

Application of Markowitz and Index Model during the period of COVID-19

Zhifeng Yu*

Department of Guangdong University of Finance and Economics, Guangzhou, China

*Corresponding author: 1258989560@qq.com

Abstract. Markowitz Model and Index Model both play a important part in making strategies when investors decide to make an investment. There is no denying that nobody can give you a guarantee that he can determine whether the stocks' price will rise or not in the future. However, if you can use these two models correctly, you will acquire quite a lot of effective information such as which stock you should long or short and what percentage you should allocate to each stock which can help you make an investment strategy accurate relatively. As is known to all, whole world suffered from COVID-19 not only in death but finance. If we use the previous strategy to invest, it will definitely not work in current environment. But that no mean that we don't have the opportunity to invest. What we should do is research the new investment strategy to adapt to current environment and embrace the better chance to earn. In order to research special investment method different from the period before the COVID-19 by building these two models, this paper select S&P500 and 8 companies which are large scale and great enough to have the qualification to behalf of their industry.

Keywords: Markowitz Model; Index Model; COVID-19; constraint.

1. Introduction

In 1981, James Tobin, the Nobel Laureate in economics, said, "don't put eggs in one basket.". he emphasizes the significance of investment portfolio. Markowitz model is used to devise the optimal portfolio through consider with means and variance. [1] However, Markowitz model need strong computing power so that most of investors couldn't applicate it in the daily life. [2] Hence, there was a simple relatively method called Index model created by Sharpe. [3] Sharpe's opinion is that no matter what the stock is, there is a linear correlation between the return and the index where the stock is included in. [4] And this is the theory of Index model. Through these two models, we can calculate the weight of each stock which means how many percentages we should invest in each stock. [5] we also designed 5 constrains to simulate 5 different kinds of situations which can make the conclusion more credible. [6] In addition, there is no exaggeration to say that the whole world is suffering from COVID-19, not only the life but economy. [7] The sudden natural disaster had broken the original assumption of Markowitz and Index model [8]. And the virus will last for long time.[9] But it doesn't mean we lost the opportunity to earning from capital market, there are still high-quality stocks seems not be impacted by epidemic.[9] Hence, the traditional portfolio is out of date.[10] We should explore the new portfolio to replace the old one and adapt to the new environment.[11]

2. The basic introduction of Markowitz model and index model

2.1 The theory of Markowitz model

Markowitz model is also called mean-variance model. It is a venture capital model proposed by Harry Markowitz in 1952. Markowitz defined risk as the volatility of return, and applied the method of mathematical statistics to the study of portfolio selection for the first time. This method makes the multi-objective optimization of income and risk achieve the best balance effect. Mean variance model investors invest a given amount of money in a certain period of time. At the beginning of the period, he buys some securities and then sells them at the end of the period. Then at the beginning of the period, he has to decide which securities to buy and how to allocate the funds on these securities, that is, investors need to choose an optimal combination from all possible securities portfolios at the

beginning of the period. At this time, investors have two decision-making objectives: the highest yield and the lowest uncertainty risk. The best goal should be to achieve the best balance between these two mutually restrictive goals. The investment model thus established is the mean variance model.

The Markowitz model consists of three basic elements, which are:

- (1) Return. Markowitz obtains the average rate of return of the portfolio through the weighted average method
- (2) Risk. Markowitz use standard deviation or variance express the Risk.
- (3) Beta. It is used to measure the sensitivity of the stock price when the other stock price change

$$E(R_p) = \sum W_i \times E(R_i). \quad (1)$$

$$\sigma_p^2 = \sum_{i=1}^n \sigma_i^2 w_i^2 + 2 \sum_{i=1}^n \sum_{j=1}^n \sigma_i \sigma_j w_i w_j \rho_{ij} \quad (2)$$

$$\beta = \rho \times \sigma_i / \sigma_m \quad (3)$$

In the above formulas, $E(R_p)$ means they expect of the portfolio return. R_i is the return of individual stock. σ is the standard deviation. ρ is the correlation coefficient.

2.2 The theory of the Index model

The index model was put forward by the Nobel laureate William Sharpe in his article "simplified model for" portfolio "analysis published in 1963. The basic idea of Sharpe's single factor model is: when the market stock price index rises, a large number of stock prices in the market rise; on the contrary, when the market index falls, a large number of stock prices tend to fall. Therefore, the following model can be obtained by using the correlation between the return of a security and the return of stock index:

$$r_{it} - r_{ft} = A_i + \beta_i (r_{mt} - r_{ft}) + \varepsilon_{it} \quad (4)$$

This formula reveals the relationship between securities return and index (a factor). Where R_i is the yield of i securities during the period. R_{mt} is the rate of return of the market index in period t . A_i is the intercept, which reflects the yield of securities I when the market yield is 0. It is related to the fundamentals of the listed company itself and has nothing to do with the overall fluctuation of the market. Therefore, a value is relatively fixed. β_i is the slope, which represents the degree of self-influence of the fluctuation of the market index on the securities yield. ε_{it} is the residual between the actual rate of return and the estimated value in period t .

2.3 The constraints

To examine the performance of the portfolios, this paper applies several constraints. There are 5 constraints are as follow

- Constraint 1: Free.

It means that there is no constraint on the portfolio, you can do whatever you want to do in your portfolio.

- Constraint 2: $w_i = 1$.

You can't long the SPX, which means is that you can't invest in the bench mark. The reason why this paper adds this constraint is that we would like to see if the inclusion of the broad index into our portfolio has positive negative effect.

- Constraint 3: $w_i \geq 0$

This constraint means that we can't short the SPX and individual stock. The purpose adding this constraint is to simulate the typical limitations existing in the U.S. mutual fund industry: a U.S. open-ended mutual fund is *not allowed to have any short positions*

- Constraint 4: $|w_i| \leq 1$

This additional optimization constraint is designed to simulate some *arbitrary "box" constraints*

on weights.

- Constraint 5: $\sum |w_i| \leq 2$

This additional optimization constraint is designed to simulate the *Regulation T by FINRA*, which allows broker-dealers to allow their customers to have positions, 50% or more of which are funded by the customer's account equity

3. Data

3.1 The introduction of 8 companies

This paper investigates the portfolio performance covering sectors: technology, financial services, consumer defensive, healthcare. In order to make the research more representative and accurate, this paper selected the following 8 listed companies.

The technology selects NVIDIA Corporation (NVDA) and Cisco (CSCO). NVDA is the largest Graphics chip manufacturer of the world. CSCO is the world's leading provider of network solutions, which industry is communication equipment.

The financial services select Goldman Sachs (GS), US Bancorp (USB) and Allstar insurance (ALL). GS is the largest investment bank of the world, which industry is capital market. USB is a diversified financial service holding company in the America, which industry is commercial bank. And ALL is an excellent insurance enterprise.

The consumer defensive selects Procter & Gamble (PG) and Colgate (CL). PG is one of the world's largest consumer goods companies, which industry is household products. CL is a personal and family oral care and pet food company, which industry is personal items.

The healthcare selects only one company called Johnson & Johnson (JNJ). JNJ is the world's largest healthcare and consumer care company, which industry is pharmaceutical industry.

3.2 Stock price figure

Stock price of 8 individual stock and price of SPX is as follow (Closing price)

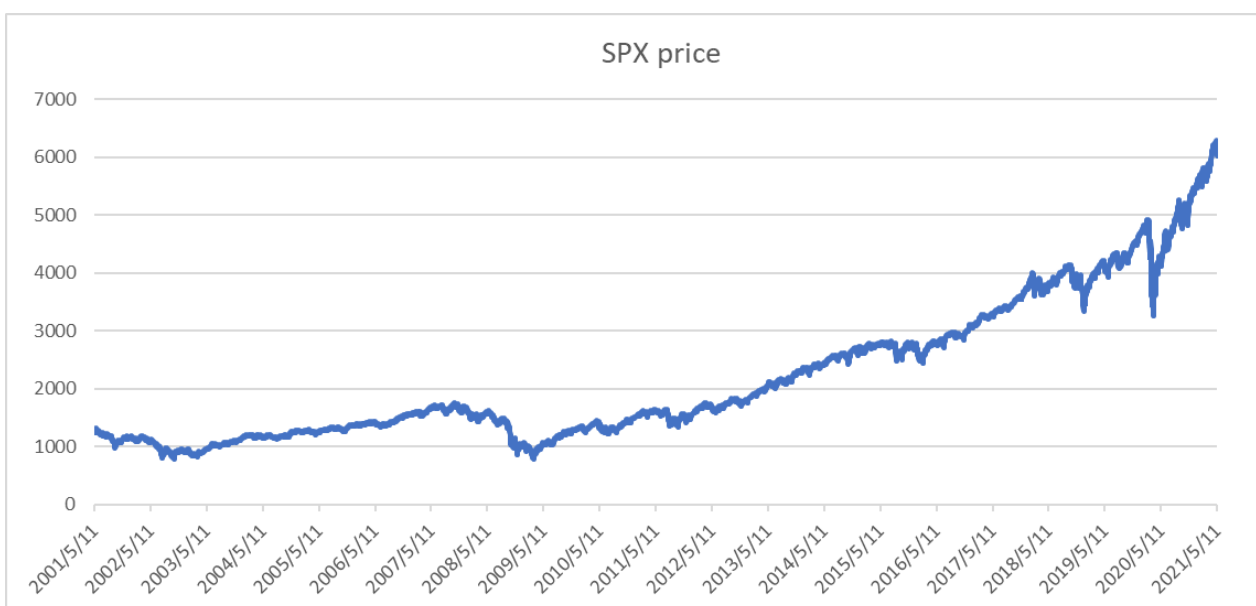


Figure 1. SPX price



Figure 2. Goldman Sachs price

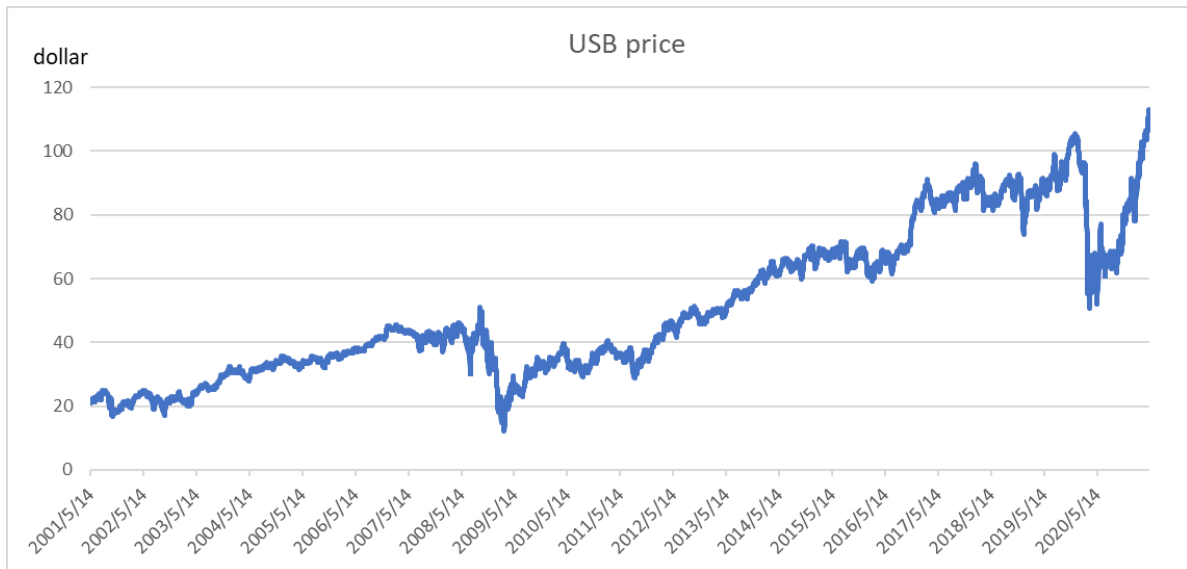


Figure 3. US Bancorp price

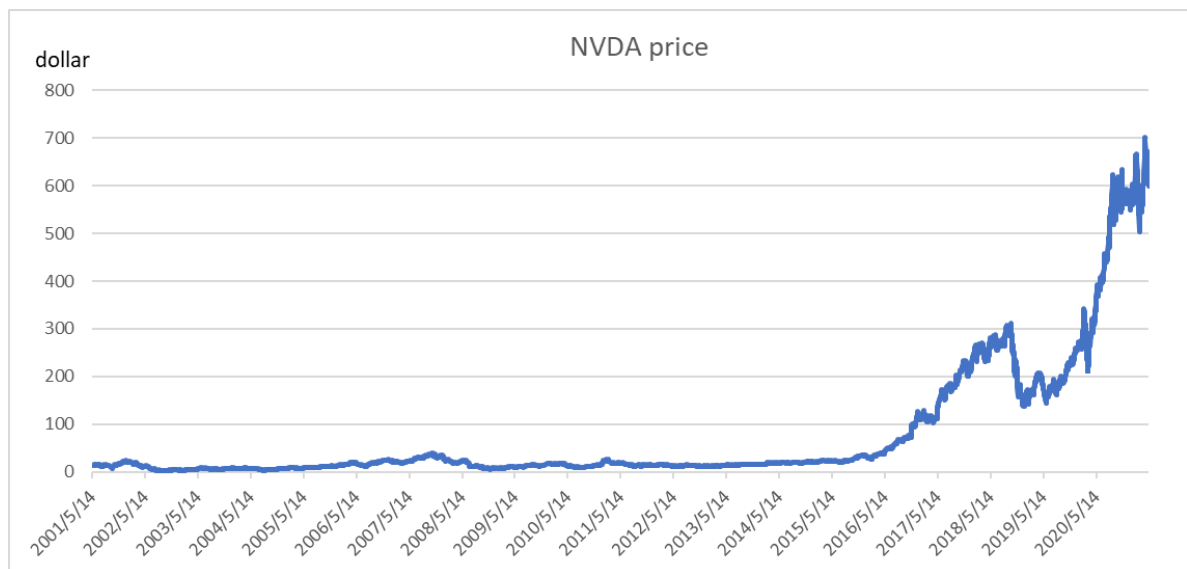


Figure 4. NVIDIA Corporation price



Figure 5. Cisco price

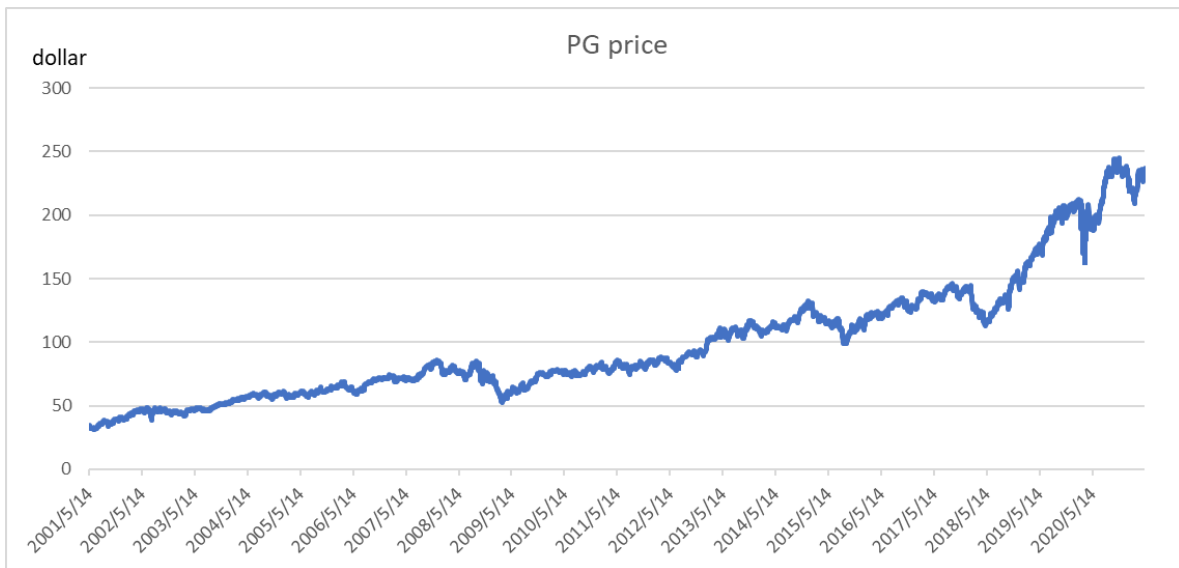


Figure 6. Procter & Gamble price

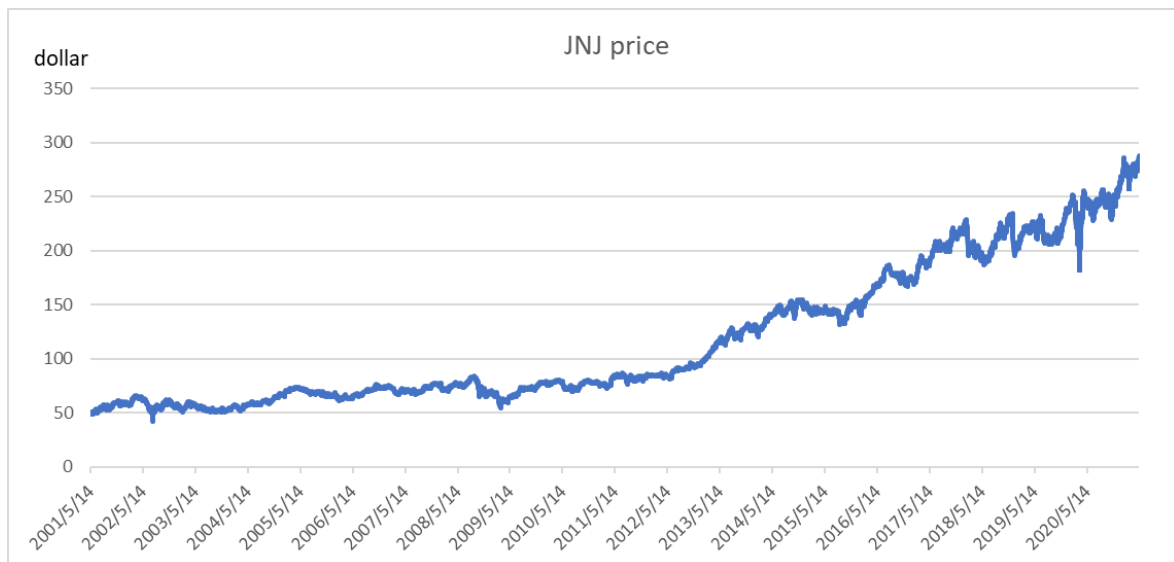


Figure 7. Johnson & Johnson price



Figure 8. Allstar insurance price



Figure 9. Colgate price

All the pictures above were made by myself, and the data of stocks and SPX closing price which was used to made these line chart is collected from yahoo!!

4. Result

4.1 Building these models which base on a decade data (2011-2021)

4.1.1 The weight of SPX and individual stock when we only considered the risk

When we only think about the risk without care other factors, we can acquire the optimal weight of the portfolio under the minimum variance.

Table 1. Markowitz model-weight

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0.113098	0	0	0.054177	0.094242	0.354667	0.18241	0	0.201405
w1=0	0	0	0	0.068626	0.115841	0.373274	0.210795	0	0.231464
wi≥0	0.113098	0	0	0.054177	0.094242	0.354667	0.18241	0	0.201405
wi ≤1	0	0	0	0.320544	0.109604	0.265859	0.154295	0.149699	0
sum wi ≤2	0.113098	0	0	0.054177	0.094242	0.354667	0.18241	0	0.201406

Table 2. Index model-weight

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0	0	0	0	0	0.239217	0.606268	0	0.154515
w1=0	0	0	0	0	0.036846	0.376785	0.262313	0	0.324056
wi≥0	0	0	0	0	0.036846	0.376785	0.262313	0	0.324056
wi ≤1	0	0	0	0	0.036915	0.377173	0.261612	0	0.3243
sum wi ≤2	0	0	0	0	0.037167	0.377033	0.262063	0	0.323737

We can get some useful information from the above data. Initially, if we only observe the weight calculated by Markowitz model, we will find that no matter what constraint it is, none of us should allocate assets into the GS and USB. And ALL is as same as GS and USB except constraint 4. Hence, combined with the introduction of 8 companies which is mentioned before, we can know that when only considered the risk and pursuit the minimum risk, we shouldn't allocate our asset to the financial services industry, because they will increase your standard deviation.

Simultaneously, when we observe the weight calculated by Index model, we will find something different from the Markowitz model. The distribution of the asset in the Index model is more concentrated compare with that in the Markowitz model. Through Index model we can understand that whatever constraint it is, we can get the minimum risk if we investment the consumer defensive and healthcare industry.

Table 3. Markowitz model-return, standard deviation and Sharpe ratio

MM model	return	stdev	sharpe
Free	13.285%	13.129%	1.012
w1=0	13.525%	13.155%	1.028
wi≥0	13.285%	13.129%	1.012
wi ≤1	22.409%	16.903%	1.326
sum wi ≤2	13.285%	13.129%	1.012

Table 4. Index model-return, standard deviation and Sharpe ratio

IM model	return	stdev	sharpe
Free	11.769%	13.419%	0.877
w1=0	10.994%	12.451%	0.883
wi≥0	10.994%	12.451%	0.883
wi ≤1	10.993%	12.451%	0.883
sum wi ≤2	10.996%	12.451%	0.883

Ultimately, Through the return, standard deviation and Sharpe ratio of these two models, we can find that when added the constraint 4, we can get a bigger Sharpe ratio using the Markowitz model. And when no constraint, we can get a bigger Sharpe ratio using the IM model. Hence, we can get a conclusion: under the constraint 4 we can find an optimal portfolio using Markowitz model, and without constraint we can find an optimal portfolio using the Index model.

4.1.2 The weight of SPX and individual stock when we both consider the return and risk

When consider the return and risk together, the investor will go after the max Sharpe ratio. In this situation, we can also get the optimal weight of the portfolio.

Table 5. Markowitz model-weight

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0	0	0	0.326243	0.119271	0.324363	0.193585	0.173485	-0.13695
w1=0	0	0	0	0.068626	0.115841	0.373274	0.210795	0	0.231464
wi≥0	0.113098	0	0	0.054177	0.094242	0.354667	0.18241	0	0.201405
wi ≤1	0	0	0	0.320544	0.109604	0.265859	0.154295	0.149699	0
sum wi ≤2	0.113098	0	0	0.054177	0.094242	0.354667	0.18241	0	0.201406

Table 6. Index model-weight

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0	0	0	0.336381	0.1288	0.191006	0.214268	0.229684	-0.10014
w1=0	0	0	0	0.336383	0.128799	0.191006	0.214272	0.229683	-0.10014
wi≥0	0	0	0	0.321209	0.115102	0.171993	0.188899	0.202796	0
wi ≤1	0	0	0	0.336392	0.128771	0.190998	0.214291	0.22969	-0.10014
sum wi ≤2	0	0	0	0.336392	0.128771	0.190998	0.214291	0.229691	-0.10014

Table 7. Markowitz model-return, standard deviation and Sharpe ratio

MM model	return	stdev	sharpe
Free	23.076%	17.345%	1.330
w1=0	23.076%	17.345%	1.330
wi≥0	22.409%	16.903%	1.326
wi ≤1	22.409%	16.903%	1.326
sum wi ≤2	23.074%	17.344%	1.330

Table 8. Index model-return, standard deviation and Sharpe ratio

IM model	return	stdev	sharpe
Free	23.827%	18.866%	1.263
w1=0	23.827%	18.866%	1.263
wi≥0	22.909%	18.181%	1.260
wi ≤1	23.828%	18.867%	1.263
sum wi ≤2	23.828%	18.867%	1.263

First, there are obvious difference compare with those data which are only care about the risk. We can find that both Markowitz model and Index model have an evident diversification display in their asset allocation. However, there also have some same point deserve our attention. For instance, whatever pursue max Sharpe ratio or minimum variance, these two models show us that investor shouldn't long or short the GS and USB. In other word, if we hope to acquire the optimal portfolio using these two models, we shouldn't invest GS and USB under these 5 constraints. As we all know, GS and USB both have considerable scale and sufficient strength in the industry of financial service. So, we should spend more time investigating these two companies or even this industry and find the reason why we can't invest them. It is one of the benefits of these two models.

Let's change the subject. Through the Sharpe ratio we can find that, when added constraint 3 and 4, investor can get a maximum Sharpe ratio, which means it is the optimal portfolio in the Markowitz model. And except added the constraint 3, investor can get an optimal portfolio in the Index model when added another 4 constraints.

4.2 Difference in these models before and during the COVID-19

The COVID-19 has had a noticeable impact on the global economy I mentioned it before. Therefore, I chose the data from 2018 to 2020 and the data from 2020 to 2021 to build the model. As we all know that COVID-19 began in 2020 so the 2020 is a key time, which divides the period into pre COVID-19 and COVID-19 period. Through building Markowitz and Index model and then interpret their contents, we would know how to make a portfolio during the COVID-19.

4.2.1 Only consider the risk in the Markowitz model

Table 9. The weight before COVID-19

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0.299546	0	0	0	0.005643	0.504059	0	0.217959	-0.02721
$w_1=0$	0	0	0	0	0.083075	0.534697	0.037671	0.315374	0.029182
$w_i \geq 0$	0.286617	0	0	0	0.003396	0.494248	0	0.215739	0
$ w_i \leq 1$	0.2996	0	0	0	0.005518	0.503853	0	0.218204	-0.02717
$\sum w_i \leq 2$	0.299548	0	0	0	0.005644	0.504059	0	0.217959	-0.02721

Table 10. The weight during COVID-19

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0	0	0	0.202668	0.180956	0.090602	0.170935	0	0.354838
$w_1=0$	0	0	0	0.202687	0.180953	0.09164	0.170507	0	0.354213
$w_i \geq 0$	0	0	0	0.202688	0.180959	0.091642	0.170517	0	0.354194
$ w_i \leq 1$	0	0	0	0.202685	0.18095	0.091643	0.170505	0	0.354217
$\sum w_i \leq 2$	0	0	0	0.202686	0.180953	0.091643	0.170505	0	0.354213

In terms of the weight which is allocated in each individual stocks, there are quite a lot of useful information.

Initially, before the epidemic broke out, investor can allocate 30% asset approximately in the SPX to acquire the minimum variance besides under the constraint 2. But when during the COVID-19, the weight of the SPX is 0, which mean that if you invest the SPX, the risk of your portfolio will increase. Hence, we can get a conclusion: the American bench mark was shocked by COVID-19. Of course, not only America, but other countries all suffer from the negative influence of the virus. This is inevitable.

Secondly, whatever constraints it is and whatever period it is, it seems that investor shouldn't put your asset on the GS and USB. As far as I know, bank is a low risky industry, at least in China. Maybe the bank in the America is different from the Chinese bank. This requires us to do more in-depth investigation.

Thirdly, let's pay attention to the NVDA. In period of 2018 to 2020, no matter what constraints I added, the weight of the NVDA is zero. And when the COVID-19 broke out, which is in period of 2020 to 2021, the weight of the NVDA is 20% approximately under all constraints. We can acquire some useful information. Compare with the stock price table of NVDA I mentioned before, we can find that the stock price of NVDA actually increase. It seems that NVDA had not been affected by the virus. Simultaneously we look at the weight of CSCO, we can also find that the weight of CSCO increase as same as the NVDA. Hence, we get a conclusion: technology industry had received less impact from the epidemic compared with other industries, so during the COVID-19, investor should long these stocks of technology industry

Fourthly, let's look at the ALL. I said ALL is an excellent insurance company before. When there was no virus, we would allocate 21%-22% weight on the ALL. However, there are thousands of people suffer from virus or even died during the COVID-19. The insurance companies would face to a lot of compensation fee. If a small-scale insurance company was going to face to these compensation fee, maybe it would bankruptcy. And the big scale like the ALL also would suffer from the negative influence on the operation. That is why the weight of ALL is 0 on the "during" table.

Table 11. The return, standard deviation and Sharpe ratio before the COVID-19

before	return	stdev	sharpe
Free	13.160%	10.373%	1.2686
$w_1=0$	12.509%	10.692%	1.1699
$w_i \geq 0$	12.749%	10.380%	1.228
$ w_i \leq 1$	13.157%	10.373%	1.268
$\sum w_i \leq 2$	13.160%	10.373%	1.269

Table 12. The return, standard deviation and Sharpe ratio during the COVID-19

during	return	stdev	sharpe
Free	26.052%	14.052%	1.8540
$w_1=0$	26.049%	14.052%	1.8538
$w_i \geq 0$	26.049%	14.052%	1.8538
$ w_i \leq 1$	26.049%	14.052%	1.8538
$\sum w_i \leq 2$	26.049%	14.052%	1.8538

And then let's pay attention to the return, standard deviation and Sharpe ratio. There is something unbelievable which is displayed through these two tables. In our opinion, the COVID-19 should make economy worse and we impossibly get a portfolio better than that portfolio before the COVID-19. However, it's not the truth. We can find that the Sharpe ratio in the "during" table is higher than that in the "before" table and even higher than the Sharpe ratio based on 10 years data. It can be seen that many times the stock market will not change as we think. But the data is objective, and the data will not lie. So, we can learn a truth from that: whatever the economy is prosperous or terrible, we can all build an excellent portfolio as long as we allocate our asset rationally.

Finally, I make a summary: during the COVID-19, we should reduce the proportion of funds invested in SPX and ALL, and invest this part of fund into the NVDA, JNJ and CL, and then we can get the optimal portfolio under each constraint when we only consider the risk.

At the same time, we can also know that the COVID-19 It has a great impact on the benchmark, bank and insurance.

4.2.2 Consider the return and the risk in the Markowitz model

Table 13. The weight before the COVID-19

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0.299546	0	0	0	0.005643	0.504059	0	0.217959	-0.02721
$w_1=0$	0	0	0	0	0.083075	0.534697	0.037671	0.315374	0.029182
$w_i \geq 0$	0.286617	0	0	0	0.003396	0.494248	0	0.215739	0
$ w_i \leq 1$	0.2996	0	0	0	0.005518	0.503853	0	0.218204	-0.02717
$\sum w_i \leq 2$	0.299548	0	0	0	0.005644	0.504059	0	0.217959	-0.02721

Table 14. The weight during the COVID-19

	SPX	GS	USB	NVDA	CSCO	PG	JNJ	ALL	CL
Free	0	0	0	0.585982	0.359965	0	0	0	0.054053
$w_1=0$	0	0	0	0.585982	0.359965	0	0	0	0.054053
$w_i \geq 0$	0	0	0	0.585982	0.359965	0	0	0	0.054053
$ w_i \leq 1$	0	0	0	0.585982	0.359965	0	0	0	0.054053
$\sum w_i \leq 2$	0	0	0	0.585982	0.359965	0	0	0	0.054053

Table 15. The return, standard deviation and Sharpe ratio before the COVID-19

before	return	stdev	sharpe
Free	28.370%	15.132%	1.8748
w1=0	29.674%	16.356%	1.8143
wi≥0	17.149%	11.923%	1.438
wi ≤1	26.815%	14.336%	1.870
sum wi ≤2	24.349%	13.195%	1.845

Table 16. The return, standard deviation and Sharpe ratio during the COVID-19

during	return	stdev	sharpe
Free	45.847%	18.304%	2.5047
w1=0	45.847%	18.304%	2.5047
wi≥0	45.847%	18.304%	2.5047
wi ≤1	45.847%	18.304%	2.5047
sum wi ≤2	45.847%	18.304%	2.5047

When we consider the return and risk, which means that we want a Maximum Sharpe ratio. We can discover that the conclusion is roughly as same as that which is only consider the risk. They all reduce the weight of SPX and ALL and increase the weight of NVDA and CL.

However, there are something different. when we add a factor “return”, we should not long or short the JNJ and PG during the epidemic which are different.

Thought JNJ and PG have a relative risk, its profitability is not as wonderful as those companies such as NVDA. Hence, when we balance the risk and return, investor prefer to allocate more fund to NVDA, CSCO and ALL.

Through the Markowitz model we can know that the optimal portfolio during the COVID-19 is longing NVDA, CSCO and CL.

5. Conclusion

Initially, I emphasize again that the theme of this paper is seek for how to investment and building a portfolio during the period of COVID-19. And then we compare the Markowitz model and Index model which are based on a decade data. After that we focused on comparing the difference between the period of 2018 to 2020 and 2020 to 2021. Finally acquire the conclusion which is as follow.

COVID-19 bring a negative influence to the global economy. And SPX can reflect the economic situation of the America. Therefore, in this turbulent period, economic instability is normal. It's not just the United States, it's the world. That is the reason why we couldn't allocate fund to the SPX, because it has high risk.

During the period of COVID-19, banks and insurance were greatly affected by the epidemic. Banks has a relationship with economy, when economy is terrible, banks will face to enormous difficulty; insurance has a relationship with life. Thousands of people ill or died in the period of COVID-19, insurance companies would face to the huge risk. That is the reason why we couldn't invest the GS, USB and ALL.

Ultimately, compared with the period of 2018-2020, I suggest that investor can allocate our capital to NVDA, CSCO and CL. From a macroeconomic point of view, technology and healthcare have greater investment value.

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