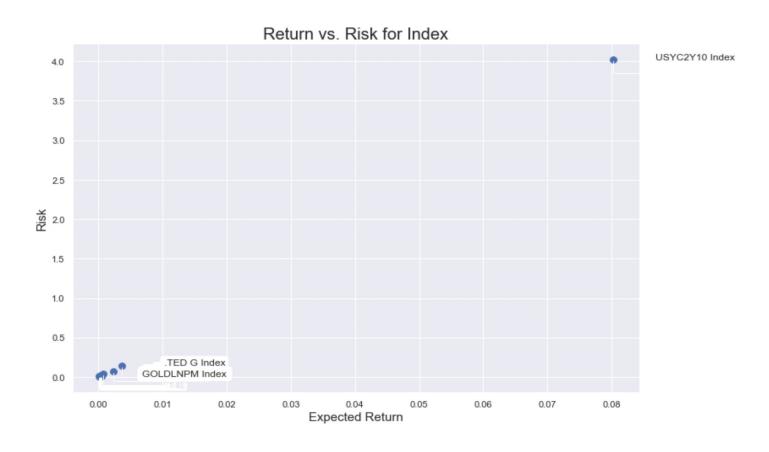
# Portfolio Optimization

## 1. Input Data EDA

## **Return & Risk for Input Data**





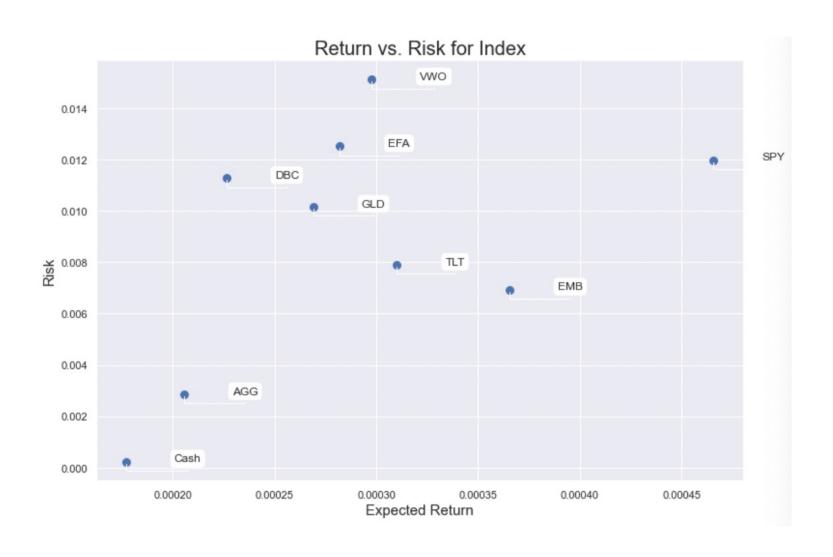
# 1. Input Data EDA

## **Return & Risk for Input Data**



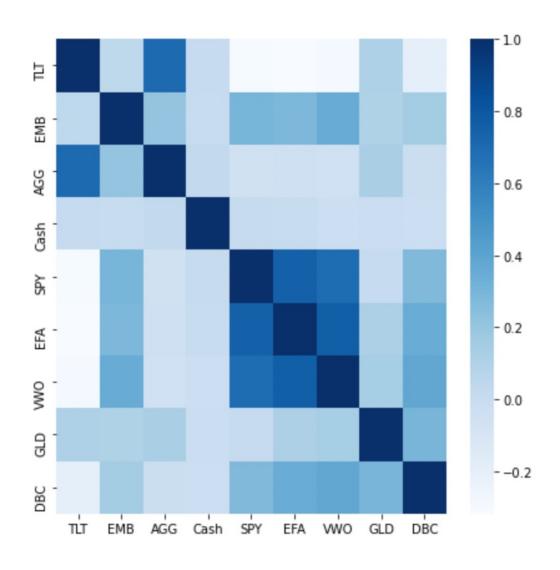
# 2. Target Data EDA

## **Return & Risk for Target Data**



# 2. Target Data EDA

## **Target Data Correlation**



# 2. Target Data EDA

## **Target Data Detail**

	Returns	Risk	Sharpe Ratio	Max Returns	Min Returns	Median Returns	Total Return
TLT	0.000310	0.007899	-1.226716	0.075196	-0.066683	0.000246	0.231300
EMB	0.000365	0.006937	-1.388965	0.100498	-0.101104	0.000088	0.288800
AGG	0.000205	0.002862	-3.422357	0.038688	-0.068395	0.000156	0.104900
Cash	0.000177	0.000237	-41.454003	0.004194	-0.000105	0.000108	0.002429
SPY	0.000466	0.011981	-0.795774	0.145197	-0.109424	0.000485	-0.657000
EFA	0.000282	0.012521	-0.776152	0.158875	-0.123889	0.000000	-1.251600
vwo	0.000298	0.015119	-0.641707	0.202822	-0.153423	0.000672	-1.469200
GLD	0.000269	0.010164	-0.957426	0.112905	-0.087808	0.000000	-0.336900
DBC	0.000226	0.011282	-0.866286	0.068745	-0.077844	0.000036	-0.830600

## 3. The ways of setting weights

### **Maximize Sharpe-Ratio, Optimization (MVO)**

```
Asset labels of Portfolio:
 ['TLT', 'EMB', 'AGG', 'Cash', 'SPY', 'EFA', 'VWO', 'GLD', 'DBC']
Mean Returns:
 [0.031 0.037 0.021 0.018 0.047 0.028 0.03 0.027 0.023]
Variance-Covariance Matrix of Returns:
 \begin{bmatrix} 0.624 & 0.024 & 0.159 & 0. & -0.287 & -0.314 & -0.354 & 0.089 & -0.168 \end{bmatrix}
 \begin{bmatrix} 0.159 & 0.042 & 0.082 & 0. & -0.019 & -0.014 & -0.021 & 0.039 & -0.005 \end{bmatrix}
          0. 0. 0.001 0. 0. -0.001 -0.
 .0
                                                             -0.001
 \begin{bmatrix} -0.287 & 0.25 & -0.019 & 0. & 1.435 & 1.124 & 1.255 & 0.018 & 0.378 \end{bmatrix}
 \begin{bmatrix} -0.314 & 0.245 & -0.014 & 0. & 1.124 & 1.568 & 1.441 & 0.15 \end{bmatrix}
                                                             0.495]
 [-0.354 \quad 0.37 \quad -0.021 \quad -0.001 \quad 1.255 \quad 1.441 \quad 2.286 \quad 0.222 \quad 0.648]
 [-0.168 \quad 0.122 \quad -0.005 \quad -0.001 \quad 0.378 \quad 0.495 \quad 0.648 \quad 0.339 \quad 1.273]]
Risk free rate (daily %): 0.000
Maximal Sharpe Ratio: [[11.713]]
Annualized Risk (%): [[0.378]]
Annualized Expected Portfolio Return(%): [4.455]
Optimal weights (%):
 [[ 0.366]
 [ 0. ]
 [ 0. ]
 [99.49]
 [ 0. ]
 [ 0. ]
 [ 0. ]
 [0.144]
 [ 0. ]]
```

## 3. The ways of setting weights

### **Maximize Sharpe-Ratio, Optimization (MVO)**

```
# weight = Clusetered_Bond -> 6, Clustered_Stock -> 4
# TLT, AGG, GLD, CASH = 0.6
# EMB, SPY, EFA, VWD, DBC = 0.4

weights = np.array([0.15, 0.15, 0.15, 0.15, 0.06, 0.01, 0.14, 0.08, 0.11])
```

```
Daily Portfolio Risk: 0.17 %

Annualized Portfolio Risk: 6.62 %

Daily Portfolio Return: 0.03 %

Annualized Expected Portfolio Return: 6.97 %

PortfolioSharpe Ratio: 1.05 %
```

## 4. Rebalancing & Extracting Weight

print('Optimal Rebalanced Portfolio Weights', OptimalRebalWeights)

# extract the optimal solution (rebalanced weights)

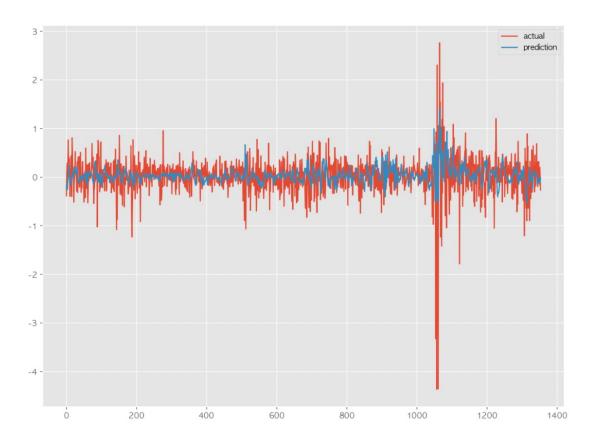
OptimalRebalWeights = HOFIndividualW

### **Rebalancing Portfolio with Transaction**

```
# compute risk, return and Sharpe Ratio of the optimal rebalanced portfolio
DailyRebalancedPortfolioReturn = np.sum(np.multiply(MeanData, OptimalRebalWeights))
# number of trading days = 261
AnnualRebalancedPortfolioReturn = 261 * DailyRebalancedPortfolioReturn*100
print('Rebalanced portfolio annualized return ', AnnualRebalancedPortfolioReturn)
DailyRebalancedPortfolioRisk= np.sqrt(np.matmul( np.matmul(OptimalRebalWeights, CovData), OptimalRebalWeights.T))
AnnualRebalancedPortfolioRisk = np.sqrt(261) * DailyRebalancedPortfolioRisk*100
print('Rebalanced portfolio annualized risk', AnnualRebalancedPortfolioRisk)
SharpeRatio = (AnnualRebalancedPortfolioReturn-RiskFreeRate)/AnnualRebalancedPortfolioRisk
print('Rebalanced portfolio Sharpe Ratio', SharpeRatio)
# compare results with risk, return and Sharpe Ratio of the original portfolio
print('Original portfolio annualized return ', OriginalPortfolioAnnReturn)
print('Original portfolio annualized risk', OriginalPortfolioAnnRisk)
print('Original portfolio Sharpe Ratio', OriginalPortfolioSharpeRatio)
['TLT', 'EMB', 'AGG', 'Cash', 'SPY', 'EFA', 'VWO', 'GLD', 'DBC']
Optimal Rebalanced Portfolio Weights [0.081 0.107 0.205 0.265 0.071 0.035 0.135 0.06 0.042]
Rebalanced portfolio annualized return 87024145.93077376
Rebalanced portfolio annualized risk 92906.87221109867
Rebalanced portfolio Sharpe Ratio 936.6814728521002
Original portfolio annualized return 6.58
Original portfolio annualized risk 5.53
Original portfolio Sharpe Ratio 1.19
```

### **Rebalancing Portfolio with Transaction**

```
for data in train_data.take(1):
    print(f'데이터셋(X) 구성(batch_size, window_size, feature갯수): {data[0].shape}')
    print(f'데이터셋(Y) 구성(batch_size, window_size, feature갯수): {data[1].shape}')
데이터셋(X) 구성(batch_size, window_size, feature갯수): (32, 20, 30)
데이터셋(Y) 구성(batch_size, window_size, feature갯수): (32,)
```



## 6. Without Cash

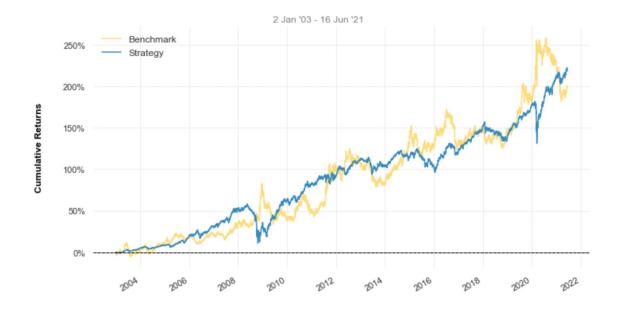
#### **Backtesting**

```
p = Engine(
start_date = '2003-01-01',
portfolio = ['TLT', 'EMB', 'AGG', 'SPY', 'EFA', 'VWO', 'GLD', 'DBC'],
weights = [0.11, 0.145, 0.28, 0.096, 0.047, 0.183, 0.081, 0.057],
benchmark = ['EFA'])
```

#### **Backtest**

Annual return	6.0%
Cumulative return	218.53%
Annual volatility	8.8 %
Winning day ratio	54.8%
Sharpe ratio	0.76
Calmar ratio	0.22
Information ratio	-0.0
Stability	0.95
Max Drawdown	-0.3 %
Sortino ratio	1.08
Skew	-0.13
Kurtosis	19.57
Tail Ratio	0.99
Common sense ratio	1.14
Daily value at risk	-1.0 %
Alpha	0.03
Beta	0.34

#### **Cumulative Returns vs Benchmark**



# 6. Without Cash

Years

## **Feature Correlation**

#### Monthly Returns (%)

- 0%

- -2%

- -5%

- -8%

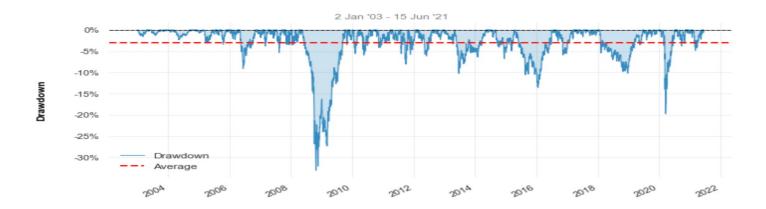
-- -10%

	2003	-0.47	0.12	-0.20	1.38	1.51	0.01	-0.89	0.51	0.84	0.21	0.37	1.31
	2004	0.58	0.81	0.24	-1.82	0.10	0.66	-0.08	0.99	0.45	0.73	0.37	0.80
	2005	-0.07	0.37	-1.83	0.35	1.07	1.55	0.97	1.20	1.66	-1.94	2.45	2.47
	2006	3.21	-0.47	0.29	2.77	-2.71	-0.21	1.52	1.10	0.38	1.88	3.16	0.27
	2007	0.21	0.76	0.79	1.78	0.93	0.36	1.27	0.78	3.99	4.25	-1.04	0.55
	2008	-0.58	1.19	-0.80	2.25	0.41	-2.16	-1.53	-2.01	-5.42	-13.24	2.23	8.60
	2009	-5.60	-3.24	5.31	4.82	6.34	-0.65	4.40	1.22	4.17	-0.27	4.00	-1.00
	2010	-1.76	1.44	2.44	1.43	-2.65	0.96	3.69	0.87	4.19	1.51	-1.61	2.59
,	2011	-1.12	1.46	1.38	3.10	-0.22	-1.08	1.78	0.14	-5.54	5.71	-0.24	-0.73
	2012	4.09	1.78	-0.96	0.44	-3.45	2.42	1.94	1.21	1.77	-0.64	0.86	1.06
	2013	-0.17	-0.70	0.16	1.29	-3.44	-3.68	1.51	-1.14	2.26	2.14	-1.01	-0.28
	2014	-1.07	2.79	0.88	1.05	1.70	1.42	-0.59	2.09	-3.26	1.09	-0.01	-1.49
	2015	2.01	0.63	-0.86	1.71	-1.06	-1.81	-1.36	-2.77	-0.95	2.63	-1.50	-1.54
	2016	-0.62	1.53	4.13	1.53	-0.80	3.80	1.82	-0.00	0.67	-1.42	-3.30	0.51
	2017	2.18	1.70	0.46	1.17	0.92	-0.01	1.91	1.88	-0.38	0.98	0.36	1.71
	2018	1.95	-2.77	0.46	-1.04	0.07	-1.40	1.11	-0.72	-0.19	-3.45	0.90	-0.09
	2019	4.46	0.35	1.94	0.69	-0.91	3.72	-0.14	1.73	-0.29	1.45	0.04	2.38
	2020	0.27	-1.23	-7.16	4.67	2.93	2.73	4.82	0.95	-1.42	-0.95	4.49	2.76
	2021	-0.47	-0.79	-0.67	2.54	1.58	0.11	0.00	0.00	0.00	0.00	0.00	0.00
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

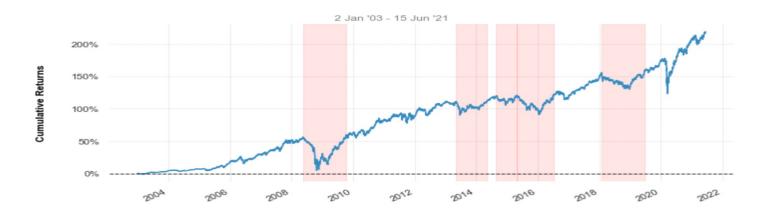
# 6. Without Cash

## **Drawdown Point**

#### **Underwater Plot**



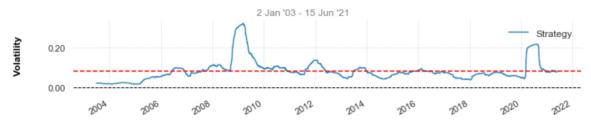
**Top 5 Drawdown Periods** 



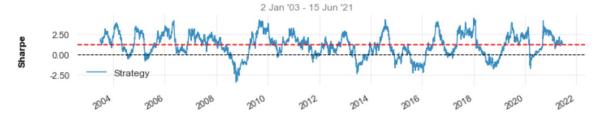
# 6. Regression Analysis

## **Volatility**

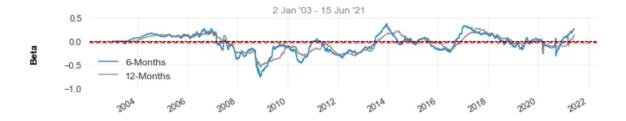
#### Rolling Volatility (6-Months)



#### Rolling Sharpe (6-Months)



Rolling Beta to Benchmark



# THANK YOU