

Markowitz Portfolio Optimization

Group 25

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Introduction

Markowitz portfolio theory, pioneered by Harry Markowitz is used to construct diversified investment portfolios.

Given certain assets, their risks and returns, we essentially find out the proportions in which investment should be made into these assets i.e. finding out weights corresponding to each asset. This is what makes up the portfolio.

Limitations of Markowitz Portfolio Theory

- **Efficient Market Hypothesis (EMH) Assumption:** Markowitz assumes that markets are efficient, meaning all available information is already reflected in asset prices. However, real-world markets may not always be perfectly efficient due to factors like behavioral biases or information asymmetry.
- **Estimation Error:** The inputs to Markowitz's model, such as expected returns, variances, and covariances of assets, are based on historical data and estimates. These inputs are subject to estimation error, which can affect the accuracy of portfolio optimization.
- **Assumption of Normal Distribution:** Markowitz assumes that asset returns are normally distributed, which may not hold true in reality, especially during periods of market turmoil when asset returns can exhibit fat tails or skewness.

Real word applications of Markowitz Portfolio Theory

- **Asset Allocation:** Investment managers use Markowitz's mean-variance optimization to determine the optimal allocation of assets in a portfolio to achieve a desired level of return while minimizing risk.
- **Factor Investing:** Investors use Markowitz's model to construct factor-based portfolios that target specific risk factors such as value, size, momentum, or quality, aiming to achieve enhanced returns or reduced risk exposure.
- **Portfolio Risk Management:** Institutional investors and asset managers use Markowitz portfolio theory to monitor and manage portfolio risk by assessing the impact of changes in asset allocations on overall portfolio risk and return.

Assets

We need to choose any 10 risky assets that'll be used to build our portfolio. Markowitz optimization relies on several assumptions that may not hold true in the real world. Certain factors must be considered while choosing an asset.

- **Diversification:**
 - Choose assets from different industries and sectors. Reduces risk by reducing dependence on a single sector's performance
- **Correlation:**
 - Choose assets that have low or negative correlation with each other i.e. given asset prices move independently and do not affect each other.
 - Correlations between assets remains constant over time.
- Returns are normally distributed and that investors are solely focused on maximizing returns while minimizing risk.

Assets Description

- **Apple (AAPL):** Leading technology company known for consumer electronics and digital services.
- **Pfizer (PFE):** Global pharmaceutical company specializing in medicines and vaccines.
- **Procter & Gamble (PG):** Multinational consumer goods corporation producing household and personal care products.
- **JPMorgan Chase (JPM):** Global financial services firm offering banking and investment services.
- **Exxon Mobil (XOM):** One of the world's largest oil and gas companies.
- **Amazon (AMZN):** Multinational e-commerce company offering retail and digital services.
- **AT&T (T):** Multinational telecommunications conglomerate.
- **Disney (DIS):** Entertainment and media conglomerate known for film studios and theme parks.
- **Tesla (TSLA):** Leading electric vehicle and clean energy company.
- **Boeing (BA):** Multinational aerospace company specializing in commercial jetliners and defense systems.

Why were these assets chosen?

- **Diversification:**
 - Stocks from various sectors such as technology, healthcare, consumer goods, financial services, energy, retail, telecommunications, entertainment, automotive, and aerospace/defense.
- **Low market correlation**
- **Stability and Growth Potential:**
 - Stocks represent established companies with stable revenue streams.
 - Have a history of generating consistent returns over the long term, which can contribute to the stability and performance of the portfolio.
- **Low Risk:**
 - Stocks from sectors like healthcare, consumer goods, and telecommunications tend to exhibit defensive characteristics, i.e. are less sensitive to economic downturns.

Log Returns

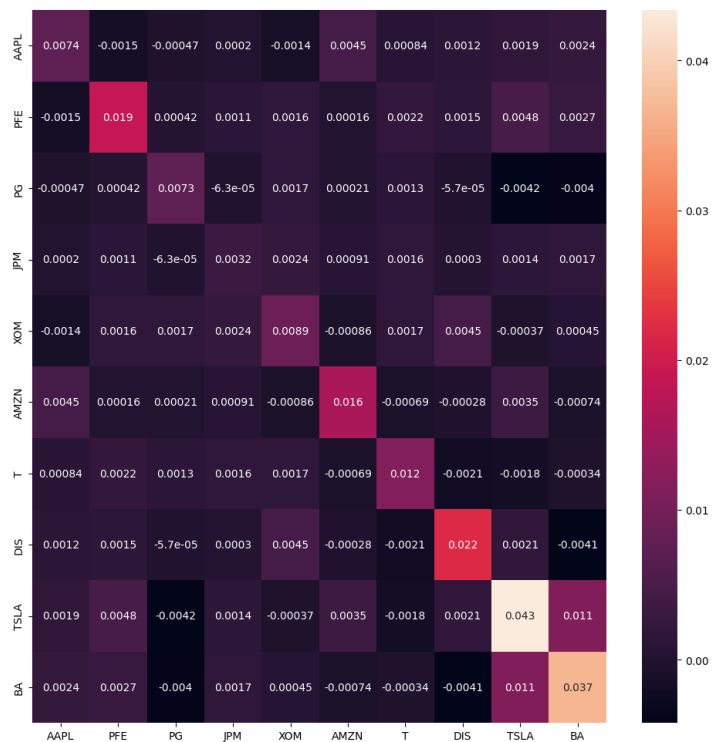
$\log(r_t) = \log(p_t/p_{t-1})$ where p_t is the price of asset at time t and p_{t-1} is the price of the asset at time $t - 1$.

Log returns are used because they are:

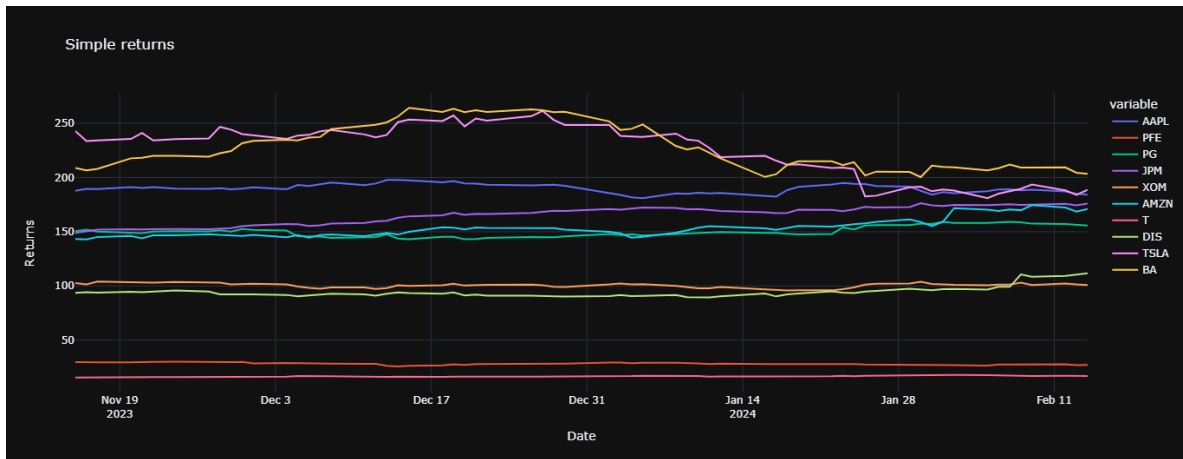
- Helpful in analyzing long-term investment performance.
- Provide accuracy in compounding effects over time.
- Additive and normally distributed.

Risks and returns

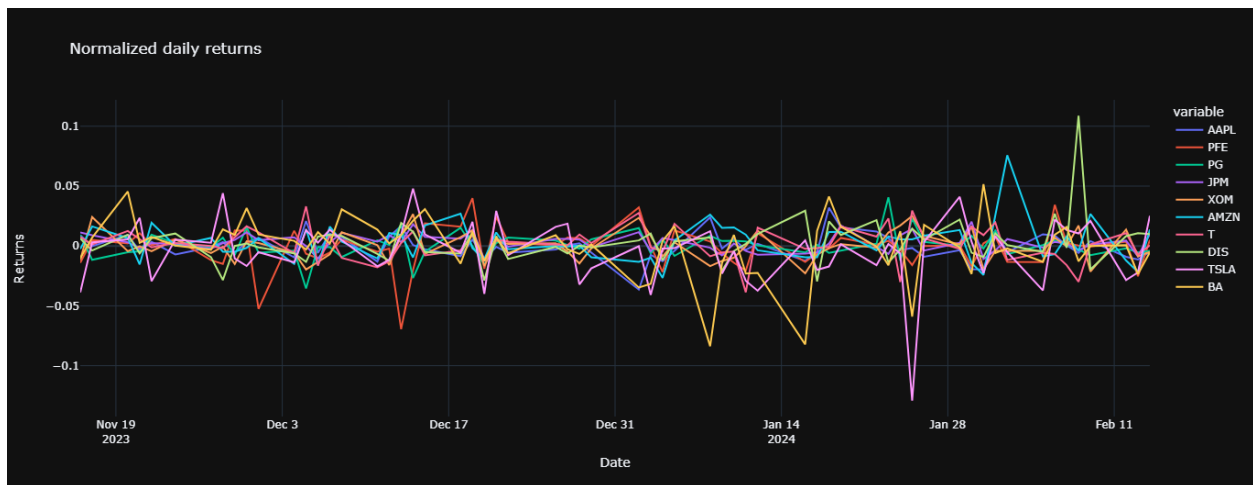
Correlation Matrix



Simple Returns

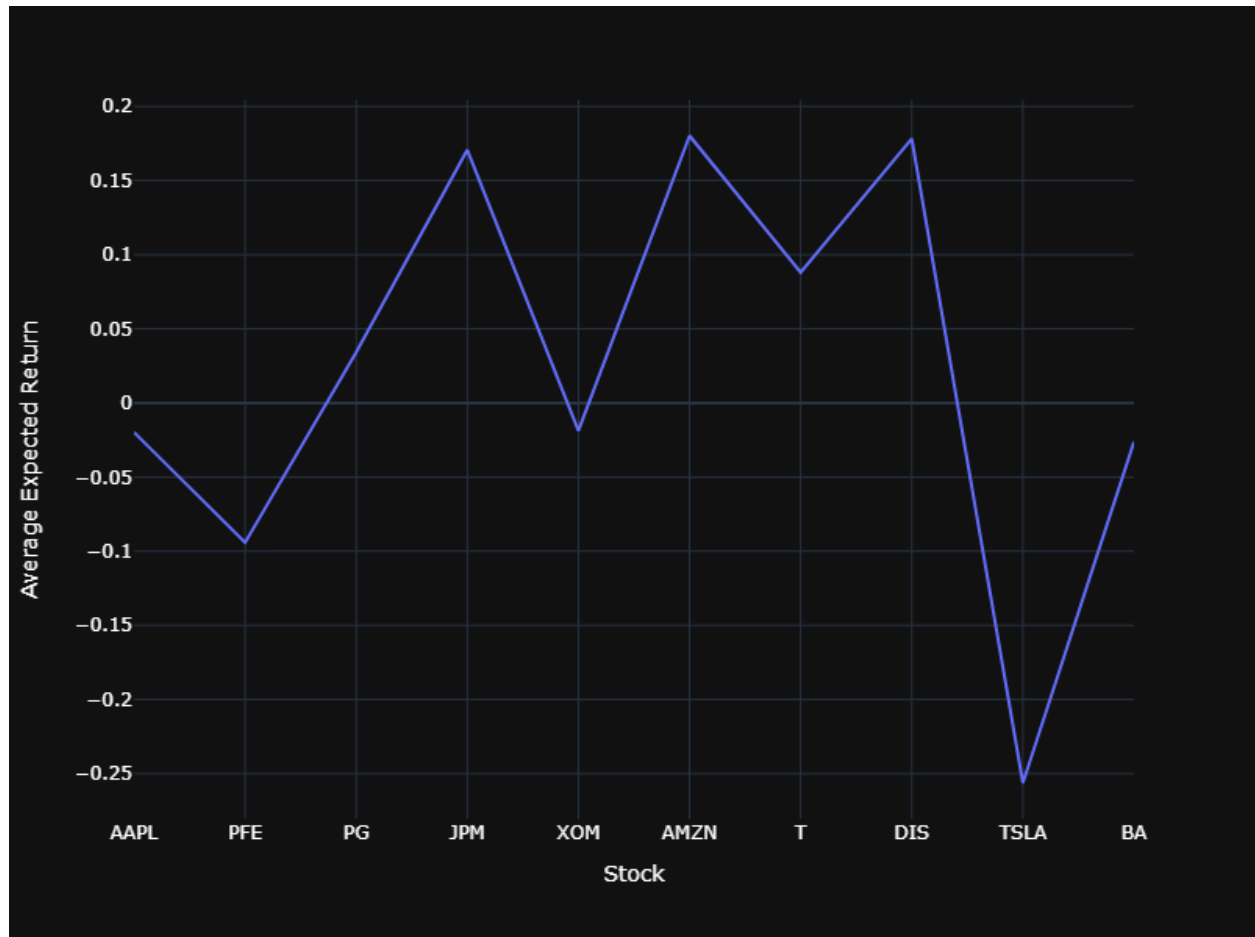


Log Returns

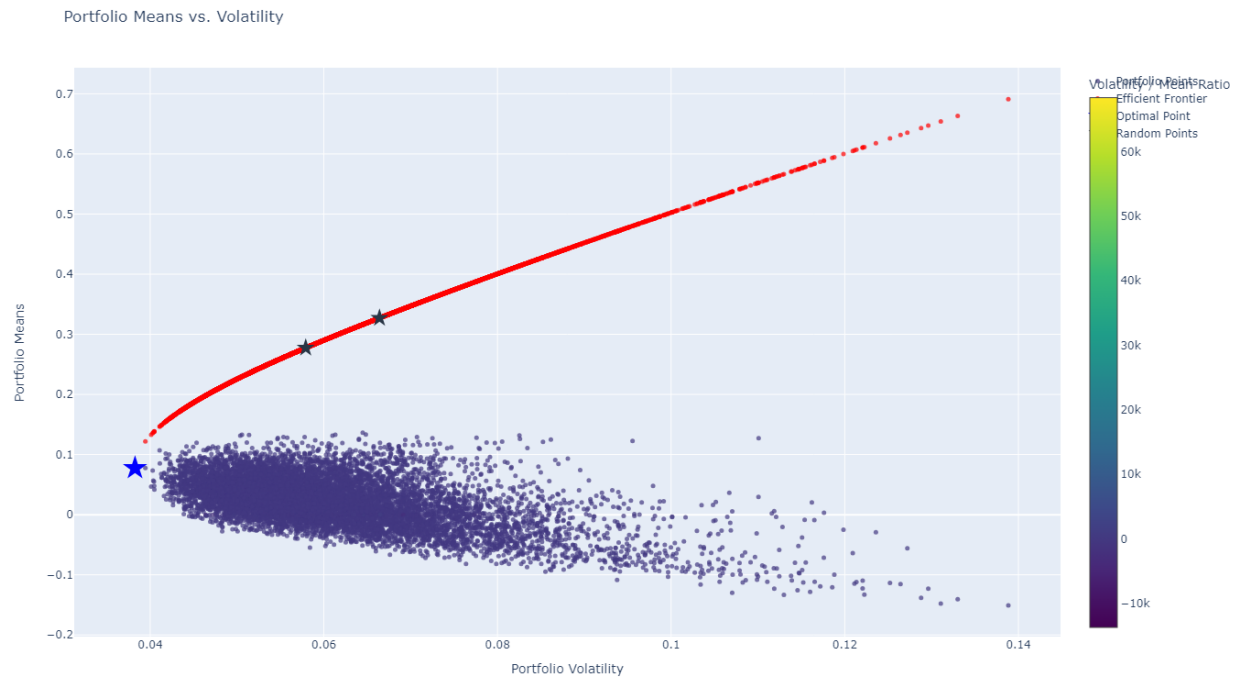


Stock	Expected returns
AAPL	-0.019788
PFE	-0.09419
PG	0.034272
JPM	0.170654
XOM	0.018631
AMZN	0.180211
T	0.088031
DIS	0.178140
TSLA	0.256326
BA	0.026294

Average Expected Return



Markowitz Efficient Frontier



Randomly selected points:

Point 1: (0.06960516138541444, 0.3449509446378513)

Point 2: (0.06309528229720737, 0.3082883226572738)

Corresponding weights:

Point 1: [-0.27610503 -0.11198081 0.19006307 1.1314967 -0.49370743 0.19633005
0.12323161 0.27286653 -0.10628662 0.07409194]

Point 2: [-0.21557194 -0.0907904 0.1963025 1.02801989 -0.42639286 0.1722598
0.11250738 0.24374657 -0.08897561 0.06889468]

Trade-off between risk and return

1. Point 1:

- This point towards the right represents a portfolio with relatively higher expected return but also higher risk. Investors at this point are willing to accept greater volatility in exchange for the potential for higher profits.
- They might be more aggressive in their investment strategy, seeking out opportunities with higher returns, even if they come with increased uncertainty.

2. Point 2:

- On the other hand, Point B towards the lower left represents a portfolio with a lower expected return but lower risk.

- Investors here prioritize stability and capital preservation over maximizing returns. They are likely more risk-averse, preferring investments with less volatility, even if it means sacrificing some potential gains.

In summary, the trade-off between risk and return along the Markowitz frontier illustrates that investors must make decisions based on their risk tolerance and investment objectives. They can choose to optimize for higher returns at the expense of increased risk or prioritize lower risk even if it means accepting lower returns. The key is finding the balance that aligns with their individual preferences and financial goals.

Portfolio Weights

The optimum portfolio weights represent by the blue star are as give below

AAPL	0.16534659
PFE	0.04255531
PG	0.2355657
JPM	0.37686836
XOM	-0.0028004
AMZN	0.02079187
T	0.0450225
DIS	0.06050238
TSLA	0.01995811
BA	0.03618967
Portfolio Volatility	0.03824984
Portfolio Return	0.077580178

Presentation

https://docs.google.com/presentation/d/1JLgUwI0b1CQpkvuFuVCx4bnioRvbl_tCmuz52FI9ROw/edit?usp=sharing