(0, 0.5, 'Quantities')



10 Year Investment

In [666...]

```
fix_history_length = 250 # 2~1 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[666...]: 2

In [677...]

```
# an array for saving 50 final best profit
lambda_list = np.array([ 2**(-11), 2**(-7), 2**(-3), 2**(-1), 2**(1),
C_list = np.array([ 2**(-3), 2**(-1), 2**(1), 2**(3), 2**(5), 2**(9),
profit_final = np.array([])

for i in range(sample_size):
```

```

PnL_logistic = np.array([])
np.random.seed(i)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

# use BeginTime and EndTime to filter test and train_valid
train_valid = BTC.iloc[BeginTime:timestamp, :]
test = BTC.iloc[timestamp:EndTime, :]
Best_Inner_SVM_Profit = np.array([])
Best_C = np.array([])
for lamb in lambda_list:
    Inner_SVM_Profit = np.array([])
    for c in C_list:
        Inner_SVM_Profit = np.append(Inner_SVM_Profit, kfold_SVM(t))
    Best_Inner_SVM_Profit = np.append(Best_Inner_SVM_Profit, Inner_SVM_Profit)
    Best_C = np.append(Best_C, np.argmax(Inner_SVM_Profit))

lamb_selected = lambda_list[Best_Inner_SVM_Profit.argmax()]
C_selected = Best_C[np.argmax(Best_Inner_SVM_Profit)]
C_selected = C_selected.astype(int)
C_selected_1 = C_list[C_selected]

## Balance the data for binary prediction
up_raw = train_valid[train_valid[target] == 1]
down_raw = train_valid[train_valid[target] == 0]

print('up_raw = ', up_raw.shape[0])
print('down_raw = ', down_raw.shape[0])

if up_raw.shape[0] / down_raw.shape[0] < 1:

    percentage = up_raw.shape[0] / down_raw.shape[0]
    down = down_raw.sample(frac=percentage, random_state = 1)
    up = up_raw

    train_valid = up.append(down)

elif up_raw.shape[0] / down_raw.shape[0] >= 1:

    percentage = down_raw.shape[0] / up_raw.shape[0]
    up = up_raw.sample(frac=percentage, random_state = 1)
    down = down_raw

    train_valid = down.append(up)

print('up = ', train_valid[train_valid[target] == 1].shape[0])
print('down = ', train_valid[train_valid[target] == 0].shape[0])

X_cv = train_valid.drop(target, axis = 1).drop('Return', axis = 1)
Y_cv = train_valid[target]

X_test_cv = test.drop(target, axis = 1).drop('Return', axis = 1)
Y_test_cv = test[target]

```

```

svc_rbf = SVC(kernel='rbf', C=C_selected_1, gamma =lamb_selected)
svc_rbf.fit(X_cv, Y_cv)
Y_test_cv_fit = svc_rbf.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': test['Return'].iloc[:].values,
                               'Binary_Return': Y_test_cv.values.reshape(-1,1),
                               'Predicted_Binary_Return': Y_test_cv_fit,
                               'Capital': np.zeros(len(Y_test_cv))})
index = Y_test_cv.index

cols = ['Return', 'Binary_Return', 'Predicted_Binary_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0,0,0,1]).reshape(-1,4),
                        columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1, :])

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='% , ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

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up_raw = 132
down_raw = 93
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Returns :
-19%, Maximum Return: -19.0
Minimum Return: -19.0
Average Return: -19.0
Standard Deviation: 0.0
320 training days
```

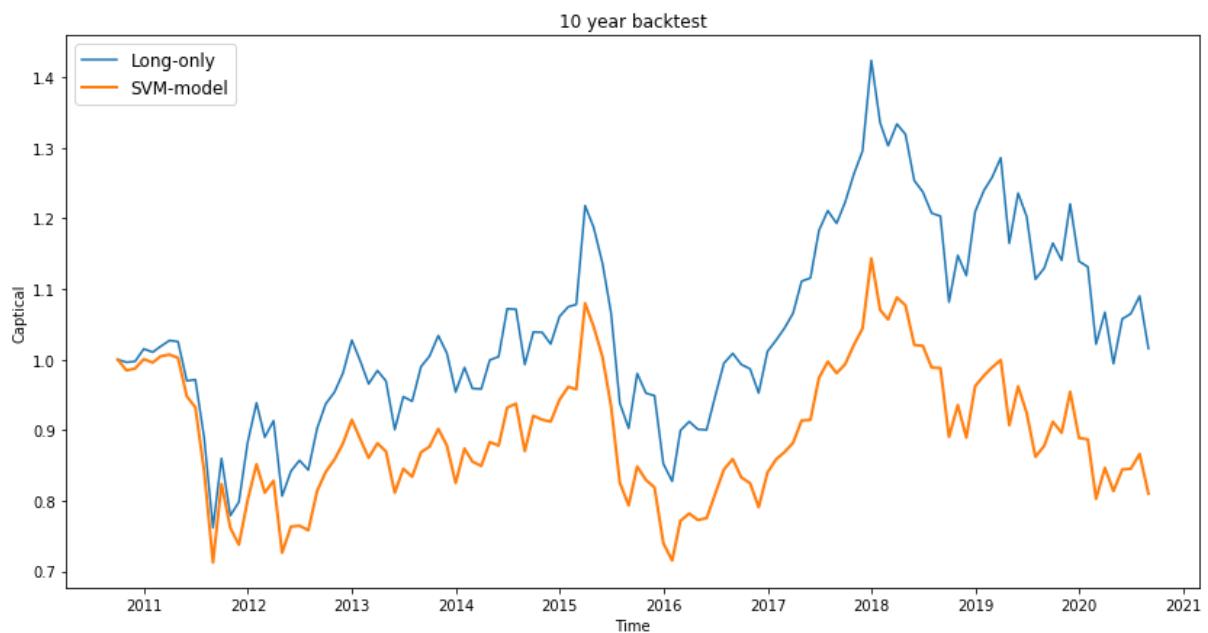
80 validation days
100 test days

In [678...]

```
# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], label='Long-only')
plt.plot(long_short_df_final.Capital[1:], lw=2, label='SVM-model')
plt.xlabel('Time')
plt.ylabel('Capital')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)
```

Out[678...]

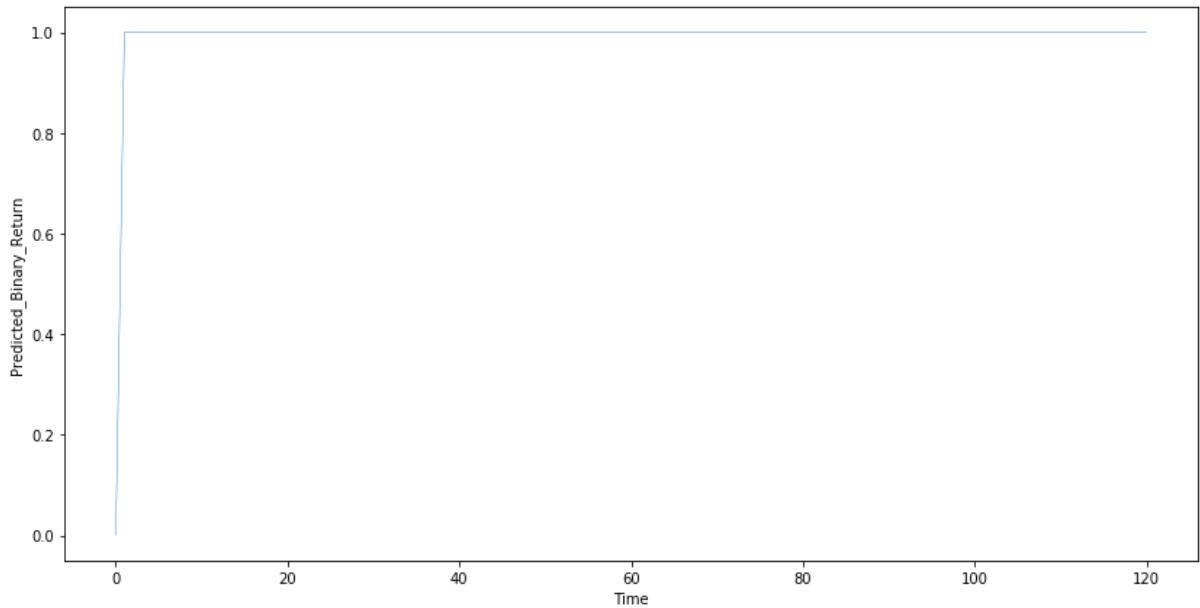


In [679...]

```
plt.figure(figsize=(14, 7))
plt.plot(range(long_short_df_final.shape[0]), long_short_df_final.Pred)
plt.xlabel('Time')
plt.ylabel('Predicted_Binary_Return')
```

Out[679...]

Text(0, 0.5, 'Predicted_Binary_Return')



Random Forest + K-Fold Cross-Validation on PnL

In [630...]

```
BTC['Binary_Return'] = BTC.Return.shape[0]
BTC.Binary_Return[BTC.Return > 0] = 1
BTC.Binary_Return[BTC.Return <= 0] = 0
target = 'Binary_Return'
BTC
```

Out[630...]

	Open	High	Low	Close	RF	Return-RF
--	------	------	-----	-------	----	-----------

Date

1989-11-30	2748.000000	2962.000000	2735.000000	2836.600098	0.69	0.032242
1989-12-31	2836.000000	2889.000000	2732.000000	2751.600098	0.61	-0.029760
1990-01-31	2751.000000	2982.000000	2697.000000	2952.000000	0.57	0.073064
1990-02-28	2951.000000	3027.000000	2862.000000	2997.000000	0.57	0.015588
1990-03-31	2997.000000	3073.000000	2931.000000	2951.000000	0.64	-0.015349
1990-04-30	2948.000000	3137.000000	2906.000000	3132.000000	0.69	0.062415
...
2020-05-31	23539.910156	25303.779297	23539.910156	24427.189453	0.01	0.037693
2020-06-30	24563.570312	26782.619141	24526.910156	24595.349609	0.01	0.001294

	Open	High	Low	Close	RF	Return-RF
Date						
2020-07-31	24566.810547	25847.109375	24167.789062	25177.050781	0.01	0.024840
2020-08-31	25085.669922	25254.140625	23124.250000	23459.050781	0.01	-0.064843
2020-09-30	24039.390625	24970.589844	23674.519531	24107.419922	0.01	0.002830
2020-10-31	24274.830078	27040.410156	24232.660156	26341.490234	0.01	0.085136

372 rows × 21 columns

In [631...]

```
# Long & Short
def computation(df):
    for i in range(1, len(df)):
        if i == 1:
            df.loc[df.index[i], 'Capital'] = 1
        elif df.loc[df.index[i], 'Predicted_Binary_Return'] == 1:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        elif df.loc[df.index[i], 'Predicted_Binary_Return'] == -1:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        else:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
    return df
```

In [632...]

```
def Random_Forest(Y_valid_Return, x_train, y_train, x_valid, y_valid, depth):

    # create a linear model
    X_train = x_train
    Y_train = y_train
    X_valid = x_valid
    Y_valid = y_valid

    model = RandomForestClassifier(max_depth=depth, min_impurity_decrease=0.001)
    model.fit(X_train, Y_train)
    Y_valid_fit = model.predict_proba(X_valid)
    Y_valid_fit = Y_valid_fit[:, 1]

    n_days = len(Y_valid_fit)
    cash = 1
    stock = 0

    position = []

    for d in range(0, n_days):

        # Long if spread < lower band & if not bought yet
        if Y_valid_fit[d] > 0.50 + Confident[0] and cash == 1:
```

```

    signal = 1
    cash = 0
    stock = 1
    position.append(signal)

    # Take Profit if spread > moving average & if already bought
    elif (Y_valid_fit[d] < 0.50+Confident[1] ) and stock == 1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    # Short if spread > upper band and no current position
    elif Y_valid_fit[d] < 0.50-Confident[0] and cash == 1:
        signal = -1
        cash = 0
        stock = -1
        position.append(signal)

    # Take Profit if spread < moving average & if already short
    elif (Y_valid_fit[d] > 0.50-Confident[1] ) and stock == -1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    else:
        signal = 0
        position.append(signal)

df = pd.DataFrame()

df['Position'] = position
df['Position'] = df['Position'].replace(to_replace=0, method= 'ffill')
df['Position'] = df['Position'].replace(3,0)

Y_valid_fit = df['Position'].values

print(model.classes_)
print(Y_valid_fit)

# a data frame for computing and saving long_short value
long_short_df = pd.DataFrame({'Return': Y_valid_Return.iloc[:,].values,
                               'Binary_Return': Y_valid.iloc[:,].values,
                               'Predicted_Binary_Return': Y_valid.iloc[:,].values,
                               'Capital': np.zeros(len(Y_valid))},
                               index = Y_valid.index)

cols = [ 'Return', 'Binary_Return', 'Predicted_Binary_Return', 'Capital']
long_short_df = long_short_df[cols]

# give an initial point
initial = pd.DataFrame(np.array([0,0,0,1]).reshape(-1,4),
                        columns = long_short_df.columns)

```

```
# combine df and initial point
long_short_df = pd.concat([initial, long_short_df])

# compute long_short value
long_short_df_final = computation(long_short_df)

# return final long_short value of this period
return long_short_df_final.iloc[-1,3]
```

In [633...]

```
def kfold_randomForest(data, target, n, Confident, depth, impurity):
    # We need a vector to record mse from k-fold
    profit = np.array([])

    # KFold is a build-in function in Scikit-learn
    # it can help us cut data into n pieces
    # (compare with simple cross validation)
    kf = KFold(n_splits = n)

    for train_index, validation_index in kf.split(data):

        # obtain the train and validation ,opart
        train, valid = data.iloc[train_index,:], data.iloc[validation_index,:]

        ## Balance the data for binary perdition
        up_raw = train[train[target] == 1]
        down_raw = train[train[target] == 0]

        print('up_raw = ', up_raw.shape[0])
        print('down_raw = ', down_raw.shape[0])

        if up_raw.shape[0] / down_raw.shape[0] < 1:

            percentage = up_raw.shape[0] / down_raw.shape[0]
            down = down_raw.sample(frac=percentage, random_state = 1)
            up = up_raw

            train = up.append(down)

        elif up_raw.shape[0] / down_raw.shape[0] >= 1:

            percentage = down_raw.shape[0] / up_raw.shape[0]
            up = up_raw.sample(frac=percentage, random_state = 1)
            down = down_raw

            train = down.append(up)

        print('up = ', train[train[target] == 1].shape[0])
        print('down = ', train[train[target] == 1].shape[0])
```

```

# extract X and Y to be fit in a model
X_train = train[features]
Y_train = train[target]
X_valid = valid[features]
Y_valid = valid[target]
Y_valid_Return = valid['Return']

# Calculate PnL
profit_temp = Random_Forest(Y_valid_Return, X_train, Y_train,
                             profit = np.append(profit, profit_temp))

return profit.mean()

```

In [634...]: `np.arange(0.0, 1.0, 0.1)`

Out[634...]: `array([0., 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9])`

6 Month Investment

In [635...]:

```

fix_history_length = 250 # ~21 year
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange

```

Out[635...]: 116

In [636...]:

```

# an array for saving 50 final best profit
# depth_list = np.random.randint(1, high=10, size=3)
# impurity_list = np.random.uniform(0, high=0.1, size = 5)
depth_list = [2, 15]
impurity_list = [0.0]
profit_final = np.array([])
Confident = [0.00,0.00]

for i in range(sample_size):

    PnL_logistic = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

```

```

Best_Inner_RandomForest_Profit = np.array([ ])
Best_Impurity = np.array([ ])
for depth in depth_list:
    Inner_RandomForest_Profit= np.array([ ])
    for impurity in impurity_list:
        Inner_RandomForest_Profit = np.append(Inner_RandomForest_Profit, Best_Inner_RandomForest_Profit)
    Best_Inner_RandomForest_Profit = np.append(Best_Inner_RandomForest_Profit, Best_Impurity)
    Best_Impurity = np.append(Best_Impurity,np.argmax(Inner_RandomForest_Profit))

depth_selected = depth_list[Best_Inner_RandomForest_Profit.argmax()]
Impurity_selected = Best_Impurity[np.argmax(Best_Inner_RandomForest_Profit)]
Impurity_selected = Impurity_selected.astype(int)
Impurity_selected_1 = impurity_list[Impurity_selected]

print('depth_selected = ', depth_selected)
print('Impurity_selected = ', Impurity_selected_1)

## Balance the data for binary prediction
up_raw = train_valid[train_valid[target] == 1]
down_raw = train_valid[train_valid[target] == 0]

print('up_raw = ', up_raw.shape[0])
print('down_raw = ', down_raw.shape[0])

if up_raw.shape[0] / down_raw.shape[0] < 1:

    percentage = up_raw.shape[0] / down_raw.shape[0]
    down = down_raw.sample(frac=percentage, random_state = 1)
    up = up_raw

    train_valid = up.append(down)

elif up_raw.shape[0] / down_raw.shape[0] >= 1:

    percentage = down_raw.shape[0] / up_raw.shape[0]
    up = up_raw.sample(frac=percentage, random_state = 1)
    down = down_raw

    train_valid = down.append(up)

print('up = ', train_valid[train_valid[target] == 1].shape[0])
print('down = ', train_valid[train_valid[target] == 1].shape[0])

X_cv = train_valid[features]
Y_cv = train_valid[target]

X_test_cv = test[features]
Y_test_cv = test[target]

model_cv = RandomForestClassifier( max_depth=depth_selected, min_samples_leaf=1)
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict_proba(X_test_cv)
Y_test_cv_fit = Y_test_cv_fit[:,1]

```

```

n_days = len(Y_test_cv_fit)
cash = 1
stock = 0

position = []

for d in range(0, n_days):

    # Long if spread < lower band & if not bought yet
    if Y_test_cv_fit[d] > 0.50+Confident[0] and cash == 1:
        signal = 1
        cash = 0
        stock = 1
        position.append(signal)

    # Take Profit if spread > moving average & if already bought
    elif (Y_test_cv_fit[d] < 0.50+Confident[1]) and stock == 1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    # Short if spread > upper band and no current position
    elif Y_test_cv_fit[d] < 0.50-Confident[0] and cash == 1:
        signal = -1
        cash = 0
        stock = -1
        position.append(signal)

    # Take Profit if spread < moving average & if already short
    elif (Y_test_cv_fit[d] > 0.50-Confident[1]) and stock == -1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    else:
        signal = 0
        position.append(signal)

df = pd.DataFrame()

df['Position'] = position
df['Position'] = df['Position'].replace(to_replace=0, method= 'ffill')
df['Position'] = df['Position'].replace(3,0)

Y_test_cv_fit = df['Position'].values

long_short_df = pd.DataFrame({'Close': test['Close'].values,
                               'Return': test['Return'].values.toli:
                               'Binary_Return': Y_test_cv.values.re

```

```

'Predicted_Binary_Return': Y_test_cv,
'Capital': np.zeros(len(Y_test_cv)),
'Gain': np.zeros(len(Y_test_cv))},
index = Y_test_cv.index)

initial = pd.DataFrame(np.array([0,0,0,0,1,0]).reshape(-1,6),
columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

profit_final = (profit_final - 1)*100

long_short_df['Gain'] = long_short_df['Capital'].values - long_short_df['Predicted_Binary_Return']

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='% , ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

```

up_raw = 108
down_raw = 79
up = 79
down = 79
[0 1]
[ 1  1  1  1  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1  0  1  0  1  0 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1]
up_raw = 110
down_raw = 77
up = 77
down = 77
[0 1]
[-1 -1 -1 -1 -1  0 -1  0  1  1  1  1  1  1  1  0 -1 -1 -1 -1 -1  0  1
 1
 1  1  0 -1  0  1  1  1  1  0 -1  0  1  0 -1 -1 -1  0  1  1  1  1
 1
 0 -1 -1 -1 -1 -1 -1 -1 -1 -1  0  1  1  1  1]
up_raw = 103
down_raw = 85
up = 85
down = 85
[0 1]
[ 1  1  1  1  1  0 -1  0 -1  0  1  1  1  0  1  1  1  1  1  1  1  1  1
 1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 0
-1
 0 -1 -1 -1 -1 -1 -1 -1 -1 -1  0  1  1  1  1  1]

```



```

-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1  0  1  0 -1 -1]
up_raw = 117
down_raw = 70
up = 70
down = 70
[0 1]
[ 1  1  1  1  1  0 -1  0  1  1  1  1  0  1  0  1  1  1  1  0 -1 -1
-1
 -1  0  1  0  1  0  1  0 -1 -1 -1 -1  0  1  0  1  1  0  1  1  0  1  1  1
0
 1  1  1  1  0 -1  0 -1  0 -1  0  1  1  1  1  1
up_raw = 100
down_raw = 88
up = 88
down = 88
[0 1]
[-1  0  1  1  1  1  1  1  1  1  1  1  0  1  1  0  1  1  1  1  1  1  1
1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1 -1
-1
 -1  0 -1  0  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 111
down_raw = 77
up = 77
down = 77
[0 1]
[-1 -1  0 -1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1
 1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  0 -1  0 -1 -1 -1 -1 -1  0  1
1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
up_raw = 107
down_raw = 80
up = 80
down = 80
[0 1]
[ 1  1  1  1  1  0  1  1  1  1  1  1  1  0  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1  0 -1 -1 -1 -1  0 -1  0  1  0 -1 -1
up_raw = 117
down_raw = 70
up = 70
down = 70
[0 1]
[ 1  1  1  1  1  0 -1 -1 -1  0  1  1  1  1  0  1  1  1  1  1  1  1  0 -1
-1
 -1  0  1  1  1  0  1  1  1  0 -1  0  1  1  1  1  1  1  1  1  1  1  1  1
1
 1  1  1  1  0  1  1  0  1  1  1  1  1  1  1  1  1
up_raw = 100
down_raw = 88
up = 88
down = 88
[0 1]
[-1  0 -1  0  1  1  1  1  1  1  1  1  1  0 -1 -1  0 -1  0  1  1  1  1  1  0  1
1
 1  1  1  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1 -1
-1
 -1  0 -1  0  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 111
down_raw = 77

```



```

1
    1   1   1   1   1   1   1   1   1   1   1   1   0   1   1   1]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[-1 -1 -1 -1  0 -1  0 -1  0  1  1   1   1   1   1   1   1   1
-1
-1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
0
    1   0   -1  -1 -1  0  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1]
up_raw = 108
down_raw = 79
up = 79
down = 79
[0 1]
[ 1   0   1   1   1   1   1   0   1   1   1   1   1   1   0  -1  -1
-1
-1   0   1   0  -1  -1  0  -1  -1  -1  0   1   1   1   0   0   1
1
    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1]
up_raw = 100
down_raw = 87
up = 87
down = 87
[0 1]
[ 1   1   1   1   1   1   1   0  -1  -1  -1  -1  0  -1   0   1   0
-1  -1  -1  -1  -1  0   1   1   1   1   1   1   1   1   1   0   -1
-1
-1   0  -1  -1  0  -1  -1  -1  -1  -1  0   1   1   1   1   1   1
1]
up_raw = 106
down_raw = 82
up = 82
down = 82
[0 1]
[ 1   0  -1  -1  -1  -1  -1  -1  0  -1   0  -1  -1  -1   0   1
1   1   0  -1  -1  -1  -1  -1  0   1   1   1   1   1   1   1   1
0
    1   1   1   1   1   1   1   0  -1  -1   0   1   0   1   0   0]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[-1 -1 -1 -1 -1 -1 -1  0  -1   0   1   1   1   1   1   1   1
-1
-1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
0
    -1  -1  -1  -1  -1  0  -1  -1  -1  -1  -1  -1  -1  -1  -1
depth_selected = 15
Impurity_selected = 0.0
up_raw = 141
down_raw = 109
up = 109
down = 109
up_raw = 108
down_raw = 79
up = 79
down = 79
[0 1]
[ 1   1   1   1   0  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
-1
-1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1]

```



```

up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[ 1 1 1 1 0 1 1 0 -1 -1 0 1 1 1 0 1 1 1 1 0 -1 -1 -1
-1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1 -1 0 1
1 1 1 1 1 1 1 1 0 -1 0 -1 -1 -1 ]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 142
down_raw = 108
up = 108
down = 108
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1 0 1 1 0 1 0 1 0
-1
-1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 0 1 1 1 0 -1
-1
0 1 1 1 1 1 1 1 1 0 -1 0 -1 0 1 ]
up_raw = 93
down_raw = 94
up = 93
down = 93
[0 1]
[-1 -1 0 1 1 1 1 1 1 1 1 1 1 1 0 -1 -1 0 1 1 1 1 0
-1
-1 -1 0 1 1 1 0 -1 0 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1
1
1 1 1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 ]
up_raw = 104
down_raw = 84
up = 84
down = 84
[0 1]
[-1 -1 -1 -1 -1 -1 -1 0 -1 0 1 0 -1 -1 0 1 0 1 0 1 0 -1 -1 -1 0
1
1 1 1 1 1 0 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 0 1 0 1 0 -1 0 ]
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[ 1 1 1 0 -1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
0 -1 -1 0 -1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 ]
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1 -1 -1 -1 0 -1 -1 0 -1 -1 -1 -1 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 0
-1
0 -1 0 1 0 -1 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 1 1 1 1 0 -1
-1

```

```

-1
  0  1  1  1  1  1  1  1  1  0 -1  0 -1 -1 -1]
up_raw =  93
down_raw =  94
up =  93
down =  93
[0 1]
[-1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1 -1 -1  0  1  0 -1  0
-1
 -1  0  1  1  0  1  0  1  1  1  0  1  1  1  0  1  1  0  1  1  1  0  1  1  0
1
 1  1  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1]
up_raw =  104
down_raw =  84
up =  84
down =  84
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1  0  1  1  1  0 -1 -1
1
 1  1  1  1  1  0 -1 -1  0  1  1  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1]
up_raw =  108
down_raw =  80
up =  80
down =  80
[0 1]
[ 1  1  1  0  1  1  0  1  1  1  0  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  0
1
 0 -1 -1  0 -1  0 -1 -1  0  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1
 1  1  1  1  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1]
depth_selected =  15
Impurity_selected =  0.0
up_raw =  138
down_raw =  112
up =  112
down =  112
up_raw =  109
down_raw =  78
up =  78
down =  78
[0 1]
[ 1  1  1  0 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1]
up_raw =  112
down_raw =  75
up =  75
down =  75
[0 1]
[ 1  0 -1 -1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1  0
1
 0  1  0 -1 -1  0 -1  0  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1]
up_raw =  111
down_raw =  77
up =  77
down =  77
[0 1]
[-1 -1  0 -1 -1 -1 -1 -1 -1  0 -1 -1  0  1  0 -1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1]
```

```

0
-1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[ 1   1   1   1   1   1   1   1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   0   -1   -1
-1
-1   -1   -1   -1   -1   -1   -1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0   1   0   1
1
1   1   1   1   1   1   1   1   0   1   1   1   1   1   0 ]
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1   -1   -1   -1   -1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0   1   0   -1   -1   -1   -1
-1
-1   -1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   0 ]
up_raw = 112
down_raw = 75
up = 75
down = 75
[0 1]
[ 1   1   0   -1   -1   -1   -1   -1   0   -1   -1   -1   -1   -1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   0
1
0   1   0   -1   -1   0   -1   -1   0   1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   0
-1
-1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1 ]
up_raw = 111
down_raw = 77
up = 77
down = 77
[0 1]
[ 1   0   -1   -1   -1   -1   0   -1   -1   0   1   0   1   1   1   1   0   1   1   1   0   1   1   0   1   0   1
1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0   1   1   1   1   1   1   1
1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[ 1   1   0   0   1   1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1
-1
-1   -1   -1   -1   -1   -1   -1   0   -1   -1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   0   1   0
-1
-1
0   -1   0   -1   0   1   0   -1   -1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1
depth_selected = 2
Impurity_selected = 0.0
up_raw = 147
down_raw = 103
up = 103
down = 103
up_raw = 109
down_raw = 78
up = 78
down = 78

```

```

[0 1]
[ 1  1  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1  0  1  1  0 -1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
0  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1 -1  0 -1 -1  0 -1  0  1  1  0 -1 -1 -1 -1 -1  0  1  0 -1 -1 -1 -1  0
0
-1  0  1  0 -1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1
-1
-1 -1  0 -1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1  1  0 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1
1  1  1  1  1  1  1  1  1  1  1  0  1  0  1  1  0  1  0  1  0 -1  0 -1
0
-1 -1 -1 -1 -1 -1  0  1  0 -1 -1  0  1  1
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[ 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1
0 -1 -1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1  0  1  1  1  1  1
1
1  0  1  1  1  1  1  0  1  1  0  1  1  1  1  1
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[ 1  1  0 -1  0  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1 -1  0  1  0 -1 -1 -1 -1
-1
1  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1 -1  0 -1 -1 -1 -1  0  1  1  0 -1 -1 -1 -1 -1  0  1  1  0 -1 -1 -1 -1
0
-1 -1  0  0 -1  0 -1 -1  0 -1 -1 -1 -1 -1 -1 -1  0  1  1  1  1  1  1  0
1
0 -1  0 -1 -1 -1 -1  0  1  1  1  1  1  1  1  1
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1  0 -1 -1 -1  0 -1  0  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1
1
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1  0 -1

```

```

-1
 -1 -1 -1 -1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1]
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[ 1  0  1  1  1  1  0 -1 -1 -1 -1 -1  0  1  1  0  1  1  1  1  0 -1 -1 -1 -1 -1
-1
 -1 -1 -1  0 -1 -1 -1 -1  0  1  0  1  1  1  0  1  1  1  0  1  1  1  0  1  1  1  1  1
1
 1  1  1  1  1  1  1  0 -1  0 -1  0 -1 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
depth_selected = 2
Impurity_selected = 0.0
up_raw = 142
down_raw = 108
up = 108
down = 108
up_raw = 103
down_raw = 84
up = 84
down = 84
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 80
up = 80
down = 80
[0 1]
[-1  0  1  0 -1 -1  0  1  0  1  0  1  1  1  0 -1  0 -1  0 -1  0  1  0  1  0  1  0  1
0
 1  1  0 -1 -1 -1  0 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1  0 -1  0 -1  0 -1
-1
 -1 -1  0  1  0 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1  0 -1 -1 -1  0  1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 112
down_raw = 76
up = 76
down = 76
[0 1]
[-1 -1  0 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1  0 -1  0 -1 -1  0  1  1  1  0 -1  0  1  0 -1  0  1  0 -1  0  1  0 -1  0  1  1  1  1
1
 1  1  1  1  1  1  1  1  0 -1 -1  0 -1  0  1
up_raw = 103
down_raw = 84
up = 84
down = 84
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1

```

```

-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 80
up = 80
down = 80
[0 1]
[-1 0 1 0 1 0 1 1 0 1 0 0 1 0 1 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
 1 1 0 1 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0
 1 0 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1 1 1 1 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1 -1
-1
 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0
 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 112
down_raw = 76
up = 76
down = 76
[0 1]
[-1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1
-1
 0 0 1 1 1 1 0 1 1 1 0 -1 0 1 1 0 -1 -1 0 -1 -1 0 1 1 0 -1 -1 0 1 1 1 1 1
1
 1 1 1 1 1 1 1 0 -1 -1 0 -1 0 ]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 141
down_raw = 109
up = 109
down = 109
up_raw = 111
down_raw = 76
up = 76
down = 76
[0 1]
[ 1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0
 1 1 0 -1 -1 0 -1 -1 -1 -1 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 95
down_raw = 92
up = 92
down = 92
[0 1]
[ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
-1
 -1 0 1 0 1 0 -1 -1 -1 -1 0 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
 -1 0 1 1 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 81
up = 81
down = 81

```

```

[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 0 -1 -1 0 -1 0 1
1
1 0 1 0 1 1 1 0 1 1 0 1 0 -1 -1 0 1 0 1 0 1 0 1 0 1 0 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[ 1 1 1 1 1 1 1 1 1 0 -1 0 1 0 -1 0 -1 0 1 1 1
1
1 1 1 1 1 1 0 -1 -1 0 -1 0 1 1 1 1 1 1 1 1 0 -1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1
up_raw = 111
down_raw = 76
up = 76
down = 76
[0 1]
[-1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0
1 1 0 -1 -1 -1 -1 -1 -1 0 1 0 -1 -1 0 1 0 -1 -1 0 1 0 -1 0
1
1 1 1 1 0 -1 -1 -1 -1 0 0 -1 -1 -1 0
up_raw = 95
down_raw = 92
up = 92
down = 92
[0 1]
[ 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0
-1 0 1 1 1 0 -1 -1 0 1 1 1 1 1 1 1 1 1 0 -1 0 -1 0 1
1
1 1 1 0 1 1 1 1 1 0 -1 -1 -1 -1
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[-1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 0 1
1
1 0 1 0 1 1 1 0 1 0 -1 0 -1 -1 -1 0 1 0 1 0 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[ 1 0 1 1 1 1 1 0 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 0 -1 -1 0 -1 0 -1 -1 0 1 1 1 1 0 1
1
1 1 1 1 1 1 1 1 1 1 1 1 0 -1
depth_selected = 15
Impurity_selected = 0.0
up_raw = 140
down_raw = 110
up = 110
down = 110
up_raw = 110
down_raw = 77

```



```

1
1   1   1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   0   1   1   1   1   0   -1   0   1   1   1   1
1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0   1]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[ 1   1   1   1   0   1   1   1   1   0   1   1   1   1   1   1   0   -1   -1   -1   -1   -1   -1   -1   -1
-1
-1   -1   -1   -1   -1   -1   -1   -1   -1   -1   0   1   1   1   1   1   1   1   0   -1   -1   0   -1
-1
-1   0   0   1   0   1   1   1   0   -1   -1   -1   -1   0]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 147
down_raw = 103
up = 103
down = 103
up_raw = 108
down_raw = 79
up = 79
down = 79
[0 1]
[ 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
1   1   1   1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1
-1
-1   -1   -1   0   1   1   0   1   1   0   1   0   1   1   1   1]
up_raw = 113
down_raw = 74
up = 74
down = 74
[0 1]
[-1   0   -1   -1   -1   -1   -1   -1   -1   -1   0   -1   -1   -1   0   -1   -1   0   -1   -1   0   -1
-1
-1   -1   0   -1   -1   0   1   1   0   -1   -1   -1   -1   0   1   0   -1   -1   -1   0   -1   -1
-1
-1   -1   -1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   0   -1]
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
0
1   1]
up_raw = 113
down_raw = 75
up = 75
down = 75
[0 1]
[ 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
1]
up_raw = 108
down_raw = 79
up = 79
down = 79
[0 1]
[ 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
0
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
1]
```

```

1
  1   1   1   1   1   1   1   1   1   1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1
-1
  -1   -1   -1   0   1   1   1   1   0   -1   0   -1   0   1   1]
up_raw = 113
down_raw = 74
up = 74
down = 74
[0 1]
[ 1   1   0   -1   -1   -1   -1   -1   0   -1   0   -1   0   1   1   0   -1   0   -1   -1   -1   -1   0
1
  1   0   1   1   1   1   1   1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   0   1   0
1
  1   0   1   1   0   1   1   1   0   -1   -1   -1   -1   -1   -1   0   -1]
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1   1   1   1   1   1   1   1   1   1   1   1   1   0   1   1   1   1   1   1   1   1   1
1
  1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0   1   1
1
  1   1   1   1   1   1   1   1   0   -1   -1   0   -1   0]
up_raw = 113
down_raw = 75
up = 75
down = 75
[0 1]
[ 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
  1   1   1   1   1   1   1   0   1   1   1   1   1   1   1   1   0   0   -1   -1   -1   -1   -1   -1   0
1
  1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 145
down_raw = 105
up = 105
down = 105
up_raw = 104
down_raw = 83
up = 83
down = 83
[0 1]
[-1   -1   -1   -1   0   -1   0   -1   -1   -1   0   1   1   0   -1   -1   -1   -1   -1   -1   -1   0   -1
-1
  -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   0   -1   -1   -1   0   -1   -1
-1
  -1   -1   -1   0   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1]
up_raw = 101
down_raw = 86
up = 86
down = 86
[0 1]
[-1   -1   -1   0   1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   0   -1   0   1   0   1   1
0
  -1   -1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   0   -1   -1   -1   -1   0   1   0   1   0
-1
  -1   0   1   1   1   0   -1   0   1   1   0   1   1   1   1   1   1]
up_raw = 103
down_raw = 85
up = 85
down = 85

```

```

[0 1]
[-1 0 1 1 1 1 1 1 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 0 1 1 0 -1 -1 -1 -1 0 -1 0 -1 -1 -1 0 1
0
1 0 -1 -1 0 -1 -1 -1 0 1 1 1 1 0 1]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1 -1 0 1 1 1 1 1 1 1 1
1
1 1 1 0 -1 0 1 1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
0 -1 -1 0 -1 0 -1 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1]
up_raw = 104
down_raw = 83
up = 83
down = 83
[0 1]
[-1 -1 -1 0 1 1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1]
up_raw = 101
down_raw = 86
up = 86
down = 86
[0 1]
[-1 -1 -1 0 1 1 0 -1 -1 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1]
up_raw = 103
down_raw = 85
up = 85
down = 85
[0 1]
[-1 0 1 1 1 0 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 0 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 0 -1 -1 0 0 -1 -1 0 -1 -1 0 -1 -1 -1 0 1
1
1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 1 0 1]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1 0 1 1 1 1 1 1 1 1 1
1
1 1 1 0 -1 0 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
0 -1 -1 0 -1 0 1 0 1 1 1 1 1 0 1]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 139
down_raw = 111
up = 111
down = 111
up_raw = 108
down_raw = 79

```

```

up = 79
down = 79
[0 1]
[ 1 0 -1 0 1 1 0 1 0 1 1 0 1 0 1 0 1 0 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 0 1 0 1 0 1 0 -1 -1 -1 -1 -1 -1 0 1 0
1
0 1 0 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1]
up_raw = 101
down_raw = 86
up = 86
down = 86
[0 1]
[ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 0 -1 0 1 0 -1 0 -1 0 -1 -1 -1 0 1 1 1 1 1 1 1
0
1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[ 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
0 1 0 1 0 -1 -1 0 -1 -1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0
-1
-1 0 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 1 ]
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[-1 -1 -1 -1 0 1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1 -1 0
-1
0 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1]
up_raw = 108
down_raw = 79
up = 79
down = 79
[0 1]
[-1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 0 1 1 0 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1
-1
-1 -1 -1 -1 -1 -1 0 -1 -1 0 -1 -1 0 -1 -1 1 ]
up_raw = 101
down_raw = 86
up = 86
down = 86
[0 1]
[ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 0 -1 -1 -1 -1 0 1 0 -1 -1 -1 -1 -1 0 1 1 1 1 1 1
1
1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[ 1 1 0 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1
-1
-1 -1 -1 -1 -1 -1 0 -1 -1 0 -1 -1 0 -1 -1 1 ]

```

```

-1
  0 -1 -1 -1 -1 -1 -1  0  1  1  1  0 -1 -1  0 -1  0 -1 -1 -1 -1 -1 -1
-1
 -1 -1 -1  0  1  0 -1 -1 -1 -1 -1  0 -1 -1]
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[-1 0  1  1  1  1  0 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
1
 0 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1  0 -1  0
1
 0  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
depth_selected = 2
Impurity_selected = 0.0
up_raw = 142
down_raw = 108
up = 108
down = 108
up_raw = 107
down_raw = 80
up = 80
down = 80
[0 1]
[-1 0  1  1  1  1  1  0  1  1  1  1  1  1  1  0 -1 -1 -1 -1 -1  0  1  0 -1 -1 -1
-1
 -1  0 -1 -1 -1  0 -1 -1 -1 -1  0  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1
1
 1  0 -1  0 -1  0  1  1  0  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
up_raw = 99
down_raw = 88
up = 88
down = 88
[0 1]
[ 1  1  1  1  1  1  1  0 -1 -1  0  1  1  1  0 -1 -1 -1 -1 -1  0  1  1  1  0 -1 -1 -1
1
 0  1  1  1  1  1  0 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1  0  1]
up_raw = 106
down_raw = 82
up = 82
down = 82
[0 1]
[-1 0  1  0  1  1  1  1  1  1  0 -1 -1  0 -1  0  1  1  1  1  1  1  1  1  1  1  0  1
1
 1  1  1  1  1  1  0 -1 -1 -1 -1 -1 -1 -1  0 -1  0 -1  0  1  0  1  0  1  0  1
1
 1  1  1  1  1  1  1  1  1  1  0  1  0  1  0 -1]
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[-1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1  0 -1  0
1
 1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1
-1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 80
up = 80
down = 80

```

```

[0 1]
[ 1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  1  0 -1 -1  0  1  1  1  0  1
1
   0  1  1  0 -1  0  1  0 -1  0  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1
1
   1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
up_raw =  99
down_raw =  88
up =  88
down =  88
[0 1]
[ 1  1  1  1  1  1  0 -1 -1 -1  0  1  1  0  1  1  1  1  1  1  1  1  1  1  0
1
   1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1 -1
0
   1  0  1  1  1  0 -1 -1 -1 -1  0  1  1  0  1  1  1
up_raw = 106
down_raw =  82
up =  82
down =  82
[0 1]
[ 1  1  0 -1  0 -1 -1  0 -1 -1 -1 -1 -1 -1 -1 -1  0 -1  0  1  1  1  1  0 -1
-1
   -1  0 -1  0 -1  0 -1 -1 -1 -1 -1 -1  0 -1 -1 -1  0  1  0 -1 -1 -1  0
1
   1  1  1  1  1  1  1  1  1  1  0  1  1  1  1  1
up_raw = 108
down_raw =  80
up =  80
down =  80
[0 1]
[-1 -1 -1  0 -1  0  1  1  1  1  1  1  1  1  1  1  0  1  0 -1 -1 -1 -1 -1  0 -1
-1
   0  1  1  1  1  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  0 -1 -1 -1 -1
-1
   -1 -1  0 -1  0 -1 -1 -1 -1 -1 -1  0 -1 -1
depth_selected =  2
Impurity_selected =  0.0
up_raw = 140
down_raw =  110
up =  110
down =  110
up_raw = 105
down_raw =  82
up =  82
down =  82
[0 1]
[ 1  1  1  0 -1 -1 -1 -1 -1  0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
   -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
   -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
   up_raw = 105
down_raw =  82
up =  82
down =  82
[0 1]
[-1  0  1  0 -1  0  1  1  1  0 -1 -1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1
0
   -1 -1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0 -1 -1  0
1
   -1 -1 -1 -1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
up_raw = 103
down_raw =  85

```

```

up = 85
down = 85
[0 1]
[ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1 1 1 0 1 0 1 1 1 1 0 -1 -1
-1
-1 0 1 1 1 0 -1 -1 -1 -1 0 -1 -1]
up_raw = 110
down_raw = 78
up = 78
down = 78
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 1 1
1
1 0 1 1 1 0 -1 0 -1 -1 -1 -1 0 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 0 -1 -1 0 -1 0 -1 -1 0 1 1]
up_raw = 105
down_raw = 82
up = 82
down = 82
[0 1]
[-1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0
-1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
up_raw = 105
down_raw = 82
up = 82
down = 82
[0 1]
[-1 0 1 0 -1 0 1 1 0 -1 -1 -1 0 1 1 1 1 1 1 1 1 1 1 1 0 -1
0
-1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1 0 -1 0 1
0
-1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1]
up_raw = 103
down_raw = 85
up = 85
down = 85
[0 1]
[ 1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 0 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
0 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
up_raw = 110
down_raw = 78
up = 78
down = 78
[0 1]
[-1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1 -1 0 1 1
1
1 1 1 1 1 0 1 1 0 -1 -1 -1 0 -1 0 1 1 1 1 1 1 1 1 1
1
1 1 1 0 -1 -1 -1 -1 0 -1 -1 0 1 1]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 141
down_raw = 109
up = 109
down = 109

```

```
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[ 1 0 1 1 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
up_raw = 111
down_raw = 76
up = 76
down = 76
[0 1]
[-1 -1 -1 -1 -1 -1 0 -1 0 -1 0 -1 -1 0 1 1 0 -1 -1 -1 -1 0 1
0
-1 -1 0 1 0 -1 -1 0 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1 1 1 1 1 1 1 0 1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0
1
1
1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 1
1
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[ 1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[ 1 0 1 1 1 1 1 1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1
1
up_raw = 111
down_raw = 76
up = 76
down = 76
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 0 1 1 1 0 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 0 1 1 0 -1 0 -1 -1 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 0 1 1
1
up_raw = 101
down_raw = 87
up = 87
down = 87
```



```

up = 79
down = 79
[0 1]
[ 1 0 -1 0 1 1 1 1 1 0 -1 0 -1 -1 0 1 1 1 0 1 1 0 1 1 0
-1
-1 0 1 0 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1
0
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1
up_raw = 100
down_raw = 87
up = 87
down = 87
[0 1]
[ 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 0 0 1 0 1 1
0
1 0 1 0 -1 0 0 1 0 1 1 1 1 1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 0 1 1 1 0 1 0 1 0 1 ]
up_raw = 106
down_raw = 82
up = 82
down = 82
[0 1]
[-1 -1 -1 0 1 1 0 -1 -1 0 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1
1
0 1 0 1 0 -1 -1 -1 -1 0 1 1 0 1 1 0 0 -1 0 1 1 1 1 1 1
1
1 1 1 0 1 0 -1 0 -1 -1 -1 -1 0 ]
up_raw = 109
down_raw = 79
up = 79
down = 79
[0 1]
[-1 0 1 1 1 1 1 1 1 1 1 0 -1 -1 0 -1 0 1 0 1 1 0 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1 0 1 0 1 0
-1
0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 ]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 141
down_raw = 109
up = 109
down = 109
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[ 1 1 1 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 ]
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1 -1 -1 -1 -1 -1 0 -1 0 1 0 1 1 0 1 0 -1 -1 -1 0 1 1
0
-1 0 1 0 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0 1 ]

```

```

up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1 1 1 1 1 1 1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1 -1 0
1
0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 0]
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[-1 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 0 -1 -1 0 -1 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1 0 1 1 1 1 1 1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 0 -1 0 1 0 1 0 -1 -1 -1 -1 0]
up_raw = 109
down_raw = 78
up = 78
down = 78
[0 1]
[-1 -1 -1 -1 -1 -1 -1 0 -1 -1 0 -1 0 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 0
-1
-1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 1 1 0 -1 -1 -1 -1 0 1 1 0 1 1 1 0
0
1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 1 1 1]
up_raw = 101
down_raw = 87
up = 87
down = 87
[0 1]
[ 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0 -1
1
-1 -1 0 -1 -1 -1 -1 -1 -1 -1 0 1 1 1]
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[-1 -1 0 1 1 1 1 1 1 0 1 0 1 0 -1 -1 0 0 0 1 0 1 0 -1 0
-1
-1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 0 1 0
-1
-1 -1 -1 0 -1 0 1 0 -1 -1 0 1 0 -1 1]
depth_selected = 15
Impurity_selected = 0.0
up_raw = 142
down_raw = 108

```

```
up = 108
down = 108
up_raw = 110
down_raw = 77
up = 77
down = 77
[0 1]
[-1 0 -1 0 1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 0 1
0
1 0 1 0 -1 -1 -1 -1 0 1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1
-1
-1 0 -1 -1 -1 -1 -1 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1
up_raw = 95
down_raw = 92
up = 92
down = 92
[0 1]
[ 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 0 -1 0 1 1 1 1 1 0 1 1 1 0 1 1 0 1 1 0 1 1 0 1 1 1 1
1
1 1 1 1 1 1 1 1 0 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 81
up = 81
down = 81
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 1 1 1 1 0 -1 -1 -1 -1
-1
-1 -1 -1 0 1 0 1 1 1 1 0 -1 -1 0 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 0 -1 -1 0 -1 0 -1 0 -1 0 1 1 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 -1
up_raw = 110
down_raw = 77
up = 77
down = 77
[0 1]
[-1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0 -1 -1 -1
-1
-1 -1 0 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0 -1 -1 -1
-1
0 1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0 -1
up_raw = 95
down_raw = 92
up = 92
down = 92
[0 1]
[ 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
-1
0 1 0 1 0 -1 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 0 -1 0 -1
0
1 1 1 1 1 1 1 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 107
down_raw = 81
```

```

up = 81
down = 81
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 0 -1 0 -1 -1 -1 -1 0 1 0
1
0 1 0 1 0 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[ 1 1 1 1 1 0 1 1 1 0 -1 0 1 0 -1 0 -1 0 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 0 -1 -1 0 -1 0 1 0 1 1 1 1 1 1 1 0 -1]
depth_selected = 2
Impurity_selected = 0.0
up_raw = 140
down_raw = 110
up = 110
down = 110
Returns :
-1%, -6%, 0%, 3%, 10%, -1%, 9%, -4%, 8%, -2%, 17%, 3%, 6%, 15%, -2%,
2%, -3%, 9%, 4%, 13%, Maximum Return: 17.0
Minimum Return: -6.0
Average Return: 4.0
Standard Deviation: 6.0
320 training days
80 validation days
100 test days

```

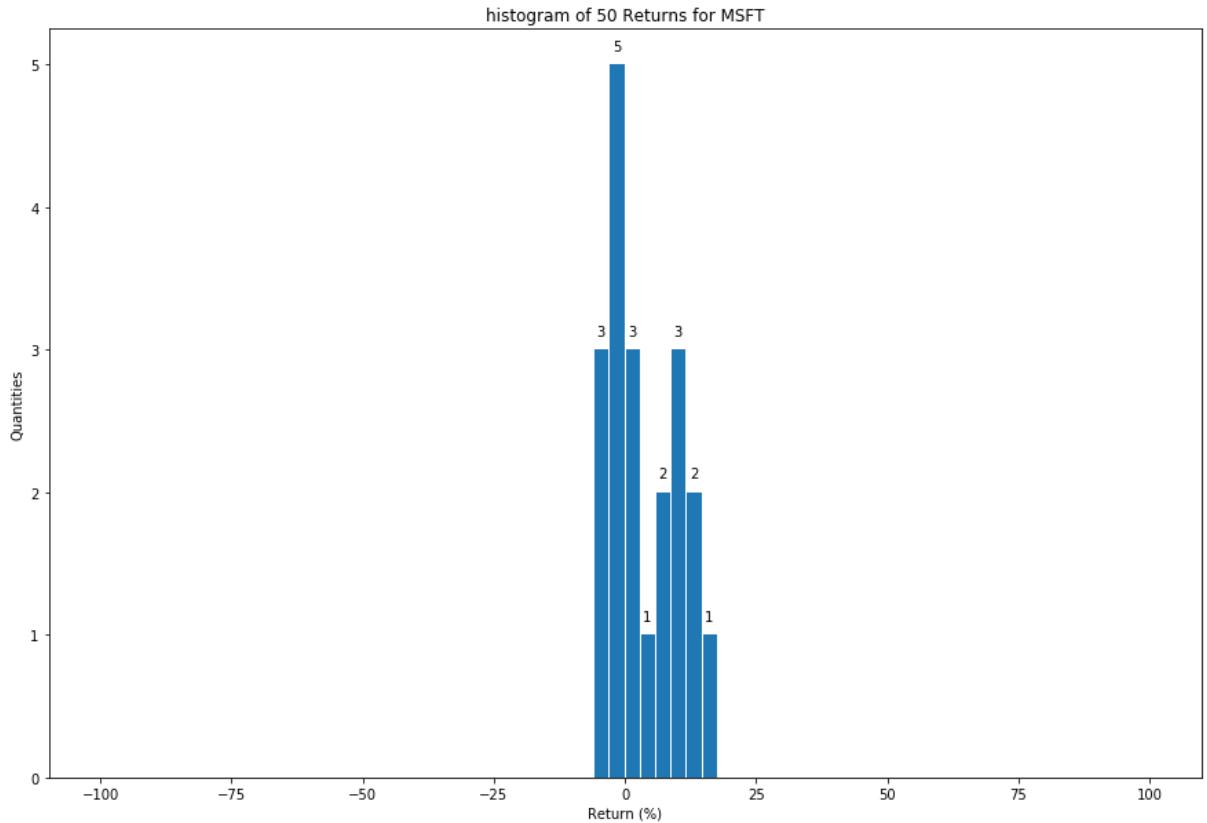
In [637...]

```

fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')

```

Out[637...]: Text(0, 0.5, 'Quantities')



10 Year investment

In [638...]

```
fix_history_length = 250 # 2~1 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

Out[638... 2

In [639...]

```
# an array for saving 50 final best profit
# depth_list = np.random.randint(1, high=10, size=5)
# impurity_list = np.random.uniform(0, high=0.1, size = 5)
depth_list = [2,5,15]
impurity_list = [0.0]
profit_final = np.array([])
Confident = [0.00,0.00]

for i in range(sample_size):

    PnL_logistic = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, : ]
```

```

test = BTC.iloc[timestamp:EndTime, : ]
Best_Inner_RandomForest_Profit = np.array([ ])
Best_Impurity = np.array([ ])
for depth in depth_list:
    Inner_RandomForest_Profit = np.array([ ])
    for impurity in impurity_list:
        Inner_RandomForest_Profit = np.append(Inner_RandomForest_Profit, Best_Inner_RandomForest_Profit)
    Best_Inner_RandomForest_Profit = np.append(Best_Inner_RandomForest_Profit, np.argmax(Inner_RandomForest_Profit))
    Best_Impurity = np.append(Best_Impurity, np.argmax(Inner_RandomForest_Profit))

depth_selected = depth_list[Best_Inner_RandomForest_Profit.argmax()]
Impurity_selected = Best_Impurity[np.argmax(Best_Inner_RandomForest_Profit)]
Impurity_selected = Impurity_selected.astype(int)
Impurity_selected_1 = impurity_list[Impurity_selected]

print('depth_selected = ', depth_selected)
print('Impurity_selected = ', Impurity_selected_1)

## Balance the data for binary prediction
up_raw = train_valid[train_valid[target] == 1]
down_raw = train_valid[train_valid[target] == 0]

print('up_raw = ', up_raw.shape[0])
print('down_raw = ', down_raw.shape[0])

if up_raw.shape[0] / down_raw.shape[0] < 1:

    percentage = up_raw.shape[0] / down_raw.shape[0]
    down = down_raw.sample(frac=percentage, random_state = 1)
    up = up_raw

    train_valid = up.append(down)

elif up_raw.shape[0] / down_raw.shape[0] >= 1:

    percentage = down_raw.shape[0] / up_raw.shape[0]
    up = up_raw.sample(frac=percentage, random_state = 1)
    down = down_raw

    train_valid = down.append(up)

print('up = ', train_valid[train_valid[target] == 1].shape[0])
print('down = ', train_valid[train_valid[target] == 1].shape[0])

X_cv = train_valid[features]
Y_cv = train_valid[target]

X_test_cv = test[features]
Y_test_cv = test[target]

model_cv = RandomForestClassifier( max_depth=depth_selected, min_samples_leaf=1 )
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict_proba(X_test_cv)
Y_test_cv_fit = Y_test_cv_fit[:,1]

```

```

n_days = len(Y_test_cv_fit)
cash = 1
stock = 0

position = []

for d in range(0, n_days):

    # Long if spread < lower band & if not bought yet
    if Y_test_cv_fit[d] > 0.50+Confident[0] and cash == 1:
        signal = 1
        cash = 0
        stock = 1
        position.append(signal)

    # Take Profit if spread > moving average & if already bought
    elif (Y_test_cv_fit[d] < 0.50+Confident[1] ) and stock == 1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    # Short if spread > upper band and no current position
    elif Y_test_cv_fit[d] < 0.50-Confident[0] and cash == 1:
        signal = -1
        cash = 0
        stock = -1
        position.append(signal)

    # Take Profit if spread < moving average & if already short
    elif (Y_test_cv_fit[d] > 0.50-Confident[1]) and stock == -1:
        signal = 3
        cash = 1
        stock = 0
        position.append(signal)

    else:
        signal = 0
        position.append(signal)

df = pd.DataFrame()

df['Position'] = position
df['Position'] = df['Position'].replace(to_replace=0, method= 'ffill')
df['Position'] = df['Position'].replace(3,0)

Y_test_cv_fit = df['Position'].values

long_short_df = pd.DataFrame({'Close': test['Close'].values,
                               'Return': test['Return'].values.tol

```

```

'Binary_Return': Y_test_cv.values.reshape(-1,1),
'Predicted_Binary_Return': Y_test_cv,
'Capital': np.zeros(len(Y_test_cv)),
'Gain': np.zeros(len(Y_test_cv))},
index = Y_test_cv.index

initial = pd.DataFrame(np.array([0,0,0,0,1,0]).reshape(-1,6),
columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

profit_final = (profit_final - 1)*100

long_short_df['Gain'] = long_short_df['Capital'].values - long_short_df['Predicted_Binary_Return']

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

```

up_raw = 111
down_raw = 76
up = 76
down = 76
[0 1]
[ 1 1 0 -1 -1 -1 0 1 1 0 -1 -1 0 -1 -1 0 1 1 1 1 1 1 1 1 1
1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
1
up_raw = 111
down_raw = 76
up = 76
down = 76
[0 1]
[-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
0 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1
-1
-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0
1
up_raw = 114
down_raw = 74
up = 74
down = 74
[0 1]
[-1 -1 -1 -1 0 -1 0 -1 -1 0 1 0 -1 -1 -1 0 1 0 1 0 1 0 -1 -1 0
1
1 0 -1 -1 0 -1 0 -1 0 1 0 -1 0 -1 0 1 1 1 1 1 1 1 1 1 1
1

```



```

down = 76
[0 1]
[-1 -1 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
0 -1 -1 -1 -1 -1 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
0 -1 -1 -1 -1 0 -1 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1
up_raw = 114
down_raw = 74
up = 74
down = 74
[0 1]
[ 1 0 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
0
0 0 -1 -1 0 -1 0 -1 0 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1
1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
up_raw = 108
down_raw = 80
up = 80
down = 80
[0 1]
[ 1 1 1 1 1 1 1 1 1 1 1 0 -1 0 1 1 0 1 0 1 0 1 0 1 0 1 0 1
0
-1 -1 -1 0 -1 -1 0 1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
1
0 1 1 1 0 -1 0 0 -1 -1 0 1 1 0 1 0 1 0
depth_selected = 15
Impurity_selected = 0.0
up_raw = 148
down_raw = 102
up = 102
down = 102
Returns :
76%, Maximum Return: 76.0
Minimum Return: 76.0
Average Return: 76.0
Standard Deviation: 0.0
320 training days
80 validation days
100 test days

```

In [640...]

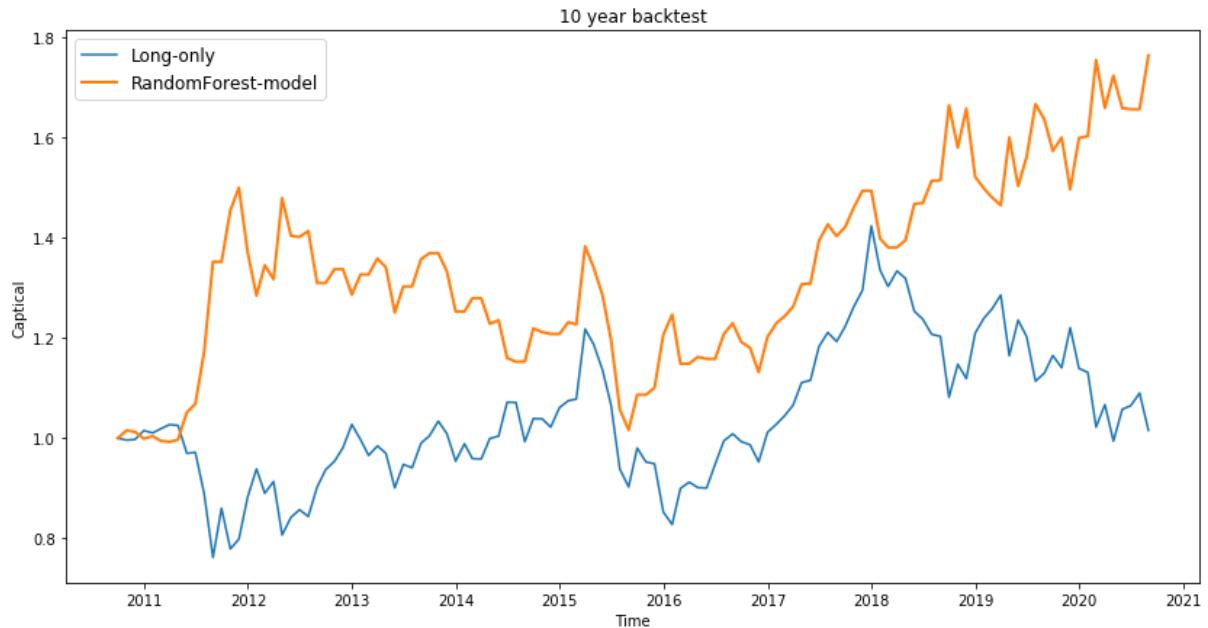
```

# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], label='Actual')
plt.plot(long_short_df_final.Capital[1:], lw=2, label='RandomForest-model')
plt.xlabel('Time')
plt.ylabel('Capital')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)

```

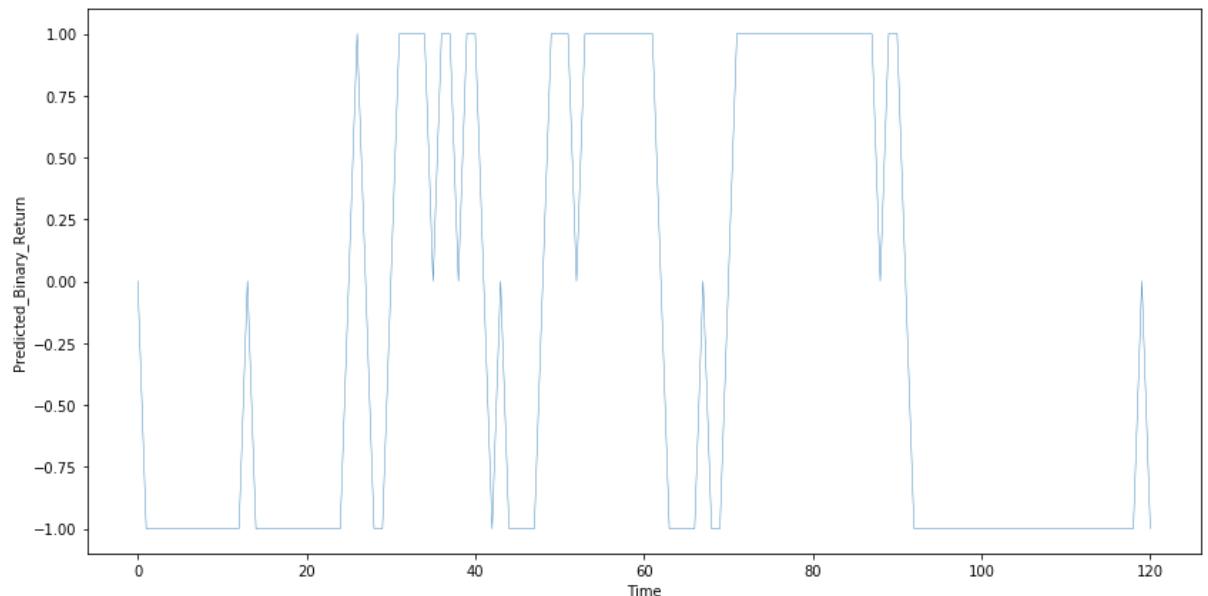
Out[640... <matplotlib.legend.Legend at 0x13abe5b70>



In [641...]

```
plt.figure(figsize=(14, 7))
plt.plot(range(long_short_df_final.shape[0]), long_short_df_final.Predicted_Binary_Return)
plt.xlabel('Time')
plt.ylabel('Predicted_Binary_Return')
```

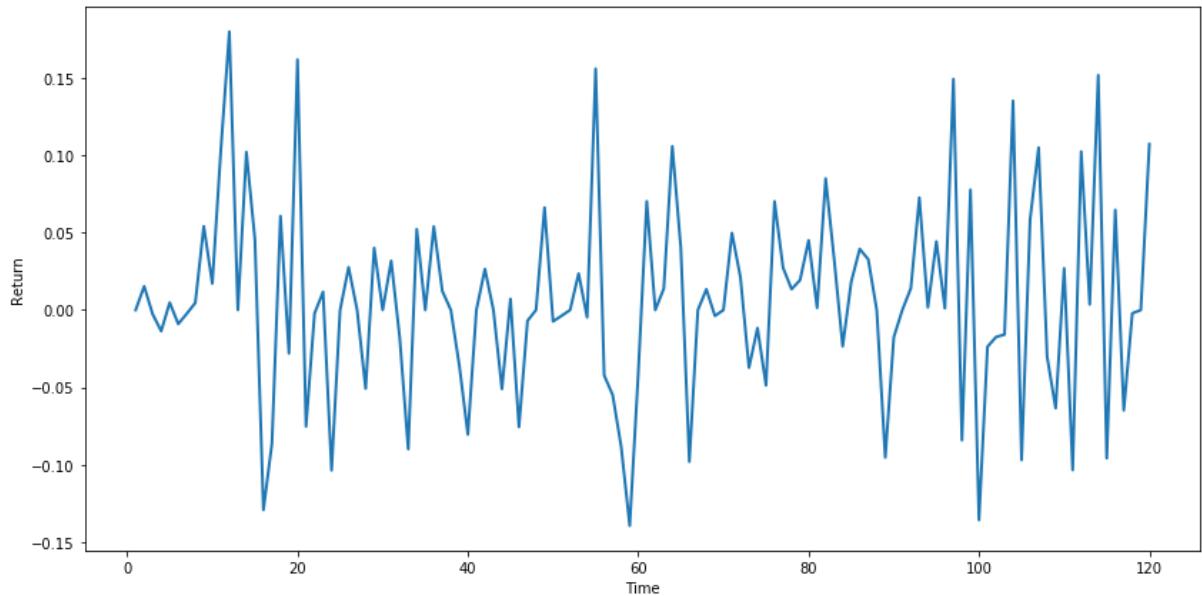
Out[641...]



In [642...]

```
plt.figure(figsize=(14, 7))
plt.plot(range(long_short_df_final.shape[0]), long_short_df_final.Return)
plt.xlabel('Time')
plt.ylabel('Return')
```

Out[642...]



In []:

Neural Networks (In progress)

In []:

```
features = ['Mkt-RF', 'SMB', 'HML', 'RMW', 'CMA', 'MACD', 'MACDH', 'ADX', 'RSI']
target = ['Return-RF']
```

In []:

```
# compute Capital
def computation(df):
    for i in range(1, len(df)):
        if df.loc[df.index[i], 'Predicted_Return'] >= 0:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
        else:
            df.loc[df.index[i], 'Capital'] = df.loc[df.index[i-1], 'Capital']
    return df
```

In []:

```
def PnL_Lasso(x_train, y_train, x_valid, y_valid, lamb):

    # create a linear model
    X_train = x_train
    Y_train = y_train
    X_valid = x_valid
    Y_valid = y_valid

    model = linear_model.Lasso(alpha = lamb)
    model.fit(X_train, Y_train)
    Y_valid_fit = model.predict(X_valid)

    # a data frame for computing and saving long_short value
    long_short_df = pd.DataFrame({'Return': Y_valid.iloc[:, 0].values,
                                   'Predicted_Return': Y_valid_fit.reshape(-1),
                                   'Capital': np.zeros(len(Y_valid))},
                                 index = Y_valid.index)
```

```

cols = [ 'Return', 'Predicted_Return', 'Capital' ]
long_short_df = long_short_df[cols]

# give an initial point
initial = pd.DataFrame(np.array([0,0,1]).reshape(-1,3),
                        columns = long_short_df.columns)

# combine df and initial point
long_short_df = pd.concat([initial, long_short_df])

# compute long_short value
long_short_df_final = computation(long_short_df)

# return final long_short value of this period
return long_short_df_final.iloc[-1,2]

```

In []:

```

# Build a general function that can perform k-fold Cross Validation or
# Data: a subset of feature columns plus the target column
# Target: the name of the target column
# n: cut data into n pieces

def kfold_Lasso(data, target, n, lamb):
    # We need a vector to record mse from k-fold
    profit = np.array([])

    # KFold is a build-in function in Scikit-learn
    # it can help us cut data into n pieces
    # (compare with simple cross validation)
    kf = KFold(n_splits = n)

    for train_index, validation_index in kf.split(data):

        # obtain the train and validation part
        train, valid = data.iloc[train_index,:], data.iloc[validation_]

        # extract X and Y to be fit in a model
        X_train = train[features]
        Y_train = train[target]
        X_valid = valid[features]
        Y_valid = valid[target]

        # Calculate PnL
        profit_temp = PnL_Lasso(X_train, Y_train, X_valid, Y_valid, la
        profit = np.append(profit, profit_temp)

    return profit.mean()

```

6 Month Investment

In []:

```
fix_history_length = 250 # ~21 year
```

```
fix_test_length = 6 # 6 months
sample_size = 20

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange
```

In []:

```
%%time
# an array for saving 50 final best profit
lambda_list = np.array([1e-5, 1e-4, 1e-3])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1], sample_size))

for i in range(sample_size):

    PnL_lasso = np.array([])
    np.random.seed(i)
    random_Num = np.random.randint(randomRange)
    BeginTime = random_Num
    timestamp = fix_history_length + random_Num
    EndTime = timestamp + fix_test_length

    # use BeginTime and EndTime to filter test and train_valid
    train_valid = BTC.iloc[BeginTime:timestamp, :]
    test = BTC.iloc[timestamp:EndTime, :]

    for lamb in lambda_list:
        PnL_lasso = np.append(PnL_lasso, kfold_Lasso(train_valid, target='Return', alpha=lamb))

    lambda_selected_lasso = lambda_list[PnL_lasso.argmax()]

    print('lambda selected', lambda_selected_lasso)

    X_cv = train_valid[features]
    Y_cv = train_valid[target]

    X_test_cv = test[features]
    Y_test_cv = test[target]

    model_cv = linear_model.Lasso(alpha = lambda_selected_lasso)
    model_cv.fit(X_cv, Y_cv)

    Y_test_cv_fit = model_cv.predict(X_test_cv)

    long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(-1, 1),
                                  'Predicted_Return': Y_test_cv_fit.reshape(-1, 1),
                                  'Capital': np.zeros(len(Y_test_cv))})
    long_short_df.index = Y_test_cv.index

    cols = ['Return', 'Predicted_Return', 'Capital']
    long_short_df = long_short_df[cols]

    initial = pd.DataFrame(np.array([0, 0, 1]).reshape(-1, 3),
                           columns=long_short_df.columns)
    long_short_df = pd.concat([initial, long_short_df])
    long_short_df_final = computation(long_short_df)
```

```

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(len(model_cv.coef_)):
    model_coef[j][i] = model_cv.coef_[j]

for i in range(len(model_cv.coef_)):
    print(i, ' feature coef = ', model_coef[i].mean())

```



```

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%, ')

```



```

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))
print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

In [772...]

```

fig = plt.figure(figsize=(15,10))
bins = np.linspace(-100, 100, 69)
a = plt.hist(profit_final, bins, histtype='bar', rwidth=0.9)
for i in range(len(bins)-1):
    if(int(a[0][i]) != 0):
        plt.text(a[1][i]+0.5,a[0][i]+0.1,int(a[0][i]))
plt.title("histogram of 50 Returns for MSFT")
plt.xlabel('Return (%)')
plt.ylabel('Quantities')

```

10 Year Investment

In []:

```

fix_history_length = 250 # 2~1 Year
fix_test_length = 120 # 10 Year
sample_size = 1

# the range of t
randomRange = len(BTC)-fix_history_length-fix_test_length
randomRange

```

In []:

```

%%time
# an array for saving 50 final best profit
lambda_list = np.array([1e-5, 1e-4, 1e-3])
profit_final = np.array([])
model_coef = np.zeros((BTC.shape[1], sample_size))

for i in range(sample_size):

    PnL_lasso = np.array([])
    np.random.seed(i)

```

```

random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

# use BeginTime and EndTime to filter test and train_valid
train_valid = BTC.iloc[BeginTime:timestamp, :]
test = BTC.iloc[timestamp:EndTime, :]

for lamb in lambda_list:
    PnL_lasso = np.append(PnL_lasso, kfold_Lasso(train_valid, target))

lambda_selected_lasso = lambda_list[PnL_lasso.argmax()]

print('lambda_selected', lambda_selected_lasso)

X_cv = train_valid[features]
Y_cv = train_valid[target]

X_test_cv = test[features]
Y_test_cv = test[target]

model_cv = linear_model.Lasso(alpha = lambda_selected_lasso)
model_cv.fit(X_cv, Y_cv)

Y_test_cv_fit = model_cv.predict(X_test_cv)

long_short_df = pd.DataFrame({'Return': Y_test_cv.values.reshape(1, -1),
                               'Predicted_Return': Y_test_cv_fit.reshape(1, -1),
                               'Capital': np.zeros(len(Y_test_cv))})
index = Y_test_cv.index

cols = ['Return', 'Predicted_Return', 'Capital']
long_short_df = long_short_df[cols]

initial = pd.DataFrame(np.array([0, 0, 1]).reshape(-1, 3),
                        columns = long_short_df.columns)
long_short_df = pd.concat([initial, long_short_df])
long_short_df_final = computation(long_short_df)

profit_final = np.append(profit_final, long_short_df_final.iloc[-1])

for j in range(len(model_cv.coef_)):
    model_coef[j][i] = model_cv.coef_[j]

for i in range(len(model_cv.coef_)):
    print(i, ' feature coef = ', model_coef[i].mean())

profit_final = (profit_final - 1)*100

print('Returns :')
for idx, num in enumerate(profit_final):
    print(round(profit_final[idx]), end='%', ' ')

print('Maximum Return: ', np.around(max(profit_final)))
print('Minimum Return: ', np.around(min(profit_final)))

```

```

print('Average Return: ', np.around(profit_final.mean()))
print('Standard Deviation: ', np.around(profit_final.std()))
print("320 training days")
print("80 validation days")
print("100 test days")

```

In []:

```

# seed is the same at 0
np.random.seed(0)
random_Num = np.random.randint(randomRange)
BeginTime = random_Num
timestamp = fix_history_length + random_Num
EndTime = timestamp + fix_test_length

plt.figure(figsize=(14, 7))
plt.plot(BTC['Close'][timestamp:EndTime] / BTC['Close'][timestamp], label='Actual')
plt.plot(range(long_short_df_final.shape[0]), long_short_df_final.Captical, label='Strategy')
plt.xlabel('Time')
plt.ylabel('Captical')
plt.title("10 year backtest")
plt.legend(loc='upper left', fontsize=12)

```

In []:

In [293...]

BBTC >1

Out[293...]

	Return	MACD	MACDH	ADX	RSI	BB	Binary_Return
201807201300	False	False	False	False	False	False	False
201807201305	False	False	False	False	False	False	False
201807201310	False	False	False	False	False	False	False
201807201315	False	False	False	False	False	False	False
201807201320	False	False	False	False	False	False	False

	Return	MACD	MACDH	ADX	RSI	BB	Binary_Return
...
201912241135	False	False	False	False	False	False	False
201912241140	False	False	False	False	False	False	False
201912241145	False	False	False	False	False	False	False
201912241150	False	False	False	False	False	False	False
201912241155	False	False	False	False	False	False	False

62352 rows × 7 columns

In []:

```
[ ]: 
```

In [75]:

```
[75]: np.arange(0.0, 1.0, 1)
```

Out[75]: array([0.])

In []:

```
[ ]: 
```