Application of Modern Portfolio Theory on the China Stock Market from 2018–2022

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Abstract—**Modern portfolio theory is the theory of investment that allows the investor to construct a portfolio that maximizes the expected returns for the given risk level. With the medium of this report, the main intention is to present the application of the modern portfolio theory on the stock market of China. For this purpose, the data is collected between 2018-2020. The portfolio undertakes the 10 listed companies' stock for the Chinese stock exchange that is Shanghai Stock Exchange. The three portfolios have been prepared with the allocation of these 10 stocks. First, the minimum variance portfolio, Secondly, the maximum returns portfolio and lastly, the optimal portfolio maximizing the Sharpe ratio has been generated. For all three portfolios, the efficient frontier has also been generated. The results of the portfolio stated that the MVP has the highest risk with low returns, while the maximum returns portfolio has the highest returns with low risk and lastly the optimal portfolio provides the highest risk-adjusted returns.**

Keywords—**Chinese stock market, modern portfolio theory, portfolio optimization risk-adjusted returns, Sharpe ratio**

I. INTRODUCTION

A. Background

The Markowitz modern portfolio theory is the widely used method for selecting different investments with the main aim of maximizing the overall returns of the portfolio with an acceptable risk level (Mittal *et al.* 2021). It is the mathematical framework that is widely used by investors for maximizing their investment returns while minimizing the risk for the investment by constructing the assets portfolio. The theory assumes that the investors are risk-averse and rational which states that they tend to undertake additional risk only at the cost of proper compensation in the form of increasing returns, and investors have all the relevant information relating to the assets that they are considering for their investment. This research mainly focuses on the application of modern portfolio theory in the stock exchange of China.

The China Stock Exchange is termed one of the most volatile markets in the world. There are mainly two stock exchanges in the country which include the Shanghai stock exchange and the Shenzhen stock exchange. With the growing stock exchange in the country, there has been growth seen in the fluctuation and volatility in the stock exchange of China (Wen *et al.* 2021). There are major speculative activities that take place by buying and selling various stocks based on rumors, herd behavior, misinformation, short-term trading, etc. with the ultimate aim of making profits quickly. Therefore, there is a large-scale investment by investors that took place in the stock that has a high-risk level without proper analysis and due diligence. In this study, the application of the modern portfolio theory on the stock market of China has been tested.

B. Related Research

The literature provides extensive studies conducted on the Markowitz model, In the study by Gunjan & Bhattacharyya, (2023) the review of the modern portfolio theory and optimization has been done. The study found that portfolio optimization has been unable to properly manage risk in the portfolio. However, the downside of the Modern Portfolio Theory (MPT) theory is that it has been facing the challenges of the irrational movement of the market, and as a way of reducing this problem behavioral finance has been introduced. In another study by Lin *et al.* (2023) the main findings of the MPT have been stated. It further states that the optimal allocation of risk is an essential tool for ensuring the portfolio in the market. In the study (Cui & Cheng, 2022) the application of the modern portfolio theory in Australia has been tested. The results of the study stated the MPT does not make any significant difference in the performance of the portfolio with optimization. However, it further stated that the MPT can play better in the international financial market which is highly volatile. Therefore the study gave the idea that the MPT is the better model to be utilized in highly volatile and speculative markets.

There have been various studies conducted in which the implementation of the modern portfolio theory on the stock market of China has been estimated. In the study by Xiao, (2021) a review of the portfolio theory application taking the case of the Chinese stock market has been undertaken. It was found in the study that the CAPM model does not seem to be fully applicable to the stock market of China. This is because various other factors also have a significant impact on the performance of the stocks and therefore the Fama French 5-factor model explains the movement in the share prices more efficiently. In another study by Vo (2019) portfolio optimization and diversification have been applied to the China stock market. The findings of the study conclude first that diversification is essential for managing risk. In the Chinese market, the fluctuations and volatility are high scales and the only way for managing the risk and achieving higher returns is by mitigating the risk through diversification. Furthermore, it has been stated in the study that a long-term holding strategy plays a vital role in enhancing the returns of investment in China. It enables the country to achieve a sustainable rate of growth and development. Furthermore, it has been recommended that investors in Vietnam should focus on long-term investment along with selecting quality companies with sound fundamentals.

C. Aim and Objective

The main aim of the study is the make the application of

modern portfolio theory on the stock market of China taking the period between 2018–2022. The following is the objective of the study first to determine the minimum variance portfolio and take the stock listed on the stock market of China. Secondly, to determine the optimal portfolio, take the stock listed on the stock markets of China. Third, to determine the maximum return portfolio by taking the stock listed on the stock market of China.

II. MODERN PORTFOLIO THEORY

A. Instruments of Modern Portfolio Model Based on Historical Data of Stock Prices

1) Rate of return

The rate of return of the individual stock refers to the increase or decrease in the investment value for a specific time. The rate of return is estimated by dividing the value of the change in investment by the initial value (Krishnamoorthy & S, 2022). In this study, the monthly rate of returns is estimated, and then the average returns that the stock has generated for the given period. The portfolio return is estimated by taking the weighted average of the returns of each stock and their corresponding weights.

2) Expected return

The expected return is the anticipated rate of returns that the investor expects to earn. As per the CAPM model the expected returns are equal to the risk-free return minus the market risk premium into beta (Zhou, 2021). Where the beta is the measure of systematic risk of the stock, market risk premium is the returns from the market minus the risk-free return. The CAPM is the most widely used for estimating the expected returns of the individual stock.

3) Standard deviation

Standard deviation estimates the volatility of the stock returns by quantifying the variability and dispersion in the stock returns around its mean returns. The higher the standard deviation means that the returns of the stock are spread across the average returns stating a higher risk level. The portfolio standard deviation measures the volatility of the entire portfolio (Aragon & Ferson, 2006). The portfolio SD is estimated by first determining the weight of each stock in the portfolio then calculating the covariance between the returns of pairs of the stock and then the weights and standard deviation are used for calculating the portfolio variance and the square root of the portfolio variance is the portfolio standard deviation.

B. Variance and Covariance

The variance of stock returns estimated is the extent to which the stock returns deviate from the expected returns. It measures the degree of volatility of the stock. The covariance measures the degree to which the two stocks move together (Banchit *et al.* 2020). The variance and covariance are mainly estimated for stock and portfolio to understand the characteristics of the investment and make informed investment decisions.

C. Markowitz Model

The Markowitz model was introduced by Harry Markowitz in the year 1952 which provides a mechanism for the investor to maximize the returns while minimizing the risk in their portfolio (Markowitz, 1952). The model is a widely used statistical model for constructing the optimal portfolio (Miller, 2023). The Markowitz model mainly states that the investors are required to diversify their portfolio across different assets and stocks to mitigate the risk. Diversification is the process in which the investors add a variety of assets to their portfolio to mitigate the risk. It allows the investor to earn higher returns for the given risk level. Though the model is widely used in investment management, still has a certain limitation which includes first the model assumes that the returns are normally distributed and secondly, there are no liquidity constraints and involvement of transaction costs. Such unrealistic assumptions are somehow the limitation of the model.

D. The Efficient Frontier

The concept of Markowitz model mainly relies on the concept of the efficient market frontier. The efficient frontier is the set of optimal portfolios that provides the highest possible expected return for the given level of risk (Sánchez-Granero *et al.* 2020). The Markowitz model estimated the efficient frontier by measuring the correlation between the volatilities and the assets returns and by considering the risk aversion level of the investor. The main significance of the frontier is that helps in making rational decisions for the investment by identifying the optimal portfolio providing the highest expected returns for a given risk (Maiti, 2021). The efficient frontier tends to shift with time due to various market conditions as well as the performance of individual stocks. Therefore, the investors are required to closely monitor the curve and adjust the portfolio to ensure that they are required to remain on the efficient frontier to achieve higher returns for their risk level.

E. Sharpe Ratio

Sharpe ratio is the risk-adjusted measure that was introduced by William F. Sharpe in the year 1966. It is estimated by dividing the value of excess return for the portfolio by the standard deviation of that portfolio (Barillas *et al.* 2019). The higher Sharpe ratio represents that the risk-adjusted performance of the portfolio is better. The formula used for measuring the Sharpe ratio is portfolio return- Risk-free rate of return/Portfolio standard deviation. Though the measure is useful for analyzing when the portfolio generates excess returns and comparing the performance of the various portfolios at different risk levels there is a certain limitation of the measure. The Sharpe ratio assumes that the returns are normally distributed which is not possible in reality (Wang *et al.* 2022). Furthermore, the measure does not take into account the abnormalities of the distribution of returns and various extreme market situations that can have a significant impact on portfolio performance. However, even though there are certain limitations the Sharpe would always remain a useful tool for those investors who seek to evaluate the portfolio's risk-adjusted performance.

III. EVALUATION AND REVIEW OF RESULTS

A. Selecting Stocks

The first step toward the construction of a portfolio is

selecting the stocks. Following the modern portfolio theory, diversification has been the key element of the stock selection process. Diversification across Chinese industry and correlation analysis are used for selecting stocks and the stocks with the least correlation are added to the portfolio to get the maximum benefit of portfolio diversification (Koumou, 2020). Ten stocks including Kweichow Moutai Co., Ltd, Industrial and Commercial Bank of China Limited, Shanghai, Wondertek Software Co. Ltd, Joeone Co. Ltd, Comefly Outdoor Co. Ltd A, Yantai Yuancheng Gold Co. Ltd A, Changzhou Langbo Sealing Technology Ltd A, CIG Shanghai Co. Ltd A, Dawning Information Ltd, PetroChina Company.

B. Risk and Return of Individual Stock

Once the stocks are selected the next step is to calculate the risk and returns of the individual stock. The adjusted closing monthly price for each stock for the last 5 years from 2018–2022 are taken from Yahoo Finance. The adjusted closing price is used for estimating the monthly returns of the stock. The monthly return is estimated by dividing the change in adjusted price by the initial adjusted price. The estimated average returns for the last 5 years for each of the stocks are estimated and annualized. Next, the standard deviation is estimated by using the STDV.S function from Excel and then the annual SD is estimated by multiplying the average SD with the square root of 12. The following table shows the average and annual returns and SD.

Table 1. Risk and return of individual stock

	Average returns (%)	Annual returns (%)	Monthly SD (%)	Annual SD (%)
Kweichow Moutai Co., Ltd	1.98	23.8	10	34
Bank of China Limited	−0.39	−4.7	4	15
Shanghai Wondertek	1.13	13.5	13	44
Joeone Co. Ltd	0.15	1.8	9	32
Ltd A	2.81	33.7	18	62
Yantai Yuancheng	2.23	26.8	14	48
Changzhou	2.69	32.2	19	65
CIG Shanghai	1.05	12.6	15	51
Dawning Information	1.36	16.3	11	37
PetroChina Company	−0.42	−5.1	7	24

1) Minimum risk portfolio

The minimum risk portfolio is the combination of stocks in the portfolio that provides the least risk. It is also known as the global minimum variance portfolio which provides the lowest risk possible across all the portfolios that could be generated for the given set of assets (Fahmy, 2020). To get the weights for the minimum variance portfolio the solver function in Excel is utilized. The various constraints in the portfolio are used which include first that the portfolio risk is minimized. Secondly, the sum of the weights of all portfolios is equal to 1. The third constraint is that short selling is allowed. The following portfolio shows the estimation of the global minimum variance portfolio.

Table 2. Results of minimum variance portfolio

	Weights (%)	Returns (%)	SD (%)
Kweichow Moutai Co., Ltd	2.76	2	34
Industrial and Commercial Bank of China Limited	67.28	0	15
Shanghai Wondertek Software Co. Ltd	5.35	1	44
Joeone Co. Ltd	8.08	0	32
Comefly Outdoor Co. Ltd A	0.08	3	62
Yantai Yuancheng Gold Co. Ltd A	2.69	2	48
Changzhou Langbo Sealing Technology Co. Ltd A	0.00	3	65
CIG Shanghai Co. Ltd A	0.10	1	51
Dawning Information Industry Co. Ltd	11.69	1	37
PetroChina Company Limited	1.98	0	24
	100		
Portfolio returns	0.08		
Annualized Return	0.96		
Variance	0.12		
SD	3.43		
Annualized SD	11.90		

The results of the minimum variance portfolio show that the minimum variance of the portfolio is 11.90% which would provide portfolio returns of 0.96%. The highest weightage has been allocated to Industrial and Commercial Bank of China Limited since it has the lowest possible SD amongst the other stocks. The lowest weightage has been allocated to Changzhou Langbo Sealing Technology Co. Ltd since it has the highest individual risk of 67.28% and has the lowest risk amongst the other stocks available.

2) Efficient frontier of minimum risk portfolio

The minimum variance portfolio lies at the lowest point in the efficient frontier which provides the lowest possible risk given the expected returns of the portfolio. The efficient frontier for the MVP has been created by varying the proportion of assets in a different portfolio. Each of the portfolios on the efficient frontier provides the highest return for its given risk level.
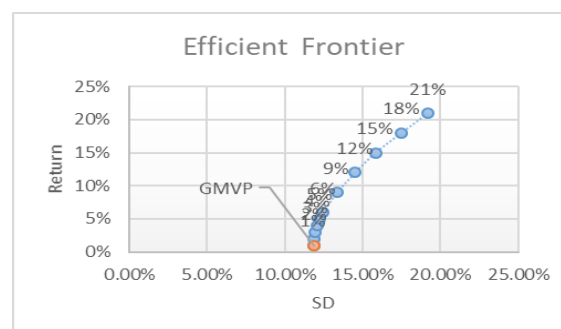

Fig. 1 Efficient frontier for minimum variance portfolio.

The graph presents the efficient frontier for the minimum variance portfolio in which the expected returns are shown on the y-axis and the risk is shown on the x-axis. The graph states minimum variance portfolio is the one that has the lowest risk with the lowest returns and as the returns increase the risk also starts to increase leading to an upper portfolio lying on the efficient frontier.

C. Maximum Return Portfolio

The maximum portfolio return provides the highest possible portfolio return for the given level of risk of the portfolio. To attain the maximum return portfolio, the solver

function with constraints to find the weights for each stock to achieve the maximum returns for the portfolio has been estimated. This constraint includes first the portfolio return has been maximized. The sum of the weights of each stock is kept equal to 1. The following is the estimation that has been obtained for the maximum returns portfolio.

Table 3. Maximum return portfolio

	Weights	Returns	SD
Kweichow Moutai Co., Ltd	0	1.98%	34%
Bank of China Limited	0	−0.39%	15%
Shanghai Wondertek	0	1.13%	44%
Joeone Co. Ltd	0	0.15%	32%
Comefly Outdoor Co. Ltd A	0.999	2.81%	62%
Yantai Yuancheng Gold	0	2.23%	48%
Changzhou Langbo Sealing	0	2.69%	65%
CIG Shanghai Co. Ltd A	0	1.05%	51%
Dawning Information	0	1.36%	37%
PetroChina Company	0	−0.42%	24%
	100.00%		
Portfolio Return	2.81%		
Annualized Return	33.75%		
Variance	3.19%		
SD	17.870%		
Annualized SD	61.905%		

The estimation of the maximum returns portfolio shows that the highest possible returns that can be earned is 61.905% and the weight is entirely allocated to a single stock that is Comefly Outdoor Co. Ltd which provides a risk of 17.870%. Therefore, for attaining the maximum returns in the portfolio the risk has also increased to a large extent. However, this portfolio no longer provides the benefits of diversification as the entire weightage has been allocated to a single stock.

D. Efficient Frontier of Maximized Portfolio Return

The maximum returns portfolio lies on the highest point on the efficient frontier. It is the point that offers the highest expected returns for a given risk level. For getting the maximum return portfolio the portfolio has been optimized in which the returns are maximized as shown in the graph.
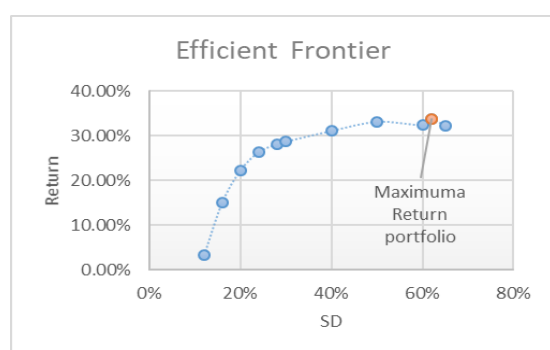

Fig. 1. Maximum returns portfolio on the efficient frontier.

The graph depicts the maximum returns portfolio, which lies on the highest point on the frontier. It can be seen from the graph that at the point after the maximum return portfolio the frontier started to decline to provide lower returns. Therefore, the investor can achieve high returns when undertaking higher risk. Since the higher the risk the higher the returns from the investment.

E. Optimal Portfolio –Maximum Share Ratio Portfolio

The optimal portfolio provides the highest possible returns for the given risk level. It provides the highest risk-adjusted returns of the portfolio. To obtain the optimal portfolio using the solver function, the Sharpe has been maximized. Therefore, maximizing Sharpe provides weights to individual stock in such a way that it provides the highest possible returns for the given level of risk. Any point above the optimal portfolio or tangency portfolio is considered non-optimal it would have a high risk for low returns. The main constraint includes the sum of the weight of each stock being kept as equal to 1. Short selling is not allowed. The following table shows the estimation of the optimal portfolio.

Table 4. Optimal Portfolio (Sharpe ratio maximization)

	Weights	Returns	SD
Kweichow Moutai Co., Ltd	46%	24%	34%
Bank of China Limited	0%	-5%	15%
Shanghai Wondertek	0%	14%	44%
Joeone Co. Ltd	0%	2%	32%
Comefly Outdoor Co. Ltd A	7%	34%	62%
Yantai Yuancheng Gold Co.	22%	27%	48%
Changzhou Langbo Sealing	9%	32%	65%
CIG Shanghai Co. Ltd A	0%	13%	51%
Industry Co. Ltd	16%	16%	37%
PetroChina Company Limited	0%	−5%	24%
Portfolio returns	24.73%		
Portfolio risk	21.687%		
Risk-free return	2.73%		
Sharpe ratio	1.015		

The estimation shows that in the optimal portfolio, the highest Sharpe that can be achieved is 1.015. At this maximum, Sharpe the portfolio can earn a return of 24.73% and a portfolio SD of 21.687%. The risk-free return is taken as 2.73% which is the rate 5-year T-bill rate in China. The weight allocated in the optimal portfolios is in such a way that Kweichow Moutai Co. Ltd has the highest proportionate investment with 46% of the total portfolio. In the optimal portfolio, the allocation will be made only in the 5 stocks since the others have 0% investment in them.

F. Efficient Frontier of Optimal Portfolio

The ultimate aim of the efficient frontier is to determine the optimal portfolio. The optimal portfolio is the one that provides the highest risk-adjusted returns for the portfolio. It is considered the most suitable portfolio for the investor since it provides the highest returns for the given risk level. The graph below shows the optimal portfolio which maximizes the Sharpe of the portfolio.
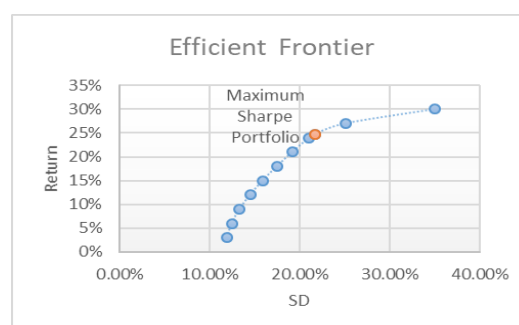

Fig. 3. Optimal portfolio–maximum Sharpe portfolio.

The graph above depicts the position of the optimal portfolio that lies between the other portfolios. The portfolio above the optimal portfolio offers higher returns but with a higher level of risk. On the other hand, the portfolio below the optimal portfolio is the one that has lower returns for the lower risk level. However, the maximum Sharpe portfolio is the one that offers the highest risk-adjusted returns to the portfolio

IV. DISCUSSION

The MPT uses the diversified portfolio of investment which seeks to maximize the expected returns of the portfolio at a given level of risk. By applying MPT to the stock market of China it has been found that diversification plays a vital role in portfolio investment. Various largely growing industries in China are providing high returns with high risk also therefore to earn higher returns with lower risk levels there is a wider need for diversification in the stock market of China. The key findings state that, with the minimization of the risk, there has been an increase in the portfolio returns. Therefore, MPT in China's stock market supports the argument by Coqueret (2014) that stated the performance of the MVP is somehow lower than the optimal and maximum returns portfolio because the objective of the portfolio was to reduce the risk of the portfolio. Therefore, the MVP provides the lowest risky portfolio however with lower risk the returns are also low.

The second portfolio is the maximum returns portfolio indicated that when the returns have increased the diversification in the portfolio has been reduced. Furthermore, it has been found that the increasing returns also lead to increased risk in the portfolio. Compared to the other two portfolios, it has generated the highest returns however the risk of this portfolio is also the highest among the other two portfolios. The last portfolio generated is the optimal portfolio in which the Sharpe has been maximized. The Sharpe maximization provides the allocation of the stocks in such a way that risk-adjusted returns of the portfolio have increased. On comparing the three portfolios it has been found as shown in graph 4 that MVP has the lowest risk for the lowest returns among the three portfolios, whereas the maximum returns portfolio has the highest risk for the highest returns and the optimal portfolio has the risk-adjusted return.
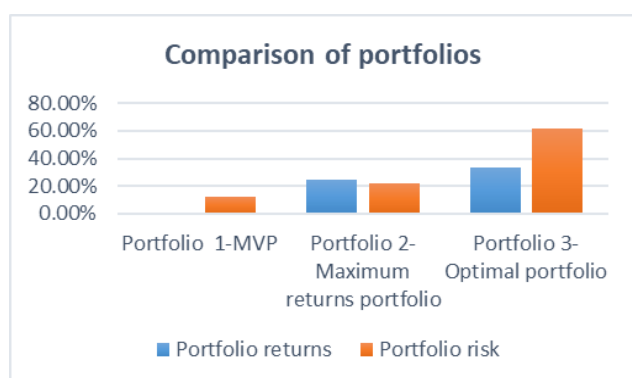

Fig. 4. Comparison of risk and return of portfolios.

V. CONCLUSION

In conclusion, in conclusion, investors employ Markowitz's theory to build optimal portfolios, considering expected returns, stock correlations, and risk attitudes of investors. Each type of investment has some certain level of risk and the factor responsible for the determination of the favorable investment for the portfolio is the compatibility between the risk that the investors want to take and the individual return of the stock. Furthermore, it is that diversifying the portfolio by including no. of stocks can help in the reduction of the portfolio's risk level. Next, from the construction of the three portfolios, it is concluded that the efficient frontier and optimization process helps analyze the best portfolio that meets the needs of the investors. The efficient frontier helps identify the optimal mix of assets that enables the investor to balance the returns and risk. It has been found that by utilizing efficient frontier the investors are in a better position to manage the risk by identifying the optimal risk level which they should take based on the objective of the investment. With the help of the efficient frontier, the investor can easily determine the minimum amount that is necessary to achieve the desired return level. Overall, Modern Portfolio Theory proves effective in China's stock market, facilitating portfolio diversification, allocation, and performance evaluation.

While the study highlights the effectiveness of the MPT in the Chinese stock market, it also acknowledges several limitations. Firstly, the study mainly focused on the application of the Markowitz model in the MPT and overlooked the other essential factors including behavioral sentiments, geopolitical risks, and economic conditions. Secondly, the study assumes that the investors are rational, overlooking the impact of cognitive biases and emotions on decision-making. Thirdly, the study's portfolio construction is limited, restricting the universality of its findings. Lastly, practical constraints such as liquidity and transaction costs are not factored into the optimization process.

In future studies, the integration of behavior finance in portfolio construction can be done which includes emotions, cognitive biases, and undertake samples beyond China to find the effectiveness of MPT in various countries. Furthermore, there has been wider advancement in big data and machine learning which can utilize larger data for getting universal results and provide accuracy in the estimations of risk, returns, and portfolio estimates.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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