Artificial Intelligence (AI) for Investments

Week 9

Artificial Intelligence (AI) for Investments

Introduction

- Risk measures with Mean-Variance framework: Variance, Conditional Value-at-Risk (CVaR), and VaR
- Data Preparation: Data visualization and return Computation
- Working with portfolios: Initiating a portfolio Object, formulating portfolio constraints, creating portfolios with different risk/return objectives
- Interactive visualization of efficient frontier
- Initiating short portfolio objects and working with Mean-CVaR framework

Mean-Variance Framework Recap

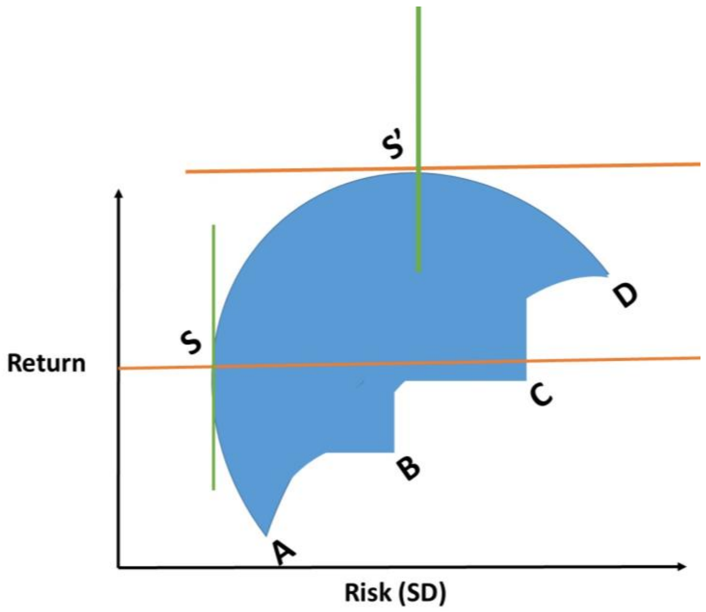
Mean-Variance Framework Recap

As we keep on forming these combinations infinitely, we will get the following convex egg-cut shape:

- Each point represents the combination of risk and returns that are available to investors in the form of investment into portfolios

- We want to move up (increase returns) and move to the left (reduce risk)

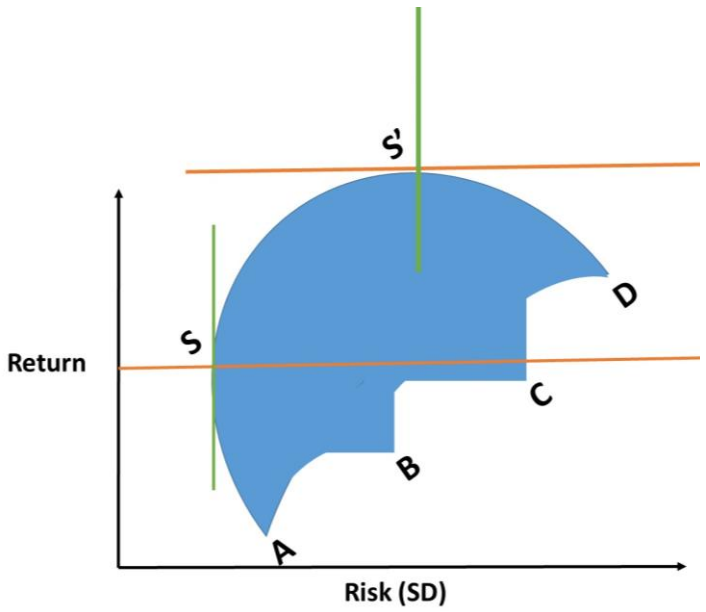
- This region would be called the efficient frontier



Mean-Variance Framework Recap

All the points on this region offer the highest return for the given level of risk (or the lowest risk for a given level of returns)

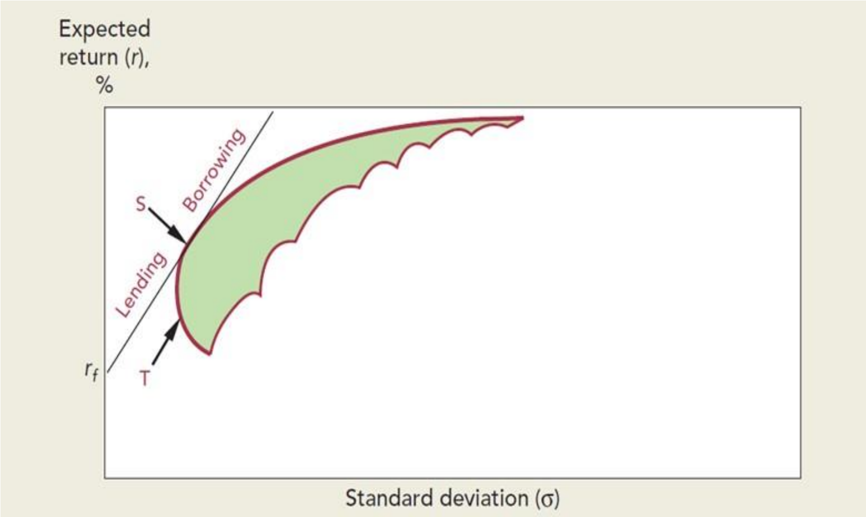
- Also, each investor depending on his risk preference may choose a specific risk level
- Two points S and S’ are particularly important
- All the points between SS’ presents the unique and best combinations of risk and return on the feasible region



Mean-Variance Framework Recap

What if a risk-free lending borrowing rate is available to the investors?

- A new set of efficient portfolios emerge in lending and borrowing segments
- Only two portfolios are required to be identified now



Brealey, Myers, and Allen, *Principles of Corporate Finance*, 10th, 11th, or 12th edition. Chapter 8

Summary

Mean-variance employs variance (or standard deviation) as a risk measure

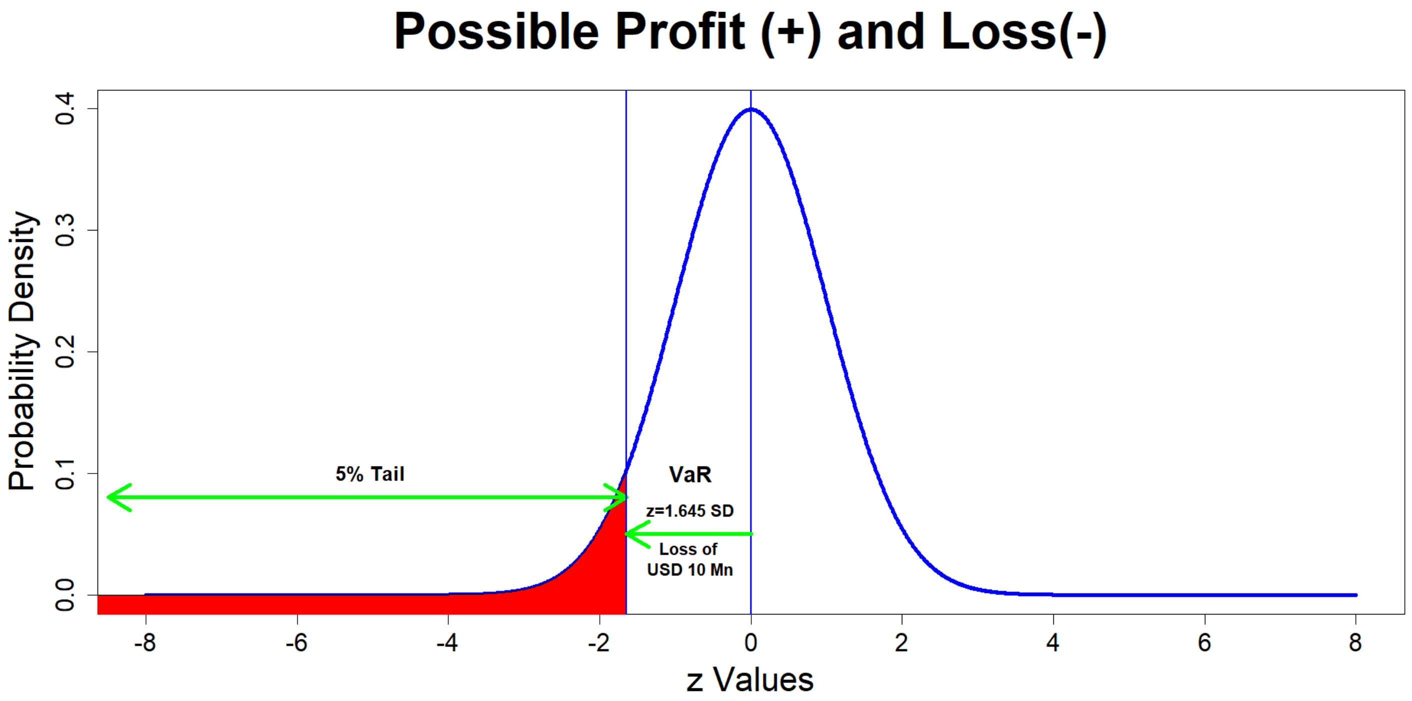
- There are two more important risk measures that we will implement
- Value at risk (VaR)
- Conditional VaR or expected shortfall (ES) measure

Value-at-Risk (VaR) Models

Value-at-Risk (VaR) Models

- If you are asked on any given day, what is the probability that you can lose more than USD 10 Mn. Then, you may reply saying that there is a 5% probability that on any given day, your loss can be more than 10 Mn or X% negative return, i.e., losses)

- Or you may say that 5% daily VaR is USD 10 Mn (or X% negative return, i.e., losses)

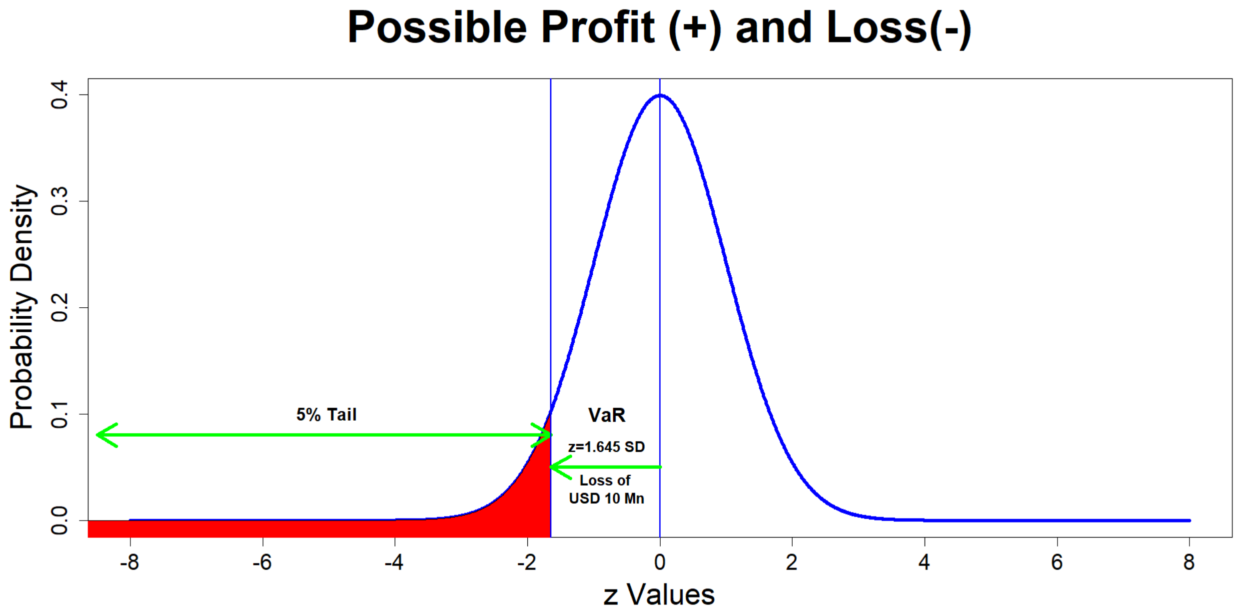


Value-at-Risk (VaR) Models

$$\mathbf{VaR}_{\alpha}(X) = \min\{z|F_x(z) > \alpha\} \text{ for } \alpha \in [0, 1]$$

- Here, three important inputs are (a) time period (e.g., daily, weekly), (b) level of confidence (95% or 99%), and (c) estimate of loss (in absolute amount or in % return terms)

- To estimate this probability, you can (1) assume that returns follow a distribution (standard normal distribution), or (2) use empirical data



Summary

- This measure is widely employed by banks for their portfolio performance and financial markets for margin requirements.
- But what about those instances of losses that exceed this threshold of VaR?

Conditional VaR (CVaR) or Expected Shortfall (ES)

Conditional VaR

- The VaR method covers all the possibilities within a certain confidence interval. However, the position is exposed to those losses that are beyond the confidence interval.
- To cover this exposure/risk, a more advanced version of risk measure, that is, CVaR, is proposed.
- The measure computes expected losses given that (conditional upon) the confidence level is breached. That is, what were to happen if the scenarios beyond that 99% (or 95%) were to occur?

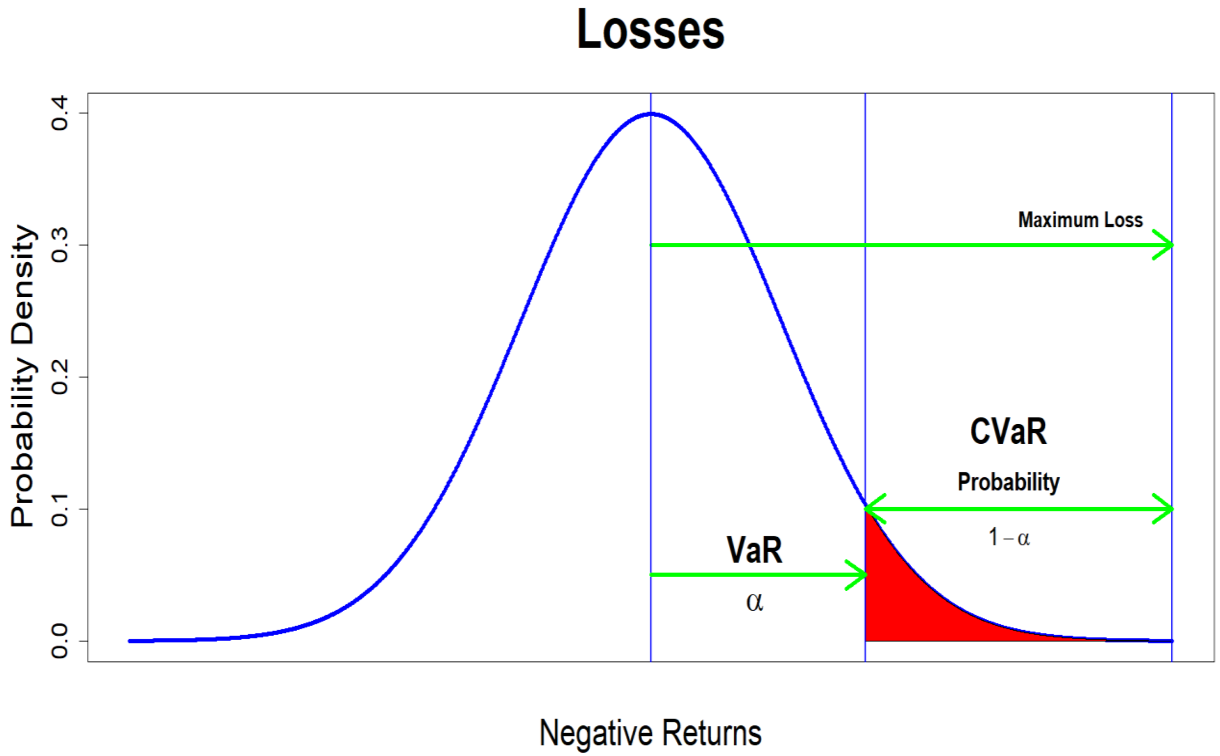
Conditional VaR

- In that extreme event case, what is the expected value of a loss?

- Objective here is to compute the expected (mean or average) losses for that extreme 1% (or 5%) scenario.

$$\mathrm{CVaR}_\alpha = E[X|X > \mathrm{VaR}_\alpha(X)]$$

$$\mathrm{CVaR}_\alpha(X) = \int_{1-\alpha}^{1} X * dF^\alpha(X)$$



Summary

- CVaR method accounts for the extreme scenarios not captured by VaR.
- For continuous distribution, an area under the tail (loss segment) obtained through integration is an accurate measure.
- For discrete observations, probability-weighted expectations are employed to compute CVaR.

Data Download

Data Download

- We will download data from Yahoo Finance that is a very interesting and useful publically available data source
- We will download daily adjusted price for seven securities namely, Nifty50 (India), S&P500 (USA), DAX (Germany), CAC (France), FTSE100 (UK), Euro-Stoxx (Europe), Russell-2000 (U.S.A.)

Summary

- First, we loaded the relevant packages
- Then we downloaded the data for one security Amazon (AMZN) for demonstration purposes
- Then we downloaded the data for seven securities using their ticker symbols on Yahoo Finance: S&P500 (USA), DAX (Germany), CAC (France), FTSE100 (UK), Euro-Stoxx (Europe), Russell-2000 (U.S.A.)
- We merged the downloaded data and then selected adjusted prices for these securities

Return Computation

Return Computation

- In this video, we will organize the data, name it it appropriately and compute the returns

Summary

- First, we have appropriate names to the return variables
- Then we computed the returns for the adjusted prices for our sample securities
- Then we removed incomplete (NA) observations
- Lastly, we converted our return object to timeseries object for further processing
- In the next video, we will start with visualization of the returns data

Data Visualization: Part 1

Data Visualization

- In this video, we will perform basic visualization of returns and understand properties of the data
- We will plot price and return series

Summary

- In video, we plotted price and return data
- Then we further examined the properties of the data through summary measure
- Returns appear to be negatively skewed, even more so during the Covid period
- In the next video, we will examine the density distribution of returns

Data Visualization: Part 2

Data Visualization

- In this video, we plotted the density distribution of all the seven securities in our sample set
- We find that the distribution appears very similar to normal distribution

Summary

- In video, we plotted price and return data
- Then we further examined the properties of the data through summary measure
- Returns appear to be negatively skewed, even more so during the Covid period
- In the next video, we will examine the density distribution of returns

Initiate with the portfolio object

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

Portfolio Object

- In this video, we will initiate and interpret a simple portfolio object

Summary

- In this video, we initiated a simple portfolio object
- We discussed components of this portfolio object, including model list comprising the type of portfolio, risk measure employed to optimize the portfolio, and the name of the estimator
- We also examined the portfolio list, comprising portfolio weights, target returns, target risk, risk-free rate and frontier points
- Lastly, we also noted the optim list which included the name of solver to be employed

Portfolio Constraints

Portfolio Constraints

- In this video, we will discuss how to set the portfolio constraints

Summary

- In this video, we discussed various constraints that are employed in portfolio optimization
- These constraints included long/short position constraints, box and group constraints, risk-budget constraints
- Finally, we combined all these constraints to create a complex constraint object with all the three box, group, and risk-budget constraints combined

Equal Weighted (EW) Feasible Portfolio

EW Feasible Portfolio

- In this video, we will compute an equal weighted feasible portfolio
- We will also visualize various aspects of this portfolio

Summary

- In this video, we created a feasible portfolio with equal weights assigned to all the seven securities
- Then we visualized these portfolios in terms of weights, weighted returns, and risk contributions through pie charts

Minimum Variance Portfolio

Minimum Variance Portfolio

- In this video, we will compute minimum variance portfolio
- For a portfolio with given expected returns, one can find a portfolio with minimum risk, such portfolio is also called efficient portfolio
- We will try to find such efficient portfolio with a target return that is same as the mean return of our sample set
- We will also visualize various aspects of this portfolio

Summary

- In this video, we created a efficient portfolio with target return same as the mean return with long only constraints
- Subsequently, we visualized this portfolio with the following aspects: weights, weighted returns, and risk-budget
- We found that only three (out of seven) securities are considered to arrive at this portfolio

Global Minimum Variance (GMV) Portfolio

GMV Portfolio

- On the feasible region, one portfolio can be identified that has the minimum risk across all the risk-return combinations
- This portfolio is referred to as Global Minimum Variance (GMV) Portfolio
- In this video, we will identify and visualize this GMV portfolio

Summary

- In this video, we identified the GMV portfolio with long only constraints
- The portfolio comprised three (out of seven) securities, i.e., Nifty, SnP, and FTSE
- We examined the weight, weighted returns, and risk-budgets in the form of pie-charts
- In this portfolio the risk contribution of Nifty, SnP, and FTSE are ~ 40%, 32%, and 27%

Tangency Portfolio

Tangency Portfolio

- In the presence of risk-free lending and borrowing one portfolio is the best among all
- This portfolio is identified through a tangent line from risk-free rate to the efficient frontier
- In this video, we will identify and visualize this tangency portfolio for our sample securities with long only constraints
- This portfolio is the best most efficient portfolio as it offers the highest Sharpe ratio

Summary

- In this video, we identified the tangency portfolio for our sample securities with long only constraints
- We visualized various important aspects of this portfolio, including weights, weighted returns and risk-budgets
- The tangency portfolio composition suggests that only two securities (out of seven), namely Nifty and SnP were identified to construct this tangency portfolio with 35% and 65% weights respectively
- The contribution to risk from these securities, Nifty and SnP, amounted to ~ 28% and 72% respectively

Mean-Variance (MV) Frontier

MV Frontier

- In this video, we will construct and visualize mean-variance frontier portfolios

Summary

- In this video, we plotted the MV frontier in an interactive manner
- First, we plotted the efficient frontier
- Next, we added the tangency portfolio and risk-return points for individual assets and equal weight feasible portfolio
- We also added the possible two asset combinations of the securities
- Finally we added the simulated MonteCarlo simulated portfolios and complete our feasible region

Customized MV Frontier Plot

Customized MV Frontier Plot

- In the previous video we constructed our long MV frontier plot in an interactive manner
- In this video, we will construct our long MV frontier plot in a more customized manner

Summary

- In this video, plotted our long MV frontier in a more customized manner
- We first drew the frontier plot, then we added a customized tangency point
- Next, we added the individual assets and equal weight portfolio in a more customized manner
- Similarly, we also added two asset lines and simulated MonteCarlo portfolios and constructed our feasible region in a more customized manner

Efficient Frontier Visualization

Efficient Frontier Visualization

- In this video, we will examine and visualize our efficient frontier plot
- More specifically, we examine the efficient frontier points for their weights, weighted returns, and risk-budget contribution through bar charts

Summary

- In this video, we plotted and summarized the efficient frontier points
- We visualized and summarized the weights, weighted returns, and risk-budget compositions of 25 efficient frontier points
- We noted that these frontier points mostly comprised DAX, Nifty50, S&P500, and Russell-2000 securities out of all the seven securities

Short-Portfolio Object

Short-Portfolio Object

- In this video, we will initiate and visualize a short-portfolio object
- We constructed the efficient frontier with this short-portfolio object
- Subsequently, we also visualized the weights, weighted returns, and risk-budget composition of efficient frontier points for this short-portfolio object

Summary

- In this video, we plotted and summarized a short-portfolio object (portfolio that allows negative weights, i.e., short positions)
- First, we plotted the efficient frontier points for this short-portfolio object
- We added a tangency line to this efficient frontier, and then we added individual asset points to this plot
- Lastly, we visualized their weights, weighted returns, and risk-budget composition for this short-portfolio object

Box Portfolio Constraints

Box Portfolio Constraints

- In the next four videos, we will initiate portfolio objects with box, group, and risk-budget constraints, and finally combine them in a complex constrained portfolio object
- In this first video, we will initiate a Box Constrained Portfolio Object

Summary

- In this video, we initiated a box constrained portfolio object
- First, we plotted the efficient frontier for this box constrained portfolio object
- In the presence of additional constraints, some of the initial feasible portfolios may be excluded
- Then we examined various properties of these frontier points including weights, weighted returns, and risk-budget compositions

Group Constrained Portfolio

Group Constrained Portfolio

- In this video, we will initiate a Group Constrained Portfolio Object
- We will visualize various properties of the efficient frontier points associated with this group constrained object

Summary

- In this video, we initiated a group constrained portfolio object
- First, we plotted the efficient frontier for this group constrained portfolio object
- In the presence of additional constraints, some of the initial feasible portfolios may be excluded
- Then we examined various properties of these frontier points including weights, weighted returns, and risk-budget compositions

Risk-Budget Constrained Portfolio

Risk-Budget Constrained Portfolio

- In this video, we will initiate a Risk-Budget Constrained Portfolio Object
- We will visualize various properties of the efficient frontier points associated with this risk-budget constrained object

Summary

- In this video, we initiated a risk-budget constrained portfolio object
- First, we plotted the efficient frontier for this risk-budget constrained portfolio object
- In the presence of additional constraints, some of the initial feasible portfolios may be excluded
- Then we examined various properties of these frontier points including weights, weighted returns, and risk-budget compositions

Complex Constrained Portfolio

Complex Constrained Portfolio

- In this video, we will initiate a Complex Constrained Portfolio Object
- This object is a combination of all the three portfolio constraints discussed in the previous videos, including box, group, and risk-budget constraints
- We will visualize various properties of the efficient frontier points associated with this complex constrained object

Summary

- In this video, we initiated a complex constrained portfolio object that comprised three types of constraints, including box, group, and risk-budget
- First, we plotted the efficient frontier for this complex constrained portfolio object
- In the presence of additional constraints, many of the initial feasible portfolios may be excluded
- Then we examined various properties of these frontier points including weights, weighted returns, and risk-budget compositions

Conditional VaR (CVaR) Portfolio

CVaR Portfolio

- Till now we have considered the variance risk measure (total risk of the portfolio) to construct the mean-variance framework
- In this video, we will initiate a CVaR Portfolio Object that will employ CVaR as a risk measure to construct the Mean-CVaR framework and the corresponding efficient portfolios

Summary

- In this video, we initiated a CVaR risk based portfolio object
- We noted that solver employed in the optimization function needs to be suitably modified to accommodate this change in portfolio properties
- We noted that other functionalities to construct feasible portfolios, efficient frontier interactive plotting, construction of tangency point, equal weighted portfolio, minimum variance portfolios, etc. remain the same, and not constructed in the interest of brevity

Summary and Concluding Remarks

Summary and Concluding Remarks

- Mean-Variance framework relies on portfolio variance (or standard deviation) as a measure of risk
- More recently tail risk measures such as CVaR have been employed to examine the extreme risk scenarios
- We augment our Mean-Variance framework with CVaR measure to construct and visualize Mean-CVaR portfolios
- We start the discussion with introducing these risk measures

Summary and Concluding Remarks

- Next, we implement the portfolio concepts using R programming
- We start by downloading the data from Yahoo Finance; subsequently we compute the returns and visualize the data
- We initiate our portfolio object with simple long only constraints
- Then we construct and visualize portfolios with specific risk-return objectives; these include equal weighted feasible portfolio, minimum risk portfolio, global minimum variance portfolio, tangency portfolio
- Then we plot efficient frontier in an interactive customized manner

Summary and Concluding Remarks

- We also initiate a short portfolio object with box, group, and risk-budget constraints and visualize various attributes of this portfolio, including weights, weighted returns, and risk-budget composition
- We also combine these constraints and create a complex constrained portfolio object
- We comprehensively examine this portfolio object with complex contraints
- Lastly, we also learn how to initiate a portfolio in Mean-CVaR framework

Thanks!