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Original Article

Application of Markowitz Efficiency Frontier on Indian IT Sector with Accentuation on Infosys

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Abstract *- Indian IT sector has grown tremendously, and thus it contributes a fair share to Indian GDP growth. the employment opportunities in the sector help the country reduce the unemployment rate. Thus IT sector has become an alluring vertical for the investor to dive into and make considerable gains. Fundamental analysis can help us narrow down on a few selected stocks. Still, how much weight should be allocated to each stock in the portfolio to bag maximum gains arises. This paper makes a humble attempt to narrow down on a firm, i.e., Infosys, and involves the creation of Markowitz efficiency frontier using an algorithm in Python. the algorithm is articulated to be used for any number of stocks in a portfolio for any given timeframe. the paper tries to highlight how an efficiency frontier can be created for any given portfolio and how its analysis can provide surmountable insights to an investor.*

Keywords *- Covariance, Standard Deviation, Markowitz Efficiency Frontier, Beta, IT sector, Rate of return, Expected Return, Volatility, Portfolio Returns, Portfolio Risk.*

1. Introduction

With the world's largest pool of qualified technical graduates, India is the world's largest sourcing destination. the country has a cost advantage over the US, 5-6 times less expensive. the demand for Big Data, Data Analytics, Artificial Intelligence (AI), and the Internet of Things is projected to propel India's cloud industry to Rs. 49,621 crore (US$ 7.1 billion) by 2022, according to the Cloud Next Wave of Growth in India survey. India's IT industry contributed 7.7% of the country's GDP in 2015, and it is expected to contribute 10% by 2025. in FY20, the IT industry employed 4.3 million workers. in FY20, the sector gained 205,000 employees, up from 185,000 in FY19. the cumulative number of employees for four Indian IT majors (TCS, Infosys, Wipro, and HCL Tech) has risen to 1.02 million as of December 31, 2019. the Indian IT industry employed 205,000 new workers in 2019 and had 884,000 digitally qualified employees.

In FY20, the IT & BPM industry revenue was reported to be around US$ 191 billion, representing a 7.7% year-on-year increase. the sector gained 205,000 employees in FY20, up from 185,000 workers in FY19. in FY20, the IT industry is expected to generate US$ 44 billion in domestic revenue and US$ 147 billion in export revenue. India's IT and BPM industry is projected to expand to US$ 350 billion in market value by 2025, with BPM accounting for US$ 50-55 billion of total sales.

The key competencies and capabilities of Indian IT have drawn substantial investment from major countries. Between April 2000 and September 2020, India's computer software and hardware market received a total of US$ 62.47 billion in foreign direct investment (FDI). According to DPIIT info, the sector ranked second in FDI inflows. Leading Indian IT companies such as Infosys, Wipro, TCS, and Tech Mahindra diversify their products and present cutting-edge ideas in blockchain and artificial intelligence to clients through innovation hubs and R&D centers. the above-mentioned developments make the IT sector an alluring destination to park investments and multiply earnings considerably.

2. Literature Review

- Rita Ambrozaite researched the topic of "Danish Mortgage Bond Portfolio Optimization Using the Mean-Variance Approach." This portfolio's goal was to build a portfolio with the highest possible yield in the Danish mortgage market. in other words, how will the Sharpe Ratio be increased? Data from the Danish mortgage bond market was used to apply Markowitz's mean-variance methods to accomplish a target. According to the author, the vulnerability of the ideal portfolio's valuation to market interest rate volatility was not significantly different.
- Ioana Coralia Zavera tested the Markowitz model in the Romanian stock market by building a portfolio of three shares in his paper "Application of Markowitz Model on Romanian Stock Market." For the stock in the Romanian Market, the author estimated an effective frontier and a Minimum Variance Portfolio.
- M. Ivanova and L. Dospatliev conducted research titled, "Application of Markowitz portfolio optimization on Bulgarian stock market from 2013 to 2016". This paper

aims to provide a practical analysis and implementation of the Markowitz model on the Bulgarian stock market over three years. By simulating different weight options, the author generated an efficient frontier and a Minimum Variance Portfolio.

- Optimal Portfolio Construction Using N – Assets Mean-Variance Portfolio Model: Study of Four Etfs of BSE was written by Raghavendra S Bendiger to create an optimal portfolio comprised of exchange-traded funds using the N – Asset Mean-variance Portfolio model. A Variance – Covariance matrix and a Correlation matrix have been determined to make the model more useful. the researchers calculated the optimal weight for a portfolio using the GRG – Non-Linear Optimization Method.
- Mark Rubinstain wrote in his paper that Markowitz had a great idea that, while diversification reduces risk, it does not eradicate it. the theory of diversification of portfolios was first mathematically formalized in Markowitz's paper: the financial version of the whole is greater than the value of its components. Diversification may minimize Danger, though not removed, without affecting the portfolio's projected return. According to Markowitz, an investor should seek to optimize anticipated portfolio performance while limiting portfolio variance. the most significant feature of Markowitz's work was to demonstrate that an investor is more concerned with a security's contribution to the variance of his entire portfolio than with its own risk. This was mainly a matter of its covariance with all other securities in his portfolio.

3. Research Objectives

- To compare the firms in the IT sector with Infosys via logarithmic return analysis and arrive at covariance and a correlation matrix to gauge the performance and relation between the stocks.
- To study Markowitz Efficiency Portfolio and understand its significance in the financial landscape as it is a widely used tool by the investors to gain perspective on maximum returns a portfolio can earn for a given value of risk.
- To device an algorithm in Python to plot the risk and return values for different portfolios taken for analysis to derive Markowitz efficiency frontier and then arrive at maximum returns conclusion based on the graph for each portfolio and IT sector portfolio.

4. Research Methodology

The data extracted for analysis was taken from the official website of NSE. All the collected and analyzed is secondary data. the data were extracted for the period starting from 1/01/2010 to 1/01/ 2021. the extracted data was used to perform various arithmetic operations to compare the logarithmic returns of the stocks. the correlation between the stocks was calculated to be further used for analysis in Markowitz Efficiency Portfolio. the sharp ratio of portfolios was calculated to compare the same are arrive at a plausible conclusion.

The stocks being considered are

- Infosys
- TCS
- Wipro
- Tech Mahindra
- L&T Infotech

4.1. Markowitz Portfolio Theory

4.1.1. Parameters of Markowitz Model Based on Historical Data of Stock Prices

Rate of Return

Rate of return is the ratio of the return of money gained or lost from the investor's investment. the money invested may be referred to as an asset, capital, principal, or the investment's cost basis. the rate of return expected by an investor can be calculated from the existing data and future investor's expectations. the result of the rate of return is usually expressed as a percentage.

The formula calculates the arithmetic rate of return rt on investments in the asset between time t and t − 1.

$$r_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

Where Pt is the price of the stock at time t, we assume for now that this stock pays dividends and let Pt−1 be the price at time t − 1.

Expected Return

Let us have n number of assets. Then the expected return μi on asset i, i = 1, . . . , n is calculated by

$$\mu_i = E(r^i) = \frac{\sum_{t=1}^{m} r_t^i}{m}$$

Where r i t is the return on asset i between periods t − 1 and t, t = 1, . . . , m and m is the number of periods whose return we have calculated.

Variance and Standard Deviation

The variance on asset i is calculated using the following formula

$$\sigma_i^2 = Var(r^i) = \frac{\sum_{t=1}^{m} \left(r_t^i - \mu_i\right)^2}{m-1}$$

Investors often use the standard deviation to measure the risk of their assets. in the equation below, the standard deviation is the most common statistical indicator of an asset's risk, which measures the dispersion around the expected value. the higher the standard deviation means, has greater the risk and vice versa. the formula of standard deviation is as follows

$$\sigma_i = \sqrt{\sigma_i^2} = \sqrt{\frac{\sum_{t=1}^{m}\left(r_t^i - \mu_i\right)^2}{m-1}}$$

Covariance

When we work with assets, dimensions of risk are organized in the return covariance matrix, denoted by Ωn×n. This matrix contains variances in its main diagonal and covariances between all pairs of assets and other items, i.e.

$$\Omega_{nxn} = \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \dots & \sigma_{1n} \\ \sigma_{21} & \sigma_2^2 & \dots & \sigma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \dots & \sigma_n^2 \end{pmatrix}$$

Where,

$$\sigma_{ij} = Cov(r^i, r^j) = \frac{\sum_{t=1}^{m}\left(r_t^i - \mu_i\right)\left(r_t^i - \mu_j\right)}{m}$$

4.1.2. Portfolio Efficient Frontier

Every possible asset combination can be plotted in risk-return space, and the collection of all such possible portfolios defines a region in this space. the line along the upper edge of this region is known as the efficient frontier, sometimes called the" Markowitz bullet ."Combinations along this line represent portfolios (excluding the risk-free alternative) for which there is the lowest risk for a given level of return. Conversely, the portfolio lying on the efficient frontier represents the combination offering the best possible return for a given amount of risk. Mathematically the efficient frontier is the intersection of the set of portfolios with minimum risk and the set of portfolios with maximum return.

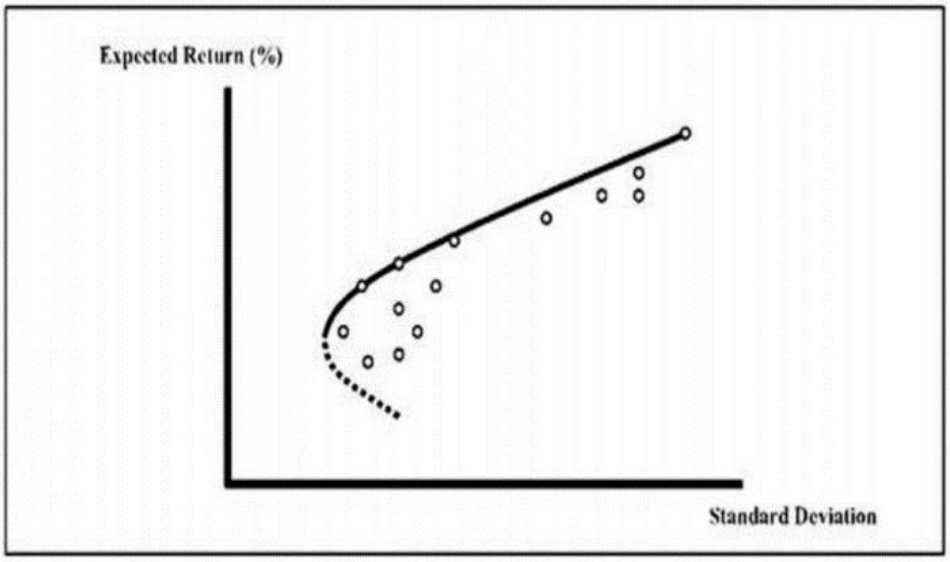

Fig. 1

The above fig.1 shows investors the entire investment opportunity set, which is the set of all attainable combinations of risk and returns offered by portfolios formed by assets in differing proportions. The combination of the specific risky assets in the portfolio plotted on the efficient frontier represents the lowest risk possible for the portfolio for the desired level of expected return or the best possible expected return for an acceptable risk level.

5. Analysis and Interpretation

5.1. Python Code for comparison using Log returns, Correlation matrix, and Markowitz Efficiency Frontier

```
import pandas as pd
import numpy as np
from pandas_datareader import data as wb
import matplotlib.pyplot as plt
assets = ['INFY.NS',
'TECHM.NS','TCS.NS','WIPRO.NS','HCLTECH.NS']
pf_data = pd.DataFrame()
for a in assets:
    pf_data[a] = wb.DataReader(a, data_source = 'yahoo',
start= '2010-1-1')['Adj Close']
(pf_data/pf_data.iloc[0]*100).plot(figsize=(10,6))
plt.show()
log_returns = np.log(pf_data/pf_data.shift(1))
log_returns.mean()*250
log_returns.cov()*250
log_returns.corr()
num_assets = len(assets)
pfolio_return=[]
pfolio_vol = []
for x in range(1000):
```

```
    weights = np.random.random(num_assets)
    weights /= np.sum(weights)
    pfolio_return.append(np.sum(weights * log_returns.mean())*250)
pfolio_vol.append(np.sqrt(np.dot(weights.T,np.dot(log_returns.cov()*250,weights))))
  pfolio_return = np.array(pfolio_return)
  pfolio_vol = np.array(pfolio_vol)
  pfolio_return, pfolio_vol
  portfolio = pd.DataFrame({'Returns':pfolio_return, 'Volatality':pfolio_vol})
  portfolio.plot(y = 'Returns', x = 'Volatality', kind= 'scatter', figsize=(10,6))
  plt.ylabel('Expected Return')
  plt.xlabel('Expected Volatality')
  plt.show()
```

5.2. Annual Logarithmic Returns, Efficiency Frontier, Portfolio return

5.2.1 Portfolio 1: Infosys and TCS

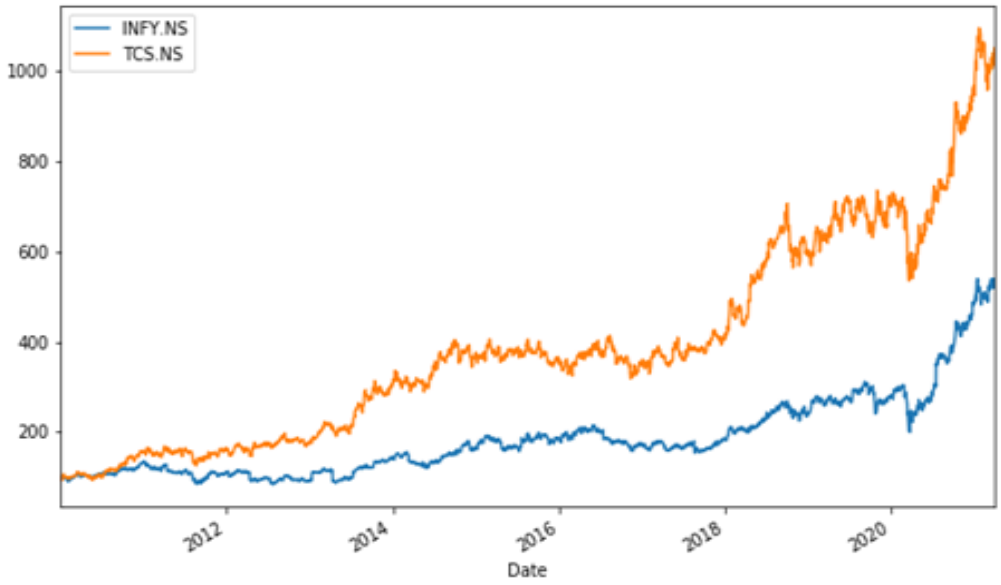

Fig. 2 Logarithmic annual returns of Infosys wrt TCS

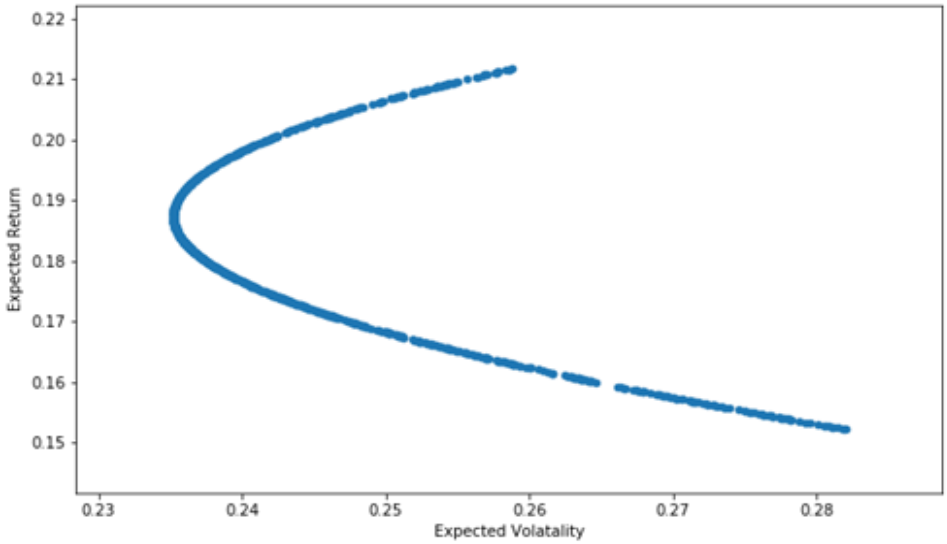

Fig. 3 Markowitz efficiency frontier with Infosys & TCS

- The Covariance of Infosys concerning TCS is 0.038347
- The Correlation coefficient of the Infosys and TCS is 0.52. This signifies that the price changes in Infosys affect the price changes in TCS by 0.52.
- Comparing the annual logarithmic returns, it is quite certain that TCS has performed much better than Infosys starting 1 Jan 2010.
- The maximum return for the portfolio is around 21%, with a risk of 25% associated with the portfolio.

5.2.2. Portfolio 2: Infosys and Wipro

Fig. 4 Logarithmic annual returns of infosys wrt wipro

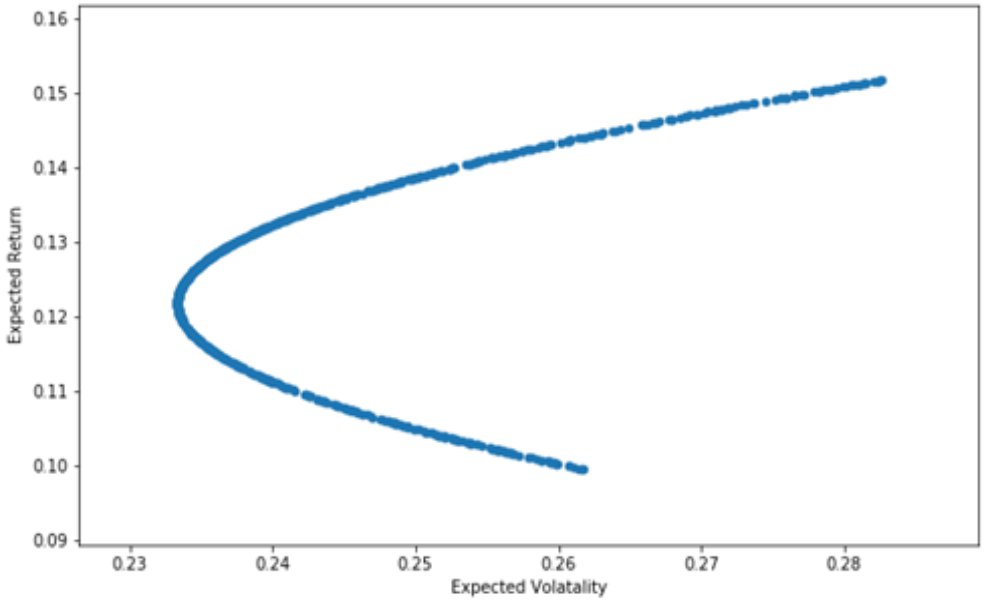

Fig. 5 Markowitz efficiency frontier with infosys & wipro

- The Covariance of Infosys concerning WIPRO is 0.035376
- The Correlation coefficient of Infosys and WIPRO is 0.48. This signifies that the price changes in Infosys affect the price changes in WIPRO by 0.48.
- On comparing the annual logarithmic returns, it is quite certain that Infosys has performed much better than Wipro starting

1 Jan 2010.

- The maximum return for the portfolio is around 14%, with a risk of 25% associated with the portfolio.

5.2.3. Portfolio 3: Infosys and HCL

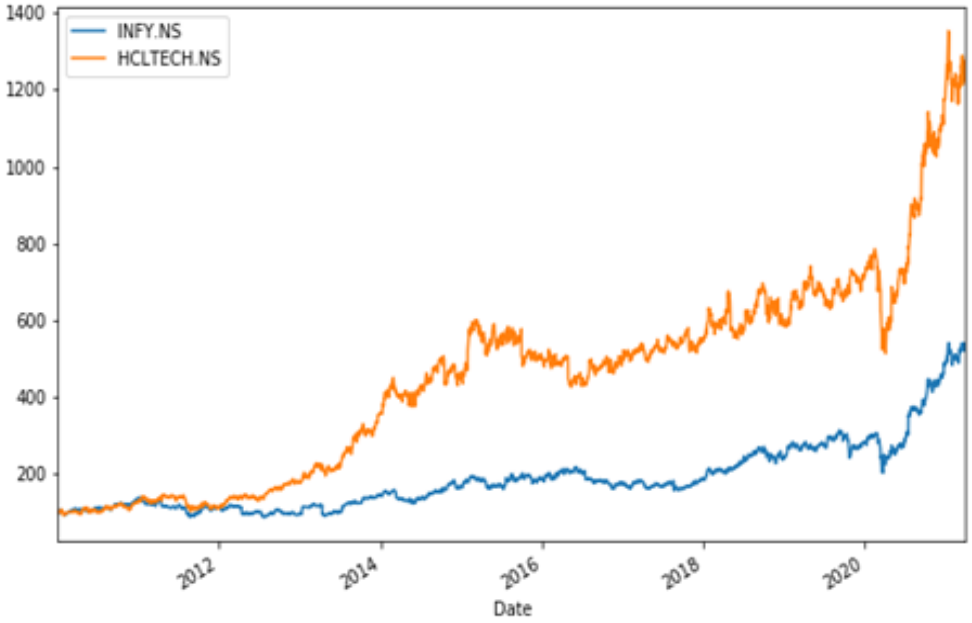

Fig. 6 Logarithmic annual returns of infosys wrt hcl

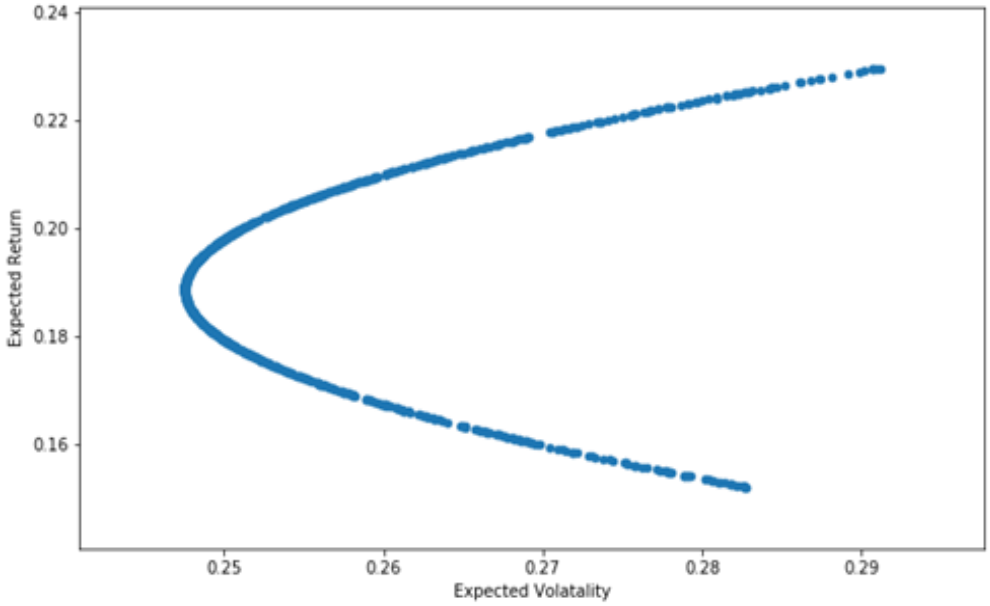

Fig. 7 Markowitz efficiency frontier with infosys & tcs

- The Covariance of Infosys concerning HCL is 0.04005
- The Correlation coefficient of the Infosys and HCL is 0.485. This signifies that the price changes in Infosys affect the price changes in HCL by 0.485.
- On comparing the annual logarithmic returns, it is quite certain that HCL has performed much better than Infosys starting 1 Jan 2010.
- The maximum return for the portfolio is around 20%, with a risk of 25% associated with the portfolio.

5.2.4. Portfolio 4: Infosys and Tech Mahindra

Fig. 8 Logarithmic annual returns of infosys wrt tech mahindra

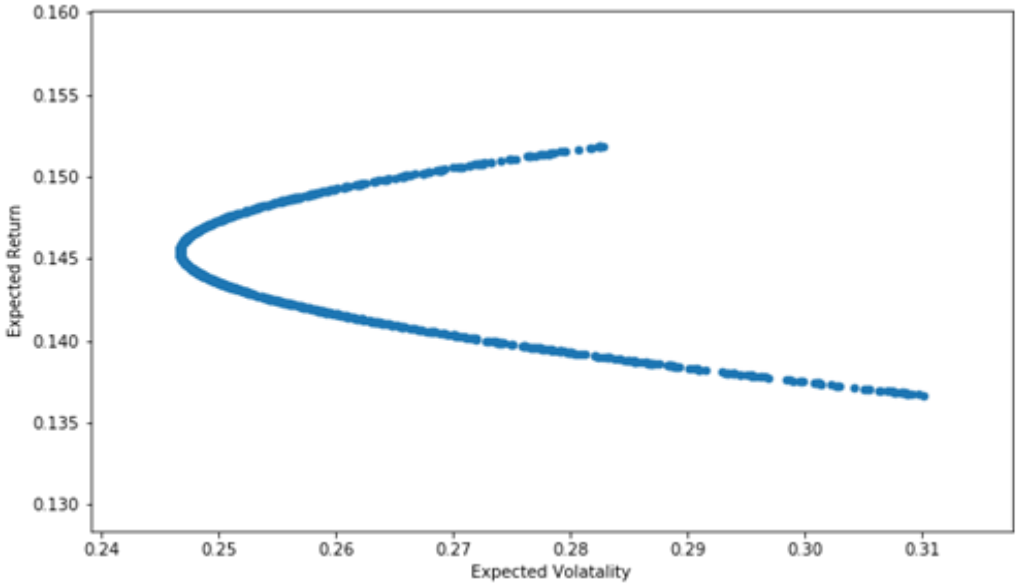

Fig. 9 Markowitz efficiency frontier with infosys & tech mahindra

- The Covariance of Infosys concerning TECH MAHINDRA is 0.03481
- The Correlation coefficient of the Infosys and TECH MAHINDRA is 0.397. This signifies that the price changes in Infosys affect the price changes in TECH MAHINDRA by 0.397.
- On comparing the annual logarithmic returns, it is quite certain that TECH MAHINDRA has performed at par with Infosys starting 1 Jan 2010.
- The maximum return for the portfolio is around 15%, with a risk of 25% associated with the portfolio.

5.3. Overall Portfolio Analysis and Efficiency Frontier

Portfolio IT Sector: Infosys and peers

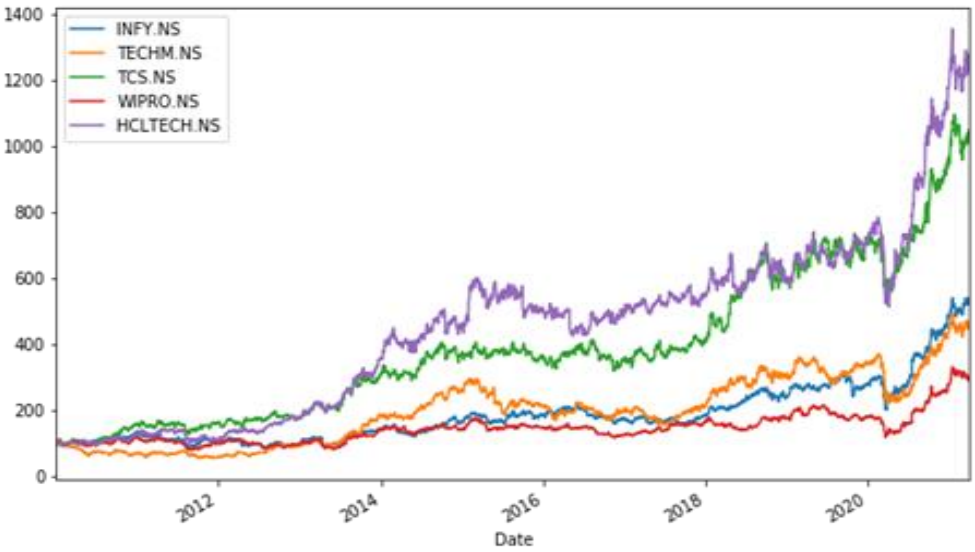

Fig. 10 Logarithmic annual returns of stocks in the portfolio

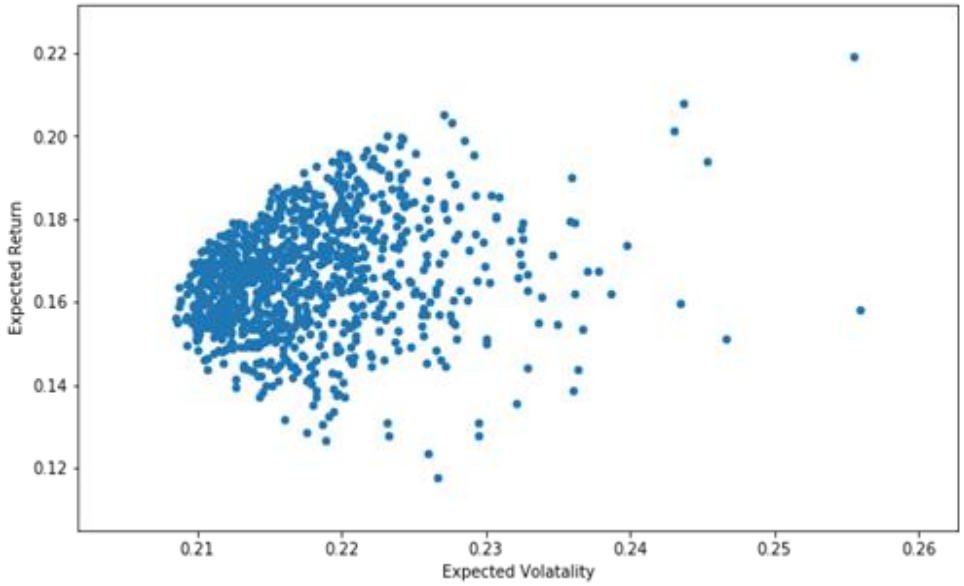

Fig. 11 Markowitz efficiency frontier for stocks in the portfolio

- On comparing the annual logarithmic returns, it is quite certain that HCL has performed much better than other peers starting 1 Jan 2010. the order of best-performing stocks is HCL, TCS, Infosys, Tech Mahindra, Wipro
- The maximum return for the portfolio is around 22%, with a risk of 26% associated with the portfolio.
- A best-fit curve can be drawn for the efficiency frontier to determine the maximum returns for a given risk. the accurate values can be found using 1st derivative of the best fit curve.

5.4. Covariance, Correlation ratios, and Inferences

Table 1. Covariance of Infosys with peers

Tech Mahindra	0.035
TCS	0.038
WIPRO	0.035
HCL	0.040

Table 2. Correlation of Infosys with peers

Tech Mahindra	0.397
TCS	0.524
WIPRO	0.477
HCL	0.485

- The covariance of Infosys, when compared to TCS, is 0.038; similarly, for Wipro, HCL, and Tech Mahindra, it is 0.035, 0.035, and 0.040, respectively.
- The correlation coefficient of Infosys wrt to TCS is 0.524 similarly, for Wipro, HCL, and Tech Mahindra, and it is 0.477, 0.397, and 0.485, respectively.

6. Limitations

6.1. Data Conundrum

The data considered for analysis was extracted from the yahoo finance website, and thus there is a secondary data dependence when the analysis of this project is concerned. the inherent assumption is taken that the source data is reliable and does not have errors and thus best supports the analysis performed in the report.

6.2. Assumptions to theory

The data the Portfolio Theory of Markowitz is based on the following assumptions:

- Investors are rational and behave to maximize their utility with a given level of income or money.
- Investors have free access to fair and correct information on the returns and risks.

The first assumption does not comprehend real-life market situations. the markets are dynamic, and the investment decisions are not always rational. Investors' decision to invest depends on peer review, market research, data flowing in the newspapers, and most importantly, own sentiments.

The second assumption also does not hold in every market, and there is always some insider trading. and this provides leverage to the one who has access to the data and uses it to make capital gains from the market.

7. Conclusion

- The logarithmic returns graph portrays a picture of Infosys with its peers in the IT sector. the firm has done well when annual logarithmic returns are compared with Wipro and Tech Mahindra, but the firm has not performed up to the mark of HCL and TCS. the normalized price curve above Wipro and Tech Mahindra bolsters the statement above. Whereas the price curve of Infosys below TCS and HCL price curve indicates, the firm has not outdone these peers.
- Variance is the square of standard deviation and standard deviation of a firm that accounts for total risk associated with it, i.e., systematic and unsystematic. the covariance matrix found after the simulations provides a relationship between the stocks, i.e., Variance of Infosys not with any benchmark but with each peer taken for this analysis and the name covariance. the covariance matrix is not enough to find the relationship between the stocks, and therefore we require a correlation matrix. the numbers on the correlation matrix are less than one and thus signify that the stocks used for analysis are perfect for a portfolio as they are not related. Because an investor would like to diversify her portfolio and add stocks that are not correlated. If one stock hits a trough, the other stocks remain on the crest to account for the losses from the given stock in a downward price trend.
- The risk to return for each of the four portfolios was calculated. It was done for a portfolio of all 5 stocks considered (called the IT sector portfolio in this study). When presented on the x and y-axis, the risk and return portray Markowitz's efficiency frontier for every considered portfolio. the efficiency frontier provides insight on maximum gains an investor can make given the amount of risk she is willing to take.
- This study can be broadened to account for any risk-free securities in the portfolio. It can be achieved by using Capital Market Line, which connects Rf and a point on the efficiency frontier tangent to the frontier. Thus, an investor can gauge blurred returns she can avail by placing her money in any given portfolio**.**

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