Financial Research Final Report:
Portfolio Construction and COVID-19
Effects on Securities Returns

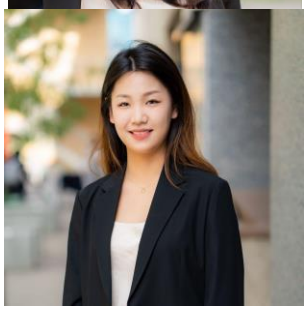
About the Analysts

Brandon Palacios | Master of Finance Class of 2023

Haoxin Huang | Master of Finance Class of 2023

Yiming Zhang | Master of Finance Class of 2023

Manvitha Vulavala | Master of Finance Class of 2023



Ziyi Yuan | Master of Finance Class of 2023

CONTENTS

INTRODUCTION

COVID-19 pandemic was an extreme event that has triggered different reactions across the globe and brought uncertainty to the financial markets, led to a sudden fall in stock prices, and gave rise to financial volatility (Mahata et al., 2021). The stock market is an important indicator of economic health, and therefore, understanding the impact of COVID-19 on the stock market can help us better understand the overall economic impact of the pandemic. For investors, analyzing the impact can aid in making informed investment decisions in response to the pandemic. Governments and policymakers may use data on the impact of COVID-19 on the stock market to guide their public policy decisions. For example, they may use this data to determine how much economic stimulus is needed to offset the negative impact of the pandemic on the stock market. In summary, analyzing the impact of COVID-19 on the stock market is important for understanding the economic impact of the pandemic, making informed investment decisions, and informing public policy decisions.

To investigate the impact of COVID-19 on the investor's self-constructed portfolio, we use the Markowitz efficient frontier theory to construct an optimal investment portfolio by selecting stocks from different industries in consideration of high return and diversification. Then we use the t-test to determine if there is a significant difference in the return and volatility of the investment portfolio before and after the outbreak of the COVID-19 pandemic i.e., March 11, 2020 (the day that the World Health Organization (WTO) officially declared the COVID-19 outbreak to be a pandemic). We confirm that pandemic increased the risk hypothesis that the COVID-19 pandemic has a significant impact on the stock market, which means that investment in self-selected stocks at a company level is risky during extreme events such as a pandemic.

DATA DESCRIPTION

2.1 Data Resource

Based on the group's research, we built a diversified portfolio composed of stocks that either had an impact on COVID-19 or were significantly impacted by the pandemic. We also incorporated securities with a significant weight on the market index as well as an emerging markets mega cap company.

This is different from a fund portfolio that is anchored to the overall market. The stocks under consideration must meet the following conditions:

> *(1) Listed for over 2 years with no asset restructuring events have occurred recently.;*
> *(2) Total continuous suspension time within 500 trading days does not exceed 5 days;*
> *(3) Sound financial condition with no significant liquidity risk.*

In order to eliminate the interference brought by the new shares from the capital side, and to ensure the adequacy of the data quantity in terms of time, we use the earliest stocks' prices to run the 4-Factors Model. In the hypothesis test section, we select the closing prices of the stocks on all trading days in the six years from 2017.03.11 to 2023.03.11 and divide it into two parts, satisfying the requirement of at least 500 trading days. Disturbance of the stock price at the capital level is normal from a long-term perspective. Regardless of the capital behavior of hot money, institutional investors, or individual investors, the unpredictability of the aggregated capital flow and movement date is inevitable. Therefore, We consider the stock price fluctuations of 10 companies listed below from a long-term perspective.

2.2 Selection of Individual Securities

As a group of analysts, we researched and selected individual securities using a broad range of factors to create a diversified portfolio with a compelling return and a reasonable risk level. The overarching theme of the portfolio was to select companies with significant weight on the market index, had an impact and/or were impacted by the COVID-19 pandemic.

To understand the effects of COVID-19 in our assembled basket of securities, we utilized various benchmarks to select individual stocks. For instance, we wanted to select one or two stocks with strong

weights in the market index. Since these securities have a large influence on the market, we wanted to be sure they also played a role in our portfolio. For this reason, we selected Apple (AAPL) and Microsoft (MSFT) as they represent the number one and number two stocks with the largest weights in the S&P 500 index at 6.864099% and 5.733366% respectively. These securities also introduce a growth factor in our portfolio, which will allow for expected returns to be positively impacted. Further, for our selection in NVIDIA (NVDA), we wanted to include a high growth stock to provide us the opportunity to elevate the Sharpe ratio of our portfolio.

Another objective of the portfolio was to illustrate the role of diversification across industries, also through incorporating a mega cap from emerging markets. We agreed that the most compelling option for this objective was to include Alibaba (BABA). The main reason for the inclusion of Alibaba was the large reach that the company has and its exposure to the Chinese economy. Additionally, Alibaba, we contend, is trading at a steep discount from its fundamental value. For these two reasons we decided to incorporate this mega cap into our portfolio.

There is not much commentary to be made regarding including the risk-free asset. The risk-free asset is a crucial component of any portfolio, and in our case, it will be an important part of our calculations. Further, the group also believed it was essential to include another form of a 'safe haven' asset. In our case we included Barrick Gold (GOLD) to analyze what effect the pandemic had on 'safe haven' asset performance.

The team also felt it necessary to include some form of travel/discretionary spending element to the portfolio to try and get a sense of how consumer/travel demand was impacted. To achieve this purpose, we included two securities. First, Delta airlines was included given the sheer size of the company and to try and see how sensitive these types of stocks were during COVID.

Similarly, we believed Disney was a compelling candidate for the portfolio because of the steep decline and business impact it suffered given the close of their theme park and vacation businesses. However, this stock also adds a strong comeback factor to the portfolio because with the development of Disney Plus, the stock benefitted from the so-called 'stay at home' stocks.

One of the businesses that played a significant role in the pandemic was Pfizer. In lieu of their development of the COVID-19 vaccine along with BioNTech. We opted not to include BioNTech and Moderna because their performance would represent higher volatility to our overall portfolio. Comparing all three securities, Pfizer proved to be the one relatively more stable from the group. Additionally, the company also played a crucial role during the pandemic and we felt it was important to include it in our study.

Lastly, we wanted to get exposure from the banking sector given unprecedented actions taken by policy makers and its effects on banks. We selected Bank of America (BAC) because they were the institution used for the historic unemployment benefits. For this reason, we decided to include Bank of America over JP Morgan Chase. Although JP Morgan is the largest bank by market capitalization, BAC came in second place and played an important role during the COVID-19 pandemic.

Ultimately, we built this portfolio in such a way that we could further understand the impact of the COVID-19 pandemic in the stock market as self-directed investors. Upon analysis we contend that investment in self-selected stocks is especially risky, particularly during unprecedented events such as the pandemic.

METHODOLOGY

3.1 Hypothesis

As mentioned above, we are verifying whether the mean and the variance of the portfolio of stocks that we have picked changed subsequent to the COVID-19 pandemic. We are considering the 3-year period from March 11, 2017 to March 11, 2020 as the 'before' period and the period March 11, 2020 to March 11, 2023 as the 'after' period. Keeping the significance level at 95%, our hypothesis testing is formulated as follows:

1. Mean: Letting μ_1 represent the population mean return for March 11, 2017 to March 11, 2020 and μ_2 represent the population mean return for March 11, 2020 to March 11, 2023, we formulate the following hypotheses:

   H_0: $\mu_1 - \mu_2 = 0$ versus H_1 : $\mu_1 - \mu_2 \neq 0$

2. Variance: Letting σ^2_{Before} represent the population variance for March 11, 2017 to March 11, 2020 and σ^2_{After} represent the population mean return for March 11, 2020 to March 11, 2023, we formulate the following hypotheses:

   H_0: $\sigma^2_{Before} = \sigma^2_{After}$ versus H_1: $\sigma^2_{Before} \neq \sigma^2_{After}$

3.2 Data Processing

Details of our process and econometric methods used are as follows:

1. Data: We have obtained the earliest available data for each of the stocks in our portfolio and the Fama-French Carhart Four Factor Model to calculate the returns, variance, regression coefficient and the Sharpe Ratio. The 4-Factors Model data used in our analysis is obtained from Fama/French's website. Stock price data was sourced from Yahoo Finance.

2. OLS regression: We use the Fama French Carhart 4-Factor Model to determine the regression coefficient of a stock. This model includes 4 factors - expected market return, value factor, size factor, and momentum factor. Here, we mainly focus on the expected market return and the regression coefficient. The regression coefficient of the expected market return factor represents how sensitive the stock is to the expected market return factor. It is calculated using regression analysis:

$$R_{i,t} - r_{f,t} = \alpha_{i,t} + b_{i1}(R_{m,t} - r_{f,t}) + b_{i2}SMB_t + b_{i3}HML_t + b_{i4}MOM_t + \varepsilon_{i,t} \qquad (1)$$

3. Calculate theoretical return using CAPM: Using the data from the Fama-French Carhart Four Factor Model and the b_{i1} as calculated, we calculate the theoretical return for each stock.

4. Markowitz Efficient Frontier to get Sharpe Ratio and weights of the portfolios:

   - We use Markowitz's theory to construct the investment portfolio. In estimating the expected return and covariance matrix of individual stocks, we assume that historical returns follow an independent and identically distributed condition, thus directly using the sample mean and sample covariance of returns as estimators. We use Python to calculate the expected return rate R_i and covariance matrix Ω of stocks in the portfolio. Denoting the expected return rate of the investment portfolio as R_p and the weight of each stock as ω, (we assume no short sale in our portfolio so that ω cannot be negative) we obtain the following optimization problem:

$$Sharpe\ Ratio = max\ (R_p - R_m)/\sigma_p$$
$$\sigma_P = 1/2\omega'\boldsymbol{\Omega\omega} \qquad (2)$$

$$s.t.\omega' r = R_p, \omega' 1 = 1, \omega > 0$$

- Further, based on the Market Portfolio Theory, it is possible to construct an efficient frontier, which is a set of investment portfolios that are expected to provide the highest returns at a given level of risk. To obtain this set of investment portfolios to choose from, we use Monte Carlo method to construct 20,000 portfolios, compute every combination of stocks to form a portfolio and calculate its expected return and variance. We then plot the same to obtain the efficient frontier as shown in Figure 1.

- Based on the return and variance of the 20,000 portfolios constructed, we compute the Sharpe Ratio to identify the portfolio with the highest Sharpe Ratio. Sharpe Ratio refers to the portfolio's performance of return in excess of the risk-free rate per unit of risk (standard deviation). Therefore, the higher the Sharpe Ratio, the more attractive the risk-adjusted return. Once we have identified the portfolio with the highest Sharpe Ratio, we then use the weights of this best performing portfolio to execute the hypothesis testing.

5. Perform hypothesis testing: based on the data calculated in the previous step, we then perform the hypothesis testing.

RESULTS AND DISCUSSION

Descriptive Statistics Analysis

We constructed the portfolio with certain weights assigned to each stock with a view to achieve optimized return based on the efficient frontier. The weights we allocate to each of the securities are shown in table 1. Figure 2 shows the price change with time over the last 6 years. Descriptive data from price changes to our portfolio also demonstrates the price direction, range and distribution of price change.

Table 2 reports descriptive statistics for the return of stocks before COVID-19 and after. We summarize the changes in price in dataset format that include the mean, standard deviation, max and min values, 25th percentile, and also 75th percentile values based on pre-pandemic to post-pandemic stock performance. The maximum value increased by 97% from 0.0642625 to 0.1266139, indicating a broader spread in the dataset ceiling after the pandemic. However, the minimum value has also decreased from -0.0854779 before to -0.1226069 at 43%, indicating that the portfolio performance is reaching a lower level. The 25th percentile value has decreased from -0.0037183 to -0.0066650, indicating that there are now more values in the lower range after the changes. Likely, the 75th percentile value has increased from 0.0064933 to 0.0096185, meaning there are now more values in the upper field.

The variations in the dataset's range and distribution of values following the change are indicated by the variations in the dataset's maximum, minimum, 25th percentile, and 75th percentile values. Figure 3 shows the returns of post-pandemic period are more disperse than pre-pandemic period. The plot of portfolio's return has demonstrated increased volatility of portfolio after the pandemic.

We also concluded that the mean of price changes after pandemic is slightly higher than that of pre the pandemic, but not significant. The std (standard deviation) represents the volatility and so does the risk. The post-pandemic standard deviation increased drastically by approximately 47% compared to that of pre-pandemic, therefore, we conclude that the risk of the investment portfolio has also increased.

Result Analysis

The results of t-test and hypothesis show that, based on the daily returns for two distinct time periods: pre-Covid-19 pandemic (date range: 2017-3-11 to 2020-3-11) and post-pandemic (date range: 2020-3-11 to 2023-3-11) — there are differences in statistics like mean and variance.

We utilize a set of sample relative t-tests to determine whether the mean return of the portfolio prior to the pandemic differs significantly from zero, and also an f-test to decide the changes in volatility.

The purpose of our null hypothesis is to test whether the mean return is going to be zero, whereas the alternative theory assumes that the mean return is not zero. The result's t-statistic of 1.721 and p-value of 0.086 show that the null hypothesis is only weakly supported and that it cannot be ruled out at the accepted level of significance of 0.05. The outcome shows that there is no significant difference between the portfolio's mean return prior to the date under 0.05 confidence interval. The post-pandemic data are also evaluated by our model, and the results show a t-statistic of 1.494 and a p-value of 0.136, which indicates that we can hardly reject the null hypothesis at the 0.05 level of significance. Because of this, there is no discernible difference between zero and the mean return of the portfolio after the date.

We need to see if the portfolio's mean return before and after the pandemic differed significantly from one another, we also created a paired t-test. The assumption under consideration is that the mean returns are equal, while the alternative is that they are not. The outcome has a t-statistic of -0.275 and a p-value of 0.783, indicating that we cannot, at the 0.05 significance level, reject the null hypothesis. We can infer from the foregoing that there is no appreciable change between the portfolio's mean return before and after the epidemic.

For the variance, our group used F-test to determine whether there is a significant distinction between two population variances based on the before and after columns in the portfolio dataset. The p-value result of our variance test is 1.110223e-16, which is very small (close to zero), which means strong evidence supporting the alternative hypothesis that the variances of the two samples are different. This means the test suggests that the variance of the pre-pandemic portfolio performance is significantly different from the variance of that of our preset post-pandemic period.

CONCLUSION

In our research, we use the Markowitz efficient frontier theory to construct an optimal investment portfolio by selecting stocks from different industries in consideration of high return and diversification. Then we use the t-test and find out that the variance of the pre-pandemic portfolio performance is significantly different from the variance of that of our post-pandemic period at 95% confidence interval. The mean of the pre-pandemic period shows no significant difference from the post-pandemic period, but the expected rate of return did increase from evidence of descriptive statistics analysis. This suggests that while the pandemic has created uncertainty and instability in the financial markets, investors can still expect to earn a similar level of return on their investments as they would in a normal market environment, provided they are willing to tolerate the increased level of risk. Therefore, investors may need to adjust their risk management strategies to account for the increased volatility caused by the pandemic.

COVID-19 has impacted the stock market in several ways. Here are some possible explanations:

Economic uncertainty: The outbreak of COVID-19 has created a high degree of economic uncertainty, which has led to a decline in investor confidence. The uncertainty surrounding the duration and severity of the pandemic, as well as the government's response, has led investors to become more risk-averse, resulting in a sell-off in the stock market.

Disruption of supply and consumer’s spending: The spread of COVID-19 has disrupted global supply chains, as factories and businesses have been shut down or faced supply shortages. The pandemic has resulted in reduced consumer spending, as people have been forced to stay at home and limit their social interactions. This has had a negative impact on companies' earnings, particularly for industries such as travel, hospitality, and entertainment, which has in turn led to a decline in stock prices.

Contributions

To address this issue, policymakers could provide more information and transparency about the impact of the pandemic on the economy and the stock market. This could help reduce uncertainty and restore

investor confidence, which in turn could lead to lower volatility in the market. Additionally, policymakers could implement economic stimulus measures to support the market and the economy during the pandemic, such as providing financial support to affected industries and businesses.

For investors, diversification of their investment portfolios across different industries and sectors can help reduce their exposure to market volatility caused by COVID-19. This could be achieved by using the Markowitz efficient frontier theory, as demonstrated in the empirical analysis, to construct an optimal investment portfolio with stocks from different industries with high investment value.

Limitations and further research

We only test the mean and variance changes after the time point of the pandemic, but there are several other factors that have impacted stock prices over the past three years, such as changes in interest rates, global economic trends, political events, corporate earnings and performance, as well as investor sentiment and speculation. These factors can individually or collectively affect the demand and supply of stocks, leading to fluctuations in their prices. With the pandemic expected to conclude in the near future, studying its impact over a more extensive time frame would be feasible.

Further research could investigate the reasons behind the observed impact of COVID-19 on stock volatility. For example, the study could explore how investor sentiment and behavior were affected by the pandemic and how these changes led to increased volatility. Additionally, further research could examine how different sectors and industries were affected differently by the pandemic and how this influenced stock returns and volatility. Another avenue for future research could be to explore how government policies and interventions aimed at mitigating the pandemic's economic impact may have influenced stock returns and volatility.

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APPENDIX

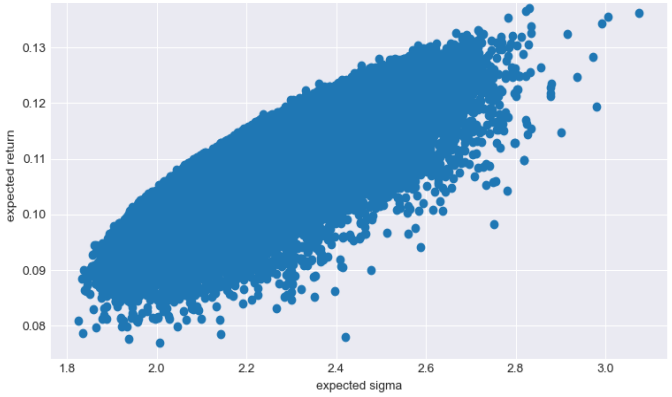

Figure 1: Efficient Frontier

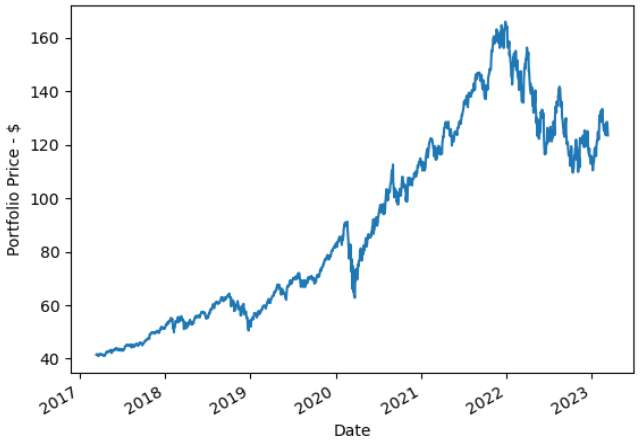

Figure 2: Portfolio Price Over Time

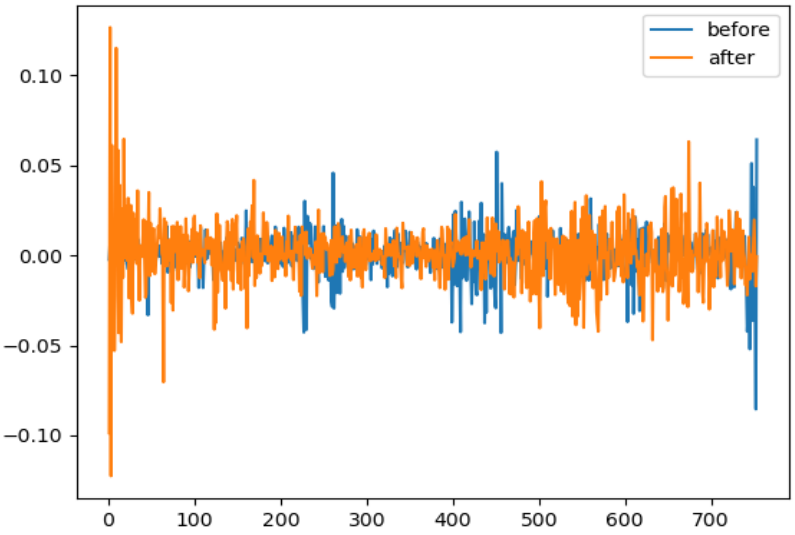

Figure 3: Portfolio Rate of Return Spread

Table 1: Summary of Weights

Stock/Index	Stock Ticker	Weights	Weights %
Apple Inc.	AAPL	0.17070	17%
Microsoft Corp.	MSFT	0.26714	27%
NVIDIA Corp.	NVDA	0.04697	5%
Alibaba Group Holding Ltd.	BABA	0.00771	1%
Treasury Yield 10 Years	^TNX	0.00833	1%
Barrick Gold Corp	GOLD	0.03757	4%
Delta Air Lines Inc.	DAL	0.03810	4%
Pfizer Inc.	PFE	0.13953	14%
Bank of America Corp.	BAC	0.21690	22%
Walt Disney Company	DIS	0.06703	7%

Table 2: Descriptive Statistics

	before	after
count	753	753
mean	0.0007351	0.0009395
std	0.0117193	0.0172537
min	-0.0854779	-0.1226069
25%	-0.0037183	-0.0066650
50%	0.0011384	0.0009443
75%	0.0064933	0.0096185
max	0.0642625	0.1266139