sy3420_HW2

October 25, 2022

Homework - build a walk-forward testing harness

This version: 8-22-2002

Background

0.1 0.1 Business context

You are working on a trading desk and have been asked by a trader to evaluate whether a simple model can be used to make useful predictions about market direction.

0.2 0.2 Mandate

In order to demonstrate the robustness of your models (or highlight the lack thereof) you will need to build a walk-forward testing harness. The harness should include the following functions:

```python
# ------------------------
# ------------------------


def walk_forward_harness(df, preprocessor, estimator, predictor,
                         start, date_col = 'Date', step_size = 1):
    # your code here
    return(predictions, model_list, stats_list)


# ------------------------

def predictor_harness(new_df, model, preprocessor, preproc_params = {}):

    # your code here
    return(predictions)


# ------------------------

def preprocessor(df, preproc_params = {}, new = True):
    # your code here
    return(new_df, preproc_params)
```

```python
    # -----------------------

    def estimator(df, fitting_algo, est_params = {}):
        # your code here
        return(model)

    # -----------------------

    def predictor(new_df, model):
        # your code here
        return(predictions)

    # -----------------------
    # -----------------------
```

where

argument | Description| Returns |
:– | -:- | :– |

|df, new_df| a Pandas `DataFrame` containing the data to be modeled | NA |start | a date index value after which to start the walk-forward test| NA |`date_col` | the column index (integer or str) of the column in `df` that holds the date information for each row | NA |`step_size`| the number of time units to move forward in each walk-forward step. | NA |model | a fitted model that can be used to make predictions. (This may, itself, be a function.) | NA |`model_list` | a list of models, one for each walk-forward step, of length equal to the number of walk-forward steps| NA |`stats_list` | a list of statistics (possibly a list of lists or tupples), with one entry for each walk-forward step, of length equal to the number of walk-forward step| NA |`preproc_params` | parameters used by `preprocessor` | NA |`new` | boolean indicating whether `df` should be used to estimate the parameters required by `preproc` |`predictions` | a vector of predictions of the same length as the number of rows in `new_df`. If data record `i` cannot be processed (e.g., due to missing values or division by zero, etc.), predictions `i` should be set to `np.nan` | NA |`preprocessor` | a function that takes as input `df` containing raw data to be modeled; `preproc_params`, a list of preprocessing parameters if needed; and `new`, a flag indicating whether new parameters should be estimated | `new_df`, the preprocessed data to be modeled, `preproc_params` a list that is either empty or that contains any parameters estimated during preprocessing |`estimator` | a function that takes as input `df` of data to be modeled, `fitting_algo`, a function that estimates the model; and `est_params`, any other arguments required. | a model object that can be read by `predictor` |`predictor` | a function that takes as input `new_df` containing raw data for which predictions should be generated; a `model`, a model object estimated by `estimator`, `preprocessor`, see above; and any other arguments required | a vector containing one entry for each row in the data frame |`predictor_harness` | a function that takes in a raw data set and produces a dataset structured and formatted in the manner required by `predictor` | a vector containing one entry for each row in the data frame

[1114]:
```python
import pandas as pd
import numpy as np
```

[1115]:
```python
HW01_SPX = pd.read_csv("HW01_SPX.csv")
```

```
[1116]:  HW01_SPX
```

```
[1116]:          Date      Open      High      Low     Close
         0     2000-01-03  1455.22  1478.00  1438.36  1455.22
         1     2000-01-04  1399.42  1455.22  1397.43  1399.42
         2     2000-01-05  1402.11  1413.27  1377.68  1402.11
         3     2000-01-06  1403.45  1411.90  1392.02  1403.45
         4     2000-01-07  1441.47  1441.47  1400.53  1441.47
         ...          ...      ...      ...      ...      ...
         5414  2021-07-12  4372.41  4386.68  4364.03  4384.63
         5415  2021-07-13  4381.07  4392.37  4366.92  4369.21
         5416  2021-07-14  4380.11  4393.68  4362.36  4374.30
         5417  2021-07-15  4369.02  4369.02  4340.70  4360.03
         5418  2021-07-16  4367.43  4375.09  4322.53  4327.16

         [5419 rows x 5 columns]
```

0.3 0.3 Requirements

- Please use `statsmodels.api` for your analysis.

- Please use the raw data from 1.1.1 of HW01 (`HW01_Financial_Mathematics.ipynb`) for your modeling.
- Please use the data prior to 07/17/2017 (July, 17) and assume that you will know the prior trading day's closing price before the next day's market open.
- Please ignore the effects of weekends and holidays on the returns and volatities.

```
[775]:  def walk_forward_harness(df, preprocessor, estimator, predictor,
                                 start, date_col = 'Date', step_size = 1):
            data = pd.DataFrame(df)
            return(predictions, model_list, stats_list)


        # ------------------------

        def predictor_harness(new_df, model, preprocessor, preproc_params = {}):

            data = pd.DataFrame(new_df)

            return(predictions)


        # ------------------------

        def preprocessor(df, preproc_params = {}, new = True):
            # your code here
            return(new_df, preproc_params)
```

```python
# -----------------------

def estimator(df, fitting_algo, est_params = {}):
    # your code here
    return(model)


# -----------------------

def predictor(new_df, model):
    # your code here
    return(predictions)


# -----------------------
# -----------------------
```

0.4   0.4 Helper functions

```python
[776]: def progress_bar(k, n, incr_txt="Step", bar_len = 10):

           bar_char  = u'\u25A5'
           line_char = u'\u21E2' # u'\u2192'  u'\u23AF' u'\u25AD'

           places   = int(np.ceil(n/bar_len))
           pct      = k/n
           n_str    = "{:,.0f}".format(n)
           k_str    = "{:,.0f}".format(k)
           pct_str  = "{:,.0f}%".format(k/n * 100)
           # d_format = "%" + str(places) + "d"

           if k == n-1:
               n_bars = bar_len
               n_spaces = 0
               text_txt = "Completed " + n_str + " " + incr_txt + "s."
           else:
               n_bars   = int(np.floor(pct * bar_len))
               n_spaces = bar_len - n_bars
               text_txt = " " + pct_str +  " (" + incr_txt + " " + k_str + " of   " +↵
       ↪n_str + ")."

           bar_txt  = "[" + "".ljust(n_bars,bar_char) + "".rjust(n_spaces,line_char) +↵
       ↪"]   "


           clear_output()
           display(bar_txt + text_txt)
```

1 1 Model Building Phase

1.1 1.1 Preprocessing

1.1.1 1.1.1 Dependent variable (target feature)

1.1.1.1 Calculate the log returns for the `Close` (price) in the data, and print the quantiles of this new variable. Add this new variable to your data set.

```python
[1117]: log_r = (np.log(HW01_SPX["Close"]/HW01_SPX["Close"].shift(1)))
        # np.quantile(HW01_SPX["log return"], 0.25)
        # HW01_SPX["log return"].dropna()
        # HW01_SPX["log return"]
        HW01_SPX["LOG_RETURN"] = log_r


        HW01_SPX["LOG_RETURN"].quantile([0.25, 0.5, 0.75, 1])
```

```
[1117]: 0.25    -0.004724
        0.50     0.000600
        0.75     0.005813
        1.00     0.109572
        Name: LOG_RETURN, dtype: float64
```

1.1.1.2 Create a new variable `positive_return_dummy` that takes the value 1 if the return for the day is greater than 0 and 0 otherwise. This will be your dependent variable.

```python
[1118]: HW01_SPX["positive_return_variable"] = HW01_SPX["LOG_RETURN"].apply(lambda x: 1␣
        ↪if x > 0 else 0)
```

1.1.2 1.1.2 Independent variables

1.1.2.1 Create a new variables for the 30 day volatility of the returns, and print the quantiles of this new variable and print the quantiles. Add this new variable to your data set.

```python
[1119]: log_ret = HW01_SPX["LOG_RETURN"].to_frame()
        # HW01_SPX["Volatility 30 days"] = log_ret.rolling(30).mean()
```

```python
[780]: # log_ret.groupby(np.arange(len(log_ret))//30).std()
```

```python
[1120]: # HW01_SPX["30_vol"] = log_ret.groupby(np.arange(len(log_ret))//30).std()
        HW01_SPX["30_vol"] = log_ret.rolling(30).std()
```

```python
[1121]: HW01_SPX["30_vol"].quantile([0.25, 0.5, 0.75, 1])
```

```
[1121]: 0.25     0.006324
        0.50     0.008611
```

```
0.75    0.012904
1.00    0.054091
Name: 30_vol, dtype: float64
```

1.1.3 1.1.3 Time structure

1.1.3.1 Please shift your dependent variable by one day (as we did in 4.1 of HW01) so that the values of x_{t-1} of the independent variables are associated (in the same row as) the values of y_t (the dependent variable). Now please relabel all of your independent variables xxx_L01d, where xxx is the original name of the variable (e.g., Close would become Close_L01d). This will help us remember which variables were shifted forward go with which dates (i.e., the _L01d suffix reminds us that that varaible represents the value as of the previous trading period.) Please print the head of your newly labeled dataframe.

```
[1122]:  HW01_SPX["positive_return_variable"] = HW01_SPX["positive_return_variable"].
         ↪shift(1)
```

```
[1123]:  HW01_SPX = HW01_SPX.add_suffix("_L01d")
```

```
[1132]:  HW01_SPX
```

```
[1132]:        Date_L01d  Open_L01d  High_L01d  Low_L01d  Close_L01d  LOG_RETURN_L01d  \
        0     2000-01-03    1455.22    1478.00   1438.36     1455.22              NaN
        1     2000-01-04    1399.42    1455.22   1397.43     1399.42        -0.039099
        2     2000-01-05    1402.11    1413.27   1377.68     1402.11         0.001920
        3     2000-01-06    1403.45    1411.90   1392.02     1403.45         0.000955
        4     2000-01-07    1441.47    1441.47   1400.53     1441.47         0.026730

        ...          ...        ...        ...       ...         ...              ...
        5414  2021-07-12    4372.41    4386.68   4364.03     4384.63         0.003445
        5415  2021-07-13    4381.07    4392.37   4366.92     4369.21        -0.003523
        5416  2021-07-14    4380.11    4393.68   4362.36     4374.30         0.001164
        5417  2021-07-15    4369.02    4369.02   4340.70     4360.03        -0.003268
        5418  2021-07-16    4367.43    4375.09   4322.53     4327.16        -0.007568

              30_vol_L01d  positive_return_variable
        0             NaN                       NaN
        1             NaN                       0.0
        2             NaN                       0.0
        3             NaN                       1.0
        4             NaN                       1.0

        ...           ...                       ...
        5414     0.005431                       1.0
        5415     0.005505                       1.0
        5416     0.005495                       0.0
        5417     0.005559                       1.0
        5418     0.005720                       0.0
```

6

```
[5419 rows x 8 columns]
```

1.1.4 1.2 Building a basic to toy model

1.1.5 1.2.1 Take 1

1.2.1.1 Please estimate a logit model in which the dependent variable is `positive_return_dummy` and your lagged variables are the previous day's 30 day volatility, the previous day's return, and the the previous days' closing priceusingstatsmodels.api' and print the summary of the model. As an example, if you were using the `formula` version of the API and had imported `statsmodels.api.formla` as `sm`, your code might look like the following:

```
model = sm.logit(my_formula, data = df)
logit_model_sm = model.fit()
print(logit_model_sm.summary())
```

(Hint, you will find it much easier to do the modeling if you use `statsmodels.api.formula` version of the API, which allows you to try different variables and variable transformations in your model without creating a new dataframe, by using R-style formula. You can find a short tutorial on using `statsmodels.api.formula` here: https://www.statsmodels.org/dev/example_formulas.html . Once you get comfortable with the formula langauage, you can use it to create dataframes for other models (e.g., some of those in `sklearn`) by just writing the formula. Super handy.)

```
[879]: import statsmodels.api as sm
       import statsmodels.formula.api as smf
```

```
[914]: HW01_SPX = HW01_SPX.dropna().reset_index(drop=True)
       y = HW01_SPX[["positive_return_variable"]]
       x = HW01_SPX[["30_vol_L01d", "Close_L01d", "LOG_RETURN_L01d"]]


       log_reg = sm.Logit(y, x).fit()
```

```
Optimization terminated successfully.
        Current function value: 0.688376
        Iterations 4
```

```
[881]: log_reg.summary()
```

```
[881]: <class 'statsmodels.iolib.summary.Summary'>
       """
                            Logit Regression Results
       ===============================================================================
       ====
       Dep. Variable:     positive_return_variable   No. Observations:
       5389
```

```
Model:                          Logit   Df Residuals:
5386
Method:                           MLE   Df Model:
2
Date:                 Tue, 25 Oct 2022   Pseudo R-squ.:
0.002736
Time:                        09:16:22   Log-Likelihood:
-3709.7
converged:                       True   LL-Null:
-3719.8
Covariance Type:             nonrobust   LLR p-value:
3.806e-05
================================================================
===
                   coef    std err         z      P>|z|      [0.025
0.975]
----------------------------------------------------------------
---
30_vol_L01d     -3.4229      3.161     -1.083      0.279      -9.619
2.773
Close_L01d       0.0001   2.11e-05      5.045      0.000    6.52e-05
0.000
LOG_RETURN_L01d -8.1171      2.233     -3.634      0.000     -12.494
-3.740
================================================================
===
"""
```

**1.2.1.2 Please examine the marginal effects of the variables in the model and print
these out.** (Hint: use the `logit_model_sm.get_margeff.summary()` method.)

```
[882]: print(log_reg.get_margeff().summary())
```

```
            Logit Marginal Effects
=========================================
Dep. Variable:      positive_return_variable
Method:                            dydx
At:                             overall
================================================================
===
                   dy/dx    std err         z      P>|z|      [0.025
0.975]
----------------------------------------------------------------
---
30_vol_L01d     -0.8476      0.782     -1.083      0.279      -2.381
0.686
Close_L01d     2.639e-05   5.18e-06      5.093      0.000    1.62e-05
```

```
3.65e-05
LOG_RETURN_L01d     -2.0100        0.550       -3.652        0.000        -3.089
-0.931
================================================================================
===
```

1.2.1.3 On average, if the lagged 30 day volatility were 1% higher (i.e., if vol were 10%, the higher value would be 11%) how much higher or lower would the probability of an upward move in prices be? From this summary, we can multiply by 1.01 or 0.01% with the vol_30 days. The probability would change by negative -0.8476.

1.1.6 1.2.2 Take 2

1.2.2.1 Now add `Open_L01d` to your model and print the summary and redo your logit regression.

```
[883]: import scipy
       from scipy import stats
```

```
[884]: y = HW01_SPX[["positive_return_variable"]]
       x = HW01_SPX[["30_vol_L01d", "Close_L01d", "LOG_RETURN_L01d", "Open_L01d"]]

       log_reg_1 = sm.Logit(y, x).fit()
```

```
Optimization terminated successfully.
         Current function value: 0.688374
         Iterations 4
```

```
[885]: log_reg_1.summary()
```

```
[885]: <class 'statsmodels.iolib.summary.Summary'>
       """
                          Logit Regression Results
       ================================================================================
       ====
       Dep. Variable:      positive_return_variable   No. Observations:
       5389
       Model:                                Logit    Df Residuals:
       5385
       Method:                                 MLE    Df Model:
       3
       Date:                      Tue, 25 Oct 2022   Pseudo R-squ.:
       0.002739
       Time:                              09:16:35   Log-Likelihood:
       -3709.6
       converged:                             True    LL-Null:
       -3719.8
```

```
Covariance Type:                 nonrobust   LLR p-value:
0.0001419
================================================================================
===
                   coef     std err          z      P>|z|      [0.025
0.975]
--------------------------------------------------------------------------------
---
30_vol_L01d      -3.4206       3.161     -1.082      0.279      -9.617
2.775
Close_L01d       -0.0003       0.003     -0.109      0.913      -0.005
0.005
LOG_RETURN_L01d  -7.7889       3.116     -2.500      0.012     -13.896
-1.682
Open_L01d         0.0004       0.003      0.151      0.880      -0.005
0.005
================================================================================
===
"""
```

1.2.2.2 Do you notice anything about the coefficients on `Close_L01d` and `Open_L01d` ? What do you think could explain this? Compare the coeffiecent on `Close_L01d` to the one we got in *Take 1*, above. Coefficients on Close_L01d and Open_L01d are both very small. They are both small to a point where they are simillar.

The coefficient of a variable is interpreted as the change in response based on change in the corresponding explanatory variable. So adding Open_L01d had an influence on the coefficient of Close_L01d. The change in nthe criterion variable related with a change of one in the prediction variable when the rest of the other prediction variables are held constant.

Compared to the Close_L01d from Take 1, the coefficient is bigger.

1.1.7   1.2.3 Take 3

1.2.3.1 Now standardize the value of the 30 day volatility to create a new variable with a mean of zero and a standard deviation of 1, and print the quantiles. Save the mean and SD as `vol_30d_mean` and `vol_30d_sd`.

```
[886]: HW01_SPX["30_vol_std"] = stats.zscore(HW01_SPX["30_vol_L01d"], ␣
       ↪nan_policy='omit').dropna()

       vol_30d_mean = HW01_SPX["30_vol_std"].mean()
       vol_30d_sd = HW01_SPX["30_vol_std"].std()
```

```
[887]: HW01_SPX
```

```
[887]:         Date_L01d  Open_L01d  High_L01d  Low_L01d  Close_L01d  LOG_RETURN_L01d  \
        0     2000-02-15   1402.05    1407.81   1376.21    1402.05         0.008675
        1     2000-02-16   1387.67    1404.72   1385.58    1387.67        -0.010309
        2     2000-02-17   1388.26    1399.83   1380.07    1388.26         0.000425
        3     2000-02-18   1346.09    1388.26   1345.29    1346.09        -0.030847
        4     2000-02-22   1352.17    1358.11   1331.97    1352.17         0.004507
        ...          ...       ...        ...       ...        ...              ...
        5384  2021-07-12   4372.41    4386.68   4364.03    4384.63         0.003445
        5385  2021-07-13   4381.07    4392.37   4366.92    4369.21        -0.003523
        5386  2021-07-14   4380.11    4393.68   4362.36    4374.30         0.001164
        5387  2021-07-15   4369.02    4369.02   4340.70    4360.03        -0.003268
        5388  2021-07-16   4367.43    4375.09   4322.53    4327.16        -0.007568

              positive_return_variable_L01d  30_vol_L01d  positive_return_variable  \
        0                               1.0     0.014976                       1.0
        1                               1.0     0.013294                       1.0
        2                               0.0     0.013289                       0.0
        3                               1.0     0.014404                       1.0
        4                               0.0     0.013448                       0.0
        ...                             ...          ...                       ...
        5384                            1.0     0.005431                       1.0
        5385                            1.0     0.005505                       1.0
        5386                            0.0     0.005495                       0.0
        5387                            1.0     0.005559                       1.0
        5388                            0.0     0.005720                       0.0

              30_vol_std
        0       0.655142
        1       0.409056
        2       0.408216
        3       0.571462
        4       0.431507
        ...          ...
        5384   -0.741654
        5385   -0.730831
        5386   -0.732314
        5387   -0.722969
        5388   -0.699332

        [5389 rows x 10 columns]
```

1.2.3.2 Please estimate a logit model in which the dependent variable is `positive_return_dummy` and your lagged variables are the previous day's standardied 30 day volatility (from the previous question), and previous day's return using `statsmodels` and print the summary of the model.

```
[888]: y = HW01_SPX[["positive_return_variable"]]
       x = HW01_SPX[["30_vol_std","LOG_RETURN_L01d"]]

       log_reg_1 = sm.Logit(y, x).fit()
       log_reg_1.summary()
```

```
Optimization terminated successfully.
        Current function value: 0.691693
        Iterations 4
```

```
[888]: <class 'statsmodels.iolib.summary.Summary'>
       """
                             Logit Regression Results
       ================================================================================
       ====
       Dep. Variable:     positive_return_variable   No. Observations:
       5389
       Model:                               Logit   Df Residuals:
       5387
       Method:                                 MLE   Df Model:
       1
       Date:                   Tue, 25 Oct 2022   Pseudo R-squ.:
       -0.002069
       Time:                            09:16:41   Log-Likelihood:
       -3727.5
       converged:                           True   LL-Null:
       -3719.8
       Covariance Type:                 nonrobust   LLR p-value:
       1.000
       ================================================================================
       ===
                           coef    std err          z      P>|z|      [0.025
       0.975]
       --------------------------------------------------------------------------------
       ---
       30_vol_std         -0.0524      0.028     -1.900      0.057      -0.107
       0.002
       LOG_RETURN_L01d    -7.6910      2.225     -3.457      0.001     -12.052
       -3.330
       ================================================================================
       ===
       """
```

1.2.3.3 Please save the coefficients of this model.

```
[889]: vol_30_standardized_coef = -0.0524
       LOG_RETURN_L01d_coef = -7.6910
```

1.2 1.3 Validating the model (a teeny bit)

1.2.1 1.3.1 Data prep

1.3.1.1 Please preprocess your test data set and print the head of the final dataframe.

```
[1134]: test = HW01_SPX[4412:].reset_index(drop=True)
        #I had to reindex because statsmodel couldn't interpret data without reindexing
        #but the result should not be affected
```
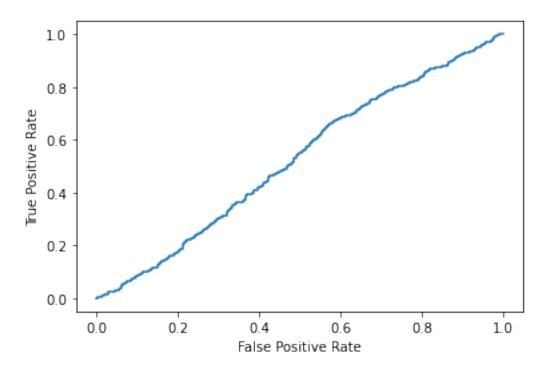
1.3.1.2 Please use the `xxx.predict(X)` method (where xxx is the model from 1.2.3.2) to produce a vector of predictions based on the new data. Create a new dataframe made up of a column of the actual value for the dependent variable, and a column for your model's predicted probability (of an up move). Print the head of the new data frame.

```
[890]: pred = log_reg_1.predict()


       pred_1 = pd.DataFrame(pred)
       pred_1["positive_return_variable"] =␣
        ↪HW01_SPX[["positive_return_variable_L01d"]].reset_index(drop=True)
```

```
[891]: pred_1 = pred_1.rename(columns={0:"prob"})
```

```
[892]: pred_1
```

```
[892]:             prob  positive_return_variable
       0       0.474752                       1.0
       1       0.514455                       1.0
       2       0.493831                       0.0
       3       0.551633                       1.0
       4       0.485681                       0.0
       ...          ...                       ...
       5384    0.503100                       1.0
       5385    0.516350                       1.0
       5386    0.507363                       0.0
       5387    0.515757                       1.0
       5388    0.523702                       0.0

       [5389 rows x 2 columns]
```

```
[625]: pred_1.columns
```

```
[625]: Index(['prob', 'positive_return_variable'], dtype='object')
```

1.3
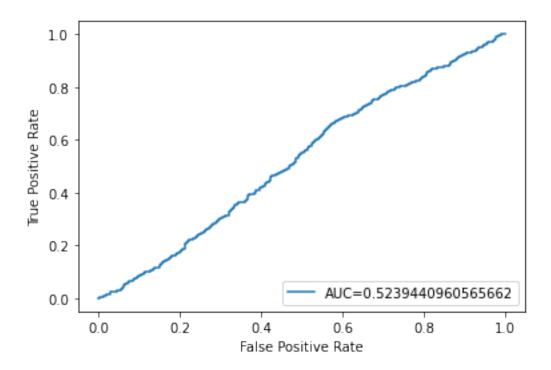
1.3.1.3 Calculate the area under the ROC for your model on the test data. (you may use `sklearn` for this) and print your result.

```python
[893]: from sklearn import svm, datasets
       from sklearn.metrics import roc_curve, auc
       from sklearn.model_selection import train_test_split
       from sklearn.preprocessing import label_binarize
       from sklearn.multiclass import OneVsRestClassifier
       from sklearn.metrics import roc_auc_score
       from sklearn import metrics
       from sklearn.linear_model import LogisticRegression
       import matplotlib.pyplot as plt
```

```python
[894]: # positive_values = pred_1[pred_1["positive_return_variable"] > 0]
       # sort = positive_values.sort_values(by = ["prob"])
       # X = sort["prob"]
       # Y = sort["positive_return_variable"]
       # # sklearn.metrics.auc(X, Y)
       # fpr, tpr, thresholds = metrics.roc_curve(Y, X, pos_label=2)
```

```python
[895]: X = np.array(pred_1["prob"])
       y = np.array(pred_1["positive_return_variable"])


       X_train, X_test, y_train, y_test = train_test_split(X,y,test_size=0.33,
         ↪random_state=1)
```

```python
[896]: clf_reg = LogisticRegression()
       clf_reg.fit(X_train.reshape(-1, 1), y_train)
```

```
[896]: LogisticRegression()
```

```python
[897]: plt.plot(fpr,tpr)
       plt.ylabel('True Positive Rate')
       plt.xlabel('False Positive Rate')
       plt.show()
```

[898]:
```
y_pred_proba = clf_reg.predict_proba(X_test.reshape(-1, 1))[::,1]
fpr, tpr, _ = metrics.roc_curve(y_test,  y_pred_proba)
auc = metrics.roc_auc_score(y_test, y_pred_proba)

#create ROC curve
plt.plot(fpr,tpr,label="AUC="+str(auc))
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.legend(loc=4)
plt.show()
```

2 2 Building the components of the harness

2.1 2.1 Coding

2.1.1 2.1.1 preprocessor

2.1.1.1 Please use your code from 1.1 to write your preprocessor function. Please test your code on the training sample to confirm that it produces the same results as in 1.3.1.1. Make sure to match the specs given in 0.2.

```
[996]:  # HW01_SPX[HW01_SPX["Date_L01d"] == "2017-07-17"]
        train = HW01_SPX[:4411].reset_index(drop=True)
        #I had to reindex since the statsmodel couldn't interpret default indexing
```

```
[1135]:  def preprocessor(df, preproc_params = {}, new = True):
             new_df = pd.DataFrame(df)
             preproc_params = {"mean":new_df.mean(), "standard deviation": new_df.std()}
             return(pd.DataFrame(new_df), preproc_params)
```

```
[1136]:  preprocessor(test)
```

```
/Users/seonhyeyang/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:3: FutureWarning: Dropping of nuisance columns in
DataFrame reductions (with 'numeric_only=None') is deprecated; in a future
```

version this will raise TypeError. Select only valid columns before calling the reduction.
  This is separate from the ipykernel package so we can avoid doing imports until

```
[1136]:  (       Date_L01d  Open_L01d  High_L01d  Low_L01d  Close_L01d  LOG_RETURN_L01d
       \
       0     2017-07-18    2455.88    2460.92   2450.34     2460.61         0.000598
       1     2017-07-19    2463.85    2473.83   2463.85     2473.83         0.005358
       2     2017-07-20    2475.56    2477.62   2468.43     2473.45        -0.000154
       3     2017-07-21    2467.40    2472.54   2465.06     2472.54        -0.000368
       4     2017-07-24    2472.04    2473.10   2466.32     2469.91        -0.001064

       ...          ...       ...       ...       ...         ...             ...
       1002  2021-07-12    4372.41    4386.68   4364.03     4384.63         0.003445
       1003  2021-07-13    4381.07    4392.37   4366.92     4369.21        -0.003523
       1004  2021-07-14    4380.11    4393.68   4362.36     4374.30         0.001164
       1005  2021-07-15    4369.02    4369.02   4340.70     4360.03        -0.003268
       1006  2021-07-16    4367.43    4375.09   4322.53     4327.16        -0.007568


             30_vol_L01d  positive_return_variable
       0        0.004505                       0.0
       1        0.004556                       1.0
       2        0.004554                       1.0
       3        0.004557                       0.0
       4        0.004560                       0.0

       ...          ...                       ...
       1002     0.005431                       1.0
       1003     0.005505                       1.0
       1004     0.005495                       0.0
       1005     0.005559                       1.0
       1006     0.005720                       0.0

       [1007 rows x 8 columns],
       {'mean': Open_L01d                 3058.035919
        High_L01d                 3074.221053
        Low_L01d                  3040.414340
        Close_L01d                3058.510467
        LOG_RETURN_L01d              0.000561
        30_vol_L01d                  0.010251
        positive_return_variable     0.567031
        dtype: float64,
        'standard deviation': Open_L01d              487.561715
        High_L01d                 488.749509
        Low_L01d                  487.116147
        Close_L01d                488.376168
        LOG_RETURN_L01d             0.013241
        30_vol_L01d                 0.008463
```

```
        positive_return_variable       0.495733
        dtype: float64})
```

[979]: `type(train)`

[979]: pandas.core.frame.DataFrame

2.1.1.2 Please test your preprocessor code on the training sample to confirm that it produces the same results as in 1.3.1.1.

[1000]: `preprocessor(train)`

/Users/seonhyeyang/anaconda3/lib/python3.7/site-packages/ipykernel_launcher.py:3: FutureWarning: Dropping of nuisance columns in DataFrame reductions (with 'numeric_only=None') is deprecated; in a future version this will raise TypeError. Select only valid columns before calling the reduction.
  This is separate from the ipykernel package so we can avoid doing imports until

[1000]: (

	Date_L01d	Open_L01d	High_L01d	Low_L01d	Close_L01d	LOG_RETURN_L01d
0	2000-02-15	1402.05	1407.81	1376.21	1402.05	0.008675
1	2000-02-16	1387.67	1404.72	1385.58	1387.67	-0.010309
2	2000-02-17	1388.26	1399.83	1380.07	1388.26	0.000425
3	2000-02-18	1346.09	1388.26	1345.29	1346.09	-0.030847
4	2000-02-22	1352.17	1358.11	1331.97	1352.17	0.004507
...	...	...	...	...	...	...
4406	2017-08-21	2425.50	2430.58	2417.35	2428.37	0.001162
4407	2017-08-22	2433.75	2454.77	2433.67	2452.51	0.009892
4408	2017-08-23	2444.88	2448.91	2441.42	2444.04	-0.003460
4409	2017-08-24	2447.91	2450.39	2436.19	2438.97	-0.002077
4410	2017-08-25	2444.72	2453.96	2442.22	2443.05	0.001671

	positive_return_variable_L01d	30_vol_L01d	positive_return_variable
0	1.0	0.014976	1.0
1	1.0	0.013294	1.0
2	0.0	0.013289	0.0
3	1.0	0.014404	1.0
4	0.0	0.013448	0.0
...	...	...	...
4406	0.0	0.004939	0.0
4407	1.0	0.005254	1.0
4408	1.0	0.005132	1.0
4409	0.0	0.005133	0.0
4410	0.0	0.005065	0.0

18

```
        30_vol_std
0         0.655142
1         0.409056
2         0.408216
3         0.571462
4         0.431507
...            ...
4406     -0.813637
4407     -0.767518
4408     -0.785467
4409     -0.785285
4410     -0.795165

[4411 rows x 10 columns],
{'mean': Open_L01d                          1413.076844
 High_L01d                        1421.509587
 Low_L01d                         1404.054917
 Close_L01d                       1413.301406
 LOG_RETURN_L01d                     0.000128
 positive_return_variable_L01d       0.530719
 30_vol_L01d                         0.010516
 positive_return_variable            0.530719
 30_vol_std                          0.002529
 dtype: float64,
 'standard deviation': Open_L01d                    404.004636
 High_L01d                         403.734603
 Low_L01d                          404.208001
 Close_L01d                        404.130584
 LOG_RETURN_L01d                     0.012229
 positive_return_variable_L01d       0.499112
 30_vol_L01d                         0.006399
 positive_return_variable            0.499112
 30_vol_std                          0.936392
 dtype: float64})
```

2.1.2   2.1.2 `estimator`

2.1.2.1 Please use your code in 1.2.3 to write the function `estimator`. Make sure to match the specs given in 0.2. One way to do this is to create a harness function for your estimation, e.g.,

```python
def my_estimation_fn(df):
    import import statsmodels.formula.api as smf

    f = 'y ~ x1 + x2 + x3
    model_ols = sm.ols(f, data=df).fit(disp=0)
    return(model_ols)
```

Of course there are more elegant approaches to acomplishing this that would be more extensible, and you can experiment with these when you have the time.

```python
[949]: def estimator(df, fitting_algo, est_params = {}):
           import statsmodels.api as sm

           y = (df[["positive_return_variable"]])
           x = (df[["30_vol_std","LOG_RETURN_L01d"]])
           log_reg_1 = sm.Logit(y, x).fit()
           model = log_reg_1
           return(model)
```

2.1.2.2 Please test your code on the training sample to confirm that it produces the same results as in 1.2.3.

```python
[950]: Logit = sm.Logit(y, x)
       estimator(train, Logit)
```

```
Optimization terminated successfully.
         Current function value: 0.691500
         Iterations 4
```

2.1.3 2.1.3 predictor

2.1.3.1 Please use your code from 1.3.1.2 to write the function predictor. Make sure to match the specs given in 0.2.

```python
[944]: def predictor(new_df, model):
           import statsmodels.api as sm

           y = new_df[["positive_return_variable"]]
           x = new_df[["30_vol_std","LOG_RETURN_L01d"]]

           log_reg_1 = sm.Logit(y, x).fit()
           predictions = log_reg_1.predict()
           return(predictions)
```

2.1.3.2 Please test your predictor function using the training data and confirm that the results match your previous results.

```python
[945]: Logit = sm.Logit(y, x)
       predictor(train, Logit)
```

```
Optimization terminated successfully.
         Current function value: 0.691500
         Iterations 4
```

```
[945]: array([0.47247108, 0.51637144, 0.4934653 , …, 0.51820777, 0.51525513,
              0.50739143])
```

2.1.4 2.1.4 `predictor_harness`

2.1.4.1 Please write the function `predictor_harness`. Make sure to match the specs given in 0.2. This harness will take in a dataframe, a model and some preprocessing function (as well as any additional arguments you may require) and produce a vector of predictions of the same length as the number of rows in the dataframe.

```
[ ]: def predictor_harness(new_df, model, preprocessor, preproc_params = {}):
         new_df = df
         y = new_df[["positive_return_variable"]]
         x = new_df[["30_vol_L01d_standardized","LOG_RETURN_L01d"]]

         model = sm.Logit(y, x).fit()

         return(predictions)
```

2.1.5 2.1.5 `walk_forward_harness`

2.1.5.1 Please write your `walk_forward_harness` function. Be sure to match the specs given in 0.2. This is the main function you will be calling to test your model.

```
[1104]: def walk_forward_harness(df, preprocessor, estimator, predictor,
                                 start, date_col = 'Date', step_size = 1):
            from sklearn.metrics import roc_auc_score as AUC

            predictions = []
            model_list = []
            stats_list = []

            y_1 = "positive_return_variable"
            x_1 = [["30_vol_std","LOG_RETURN_L01d"]]
            new_df = df

            start_split = new_df[new_df[date_col+'_L01d']==start].index[0]
            split = start_split

            while split < len(new_df):
                #estimation
                train = new_df.iloc[:split]
                test = new_df.iloc[split:]

                y = new_df[["positive_return_variable"]]
                x = new_df[["30_vol_std","LOG_RETURN_L01d"]]
```

```
        log_reg_1 = sm.Logit(y, x).fit()
        model_list.append(log_reg_1)

#          Prediction
        pred = log_reg_1.predict()
        predictions.append(pred)

        #Statistic
        real = test[y_1]
        stats_list.append(AUC(real,pred))

        split += step_size


    return(predictions, model_list, stats_list)
```

2.2   2.2 Validation (a little bit)

2.2.1   2.2.1 SW testing

2.2.1.1Please test your `walk_forward_harness` function You may wish to include the `progress_bar` function at the beginning of the notebook to provide feedback since w.f. analysis can be very time consuming.

```
[989]:  HW01_SPX=HW01_SPX.reset_index(drop=True)
```

```
[1002]:  e = estimator(train, Logit)
```

```
Optimization terminated successfully.
         Current function value: 0.691500
         Iterations 4
```

```
[1003]:  preprocessor=preprocessor(train)
         # walk_forward_harness(HW01_SPX)
```

```
/Users/seonhyeyang/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:3: FutureWarning: Dropping of nuisance columns in
DataFrame reductions (with 'numeric_only=None') is deprecated; in a future
version this will raise TypeError.  Select only valid columns before calling the
reduction.
  This is separate from the ipykernel package so we can avoid doing imports
until
```

```
[1053]:  p = predictor(train, Logit)
```

```
Optimization terminated successfully.
         Current function value: 0.691500
```

```
                Iterations 4
```

[1105]: `walk_forward_harness(train, preprocessor, e, p, "2000-02-15", "Date")`

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<statsmodels.discrete.discrete_model.BinaryResultsWrapper at 0x7fdf5de84a90>,
…])
```

2.2.2   2.2.2 Model performance

Please produce the following exhibits:

2.2.2.1 An ROC curve and AUC for *all* walk-forward predictions

[1112]:

2.2.2.2 An ROC curve and AUC for walk-forward predictions on days when the (previous day's) 30 day volatility was above (below) the median in the training data.

[ ]:

2.2.2.3 A line plot showing the coefficient on the variable 30 day volatility for each step of the walk-forward analysis

```
[ ]:
```

2.2.3 2.2.3 One more thing...

2.2.3.1 In your own words, please describe why walk-forward analysis is useful? Give an example of a scenario in which you would use it? When would it be wise to steer clear of using walkforward analysis. A walk forward analysis is useful because optimisations can give some insight of the future. A walk forward analysis is a way for testing trading strategy by finding the optimal trading parameters in specific time period, either in cample or training data. Then we check the performance of the parameters in speicific periods of time.

For example, lets say a company wants to trade a certain crypto currency. They can use walk forward optimization to find optimal trading parameters in a given specific period and check the performance (lets say performance is measured by price) of the parameters in the follwoing time period.

2.3 2.3 Extra Credit* (not required)

2.3.1 2.3.1Flexing with more modeling tricks

2.3.1.1 See if you can build a model that performs better in walk-forward analysis than your logit model did. You may use additional tranformations and additional variables from the data set or that you have created from the current variables in the data set; and you may use other algorithms such as recursive partitioning, Naive Bayes, etc.

```
[1149]: def walk_forward_harness_1(df, preprocessor, estimator, predictor,
                                   start, date_col = 'Date', step_size = 1):
            from sklearn.metrics import roc_auc_score as AUC
            import numpy as np

            predictions = []
            model_list = []
            stats_list = []

            y_1 = "positive_return_variable"
            x_1 = [["30_vol_std","LOG_RETURN_L01d"]]
            new_df = df

            start_split = new_df[new_df[date_col+'_L01d']==start].index[0]
            split = start_split

            while split < len(new_df):
                #estimation
                train = new_df.iloc[:split]
                test = new_df.iloc[split:]
```

```
        y = new_df[["positive_return_variable"]]
        x = new_df[["LOG_RETURN_L01d"]]
        log_reg_1 = sm.Logit(y, x).fit()
        model_list.append(log_reg_1)

#        Prediction
        pred = log_reg_1.predict()
        predictions.append(pred)

        #Statistic
        r = test[y_1]
        stats_list.append(AUC(r,pred))

        split += step_size


    return(predictions, model_list, stats_list)
```

[1150]: `walk_forward_harness_1(train, preprocessor, e, p, "2000-02-15", "Date")`

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