WEP Warwick Evans Publishing

Transactions on Economics, Business and Management Research
ISSN: 2960-1789, eISSN: 2960-2254 | Volume 13
BMMFT 2024

Empirical Analysis of the Portfolio Theory

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Abstract. As financial markets expand rapidly, investors face complex challenges while pursuing high returns. Therefore, it is necessary for investors to have knowledge of investment theory so that they can take a more rational approach to the actual investment process and decision-making. Portfolio theory, proposed by Markowitz, emphasizes the reduction of risk through diversified investment and becomes the basis of modern financial theory. This paper introduces the basic principles and assumptions of portfolio theory and shows how to apply this theory to portfolio optimization in Excel. Three stocks, Tesla (TSLA.O), Mediea Group (000333.SZ) and Wuliangye (000858.SZ), were selected as examples in this research. It is found that the Markowitz model performs well in reducing risk and increasing the Sharpe ratio, but there are problems with high computational complexity and ideal assumptions in practice. It can be found that portfolio theory plays a key role in asset allocation and risk management, providing some reference for investors and improving direction for future research.

Keywords: Portfolio Theory; Markowitz Model; Risk and Return.

1. Introduction

In the current economic environment, the global investment market is rapidly expanding. According to the World Bank, the global financial market reached $286.5 trillion in 2019, nearly double a decade ago [1]. This increase is not accidental but results from a combination of many factors. First, accelerating global economic integration has brought closer economic ties between countries and more capital flows, providing a broad space for expanding financial markets. Second, the development and application of emerging technologies such as fintech, blockchain and digital currency have changed the operation mode of traditional financial business and brought new growth points and investment opportunities to the financial market [2]. Third, national governments have introduced a series of supportive policies to promote economic growth and financial market stability. These policies have not only lowered the market access threshold and attracted more investors and financial institutions to participate in the market but also strengthened regulatory cooperation and improved the transparency and stability of the financial market. In addition, increasing investor confidence is also an essential factor driving the expansion of financial markets. Despite the challenges and uncertainties in the global economy, investor confidence in financial markets has not waned [3]. Instead, with the economic recovery and the improving market environment, more and more investors begin to look to the financial markets for higher returns and more investment opportunities.

As it's known to all, the ultimate goal of investors is to achieve the maximum return on investment while controlling the risk. However, investment decisions face many challenges, including market uncertainty, information asymmetry, and investors' different risk preferences [4]. In order to solve these problems, portfolio theory has arisen at the historical moment and has become an important research direction in finance and investment circles. However, despite the importance of portfolio theory in the financial field, not all investors can fully understand and skillfully use this theory to conduct portfolio construction. Many investors may know very little about the basic concepts and principles of the theory and still less about how to apply them effectively in practical investment decisions. This situation may lead them to face higher risk in the investment process, be unable to

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achieve steady growth of assets, and even suffer unnecessary losses due to the lack of scientific investment guidance.

Investors with little understanding of portfolio theory may rely too much on a single asset or market and ignore the correlation between assets, which leads to a risk that is too high for the portfolio [5]. In addition, they may be unable to accurately assess the risk and return potential of different assets and make scientific investment decisions.

Therefore, investors need to understand and master the portfolio theory. By learning this theory, investors can better understand the correlation between assets, master the principles of diversification, and reduce the investment portfolio's risk. At the same time, investors can apply this theory to real life to help them find the best portfolio.

2. Methodology

2.1. Definition

Portfolio theory is a financial theory first proposed by American economist Markowitz in 1952 [6]. It suggests that investors should diversify their risk. This means that investors should allocate money to different types of assets, such as stocks, bonds, and cash, to maintain expected returns while reducing investment risk. It is the foundation for developing a series of critical modern financial theories [7].

2.2. Theory and Hypothesis

The portfolio theory is based on several hypotheses, which will be listed below.

Hypothesis 1. The more money investors want, the better, and the utility is becoming more and more a function of wealth, but its marginal utility is decreasing. Hypothesis 2. Investors know ahead of time that the distribution of returns on investments is normal. Hypothesis 3. The expectation value is the highest, and the expectation value is a function of expectation rate and risk. Therefore, the main influencing factors are expected yield and risk. Hypothesis 4. The investors dislike the risk, which is expressed by the variance or standard deviation of the expected return. Hypothesis 5. Investors are sensible. His principle is to select the least risky securities with the same expected return or to choose the one with the highest expected return. Hypothesis 6. The effectiveness of the market, that is, all the information in the market is known. Suppose that the type of asset that can be invested in the whole market is n, and the rate of return for each asset is $r_1, r_2, r_3, \ldots, r_n$, The proportion of each asset in the portfolio is $w_1, w_2, w_3, \ldots, w_n$, and the return rate of the portfolio is r_p . Thus, the expected return rate of the portfolio formula can be expressed as Equation (1).

$$E(r_p) = \sum_{i=1}^{n} \omega_i E(r_i) \tag{1}$$

Inside, $\sum_{i=z}^{n} \omega_i = 1$, the variance formula is presented in Equation (2).

$$Var(r_p) = \sum_{i=1}^{n} \omega_i^2 \, Var(r_i) + \sum_{i \neq j} \omega_i \, \omega_j Cov(r_i, r_j) \tag{2}$$

3. Real-Life Example Of Using Portfolio Theory

3.1. Data and Method

Three articles were collected from the Choice Financial database to avoid the impact of excessive daily data samples on portfolio results [8]. The four-year day closing price of a stock, with dates ranging from July 26th, 2020, to July 26th, 2024. The three stocks are Tesla (TSLA.O), Midea Group (000333. SZ) and Wuliangye (000858. SZ).

Tesla, an American electric vehicle and energy company, was founded on 1 July 2003 under Martin Eberhard and Penning. Tesla designs, develops, manufactures, sells and leases high-performance all-electric vehicles, energy generation and storage systems, and other related products. Tesla is the world's first vertically integrated renewable energy company, providing end-to-end clean energy services for power generation, storage and consumption.

Midea's main business includes smart household, industrial technology, construction technology, robotics, automation, and digital innovation. It offers diversified products and services.

Wuliangye is mainly engaged in liquor production and sales. The company's main product, "Wuliangye Liquor" is the typical representative of Luzhou-Flavor liquor in China. It also deals in the fields of beverage, drug, fruit, agriculture, import and export, real estate management and investment.

After selecting the three stocks, find the weight of each financial asset when the portfolio has the highest Sharpe ratio [9]. As shown in Table 1.

Table 1. The highest Sharpe ratio

Cell	Name	Original Value	Final Value
H3	Sharpe ratio	0.159674877	0.582757197

3.2. Excel Practical operation

In fact, in Excel operation, the actual use is the form of a vector, ω_i constituting a row vector, $E(r_i)$ constitute column vector multiplication, which is the return of the final portfolio $E(r_p)$.

3.2.1. Step 1: Calculate the annual yield.

First, import the daily return data of the three stocks into Excel, calculate their average daily return respectively, subtract 1, and then multiply by 252 (the days of stock opening in the year) to get the average annual return. As shown in Table 2.

Table 2. Schematic diagram of the yield rate and the standard deviation calculation

Daily average yield	0.00040714
Average annual return	0.10259876
Standard deviation (D)	0.03152123
Standard deviation (Y)	0.50038406

3.2.2. Step 2: Calculate the covariance matrix.

Table 3. Annual returns for the three companies

	YLELD RATE (Y)
TESLA	0.10260
Media Group	0.185413732
Wuliangye	0.102890107

Among them, the uncertainty risk of each stock is the standard deviation of the respective historical stock price, while the correlation risk is the covariance correlation coefficient of the historical stock price of these two stocks. The next question is, if different proportions of stocks are allocated, what is the combination of expected returns and risk? The comprehensive income is more intuitive, the linear sum of the two in Equation (3).

$$combined\ return = \omega_a \times return_a + \omega_b \times return_b \tag{3}$$

ω_a and ω_b are the weight of the two stocks, the return represents the yield rate.

The calculation of the comprehensive risk is more complicated, and the formula is as follows in Equation (4).

$$combined\ std = \sqrt{(\omega_a \times std_a + \omega_b \times std_b)^2} \tag{4}$$

$corr_{a,b}$ is the correlation coefficient of the two.

Investors can use the Excel data analysis technology of the above two formulas to calculate the expected comprehensive returns and risks under different shareholding ratios. Use these data to establish relevant tables, including the returns, risk, correlation, and 6,000 rights issues.

To calculate the comprehensive risk and comprehensive benefit, because the formula is relatively long, it needs to be carefully checked in the calculation process. Besides, note the use of the Excel absolute reference therein.

3.2.3. Step 3: Draw scatter plots.

Finally, we can get the expected return rate and the risk based on the standard deviation under different shareholding ratios [10]. Then, using the visualization tool, turn the data into a scatter plot. As shown in Figure 1.

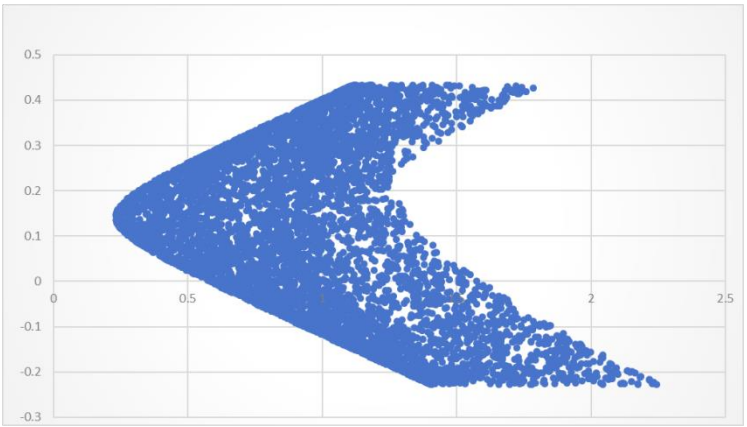

Figure 1. Scatter Plots

The horizontal axis of the scatter plot is the risk, while the vertical axis is the yield rate. From the tip to the left of this graph, the risk is lowest when the yield is between 10% and 20%. This is the best equilibrium point computed by the Markowitz mean-variance model. When staying away from this tipping point, either the yield falls and the risk increases, or the return increases, but the risk increases rapidly.

3.2.4. Step 4: Get the best investment portfolio.

The point here is that the portfolio ratio is unlimited but cannot display all the possibilities. So, it is possible to get the best portfolio of the three stocks:

Table 4. Best Portfolio

Name	Original Value	Final Value	Integer
TESLA	1	0.140451929	Contin
Media Group	0	0.864754631	Contin
Wuliangye	0	-0.00520656	Contin

4. Conclusion

Portfolio optimization has become an increasingly important area in the financial sector. The optimized portfolio has adopted Markowitz and exponential models and made extensive comparisons. This paper compares the constrained portfolio optimization of q, the Markowitz and exponential models. The Excel analysis was used to fit the data to obtain the optimal solution and make an in-depth comparison of the model effects. The results show that the Markowitz model has been widely used in the financial field, including fund management, asset allocation, and risk management, and has profoundly impacted the decision-making of financial institutions and investors. More precisely, the Markowitz model has a slight comparative advantage in more cases with lower standard deviation and higher Sharpe ratio, although the difference is insignificant. However, besides its advantages, there are several problems in the application. The Markowitz Model requires substantial estimates of expected return, variance and covariance. Therefore, as inventory size increases, the computational complexity will significantly increase. Admittedly, there are still some limitations to this study. In recent years, the stock market volatility has risen. This does not guarantee that an analysis of history can accurately predict future investments. At the same time, only three stocks were selected in the article, which does not seem enough to represent the whole industry. The model assumes that investors are rational, but real investors are often influenced by various psychological and behavioural factors, causing their decisions to deviate from rational expectations. This bias may affect the model's validity and accuracy. Therefore, more financial data and realistic factors should be considered in future studies. In conclusion, this paper provides the impetus for a deeper study of the portfolio optimization problem. In the future, the performance of the analysis on actual instances of larger problem scales or other constraints, such as the consideration of transaction costs, will be meaningful in practical application. The model needs to be appropriately adjusted and optimized according to the specific situation to improve its accuracy and applicability.

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