PSS_BEM_114_PS2

April 27, 2024

[ ]:
```
import pandas as pd
import statsmodels.api as sm
from statsmodels.regression.rolling import RollingOLS
from sklearn.linear_model import LinearRegression
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.dates import AutoDateLocator, AutoDateFormatter
```

[ ]:
```
crsp_data = pd.read_csv("/content/crsp_1926_2020.csv")
```

1A

[ ]:
```
crsp_data_filter = crsp_data[crsp_data['SHRCD'].isin([10, 11])]
crsp_data_filter = crsp_data_filter[crsp_data_filter['EXCHCD'].isin([1.0, 2.0,␣
↪3.0])]
crsp_data_filter['PRC'] = crsp_data_filter['PRC'].where(crsp_data_filter['PRC']␣
↪>= 0)
```

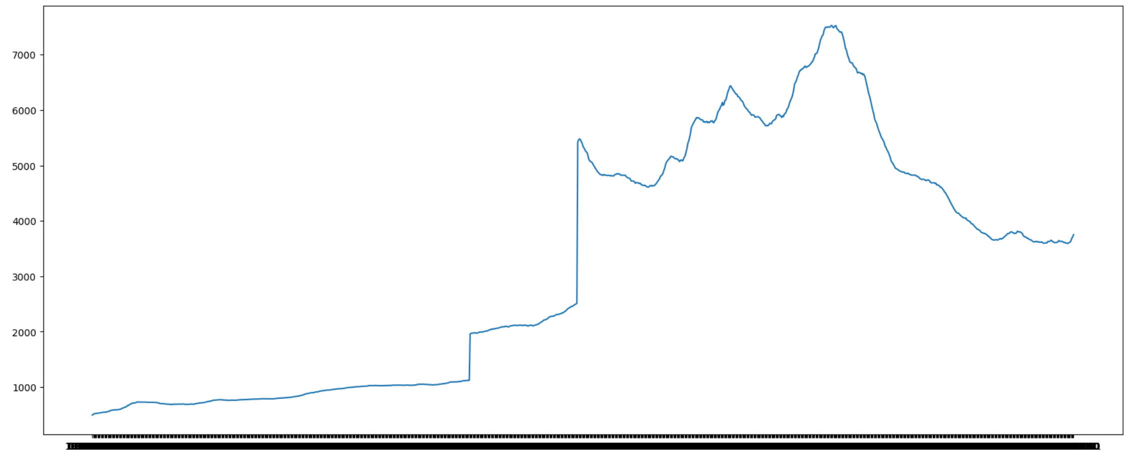
```
<ipython-input-17-34834b818604>:3: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  crsp_data_filter['PRC'] =
crsp_data_filter['PRC'].where(crsp_data_filter['PRC'] >= 0)
```

1B

[ ]:
```
dates_df = pd.DataFrame(crsp_data_filter['date'])
dates_df = dates_df.sort_values(by= 'date')

date_list = list(dates_df['date'])
date_set = sorted(set(date_list))

date_dict = {}

for date in date_set:
  date_dict[date] = date_list.count(date)
```

[ ]:
```python
plt.figure(figsize = (20, 8))
plt.plot(list(date_dict.keys()), list(date_dict.values()))
```

[ ]: [<matplotlib.lines.Line2D at 0x7a07d962c700>]



[ ]:
```python
firm_data = pd.read_csv("/content/crsp_1926_2020.csv")
ff5 = pd.read_csv('/content/ff5_factors.csv')
mom_data = pd.read_csv('/content/mom_factor.csv')
```

[ ]:
```python
firm_data['RET'] = pd.to_numeric(firm_data['RET'], errors='coerce')
firm_data = firm_data.dropna(subset = ['RET'])
firm_data['PRC'] = firm_data['PRC'].where(firm_data['PRC'] >= 0)

data_datemod = firm_data.copy()
data_datemod['date'] = np.floor(data_datemod['date'].str.replace('-','').
 ↪astype(float)/100).astype(int)

ff1926 = pd.merge(data_datemod, ff5, how = 'inner', on='date')
ff1926 = pd.merge(ff1926, mom_data, how='inner', on='date')
ff1926.columns = ff1926.columns.str.strip()
data_unique_months = ff1926.drop_duplicates(subset='date', keep='first')
```

[ ]:
```python
def get_ret(group, decile):
  print("Decile {} mean returns: {}".format(decile, np.mean(group['RET'])))

def print_mean_ret(data):
  print("BY DECILE LAG:")
  data.groupby('decile_lag').apply(lambda x: get_ret(x, x.name))
  print("BY DECILE:")
  data.groupby('decile').apply(lambda x: get_ret(x, x.name))
```

```
def calc_weights(group):
    # Calc equal weights
    group['weights_eq'] = 1 / float(group['decile'].count())
    # Calc total market equity of group
    group['TME'] = group['ME'].sum()
    # Calc value weights
    group['weights_val'] = group['ME'] / group['TME']
    return group

def get_returns(data, split_data, ret_type):
  date_set = sorted(set(data['date']))

  returns = {}

  for date in date_set:
    for i in range(1, 11):
      ret = np.sum(split_data.get_group((float(i), date))[ret_type])
      if i not in returns.keys():
        returns[i] = [ret]
      else:
        returns[i].append(ret)

  return returns
```

[ ]:
```
def estim_CAPM(portfolio_ret, data_unique_dates):
  model1 = sm.OLS(portfolio_ret, sm.add_constant(data_unique_dates['Mkt-RF'])).
↪fit()
  alpha, beta = model1.params
  print(model1.summary())
  return (beta, alpha)

def estim_FF3(portfolio_ret, data_unique_dates):
  model1=sm.OLS(portfolio_ret, sm.add_constant(data_unique_dates[['Mkt-RF',␣
↪'SMB', 'HML']])).fit()
  alpha, beta_1, beta_2, beta_3 = model1.params
  print(model1.summary())
  return (beta_1, beta_2, beta_3, alpha)

def estim_FF5(portfolio_ret, data_unique_dates):
  model1=sm.OLS(portfolio_ret, sm.add_constant(data_unique_dates[['Mkt-RF',␣
↪'SMB', 'HML', 'RMW', 'CMA']])).fit()
  alpha, beta_1, beta_2, beta_3, beta_4, beta_5 = model1.params
  print(model1.summary())
  return (beta_1, beta_2, beta_3, beta_4, beta_5, alpha)

def estim_FF5mom(portfolio_ret, data_unique_dates):
```

```
  model1=sm.OLS(portfolio_ret, sm.add_constant(data_unique_dates[['Mkt-RF', 'SMB', 'HML', 'RMW', 'CMA', 'Mom']])).fit()
  alpha, beta_1, beta_2, beta_3, beta_4, beta_5, beta_6 = model1.params
  print(model1.summary())
  return (beta_1, beta_2, beta_3, beta_4, beta_5, beta_6, alpha)

def estim_models(portfolio_ret, ret, data_unique_months):
  mean_ret = np.mean(ret) - 1
  volatility = np.std(ret)
  sharpe_ratio = mean_ret / volatility
  print("Mean returns = {:.3f}".format(mean_ret))
  print("Portfolio volatility = {:3f}".format(volatility))
  print("Strategy Sharpe Ratio = {:3f}".format(sharpe_ratio))

  portfolio_ret = [(item - 1) * 100 for item in portfolio_ret]

  # print(portfolio_ret)

  beta, alpha = estim_CAPM(portfolio_ret, data_unique_months)
  CAPM_implied = list(data_unique_months['RF'] +  beta * data_unique_months['Mkt-RF'])
  CAPM_implied_percent = [1 + CAPM_implied[i] / 100 for i in range(len(CAPM_implied))]
  CAPM_implied_cumulative = [1 * np.prod(CAPM_implied_percent[0:i+1]) for i in range(len(CAPM_implied_percent))]

  beta_1, beta_2, beta_3, alpha = estim_FF3(portfolio_ret, data_unique_months)
  FF3_implied = list(data_unique_months['RF'] +  beta_1 * data_unique_months['Mkt-RF'] + beta_2 * data_unique_months['SMB'] + beta_3 * data_unique_months['HML'])
  FF3_implied_percent = [1 + FF3_implied[i] / 100 for i in range(len(FF3_implied))]
  FF3_implied_cumulative = [1 * np.prod(FF3_implied_percent[0:i+1]) for i in range(len(FF3_implied_percent))]

  beta_1, beta_2, beta_3, beta_4, beta_5, alpha = estim_FF5(portfolio_ret, data_unique_months)
  FF5_implied = list(data_unique_months['RF'] +  beta_1 * data_unique_months['Mkt-RF'] + beta_2 * data_unique_months['SMB'] + beta_3 * data_unique_months['HML'] + beta_4 * data_unique_months['RMW'] + beta_5 * data_unique_months['CMA'])
  FF5_implied_percent = [1 + FF5_implied[i] / 100 for i in range(len(FF5_implied))]
  FF5_implied_cumulative = [1 * np.prod(FF5_implied_percent[0:i+1]) for i in range(len(FF5_implied_percent))]
```

```
  beta_1, beta_2, beta_3, beta_4, beta_5, beta_6, alpha =␣
↪estim_FF5mom(portfolio_ret, data_unique_months)
  FF5mom_implied = list(data_unique_months['RF'] +  beta_1 *␣
↪data_unique_months['Mkt-RF'] + beta_2 * data_unique_months['SMB'] + beta_3 *␣
↪data_unique_months['HML'] + beta_4 * data_unique_months['RMW'] + beta_5 *␣
↪data_unique_months['CMA'] + beta_6 * data_unique_months['Mom'])
  FF5mom_implied_percent = [1 + FF5mom_implied[i] / 100 for i in␣
↪range(len(FF5mom_implied))]
  FF5mom_implied_cumulative = [1 * np.prod(FF5mom_implied_percent[0:i+1]) for i␣
↪in range(len(FF5mom_implied_percent))]


  return CAPM_implied_cumulative, FF3_implied_cumulative,␣
↪FF5_implied_cumulative, FF5mom_implied_cumulative
```

[ ]:
```
def value_signal(group):
  # Calc equal weights
    group['signal'] = group['ME']

    return group

def calc_val_returns(returns):
  ret = [1 + (returns[1][i] - returns[10][i]) for i in range(len(returns[1]))]
  return ret

def calc_returns(returns):
  ret = [1 + (returns[10][i] - returns[1][i]) for i in range(len(returns[1]))]
  return ret

def calc_rolling_ret(group):
    # Calc equal weights
    group['signal'] = group['RET'].rolling(window=11, min_periods = 10).
↪apply(lambda x: np.prod(1+x) - 1, raw=True)
    group['signal'] = group['signal'].shift(1)

    return group

def calc_rolling_beta(group):
  # print(list(group['PERMNO'])[0])
  if (len(group) >= 36):
    model = RollingOLS(endog= 100 * group['RET'] - group['RF'], exog= sm.
↪add_constant(group['Mkt-RF']), window=36).fit()
    group['signal'] = model.params['Mkt-RF']
  else:
    group['signal'] = np.nan
  return group
  # print(group['signal'][36:])
```

```python
[ ]: def sim_portfolio(data, ret_calc, signal_func, equal):
       data = data[(data['date'] >= 196201) & (data['date'] <= 202012)]

       data['ME'] = (data['PRC'] * data['SHROUT'])/1000

       data = data.groupby('PERMNO').apply(signal_func)

       test_data = data.reset_index(drop=True)

       test_data = test_data.dropna(subset = ['signal'])

       test_data = test_data[(test_data['date'] >= 196501) & (test_data['date'] <=␣
     ↪202012)]

       test_data['rank'] = test_data.groupby('date')['signal'].rank(pct=True)

       # Label each observation with a decile based on its percentile rank
       test_data['decile'] = np.ceil(test_data['rank']*10)

       test_data = test_data.groupby(['date', 'decile']).apply(calc_weights)

       test_data['decile_lag'] = test_data.groupby('PERMNO')['decile'].shift(1)

       print_mean_ret(test_data.reset_index(drop = True))

       test_data['weights_val_lag'] = test_data.groupby('PERMNO')['weights_val'].
     ↪shift(1)
       test_data['weights_eq_lag'] = test_data.groupby('PERMNO')['weights_eq'].
     ↪shift(1)

       test_data['weighted_val_ret'] = test_data['weights_val_lag'] *␣
     ↪test_data['RET']
       test_data['weighted_eq_ret'] = test_data['weights_eq_lag'] * test_data['RET']

       test_data = test_data.dropna(subset = ['decile_lag'])

       if equal:
         returns = get_returns(test_data, test_data.reset_index(drop = True).
     ↪groupby(['decile_lag', 'date']), 'weighted_eq_ret')
       else:
         returns = get_returns(test_data, test_data.reset_index(drop = True).
     ↪groupby(['decile_lag', 'date']), 'weighted_val_ret')

       portfolio_ret_mom = ret_calc(returns)
       portfolio_val_mom = [1 * np.prod(portfolio_ret_mom[0:i+1]) for i in␣
     ↪range(len(portfolio_ret_mom))]
```

```
    date_df = test_data.reset_index(drop = True).drop_duplicates(subset='date',␣
↪keep='first')

    capm, ff3, ff5, ff5mom = estim_models(portfolio_ret_mom, portfolio_ret_mom,␣
↪date_df)

    return test_data.reset_index(drop = True), portfolio_ret_mom,␣
↪portfolio_val_mom, capm, ff3, ff5, ff5mom
```

```
[ ]: def disp_portfolio(data, rets, vals, ff3, capm, ff5, ff5mom):
  mean_ret = np.mean([i - 1 for i in rets])
  var_ret = np.std(rets)
  x_axis = sorted(set(data['date']))
  x_axis = [str(item)[:4] + '-' + str(item)[4:] for item in x_axis]
  print('Sharpe Ratio: {}'.format(mean_ret / var_ret))
  plt.figure(figsize = (20, 8))
  plt.plot(x_axis, vals, label = 'Returns')
  plt.plot(x_axis, ff3, label = 'FF3 Implied Returns')
  plt.plot(x_axis, capm, label = 'CAPM Implied Returns')
  if ff5 is not None:
    plt.plot(x_axis, ff5, label = 'FF5 Implied Returns')
  if ff5mom is not None:
    plt.plot(x_axis, ff5mom, label = 'FF5+Momentum Implied Returns')
  plt.gca().xaxis.set_major_locator(AutoDateLocator())
  plt.legend(loc = 'best')
  plt.show()
```

1 Question 2

Value Weighted Portfolio

The results of our simulated portfolio are below.

2B) As we can see from the output, the mean monthly returns for each decile are not monotonic, but we do see that Decile 1 has the largest returns and Decile 10 has the lowest returns, which was expected.

2C) Mean returns = 0.009 Portfolio volatility = 0.066862 Strategy Sharpe Ratio = 0.129848

2D) The CAPM model regression produces an alpha of 0.7575, while the FF3 model regression produces an alpha of 0.5168. It makes sense that the FF3 model produces lower alpha because the FF3 model includes size and book/market factors. Since our model is taking advantage of a size strategy, it will mostly mirror FF3 returns, making it harder to produce alpha.

2E) Size still works as we can tell from the plotted portfolio values over time. The strategy quickly shrugs off the negative returns generated by the release of the Fama French 1992 paper and the 2002 Dot-Com Bubble burst. However, we do see that after 2002, the strategy's returns are more volatile.

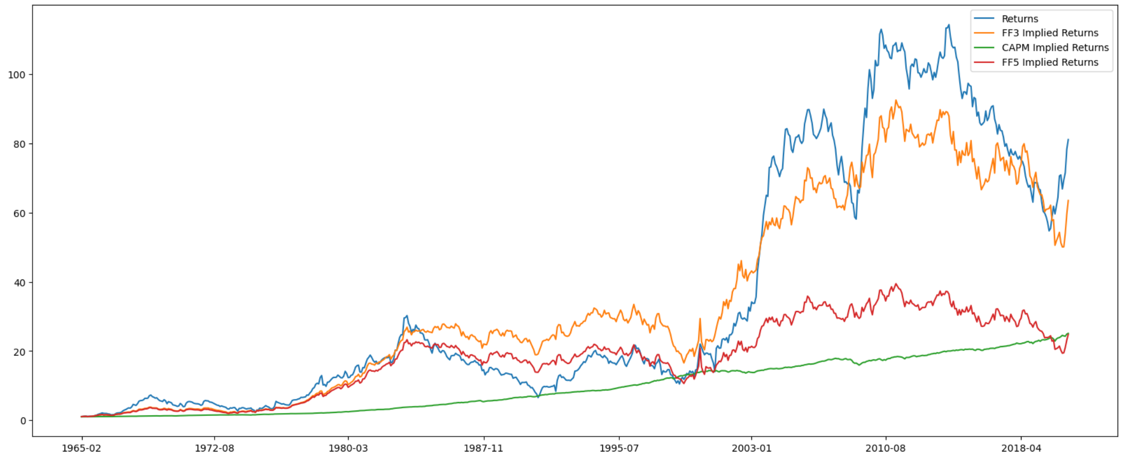
[ ]:
```
val_data, val_port_ret, val_port_val, val_capm, val_ff3, val_ff5, val_ff5mom =
    sim_portfolio(ff1926, calc_val_returns, value_signal, False)
disp_portfolio(val_data, val_port_ret, val_port_val, val_ff3, val_capm,
    val_ff5, None)
```

```
BY DECILE LAG:
Decile 1.0 mean returns: 0.022415183167563028
Decile 2.0 mean returns: 0.010055376201825787
Decile 3.0 mean returns: 0.009539231098490631
Decile 4.0 mean returns: 0.010089036310466308
Decile 5.0 mean returns: 0.009606305406117035
Decile 6.0 mean returns: 0.009809506824385807
Decile 7.0 mean returns: 0.010210128907243644
Decile 8.0 mean returns: 0.009960507740771654
Decile 9.0 mean returns: 0.009862058446141972
Decile 10.0 mean returns: 0.009507285225756973
BY DECILE:
Decile 1.0 mean returns: -0.01471417431986699
Decile 2.0 mean returns: 0.004632129783649347
Decile 3.0 mean returns: 0.009448779456211311
Decile 4.0 mean returns: 0.011645313693969423
Decile 5.0 mean returns: 0.01400943400402235
Decile 6.0 mean returns: 0.015902528380800647
Decile 7.0 mean returns: 0.01714734991559777
Decile 8.0 mean returns: 0.01824695631800705
Decile 9.0 mean returns: 0.018101130657418057
Decile 10.0 mean returns: 0.016697247639632793
Mean returns = 0.009
Portfolio volatility = 0.066862
Strategy Sharpe Ratio = 0.129848
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.018
Model:                            OLS   Adj. R-squared:                  0.017
Method:                 Least Squares   F-statistic:                     12.54
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           0.000427
Time:                        01:14:17   Log-Likelihood:                -2220.8
No. Observations:                 671   AIC:                             4446.
Df Residuals:                     669   BIC:                             4455.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.7575      0.258      2.936      0.003       0.251       1.264
Mkt-RF         0.2007      0.057      3.541      0.000       0.089       0.312
==============================================================================
Omnibus:                      240.708   Durbin-Watson:                   1.844
```

```
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1640.417
Skew:                           1.433   Prob(JB):                         0.00
Kurtosis:                      10.104   Cond. No.                         4.59
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.480
Model:                            OLS   Adj. R-squared:                  0.477
Method:                 Least Squares   F-statistic:                     205.1
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           3.14e-94
Time:                        01:14:17   Log-Likelihood:                -2007.8
No. Observations:                 671   AIC:                             4024.
Df Residuals:                     667   BIC:                             4042.
Df Model:                           3
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.5168      0.189      2.728      0.007       0.145       0.889
Mkt-RF        -0.0903      0.044     -2.040      0.042      -0.177      -0.003
SMB            1.5425      0.064     24.212      0.000       1.417       1.668
HML            0.0986      0.066      1.489      0.137      -0.031       0.229
==============================================================================
Omnibus:                      241.324   Durbin-Watson:                   2.177
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             2585.078
Skew:                           1.287   Prob(JB):                         0.00
Kurtosis:                      12.265   Cond. No.                         4.83
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.495
Model:                            OLS   Adj. R-squared:                  0.492
Method:                 Least Squares   F-statistic:                     130.6
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           2.78e-96
Time:                        01:14:18   Log-Likelihood:                -1997.6
No. Observations:                 671   AIC:                             4007.
Df Residuals:                     665   BIC:                             4034.
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
```

```
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.6545      0.193      3.399      0.001       0.276       1.033
Mkt-RF        -0.1128      0.046     -2.425      0.016      -0.204      -0.021
SMB            1.4508      0.066     21.902      0.000       1.321       1.581
HML            0.1195      0.088      1.358      0.175      -0.053       0.292
RMW           -0.4104      0.092     -4.449      0.000      -0.592      -0.229
CMA           -0.0153      0.136     -0.113      0.910      -0.283       0.252
==============================================================================
Omnibus:                      227.266   Durbin-Watson:                   2.194
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             2372.342
Skew:                           1.199   Prob(JB):                         0.00
Kurtosis:                      11.894   Cond. No.                         5.25
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.536
Model:                            OLS   Adj. R-squared:                  0.532
Method:                 Least Squares   F-statistic:                     127.8
Date:                Sat, 20 Apr 2024   Prob (F-statistic):          3.36e-107
Time:                        01:14:18   Log-Likelihood:                -1969.5
No. Observations:                 671   AIC:                             3953.
Df Residuals:                     664   BIC:                             3985.
Df Model:                           6
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.8916      0.187      4.758      0.000       0.524       1.260
Mkt-RF        -0.1654      0.045     -3.663      0.000      -0.254      -0.077
SMB            1.4633      0.064     23.010      0.000       1.338       1.588
HML           -0.0553      0.088     -0.632      0.528      -0.227       0.117
RMW           -0.3406      0.089     -3.827      0.000      -0.515      -0.166
CMA            0.0915      0.131      0.696      0.487      -0.167       0.349
Mom           -0.3337      0.044     -7.613      0.000      -0.420      -0.248
==============================================================================
Omnibus:                      162.807   Durbin-Watson:                   2.053
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              910.784
Skew:                           0.959   Prob(JB):                    1.68e-198
Kurtosis:                       8.375   Cond. No.                         5.39
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
```

```
specified.
Sharpe Ratio: 0.12984810010355963
```



Equal Weighted Portfolio

The results of our simulated portfolio are below.

2B) As we can see from the output, the mean monthly returns for each decile are not monotonic, but we do see that Decile 1 has the largest returns and Decile 10 has the lowest returns, which was expected.

2C) Mean returns = 0.013 Portfolio volatility = 0.068611 Strategy Sharpe Ratio = 0.188912

2D) The CAPM model regression produces an alpha of 1.2097, while the FF3 model regression produces an alpha of 1.0062. It makes sense that the FF3 model produces lower alpha because the FF3 model includes size and book/market factors. Since our model is taking advantage of a size strategy, it will mostly mirror FF3 returns, making it harder to produce alpha.

2E) Size still works as we can tell from the plotted portfolio values over time. In fact, the equal weighted size portfolio produces substantially more alpha than the FF3 implied returns. This is remarkable given that the FF3 model contains similar factors to size. The strategy quickly shrugs off the negative returns generated by the release of the Fama French 1992 paper and the 2002 Dot-Com Bubble burst. However, we do see that after 2002, the strategy's returns are more volatile.

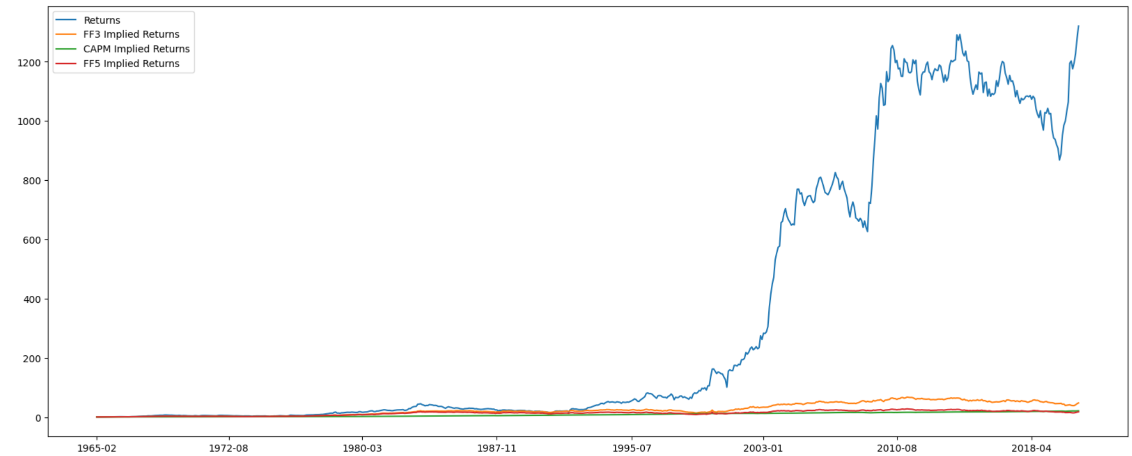
[ ]:
```
val_data, val_port_ret, val_port_val, val_capm, val_ff3, val_ff5, val_ff5mom =
  sim_portfolio(ff1926, calc_val_returns, value_signal, True)
disp_portfolio(val_data, val_port_ret, val_port_val, val_ff3, val_capm,
  val_ff5, None)
```

```
BY DECILE LAG:
Decile 1.0 mean returns: 0.022415183167563028
Decile 2.0 mean returns: 0.010055376201825787
Decile 3.0 mean returns: 0.009539231098490631
Decile 4.0 mean returns: 0.010089036310466308
```

```
Decile 5.0 mean returns: 0.009606305406117035
Decile 6.0 mean returns: 0.009809506824385807
Decile 7.0 mean returns: 0.010210128907243644
Decile 8.0 mean returns: 0.009960507740771654
Decile 9.0 mean returns: 0.009862058446141972
Decile 10.0 mean returns: 0.009507285225756973
BY DECILE:
Decile 1.0 mean returns: -0.01471417431986699
Decile 2.0 mean returns: 0.004632129783649347
Decile 3.0 mean returns: 0.009448779456211311
Decile 4.0 mean returns: 0.011645313693969423
Decile 5.0 mean returns: 0.01400943400402235
Decile 6.0 mean returns: 0.015902528380800647
Decile 7.0 mean returns: 0.01714734991559777
Decile 8.0 mean returns: 0.01824695631800705
Decile 9.0 mean returns: 0.018101130657418057
Decile 10.0 mean returns: 0.016697247639632793
Mean returns = 0.013
Portfolio volatility = 0.068611
Strategy Sharpe Ratio = 0.188912
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.011
Model:                            OLS   Adj. R-squared:                  0.009
Method:                 Least Squares   F-statistic:                     7.206
Date:                Sat, 20 Apr 2024   Prob (F-statistic):            0.00744
Time:                        01:15:51   Log-Likelihood:                -2240.8
No. Observations:                 671   AIC:                             4486.
Df Residuals:                     669   BIC:                             4495.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.2097      0.266      4.551      0.000       0.688       1.732
Mkt-RF         0.1568      0.058      2.684      0.007       0.042       0.271
==============================================================================
Omnibus:                      280.739   Durbin-Watson:                   1.853
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             2431.919
Skew:                           1.638   Prob(JB):                         0.00
Kurtosis:                      11.732   Cond. No.                         4.59
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
```

```
Dep. Variable:                      y   R-squared:                       0.367
Model:                            OLS   Adj. R-squared:                  0.364
Method:                 Least Squares   F-statistic:                     129.0
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           6.90e-66
Time:                        01:15:51   Log-Likelihood:                -2090.9
No. Observations:                 671   AIC:                             4190.
Df Residuals:                     667   BIC:                             4208.
Df Model:                           3
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.0062      0.214      4.693      0.000       0.585       1.427
Mkt-RF        -0.1126      0.050     -2.248      0.025      -0.211      -0.014
SMB            1.3947      0.072     19.342      0.000       1.253       1.536
HML            0.0441      0.075      0.588      0.556      -0.103       0.191
==============================================================================
Omnibus:                      274.356   Durbin-Watson:                   2.121
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             3008.117
Skew:                           1.511   Prob(JB):                         0.00
Kurtosis:                      12.923   Cond. No.                         4.83
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.384
Model:                            OLS   Adj. R-squared:                  0.379
Method:                 Least Squares   F-statistic:                     82.92
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           1.18e-67
Time:                        01:15:51   Log-Likelihood:                -2081.8
No. Observations:                 671   AIC:                             4176.
Df Residuals:                     665   BIC:                             4203.
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.1480      0.218      5.259      0.000       0.719       1.577
Mkt-RF        -0.1344      0.053     -2.549      0.011      -0.238      -0.031
SMB            1.2975      0.075     17.278      0.000       1.150       1.445
HML            0.0576      0.100      0.577      0.564      -0.138       0.254
RMW           -0.4359      0.105     -4.168      0.000      -0.641      -0.231
CMA            0.0041      0.154      0.027      0.979      -0.299       0.307
==============================================================================
Omnibus:                      262.013   Durbin-Watson:                   2.135
```

```
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             2738.252
Skew:                           1.440   Prob(JB):                         0.00
Kurtosis:                      12.468   Cond. No.                         5.25
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.423
Model:                            OLS   Adj. R-squared:                  0.418
Method:                 Least Squares   F-statistic:                     81.26
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           4.10e-76
Time:                        01:15:51   Log-Likelihood:                -2059.6
No. Observations:                 671   AIC:                             4133.
Df Residuals:                     664   BIC:                             4165.
Df Model:                           6
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.3880      0.214      6.476      0.000       0.967       1.809
Mkt-RF        -0.1876      0.052     -3.633      0.000      -0.289      -0.086
SMB            1.3101      0.073     18.012      0.000       1.167       1.453
HML           -0.1193      0.100     -1.192      0.234      -0.316       0.077
RMW           -0.3653      0.102     -3.588      0.000      -0.565      -0.165
CMA            0.1122      0.150      0.746      0.456      -0.183       0.407
Mom           -0.3376      0.050     -6.734      0.000      -0.436      -0.239
==============================================================================
Omnibus:                      203.223   Durbin-Watson:                   2.007
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1248.668
Skew:                           1.205   Prob(JB):                    7.16e-272
Kurtosis:                       9.233   Cond. No.                         5.39
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
Sharpe Ratio: 0.18891153624932602
```



2 QUESTION 3

Value Weighted Portfolio

The results of our simulated portfolio are below.

3B) As we can see from the output, the mean monthly returns for each decile are not monotonic, but we do see that Decile 10 has the largest returns and Decile 1 has the lowest returns, which was expected.

3C) Mean returns = 0.017 Portfolio volatility = 0.082393 Strategy Sharpe Ratio = 0.209300

3D) The CAPM model regression produces an alpha of 1.9810, the FF3 model regression produces an alpha of 2.1777, and the FF5 model produces an alpha of 1.8590. We see that the alphas are significantly positive for all 3 models which makes sense because none of the 3 models price momentum.

3E) The momentum alphas are not indiciative of managerial skill. We also ran an FF5+Momentum regression and found that the portfolio returns were essentially mirrored. This indicates that the CAPM, FF3, and FF5 models not pricing the Momentum factor is why the alphas generated are so large in comparison.

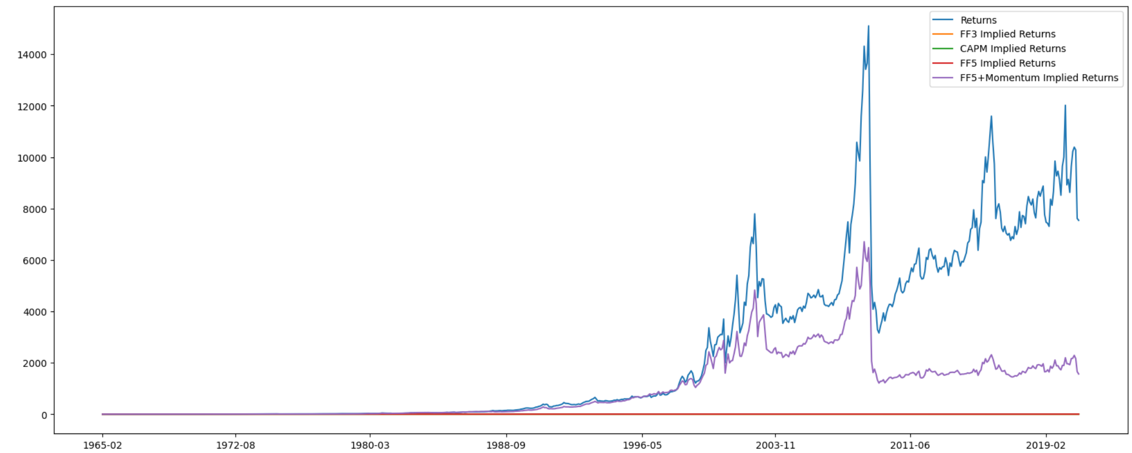
```
[ ]: data, port_ret, port_val, capm, ff3, ff5, ff5mom = sim_portfolio(ff1926,␣
      ↪calc_returns, calc_rolling_ret, False)
     disp_portfolio(data, port_ret, port_val, ff3, capm, ff5, ff5mom)
```

```
BY DECILE LAG:
Decile 1.0 mean returns: 0.010850477602610726
Decile 2.0 mean returns: 0.007986664296175141
Decile 3.0 mean returns: 0.008929823006912165
Decile 4.0 mean returns: 0.009845679627509233
Decile 5.0 mean returns: 0.009989474979250564
Decile 6.0 mean returns: 0.011053162648848867
Decile 7.0 mean returns: 0.012247417758956958
```

```
Decile 8.0 mean returns: 0.013588212537821328
Decile 9.0 mean returns: 0.01493498328610911
Decile 10.0 mean returns: 0.01718796512784129
BY DECILE:
Decile 1.0 mean returns: 0.018314203105449806
Decile 2.0 mean returns: 0.008315505839602059
Decile 3.0 mean returns: 0.00797450810219598
Decile 4.0 mean returns: 0.008828513454974013
Decile 5.0 mean returns: 0.009424004283223509
Decile 6.0 mean returns: 0.010501514377887527
Decile 7.0 mean returns: 0.011251567607604316
Decile 8.0 mean returns: 0.012029862166717545
Decile 9.0 mean returns: 0.013280379485287097
Decile 10.0 mean returns: 0.015650395424091162
Mean returns = 0.017
Portfolio volatility = 0.082393
Strategy Sharpe Ratio = 0.209300
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.068
Model:                            OLS   Adj. R-squared:                  0.066
Method:                 Least Squares   F-statistic:                     47.78
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           1.13e-11
Time:                        01:22:13   Log-Likelihood:                -2308.8
No. Observations:                 661   AIC:                             4622.
Df Residuals:                     659   BIC:                             4631.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.9810      0.312      6.347      0.000       1.368       2.594
Mkt-RF        -0.4752      0.069     -6.912      0.000      -0.610      -0.340
==============================================================================
Omnibus:                      140.264   Durbin-Watson:                   2.009
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              619.471
Skew:                          -0.894   Prob(JB):                    3.04e-135
Kurtosis:                       7.393   Cond. No.                         4.58
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.109
Model:                            OLS   Adj. R-squared:                  0.105
Method:                 Least Squares   F-statistic:                     26.87
```

```
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           2.11e-16
Time:                        01:22:13   Log-Likelihood:                -2293.7
No. Observations:                 661   AIC:                             4595.
Df Residuals:                     657   BIC:                             4613.
Df Model:                           3
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          2.1777      0.308      7.079      0.000       1.574       2.782
Mkt-RF        -0.5224      0.072     -7.227      0.000      -0.664      -0.380
SMB           -0.1520      0.104     -1.467      0.143      -0.355       0.051
HML           -0.5669      0.107     -5.283      0.000      -0.778      -0.356
==============================================================================
Omnibus:                      144.930   Durbin-Watson:                   2.017
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              675.120
Skew:                          -0.909   Prob(JB):                    2.51e-147
Kurtosis:                       7.605   Cond. No.                         4.83
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.135
Model:                            OLS   Adj. R-squared:                  0.128
Method:                 Least Squares   F-statistic:                     20.40
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           5.99e-19
Time:                        01:22:13   Log-Likelihood:                -2284.1
No. Observations:                 661   AIC:                             4580.
Df Residuals:                     655   BIC:                             4607.
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.8590      0.312      5.950      0.000       1.246       2.472
Mkt-RF        -0.4239      0.076     -5.567      0.000      -0.573      -0.274
SMB           -0.0164      0.108     -0.152      0.879      -0.228       0.195
HML           -0.8669      0.143     -6.055      0.000      -1.148      -0.586
RMW            0.5742      0.150      3.832      0.000       0.280       0.868
CMA            0.6468      0.222      2.919      0.004       0.212       1.082
==============================================================================
Omnibus:                      126.086   Durbin-Watson:                   2.012
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              564.030
Skew:                          -0.790   Prob(JB):                    3.33e-123
Kurtosis:                       7.240   Cond. No.                         5.23
```

```
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.805
Model:                            OLS   Adj. R-squared:                  0.804
Method:                 Least Squares   F-statistic:                     451.0
Date:                Sat, 20 Apr 2024   Prob (F-statistic):         1.35e-228
Time:                        01:22:13   Log-Likelihood:                -1791.0
No. Observations:                 661   AIC:                             3596.
Df Residuals:                     654   BIC:                             3628.
Df Model:                           6
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.6739      0.150      4.481      0.000       0.379       0.969
Mkt-RF        -0.1489      0.037     -4.067      0.000      -0.221      -0.077
SMB           -0.0936      0.051     -1.826      0.068      -0.194       0.007
HML            0.0161      0.070      0.228      0.820      -0.122       0.154
RMW            0.2259      0.072      3.159      0.002       0.085       0.366
CMA            0.0920      0.106      0.870      0.385      -0.116       0.300
Mom            1.6711      0.035     47.468      0.000       1.602       1.740
==============================================================================
Omnibus:                       34.563   Durbin-Watson:                   2.107
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              112.996
Skew:                           0.015   Prob(JB):                     2.91e-25
Kurtosis:                       5.025   Cond. No.                         5.39
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
Sharpe Ratio: 0.20930041997819854
```



Equal Weighted Portfolio

The results of our simulated portfolio are below.

3B) As we can see from the output, the mean monthly returns for each decile are not monotonic, but we do see that Decile 10 has the largest returns and Decile 1 has the lowest returns, which was expected.

3C) Mean returns = 0.007 Portfolio volatility = 0.071918 Strategy Sharpe Ratio = 0.099123

3D) The CAPM model regression produces an alpha of 0.8444, the FF3 model regression produces an alpha of 1.0103, and the FF5 model produces an alpha of 0.6860. We see that the alphas are significantly positive for all 3 models which makes sense because none of the 3 models price momentum. What's interesting is that the equal weighted portfolio alphas are much lower than the value weighted portfolio alphas. This indicates that weighted portfolios generate higher returns when creating a momentum strategy.

3E) The momentum alphas are not indiciative of managerial skill. We also ran an FF5+Momentum regression and found that the FF5+Momentum implied returns dominated equal weighted momentum stratgey returns. This indicates that the CAPM, FF3, and FF5 models not pricing the Momentum factor is why the alphas generated are so large in comparison.

[ ]:
```
data, port_ret, port_val, capm, ff3, ff5, ff5mom = sim_portfolio(ff1926,␣
↪calc_returns, calc_rolling_ret, True)
disp_portfolio(data, port_ret, port_val, ff3, capm, ff5, ff5mom)
```

```
BY DECILE LAG:
Decile 1.0 mean returns: 0.010850477602610726
Decile 2.0 mean returns: 0.007986664296175141
Decile 3.0 mean returns: 0.008929823006912165
Decile 4.0 mean returns: 0.009845679627509233
Decile 5.0 mean returns: 0.009989474979250564
Decile 6.0 mean returns: 0.011053162648848867
Decile 7.0 mean returns: 0.012247417758956958
Decile 8.0 mean returns: 0.013588212537821328
```

```
Decile 9.0 mean returns: 0.01493498328610911
Decile 10.0 mean returns: 0.01718796512784129
BY DECILE:
Decile 1.0 mean returns: 0.018314203105449806
Decile 2.0 mean returns: 0.008315505839602059
Decile 3.0 mean returns: 0.00797450810219598
Decile 4.0 mean returns: 0.008828513454974013
Decile 5.0 mean returns: 0.009424004283223509
Decile 6.0 mean returns: 0.010501514377887527
Decile 7.0 mean returns: 0.011251567607604316
Decile 8.0 mean returns: 0.012029862166717545
Decile 9.0 mean returns: 0.013280379485287097
Decile 10.0 mean returns: 0.015650395424091162
Mean returns = 0.007
Portfolio volatility = 0.071918
Strategy Sharpe Ratio = 0.099123
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.023
Model:                            OLS   Adj. R-squared:                  0.022
Method:                 Least Squares   F-statistic:                     15.74
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           8.05e-05
Time:                        01:24:01   Log-Likelihood:                -2234.2
No. Observations:                 661   AIC:                             4472.
Df Residuals:                     659   BIC:                             4481.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.8444      0.279      3.028      0.003       0.297       1.392
Mkt-RF        -0.2437      0.061     -3.968      0.000      -0.364      -0.123
==============================================================================
Omnibus:                      435.946   Durbin-Watson:                   2.091
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            11143.608
Skew:                          -2.515   Prob(JB):                         0.00
Kurtosis:                      22.476   Cond. No.                         4.58
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.064
Model:                            OLS   Adj. R-squared:                  0.060
Method:                 Least Squares   F-statistic:                     15.08
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           1.68e-09
```

```
Time:                        01:24:02   Log-Likelihood:                -2220.0
No. Observations:                 661   AIC:                             4448.
Df Residuals:                     657   BIC:                             4466.
Df Model:                           3
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.0103      0.275      3.671      0.000       0.470       1.551
Mkt-RF        -0.2310      0.065     -3.572      0.000      -0.358      -0.104
SMB           -0.3191      0.093     -3.443      0.001      -0.501      -0.137
HML           -0.3819      0.096     -3.979      0.000      -0.570      -0.193
==============================================================================
Omnibus:                      432.138   Durbin-Watson:                   2.114
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            12528.221
Skew:                          -2.436   Prob(JB):                         0.00
Kurtosis:                      23.764   Cond. No.                         4.83
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.099
Model:                            OLS   Adj. R-squared:                  0.092
Method:                 Least Squares   F-statistic:                     14.42
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           2.07e-13
Time:                        01:24:02   Log-Likelihood:                -2207.5
No. Observations:                 661   AIC:                             4427.
Df Residuals:                     655   BIC:                             4454.
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.6860      0.278      2.465      0.014       0.140       1.232
Mkt-RF        -0.1314      0.068     -1.937      0.053      -0.265       0.002
SMB           -0.1799      0.096     -1.872      0.062      -0.369       0.009
HML           -0.6836      0.128     -5.361      0.000      -0.934      -0.433
RMW            0.5899      0.133      4.420      0.000       0.328       0.852
CMA            0.6493      0.197      3.291      0.001       0.262       1.037
==============================================================================
Omnibus:                      401.015   Durbin-Watson:                   2.110
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            10144.771
Skew:                          -2.225   Prob(JB):                         0.00
Kurtosis:                      21.669   Cond. No.                         5.23
==============================================================================
```

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

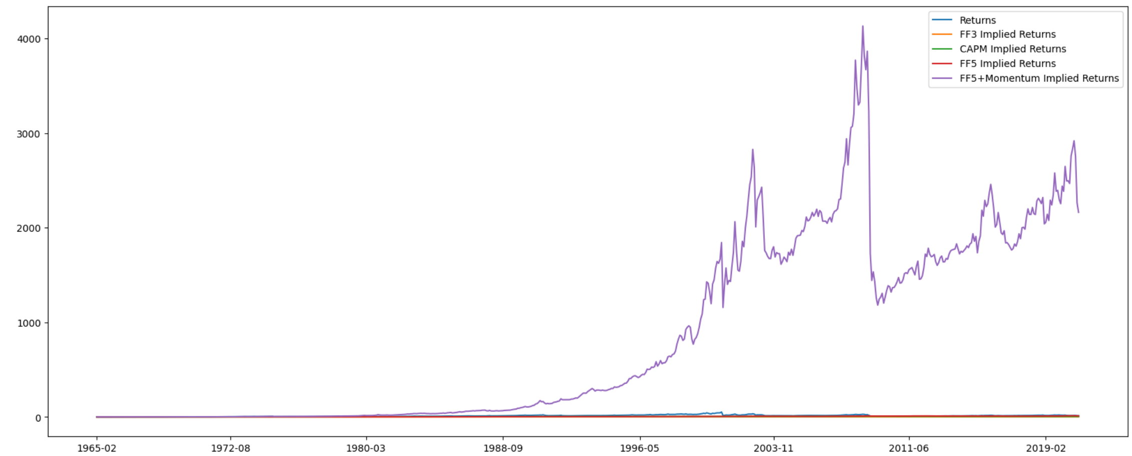
OLS Regression Results

Dep. Variable:	y	R-squared:	0.673
Model:	OLS	Adj. R-squared:	0.670
Method:	Least Squares	F-statistic:	224.2
Date:	Sat, 20 Apr 2024	Prob (F-statistic):	4.90e-155
Time:	01:24:02	Log-Likelihood:	-1872.7
No. Observations:	661	AIC:	3759.
Df Residuals:	654	BIC:	3791.
Df Model:	6		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.2708	0.170	-1.592	0.112	-0.605	0.063
Mkt-RF	0.0906	0.041	2.188	0.029	0.009	0.172
SMB	-0.2422	0.058	-4.178	0.000	-0.356	-0.128
HML	0.0292	0.080	0.367	0.714	-0.127	0.186
RMW	0.3087	0.081	3.815	0.000	0.150	0.468
CMA	0.2014	0.120	1.682	0.093	-0.034	0.437
Mom	1.3492	0.040	33.870	0.000	1.271	1.427

Omnibus:	240.087	Durbin-Watson:	1.992
Prob(Omnibus):	0.000	Jarque-Bera (JB):	2182.229
Skew:	-1.355	Prob(JB):	0.00
Kurtosis:	11.479	Cond. No.	5.39

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
Sharpe Ratio: 0.09912280990581032



3 QUESTION 4

Value weighted portfolio

4A) The code below displays the average returns (by decile lag is the average return of positions taken) along with the plots of value weighted and equal weighted portfolios of the betting-against-beta strategy.

4B) The mean returns for each decile (as grouped by decile lag since positions are taken based on decile lag) are mostly monotonic except for the 10th decile which decreases a little compared to the 9th decile.

4C) As calculated the mean returns are -.004, volatility of .075, and a sharpe ratio of -.0496. These results are listed below as well.

4D) The plots for the portoflio values of value weighted and equal weighted BAB strategies are plotted below along with the CAPM, FF3, FF5, and FF5 + momentum estimated and implied model returns. The CAPM and FF3 models support a positive alpha as seen in the results below.

4E) To reduce the volatility of this strategy we believe it may be beneficial to choose middle deciles for position-taking rather than end deciles, considering the deciles are split by beta values, the end deciles probably have very high betas in terms of magnitude which also signals higher volatility. Instead, choosing the portfolio with lower beta magnitudes should decrease volatility relative to the market and make the strategy more stable and improve Sharpe ratio.

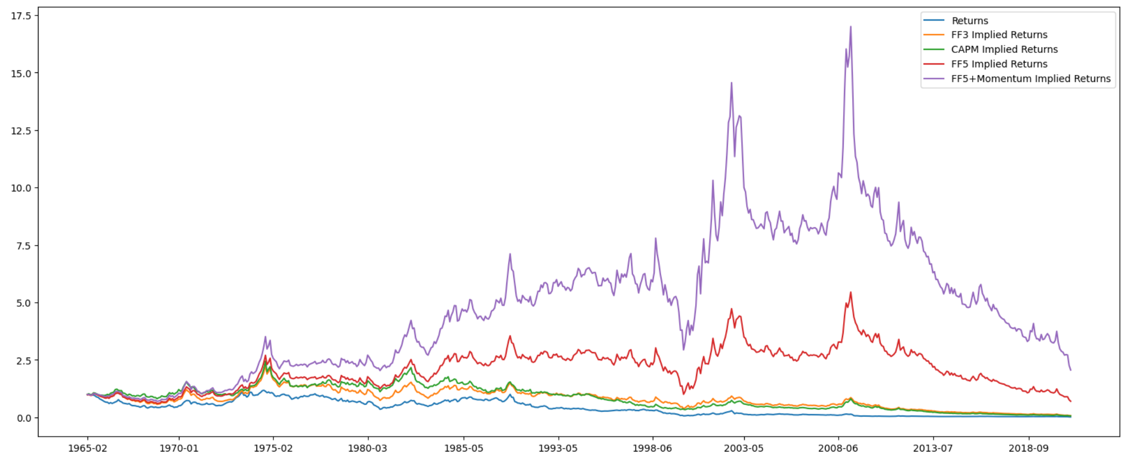
[ ]:
```
data, port_ret, port_val, capm, ff3, ff5, ff5mom = sim_portfolio(ff1926,
    calc_val_returns, calc_rolling_beta, False)
disp_portfolio(data, port_ret, port_val, ff3, capm, ff5, ff5mom)
```

```
BY DECILE LAG:
Decile 1.0 mean returns: 0.010253901674096807
Decile 2.0 mean returns: 0.011652080262312368
Decile 3.0 mean returns: 0.012226792878553312
Decile 4.0 mean returns: 0.012766960332935885
```

```
Decile 5.0 mean returns: 0.01275006180459543
Decile 6.0 mean returns: 0.013371217389299654
Decile 7.0 mean returns: 0.013103725434144703
Decile 8.0 mean returns: 0.013798727145176744
Decile 9.0 mean returns: 0.01380029890004152
Decile 10.0 mean returns: 0.013398765793813074
BY DECILE:
Decile 1.0 mean returns: 0.011674215354769903
Decile 2.0 mean returns: 0.010158279977386655
Decile 3.0 mean returns: 0.010889974206686455
Decile 4.0 mean returns: 0.011009911631782757
Decile 5.0 mean returns: 0.011131835253448692
Decile 6.0 mean returns: 0.011475427513134108
Decile 7.0 mean returns: 0.011872069694315151
Decile 8.0 mean returns: 0.012355564417618975
Decile 9.0 mean returns: 0.013880027747724188
Decile 10.0 mean returns: 0.02274921336071783
Mean returns = -0.004
Portfolio volatility = 0.075971
Strategy Sharpe Ratio = -0.049638
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.504
Model:                            OLS   Adj. R-squared:                  0.503
Method:                 Least Squares   F-statistic:                     644.0
Date:                Sat, 20 Apr 2024   Prob (F-statistic):           1.40e-98
Time:                        01:41:36   Log-Likelihood:                -1969.2
No. Observations:                 636   AIC:                             3942.
Df Residuals:                     634   BIC:                             3951.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.2904      0.214      1.356      0.176      -0.130       0.711
Mkt-RF        -1.2191      0.048    -25.376      0.000      -1.313      -1.125
==============================================================================
Omnibus:                       77.160   Durbin-Watson:                   1.891
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              214.217
Skew:                          -0.605   Prob(JB):                     3.04e-47
Kurtosis:                       5.573   Cond. No.                         4.50
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
```

```
Dep. Variable:                      y   R-squared:                       0.598
Model:                            OLS   Adj. R-squared:                  0.596
Method:                 Least Squares   F-statistic:                     313.7
Date:                Sat, 20 Apr 2024   Prob (F-statistic):          1.08e-124
Time:                        01:41:36   Log-Likelihood:                -1902.1
No. Observations:                 636   AIC:                             3812.
Df Residuals:                     632   BIC:                             3830.
Df Model:                           3
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.2373      0.194      1.221      0.222      -0.144       0.619
Mkt-RF        -1.0187      0.046    -21.983      0.000      -1.110      -0.928
SMB           -0.6284      0.065     -9.656      0.000      -0.756      -0.501
HML            0.5286      0.067      7.870      0.000       0.397       0.660
==============================================================================
Omnibus:                       65.340   Durbin-Watson:                   1.916
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              192.502
Skew:                          -0.489   Prob(JB):                     1.58e-42
Kurtosis:                       5.511   Cond. No.                         4.74
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.644
Model:                            OLS   Adj. R-squared:                  0.641
Method:                 Least Squares   F-statistic:                     228.0
Date:                Sat, 20 Apr 2024   Prob (F-statistic):          1.06e-138
Time:                        01:41:37   Log-Likelihood:                -1863.6
No. Observations:                 636   AIC:                             3739.
Df Residuals:                     630   BIC:                             3766.
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.1374      0.188     -0.730      0.466      -0.507       0.232
Mkt-RF        -0.9020      0.047    -19.214      0.000      -0.994      -0.810
SMB           -0.4492      0.065     -6.937      0.000      -0.576      -0.322
HML            0.2211      0.086      2.572      0.010       0.052       0.390
RMW            0.7637      0.090      8.523      0.000       0.588       0.940
CMA            0.6330      0.133      4.744      0.000       0.371       0.895
==============================================================================
Omnibus:                       81.066   Durbin-Watson:                   1.947
```

```
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              244.354
Skew:                          -0.610   Prob(JB):                     8.69e-54
Kurtosis:                       5.781   Cond. No.                         5.15
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.659
Model:                            OLS   Adj. R-squared:                  0.656
Method:                 Least Squares   F-statistic:                     202.6
Date:                Sat, 20 Apr 2024   Prob (F-statistic):         2.39e-143
Time:                        01:41:37   Log-Likelihood:                -1850.0
No. Observations:                 636   AIC:                             3714.
Df Residuals:                     629   BIC:                             3745.
Df Model:                           6
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.3125      0.187     -1.667      0.096      -0.681       0.056
Mkt-RF        -0.8581      0.047    -18.361      0.000      -0.950      -0.766
SMB           -0.4593      0.063     -7.239      0.000      -0.584      -0.335
HML            0.3376      0.087      3.876      0.000       0.167       0.509
RMW            0.7193      0.088      8.158      0.000       0.546       0.893
CMA            0.5652      0.131      4.304      0.000       0.307       0.823
Mom            0.2283      0.043      5.254      0.000       0.143       0.314
==============================================================================
Omnibus:                       34.565   Durbin-Watson:                   1.947
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               82.980
Skew:                          -0.266   Prob(JB):                     9.57e-19
Kurtosis:                       4.687   Cond. No.                         5.38
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
Sharpe Ratio: -0.049638046618605644
```



Equal Weighted Portfolio

[ ]:
```
data, port_ret, port_val, capm, ff3, ff5, ff5mom = sim_portfolio(ff1926,
    calc_val_returns, calc_rolling_beta, True)
disp_portfolio(data, port_ret, port_val, ff3, capm, ff5, ff5mom)
```

```
BY DECILE LAG:
Decile 1.0 mean returns: 0.010253901674096807
Decile 2.0 mean returns: 0.011652080262312368
Decile 3.0 mean returns: 0.012226792878553312
Decile 4.0 mean returns: 0.012766960332935885
Decile 5.0 mean returns: 0.01275006180459543
Decile 6.0 mean returns: 0.013371217389299654
Decile 7.0 mean returns: 0.013103725434144703
Decile 8.0 mean returns: 0.013798727145176744
Decile 9.0 mean returns: 0.01380029890004152
Decile 10.0 mean returns: 0.013398765793813074
BY DECILE:
Decile 1.0 mean returns: 0.011674215354769903
Decile 2.0 mean returns: 0.010158279977386655
Decile 3.0 mean returns: 0.010889974206686455
Decile 4.0 mean returns: 0.011009911631782757
Decile 5.0 mean returns: 0.011318352534486920
Decile 6.0 mean returns: 0.011475427513134108
Decile 7.0 mean returns: 0.011872069694315151
Decile 8.0 mean returns: 0.012355564417618975
Decile 9.0 mean returns: 0.013880027747724188
Decile 10.0 mean returns: 0.022749213360717830
Mean returns = -0.003
Portfolio volatility = 0.070571
Strategy Sharpe Ratio = -0.038104
                            OLS Regression Results
```

```
==============================================================================
Dep. Variable:                      y   R-squared:                       0.539
Model:                            OLS   Adj. R-squared:                  0.538
Method:                 Least Squares   F-statistic:                     739.8
Date:                Sat, 20 Apr 2024   Prob (F-statistic):          1.49e-108
Time:                        02:02:06   Log-Likelihood:                -1899.3
No. Observations:                 636   AIC:                             3803.
Df Residuals:                     634   BIC:                             3812.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.3721      0.192      1.940      0.053      -0.005       0.749
Mkt-RF        -1.1707      0.043    -27.200      0.000      -1.255      -1.086
==============================================================================
Omnibus:                      331.074   Durbin-Watson:                   1.915
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             5195.923
Skew:                          -1.931   Prob(JB):                         0.00
Kurtosis:                      16.459   Cond. No.                         4.50
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.627
Model:                            OLS   Adj. R-squared:                  0.625
Method:                 Least Squares   F-statistic:                     354.4
Date:                Sat, 20 Apr 2024   Prob (F-statistic):          6.12e-135
Time:                        02:02:06   Log-Likelihood:                -1831.4
No. Observations:                 636   AIC:                             3671.
Df Residuals:                     632   BIC:                             3689.
Df Model:                           3
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.4190      0.174      2.410      0.016       0.078       0.760
Mkt-RF        -0.9973      0.041    -24.050      0.000      -1.079      -0.916
SMB           -0.6889      0.058    -11.830      0.000      -0.803      -0.575
HML            0.2266      0.060      3.770      0.000       0.109       0.345
==============================================================================
Omnibus:                      343.907   Durbin-Watson:                   1.857
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             6205.329
Skew:                          -1.986   Prob(JB):                         0.00
Kurtosis:                      17.778   Cond. No.                         4.74
```

```
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.665
Model:                            OLS   Adj. R-squared:                  0.662
Method:                 Least Squares   F-statistic:                     249.8
Date:                Sat, 20 Apr 2024   Prob (F-statistic):          7.42e-147
Time:                        02:02:06   Log-Likelihood:                -1797.7
No. Observations:                 636   AIC:                             3607.
Df Residuals:                     630   BIC:                             3634.
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.1575      0.170      0.928      0.354      -0.176       0.491
Mkt-RF        -0.9341      0.042    -22.072      0.000      -1.017      -0.851
SMB           -0.5327      0.058     -9.125      0.000      -0.647      -0.418
HML            0.1053      0.078      1.359      0.175      -0.047       0.258
RMW            0.6780      0.081      8.392      0.000       0.519       0.837
CMA            0.2073      0.120      1.723      0.085      -0.029       0.444
==============================================================================
Omnibus:                      351.761   Durbin-Watson:                   1.876
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             5833.606
Skew:                          -2.081   Prob(JB):                         0.00
Kurtosis:                      17.241   Cond. No.                         5.15
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.722
Model:                            OLS   Adj. R-squared:                  0.719
Method:                 Least Squares   F-statistic:                     272.3
Date:                Sat, 20 Apr 2024   Prob (F-statistic):          3.73e-171
Time:                        02:02:06   Log-Likelihood:                -1738.1
No. Observations:                 636   AIC:                             3490.
Df Residuals:                     629   BIC:                             3521.
Df Model:                           6
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
```

const	-0.1607	0.157	-1.022	0.307	-0.469	0.148
Mkt-RF	-0.8544	0.039	-21.795	0.000	-0.931	-0.777
SMB	-0.5511	0.053	-10.355	0.000	-0.656	-0.447
HML	0.3170	0.073	4.339	0.000	0.174	0.461
RMW	0.5974	0.074	8.077	0.000	0.452	0.743
CMA	0.0842	0.110	0.765	0.445	-0.132	0.301
Mom	0.4150	0.036	11.385	0.000	0.343	0.487

Omnibus:	181.740	Durbin-Watson:	1.792
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1254.778
Skew:	-1.083	Prob(JB):	3.38e-273
Kurtosis:	9.531	Cond. No.	5.38

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
Sharpe Ratio: -0.03810392908449324