

Research on Portfolio Construction for the Chinese Stock Market Based on Monte Carlo Simulation

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Abstract. This paper investigated on the construction of the investment portfolio specifically in the detail of the Chinese stock market. The definition of portfolio was cited from Markowitz, then Monte Carlo simulation was used on top of it. By doing tests and experiments, results were obtained to prove the correctness of the portfolio selection, and the strategical moves of using Stock Index Futures to hedge the risk. Our empirical results indicated that Kwei Chow Moutai accounted for the largest proportion in the portfolio. It was concluded that using SPIF index to hedge the risk was the best investment strategy for the portfolio. The results in this paper shed lights for certain investors in the financial markets, set the foundation of a newer market's merit, and proved the necessity to invest it.

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1. Introduction

Markowitz first introduced “Investment Portfolio” in the year of 1952, [1] which put forward the portfolio selection for those who run a pilot to focus on investors' expectation of future returns. Moreover, Markowitz adopted statistical method to quantify the selected asset proportion and suggested investors to diversify the investment types. After the idea of portfolio presented, the investment risk has been significantly dispersed, the cash flow structure of assets has become more diversified, and people's investment strategies have become more abundant. This article laid the foundation of modern portfolio theory (MPT).

As the work of predecessor and precursor settled, meaning the finishing of the basement of all the theoretical models' construction, the successors' application of portfolio theory has also reached numerous achievements. Sharpe, in 1963, analyzed possible capital and established a portfolio with expected factors by employing a efficient calculating approach.[2] Then, Merton launched an article which put forward a new method to calculate the possible returns of combined assets, called as the “Efficient Pareto Frontier”.[3] This article constructed a visualization between return and risk, so that the investors would be able to acquire the optimum equilibrium between the two factors, which highly improved the investment efficiency. Pogue replenished the Merton's model by adding factors like transaction costs and short selling.[4] In 1992, Black and Litterman further detailed the Markowitz's model by generalizing the return of the portfolio.[5] That was the decision to delete the assumption of specific future returns of every asset.

By doing further investigations and customizing the time ranging between 2019-2021, the group picked six papers, all of which were focusing on a certain area of the investment portfolio.

The first paper is Yoshino's research, they investigated the Sustainable Development Goals' (SDG) definition and the construction for the models about the optimal allocation in SDGs.[6] The second paper is from Nhi. This paper majorly centered on the construction of investment portfolio, specifically for the deep and reinforcement learning branch. They also tested the strategy with 100

stocks globally over 30 years.[7] The third paper is a study from Tae, which majorly focused on the machine learning techniques and financial network indicators' strategies on the investment of the Global stock market.[8] The fourth paper is of Shushang and his group. They focused on the discussion of optimal portfolio when the crash risk existed.[9] This article conducted simulation analysis and an empirical study to test whether hedge portfolio could resist the crash risk. The fifth paper is the publication from Mahboubeh and Longsheng who created a portfolio by combining seven stocks launched by Shang Stock Exchange.[10] Then the portfolio was assessed by Gaussian random noise to verify the robustness of the proposed algorithm to random fluctuations. Last but not least, the sixth paper published by Indrajit revealing the relation between the investor and investing cost when they entered the stock market.[11] Moreover, several factors like income level, age, and financial assets selection would exert influence on the middle-income level family to carry out investing activities.

Despite the fact that these papers explained details about the selection of portfolio in the stock market and how to avoid extreme risks to protect the returns. They partially paid attention to either Chinese stock market or the potential market risks in foreign market risk. To the best of our knowledge, this paper makes the following contributions to the literature. First, the portfolios for representative corporations are constructed in the Chinese stock market. Specifically, the Monte Carlo simulation is employed to figure out the efficient frontier of ten assets. Meanwhile, the Maximum Sharpe Ratio and Minimum Risk Assets with specific proportion are calculated. The empirical results show that Kwei Chow Moutai weights the most in the portfolio. The third portion after the analysis is the test on the effectiveness. The performance of the portfolio in the year of 2019 is used and the dynamical alpha hedging strategies are adapted. The group also compares the performance of three strategies, position holding, underweighting, and stock index futures hedging, proving the integrity of the investment process. As of result, the stock index futures hedging offers the best outcome.

This paper is organized as follows. Section 2 shows the data and related methods. Section 3 presents the empirical results and Section 4 concludes the paper.

2. data and methods

2.1. Data

In this paper, we collect our dataset on the Chinese stock market from Jan 3th, 2017 to Dec 31th, 2018 from Tonghuashun. Specifically, we choose the stocks based on five different dimensions, their High, Low, Open, Close, and Volume. We transfer all these price data to difference-return and show the descriptive statistics in the following Table 1.

Table 1. Descriptive statistics of the selected data.

Name	min	max	mean	std	skew	kurt
Industrial and Commercial Bank of China	-0.058	0.061	4.701e-4	1.931e-4	-5.618e-5	2.713e-6
Kweichow Moutai	-0.100	0.082	1.367e-3	3.982e-4	-3.817e-4	3.172e-5
Ping An Insurance	-0.066	0.057	1.115e-3	3.426e-4	-2.668e-4	1.970e-5
PetroChina Company	-0.079	0.073	-1.143e-4	1.721e-4	4.417e-6	3.308e-7
Media Group	-0.100	0.063	1.258e-3	4.666e-4	-2.647e-4	2.047e-5
Wuliangye Yibin Co.,Ltd.	-0.100	0.0814	1.068e-3	5.374e-4	-1.631e-4	1.169e-5
Huagong Tech Company	-0.0998	0.0698	-3.208e-4	4.666e-4	2.006e-5	1.443e-6
Tongwei Co.,Ltd.	-0.100	0.100	1.200e-3	1.030e-3	-1.529e-4	1.396e-5
LONGi Green Energy Technology	-0.308	0.100	1.094e-3	1.051e-3	-1.957e-4	3.762e-5

Note: e-3 means 10^{-3} , e-4 means 10^{-4} , e-5 means 10^{-5} , e-6 means 10^{-6} , e-7 means 10^{-7} , respectively.

As shown in Table 1, most of the above nine stocks have positive performance on the average return, which indicates that the portfolio has the ability to make profits. Through the maximum and minimum, we find that most of the three offensive stocks have the phenomenon of limit up and limit

down, and the variance of offensive stocks is significantly higher than that of defensive stocks, which is consistent with our preliminary strategy. It is worth noting that the average daily return of Kweichow Moutai shares is as high as $1.367e-3$, which is very prominent in the portfolio.

2.2. Mean-variance model

Next, we need to calculate the return and variance of the portfolio. We decide to use the mean-variance model for calculation, because the hypothesis of the mean-variance model states that, first, investors evaluate the return level of the portfolio according to the expected rate of return, and they evaluate the risk level of the portfolio according to the variance, then choosing the optimal portfolio by common rules, feasible region, and effective boundary; second, investors have exactly the same expectations for the return, risk, and correlation of securities; third, there is no friction in the capital market. As for the first and second, in line with the group's investment decisions, the major concern is about the return and variance of the portfolio. We choose to dilute or even ignore other factors that affect the portfolio. For the third point, transaction costs, dividends, and information flow costs are very small compared with large-scale transactions, and we have enough reasons to ignore them, so as to simplify the model.

According to Markowitz [1], we can use the following equation (1) to calculate the expected return of the selected portfolio,

$$R = x^T \mu \quad (1)$$

Where R is the expected return of the portfolio, x is the weight of the selected assets and μ is the expected return of the assets. The following equation (2) achieve the variance of the portfolio return,

$$V = D(R) = D(x^T \mu) = x^T \omega x \quad (2)$$

Where V is the variance of the portfolio while ω is the variance-co-variance matrix of asset return. In this paper, we select the Monte Carlo Simulation to construct the portfolio.

2.3. Monte Carlo Simulation

Although the analytical conclusion of the minimum risk portfolio and the optimal Sharpe ratio portfolio is presenting, the results of the Monte Carlo model are indeed less accurate in comparison. However, in the article of Mahboubbeh and Longsheng, and in the article of Cesarone, Mango et al [12], the researchers used Monte Carlo to simulate the optimal Sharpe ratio portfolio of the stock portfolio. Thus, Monte Carlo simulation is feasible for investors to get the potential efficient frontier, thus in this paper, we also adopt the method to simulate the asset weights.

In short, the base of Monte Carlo simulation is the distribution of different parameters of a certain function and their correlation, so that a large number of random samples can simulate the function value. In this paper, the value of a function is the returns and standard deviation, and the different parameters are the different weights of nine stocks. That is to say, using a large number of simulations, the weights of nine stocks' generation are random, then us using the weights to obtain the yields and standard deviations of the corresponding portfolios.

Although randomly generating weights is an effective and convenient method for Monte Carlo simulation. If the sum of the nine generated random numbers is not equal to one, this will mean the generated portfolio does not meet the requirements and is an invalid portfolio. Therefore, in order to avoid invalid portfolios affecting the generation of effective boundaries, we divide each random number by the sum of the nine random numbers to ensure the security of the positions in our hands' engagement in investment activities, then the simulated set of portfolio returns is valid, and we can figure out the Markowitz effective frontier.

The weights of the nine stocks need to undergo the following equation (3), in which U_i is the weight of every asset, and it follows uniform distribution with range $[0,1]$.

$$\sum_{i=1}^n \left(\frac{U_i}{\sum_{i=1}^n U_i} \right) = 1 \quad (3)$$

In addition, in order to make the randomly generated revenue set of Monte Carlo simulation more credible, we select the scale of 10,000 simulations. By using the theorem of large numbers, we guarantee the result and make sure its acceptance.

3. Results

In this paper, we implement the Monte Carlo simulation 10,000 times and calculate the related portfolio return and variance. Although there are many portfolios and different returns to meet the needs of investors. In practice, it is the portfolio on the efficient frontier that raises our interests. In this paper, we focus on two specific portfolios within the effective frontier, the minimum risk portfolio and the maximum Sharpe ratio portfolio, which is defined as the excess return that can be obtained from the risk per unit of a certain portfolio. The results are shown in the following Figure 1 and Table 2, respectively.

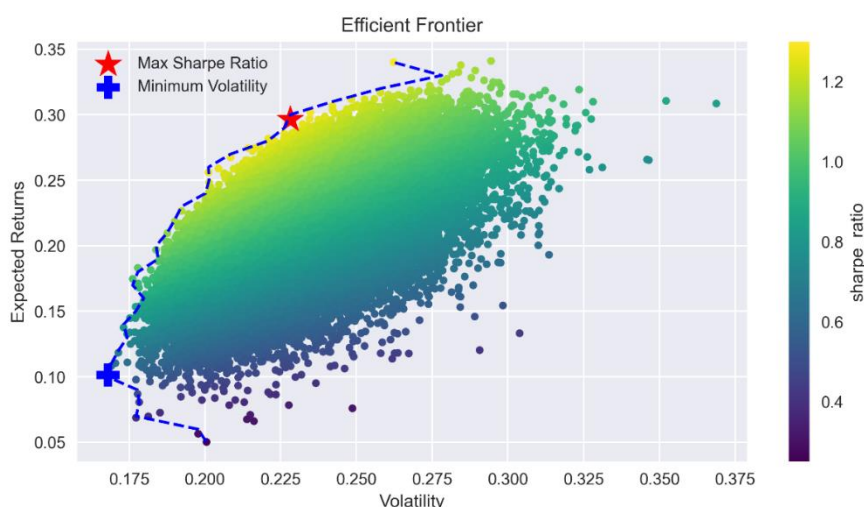


Figure 1. Efficient Frontier and Two Portfolios

Table 2. Portfolios Proportion

	Maximum Sharpe Ratio Portfolio	Minimum Variance Portfolio
Kweichow Moutai	35.47%	4.44%
Ping An Insurance	18.66%	0.72%
Industrial and Commercial Bank of China	15.47%	31.54%
LONGi Green Energy Technology	13.85%	2.28%
Media Group	11.78%	5.59%
PetroChina Company	2.6%	31.64%
Tongwei Co.,Ltd.	1.11%	2.13%
Wuliangye Yibin Co.,Ltd.	0.85%	6.80%
Huagong Tech Company	0.22%	13.96%
Return	29.65%	10.00%
Variance	22.825%	16.79%
Sharpe Ratio	129.97%	60.44%

As shown in Figure 1, in the minimum risk portfolio, PetroChina accounts for 31.64% which has the highest proportion among individual stocks. Industrial and Commercial Bank of China had the second-highest proportion, reaching 31.54%. Combining the ten shares, the yield of the portfolio is 10%, accompanied by volatility of 16.79% and Sharpe ratio is 60.44%; In the largest Sharpe ratio portfolio, Kweichow Moutai take up as high as 35.47% proportion among ten assets, and Ping an insurance is the second-largest stock asset, accounting for 18.66%. Combining the ten shares, the yield of the portfolio reached 29.65%, accompanied by volatility of 22.82% and the Sharpe ratio is 129.97%.

We believe that rational investors will choose and hold effective portfolios, that is, those that maximize the expected return at a given level of risk, or those that minimize the risk at a given level of expected return. The maximum Sharpe ratio portfolio means that the risk-return will reach the highest by paying extra unit risk, which is the most effective portfolio in our opinion, so we choose the maximum Sharpe ratio to build the portfolio.

To observe the performance of the largest Sharpe ratio combination, we will compare the performance of the combination with which of the market. In order to make the results more intuitive, we draw the net value trend chart. Assume NV is the net value of the portfolio, V_p is the present value of the portfolio, and V_i is the initial value of the portfolio,

$$NV = \frac{V_p}{V_i} \quad (4)$$

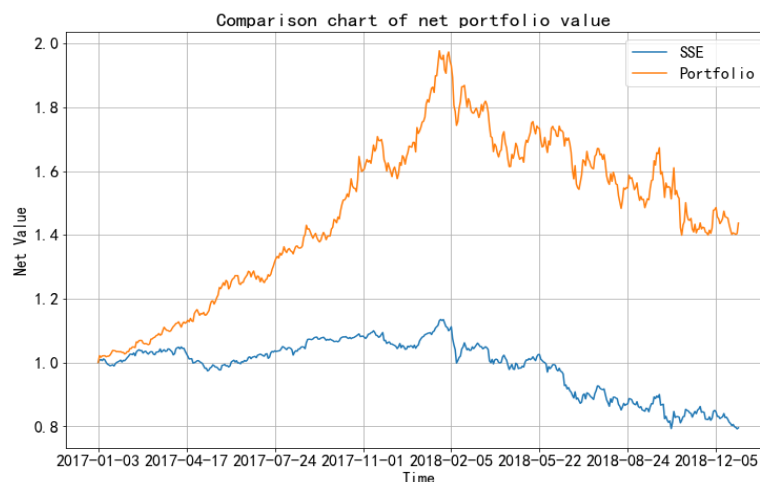


Figure 2. Comparison of the maximum Sharpe ratio portfolio and SSE index return

From the net value chart, we can see that from 2017 to 2018, the Shanghai stock index has a downward trend, but the upward momentum of the portfolio is sufficient, with about 40% of the income in the past two years.

After determining the investment portfolio, we conduct practical research, assuming that we have an initial capital of 10 million RMB. We take the portfolio of the whole natural year of 2019 as the research object. Through technical analysis, we find that most of the stocks in the portfolio send a downward signal in late April.

Based on this, we have three ways to deal with it, the first is to keep position, by which case, we not making changes to the position operation; the second is the reduction of the position, which means we will clear the portfolio positions currently held, and the gained earnings will be invested in fixed-income assets. When the market releases the upward signal, we will do a repurchase; the third method is using Stock Index Futures to hedge the market risk, in which case, it is choosing to short the Stock Index Futures and holding a long position of assets when the market release downward signals. At a certain time, the futures will hedge the risks in the spot market.

For hedging strategies, we need to determine the number of hedging hands, which is based on the parameter β . The β is estimated by a linear regression model. The estimation results are shown in the following Table 3.

Table 3. β coefficient of the selected stock

Industrial and Commercial Bank of China	Kweichow Moutai	Ping An Insurance	PetroChina Company	Media Group
0.668	1.055	1.185	0.693	1.293
Wuliangye Yibin Co.,Ltd.	Huagong Tech Company	Tongwei Co.,Ltd	LONGi Green Energy Technology	
1.332	1.261	1.305	1.123	

According to the beta coefficient of individual stocks, we calculate the beta coefficient of portfolio.

$$\beta = \sum_{i=1}^n \omega_i \beta_i \quad (5)$$

It is assumed that the β coefficient of the portfolio is β_A and the β coefficient of the futures contract is β_F (since the futures contract are stock index futures, it can be considered that $\beta_F = 1$), the current value of the portfolio is V_A and the current value of one futures contract is V_F . The number of hedging hands is N . Then N is calculated by the following equation (6),

$$N = \frac{\beta_A N_A}{\beta_F N_F} \quad (6)$$

According to the number of hedging hands, we calculate the net value of the strategy.

We compare the three strategies, and the results are shown in the following Figure by the following 3.

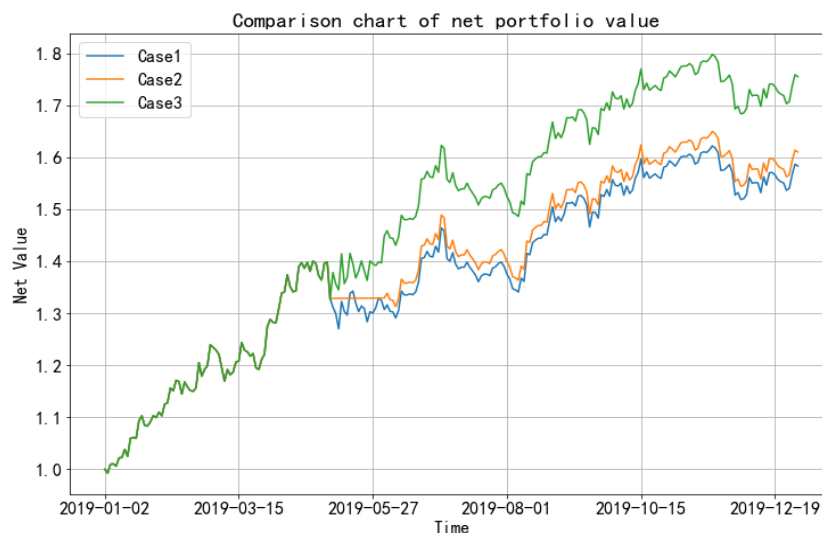


Figure 3. Comparison of the three strategies

From the performance of portfolio net value, the hedging effect of stock index futures outperforms the other two strategies, and the performance of the first strategy is the worst.

4. Conclusion

This paper made the research on the build of the investment portfolio, specifically focusing on the Chinese stock market. The group used Monte Carlo simulation based on the definition of investment portfolio created by Markowitz, in which ways, creating a different and newer branch for the whole investment portfolio's research based on the act of studying the Chinese market. The results were found to indicate that Kwei Chow Moutai weighted the most in the portfolio, and also it was proven that using SPIF index hedging the risks would bring us most benefit. However, this paper is not flawless. The data was majorly constructed to concete between January 3rd of 2017 and December 31st of 2018, but there were also necessities to use data from other years. Instead, we believed using the date between January 3rd of 2017 and December 31st of 2018, not the years of, for example, 2008, which was a year of economic crisis, was based on the trust of the portfolio outperforming in a steadier year. Also, there were reasons to study the closer and later years than the older years of almost 15 years ago. The second imperfection part of the paper is the method we used, Monte Carlo simulation, but it is not accurate to compare to the usage of analytical solution. With all the previous flaws, we indeed hold a strong belief on the successors and their future studies, and there will definitely be new and more rational models' using in future.

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