

# **ASSIGNMENT ON MODERN PORTFOLIO THEORY (MPT)**

## ***ACKNOWLEDGEMENT***

I would like to thank Dr. Shreya Biswas, for providing us this opportunity to work on this assignment, which helped us in applying the concepts and knowledge learned in the course in real life. I am deeply grateful for her timely guidance throughout the course of this project, which was crucial to the completion of this project. I shall remain indebted to her for her help and guidance throughout the course and this assignment. We are also thankful to the Economics Department, BITS Pilani Hyderabad Campus, for creating such provisions for students to participate in innovative, useful projects, while also giving us hands-on experience in applying our knowledge to real-world data. This project has certainly developed my skills and has given me the necessary tools to excel further in this field. This assignment gave me a sense of the real- world application of how to create portfolios using the Markowitz Model, which is essential in today's financial world.

## ***ABSTRACT***

This report shows thorough analysis and construction of a portfolio of ten securities diversified with eight domestic companies, one international company and one cryptocurrency using the Markowitz Portfolio Theory. The period of study for the securities is from 01-01-2023 to 01-01-2024. The returns of the securities were calculated using the basic formula  $(P_t - P_{t-1}) / P_{t-1}$  where  $P_t$  stands for the price of the security at time  $t$ . Since we have used a ratio for each security, the Exchange Rate is not used by us. The risk-free rate has been calculated using the average rate of a 1-year India Treasury Bond (data used from investing.com). We did a similar analysis for the market using the NIFTY50 index as the benchmark for the market. We calculated the value of the Risk-Free rate using the mean of the data for the same period. For the domestic portfolio, we formulated the Annualized Covariance Matrix, and used it for calculating the Expected Returns and Risk associated with the portfolio. The portfolio analysis was done using Markowitz Model Portfolio with these values to get the minimum variance portfolios and tangency portfolios. Then finally, the efficient frontier was created using the same model. To further diversify the portfolio, we included an International Security (NVIDIA) and a Cryptocurrency (SOLANA) in our portfolio to check the impact on the risk-adjusted returns. We then made important inferences by comparing the risk and returns of the 2 portfolios we created with the risk and returns of NIFTY50.

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### **Portfolio Overview:**

#### **1. AEGIS Logistics Ltd. (AEGISLOG)**



Aegis Logistics Ltd. is a major player in India's oil, gas, and chemical logistics sector. Founded in 1956 and headquartered in Mumbai, Aegis Logistics Ltd has a market capitalization of ₹255.35 billion. The company reported a revenue of ₹65.47 billion for FY 2024, driven by its expanding LPG distribution and liquid terminals across multiple ports in India. In our period of analysis, AEGISLOG has provided 10.575% returns with annualized risk of 38.33%.

#### **2. Canara Bank Ltd: (CANBK)**



Canara Bank is one of India's leading public sector banks, established in 1906 and it is headquartered in Bangalore. Canara Bank's market capitalization stands at approximately ₹634.5 billion in 2024. For our period of analysis, Canara Bank provided 46.23% annualized return with 30.98% of annualized risk.

**3. *Star Health and Allied Insurance Company Ltd: (STARHEALTH)***



Star Health and Allied Insurance was founded in 2006. It is a leading health insurance provider in India. The company has a strong presence in the retail health insurance sector, holding a significant market share with steady growth over the years. As of the latest FY, Star Health has a market capitalization of ₹462 billion. The company has benefitted from the upsurge in healthcare post - COVID 19. For our period of analysis, STARHEALTH provided -5% returns and had a volatility of 30.3% causing it to be one of the underperformers in our portfolio.

**4. *Piramal Pharma Ltd: (PPLPHARMA)***



Piramal Pharma Limited (PPL) is a pharmaceutical company based in Mumbai, India, founded in 2020. Its business segments include complex hospital generics, consumer healthcare, and a partnership with Allergan in the Indian ophthalmology market. Piramal Pharma's market capitalization is estimated at ₹144 billion in 2024. For our period of analysis, PPLPHARMA gave returns worth 27.66% with an annualized risk of 40.34%. This led to high volatility and low risk-adjusted returns by this company in the portfolio.

**5. *Kajaria Ceramics Ltd: (KAJARIACER)***



Kajaria Ceramics is one of India's leading manufacturers and distributors of ceramic and vitrified tiles. It was established in 1985 and is headquartered in New Delhi. Kajaria Ceramics has a market capitalization of ₹205 billion as of 2024. It holds a strong position in India's ceramic and tiles industry. For our period of analysis, it provided 19.44% returns with 25.63% volatility.

**6. *Birlasoft Ltd: (BSOFT)***



Birlasoft is a global IT services provider, primarily focused on IT consulting and outsourcing. In 2024, Birlasoft Ltd market capitalization is around ₹93 billion, with annual revenues of ₹4,050 crore, reflecting solid demand for its IT services in various industries. For our portfolio, BSOFT is the best performer, with returns of 184.45% and volatility of 34.16%, providing the best risk-adjusted return for our period of analysis.

**7. 360 One Wam Ltd: (360ONE)**



360One WAM, formerly known as IIFL Wealth Management, is a leading wealth and asset management firm in India. It manages around \$63 billion in assets and operates through two main divisions - Wealth Management and Asset Management. The company's market cap is approximately ₹22.3 billion in 2024. This company provided 81.81% returns with a risk of 31.31%, making it one of the best performers in our portfolio.

**8. Gujarat Narmada Valley Fertilizers and Chemicals Ltd: (GNFC)**



Gujarat Narmada Valley Fertilizers & Chemicals Limited (GNFC) is a leading Indian manufacturer of fertilizers and chemicals. The company was founded in 1976 and is headquartered in Bharuch, Gujarat. The company has a market capitalization of ₹150 billion. For our period of analysis, it provided 52.34% returns with 31.42% associated annualized risk. This company was also a strong performer in our portfolios.



**9. NVIDIA Corp: (NVDA)**



Nvidia, founded in 1993, is a leader in accelerated computing, recognized for inventing the GPU (Graphics Processing Unit) in 1999. Nvidia is valued at over \$1 trillion, making it one of the most valuable companies worldwide. NVIDIA's market cap is approximately \$1.15 trillion as of 2024. In our period of analysis, NVIDIA has provided 292.59% of returns with an associated risk of 48.46%. Although the associated risk is high, the risk-adjusted return is significantly high making it one of the best performers in our portfolio.

**10. SOLANA Labs: (SOL-USD)**



Solana Labs is a key player in blockchain technology, focusing on building tools and products for the Solana blockchain, which is known for its high-speed, scalable infrastructure. Its valuation surged to over \$10 billion as of 2024, driven by the continued rise in decentralized finance (DeFi) applications and Web3 developments built on the Solana blockchain. In our portfolio, SOLANA is the best performer, giving over 1149% of returns, however with an annualized risk of 94.83%. Despite the high volatility, SOL-USD had the highest weight in our Tangency Portfolios.

### **Markowitz Portfolio Theory (MPT)**

The Markowitz Portfolio theory was developed by Harry Markowitz. Its concept is to develop a set of portfolios that provide the best risk-adjusted return. Some of the key terminologies in this model are explained on the next page. The key assumptions of the Markowitz Theory are:

- Investors are **rational** (risk-averse)
- Risk-free borrowing and lending
- Perfect Market Information
- No transaction costs and taxes

The MPT captures the benefits of diversification and risk-minimization, optimizing the utility of the investors. This is done through the efficient frontier and tangency portfolios generated through this model. The MPT helps minimize the firm-specific risk (Unsystematic risk) through diversification. It efficiently calculates the weights of the risky-assets to maximize the Sharpe Ratio.

Despite the positives of the MPT, it has several underlying downsides:

- The input list explodes as the number of securities in the portfolio increases. (The size of the Covariance Matrix increases drastically)
- Industry specialization makes it harder to estimate correlation
- The SIM (Single Index Model) proposed by William Sharpe simplified the estimation of covariance and correlation.

However, our assignment is based on the application of the Markowitz theory to 2 portfolios – the Domestic and International. The Domestic portfolio contains 8 Indian Securities, while the International Portfolio contains the 8 Securities + 1 Cryptocurrency + 1 International Security.

We have chosen SOLANA (SOL-USD) as our cryptocurrency and NVIDIA (NVDA) as our International Security.

### ***Some Key Terminologies:***

- ***Minimum Variance Portfolio***

A portfolio constructed with the main objective of minimizing overall volatility is referred to as a minimum variance portfolio. This portfolio allocation represents the combination of assets that offers the lowest risk level among all possible asset combinations in the investment universe. The **Minimum Variance Portfolio (MVP)** represents the portfolio with the lowest possible risk on the efficient frontier. It does not provide the highest projected return, but it does give the least amount of volatility of any portfolio that can be built. This portfolio is ideal for very risk-averse investors because it carries the least amount of risk.

- ***Tangency Portfolio***

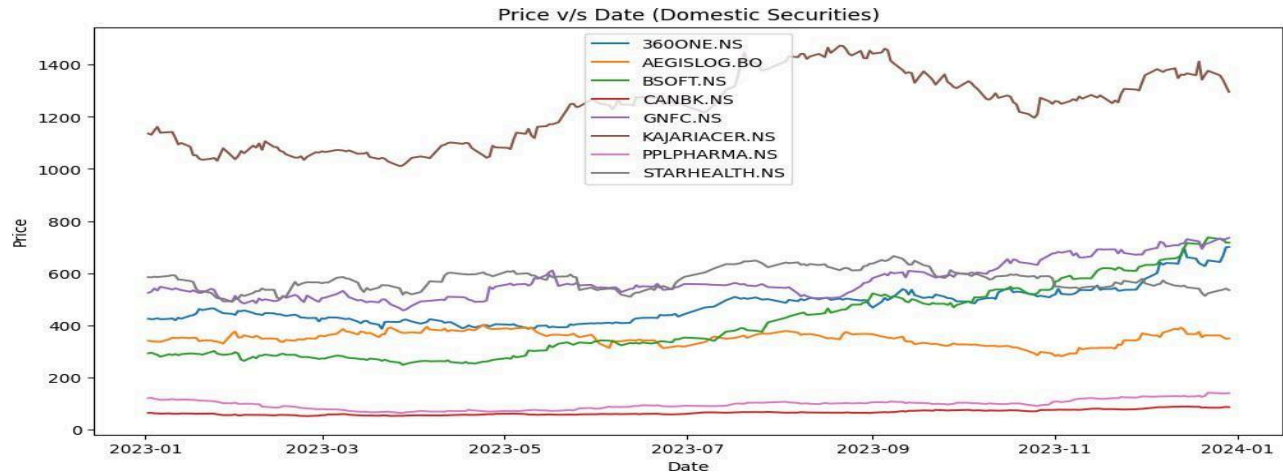
In modern portfolio theory, the Tangency Portfolio is a central concept. It represents the portfolio where the efficient frontier intersects with the capital allocation line (CAL). This portfolio is considered optimal for investors who want to maximize their risk-adjusted returns. Out of all the portfolios, this one has the **greatest Sharpe Ratio**. The highest returns per unit of risk exposure are possible when these assets are combined. The tangency portfolio should be used by investors who are prepared to take on risk in order to maximize efficiency when building their portfolios as it offers the finest risk-adjusted returns.

- ***Efficient Frontier***

The efficient frontier is a fundamental concept representing a set of optimal portfolios that offer the maximum expected return for a specified level of risk or the minimum risk for a given expected return. The efficient frontier (the green curved line) indicates the line, which represents the portfolios, which are offering the highest return on investment for a given level of risk or a level of return. A portfolio is said to be fully maximized, or ideally diversified, if it falls within the area of the efficient frontier. Portfolios with lesser risk and lower returns are indicated by the frontier's wearing ridges, whereas portfolios with higher risk and higher expected returns are indicated by the lower ridge.

## 1. Generating a Domestic Portfolio

To generate the domestic portfolio, we have used the stock price data for the one-year period: 01-01-2023 to 01-01-2024. To ensure that none of the companies have very negative weights due to continuous negative returns, we created lineplots for the price v/s date of each security. Since the returns were steady throughout the period, we proceeded with the portfolio creation.



**Fig 1: Price fluctuations of domestic securities with time**

The next step was to generate the annualized returns for each security. The formula that we used for getting returns was  $(P_t - P_{t-1}) / P_t$ . We then annualized the returns by finding the mean of all the returns and finding the EAR (Effective Annual Rate) by the formula:

$EAR = (1 + \text{mean\_returns})^{252} - 1$ . The domestic annualized returns are given by the following matrix.

risk_return_df_domestic		
Ticker	Annualized Return	Annualized Risk
360ONE.NS	0.818156	0.313120
AEGISLOG.BO	0.105725	0.383356
BSOF.T.NS	1.844554	0.341611
CANBK.NS	0.462369	0.309837
GNFC.NS	0.523443	0.314205
KAJARIACER.NS	0.194458	0.256335
PPLPHARMA.NS	0.276331	0.403464
STARHEALTH.NS	-0.050636	0.303076

**Fig 2: DataFrame of annualized domestic returns**

It can be observed that the returns for BSOF.T, 360ONE, GNFC and CANBK are high, so their weights must also be high according to the Markowitz theory if their risks are relatively low.

### 1a. Generating the Efficient Frontier

For generating the efficient frontier, we first created the covariance matrix for the 8 securities, and annualized it by multiplying by 252.

```

cov_matrix = returns_domestic.cov()*252
cov_matrix

```

	Ticker	360ONE.NS	AEGISLOG.BO	BSOFT.NS	CANBK.NS	GNFC.NS	KAJARIACER.NS	PPLPHARMA.NS	STARHEALTH.NS
	Ticker								
	360ONE.NS	0.098044	-0.000251	0.008484	0.021914	0.002752	-0.001659	0.011153	0.003768
	AEGISLOG.BO	-0.000251	0.146962	-0.003169	0.027054	0.006715	0.007510	0.014733	0.017362
	BSOFT.NS	0.008484	-0.003169	0.116698	0.013258	0.021709	0.019410	0.030575	0.007609
	CANBK.NS	0.021914	0.027054	0.013258	0.095999	0.029788	0.003682	0.030037	0.002722
	GNFC.NS	0.002752	0.006715	0.021709	0.029788	0.098725	0.005057	0.031108	0.015072
	KAJARIACER.NS	-0.001659	0.007510	0.019410	0.003682	0.005057	0.065708	0.014494	0.002340
	PPLPHARMA.NS	0.011153	0.014733	0.030575	0.030037	0.031108	0.014494	0.162783	0.008102
	STARHEALTH.NS	0.003768	0.017362	0.007609	0.002722	0.015072	0.002340	0.008102	0.091855

*Fig 3: covariance matrix for domestic securities*

The covariance matrix provides insight into how different securities move in relation to each other. The diagonal elements of the covariance matrix represent the variance of each security. Positive covariance indicates that the securities tend to move in the same direction. For instance, the covariance between **CANBK.NS** and **GNFC.NS** (0.029788) suggests that these two securities tend to move in the same direction, indicating a positive relationship. On the other hand, a slightly negative covariance between **360ONE.NS** and **KAJARIACER.NS** (-0.001659) implies a weak negative relationship, which might be beneficial for diversification.

Before tracing the efficient frontier, we calculated the risk-free rate as  $rf = 0.07021$  or 7.021% using the rates of the 1-year risk-free bond from investing.com.

Next in the code, we defined functions for the Tangency Portfolio (calculating optimal weights) and the Minimum Variance Portfolio. In the tangency portfolio function, we used the `scipy.optimize` function to minimize the negative Sharpe Ratio and find the corresponding weights. (`scipy` only has a minimize function and hence we minimized the negative Sharpe ratio as a substitute for maximizing the positive Sharpe Ratio). We then proceeded to create a DataFrame to store the Optimal Weights of the Portfolio, and the Metrics (Maximum Sharpe Ratio, Expected Returns and Risk of the Tangency Portfolio).

### 1b. Finding the Tangency Portfolio and Minimum Variance Portfolio:

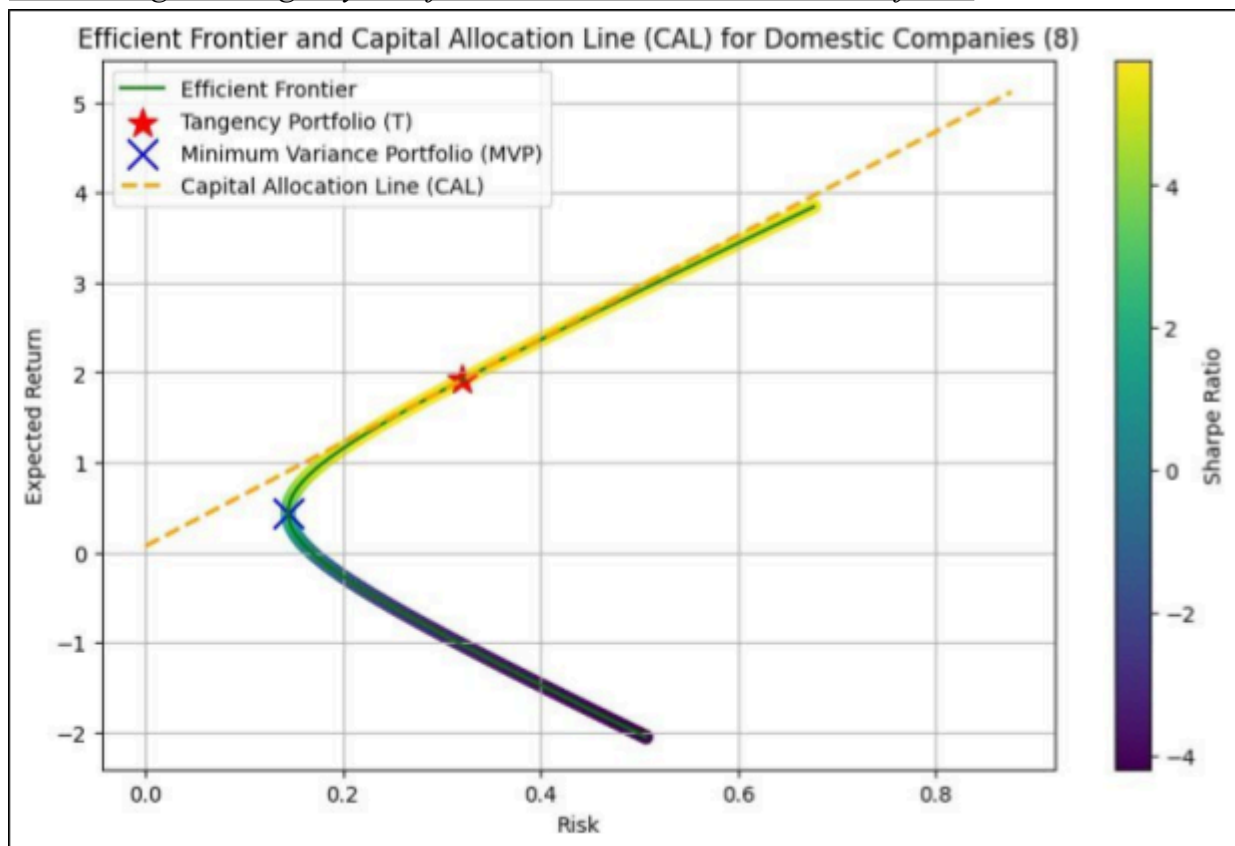


Fig 4: Efficient Frontier and CAL for Domestic Securities

The \* mark indicates the point of tangency, and the x indicates the point of Minimum Variance. The Capital Allocation Line with the Maximum Sharpe Ratio passes through the point of Tangency. The Portfolio Possibility Frontier has a gradient indicating the Sharpe Ratio. The efficient frontier is the plot of the plot of the portfolios giving the highest returns for a given value of risk. The curve above the Minimum Variance Point is known as the efficient frontier, and the curve below it is the inefficient frontier. (Since we can get higher returns for the same risk).

The Index used here for comparison is the NIFTY50 index. The risk and returns of the NIFTY50 index are given as follows:

```
[262] nifty_risk_annualized
```

```
0.09825602059591837
```

```
[106] nifty_returns_annualized
```

```
0.206952264469775
```

```
nifty_sharpe_ratio
```

```
1.39165998642515
```

NIFTY50 Sharpe Ratio = 1.3917

Annualized NIFTY50 risk = 9.825%

Annualized NIFTY50 returns = 20.69%

### 1c. Comparing the performance of the Portfolio with NIFTY50, and gaining Inferences

The weights of the securities for the Tangency Portfolio, and the performance metrics are:

	Weight
360ONE.NS	0.361992
AEGISLOG.BO	0.063658
BSOFT.NS	0.864401
CANBK.NS	0.020957
GNFC.NS	0.119206
KAJARIACER.NS	-0.123620
PPLPHARMA.NS	-0.129153
STARHEALTH.NS	-0.177440

	Metric	Value
0	Returns	1.918676
1	Risk	0.321001
2	Sharpe Ratio	5.758426

We can observe that the weights of the 3 securities – KAJARIACER, PPLPHARMA and STARHEALTH are negative, indicating that these securities are shorted in our portfolio. The possible reason behind this could be negative risk-adjusted return throughout the period of analysis. BSOFT and 360ONE have very high weights, indicating that these securities have had significantly high risk-adjusted return throughout the year. This can be observed in the table of returns and risk per security provided earlier. PPLPHARMA provided decent returns, but had significantly higher risk (40.34%) and hence our code considered negative weights for it.

The CSV files containing this data have also been extracted in the Code. The maximum Sharpe Ratio turned out to be 5.758, and the Tangency Domestic – Portfolio return turned out to be 191.8%. This indicates that the portfolio performs very well since the returns are very high for the associated risk of 32.1%.

mvp_data			
	Risk	Returns	Sharpe Ratio
0	0.144756	0.437786	2.539258

Similarly, we calculated the metrics for the Minimum Variance Domestic – Portfolio. This was achieved at a risk of 14.47% and the portfolio yielded returns of 43.78%. The Sharpe Ratio noted was 2.539.

From this portfolio, we can observe that compared to NIFTY50, the domestic – portfolio yielded significantly higher Sharpe Ratio for both Minimum Variance and Tangency Portfolios. The comparison table is given below:

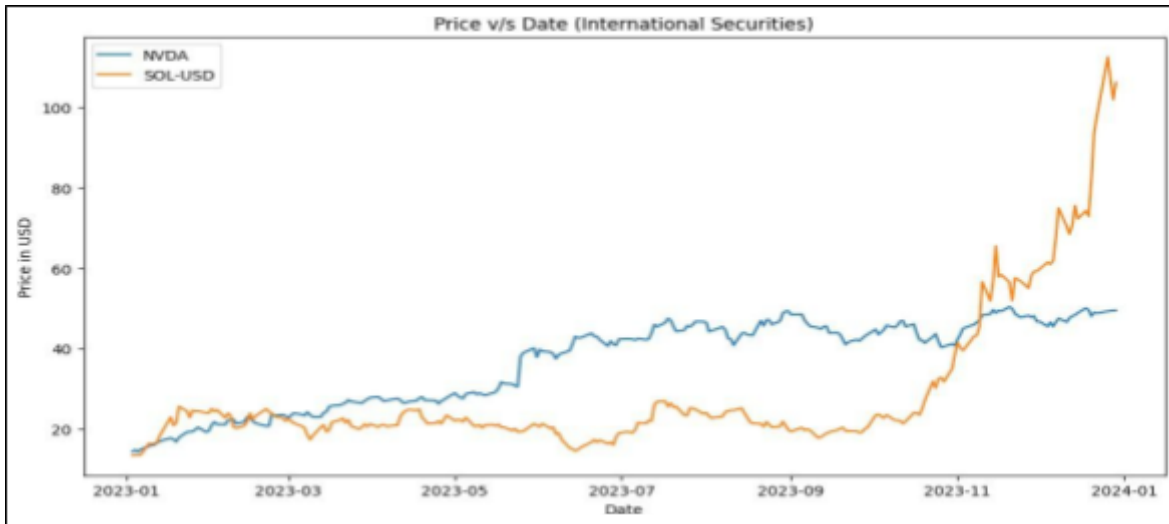
<b>Metric</b>	<b>Domestic Tangency Portfolio</b>	<b>Domestic MV Portfolio</b>	<b>NIFTY 50</b>
Expected Return	191.87%	43.77%	20.69%
Risk	32.10%	14.48%	9.825%
Sharpe Ratio	5.758	2.539	1.3912

We can observe that the Sharpe Ratio for both, the Domestic Tangency and Domestic Minimum Variance Portfolio is significantly greater than the Sharpe Ratio of NIFTY 50. This provides a standard metric implying that the performance of the Domestic Portfolios is better.



## 2. Generating an International Portfolio

To generate the international portfolio, we have used the stock price data for the one-year period: 01-01-2023 to 01-01-2024. To ensure that none of the companies (NVIDIA, SOLANA) have very negative weights due to continuous negative returns, we created lineplots for the price v/s date of each security. Since the returns were steady throughout the period, we proceeded with the portfolio creation.



**Fig 5: Price fluctuations of international securities with time**

The next step was to generate the annualized returns for each security. The formula that we used for getting returns was  $(P_t - P_{t-1}) / P_{t-1}$ . Since we are using a ratio, we need not use the FOREX conversion rates for USD to INR. We then annualized the returns by finding the mean of all the returns and finding the EAR (Effective Annual Rate) by the formula:  $EAR = (1 + \text{mean\_returns})^{252} - 1$ . The international annualized returns are given by the following matrix. The coefficient of variance given by  $(\text{Annualized Risk}) / (\text{Annualized Return})$  is also calculated here.

```
[347] risk_return_df_international
```

	Annualized Return	Annualized Risk	C.V
Ticker			
NVDA	2.925978	0.484566	0.165608
SOL-USD	11.496844	0.948331	0.082486

**Fig 6: DataFrame of annualized international returns**

It can be observed that the returns for both NVDA and SOL-USD are high, so their weights must also be high according to the Markowitz theory if their risks are relatively low. However, since the risk associated with SOLANA is close to 94%, its weights must be lower than what we expect.

## 2a. Generating the Efficient Frontier (International)

For generating the efficient frontier, we first created the covariance matrix for the 10 securities (8 Domestic + 2 International), and annualized it by multiplying by 252.

Ticker	360ONE.NS	AEGISLOG.BO	BSOFT.NS	CANBK.NS	GNFC.NS	KAJARIACER.NS	PPLPHARMA.NS	STARHEALTH.NS	NVDA	SOL-USD
Ticker										
360ONE.NS	0.098044	-0.000251	0.008484	0.021914	0.002752	-0.001659	0.011153	0.003768	0.001388	0.008313
AEGISLOG.BO	-0.000251	0.146962	-0.003169	0.027054	0.006715	0.007510	0.014733	0.017362	-0.010816	0.000443
BSOFT.NS	0.008484	-0.003169	0.116698	0.013258	0.021709	0.019410	0.030575	0.007609	-0.001874	-0.011627
CANBK.NS	0.021914	0.027054	0.013258	0.095999	0.029788	0.003682	0.030037	0.002722	-0.000035	-0.007250
GNFC.NS	0.002752	0.006715	0.021709	0.029788	0.098725	0.005057	0.031108	0.015072	0.011734	-0.009896
KAJARIACER.NS	-0.001659	0.007510	0.019410	0.003682	0.005057	0.065708	0.014494	0.002340	0.001868	-0.029128
PPLPHARMA.NS	0.011153	0.014733	0.030575	0.030037	0.031108	0.014494	0.162783	0.008102	0.017317	-0.003762
STARHEALTH.NS	0.003768	0.017362	0.007609	0.002722	0.015072	0.002340	0.008102	0.091855	-0.002164	-0.007973
NVDA	0.001388	-0.010816	-0.001874	-0.000035	0.011734	0.001868	0.017317	-0.002164	0.234804	0.066256
SOL-USD	0.008313	0.000443	-0.011627	-0.007250	-0.009896	-0.029128	-0.003762	-0.007973	0.066256	0.899331

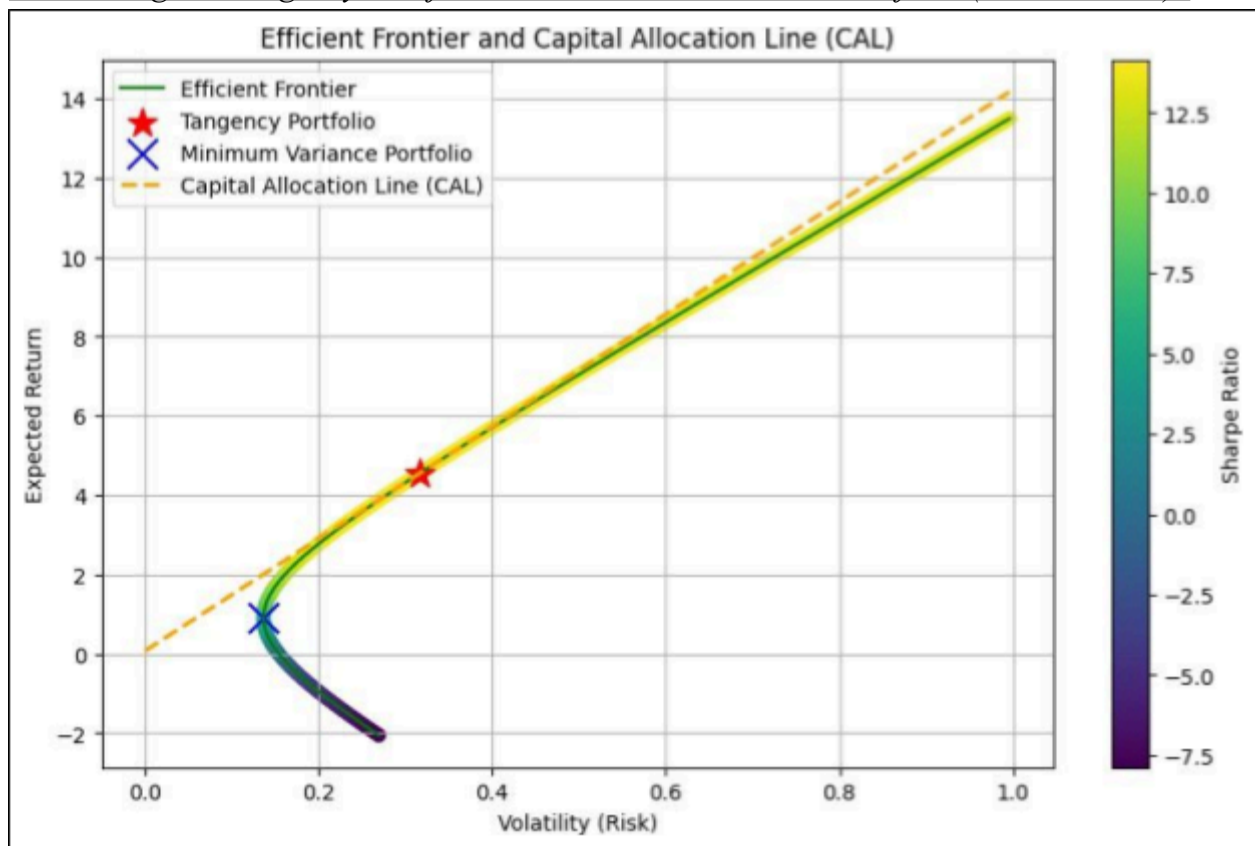
*Fig 7: covariance matrix for international securities*

The covariance matrix provides insight into how different securities move in relation to each other. The diagonal elements of the covariance matrix represent the variance of each security. Positive covariance indicates that the securities tend to move in the same direction. For instance, the covariance between **SOL-USD** and **NVDA** (0.066256) suggests that these two securities tend to move in the same direction, indicating a positive relationship. On the other hand, a slightly negative covariance between **NVDA** and **BSOFT.NS** (-0.001874) implies a weak negative relationship, which might be beneficial for diversification.

We have already calculated the risk-free rate as 7.021% using the historical data for the 1-year Government bond.

Next in the code, we defined functions for the Tangency Portfolio (calculating optimal weights) and the Minimum Variance Portfolio. In the tangency portfolio function, we used the `scipy.optimize` function to minimize the negative Sharpe Ratio and find the corresponding weights. (`scipy` only has a minimize function and hence we minimized the negative Sharpe ratio as a substitute for maximizing the positive Sharpe Ratio). We then proceeded to create a DataFrame to store the Optimal Weights of the Portfolio, and the Metrics (Maximum Sharpe Ratio, Expected Returns and Risk of the Tangency Portfolio).

## 2b. Finding the Tangency Portfolio and Minimum Variance Portfolio (International):



**Fig 8: Efficient Frontier and CAL for International Securities**

The \* mark indicates the point of tangency, and the x indicates the point of Minimum Variance. The Capital Allocation Line with the Maximum Sharpe Ratio passes through the point of Tangency. The Portfolio Possibility Frontier has a gradient indicating the Sharpe Ratio. The efficient frontier is the plot of the portfolios giving the highest returns for a given value of risk. The curve above the Minimum Variance Point is known as the efficient frontier, and the curve below it is the inefficient frontier. (Since we can get higher returns for the same risk).

The Index used here for comparison is the NIFTY50 index. The risk and returns of the NIFTY50 index are given as follows:

```
[262] nifty_risk_annualized
```

```
0.09825602059591837
```

```
[106] nifty_returns_annualized
```

```
0.206952264469775
```

```
nifty_sharpe_ratio
```

```
1.39165998642515
```

NIFTY50 Sharpe Ratio = 1.3917

Annualized NIFTY50 risk = 9.825%

Annualized NIFTY50 returns = 20.69%

## 2c. Comparing the performance of the Portfolio with NIFTY50, and gaining Inferences

The weights of the securities for the Tangency Portfolio, and the performance metrics are:

	Weight
360ONE.NS	0.114840
AEGISLOG.BO	0.028378
BSOFT.NS	0.364515
CANBK.NS	0.040630
GNFC.NS	0.038280
KAJARIACER.NS	0.064961
PPLPHARMA.NS	-0.084109
STARHEALTH.NS	-0.042807
NVDA	0.200874
SOL-USD	0.274438

metrics_df		
	Metric	Value
0	Returns	4.542632
1	Risk	0.315892
2	Sharpe Ratio	14.158067

We can observe that the weights of the 2 securities –PPLPHARMA and STARHEALTH are negative, indicating that these securities are shorted in our portfolio. Unlike the domestic portfolio, KAJARIACER has slightly positive weight in the portfolio. Since the covariance matrix has changed, the risk has also changed leading to slightly positive weight. BSOFT, NVDA and SOL-USD have very high weights, indicating that these securities have had significantly high risk-adjusted return throughout the year. This can be observed in the table of returns and risk per security provided earlier. PPLPHARMA provided decent returns, but had significantly higher risk (40.34%) and hence our code considered negative weights for it.

The CSV files containing this data have also been extracted in the Code. The maximum Sharpe Ratio turned out to be 14.158, and the Tangency International – Portfolio returns turned out to be 454.26%. This indicates that the portfolio performs very well since the returns are very high for the associated risk of 31.59%.

mvp_data			
	Risk	Returns	Sharpe Ratio
0	0.136908	0.91823	6.194052

Similarly, we calculated the metrics for the Minimum Variance International – Portfolio. This was achieved at a risk of 13.69% and the portfolio yielded returns of 91.823%. The Sharpe Ratio noted was 6.194. It is significant to note that the Sharpe ratio is very high compared to the MVP for domestic securities.

From this portfolio, we can observe that compared to NIFTY50, the International – portfolio yielded significantly high returns, for slightly higher risk (Minimum Variance Portfolio). Compared to the index, our portfolio performed marginally better yielding a maximum return of 454.26% for an associated risk of 31.59% while NIFTY50 provided 20.69% returns for 9.82% associated risk. The comparison table for the International Tangency, International MVP, and NIFTY50 portfolio is given below:

<b>Metric</b>	<b>International Tangency Portfolio</b>	<b>International MV Portfolio</b>	<b>NIFTY 50</b>
Expected Return	454.26%	91.82%	20.69%
Risk	31.56%	13.69%	9.825%
Sharpe Ratio	14.158	6.194	1.3912

From the table, we can clearly observe that our International Portfolio has over 10x the Sharpe Ratio of the NIFTY50 index. This shows how strong the portfolio's risk-adjusted returns are. Similarly for the Minimum Variance Portfolio, the Sharpe Ratio is 6.194 (4.45x the Sharpe Ratio of NIFTY50) indicating the overall strength of the Portfolio.

### **Comparing the Domestic, International and NIFTY50 metrics**

This section compares the performance of the **Tangency Portfolios** of the Domestic and International Securities with NIFTY50.

<b>Portfolio</b>	<b>Returns</b>	<b>Risk/ Volatility</b>	<b>Sharpe Ratio</b>
Domestic (8 Sec.)	191.87%	32.10%	5.758
International (8+2 Sec.)	454.26%	31.56%	14.158
NIFTY50	20.69%	9.825%	1.3917

The risk-free rate used for the calculation of the Sharpe Ratio is given by – 7.021%.

From the table, we can make the following inferences:

- Both, the domestic and international portfolios clearly outperform NIFTY50 in terms of the returns. The international portfolio has over twice the returns of the Domestic Portfolio. This is caused due to the high returns provided by both NVDA and SOL-USD (SOLANA) during the period of analysis.
- The International Portfolio provides over double the returns for even slightly lesser risk when compared to the Domestic Portfolio. This is reflected by the high Sharpe Ratio of the International Portfolio, which signifies the better performance and superior risk-adjusted returns.
- The Domestic Portfolio contains 8 securities from different industrial sectors ranging from Pharma, Banking, IT, Healthcare and Logistics. This is a perfect example of diversification, and how the risk of the portfolio can be minimized by it. Further, for the International Portfolio, includes an IT firm and a Cryptocurrency, which diversifies the portfolio more.
- Cryptocurrency is highly volatile and should always be risk-adjusted. This is observed by the high annualized returns that SOL-USD provides (1149%), but it also has a very high volatility (94.83%).
- Some securities like STARHEALTH have to be shorted due to poor risk-adjusted returns or constant decrease in returns throughout the tenure of analysis. This can clearly be observed by the negative weights in the portfolio.
- BSOF and 360ONE are strong performers in the Domestic Portfolio with very high returns and considerably low risk. They have the highest weights in the portfolio. Similarly, NVDA, BSOF and SOL-USD are the biggest winners in the International Portfolio. The weights are concentrated mainly in these securities.

This rebalancing and optimal allocation of weights based on risk-adjusted returns, is essential for an investor with any level of risk-aversion to maximize utility (Sharpe Ratio). The entire process is based on the Markowitz Portfolio theory and provides numerous insights on decision-making strategies from the Investor's and Portfolio Manager's perspective.

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