

An Empirical Study on the Relationship between American Stock Market and Exchange Rate under the COVID-19

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ABSTRACT

From 2020, the COVID-19 pandemic spread globally and had a significant impact on the economies of most countries. This article analysed the impact of the COVID-19 pandemic in the United States and the dollar exchange rate on the US stock market. We found a significant statistical correlation between the COVID-19 pandemic and the return of the US stock market, but there was no economic significance. COVID-19 impacted the volatility of the US stock market in the short term, but in the long term, it did not have an impact on the volatility of the US stock market. However, the dollar's exchange rate did have a significant impact on the return and volatility of the US stock market.

Keywords: COVID-19, Exchange rate, Stock market.

1. INTRODUCTION

From 2020, COVID-19 spread across the world. It has many negative effects on people's lives in different countries. In January 2020, COVID-19 first spread in China, and the cases of COVID-19 increased sharply in January, February, and March in China. Since March 2020, with the spread of COVID-19 around the world, there has been a very high number of confirmed cases and deaths in different countries, like Russia, India, Brazil, and the United States. After that, The U.S. also became the country most affected by the epidemic. On January 21, 2020, the first case of COVID-19 was reported in the U.S. Then, COVID-19 had been spreading quickly in the U.S. since March 2020.

Fig 1 shows the daily number of new cases in the U.S. There were many new cases every day, and the U.S. had its highest number of new daily cases between October 2020 and February 2021. The number of new daily cases in the U.S. decreased from April 2021 to July 2021.

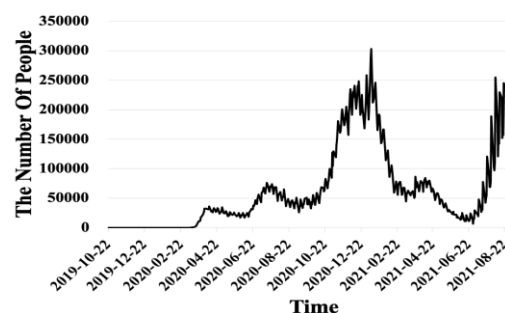


Fig 1 Daily new confirmed cases in the US

From Fig 2, we can see that the confirmed cases rose sharply between October 2020 and February 2021. After that, the rate of increase in confirmed cases was lower than before. The overall trend in the number of confirmed cases was upward. Similarly, the number of deaths had a similar trend with that of confirmed cases.

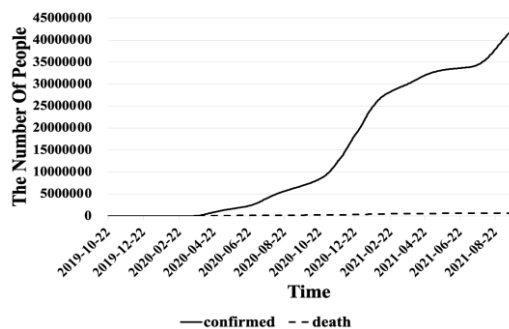


Fig 2 The confirmed cases and deaths in the US

COVID-19 had a very negative influence on financial markets. It caused uncertainty in different industries, so investors became panicked and discouraged. This influence, in turn, harmed the global economy, especially on the U.S. stock market. Since March 2020, there were 4 circuit breakers in the U.S. stock market within ten days, and the decline in the U.S. stock market was substantial. Dow Jones Industrial Average, NASDAQ Composite Index, and S&P 500 Index dropped significantly between March 2020 and June 2020. Since June 2020, the stock market in the U.S. began to recover, and there was a slow upward trend in the stock index. Besides, the emergence of COVID-19 is the black swan event in financial markets that exceeds people's expectations. It caused significant fluctuation in the exchange rate between the USD and the CNY. From Fig 3, we can see that from January 2020 to June 2020, the USD/CNY exchange rate remained stable. But from June 2020 to January 2021, the USD had depreciated significantly against the CNY. After January 2021, the exchange rate of USD/CNY remained stable, but it was significantly lower than that between January 2020 and June 2020.

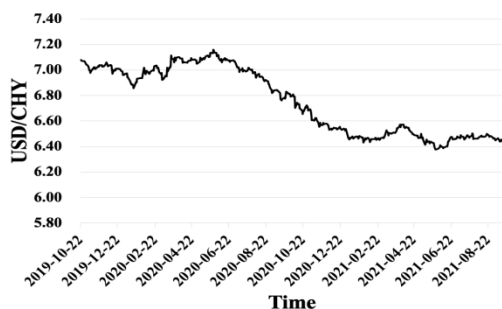


Fig 3 Exchange rate of USD/CNY

In addition, the change of exchange rate will impact capital flow and import and export trade, which indirectly affect the stock markets, especially for some import and export enterprises and transportation enterprises.

Recent research showed that the pandemic had shown harmful consequences for financial markets, especially in the U.S. stock market [1]. In addition, further research has proved that bad news like the death rate or confirmed

rate would increase U.S. stock market volatility, and good news like recovered rate would decrease U.S. stock market volatility [2]. Besides, recent research proved that an increase in the number of confirmed COVID-19 cases would increase exchange rate volatility [3].

Based on the background we mentioned above, we know that COVID-19 had a significant impact on the U.S. stock market and USD/CNY exchange rate, and we also know the exchange rate would indirectly affect the stock market. This paper researches the fluctuations of the USD/CNY exchange rate and the changes of the U.S. stock market during the epidemic, and then it finds the relationship between them to have a deeper understanding of the impact of the COVID-19 on the global financial markets. Moreover, the paper aims to conclude some experiences from changes in financial markets during COVID-19.

2. METHODS

2.1. The source of data

Data of COVID-19 in this paper was derived from the Coronavirus Resource Center conducted by The Johns Hopkins University from October 22, 2019, to September 16, 2021. Data of S&P 500 Index and exchange rate of USD/RMB was derived from Market Watch from October 22, 2019, to September 16, 2021.

2.2. The models

Introduction of the experiment: To investigate the dynamic correlation between COVID-19 in the US, the exchange rate of USD/RMB, and the return of the US stock market, we used the ARMAX model to estimate our results.

$$\text{ARMAX model: } x_t = \varphi_0 + \sum_{i=1}^p \phi_i x_{t-i} + \alpha_t - \sum_{i=1}^q \theta_i \alpha_{t-i} + \gamma_{11} x_{1,t-1} + \dots + \gamma_{1q_1} x_{1,t-q_1} + \gamma_{K1} x_{K,t-1} + \dots + \gamma_{Kq_K} x_{K,t-q_K} \quad (1)$$

Besides investigating the volatility of their variances, we used the GARCH model to estimate our results additionally.

$$\text{GARCH model: } \sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2 + \gamma_1 \sigma_{t-1}^2 + \dots + \gamma_p \sigma_{t-p}^2 \quad (2)$$

2.3. The trend of the U.S. stock market

Take the S&P 500 Index as an example; from March 2020 to April 2020, the U.S. stock market experienced a great crash. The S&P 500 Index decreased from about 3400 dollars to approximately 2200 dollars. During the same period, confirmed cases of COVID-19 started to appear, and the number of cases increased rapidly. After that, the S&P 500 Index began to increase, and until

September 2021, it grew to 4500 dollars, which was higher than the number of it before the outbreak of the epidemic. However, the number of confirmed cases increased constantly after April 2020, especially between November 2020 and March 2021.

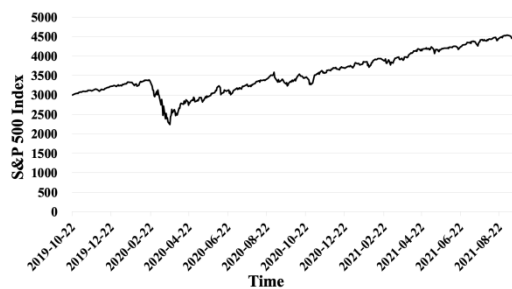


Fig 4 S&P 500 Index

3. RESULTS

3.1. Analysis of descriptive statistics

We used data covering approximately two years, starting three months before the first known case and ending at the day our research began. Only trading days data was used, as skips in COVID-19 growth were preferential to constant zeroing of stock data. Four hundred and eighty days of data were collected from JHU and MarketWatch. The figures were of market close.

We chose the Standard & Poor's 500 indexes to represent the performance of the United States stock market. As one of the most followed indices, it covers a reasonable number of large companies in trade, whose revenue is mainly dependent on the US, and thus an adequate representative for the US stock market in general.

The standard deviation of the S&P 500 indicates market volatility, which in our article is used as a method to assess investment risk, with a higher standard deviation suggesting more risk and vice versa.

The exchange rate used was that between USD and CNY. CNY is a managed float currency, meaning that its values are tied to USD but also is related to other factors. It is an important indicator of US/Chinese trade, which has been severely affected by COVID-19 amongst other issues.

Daily new cases are the number of COVID-19 cases reported in the US since the discovery of the first patient in January 2020. As a result of starting observation three months before the discovery, the standard deviation observed at 70536.66 is smaller than expected.

Through Table 1, we can see that the exchange rate has a mean of 6.7540 and a standard deviation of 0.2602, indicating a somewhat turbulent period. S&P 500 also had a similar turbulent time with a mean of 3553.286 but a high standard deviation of 533.6856. Overall, there is high growth yet also high volatility over the study period.

Table 1. Descriptive Statistics

Variable	N	Mean	SD	Min	Max
<i>Exchange Rate</i>	480	6.7540	0.2602	6.3764	7.1588
<i>Daily New Cases</i>	480	64979.56	70536.66	0	302959
<i>S&P 500</i>	480	3553.286	533.6856	2237.4	4536.95

Note: In this table, N, Mean, SD, Min, and Max represent the sample size, average value, standard deviation, minimum value, and maximum value. The calculation results are rounded up to 4 digits after the decimal point.

3.2. Unit Root test

We used an augmented Dickey-Fuller test to test for stationarity of the unit root. To reject the null hypothesis that a unit root exists, we must obtain a critical value less than the standard value displayed in Table 3. Five variables, two of them finite differences, were tested. We

chose a time lag of 1 to avoid serial correlation of the residual values while maintaining test power and used a regression model with both constant and trend. As shown in Table 2, the result falls within the approximation range shown in Table 3; hence we can reject the null hypothesis and accept the alternative hypothesis that our time series is stationary.

Table 2. Variables used and their definitions

Variable Name	Explanation
<i>Ln_exchangerate</i>	Natural logarithm of the exchange rate
<i>Ln_exchangerater</i>	Profitability expressed as the finite-difference of the natural logarithm
<i>Ln_SP</i>	Natural logarithm of the S&P 500 index

Ln_SPr	Profitability expressed as the finite-difference of the natural logarithm
Ln_new	Natural logarithm of the daily new cases

Table 3. Augmented Dickey-Fuller test for unit root

Variable	Test Statistic	<i>Interpolated Dickey-Fuller</i>		
		1% Critical Value	5% Critical Value	10% Critical Value
$Ln_exchangerate$	-1.392	-3.981	-3.421	-3.130
$Ln_exchangerater$	-15.954	-3.981	-3.421	-3.130
Ln_SP	-2.007	-3.981	-3.421	-3.130
Ln_SPr	-14.975	-3.981	-3.421	-3.130
Ln_new	-1.049	-3.981	-3.421	-3.130

Note: The estimated results are rounded up to 4 digits after the decimal point.

Table 4. Standard Critical Values for Dickey-Fuller Test

	Constant		Constant, Trend		None	
	1%	5%	1%	5%	1%	5%
Sample Size						
25	-3.75	-3.00	-4.38	-3.60	-2.66	-1.95
50	-3.58	-2.93	-4.15	-3.50	-2.62	-1.95
100	-3.51	-2.89	-4.04	-3.45	-2.60	-1.95
250	-3.46	-2.88	-3.99	-3.43	-2.58	-1.95
500	-3.44	-2.87	-3.98	-3.42	-2.58	-1.95
∞	-3.43	-2.86	-3.96	-3.41	-2.58	-1.95

Source: Fuller, W.A., *Introduction to Statistical Time Series*, Wiley, New York, 1976, p.373 [4]

3.3. PACF and ACF

We utilized PACF to determine the lag order of AR, and ACF to determine the lag order of MA. For simplicity's sake, for both models we chose an order of 1.

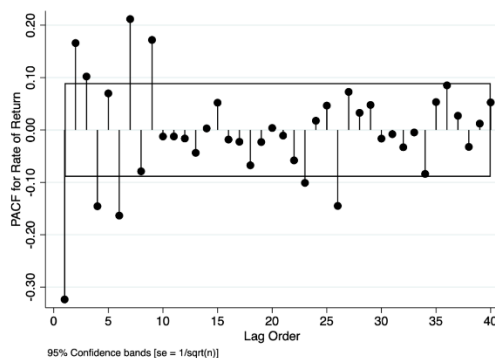


Fig 5 PACF of S&P 500 Index

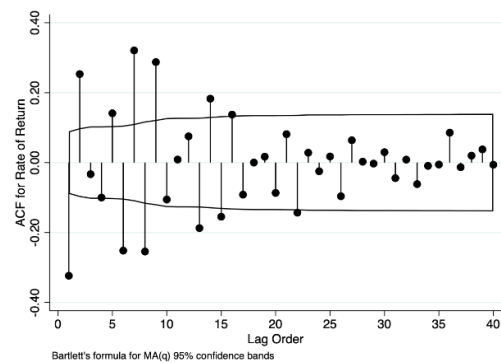


Fig 6 ACF of S&P 500 Index

3.4. ARMAX estimation results

We used an autoregressive-moving model with exogenous inputs model, which introduced daily new cases and exchange rate profitability as independent variables to assess their effects on the dependent variable, the profitability of S&P 500. The results in Table 4 indicate that the daily new cases variable has little effect and significance except at $T=-2$. However, the exchange rate variable always has a notable and significant effect: $T=0$, -1 , and -2 . There exists a negative correlation with

exchange rate profitability at T=0 and T=-2 and a positive correlation at T =-1

3.5. GARCH model estimation results

We used an autoregressive moving average model to assume the error variance of the autoregressive conditional heteroscedasticity model. This produced a generalized autoregressive conditional heteroskedasticity model, which requires fewer

parameter estimates and produces more accurate estimations of future conditional variance.

As shown in Table 5, a significant correlation between daily new cases and profitability variance could be observed; however, the effects were weak. The significance and correlation between exchange rate profitability and profitability variance could also be reconfirmed; however, these effects of these variables are not observed to last very long.

Table 5. Autoregressive–moving-average model with exogenous inputs model.

Variable	S&P 500 profitability					
	T=0	T =-1	T=-2	AR	MA	Constant
<i>Ln_new</i>	-0.0021 (0.0014)	-0.0035 (0.0023)	-0.0058*** (0.0018)			
<i>Ln_exchangerater</i>	-1.3795*** (0.2435)	0.4575** (0.2189)	-0.8829*** (0.2189)	0.5173*** (0.0568)	0.2284*** (0.0635)	0.0004 (0.0006)

Note: Robust standard errors of clusters are reported in parentheses, and the estimated results are rounded up to 4 digits after the decimal point. ***, **, and * indicate the level of significance of 1%, 5%, and 10%, respectively.

Table 6. Generalized Autoregressive Conditional Heteroskedasticity

Variable	S&P 500 profitability variance				
	T=0	T =-1	T=-2	ARCH	GARCH
<i>Ln_new</i>	-6.3607*** (1.6084)	8.9515*** (1.6798)	-2.5283*** (0.3957)		
<i>Ln_exchangerater</i>	-478.8304*** (81.5486)	-665.552*** (98.291)	161.8826 (128.682)	0.9334*** (0.0226)	0.8626*** (0.1881)

Note: Robust standard errors of clusters are reported in parentheses, and the estimated results are rounded up to 4 digits after the decimal point. ***, **, and * indicate the level of significance of 1%, 5%, and 10%, respectively.

4. DISCUSSION

4.1. Theory contributions

Through ARMAX and GARCH analysis, we found that the profitability of the U.S. stock market is dynamically correlated to the severity of the COVID-19 pandemic in the U.S. over the long run, which is in alignment with previous studies by Mazur et al. in 2020 [5] which directly attributes the March 2020 stock crash to the COVID-19 pandemic. The effects of a time lag could be seen, with the profitability having a negative correlation at no lag and two months' lag, yet a positive one at one month lag. However, it could also be argued that the effects presented through COVID-19 cases are not significant economically, as demonstrated by the paucity of the estimation coefficient, which is also consistent with previous findings of Onali in 2020 [6],

which used COVID-19 statistics from non-US countries to measure their effects on the U.S. Stock market represented by S&P 500. In addition to the COVID angle, this article approaches the U.S. stock market from the perspective of Sino-US trade represented by currency exchange rate.

While there has been no consensus on whether the exchange rate has an impact on the stock market, our findings from the significance of the exchange rate support portfolio-balance and goods-market theories of exchange, which states that growth in a domestic stock market reaffirms investor confidence and, in turn, attracts foreign interest reflected through a rising exchange rate. This is conclusive with the findings of previous studies in earlier years [7,8], suggesting a strong correlation between exchange rate and stock profitability in terms of both statistical and economic significance. We were able to gain insight into Sino-US trade through the exchange

rate. It has also been suggested by Ramelli and Wagner that close trading ties with China, which was observed to indicate an early fall, but also a faster recovery rate for companies after the worldwide spread [9]. We may also recall that Onali also reported that China was the sole exception for COVID-19 cases influencing the stock market [6]. Further investigation down this lane would require looking into the performance of individual companies as opposed to that of the whole stock market, which could be used as an indicator of the companies' resilience, in line with the findings of Yan in 2020 [10]. This could aid investment or policymaking. Benzid and Chebbi agree that a rise in the USD exchange rate could lower the volatility of the U.S. stock market [11]. While it can be argued that the short-term results are prominent, as Sansa did in 2020 [12], it is possible that this may have little to no significance over the long run, as suggested by our GARCH analysis.

4.2. Practical implications

It is possible to utilize this knowledge as rough guidance in investing. In addition to just being a risk assessment, it also provides insight on the resilience and recovery of the market, which was the characteristics that the COVID-19 pandemic tested the most. Another possible use would be to guide governments' policymaking. Relevant government intervention and other factors would have to be considered, but this may indicate that only short-term policies are required as it rights itself in the long run.

5. CONCLUSION

We got the relationship between the COVID-19 in the U.S., exchange rate of USD/RMB, and return rate of the U.S. stock market by establishing models for returns and variances.

We came to the following conclusions:

There was a correlation between the COVID-19 and the return of the U.S. stock market, but there was no economic significance because the estimated coefficient was too small. Statistically and economically, the exchange rate of USD/RMB and the return of the U.S. stock market were strongly correlated. This was consistent with traditional economic theory. In terms of the equation of variance, the appreciation of the U.S. dollar would reduce the volatility of the U.S. stock market. The new cases of COVID-19 had a minor impact on the volatility of the U.S. stock market. To be specific, the new cases of COVID-19 had caused fluctuations in the U.S. stock market in the short term, but in the long term, this relationship did not exist.

The COVID-19 had a small impact on the return and the volatility of the U.S. stock market. The exchange rate

had a great impact on the return and the volatility of the U.S. stock market.

In the future, researchers could do deeper research from various aspects. First, the COVID-19 might have indirect effects on stock markets. For instance, the COVID-19 may have an impact on import and export trade, and this may have a significant impact on stock markets. But it is hard to identify in empirical research. Besides, further research could work on various industry blocks. The COVID-19 and exchange rate may have different influences on different industry blocks. For example, the COVID-19 and exchange rate may have a greater impact on the transportation industry than the clothing industry, so further research could pay attention to industry blocks in stock markets.

By researching the relationship between the COVID-19, exchange rate, and stock markets, we knew that the COVID-19 had a certain impact on the U.S. dollar exchange rate and the U.S. stock market in the short term, and this will be helpful to study the impact of changes in global economic markets under the COVID-19.

We found a probable correlation but were unable to further confirm the causation between our variables. We used a balance of models, but we are subject to the limitation of GARCH, which includes solely using closing prices. While we used S&P 500 Index as the main stock in our research, multiple stocks could have increased the reliability of our finding. Also, we only used the daily growth of COVID-19 cases to represent the pandemic, which is not a well-rounded indicator for the severity experienced at the height of the pandemic. Besides, this paper also has some limitations. The COVID-19 is still developing and changing in the U.S. and globally, and the future changes of it could not be predicted. Therefore, it is unknown whether the COVID-19 will affect the stock market and exchange rate in other aspects in the future.

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