Portfolio Research Combined with Epidemic Changes

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Abstract—This study mainly used some mathematical methods to calculate how to invest a portfolio at the lowest risk before and after the outbreak of the COVID-19, and gave people some suggestions on how to invest under the special situation of the epidemic. To form a reasonable portfolio, we selected 4 stocks in different industries: Walmart, Facebook, Netflix, and Disney, and analyze the trend of every single stock and the correlation between the two stocks. And we chose a weighted moving average model to predict the trend of stocks. Finally, we use the combination variance to simulate the risk. After the outbreak of the COVID-19, the correlation of most stocks had increased, and the risk had also increased. Only the correlation between Disney and Walmart decreased while the other correlations increased. Moreover, Netflix had the highest return rate among the four stocks. Combined with the analysis, we concluded that investors can always invest more in Netflix no matter which periods are considered and increase the investment weight of Walmart after COVID-19. This suggests that specific events such as the COVID-19 outbreak impact investors' portfolio choices.

Keywords-portfolio; correlation; forecasting; return; COVID-19 (key words)

1. INTRODUCTION

The stock and stock market appeared in the Netherlands and the UK as early as the 17th century. Therefore, after hundreds of years of development, all countries' stock market is nearly mature, attracting many consumers to buy stocks and become shareholders. Shareholders always want to maximize their investment return at relatively low risk, so most shareholders will not invest their assets in only one stock. Still, they choose to invest in the portfolio.

In recent years, there have been many studies on how to invest portfolio at home and abroad. According to the previous studies by scholars, searching for the best investment portfolio is just from the perspective of return and risk. In terms of return, Li [1] assumed that the corresponding relationship between investment and return of each investment project is known, then adopted a dynamic programming method to obtain the investment portfolio that maximizes the total return. In terms of risk, Xia [2], to research the problem of how to choose the stock in long-term investment, selected four stocks, namely large blue chip stocks, pig cycle stocks, new energy vehicle cycle stocks, and shipping cycle stocks. And we used linear programming to set up medium and long-term stock portfolios to reduce investment risks. Moreover, Gao and Zhang [3]

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proposed that the mean-Var model can reduce an investment portfolio's overall financial risk level.

On this basis, Li [4] combined return and risk to analyze the best investment portfolio, which mainly conducted empirical analysis on the returns and risks of several stocks, established Markowitz mean square deviation model and capital asset pricing model with R language on stock data and looked for the portfolio with the minimum variance at the expected rate of return. Going one step further, Jiang and Deng [5] found a better way to reduce risk under the same return level, who screened A-shares in Shenzhen and selected 5 stocks for empirical analysis. By comparing and analyzing the mean-entropy model and mean-variance model of risk-free securities, it is found that the entropy method can better disperse investment risks under the same return level r.

Finally, Liao [6] used the relationship between expectation and variance in financial mathematics to discuss and analyze the risk and return in investment at a deeper level, who concluded that the stock portfolio is constructed in three steps. The first step is to define the scope of the portfolio. The second step is to study, analyze, and judge each specific stock's expected rate of return and risk. The third step is to determine the specific weight of each stock in the portfolio. After determining the portfolio, it is necessary to choose the appropriate time to adjust and transform the varieties in the portfolio, including eliminating the varieties that have adverse effects on the portfolio's risk and increasing securities that are beneficial to improving portfolio benefits reducing portfolio risks. However, Liao didn't consider the influence of the outbreak of COVID-19. Therefore, on this basis, we will explore the best investment portfolio based on return and risk and the influence of the outbreak of COVID-19 on the portfolio.

Our paper studies how to invest portfolio more effectively, such as studying the correlation between stocks, predicting the future of stocks, and how to choose the weight of different stocks in the portfolio. However, different from previous studies, our study selected a special period before and after the outbreak of COVID-19 because we wanted to study the impact of the epidemic on the stock market and how we should invest in the special time.

In this article, we first chose four stocks from different business fields: Disney, Facebook, Walmart, and Netflix. Second, we used the line charts, correlograms, and Augmented Dickey-Fuller tests to analyze the stationarity of each stock. Then, we used the same strategies to analyze the cointegration and correlations of these four stocks and how the cointegration and correlations have changed after the outbreak of COVID-19. And we found that the correlations of these stocks had become great after the COVID-19, but the cointegration hadn't changed a lot.

To forecast the stock prices, we chose three models: the simple moving average model, the weighted moving average model, and the exponential smoothing model. The results indicate that the weighted moving average model shows the lowest root mean square error (RMSE), so we choose this model to forecast the price. After forecasting, we used the weighted model and the formula of the variance of the portfolio to estimate the return and risk of our investment. In the end, we used linear optimization to get the best investment portfolio with the lowest risk and highest return.

The main contributions of this work are described as follows: in this article, we not only analyzed the forecasting prices of the stocks we've chosen and the optimization of the

investment portfolio but also analyzed how the correlation and cointegration of these stocks have changed after the COVID-19, which was closely bonded with our investment portfolio. We found that the correlations of these four stocks had become great after the COVID-19 while the cointegration remained non-stationary, which showed the COVID-19 had a great impact on selected stocks. Consequently, when one optimizes a probable investment portfolio, the impact of the COVID-19 should be taken into account. And after a series of analyses, we suggest that the investors can increase the weight of investment in Walmart after the outbreak of COVID-19 and invest most in Netflix at all times.

2. DATA

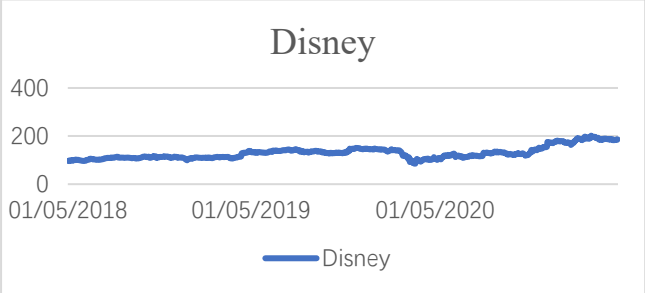
In this section, we start to analyze the choice of stocks to form a portfolio.

When we form a portfolio, lower correlation always leads to lower risk from the same industry. Because if we lose money in stocks from one industry, we may gain back from other industries. Consequently, the stocks chosen for the investment portfolio should be as irrelated as possible. In this paper, to form a portfolio, we selected Disney (DIS), Facebook (FB), Walmart (WMT), and Netflix (NFLX) to analyze. The reason to select these four stocks is that they all belong to a different industry. For Disney, Facebook, Walmart, and Netflix were separately related to entertainment, software development, chain retail stores, and streaming media, their stocks can probably be uncorrelated.

Before we started to solve the optimization problem, we analyzed how these stocks' prices changed. Then we chose "adjusted closed price" as prices of the stocks and used the prices from May 2018 to April 2021 as the time series to analyze. The daily data of the prices of the stocks are available at Yahoo Finance.

Since these stocks' prices can be taken as time series, it's important to ensure their stationarity before our optimization. And we use Eviews to achieve it.

For graphs, we chose "Basic graph" as the graph type and made the line charts.



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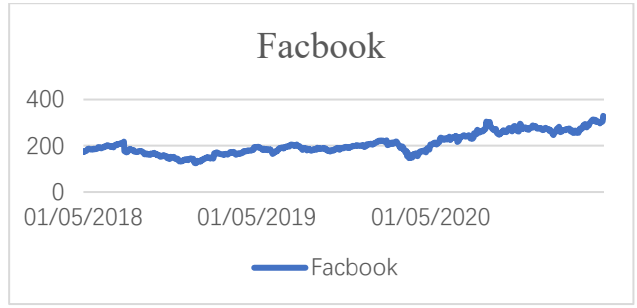

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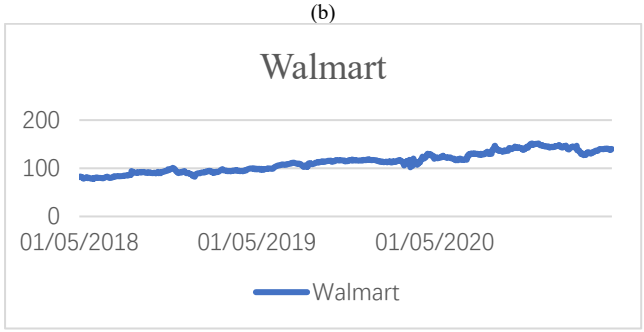

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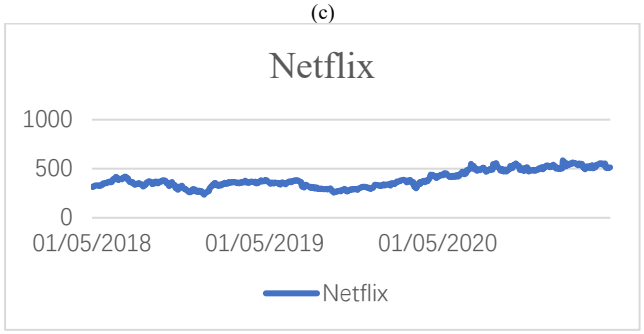


(d)

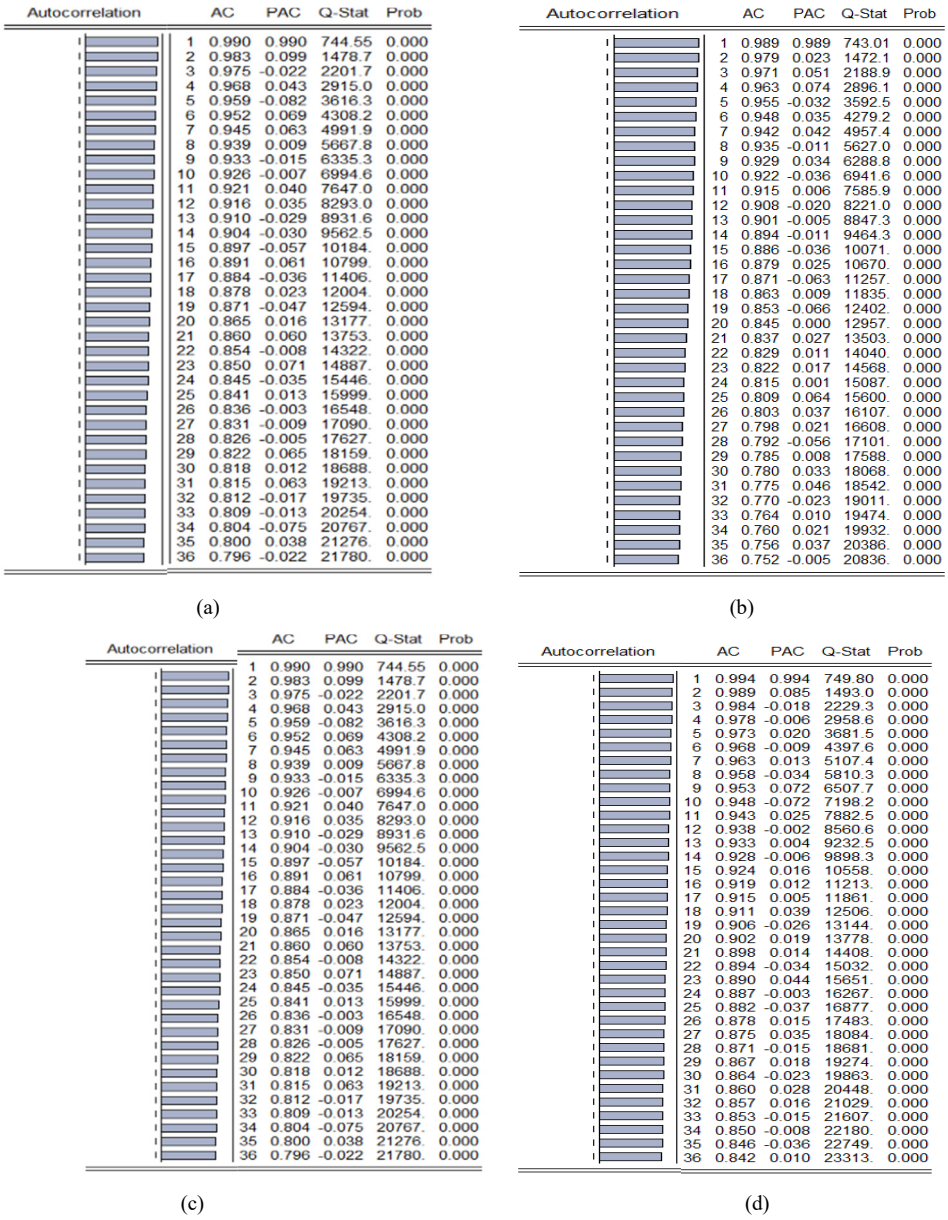
Figure 1. Stocks prices of four selected stocks

(a)Stocks prices of the Disney (b) Stocks prices of the Facebook (c) Stocks prices of the Walmart (d) Stocks prices of the Netflix

Source: Yahoo Finance

Figure1 indicates that the prices of all the stocks fluctuated a lot in the past two years. Consequently, it's hard to ensure their stationarity based on the graphs. But it should be noticed that the prices of Disney, Facebook, and Netflix stocks experienced an obvious fall during the first quarter of 2020, which was probably related to the coronavirus pandemic.

Then we took the correlogram of "Level," and the Figure 2 included 36 lags. As seen in the following figures, all the bars in each correlogram were above the dotted line, which indicated that all these time series were likely to be non-stationary.



Autocorrelation		AC	PAC	Q-Stat	Prob
	1	0.990	0.990	744.55	0.000
	2	0.983	0.099	1478.7	0.000
	3	0.975	-0.022	2201.7	0.000
	4	0.968	0.043	2915.0	0.000
	5	0.959	-0.082	3616.3	0.000
	6	0.952	0.069	4308.2	0.000
	7	0.945	0.063	4991.9	0.000
	8	0.939	0.009	5667.8	0.000
	9	0.933	-0.015	6335.3	0.000
	10	0.926	-0.007	6994.6	0.000
	11	0.921	0.040	7647.0	0.000
	12	0.916	0.035	8293.0	0.000
	13	0.910	-0.029	8931.6	0.000
	14	0.904	-0.030	9562.5	0.000
	15	0.897	-0.057	10184.	0.000
	16	0.891	0.061	10799.	0.000
	17	0.884	-0.036	11406.	0.000
	18	0.878	0.023	12004.	0.000
	19	0.871	-0.047	12594.	0.000
	20	0.865	0.016	13177.	0.000
	21	0.860	0.060	13753.	0.000
	22	0.854	-0.008	14322.	0.000
	23	0.850	0.071	14887.	0.000
	24	0.845	-0.035	15446.	0.000
	25	0.841	0.013	15999.	0.000
	26	0.836	-0.003	16548.	0.000
	27	0.831	-0.009	17090.	0.000
	28	0.826	-0.005	17627.	0.000
	29	0.822	0.065	18159.	0.000
	30	0.818	0.012	18688.	0.000
	31	0.815	0.063	19213.	0.000
	32	0.812	-0.017	19735.	0.000
	33	0.809	-0.013	20254.	0.000
	34	0.804	-0.075	20767.	0.000
	35	0.800	0.038	21276.	0.000
	36	0.796	-0.022	21780.	0.000

(a)

Autocorrelation		AC	PAC	Q-Stat	Prob
	1	0.989	0.989	743.01	0.000
	2	0.979	0.023	1472.1	0.000
	3	0.971	0.051	2188.9	0.000
	4	0.963	0.074	2896.1	0.000
	5	0.955	-0.032	3592.5	0.000
	6	0.948	0.035	4279.2	0.000
	7	0.942	0.042	4957.4	0.000
	8	0.935	-0.011	5627.0	0.000
	9	0.929	0.034	6288.8	0.000
	10	0.922	-0.036	6941.6	0.000
	11	0.915	0.006	7585.9	0.000
	12	0.908	-0.020	8221.0	0.000
	13	0.901	-0.005	8847.3	0.000
	14	0.894	-0.011	9464.3	0.000
	15	0.886	-0.036	10071.	0.000
	16	0.879	0.025	10670.	0.000
	17	0.871	-0.063	11257.	0.000
	18	0.863	0.009	11835.	0.000
	19	0.853	-0.066	12402.	0.000
	20	0.845	0.000	12957.	0.000
	21	0.837	0.027	13503.	0.000
	22	0.829	0.011	14040.	0.000
	23	0.822	0.017	14568.	0.000
	24	0.815	0.001	15087.	0.000
	25	0.809	0.064	15600.	0.000
	26	0.803	0.037	16107.	0.000
	27	0.798	0.021	16608.	0.000
	28	0.792	-0.056	17101.	0.000
	29	0.785	0.008	17588.	0.000
	30	0.780	0.033	18068.	0.000
	31	0.775	0.046	18542.	0.000
	32	0.770	-0.023	19011.	0.000
	33	0.764	0.010	19474.	0.000
	34	0.760	0.021	19932.	0.000
	35	0.756	0.037	20386.	0.000
	36	0.752	-0.005	20836.	0.000

(b)

Autocorrelation		AC	PAC	Q-Stat	Prob
	1	0.990	0.990	744.55	0.000
	2	0.983	0.099	1478.7	0.000
	3	0.975	-0.022	2201.7	0.000
	4	0.968	0.043	2915.0	0.000
	5	0.959	-0.082	3616.3	0.000
	6	0.952	0.069	4308.2	0.000
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	11	0.921	0.040	7647.0	0.000
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	19	0.871	-0.047	12594.	0.000
	20	0.865	0.016	13177.	0.000
	21	0.860	0.060	13753.	0.000
	22	0.854	-0.008	14322.	0.000
	23	0.850	0.071	14887.	0.000
	24	0.845	-0.035	15446.	0.000
	25	0.841	0.013	15999.	0.000
	26	0.836	-0.003	16548.	0.000
	27	0.831	-0.009	17090.	0.000
	28	0.826	-0.005	17627.	0.000
	29	0.822	0.065	18159.	0.000
	30	0.818	0.012	18688.	0.000
	31	0.815	0.063	19213.	0.000
	32	0.812	-0.017	19735.	0.000
	33	0.809	-0.013	20254.	0.000
	34	0.804	-0.075	20767.	0.000
	35	0.800	0.038	21276.	0.000
	36	0.796	-0.022	21780.	0.000

(c)

Autocorrelation		AC	PAC	Q-Stat	Prob
	1	0.994	0.994	749.80	0.000
	2	0.989	0.085	1493.0	0.000
	3	0.984	-0.018	2229.3	0.000
	4	0.978	-0.006	2958.6	0.000
	5	0.973	0.020	3681.5	0.000
	6	0.968	-0.009	4397.6	0.000
	7	0.963	0.013	5107.4	0.000
	8	0.958	-0.034	5810.3	0.000
	9	0.953	0.072	6507.7	0.000
	10	0.948	-0.072	7198.2	0.000
	11	0.943	0.025	7882.5	0.000
	12	0.938	-0.002	8560.6	0.000
	13	0.933	0.004	9232.5	0.000
	14	0.928	-0.006	9898.3	0.000
	15	0.924	0.016	10558.	0.000
	16	0.919	0.012	11213.	0.000
	17	0.915	0.005	11861.	0.000
	18	0.911	0.039	12506.	0.000
	19	0.906	-0.026	13144.	0.000
	20	0.902	0.019	13778.	0.000
	21	0.898	0.014	14408.	0.000
	22	0.894	-0.034	15032.	0.000
	23	0.890	0.044	15651.	0.000
	24	0.887	-0.003	16267.	0.000
	25	0.882	-0.037	16877.	0.000
	26	0.878	0.015	17483.	0.000
	27	0.875	0.035	18084.	0.000
	28	0.871	-0.015	18681.	0.000
	29	0.867	0.018	19274.	0.000
	30	0.864	-0.023	19863.	0.000
	31	0.860	0.028	20448.	0.000
	32	0.857	0.016	21029.	0.000
	33	0.853	-0.015	21607.	0.000
	34	0.850	-0.008	22180.	0.000
	35	0.846	-0.036	22749.	0.000
	36	0.842	0.010	23313.	0.000

(d)

Figure 2. Correlogram of four stocks.

(a) Correlogram of Disney (b) Correlogram of Facebook (c) Correlogram of Netflix (d) Correlogram of Walmart

To further test the stationarity of these four stocks, we used the Augmented Dickey-Fuller tests (the ADF tests) for the unit root in “Level” and only took the “intercept” in the test equation.

TABLE 1. AUGMENTED DICKEY-FULLER STATISTIC TESTS FOR STOCKS

	P-value	*t-Statistic*
Disney	0.8701	-0.589851
Facebook	0.8975	-0.452057
Netflix	0.6205	-1.322987
Walmart	0.7228	-1.086486

TABLE 1 shows that the p-value in each Augmented Dickey-Fuller test (the ADF test) was above 0.05, which was not significant. Consequently, it concluded that all of these stocks were non-stationary.

3. PORTFOLIO

After analyzing the price of these stocks, we now turn to investigate the condition to form a portfolio. First, we start by examining the relationship between these four stocks. We use the correlation coefficient and method of stationary used above to study. And observing the trend of prices for these four stocks, they appeared significant changes since the pandemic happens. We selected January 2020 as a structural break because the exact time of the outbreak was around January, and the stock market started to wobble at that time.

Therefore, we divided the time into two parts: stock correlation before COVID-19 (January 2018 to December 2019) and after COVID-19 (January 2020 to April 2021); moreover, we also analyze the overall sample correlation from January 2018 to April 2021.

When calculating the correlation coefficient, we used the correlation coefficient equation in Excel to process and calculate the data.

Before the COVID-19 outbreak, the correlation coefficient between Walmart and Disney was 0.900521, showing a very high correlation. A similar situation had been found between Disney and Facebook. In contrast, the correlation between Facebook and Walmart, and Netflix was relatively low. It was worth mentioning that the correlation coefficients of all the stocks mentioned above were all positive, indicating that they were all positively correlated. At the same time, Netflix was negatively correlated with Wal-Mart and Disney.

After the outbreak of COVID-19, the correlation coefficient also changed greatly. The correlation between Facebook and the other three stocks increased significantly, and all of them were positively correlated. Walmart and Disney, which had previously been negatively correlated with Netflix, were positively correlated and significantly correlated. The correlation between Disney and Walmart declined but remained positive overall.

It is not hard to see those correlations between most stocks have risen since the outbreak. Combined with the previous analysis of a single stock, almost all the four stock prices declined after the outbreak of the COVID-19 and gradually recovered with the control of the epidemic, which is the main reason why the four stocks were so similar during this period.

As for the overall analysis over the past three years and four months, the result from TABLE 2 indicates that the correlations between Facebook and Walmart, Walmart and Netflix, and

Netflix and Facebook were all highly correlated with 0.7. And the correlation coefficient between Disney and Walmart, Facebook, and Netflix was greater than 0.5. Although they were lower than 0.7, they also indicated a significant correlation between them.

In general, although the correlations of the four selected stocks were not so great before the COVID-19, the correlations were great after the COVID-19. So the correlations were still large during the overall period, indicating that the COVID-19 had a huge impact on the stock prices and selected industries.

TABLE 2. THE CORRELATION COEFFICIENTS OF FOUR STOCKS

		Walmart	***Disney***	***Facebook***	***Netflix***
Overall	***Walmart***	1	0.661059	0.834337	0.739635
	Disney	0.661059	1	0.687833	0.5172
	Facebook	0.834337	0.687833	1	0.876611
	Netflix	0.739635	0.5172	0.876611	1
		Walmart	Disney	Facebook	Netflix
Before COVID-19	***Walmart***	1	0.900521	0.343899	-0.44526
	Disney	0.900521	1	0.491396	-0.24015
	Facebook	0.343899	0.491396	1	0.32877
	Netflix	-0.44526	-0.24015	0.32877	1
		Walmart	Disney	Facebook	Netflix
After COVID-19	***Walmart***	1	0.525981	0.796674	0.836708
	Disney	0.525981	1	0.694196	0.579625
	Facebook	0.796674	0.694196	1	0.840858
	Netflix	0.836708	0.579625	0.840858	1

After analyzing the correlation coefficient, we started to investigate the stationary of the portfolio. We used the same strategies of determining the stationary to determine whether these 4 stocks are cointegrated. We use the software called Eviews to carry out a cointegration analysis. We set the stock price of Walmart as the dependent variable, and the stock prices of Disney, Facebook, Netflix are independent variables, respectively. The formula is denoted by

$$P_{Walmart} = c_1 + c_2 * P_{Disney} + c_3 * P_{Facebook} + c_4 * P_{Netflix} + e_i \quad (1)$$

Where e_i is the error term

Firstly, we drew a line graph of this variable error with the time on the horizontal axis and the variable's value on the vertical axis. Then we observed the Figure 3. It was exactly hard to decide whether its stationary or not. Because it fluctuates a lot, and the average value and variance also changed a lot.

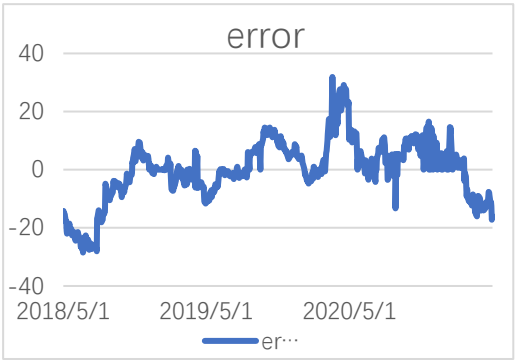
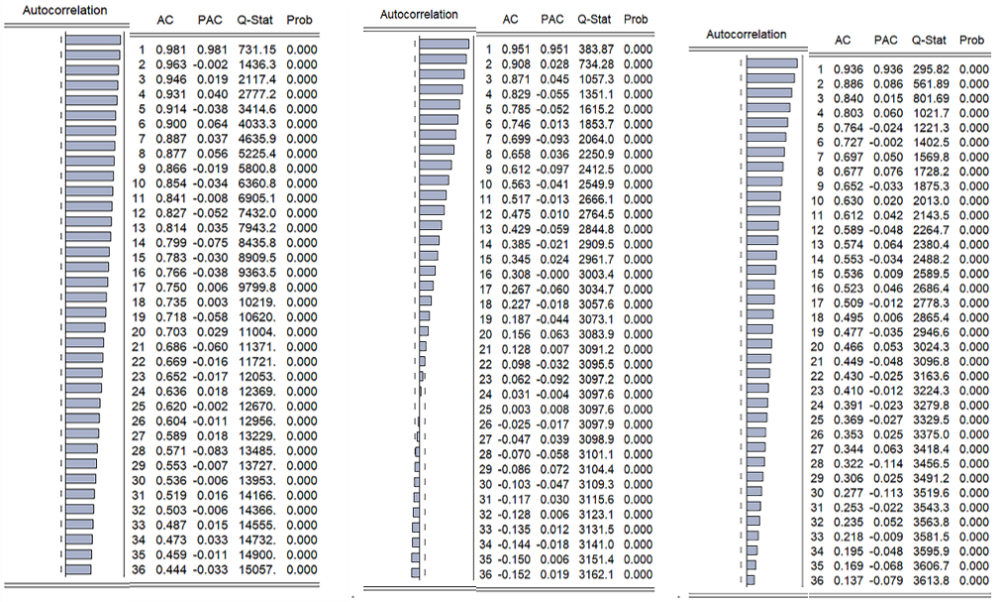


Figure 3. Line graph of the error.

Secondly, a correlogram was carried out to check the stationary of the error. From the Figure 4, check the column of Autocorrelation. The bars were all above the signature line in this sample (January 2018 to April 2021), indicating the non-stationary variable. However, the other two samples (January 2018 to December 2019 and January 2020 to April 2021), we can observe that after the 23rd bar and 38th bar, they were lower than the signature line. However, they were still non-stationary in these two samples.



(a) (b) (c)

Figure 4. Correlogram of the error.

(a) Correlogram of the error over the entire period (b) Correlogram of the error before COVID-19 (c) Correlogram of the error after COVID-19

Thirdly, we used the Augmented Dickey-Fuller test (ADF) to test the stationary. TABLE 3 shows that the p-value in the whole period was 0.1375. And the p-values period before the COVID-19 and after the COVID-19 were 0.0202 and 0.0151. So the result of the test meant that the whole period was non-stationary and not cointegrated. But the separate two periods were stationary and cointegrated.

TABLE 3. THE ADF TEST OF ERROR

Time period		***t-Statistics***	***P value***
Overall	Augmented Dickey-Fuller test statistic	-2.417030	0.1373
Before		-3.208341	0.0202**
After		-3.312688	0.0151**

Notes: ***p<0.01 **p<0.05 *p<0.1.

4. FORECAST

In this section, we choose the simple moving average model, weighted moving average model, and exponential smoothing model to forecast the price of these four stocks. The simple moving average is useful when demand is not growing or declining rapidly, and no seasonality and seasonality are present. Its theory is removing some of the random fluctuations from the data, it just following:

$$F_t = \frac{P_{t-1}+P_{t-2}+P_{t-3}+\cdots+P_{t-n}}{n} \tag{2}$$

Where F_t is the price forecast in the coming period(t)

n is the number of periods to be averaged

$P_i, i \in (t-1, t-2, \cdots t-n)$ are the actual occurrences in previous period

The weighted moving average model allows unequal weighting of prior periods. The difference between the weighted moving average and the simple moving average is that the simple moving average formula implies equal weighting for all periods. Still, more recent periods are given higher weights for the weighted moving average than periods farther in the past. The weighted moving average model is following:

$$\mathrm{F_t} = \mathrm{w_1 P_{t-1}} + \mathrm{w_2 P_{t-2}} + \cdots + \mathrm{w_n P_{t-n}} \tag{3}$$

Where w_i are weights to be given to the actual occurrence for period t-1 to t-n

The exponential smoothing model is used most in these three models, as it is relatively easy to compute, and it is following:

$$F_t = F_{t-1} + \alpha(P_{t-1} - F_{t-1}) \tag{4}$$

Where α is the desired response rate

According to these three forecast models to predict each four stock's prices, and for the weighted moving average and the exponential smoothing model, we just use the solver of Excel to calculate the best weights and α. Then we use root mean square error (RMSE) to judge

which model is the best model to predict the price of each four stocks. The lower the error, the better the model. The result is shown in TABLE 4.

TABLE 4. THE RMSE OF THREE FORECAST MODELS IN FOUR STOCKS

RMSE	***Walmart***	***Disney***	***Facebook***	***Netflix***
Simple moving average model	2.2258	3.5596	6.8914	14.6137
Weighted moving average model	1.6439*	2.6257*	4.9300*	10.6036*
Exponential smoothing model	1.6456	2.6265	4.9354	10.6096

Notes:* represents the lowest RMSE.

Surprisingly, the weighted moving average model is the most accurate model to forecast no matter which stocks are analyzed. This may be due to the weighted moving average model gives higher weight to observations that are close to the forecast period, so it can preferably reflect the tendency of recent market changes. It is precisely because of the epidemic situation that recent prices have fluctuated a little. The weighted moving average model is better than other models to forecast the future price of stocks. And we just use the solver of Excel to calculate the best weights, shown in TABLE 5, and the forecast price of four stocks on May 1, 2021, is shown in TABLE 6. As you can see, the nearest weight is the highest one, because recent periods are given higher weights than periods farther in the past.

TABLE 5. THE WEIGHTS OF EACH FOUR STOCKS

weight	***Walmart***	***Disney***	***Facebook***	***Netflix***
w1	1%	0%	0%	0%
w2	0%	0%	2%	2%
w3	0%	0%	0%	0%
w4	14%	14%	6%	11%
w5	85%	86%	92%	88%

TABLE 6. THE FORECAST PRICE OF FOUR STOCKS ON MAY 1, 2021

Forecast price	***Walmart***	***Disney***	***Facebook***	***Netflix***
Simple moving average model	138.744	184.730	313.660	508.968
Weighted moving average model	139.854	185.921	324.991	512.862
Exponential smoothing model	139.829	185.890	325.281	

5. SUMMARY

Now, we turn to analyze how to form a reasonable portfolio. The total return of the portfolio is equal to each weight multiply the corresponding stock return. The weighted moving average model gives the lowest error; it is the best model to forecast the stock prices. Therefore, we choose a weighted moving average model to forecast the return of four stocks. To begin with, if the more the return on a stock, the more weight it may have. For example, the return of Netflix is the highest in these four stocks, so it should take the largest weight. The other weights other stocks determined by the size of their returns. Furthermore, if the correlation between two stocks is quite high, the sum of these two stock's weights should decrease. For instance, for the whole period we considered in the paper, the correlations between Facebook and Walmart, Facebook and Netflix were all highly correlated with 0.8, so the sum of the weights of each two stocks should decrease a lot than others stocks. Moreover, the whole period of these four stocks is non-stationary or not cointegrated, which means that these four are suitable for long term investment.

While we may consider one other factor risk, which is equal to the square root of the variance of portfolio. The variance is following:

$$\begin{aligned}\text{variance of portfolio} = {} & w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + w_3^2\sigma_3^2 + w_4^2\sigma_4^2 + 2w_1w_2\sigma_1\sigma_2\rho_{1,2} + 2w_1w_3\sigma_1\sigma_3\rho_{1,3} + 2w_1w_4\sigma_1\sigma_4\rho_{1,4} \\ & + 2w_2w_3\sigma_2\sigma_3\rho_{2,3} + 2w_2w_4\sigma_2\sigma_4\rho_{2,4} + 2w_3w_4\sigma_3\sigma_4\rho_{3,4}\end{aligned} \tag{5}$$

Where

w_i are the weights (money allocation to each stock)

σ_i are the standard deviations of the four stocks

$\rho_{i,j}$ are the correlation coefficients among two of the four stocks

Risk is a reference when we consider how to invest. As the previous analysis shows significant changes since the pandemic, no matter for the stock prices of the correlation, especially the correlation between every two stocks before and after the outbreak has changed significantly, this result should influence the risk. For instance, after the outbreak of COVID-19, the correlation between Disney and Walmart declined, so the risk declined as well. However, the correlation between most stocks has risen since the outbreak, so after the outbreak, the total risk may increase than before. For investors, they should choose the portfolio of the investment carefully. When choosing a suitable portfolio of investment, they should weigh the risk and return and consider various factors to decide the most suitable portfolio. Therefore, consider factors such as return and correlation change to achieve a better portfolio outcome. Therefore, we suggest that the investors can invest most in Netflix no matter which period they are facing, but after the outbreak of COVID-19, the weight of investment in Walmart can be increased.

6. CONCLUSION

Our investigation aimed to study the influence of the epidemic of the COVID-19 on the stock market and optimization of the probable investment portfolio at a special time. We chose four stocks from various industries to form a portfolio based on the last three years of four selected

stocks' adjusted prices on Yahoo Finance. This article analyzed the impact of COVID-19 on the stock prices, forecasting prices of these stocks, and optimization of a probable investment portfolio. Using Eviews, we identified that the prices of selected stocks were all non-stationary in the last three years. Besides, we found that these stocks remained none-cointegrated but became more correlated after the outbreak of COVID-19. For prices forecasting, we found that the weighted moving average model gave the lowest root mean square error among forecasting models we had used, which meant this model should be the best model to forecast the stock prices. When optimizing our investment portfolio, we found weights of stocks and the total risk changed due to the COVID-19's influence on the prices, cointegration, and correlation of selected stocks. This article could be a good reference for investors interested in the stocks' prices forecasting and investment portfolio analysis. In addition, the results of our analysis could be helpful to those who intend to analyze the impact of COVID-19 on the stock market. By properly using data analysis and considering various influence factors such as the risk and return, investors can optimize and decide on a suitable investment portfolio even under the impact of COVID-19. However, our analysis has limitations that we didn't consider probable influence factors such as the impact of policy and enterprise decision, which can be worthy for future discussion and study.

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