A Comparison of Equities Portfolio Before and After The COVID-19 Under Markowitz and Index Model

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Abstract: The global stock market has undergone a historic downturn and volatility because of COVID-19's influence. This paper creates a portfolio using 10-year stock price data from the S&P 500 and 10 stocks. The varied performance of the portfolio before and after the pandemic could be examined under four different constraints using the Markowitz model and Index model to compute the portfolio's return and risk. Overall, we model a satisfactory weight distribution, even though the portfolio following the pandemic usually has a lower return-risk ratio. The weights of technology equities in a given portfolio fluctuate, whereas aviation stocks are always undervalued before and after a pandemic. This study seeks to anticipate an optimal portfolio or portfolio with the lowest risk in advance for investors in the future, assisting in the avoidance of potential unknown risk.

1. Introduction

COVID-19 has been spreading over the world since 2020, thanks to its high infectivity and pathogenicity, causing havoc on all trades and professions. Following the emergence of COVID-19 and its devastating consequences, governments have implemented several coercive laws and actions. People's fear of the financial market was heightened by the unknown epidemic and a steep drop in global crude oil prices, resulting in a significant drop in worldwide stock prices. Taking the S&P 500 index as an example, it fell as much as 30% in around a month from February 19th to March 17th. Through buying a portfolio composed of different types of stocks and handing it to professional fund managers for management, the stock risk is diversified, and investor's time and energy could be saved. However, with the outbreak of COVID-19, previous stable stock market was in an extreme state of volatility. Whether the investor's portfolio can still get better returns after the pandemic is what we want to study in this paper.

In 1952, Markowitz [1] put forward the Modern Portfolio Theory in his article breakthrough, which used mean and variance to describe return and risk correspondingly. Based on the Markowitz's research, Sharpe [2] further improved the model in 1963. He divided the risk of a security into systematic risk that cannot be avoided and nonsystematic risk that can be avoided. Furthermore, Sharpe thought only systematic risk cannot be diversified by diversification, the risk in a company and between the companies could be neglected through diversification. Therefore, the correlation between stocks could be avoided, which simplified the calculation to a great extent.

After pandemic, a group of researchers have carried out studies on different kinds of portfolios. Himanshu et al. [3] found that the choice preference of assets in investment portfolio under COVID-19 had changed by collecting data from India. Most investors had changed from being willing to take greater risks to invest in stocks and other assets to obtain greater returns before the pandemic to adding low-risk safe assets such as risk-free assets, insurance, gold in their portfolios. Although the priority of stocks in portfolio is reduced, investors still believed that the stock market had more opportunities under the pandemic. Ali et al. [4] used Dow Jones Islamic market index to analyze the changes of precious metals under the COVID-19. The results show that the inclusion of precious metal like gold in the portfolio can reduce the downside risk and improve the risk-return portfolio. In addition to Ali's research, the combination of digital cryptocurrency and other securities is an emerging portfolio that

is often studied. Researchers are very interested in the specific impact of between the digital cryptocurrency and other assets on the portfolio. Liu et al. [5] took Bitcoin as the main research objects differently. By establishing an effective frontier with analyzing the risk- return ratio based on Markowitz model, they found that cryptocurrency had a better performance in improving the two characteristics of traditional portfolio. Contrary to the research above, Aliu et al. [6] explored the impact of other assets in the portfolio on cryptocurrency. They concluded that compared with the fiat currency and commodity, incorporating stocks into the crypto portfolios could reduce the risk of portfolio to a minimum, reaching about 36%.

The main purpose of this paper is to help investors forecast an optimal investment project under external impacts in the future. Different from the current papers on portfolio research, we apply Markowitz model and Index model to a portfolio and divide the portfolio into two parts: before and after the pandemic. Then we set up four constraints which are close to the reality with calculating the minimum variance and the optimal Sharp Ratio of the portfolio under each constraint before and after the epidemic and carry out a detailed comparison respectively. To sum up, under most conditions, the post-pandemic portfolio cannot reach the risk-return ratio of the pre-pandemic portfolio. In addition, technology stocks in the portfolio will have large weight changes according to different constraints and objectives. In contrast, aviation stocks are despised by the portfolio under most constraints, and the weights of them could basically negligible. Furthermore, in financial stocks, Citigroup Inc. (C) has always been short, while the Travelers Companies Inc. (TRV) has always been long.

2. Data and method

2.1 Data

In this paper, we are trying to investigate the formation of the portfolio, so we select the price data of a market index and ten stocks from January 1st, 2010 to May 21st, 2021. All individual stocks cover different industries, including technology industry, financial industry, and airline industry. Then using them to establish an investment portfolio, which includes S&P 500 Index (SPX), Adobe, Inc. (ADBE), International Business Machines Corporation (IBM), Systems, Applications & Products in Data Processing (SAP), Bank of America Co. (BAC), C, Wells Fargo & Company (WFC), TRV, Southwest Airlines Co. (LUV), Alaska Air Group, Inc. (ALK), Hawaiian Holdings, Inc. (HA). The First, we will present the price graphs of the portfolio respectively.
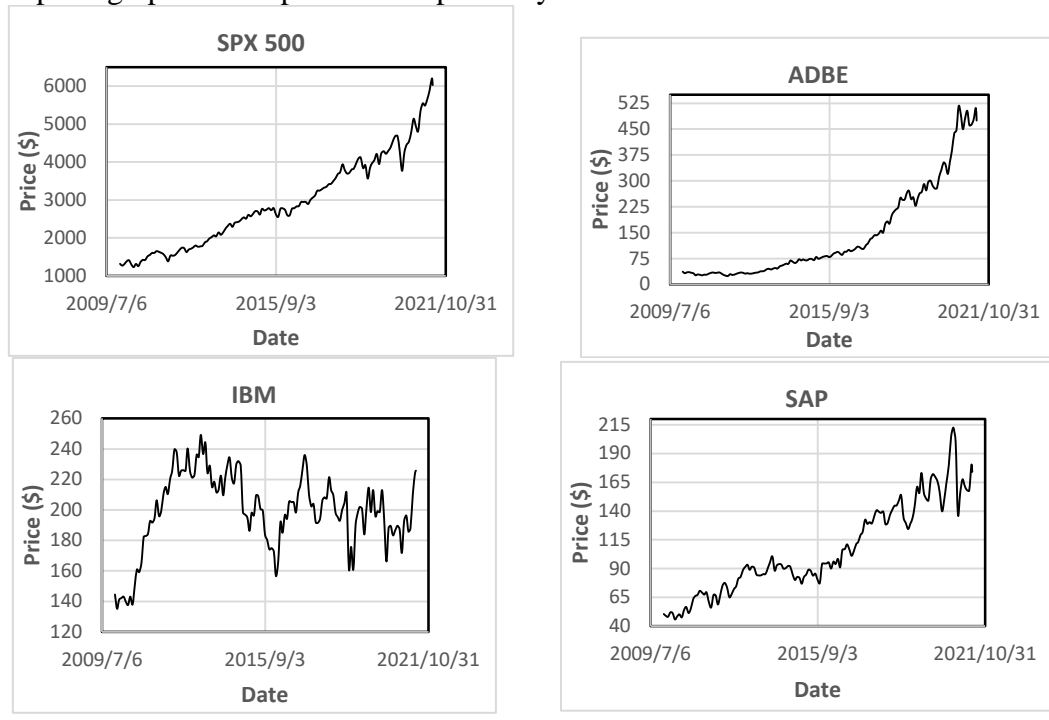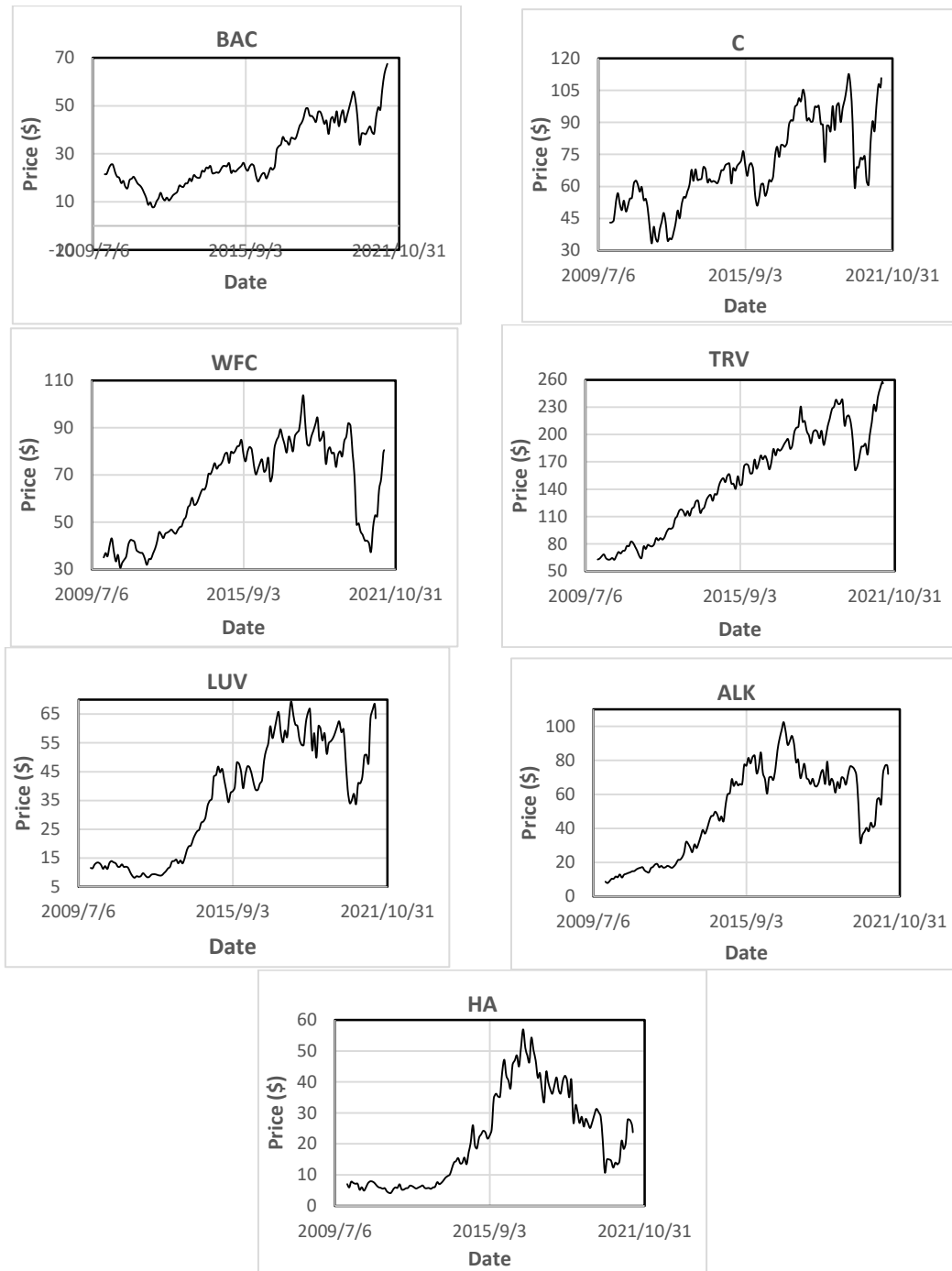
Fig 1. Stock price for individual stocks and SPX 500

Source: Bloomberg

According to the previous graphs, we could find that the prices of most stocks except Adobe experienced a dramatic decline in the around first half of 2020. To explore the reasons, Mahata et al. [7] thought that the wide spread of COVID-19 brought a severe impact the whole environment of social market, especially the economy and stock market. Therefore, we could consider confidently that COVID-19 is the main cause of the stock price decrease.

Since we want to explore the impact of different time periods before and after the pandemic on the investment weight of each stock in the portfolio, we divide the stock price data into two parts, and the segmentation date is February 19th, 2020, when the S&P 500 reached the highest point before the sharp decline in stock price caused by the COVID-19 [8]. In the following part, we convert the stock price data into excess rate of return and make the correlation coefficient matrix between 10 stocks and S&P 500 accordingly.

Table 1: The correlation matrix for the whole period

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
SPX	1.00										
ADBE	0.14	1.00									
IBM	0.40	-0.69	1.00								
SAP	0.14	0.74	-0.70	1.00							
BAC	0.42	-0.53	0.76	-0.70	1.00						
C	0.15	0.65	-0.59	0.88	-0.70	1.00					
WFC	0.31	-0.54	0.72	-0.72	0.91	-0.81	1.00				
TRV	0.00	0.57	-0.59	0.77	-0.77	0.87	-0.90	1.00			
LUV	0.30	-0.45	0.62	-0.61	0.80	-0.68	0.87	-0.84	1.00		
ALK	0.06	0.49	-0.47	0.67	-0.63	0.77	-0.75	0.87	-0.78	1.00	
HA	0.25	-0.38	0.52	-0.51	0.69	-0.57	0.73	-0.71	0.85	-0.73	1.00

Table 2: The correlation matrix before and after the COVID-19

PANEL A: Before COVID-19

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
SPX	1.00										
ADBE	0.64	1.00									
IBM	0.64	0.41	1.00								
SAP	0.65	0.48	0.46	1.00							
BAC	0.71	0.42	0.40	0.44	1.00						
C	0.75	0.44	0.46	0.49	0.83	1.00					
WFC	0.75	0.42	0.45	0.46	0.75	0.74	1.00				
TRV	0.67	0.39	0.43	0.43	0.52	0.54	0.55	1.00			
LUV	0.54	0.35	0.32	0.30	0.43	0.45	0.44	0.39	1.00		
ALK	0.54	0.34	0.32	0.32	0.41	0.43	0.43	0.37	0.64	1.00	
HA	0.42	0.28	0.24	0.23	0.34	0.36	0.33	0.30	0.49	0.51	1.00

PANEL B: After COVID-19

	SPX	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUV	ALK	HA
SPX	1.00										
ADBE	0.12	1.00									
IBM	0.53	-0.66	1.00								
SAP	0.05	0.78	-0.68	1.00							
BAC	0.48	-0.62	0.85	-0.78	1.00						
C	0.13	0.70	-0.56	0.91	-0.67	1.00					
WFC	0.39	-0.62	0.81	-0.78	0.94	-0.76	1.00				
TRV	-0.02	0.64	-0.61	0.82	-0.76	0.86	-0.86	1.00			
LUV	0.34	-0.56	0.75	-0.68	0.84	-0.65	0.89	-0.85	1.00		
ALK	0.11	0.50	-0.41	0.68	-0.56	0.76	-0.67	0.88	-0.72	1.00	
HA	0.26	-0.55	0.65	-0.61	0.77	-0.57	0.78	-0.76	0.91	-0.67	1.00

According to the comparison of the correlation matrix before and after the pandemic, we can find that the correlation between most stocks before the pandemic are positive, which in the range of 0 to 0.5, reflecting that the overall stock market is in a relatively stable growth period. Nevertheless, the correlation between stocks and between stocks and market index is not significant. This can also prove that the portfolio we built tends to diversify risk better.

We also find that the values of correlation between stocks after COVID-19 are either close to 1 or -1, indicating a strong fluctuation. However, the correlations between stocks and market index are still not very significant.

We deem that this is mainly because the coronavirus, as a severe external impact, has brought great shock and uncertainty to the whole stock market. A dramatic rise or fall of a large company's stock will greatly influence other companies' stock price.

2.2 Method

As an investment portfolio, we need to allocate corresponding weights under different periods and constraints. The portfolio could be built in the following way.

$$
\begin{aligned}
P = w_{SPX} \times SPX + w_{ADBE} \times ADBE + w_{IBM} \times \\
IBM + w_{BAC} \times BAC + w_C \times C + w_{WFC} \times WFC \\
+ w_{TRV} \times TRV + w_{LUV} \times LUV + w_{ALK} \times ALK \\
+ w_{HA} \times HA
\end{aligned}
\tag{1}
$$

Where P denotes the portfolio, $w_{SPX}, w_{ADBE}, w_{IBM}, w_{BAC}, w_C, w_{WFC}, w_{TRV}, w_{LUV}, w_{ALK}, w_{HA}$ denote the weight allocated to each stocks respectively.

Second, we use two classical models for investment selection, namely Markowitz Model and Index Model to the weight distribution of the portfolio before and after the COVID-19.

1. Markowitz Model

Markowitz [1] formally proposed the Markowitz Model to optimize the portfolio. By measuring the risk (variance) and return (mean) of the portfolio, he described that the risk between assets should consider the correlation between assets in addition to the risk addition of the assets themselves. Through the mutual restriction between return and risk, the optimal balance of the portfolio can be achieved.

Zhang [9] summarized that Markowitz Model is based on the following assumptions: Firstly, investors are risk averse. Secondly, the returns of assets obey normal distribution, and there is correlation between assets. Thirdly, investors can borrow or lend money at a risk-free interest rate. The Markowitz Model can be demonstrated in the following way:

$$
\begin{aligned}
\min Var(R_P) &= \sum_{i,j=1}^{11} w_i w_j cov(r_i r_j) \\
&= \sum_{i,j=1}^{11} (w_i w_j)(\rho_{ij}\sigma_{r_i}\sigma_{r_j}) \\
&= \sum_{i,j=1}^{11} (w_i \sigma_{r_i})(w_j\sigma_{r_j})\rho_{ij} \\
E(R_P) &= \sum_{i=1}^{11} w_i E(r_i) \\
s.t. \quad &\sum_{i=1}^{11} w_i = 1
\end{aligned}
\tag{2}
$$

Where $Var(R_p)$ denotes the variance of the portfolio, $cov(r_i r_j)$ denotes the covariance of two assets, w_i, w_j denote the weights allocated to the assets, $\sigma_{r_i}, \sigma_{r_j}$ denote the standard deviations of the assets, ρ_{ij} denotes the correlation coefficient of the assets, $E(R_P)$ denotes the expected return of the portfolio, $E(r_i)$ denotes the expected return of an asset.

2. Index Model

Differ from the Markowitz Model, Sharpe [2] proposed Index Model, which simplified the previous model. The basic opinion of Sharpe was that all securities are affected by overall market movements, when the market index rises, most stock prices in the market rise, and vice versa. The overall market can be seen as a systemic factor and others are nonsystematic factor. From this point of view, two very important assumptions have been derived. One is that the risk of securities is divided into systematic

risk and nonsystematic risk, and the factors have no impact on the nonsystematic risk. Another is that the nonsystematic risk of one security has no impact on the nonsystematic risk of other securities. Based on these two assumptions, we could present the framework of the Index Model.

$$\min Var(R_p) = \sum_{i,j=1}^{11} w_j cov(r_i r_j)$$
$$= \beta_p \sigma_M^2 + \sigma^2(e_p) \tag{3}$$
$$E(R_P) = \alpha_P + \beta_P E(R_M)$$
$$s.t. \ \sum_{i=1}^{11} w_i = 1, \ \sum_{i=1}^{11} w_i r_i - \beta_i = \beta_p$$

Where $\beta_p \sigma_M^2$ denotes the systemic risk of the portfolio, $\sigma^2(e_p)$ denotes the nonsystematic risk of the portfolio, α_P denotes the return on risk-free assets, β_i denotes the risk coefficient of an asset, β_p denotes the risk coefficient of the portfolio.

Nevertheless, only two portfolio models are not enough to an investor. How to maximize the rate of return based on balancing risk and risk is the primary consideration. So, we introduce the Sharpe Ratio to measure whether the portfolio has maximized the rate of return considering its risk.

Next, because of further researching the asset weight distribution of the portfolio under different constraints before and after the pandemic, which could be closer to the real situation.

Benchmark: No constraint

The portfolio without any constraints as the benchmark.

Constraint 1: $\sum_{i=1}^{11} |w_i| \leq 2$

This constraint is based on the T regulation of the Federal Reserve. As a securities dealer, they usually use this restriction to limit the leverage ratio of customer accounts at the end of each trading day.

Constraint 2: $|w_i| \leq 1, \ for \ \forall i$

This constraint only allows long or short less than double, which usually comes from the customer's requirements for the security management company to avoid the portfolio exceeding a specific risk level.

Constraint 3: $w_i \geq 0, \ for \ \forall i$

This constraint does not allow any security in the portfolio to be short.

Constraint 4: $w_1 = 0$

This constraint excludes the market index from the portfolio. The purpose of excluding a from the portfolio is to study the impact of incorporating the market index into the portfolio.

3. Result

In this section, we will present the weights allocation, return, standard deviation and Sharpe Ratio as well as analyze these outcomes of each portfolio with minimum variance and maximum Sharpe Ratio under two models restricted by four constraints respectively.

Table 3: Portfolio weights with minimum variance under Markowitz Model

Before	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	111.99%	-9.07%	8.58%	-2.11%	-8.04%	-18.24%
Constraint 1	111.99%	-9.07%	8.58%	-2.11%	-8.04%	-18.24%
Constraint 2	100.00%	-7.72%	11.02%	-0.48%	-7.84%	-17.81%
Constraint 3	64.94%	0.00%	13.18%	0.00%	0.00%	0.00%
Constraint 4	0.00%	3.53%	31.43%	13.13%	-6.18%	-14.23%
	WFC	TRV	LUV	ALK	HA	
Benchmark	-2.29%	20.51%	3.86%	-4.26%	-0.92%	
Constraint 1	-2.29%	20.51%	3.86%	-4.26%	-0.92%	
Constraint 2	-0.47%	23.42%	4.48%	-3.79%	-0.80%	
Constraint 3	0.00%	21.88%	0.00%	0.00%	0.00%	
Constraint 4	14.68%	47.64%	9.65%	0.19%	0.16%	
After	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	-55.13%	56.95%	36.51%	25.90%	11.91%	-7.09%
Constraint 1	-48.08%	57.41%	34.80%	17.50%	6.86%	-0.72%
Constraint 2	-55.13%	56.95%	36.51%	25.90%	11.91%	-7.09%
Constraint 3	0.00%	51.84%	21.11%	2.67%	0.00%	0.00%
Constraint 4	0.00%	50.86%	24.96%	9.62%	-5.33%	-12.50%
	WFC	TRV	LUV	ALK	HA	
Benchmark	12.56%	19.07%	0.28%	-2.16%	1.21%	
Constraint 1	15.26%	16.60%	0.03%	-1.16%	1.49%	
Constraint 2	12.56%	19.07%	0.28%	-2.16%	1.21%	
Constraint 3	10.13%	11.62%	0.00%	0.00%	2.62%	
Constraint 4	13.79%	20.52%	-1.85%	-4.22%	4.16%	

From the table describing the situation before the pandemic we could find that if we want to build different portfolios with minimum variance, Markowitz Model suggests us allocating most positive weights on S&P 500 index and TRV with shorting rest of the stocks, especially the Citigroup under the first three constraints. If we drop the S&P 500 out of the portfolio, the weights of IBM and TRV are significantly increased. However, when there is an impact of pandemic, we get a totally different situation. Under the first three constraints, we need to short S&P 500 and assign the positive weights most on Adobe, IBM, SAP, WFC and TRV. Meanwhile, if we could not short any securities, we should also short S&P 500 instead of longing it before the COVID-19.

According to the previous description, we can infer that the market index was in a stable rising process before the outbreak of the pandemic, but there was a large decline after the pandemic, which also led the model to choose to short the market index at this time. However, ADBE and WFC have changed from short to long after the COVID-19, which shows that these two companies may found some opportunities in the crisis to help their stock prices raise against the trend. The remaining IBM, SAP and TRV are selected to be long during the whole period, indicating that they are very stable and have strong risk response ability.

Table 4: Three characteristics of portfolio according to the weights allocated above

	Before			*After*		
	Return	StDev	Sharpe	Return	StDev	Sharpe
Benchmark	10.87%	12.65%	85.91%	0.33%	10.69%	3.08%
Constraint 1	10.87%	12.65%	85.91%	0.42%	10.85%	3.85%
Constraint 2	10.91%	12.68%	86.06%	0.33%	10.69%	3.08%
Constraint 3	11.96%	14.02%	85.30%	6.58%	14.31%	45.99%
Constraint 4	11.24%	14.67%	76.63%	6.92%	13.77%	50.21%

Note: StDev stands for standard deviation (risk)

We can further explore the characteristics of the portfolio. Although the risks of the portfolio under benchmark and first three constraints before and after the pandemic are basically same, the returns and Sharpe Ratios of them have an obvious decline, which are all close to the 0%. However, if we do not allow to short or invest in the market index, the degree of decline in return and Sharp Ratio is substantially reduced while keeping the portfolio variance basically unchanged.

Even if we could find a portfolio sharing almost same risk with the portfolio built before the pandemic, the return and Sharpe ratio still imply it has little profit. Nevertheless, it seems a reasonable solution if we remove the S&P 500 from the portfolio according to the previous results, which means the market index has a negative effect on the portfolio after the COVID-19.

Table 5: Portfolio weights with maximum Sharpe Ratio under Markowitz Model

Before	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	100.77%	29.19%	-38.13%	2.03%	-5.48%	-18.04%
Constraint 1	72.23%	27.98%	-19.99%	1.16%	-4.28%	-14.93%
Constraint 2	100.0%	29.29%	-37.99%	2.14%	-5.47%	-18.01%
Constraint 3	8.49%	38.70%	0.00%	0.29%	0.00%	0.00%
Constraint 4	0.00%	51.64%	-32.28%	16.53%	-3.10%	-14.48%
	WFC	TRV	LUV	ALK	HA	
Benchmark	-22.50%	27.06%	7.82%	17.64%	-0.38%	
Constraint 1	-10.78%	25.41%	6.99%	16.13%	0.08%	
Constraint 2	-22.39%	27.25%	7.86%	17.68%	-0.37%	
Constraint 3	0.00%	24.91%	6.60%	21.01%	0.00%	
Constraint 4	-13.81%	52.62%	14.04%	28.09%	0.73%	
After	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	96.31%	-0.90%	-72.36%	76.00%	39.01%	-100.00%
Constraint 1	71.49%	5.13%	-48.13%	7.37%	13.07%	-1.25%
Constraint 2	96.31%	-0.90%	-72.36%	76.00%	39.01%	-100.00%
Constraint 3	37.37%	23.29%	0.00%	12.21%	4.87%	0.00%
Constraint 4	0.00%	14.87%	-39.58%	114.2%	67.96%	-107.73%
	WFC	TRV	LUV	ALK	HA	
Benchmark	-0.77%	39.09%	5.89%	9.90%	7.84%	
Constraint 1	29.13%	22.31%	0.03%	-0.58%	1.41%	
Constraint 2	-0.77%	39.09%	5.89%	9.90%	7.84%	
Constraint 3	12.36%	4.90%	0.00%	3.42%	1.58%	
Constraint 4	-13.37%	36.80%	10.75%	13.19%	2.88%	

Now we decide to achieve the portfolio with the maximum Sharpe Ratio. Two situations are similar under constraint 2 and benchmark, which suggests increasing the weights of SAP, BAC and TRV mostly, decreasing ADBE, IBM and C after the COVID-19. Furthermore, we could also find that under constraint 3, we should decrease the weights of S&P 500, Adobe, TRV and ALK, increase the weights of SAP, BAC and LUV when we face the impact. And constraint 4, Markowitz Model is especially bullish on stock SAP and bearish on Citigroup shares.

Unlike the portfolio with minimum variance, if you want to get an optimal portfolio with max Sharpe Ratio, S&P 500 should be always maintained a positive weight during the whole period. In addition to the market index, the weights of ADBE and IBM also show a totally different distribution before and after the COVID-19. According to this phenomenon, we speculate that although ADBE and IBM have low risks after the pandemic, they could not balance the risk and return, resulting the returns of them are not satisfied. However, based on the Sharpe Ratio, S&P 500 can balance the return and risk successfully because of its positive weight after the COVID-19.

Table 6: Three characteristics of the portfolio according to the weights allocated above

	Before			After		
	Return	StDev	Sharpe	Return	StDev	Sharpe
Benchmark	22.57%	18.23%	123.81%	42.64%	37.12%	114.86%
Constraint 1	20.52%	16.87%	121.66%	25.43%	29.07%	87.46%
Constraint 2	22.58%	18.24%	123.81%	42.64%	37.12%	114.86%
Constraint 3	20.58%	18.84%	109.25%	14.73%	20.83%	70.69%
Constraint 4	26.41%	22.49%	117.45%	30.76%	29.04%	105.90%

Under the constraint 2, 4 and benchmark, while the maximum Sharpe Ratio of the portfolios almost keep the same, the risks of them increase significantly, which clearly reflects the negative impact of the COVID-19 on the stock market. Besides, the Sharpe Ratio of the portfolios under constraint 1 and 3 reduce substantially. This also reflects that if we do not allow to increase the leverage ratio of customers' accounts (Constraint 1) or short the securities (Constraint 3), we will not be able to take advantage of the market volatility caused by the pandemic to obtain a greater return.

Table 7: Portfolio weights with minimum variance under Index Model

Before	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	138.88%	-7.03%	9.79%	-1.92%	-16.20%	-20.83%
Constraint 1	122.54%	-4.67%	10.31%	0.00%	-14.65%	-18.91%
Constraint 2	100.00%	-4.11%	16.52%	2.61%	-14.00%	-18.08%
Constraint 3	64.72%	0.00%	13.31%	0.00%	0.00%	0.00%
Constraint 4	0.00%	3.40%	33.84%	14.28%	-8.33%	-11.02%
	WFC	TRV	LUV	ALK	HA	
Benchmark	-12.91%	16.16%	-0.53%	-3.50%	-1.90%	
Constraint 1	-8.66%	17.02%	0.05%	-1.89%	-1.13%	
Constraint 2	-7.64%	25.05%	2.12%	-1.53%	-0.95%	
Constraint 3	0.00%	21.97%	0.00%	0.00%	0.00%	
Constraint 4	5.94%	47.91%	8.94%	3.51%	1.52%	
After	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	29.55%	39.87%	2.88%	12.23%	-1.82%	8.05%
Constraint 1	29.55%	39.87%	2.88%	12.23%	-1.82%	8.05%
Constraint 2	29.55%	39.87%	2.88%	12.23%	-1.82%	8.05%
Constraint 3	25.99%	40.13%	2.90%	12.31%	0.00%	8.10%
Constraint 4	0.00%	47.05%	10.52%	14.25%	1.60%	10.21%
	WFC	TRV	LUV	ALK	HA	
Benchmark	-0.55%	6.62%	-0.54%	3.88%	-0.19%	
Constraint 1	-0.55%	6.62%	-0.54%	3.88%	-0.19%	
Constraint 2	-0.55%	6.62%	-0.54%	3.88%	-0.19%	
Constraint 3	0.00%	6.66%	0.00%	3.91%	0.00%	
Constraint 4	2.00%	7.30%	1.18%	5.03%	0.87%	

Starting from TABLE 7, we establish the portfolio through the Index model. Compared with the Markowitz model, when we want to get the portfolio with a minimum variance, Index Model puts more positive weights on S&P 500. And even after the pandemic, it still suggests longing the S&P 500. However, differ from the S&P 500, the weights of IBM and TRV are decrease while the weight of Citigroup is incredibly increase after the COVID-19 under all 4 constraints and benchmark. When it comes to the constraint 3, we should invest more positive weight on ADBE after the pandemic instead of longing only S&P 500, IBM and TRV before it.

Table 8: Three characteristics of the portfolio according to the weights allocated above

	Before			After		
	Return	StDev	Sharpe	Return	StDev	Sharpe
Benchmark	11.07%	12.02%	92.11%	9.41%	18.96%	49.63%
Constraint 1	11.50%	12.09%	95.16%	9.41%	18.96%	49.63%
Constraint 2	11.26%	12.25%	91.96%	9.41%	18.96%	49.63%
Constraint 3	11.95%	14.02%	85.25%	9.32%	19.02%	49.00%
Constraint 4	11.75%	14.65%	80.22%	5.65%	20.13%	28.07%

Some common features can be found above. Before the pandemic, all the variances of portfolio are around 12% to 14%. However, the variances raise to about 19% in the second period. Furthermore, the Sharpe Ratios of the portfolio all have a substantial decline after the impact outside the market. Similar to the result under Markowitz model, due to the outside impact of COVID-19, not only can we not achieve the same minimum variance before the pandemic, but the balance of return and risk of the portfolio becomes worse, which means if we try to minimize the risk of the portfolio, we have to lower the expectations of returns.

Table 9: Portfolio weights with maximum Sharpe Ratio under Index Model

Before	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	121.28%	28.48%	-32.56%	1.85%	-17.97%	-24.54%
Constraint 1	67.64%	26.51%	-9.72%	1.51%	-10.94%	-15.75%
Constraint 2	100.00%	30.78%	-29.81%	4.37%	-16.82%	-23.14%
Constraint 3	0.00%	35.29%	0.00%	0.07%	0.00%	0.00%
Constraint 4	0.00%	51.25%	-29.69%	16.69%	-12.20%	-17.96%
	WFC	TRV	LUV	ALK	HA	
Benchmark	-30.95%	16.66%	14.49%	18.02%	5.24%	
Constraint 1	-13.59%	18.67%	13.96%	16.92%	4.78%	
Constraint 2	-28.48%	21.45%	16.22%	19.52%	5.90%	
Constraint 3	0.00%	18.47%	17.58%	22.34%	6.24%	
Constraint 4	-22.64%	42.98%	28.27%	32.39%	10.91%	
After	SPX	ADBE	IBM	SAP	BAC	C
Benchmark	122.56%	18.63%	-36.19%	8.11%	-3.05%	-10.13%
Constraint 1	116.28%	19.22%	-33.46%	8.20%	-2.56%	-8.80%
Constraint 2	100.00%	23.95%	-28.58%	9.39%	-1.56%	-7.14%
Constraint 3	70.43%	16.74%	0.00%	7.28%	0.00%	0.00%
Constraint 4	0.00%	49.56%	-17.68%	18.44%	19.49%	-11.21%
	WFC	TRV	LUV	ALK	HA	
Benchmark	-1.85%	3.13%	-3.44%	3.05%	-0.82%	
Constraint 1	-1.44%	3.23%	-3.09%	3.06%	-0.65%	
Constraint 2	-0.70%	3.81%	-2.42%	3.60%	-0.33%	
Constraint 3	0.00%	2.81%	0.00%	2.74%	0.00%	
Constraint 4	14.57%	4.81%	5.89%	10.24%	5.89%	

Now we try to build the portfolio with maximum Sharpe Ratio. Overall, weights allocation in the above table is similar to that in TABLE 5. The difference is that Index Model suggests keeping positive weights on S&P 500 basically except for the constraint 3 after the pandemic. At the same time, three stocks about airline industry are paid more attention under constraint 3 and 4 in normal conditions. However, they still need to face the weight reduction after the pandemic. Atems and Yimga [10] described that the COVID-19 brought considerable declines in airline industry's revenues, profitability, and stock prices. The response to 1% of COVID-19 shock might lead to at most 0.6% of reduction in stock prices and this impact will last for a long time than other industry. That is why both Markowitz model and Index model give up investing in airline industry after the pandemic.

Table 10: Three characteristics of the portfolio according to the weights allocated above

	Before			After		
	Return	StDev	Sharpe	Return	StDev	Sharpe
Benchmark	23.19%	17.40%	133.31%	26.46%	31.79%	83.22%
Constraint 1	20.54%	16.12%	127.43%	25.43%	30.58%	83.17%
Constraint 2	23.54%	17.70%	132.96%	22.97%	27.82%	82.58%
Constraint 3	21.49%	19.14%	112.30%	16.90%	24.09%	70.17%
Constraint 4	28.59%	22.85%	125.12%	15.44%	33.28%	46.41%

Under the constraint 1 to 3 and benchmark, with the increase in the risk of the portfolios, the returns of them are decrease after the COVID-19, which share the same tendency with the previous results. However, there is a slightly difference that if we drop the market index, the Sharpe Ratio has a significant decline, which contradicts the results in TABLE 6. The reason why there is a discrepancy between the two model under the same the constraint is that the two models have different assumptions. Markowitz model believes that there is correlation between individual stocks, while Index model believes that there is correlation only between individual stock and the market. When we exclude the S&P 500 from the portfolio, whether the remaining stocks assume correlation or not becomes an important factor to determine the final result. In fact, according to the stocks correlation coefficients in Tables I and II above, we cannot reject the fact that there is correlation between them, so in general, the results of Markowitz model are more reliable.

4. Conclusion

The impact of COVID-19 has penetrated all walks of life, culminating in a highly volatile stock market. Under this situation, the main goal of this paper is how to balance risk and return with minimizing investment risk or maximizing return. According to the results of Markowitz model and Index model, S&P 500 is selected to be long in most cases, and its weight allocation occupies a large proportion, indicating that it is a valuable investment project. In addition, the weights of the three technology stocks before and after the pandemic is quite different, which means that their prices are greatly affected by the pandemic. Then, among the four financial stocks, Citigroup has even been short more with the arrival of the COVID-19. However, TRV has always been long. This fully reflects that Citigroup's performance remains unsatisfactory regardless of the outside impact, while TRV has always maintained stability. The specific results obtained in this paper can be used as a reference for investors who want to invest in US stocks. By selecting the portfolio of this paper, although the Sharpe Ratio of it will decline after the pandemic, it can still maintain a high level generally.

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