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Using Markovitz Model to Analyze Covid-19's Impact on Portfolio

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Abstract: In 2020, an unexpected pandemic struck the whole world. Covid 19 had a huge influence on the financial market, yet how it affected the performance of portfolios hasn't been systematically studied. In this paper, the Markovitz Model is utilized to study the portfolio performance before and after the covid 19. A recent 3 years of historical daily total return data for ten stocks are downloaded from Yahoo finance, which later are aggregated to the monthly observations. Then, based on the monthly observations, all proper optimization inputs for the full Markowitz Model are calculated. After that, minimal variance and max Sharpe are found under 5 cases of the additional constraints, and the regions of permissible portfolios are drawn. The results are presented in both tabular and graphical forms and the inferences and comparisons are made. It turns outs that the pandemic did jeopardize the stock market, with the return of the portfolio decreasing and risk increasing. The flight ban could be the reason for the poor performance of the portfolio. Fortunately, the low ebb was temporary. A well-diversified investment can offset the negative impact caused by covid 19.

Keywords: Markovitz Model, Covid 19, portfolio performance

1. Introduction

In the year 2020, an unexpected novel coronavirus struck the world and significantly affected almost all industries and all people's lives across the globe. According to the most updated data, by the end of September, 2022, there have been 609,070,632 diagnosed cases and 6,504,581 deaths all over the world. The negative effect can also be seen in the economic field. During the pandemic, both the capital market, global trade, and transnational investment suffered. The global financial market has experienced substantial fluctuations, and US stocks have been blown four times in less than two weeks (March 9-18,2020) [1]. However, some companies have flourished during this period, especially those in the medical industry (medical equipment and nucleic acid test). Therefore, it is an arbitrary statement that the covid 19 brought a heavy blow to all industries. To correctly assess and understand the economic impact of COVID-19, the intention of this article is to analyze the influence of COVID-19 on the portfolio's return, risk, and its Sharpe ratio, and see whether the diversified investment can avoid the impact of the covid 19.

In the economic field, the Markowitz model is frequently used to establish the calculation method of expected return and risk of the securities portfolio. This model has the following assumptions [2].

First, when an investor considers each investment option, it is based on the probability distribution of the security income over a certain holding time. Investors then estimate the risk of a portfolio based

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on the expected yield of the security. In addition, investors' decisions are based solely on the risks and returns of securities. Finally, at a certain level of risk, investors expect the maximum return; Correspondingly, at a certain income level, investors want minimal risk.

Its key insight is that an asset's risk and return should not be assessed by itself, but by its contribution to the overall risk and return of the portfolio. Therefore, in this paper, the Markowitz model is employed to calculate the return, and standard deviation (the Markowitz model uses the variance/standard deviation of asset prices as a proxy for risk) [3].

According to behavioral finance, emergencies often affect investors' sentiment to alter their choice of investment. Recent findings of a double causal relationship between investor sentiment and financial market indices in optimistic or pessimistic situations suggest that positive and negative returns in financial markets could affect the sentiment of Chinese investors [4]. The heterogeneous analytical approach is applied to research the behavior of investors, the simulation results show that the inherent characteristics of emergencies have a significant impact on the behavior of investors in China's stock market, which in turn affects the market performance after the outbreak of emergencies. However, not every unexpected event will have a significant impact on the entire stock market, and different industries are affected by unexpected events in different ways and to different degrees [5]. The Structural Change Test has been used to predict structural changes in the US stock market in relation to the 9/11 event. It was found that only 15 of the 38 companies with abnormal trading activity prior to the incident detected structural changes in share price levels, suggesting that the impact of the 9/11 attacks on the U.S. financial system was very limited [6]. Compared to other industries, the return and volatility spillover effects generated across the oil, gold, and stock markets are significant, with return spillovers being more stable and volatility spillovers being highly sensitive to emergencies, especially public health emergencies like the COVID-19 pandemic [7].

Currently, there are many relevant studies on how the pandemic affects the stock market. The short-term influence of COVID-19 has been examined on daily stock market performance in Korea and discovered that returns remained unaffected by the decaling number of cases despite an increase in the number of confirmed cases negatively affecting stock returns [8]. An event study method has been utilized research the how market performed and how Chinese industries responsed to the COVID-19 pandemic. It has been found that the transportation, mining, power and heating, and environmental sectors have all been adversely affected by the pandemic, while the manufacturing, information technology, education, and healthcare sectors are resilient [9]. Because of the pandemic, Indonesia's JCI fell more than 5%, leading to the suspension of the first trading day of the day. The JCI index fell from 5150 to the low point of 4892, with banking stocks falling the most, by 5.94% [10]. By exploiting the Asymmetric Power GARCH model, it has been found that COVID-19 did great harm to the market returns of the United States and Japan while the Asian markets still made available better prospects for portfolio optimization [11]. All these relevant researches indicate that the covid 19 may have distinct effects on different industries. However, how the covid 19 will affect the portfolio and whether the diversified portfolio has the ability to eliminate the possible negative impact if the covid 19 harmed the relevant industries remain unsystematically researched. In this case, we use the Markowitz model to conduct an in-depth study of the income change and standard deviation of a portfolio in the US market. Additionally, 5 constraints are applied to simulate different real situations and Minimal variance and Maximum Sharpe ratio under each circumstance are compared.

2. Data

In this paper, the portfolio is formed by 10 stocks， covering financial Services, industrials, and technology [12]. Among them, ADBM, IBM, SAP come from the sector of Technology; BAC, C, WFC, TRV from the sector of Financial Services; and LUV, ALK, HA from the sector of Industrials. All the raw data is downloaded from Yahoo finance. To give a comprehensive view of the covid 19's

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effect on the economic field, almost all these 10 stocks come from different industries and it is relatively irrelevant to each other.

Table 1: 10 Stocks and their industries.

Ticker	Industry
ADBE	Software-Infrastructure
HA	Airlines
LUV	Airlines
ALK	Airlines
BAC	Banks-Diversified
C	Banks-Diversified
WFC	Banks-Diversified
IBM	Information Technology Services
SAP	Software-Application
TRV	Insurance-Property & Casualty

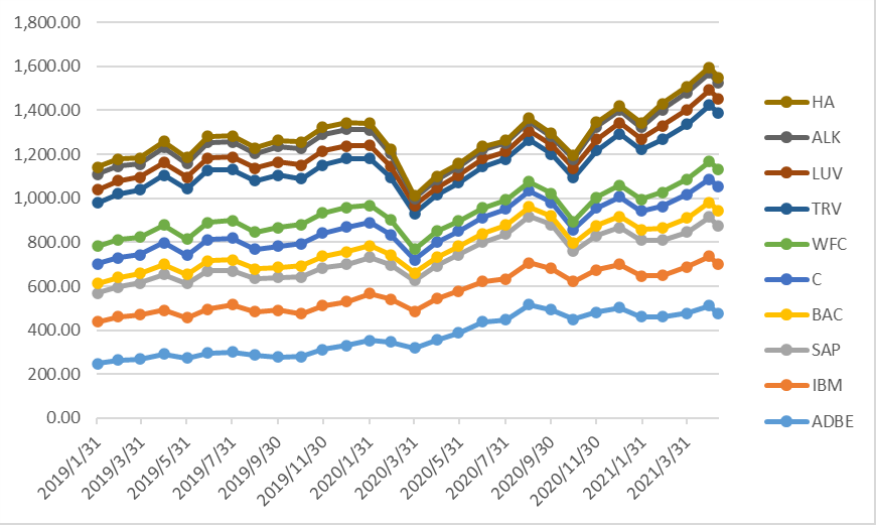

Figure 1: The price of 10 stocks in the recent 3 years. A significant drop can be seen during 2020/1/31-20203/31.

2.1. Data Preprocessing

Now, a historical daily total return data of recent 3 years (2019/1/31-2021/5/12) for ten stocks, one (S&P 500) equity index (abbreviated as SPX, a total of eleven risky assets) and a proxy for risk-free rate (1-month Fed Funds rate, abbreviated as FEDL01) are given. Here, it is assumed that the initial investment in the portfolio is $1303, and then the daily return, abbreviated as NRFR, is calculated based on the following formula：

$$NRFR_{i+1} = NRFR_i*(1+FEDL01_{i+1}/100/252) \quad (1)$$

After that, the raw data is condensed into 5-day Week Daily data to avoid lengthy calculations. Then, March 2020 is considered as the month when covid 19 fully affected the entire US financial

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market, so the period 2020/31/3 – 2021/5/12 is defined as *After covid 19* while the period 2019/1/31 – 2020/2/28 as *Before covid 19.* After that, the return rate, excess return, and residual returns of each stock are calculated.

2.2. Calculate 5 Key Parameters for Markowitz Model

For each stock, its Annualized Average Return, Annualized StDev, Beta, Alpha, Annualized Residual StDev need to be calculated. The first two are calculated as followed:

$$Annualized\ average\ return = 12 * \sum_{i=1}^{n} excess\ return_i \tag{2}$$

$$Annualized\ StDev = \sqrt{\frac{12*\sum_{i=1}^{n}(excess\ return_i - \overline{excess\ return})^2}{n-1}} \tag{3}$$

Beta is the slope of the Linear fitting of two data sets. Here, the excess return of SPX is always in one data set and the excess return of each stock of the portfolio is in another set, respectively. So, there will be 10 Betas for 10 stocks. Here, the function SLOPE in excel is used to calculate the beta.

Similar to Beta, Alpha is the intercept of the Linear fitting of two data sets. The function INTERCEPT in excel is used to calculate alphas and the results should multiply 12.

$$Annualized\ residual\ StDev = \sqrt{\frac{12*\sum_{i=1}^{n}(residual\ return_i - \overline{residual\ return})^2}{n-1}} \tag{4}$$

Then, we have the result. Similar to what can be seen in **Fig. 2,** there are five stocks that experienced negative annualized average return before the covid, indicating that there was a downward trend for the stock prices during this period.

Table 2: 5 Key parameters-Before Covid 19.

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
Annualized Average Return	0.09	0.31	0.03	0.18	0.05	0.04	-0.12	-0.03	-0.17	-0.17	-0.33
Annualized StDev	0.15	0.20	0.23	0.25	0.31	0.31	0.23	0.19	0.24	0.31	0.35
belta	1.00	0.98	1.03	1.03	1.84	1.91	1.20	0.60	1.32	1.61	1.93
alpha	0.00	0.22	-0.07	0.09	-0.12	-0.13	-0.23	-0.08	-0.29	-0.31	-0.50
Annualized Residual StDev	0.00	0.13	0.17	0.20	0.15	0.14	0.15	0.16	0.15	0.20	0.22

Table 3: 5 Key parameters-After Covid 19.

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
Annualized Average Return	0.42	0.38	0.29	0.28	0.63	0.61	0.50	0.42	0.51	0.81	0.88

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Table 3: (continued).

Annual-ized StDev	0.17	0.28	0.23	0.41	0.26	0.40	0.38	0.17	0.43	0.46	0.68
belta	1.00	1.24	1.03	1.59	1.09	1.59	0.92	0.22	0.28	1.54	2.07
alpha	0.00	-0.15	-0.15	-0.39	0.17	-0.07	0.11	0.32	0.39	0.16	0.00
Annual-ized Re-sidual StDev	0.00	0.18	0.14	0.31	0.18	0.29	0.35	0.16	0.43	0.38	0.58

2.3. Correlation Coefficients Matrix

Here, the correlation coefficient between two stocks is calculated respectively. Then, the results are transformed into a matrix so that it will be convenient to calculate the standard deviation of the whole portfolio. It is a symmetric matrix and all the values in the diagonal of the matrix are 1.

As can be seen from the table below, nearly half of the correlation coefficients are below 0.5 before the covid 19. After the covid, more coefficients are less than 0.5, which means that this portfolio is well diversified and the overall risk is relatively low.

Table 4: Correlation coefficients matrix *Before covid 19.*

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
SPX	1.00	0.72	0.65	0.60	0.87	0.90	0.75	0.47	0.79	0.77	0.79
ADBE	0.72	1.00	0.53	0.44	0.64	0.64	0.31	0.36	0.46	0.36	0.46
IBM	0.65	0.53	1.00	0.02	0.52	0.53	0.42	0.45	0.53	0.41	0.38
SAP	0.60	0.44	0.02	1.00	0.50	0.60	0.38	0.17	0.43	0.56	0.59
BAC	0.87	0.64	0.52	0.50	1.00	0.96	0.82	0.27	0.72	0.83	0.83
C	0.90	0.64	0.53	0.60	0.96	1.00	0.79	0.39	0.73	0.87	0.86
WFC	0.75	0.31	0.42	0.38	0.82	0.79	1.00	0.41	0.66	0.75	0.77
TRV	0.47	0.36	0.45	0.17	0.27	0.39	0.41	1.00	0.21	0.28	0.23
LUV	0.79	0.46	0.53	0.43	0.72	0.73	0.66	0.21	1.00	0.83	0.88
ALK	0.77	0.36	0.41	0.56	0.83	0.87	0.75	0.28	0.83	1.00	0.96
HA	0.79	0.46	0.38	0.59	0.83	0.86	0.77	0.23	0.88	0.96	1.00

Table 5: Correlation coefficients matrix *After covid 19.*

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
SPX	1.00	0.77	0.79	0.66	0.71	0.68	0.41	0.22	0.11	0.58	0.52
ADBE	0.77	1.00	0.50	0.69	0.34	0.40	0.16	0.23	0.25	0.40	0.20
IBM	0.79	0.50	1.00	0.56	0.76	0.65	0.57	0.00	0.00	0.45	0.41
SAP	0.66	0.69	0.56	1.00	0.36	0.37	0.36	-0.12	-0.06	0.16	0.00
BAC	0.71	0.34	0.76	0.36	1.00	0.88	0.80	0.38	0.41	0.80	0.66
C	0.68	0.40	0.65	0.37	0.88	1.00	0.71	0.53	0.36	0.79	0.65
WFC	0.41	0.16	0.57	0.36	0.80	0.71	1.00	0.25	0.54	0.70	0.53

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Table 5: (continued).

TRV	0.22	0.23	0.00	-0.12	0.38	0.53	0.25	1.00	0.42	0.49	0.21
LUV	0.11	0.25	0.00	-0.06	0.41	0.36	0.54	0.42	1.00	0.75	0.48
ALK	0.58	0.40	0.45	0.16	0.80	0.79	0.70	0.49	0.75	1.00	0.86
HA	0.52	0.20	0.41	0.00	0.66	0.65	0.53	0.21	0.48	0.86	1.00

3. Model

The Markowitz Model is a portfolio optimization model. It uses expected returns (mean) and the standard deviation (variance) of the various portfolios to determine the efficient set. Here, the efficient set refers to a portfolio that gives minimum risk for a given return or a maximum return for a given risk. The boundary of the efficient set is named Efficient Frontier. Both the efficient frontier and points in the efficient set provide vivid and intuitive information about the performance of certain stocks.

Here, the following notations are assigned to some parameters: $\vec{\mu}$ is the set of instruments' average returns; $\vec{w}$ is the set of instruments' weights, but it is unknown; $\vec{\sigma}$ is the set of instruments' standard deviations; P is the matrix of instruments' cross-correlation coefficients.$\vec{v}$ is an auxiliary vector.

$$\vec{v} = \vec{w} \cdot \vec{\sigma}^{T} \tag{6}$$

Then MM portfolio return and standard deviation can be written as following formula:

$$r_P = \vec{w} \cdot \vec{\mu}^{T} \tag{7}$$

$$\sigma_P = \sqrt{\vec{v} P \vec{v}^{T}} \tag{8}$$

Generally, the weights of the stocks are constrained. To be more realistic, adding constraints on the weights can better simulate the real situation. Here, 5 different constraints are introduced, and their meaning is emulated.

benchmark: free problem (Constraint 1):

If there aren't any additional optimization constraints, it is a free problem and this situation can be served as a benchmark.

Constraint 2:

According to FINRA's T regulation, traders can allow their customers to hold positions. More than fifty percent of these positions are patronized by the customer's net account value: So, the total weights of absolute value, should be less than 2.

$$\sum_{i=1}^{11} |w_i| \leq 2 \tag{9}$$

Constraint 3:

Some arbitrary "box" constraints on weights may be demanded by clients, which means that every stock's weight, in absolute value, should be less than one.

$$|w_i| \leq 1, \text{for } \forall I \tag{10}$$

Constraint 4:

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In the American mutual fund industry, American open-ended mutual funds are not allowed to have any short positions. Thus, all weights must be non-negative.

$$w_i \geq 0, \text{for } \forall i \tag{11}$$

Constraint 5：

To figure out whether the portfolio has positive or negative effect when the broad index is included, an additional optimization constraint needed to be considered:

$$w_1 = 0 \tag{12}$$

4. Result

4.1. Minimum Variance

To minimize the risk before covid, the best strategy seems to be selling most stocks, regardless of the types of constraints. After covid, with an upward trend of stocks' prices, the strategy changes into purchasing stocks. IBM, SAP, LUV performed very well, with weights assigned to them nonnegative under every constraint. The weights are given by the following table.

As for the minimum variance, under constraint 1&5, both returns are negative before the covid, indicating that the overall return of the portfolio in the efficient set is probably negative. On the contrary, the corresponding returns after the covid are all positive. Noticeably, the Standard deviation under each constraint before the covid is larger than that after the covid, which means that before the covid, not just the return decreased, the risk also increased.

Table 6: Weights before covid 19.

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
Constr1:	1.03	-0.73	0.18	0.23	1.43	-1.85	-0.49	0.91	-0.08	-0.52	0.89
Constr2:	1.07	0.07	0.00	0.07	0.00	-0.44	0.09	0.14	0.00	0.07	-0.06
Constr3:	1.00	0.61	-0.11	-0.08	-0.46	-0.55	0.55	-0.20	-0.17	1.00	-0.56
Constr4:	0.67	0.02	0.00	0.03	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Constr5:	0.00	-0.46	0.29	0.41	1.44	-1.83	-0.24	0.95	0.17	-0.37	0.64

Table 7: Weights after covid 19.

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
Constr1:	-0.14	-0.31	0.48	0.34	0.20	-0.06	-0.27	0.78	0.48	-0.83	0.33
Constr2:	0.20	0.00	0.32	0.05	0.00	-0.11	0.00	0.61	0.19	-0.39	0.12
Constr3:	-0.14	-0.31	0.48	0.34	0.20	-0.06	-0.27	0.78	0.48	-0.83	0.33
Constr4:	0.33	0.00	0.14	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00
Constr5:	0.00	-0.35	0.46	0.32	0.14	-0.04	-0.26	0.74	0.48	-0.79	0.31

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Table 8: Min variance before covid 19.

Return	StDev	Sharpe
-25.000%	15.068%	-1.66
10.500%	9.968%	1.05
20.000%	7.483%	2.67
6.500%	13.695%	0.47
-24.000%	15.414%	-1.56

Table 9: Min variance after covid 19.

Return	StDev	Sharpe
20.000%	4.964%	4.029
27.000%	7.733%	3.492
20.000%	4.964%	4.029
40.000%	13.135%	3.045
20.000%	4.991%	4.007

4.2. Max Sharpe

When taking a further look, the weights are changed to find the max Sharpe ratio. Before the covid, the max Sharpe ratio is 6.59 with no constraints. Compared to standard deviations after the covid, the Standard Deviation before the covid are much higher when reaching the max Sharpe. The max Sharpe ratios after the covid are quite close to each other, around 4, with the biggest occurring under both constraints 1&3.

Table 10: Weights before covid 19.

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
Con-str1:	0.29	0.48	-0.11	-0.10	-0.58	0.16	0.39	-0.32	-0.07	0.63	-0.50
Con-str2:	0.71	0.53	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.01	-0.50
Con-str3:	1.00	0.98	-0.20	-0.07	-1.00	0.13	0.80	-0.56	-0.09	1.00	-1.00
Con-str4:	0.00	0.97	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Con-str5:	0.00	1.14	-0.07	0.02	-0.83	-0.27	0.98	-0.38	0.05	1.45	-1.10

Table 11: Weights after covid 19.

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
Con-str1:	0.03	-0.16	0.14	0.23	0.52	-0.18	-0.18	0.69	0.33	-0.70	0.27
Con-str2:	-0.14	-0.31	0.48	0.34	0.20	-0.06	-0.27	0.78	0.48	-0.83	0.33
Con-str3:	0.03	-0.16	0.14	0.23	0.52	-0.18	-0.18	0.69	0.33	-0.70	0.27

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Table 11: (continued).

Con-str4:	0.44	0.00	0.00	0.00	0.08	0.00	0.00	0.51	0.00	0.00	0.00
Con-str5:	0.00	-0.15	0.15	0.24	0.52	-0.18	-0.18	0.70	0.33	-0.70	0.28

Table 12: Max sharpe before covid 19.

Return	StDev	Sharpe
16.234%	2.464%	6.59
43.463%	16.414%	2.65
42.470%	8.981%	4.73
30.197%	19.315%	1.56
30.000%	8.025%	3.74

Table 13: Max sharpe before covid 19.

Return	StDev	Sharpe
31.651%	6.570%	4.82
20.000%	4.964%	4.03
31.651%	6.570%	4.82
45.092%	14.239%	3.17
31.564%	6.552%	4.82

4.3. The Efficient Set

Then, the efficient sets are drawn to better compare the overall performance of the portfolio. The y-axis represents return while x-axis represents StDev. In figure 2, almost all points have negative returns, which means that before the covid fully affected the whole United States, it jeopardized the performance of the portfolio, and simply adjusting weights can't fully compensate the loss. However, the dim was temporary. After covid, the portfolio took a better term, despite the stocks' prices experiencing a sharp drop on November,2020. This means that by diversifying investment can offset the adverse impact of the covid.

Besides, the improvement of the portfolio can own credit to the performance of the stocks LUV, ALK, and HA. Considering that these stocks are in airlines industry, the declining tendency of them shortly before the covid could be relevant to flight ban decision at the beginning of 2020. But after this event, their performance gradually progressed.

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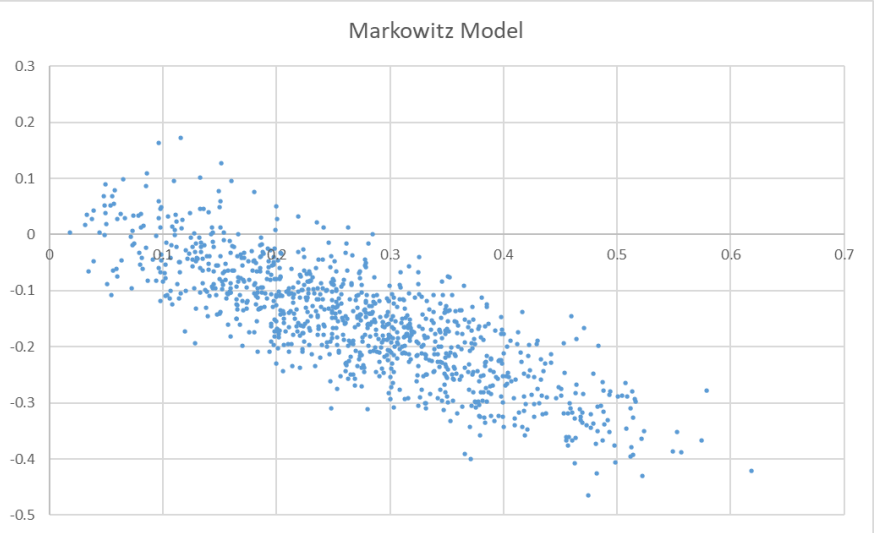

Figure 2: The efficient set before covid 19.

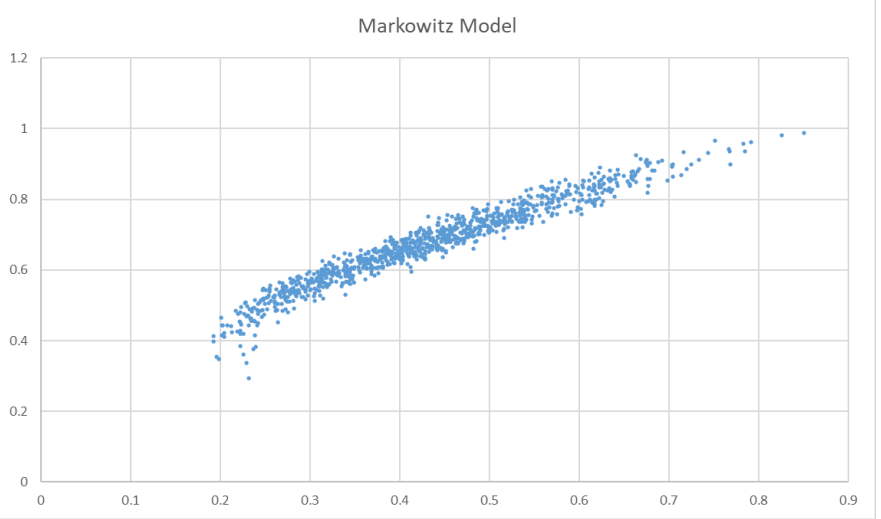

Figure 3: The efficient set after covid 19.

5. Conclusion

In this paper, the Markowitz Model is employed to analyze a certain portfolio of 10 stocks in the US market and minimal risk portfolio, optimal portfolio under five constraints are calculated. The outcomes are divided into 2 parts, the first is during the *Before covid 19* period (2019/1/31 – 2020/2/28) and the second one during *After covid 19* period (2020/31/3 – 2021/5/12), and comparison has between these 2 periods has been made. The result indicates that the covid 19 did bring an adverse impact on the US financial market and the overall performance deteriorated when the year 2020 began. During this period, the return of the portfolio was largely negative and under every constraint the investing risk was relatively high. However, the portfolio soon got out of the slump and took a better turn after March 2020. This result suggests that diversified investment can offset the negative effect brought by the pandemic. From statistical view, this improvement owns credit to 3 airline relevant stocks. One possible explanation was that after the flight ban was gradually canceled, these 3 stocks became vigorous again.

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The research done in this paper complement the relevant studies on the covid 19's impact on the performance of the portfolio, and the result may bring benefit to those who are interested in how to diversify investment to avoid or offset potential risk and negative impact. Still, it is worthwhile to point out that the research done on this paper may have potential drawbacks. The chosen stocks may not be the best sample to represent the whole financial market in the US and Markowitz Model may not be the best tool to analyze the portfolio. To further investigate into this topic, more efforts and comprehensive data are required.

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