Brief study Dow Jones 3D investing based on SDG Score by Robeco

Robeco SDG link = *https://www.robeco.com/en-int/sustainable-investing/how-do-companies-and-countries-score-on-sustainability*

Data import

```
data = readtable("DowJones.xlsx", VariableNamingRule="preserve");
price = readtable("DowJones.xlsx", Sheet="Price",
VariableNamingRule="preserve");
```

## Are SDG related to the Sector, Market Capitalization and P/E Ratio?

Sector:

```
% Extract relevant columns
sector = data.Sector;
robecoSDG = data.RobecoSDG;

% Convert 'Sector' to a categorical variable
sector = categorical(sector);

% Group the data by sector and calculate mean Robeco SDG score
[mean_scores, sector_names] = grpstats(robecoSDG, sector, {'mean', 'gname'});

% Plot the bar graph
bar(mean_scores)
xticks(1:numel(sector_names))
xticklabels(cellstr(sector_names))
xlabel('Sector')
ylabel('Mean SDG Score')
title('Mean SDG Score per Sector')
```

Mean SDG Score per Sector
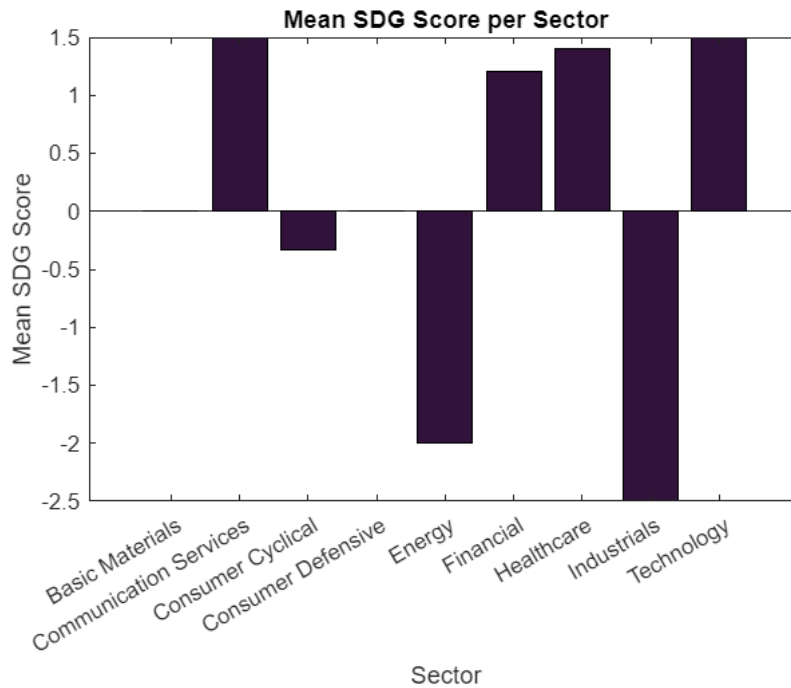
On the overall Market Cap

```
total_mkt_cap = sum(data.MarketCap);
mktCap = data.MarketCap;
groups = findgroups(sector);
% Calculate the overall weighted average
weighted_overall = splitapply(@(mktCap, robecoSDG) sum(mktCap .* robecoSDG) /
total_mkt_cap, mktCap, robecoSDG, groups);

unique_sectors = categories(sector);

% Plot the bar graph
bar(weighted_overall)
xticks(1:numel(unique_sectors))
xticklabels(cellstr(unique_sectors))
xlabel('Sector')
ylabel('Weighted Mean SDG Score')
title('Weighted SDG Score overall')
```
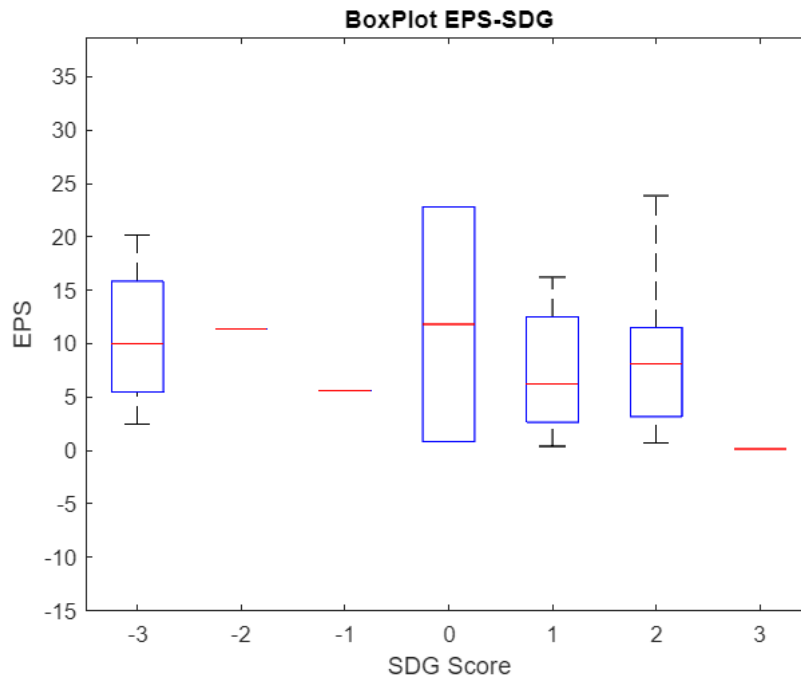
Weighted SDG Score overall
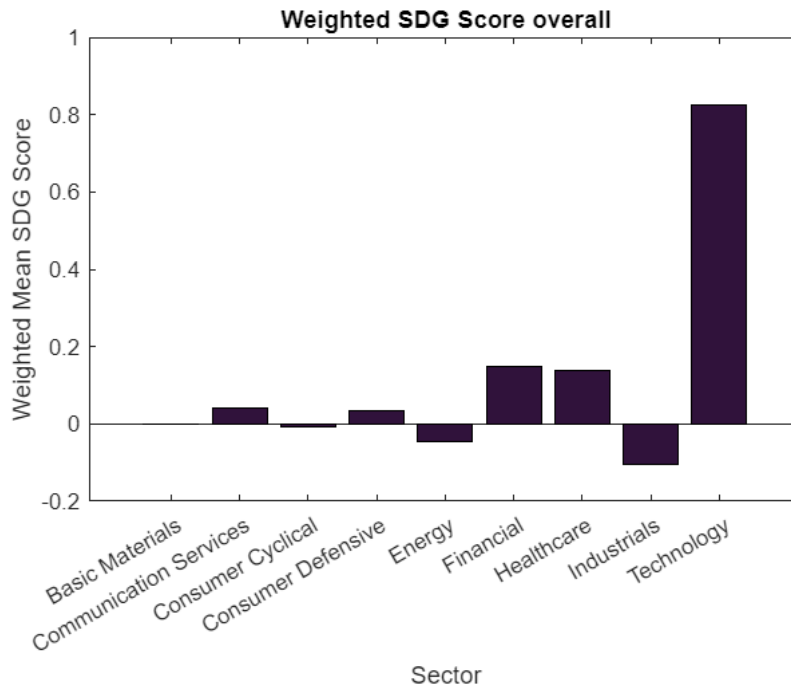
EPS:

```
pe = data.PE;
last_price = price(end,2:end);
eps = table2array(last_price)' ./ pe;

%boxplot
boxplot(eps, robecoSDG)
ylabel('EPS')
xlabel('SDG Score')
title('BoxPlot EPS-SDG')
```
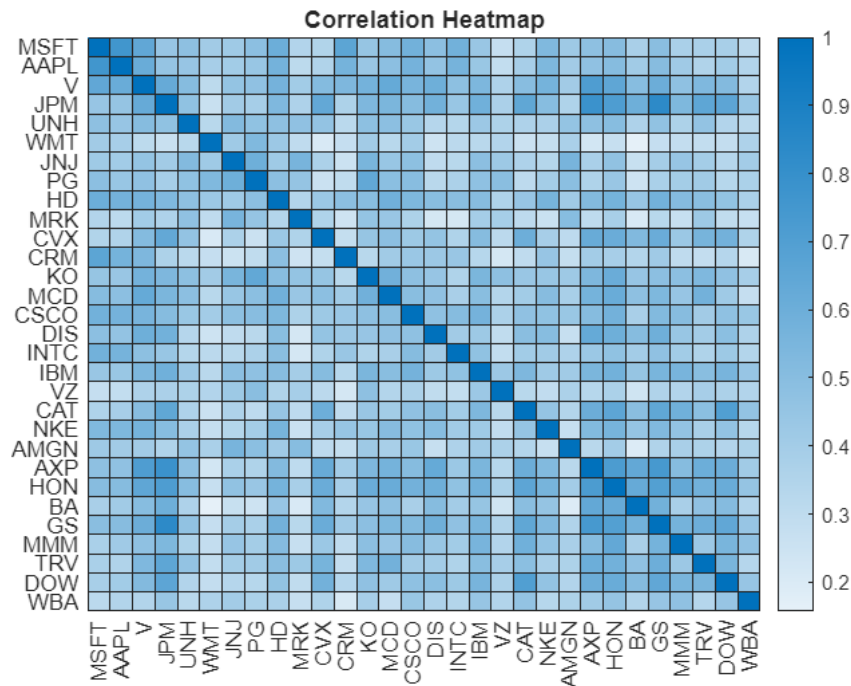
BoxPlot EPS-SDG

Portfolio Optimization

Asset returns, covariance and correlation

```
returns = tick2ret(price(:,2:end));
returns = table2array(returns);
correlation = corrcoef(returns);
asset_covariance = cov(returns);
asset = price(:,2:end).Properties.VariableNames;
%correlation heatmap
heatmap(asset, asset,correlation)
title("Correlation Heatmap")
```

Correlation Heatmap

Mean-Variance-Sustainability optimization

As first, let's see how the sustainability behaves in the classical Mean-Variance approach

$$\min_{w} \quad w^T \Sigma w$$

$$\text{s.t.} \quad w^T \mathbf{1} = 1$$

$$w \geq 0$$

$$w \leq 0.1$$

$$w^T \mu \geq \mathbb{E}$$

First, let's define a linear space of desidered returns

```
mean_returns = mean(returns);
n_ptf = 100;
exp_ret = linspace(min(mean_returns), max(mean_returns), n_ptf);

all_w = zeros(n_ptf, 30);
```

Now let's optimize the problem above

```
for i = 1:n_ptf
    % define Weights variable
    w = optimvar('w', 30, 'LowerBound',0, 'UpperBound',0.1);

    % define objective funtion
```

```matlab
    obj = w' * asset_covariance * w;
    prob = optimproblem('Objective',obj);
    prob.Constraints.sumw = sum(w) == 1;
    prob.Constraints.ret = mean_returns * w >= exp_ret(i);

    sol = solve(prob);
    % store the solution in all_w
    all_w(i,:) = sol.w;
 end
```

Compute portfolio metrics

```matlab
 ptf_ret = (all_w * mean_returns') .* 252;
 ptf_SDG = all_w * robecoSDG;

 ptf_std = zeros(n_ptf, 1);
 for i = 1:n_ptf
     ptf_std(i) = sqrt(all_w(i, :) * asset_covariance * all_w(i, :)') *
sqrt(252);
 end
```
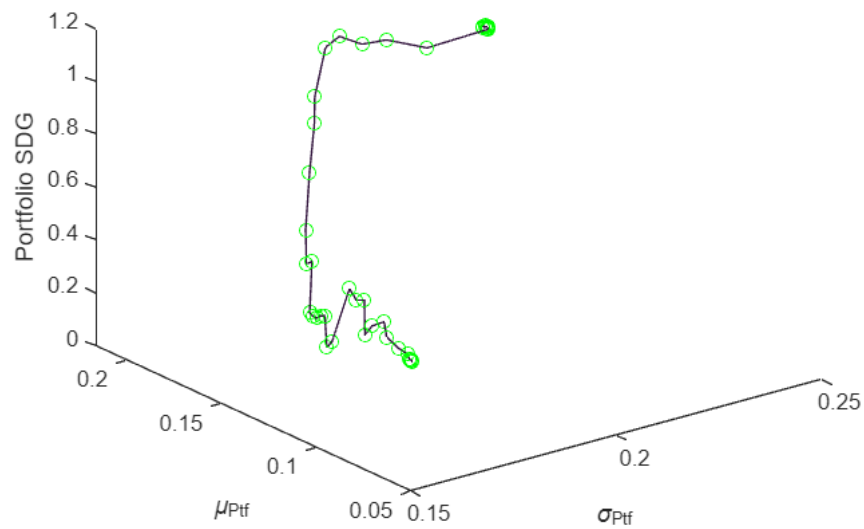
Graph of the combination

```matlab
 plot3(ptf_std, ptf_ret, ptf_SDG)
 xlabel('\sigma_{Ptf}')
 ylabel('\mu_{Ptf}')
 zlabel('Portfolio SDG')
 title('3D SDG Frontier')
 hold on
 scatter3(ptf_std, ptf_ret, ptf_SDG, 'green')
 hold off
```
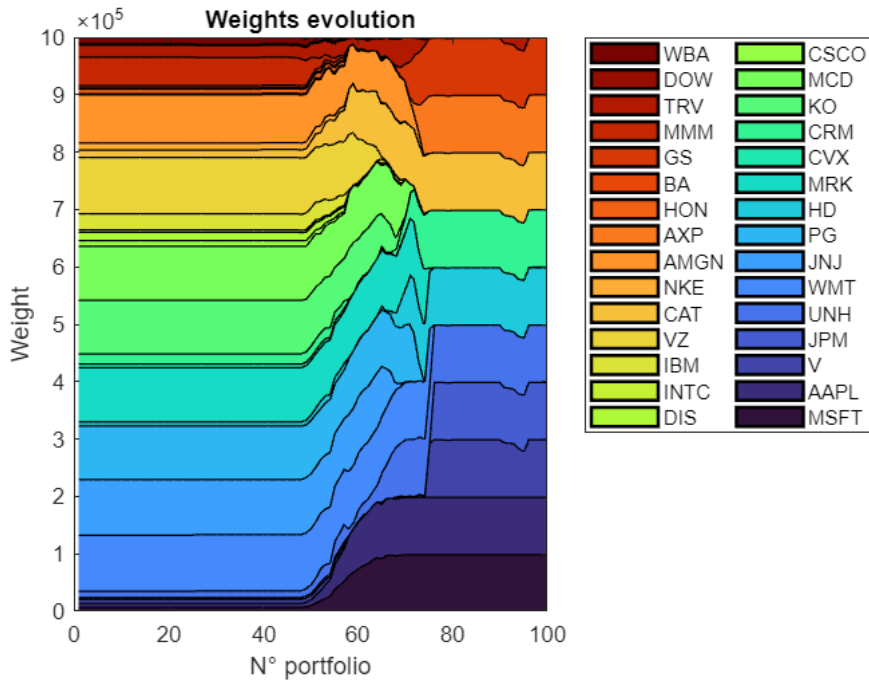
3D SDG Frontier


```
% Create the scatter plot
scatter(ptf_std, ptf_ret, 50, ptf_SDG, 'filled');
xlabel('\sigma_{Ptf}');
ylabel('\mu_{Ptf}');
title('2D with Colorbar');
% Add color bar
colorbar;
ylabel(colorbar, 'Portfolio SDG');
```

2D with Colorbar
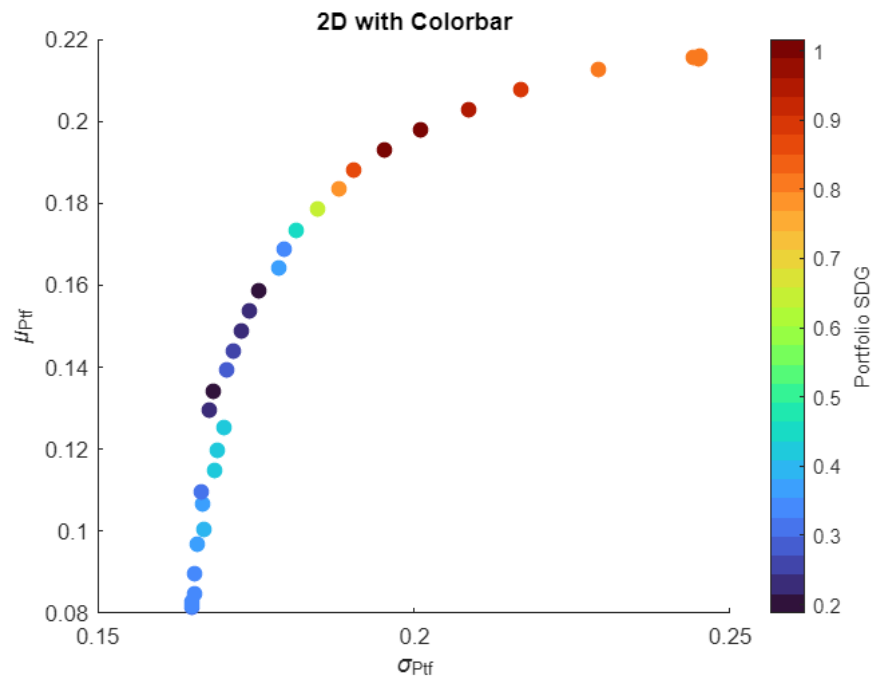
```
area(round(all_w, 3) .* 1000000, 'LineWidth', 1.5)
colororder(colormap(turbo(30)))
legend(asset, 'Location','bestoutside', 'NumColumns',2)
ylim([0,1000000])
ylabel('Weight')
xlabel('N° portfolio')
title('Weights evolution')
grid on;
```

Weights evolution (×10⁵), Weight vs N° portfolio

Legend: WBA, DOW, TRV, MMM, GS, BA, HON, AXP, AMGN, NKE, CAT, VZ, IBM, INTC, DIS, CSCO, MCD, KO, CRM, CVX, MRK, HD, PG, JNJ, WMT, UNH, JPM, V, AAPL, MSFT

Optimization with variance penalty and sustainability premium

Let's introduce a new formulation for the optimization problem, where the objective function tries to maximize the portfolio's returns with a penalty for the variance and sustinability premium

$$\max_{w,\lambda,\gamma} w^T\mu - \lambda(w^T\Sigma w) + \gamma(w^T SDG)$$

$$s.t. \quad w^T 1 = 1$$
$$w \geq 0$$
$$w \leq 0.1$$
$$w^T\mu \geq \mathbb{E}$$
$$\gamma \geq \lambda \qquad \gamma, \lambda \in [0, 1]$$

the last two constraints state that we have a preferencies for sustainability

```
all_w_2 = zeros(n_ptf, 30);
coeff = zeros(n_ptf, 2);
initial_point.w_2 = ones(30,1) / 30;
initial_point.lambda = 0.02;
initial_point.gamma = 0.03;
for i = 1:n_ptf
    w_2 = optimvar('w_2', 30, 'LowerBound',0, 'UpperBound',0.1);
    lambda = optimvar('lambda', 'LowerBound', 0, 'UpperBound', 1, 'Type',
'continuous');
    gamma = optimvar('gamma', 'LowerBound', 0, 'UpperBound', 1, 'Type',
'continuous');
```

```matlab
    obj_2 = - (mean_returns * w_2 - lambda * (w_2' * asset_covariance * w_2) +
gamma * (robecoSDG' * w_2));

    prob_2 = optimproblem('Objective',obj_2);
    prob_2.Constraints.sumw2 = sum(w_2) == 1;
    prob_2.Constraints.ret = mean_returns * w_2 >= exp_ret(i);
    prob_2.Constraints.coef = gamma >= lambda;

    sol_2 = solve(prob_2, initial_point);
    % store the solution in all_w
    all_w_2(i,:) = sol_2.w_2;
    coeff(i,1) = sol_2.lambda;
    coeff(i,2) = sol_2.gamma;
  end
```

Compute new portfolio metrics

```matlab
 ptf_ret_2 = (all_w_2 * mean_returns') .* 252;
 ptf_SDG_2 = all_w_2 * robecoSDG;

 ptf_std_2 = zeros(n_ptf, 1);
 for i = 1:n_ptf
     ptf_std_2(i) = sqrt(all_w_2(i, :) * asset_covariance * all_w_2(i, :)') *
sqrt(252);
 end
```
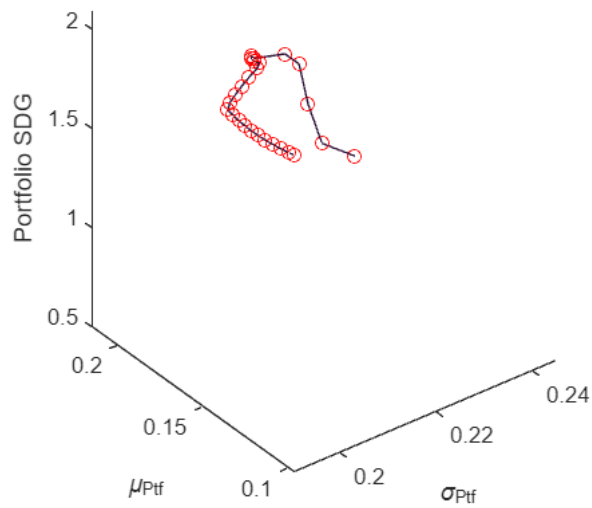
Graph of the combination

```matlab
 plot3(ptf_std_2, ptf_ret_2, ptf_SDG_2)
 xlabel('\sigma_{Ptf}')
 ylabel('\mu_{Ptf}')
 zlabel('Portfolio SDG')
 title('3D SDG Frontier')
 hold on
 scatter3(ptf_std_2, ptf_ret_2, ptf_SDG_2, 'r')
 hold off
```
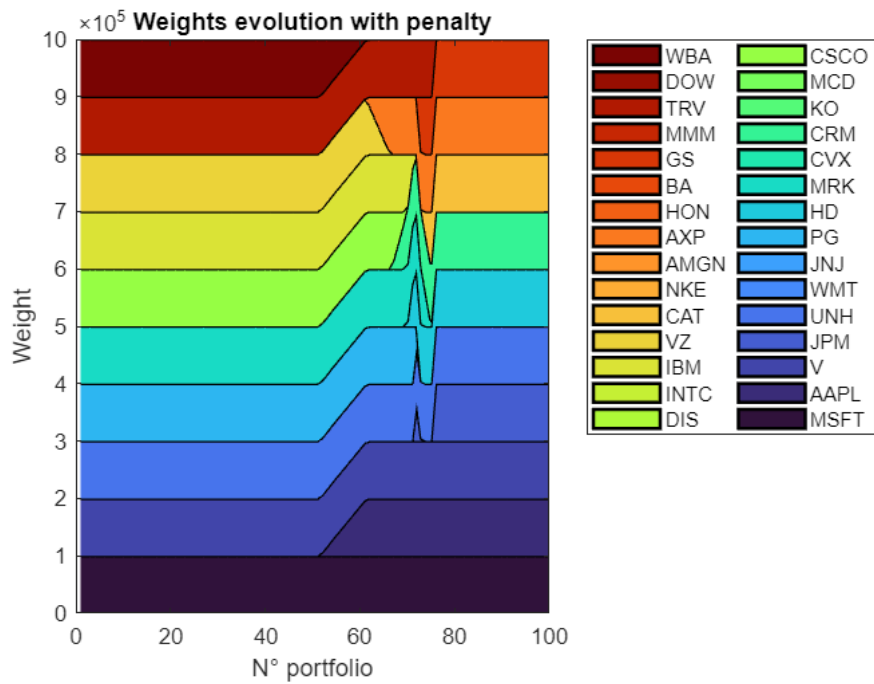
3D SDG Frontier


```matlab
% Create the scatter plot
scatter(ptf_std_2, ptf_ret_2, 50, ptf_SDG_2, 'filled');
xlabel('\sigma_{Ptf}');
ylabel('\mu_{Ptf}');
title('2D with Colorbar');
% Add color bar
colorbar;
ylabel(colorbar, 'Portfolio SDG');
```

2D with Colorbar
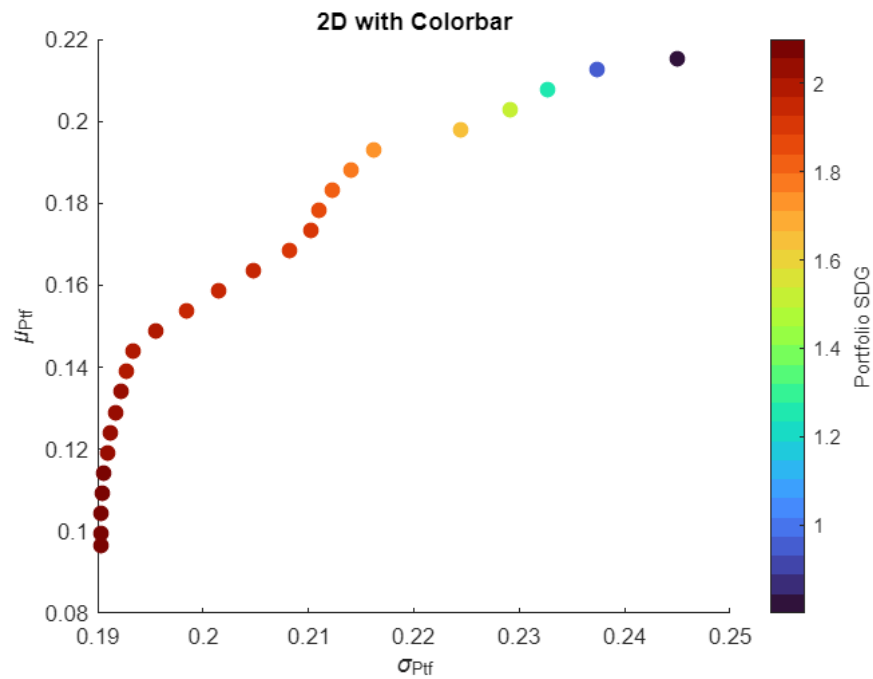

```
area(round(all_w_2, 3) .* 1000000, 'LineWidth', 1.5)
colororder(colormap(turbo(30)))
legend(asset, 'Location','bestoutside', 'NumColumns',2)
ylim([0,1000000])
ylabel('Weight')
xlabel('N° portfolio')
title('Weights evolution with penalty')
grid on;
```

Weights evolution with penalty

Legend:
WBA, DOW, TRV, MMM, GS, BA, HON, AXP, AMGN, NKE, CAT, VZ, IBM, INTC, DIS, CSCO, MCD, KO, CRM, CVX, MRK, HD, PG, JNJ, WMT, UNH, JPM, V, AAPL, MSFT

X-axis: N° portfolio
Y-axis: Weight

```matlab
%scatter plot of gamma and lambda
scatter3(coeff(:,1), linspace(1, n_ptf,n_ptf), coeff(:,2))
title('\lambda and \gamma coefficients')
xlabel('\lambda')
ylabel('N° Portfolio')
zlabel('\gamma')
```

λ and γ coefficients