Research On Portfolio Construction for Information Technology and Communication Service Industries Based on The Monte Carlo Simulation

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Abstract. Attention is paid to the portfolio construction of the information technology and the communication services industries affected by the Covid-19. Firstly, the representative stocks which cover the most varieties of different market values are selected and the preliminary analysis for return performance is performed. Then, the event-study methodology is used to explore the effect of Covid-19 on the stocks chosen by this paper. The Monte Carlo simulation is also used to do the portfolio optimization. In the process of research, the Monte Carlo simulation and event study method are mainly used. Through the former one, the efficient frontier is obtained. Besides, this research also get the minimum volatility portfolio, where AT&T has the largest share of 16.33%, and the maximum Sharpe ratio portfolio, where ZOOM has the largest share of 18.79%. Then through the results of event-study, it is found that most companies generated negative abnormal returns on event date and had negative cumulative returns during the post-event window. Finally, the back test is done by comparing our portfolio with the equal weighted portfolio and NASDAQ index, and our work performs better both in the return and the risk. The results in this paper benefit the investors in the technology and communication service industries, which is especially helpful for them to do invest decision after COVID-19.

Keywords: portfolio construction; Covid-19; information technology; communication services.

1. Introduction

Portfolio refers to the individual and institutional investors' assets which contain stocks, bonds, financial derivatives, and other financial products. And usually, people will invest their wealth into different kinds of financial securities or financial products to get professional suggestions and maximize their wealth [1]. Portfolio selection can be one of the most classic decision-making processes, in which capital is allocated over different available assets for the most return and the least risk during the process of the investment [2]. Consequently, it is significant for investors to find the balance between the high returns and the high risks, leading to the optimal portfolio selection problem.

The portfolio theory was first proposed by Markowitz [3], who used the expected return and the covariance matrix to describe the returns and risks of the portfolio. Then, Sharpe [4] proposed to use the ratio of return-to-risk to measure the effectiveness of the portfolio, etc. Based on these models, the application of portfolio theory has reached numerous achievements. For example, Gennotte [5] explored the accomplishment of the optimal asset portfolios under incomplete information. Das and Uppal [6] provided a mathematical model on the rate of return for the securities to explore the impact of systemic risk on the portfolio selection. Qarni and Gulzar [7] used the portfolio to investigate the benefits of the alternative currency investment.

However, the Covid-19 has broken the traditional stable situation of the investment market. The global panic it caused has also been reflected in the fluctuations of financial markets, which made the markets suffer a lot. For example, on February 3, 2020, the Chinese three major stock indexes plunged, with more than 3,000 stocks falling by the daily limit. From March 9, 2020 to March 18, 2020, the U.S. stock market had four circuit breakers. Meanwhile, at least eight countries, including Brazil,

Canada, Egypt, Thailand, the Philippines, South Korea, Pakistan, and Indonesia, have triggered circuit breakers. Thus, under this circumstance, we need to construct new portfolios to find new balances between the returns and the risks under the epidemic situation.

Actually, there are a lot of meaningful studies which focus on the impact of Covid-19 on markets. However, most of these studies pay attention to the impact of Covid-19 on the macroeconomics and how the government should do to guarantee the economy suffered from the infection. Others focused on improving the forecast accuracy of the portfolio return under the global epidemic. It is essential to note that there is limited research on exact portfolio optimization from the viewpoint as an investor. For example, Simone [8] concentrated on the development of sustainable finance after the Covid-19, and Baris and Ugur [9] searched the asymmetric impact of funding liquidity risk on the volatilities of the stock portfolios during this era. What is more, technically, Young and Sung [10] researched on double-shrinkage selection rule as the portfolio strategy to construct portfolio with higher values of Sharpe-ratio and lower values of conditional value at risk, and Jing and Li [11] tried to use big data analysis and deep learning method to analyze the investment decision after Covid-19. As far as we have known, there is especially less passages that take a typical industry as the object of empirical analysis under the impact of the Covid-19. Existing studies focus on the electricity and insurance market [12,13], without any consideration on the information technology and communication services, despite that the two industries are crucial to modern economy. Overall, we have enough reasons to believe that our research is focusing on a vacant part of the portfolio optimization under the impact of Covid-19 and using empirical analysis, so that it is meaningful for the development of financial market and the individual investors.

To the best of our knowledge, this paper makes the following contributions to the literature. First, we choose the stocks in the target industry and make sure that the market value of our chosen companies can cover all of the range, and then we use event study to analyze the impact of Covid-19 on the stocks we choose. We calculate the abnormal returns and cumulative abnormal returns of each stock, finding that most companies suffered a negative impact on the event date and generated negative abnormal returns. All the companies except ZOOM appeared negative cumulative returns during the event window, with absolute value rising first and then falling to close to zero. Secondly, we use Monte Carlo Simulation to find the efficient frontier as well as two optimal portfolios. By building random proportions of stocks, we get the relationship among expected return, volatility, and Sharpe ratio for different portfolios as well as the efficient frontier. And in terms of the optimal portfolio, we get the minimum volatility portfolio, which contains the largest ratio of AT&T, which accounts for 16.33%; and we get the maximum Sharpe ratio portfolio where ZOOM accounts for the largest proportion of 18.79%. Finally, we do the backtest, in which part we compare our portfolio with the equal weight portfolio and the Nasdaq index in two dimensions about the returns and risks. In addition, we also take the risk-adjusted returns into our consideration. And our portfolio performs better than them in all of our chosen indicators, which means more returns and lower risks.

This paper is organized as follow. Section 2 shows the data and methods used in this paper. Section 3 presents the empirical results and Section 4 concludes this paper.

2. Data and Methods

2.1. Data

The sample of empirical analysis in this article is the stock price of the America stock market from yahoo finance (https://finance.yahoo.com/). We select 15 stocks in the information technology and communication service industries, which are divided by the application of East-money, which is a popular finance software used in China. In this paper, we select representative companies with consideration of different market values. Then considering both the impact of covid-19 and enough history statics, we choose the time period from March 1,2019 to March 1,2021.

According to the original data, we calculate the returns of these 15 selected stocks respectively by calculating the percentage difference between the stock price of the day and the previous day, and the descriptive statistics of returns are shown in the following Table 1.

Table 1. Descriptive statistics of the selected assets

Stock code	Mean	Standard deviation	Maximum	Minimum	Skewness	Kurtosis
AAPL	0.22%	2.42%	11.98%	-12.86%	-6.95%	518.28%
ADP	0.05%	2.22%	11.80%	-15.25%	-39.42%	1091.89%
ATVI	0.19%	2.24%	9.64%	-10.64%	-2.23%	298.30%
BABA	0.08%	2.35%	8.95%	-13.34%	-47.82%	303.31%
BIDU	0.15%	3.04%	15.57%	-16.52%	59.61%	623.60%
FB	0.11%	2.41%	10.24%	-14.25%	-23.08%	474.35%
FIS	0.08%	2.29%	16.31%	-16.59%	-20.71%	1336.89%
GOOG	0.13%	2.11%	10.45%	-11.10%	-0.09%	562.15%
MSFT	0.16%	2.21%	14.22%	-14.74%	-9.00%	957.66%
NTES	0.20%	2.66%	10.93%	-11.43%	16.34%	214.10%
PYPL	0.23%	2.76%	14.11%	-15.82%	33.67%	632.97%
SHOP	0.45%	3.72%	14.55%	-17.55%	-15.05%	194.95%
T	0.01%	1.82%	10.02%	-9.24%	-9.77%	665.50%
TWTR	0.23%	3.47%	15.64%	-21.11%	-74.70%	934.19%
ZM	0.49%	4.70%	40.78%	-17.37%	146.25%	1295.97%

According to the table, we can see all of the average returns are positive and the max one of zoom can reach 0.49%, it also shows the max returns peaking over 40%, which means the selected stocks performed a profitable trend. Then considering the standard deviation profile related to the risk, most of them vary between 2% to 3% except for American Telephone and Telegraph, 1.82% and zoom, 4.70%. In addition, 11 stocks show a left skewness of their returns while the other 4 stocks show a right skewness, and 12 returns have the kurtosis over the Normal distribution.

2.2. Methods

According to Markowitz [3], the expected return of one portfolio is calculated by the following equation (1),

$$R = x^T \mu \tag{1}$$

Where R is the portfolio return, μ is the expected return of the selected assets and x refers to the weight of the assets. The variance of the portfolio can be achieved by the following equation (2)

$$\Omega = x^T \omega x \tag{2}$$

Where Ω is the variance of the portfolio, and ω is the variance-co-variance matrix of the expected assets returns.

Monte Carlo simulation was proposed by Metropolis and Ulam [14] to solve the random neutron diffusion problem of fissile material during the development of atomic bombs. With the continuous development of computers, Monte Carlo simulation has been widely used in economic research. For example, Sak and Basoglu [15] used the efficient Monte Carlo simulation to estimate portfolio market risk. And in this passage, we use Monte Carlo Simulation to find the efficient frontier as well as the optimal portfolio. The process can be summarized as follows. Firstly， we establish probability statistical models and get the weight $\boldsymbol{w} = (w_1, w_2, \cdots, w_N)$ of each stock in the random portfolio by generating seeds randomly through the computer. And we can get $\sum_{n=1}^{N} w_n' = 1$ through equation (3),

$$w_n' = w_n / \sum_{n=1}^{N} w_n \tag{3}$$

Where w_n is the weight of stock n in the portfolio.

Secondly, for each group of different proportions of stocks, we can calculate the relevant portfolio metrics, such as volatility and Sharpe ratio, as the equation (2) and (4) show,

$$\text{Shapre ratio} = [E(R_p) - R_f]/\sigma_p \tag{4}$$

Where $E(R_p)$ is the expected annualized rate of return of the portfolio, $R_f$is the risk-free rate, and σ_p is the standard deviation of the portfolio's annualized rate of return. Finally, we can get the efficient frontier by the following equation (5),

$$\boldsymbol{w} = arg \min_{1 \le i \le N} \sigma_p$$
$$\text{s.t.}\, E(R_p) = k \tag{5}$$

where k is a constant greater than 0. And we have the portfolios which have the least volatility and the largest Sharpe ratio respectively by the equation (6) and (7),

$$\boldsymbol{w} = arg \min_{1 \le i \le N} \sigma_p \tag{6}$$

$$\boldsymbol{w} = arg \max_{1 \le i \le N} \text{Shapre ratio} \tag{7}$$

Event study has been widely used to measure the effectiveness of an economic event on the value of a firm Chen, Jang, and Kim [16] used event-study methodology to research the impact of the SARS outbreak on Taiwanese hotel stocks. Since both COVID-19 and SARS are major health emergencies and dealt a heavy blow to the capital market, we use event-study methodology to research the impact of COVID-19 on stock performance. This method can be summarized as follows.

First, we estimate the performance of stock returns without the impact of COVID-19. According to the so-called market model, we regressed the stock returns against S&P 500 to estimate normal returns. The regression (8) is given as.

$$R_{j,t} - R_f = \alpha_j + \beta_j(R_{m,t} - R_f) + \varepsilon_{j,t} \tag{8}$$

Where $R_{j,t}$ represents the return of stock j on day t, $R_{m,t}$ represents the return of S&P 500 on day t, $R_{f,t}$ represents Treasury Yield 10 Years on day t, $\varepsilon_{j,t}$ represents a random error term of stock j on day t, and α_j,β_j represents regression parameters to be estimated. And we use equations (9) to calculate normal returns in the event window,

$$R_{j,t} - R_{f,t} = \alpha_j + \beta_j(R_{m,t} - R_{f,t}) \tag{9}$$

Where $R_{j,t}$ represents normal returns of stock j on day t, α_j , β_j represent estimates of parameters in regression (8), $R_{m,t}$ represents the return of S&P 500 on day t, and $R_{f,t}$ represents Treasury Yield 10 Years on day t. Then we use equations (10) to calculate abnormal returns in the event window,

$$AR_{j,t} = R_{j,t} - ER_{j,t} \tag{10}$$

Where $AR_{j,t}$ represents abnormal returns of stock j on day t, $R_{j,t}$ represents real returns of stock j on day t, and $ER_{j,t}$ represents normal returns of stock j on day t calculated by equation (9). And the equation (11) we use to calculate the cumulative abnormal returns is given as,

$$\text{CAR}_{j,t} = \sum_{i=-t_1}^{t} AR_{j,i} \tag{11}$$

Where CAR_(j,t) represents cumulative abnormal returns of stock j on day t, represents abnormal returns of stock j on day i.

2.3. Empirical Results

In this paper, we implement Monte Carlo Simulation for 10^5 times to get the efficient frontier and the efficient frontier is shown in the following Figure 1.

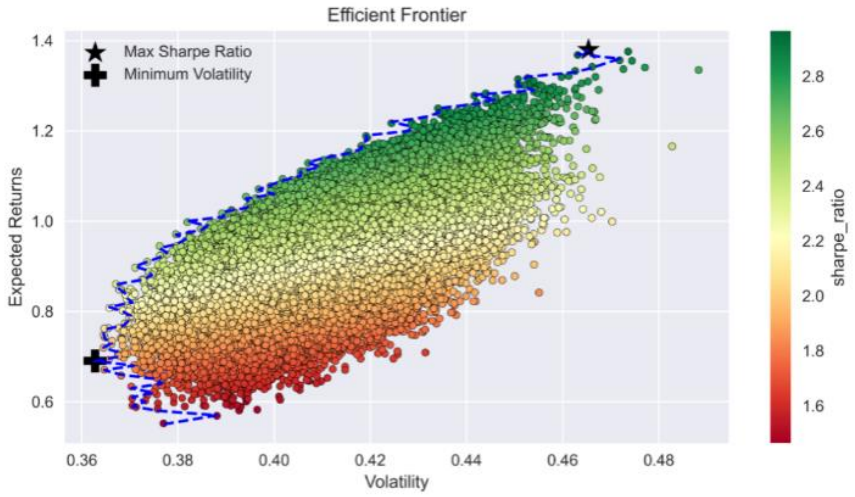


Figure 1. Efficient Frontier

As shown in the above Figure 1, two portfolios raise our great concerns, the minimum variance portfolio, and the maximum Sharpe ratio portfolio, which are the two commonly focused portfolios. Specifically, the two portfolios are summarized as follows in Table 2.

Table 2. The two Portfolios

Stock code	minimum variance	maximum sharpe ratio
AAPL	2.36%	5.40%
ADP	10.29%	0.89%
ATVI	15.48%	11.64%
BABA	10.89%	0.90%
BIDU	5.26%	0.32%
FB	8.04%	6.63%
FIS	3.19%	2.66%
GOOG	5.84%	0.21%
MSFT	4.38%	6.94%
NTES	7.65%	17.32%
PYPL	0.71%	2.50%
SHOP	1.27%	17.74%
T	16.33%	5.64%
TWTR	3.75%	2.42%
ZM	4.58%	18.79%
return	69.07%	137.99%
volatility	36.27%	46.54%
Sharpe ratio	190.40%	296.51%

According to table 2, we can get the minimum variance portfolio, in which AT&T accounts for the largest proportion of 16.33% as the most, and the portfolio's return is 69.07%, its volatility is 36.27%, and its Sharpe ratio is 190.40%. On the other hand, we also obtain the maximum Sharpe ratio portfolio, which contains the largest ratio as ZOOM, accounting for 18.79% as the most, and the portfolio has the return, 137.99%, the volatility 46.54%, and the Sharpe ratio, 296.51%.

And we use event-study methodology to research the impact of COVID-19 on the performance of stocks we choose. The official declaration of a national emergency in American happened on March 15, 2020, since that day is Sunday, the stock market stopped trading, we delay one day, choosing March 16, 2020 as the event date. We used 160 trading days for the estimation period, which is from

180 trading days before to 21 trading days before March 15, 2020, and a [-t_1, t_2] event window, 20 trading days before to 20 trading days after March 15, 2020.

In this part, we draw out the abnormal return and cumulative abnormal return of each company. The abnormal returns of each stock are shown in the following figure 2:

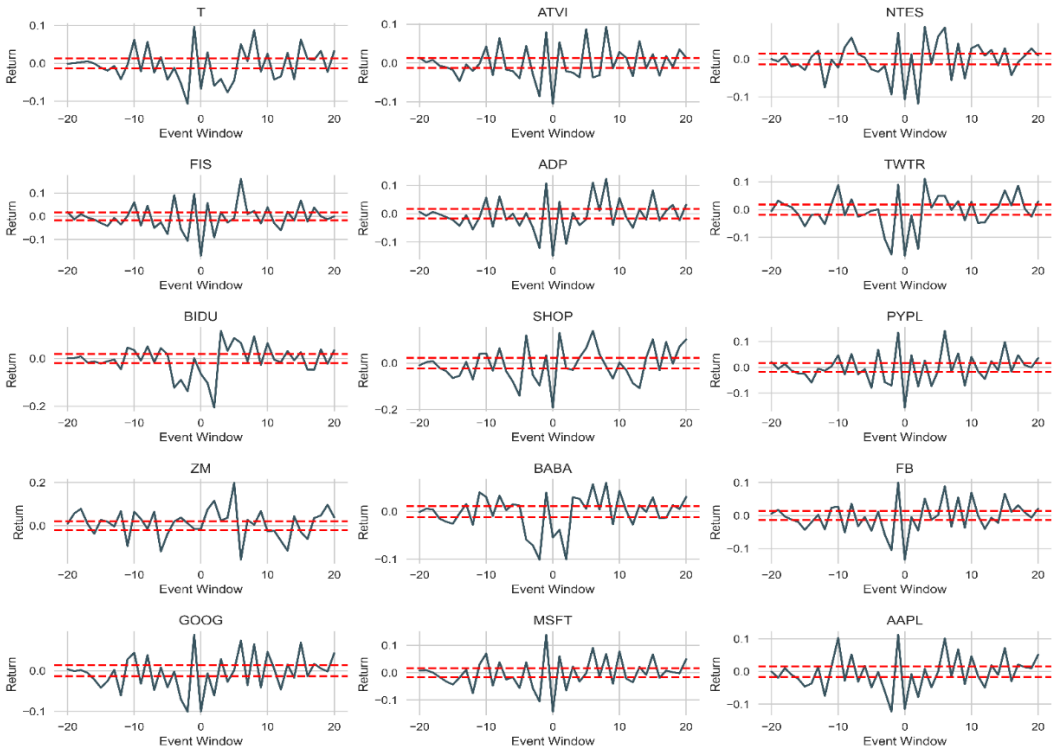


Figure 2. Abnormal Returns

According to figure 2, most companies suffered a negative impact on March 16, 2020, generating negative abnormal returns. The abnormal returns of each stock are shown in the following figure 3:

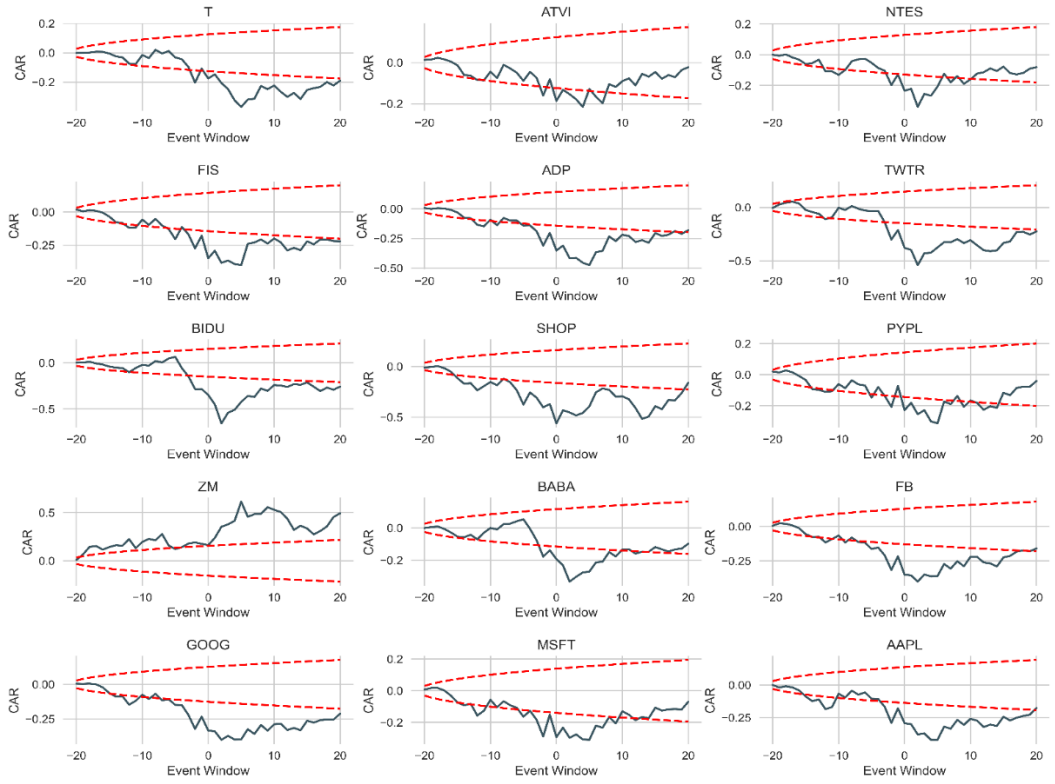


Figure 3. Cumulative Abnormal Returns

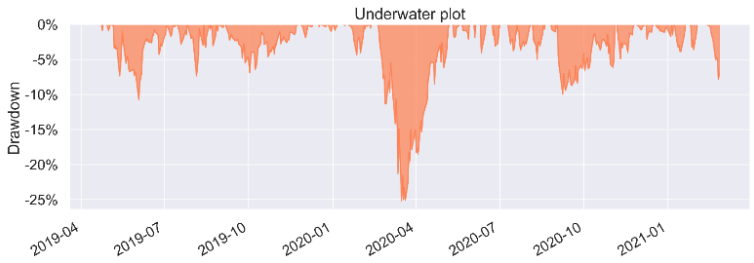
According to Figure 3, all the companies except ZOOM appeared negative cumulative abnormal returns during the post-event window. The absolute value of their cumulative abnormal returns rises first and then falls to close to zero. However, the cumulative abnormal return of ZOOM is positive. During the pandemic, ZOOM became the preferred platform for enterprises and schools. Zoom's user base is growing rapidly, with daily active users surging to 200 million in March while this number is just 10 million at the end of 2019. Zoom's first-quarter report for fiscal 2020 shows that in the first quarter, Zoom reported revenue of $328.2 million, an increase of 169% from $122 million in the same period last year. Therefore, we speculate that ZOOM's positive cumulative abnormal returns may due to the fact that after a short period of panic, investors are more optimistic about ZOOM because of its specific business situation.

Finally, we do backtest for our portfolio and compare the performance in returns and risks profile of our portfolio chosen by maximum Sharpe ratio with it of the equal-weight portfolio and NASDAQ index. The time period selected to do backtest is from April 22,2019, to February 26,2021, which contains 22 months.

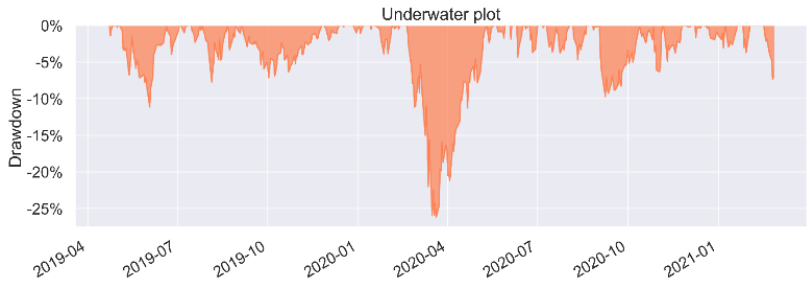
Table 3. Backtest sheet of three portfolios

	Maximum sharpe ratio	**Equal weight portfolio**	**NASDAQ index**
Annual return	56.80%	52.90%	31.70%
Cumulative returns	130.60%	119.90%	66.30%
Annual volatility	28.80%	28.50%	29.20%
Sharpe ratio	1.71	1.63	1.09
Calmar ratio	2.26	2.02	1.13
Stability	0.94	0.91	0.88
Max drawdown	-25.20%	-26.20%	-28.00%
Omega ratio	1.36	1.34	1.23
Sortino ratio	2.43	2.3	1.52
Skew	-0.79	-0.85	-0.57
Kurtosis	6.25	7.18	8.73
Tail ratio	0.96	0.87	0.77
Daily value at rise	-3.40%	-3.40%	-3.60%

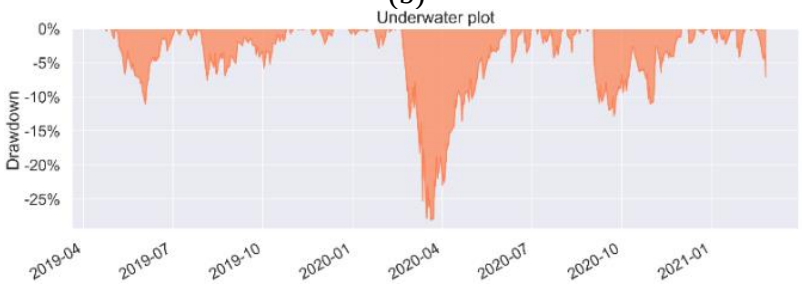
According to Table 3, firstly, it shows that the proportion of annual return of our portfolio overtakes it of equal weight portfolio and NASDAQ index 3.9% and 25.1% respectively, at the same time the percentage of cumulative returns shows a similar performance, which is 10.7% and 64.3% higher than the other two. Then considering the risk-adjusted returns, we select the Sharpe ratio, Calmar ratio, omega ratio, and Sortio ratio. It can be seen in Table 3 that all these indicators of our portfolio are higher than those of the equal-weight portfolio and NASDAQ index. As to the risk aspect, we choose stability and max drawdown as the index, the former one of our portfolios is 0.94 which is higher than 0.91 of equal weight portfolio and 0.88 of NASDAQ index. We show the results in the following Figure 4. And as shown in the following Figure 4, the max drawdown of our portfolio just -25.2% while it of the other two reaches -26.2% and -28.0% respectively.



(a)



(b)



(c)

Figure 4. Underwater plot

3. Conclusion

In this paper, we focus on portfolio construction and try to find the optimal portfolio in the technology and communication service industries during the epidemic period. Since there has been little empirical research on the impact of Covid-19 on the industry of the information technology and communication services, and the research on constructing an optimal portfolio from the perspective of investors are also lack, our job is innovative and meaningful. We choose 15 stocks in this industry and consider the different market values. Firstly, we use event-study methodology to research on the impact of Covid-19 on stock performance. Secondly, we use Monte Carlo Simulation to find the efficient frontier and the two optimal portfolios, one of which has the lowest volatility and contains 16.33% AT&T, and the other one has the highest Sharpe ratio and owns 18.79% ZOOM. And through the outcome of event-study, we find that most companies experienced a negative impact on the event date, appearing negative abnormal returns. And all of the companies, except ZOOM, appeared negative cumulative abnormal returns during the post-event window. The absolute value of their cumulative abnormal returns ascended at first, and then went down to nearly zero.

Although we can get the results conveniently through the Monte Carlo Simulation, it has some drawbacks. Specifically, this method gets the results by multiple simulations, but the results may vary with the times of simulations, changing the deterministic problems into random problems. Thus, there is still much room for choosing the methods. For instance, we can get more precise results in the form of analytical solutions. In addition, in the backtest part we can try to add more indicators to compare the performance of our portfolio and others in the future studies.

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