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

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Abstract: We use the GARCH model to consider the relationship between the exchange rate and stock price with an extra predictor of newly reported Corona Virus Disease 2019 (COVID-19) during the new coronary pneumonia epidemic in China. The data is from December 9, 2019, to June 18, 2021, since the whole period of COVID-19 starts on December 9, 2019, and ends at a new mutant case found on June 18, 2021, in Shenzhen. Our results show that the GARCH models have different mean functions and variances by only considering two independent predictors the exchange rate and newly reported cases in different lags. In conclusion, we could say that the exchange rate is a factor that could significantly influence the Chinese stock market. In the long term, COVID-19 will not impact the return and volatility of the Chinese stock market, which means that China's economic development is resilient.

Keywords-epidemic; the exchange rate; stock; GARCH modeling; ADF Test

1. INTRODUCTION

The new coronary pneumonia epidemic, the Corona Virus Disease 2019 (COVID-19), broke out in Wuhan, China, at the end of 2019 and then spread to the whole country. In the spring of 2020, the lockdown of Wuhan, the establishment of shelter hospitals, and efficient control measure across the country quickly cut off the large-scale spread of this new virus so that the number of confirmed cases and deaths in China had gradually decreased. Until the summer of 2020, the epidemic in China had entered a stable post-epidemic era. Since the epidemic in foreign countries became more serious, and the epidemic spread in China was relatively stable, the government had always adhered to the anti-epidemic measures of "preventing imports and preventing internal rebounds". Thus, there had been no large-scale infections, and people's lives returned to normal in China.

The research scope of this article starts from the Wuhan Municipal Health Commission's notification of the first case of new coronary pneumonia in Wuhan on December 8, 2019, and a famous respiratory specialist Nanshan Zhong's interview by a journalist Yansong Bai on January 20, 2020. In the notification, the National Health Commission ensured that the new coronary pneumonia caused the human-to-human transmission and determined to add the new

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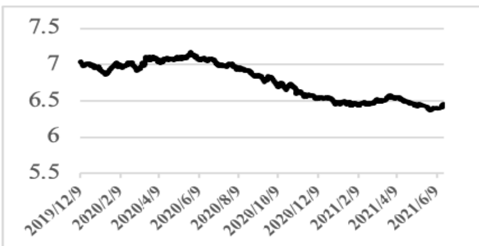
coronary pneumonia (COVID-19) into the Class B infectious diseases stipulated by "Prevention and Control of Infectious Diseases of the People's Republic of China". In the article, the first node is that although the COVID-19 was listed in the Class B infectious diseases, the government adopted the prevention and control measures for Class A infectious diseases in January 2020. After the notification was announced, Wuhan was lockdown, and several groups of doctors and nurses from other cities were volunteered to enter Wuhan and support the hospitals in Wuhan. Then, the second node is the resumption of work and production in severely affected areas on March 16, 2020. Since the transmission was controlled, more people started to walk out of home and work in the seriously affected regions. The article considers that the Coronary Virus Inactivated Vaccine produced by the Beijing Institute of Biology Products Company was officially approved of marketing as the third node on December 31, 2020. The government appealed to all the adults to vaccinate the vaccine and prevented more transmission of COVID-19. At last, the research scope of this article ends with the report on the existence of the Delta mutant strain in Shenzhen cases on June 20, 2021. In summary, the spread of the new coronary pneumonia epidemic in China reached its peak after the first node; After the second node, China had basically controlled the spread of the epidemic and entered a post-epidemic era; After the third node, China entered into a new timeline for the prevention of COVID-19. In addition, since the existence of the Delta mutant strain was in a relatively short period in China, the overall dataset was quite small. Therefore, the influence of the COVID-19 virus with Delta mutant strain on China is ruled out in the article.

At the beginning of the epidemic, China seemed to press the pause button. The suspension of productive financing and investments, the fluctuations of commodity prices, the imbalance of supply and demand of commodities, and the suspension of import and export trade have greatly impacted China's economy. There is no denying that the outbreak has had a strong impact on capital markets around the world, as well as a rapid acceleration of economic growth. As one of the countries with the fastest recovery of production, China has also been hit and stimulated by the epidemic in pharmaceutical production and manufacturing. After the epidemic was brought under control, China's economic life gradually recovered. From the Figure 1, we can clearly see that the exchange rate between US dollar and RMB (USD/CNY) had a decreasing tendency under the overall period of the epidemic. Two obvious variables are the changes in the exchange rate and the fluctuations in stock market. Most existing research focus on the background under the global financial crisis, while few looks into a real-time background, especially under the serious epidemic COVID-19. Therefore, this research paper focuses on exchange rate and stock market volatility and explores the relationship between the exchange rate of the US dollar to RMB (USD/CNY) and China's stock market index during COVID-19.



source: CSMAR

Figure 1. The Exchange Rate Between CNY and USD

Our article is arranged as the following order: the second section is the literature review, which is the research of the predecessors; The third section is an introduction to the data sources and data of this article; The fourth section builds up 4-time series in order to prepare for modeling and empirical analysis; The fifth section is the Augmented Dickey-Fuller test (ADF test) on all variables; The sixth section is the Granger test between the variables so that we could check the relationship between independent and dependent variables; The seventh section constructs the ARMA-GARCH model, and get the results that the exchange rate is an important factor that influences the price of the stock market, and COVID-19 will not cause a huge negative impact on the Chinese stock market, which indicates that the future of the Chinese economy is full of hope and vitality.

2. LITERATURE REVIEW

US dollars (USD) is a commonly recognized currency to complete the transaction in the international market. Stock market is also an important indicator of a country's economy condition. This is an important reason for researchers to think about the relation between the Forex and stock markets. For example, Chen Chuanglian et al. found that the exchange rate shock had a positive effect on the stock market in the short term and had a relatively large impact on the stock market. [1]. Researchers Walid Chkili and Duc Khuong Nguyen viewed that the relationship between the exchange rate and the stock market was affected by governmental economic policies and decisions on international capital budgets under the global financial crisis period [2]. These two factors are simply two of several reasons that affect the linkages between the exchange rate and stock prices, which could also be studied in different situations. Based on the data from the 811-exchange rate reform to the end of June 2016, He Fengjie's empirical study shows that there is A stable positive correlation between RMB exchange rate and a-share market, and there is A reverse correction mechanism from short-term fluctuation of long-term equilibrium. Exchange rate fluctuation is the Granger cause of stock market fluctuation [3]. In the article, we want to investigate the impact of the exchange rate between USD and Chinese Yuan (CNY) on the Chinese stock market under the new coronary pneumonia epidemic (COVID-19).

Under the background of COVID-19, the article will tidy up and refer to some research and experimental models. By considering the correlations between the exchange rate and stock volatility, researchers Benzid and Chebbi, Syahri and Robiyanto use the same model called the GARCH method. Benzid and Chebbi used reported cases and related deaths data by applying the GARCH model to predict the daily volatility of three exchange rates (USD/EUR, USD/CNY and USD/LivreSterling) [4]. However, Syahri and Robiyanto considered the calculations of the CSPI stock market and the exchange rate from USD to Rupiah (USD/IDR), so they concluded that the exchange rate will not affect the CSPI stock market. Since these articles only refer to the basic aspects through the data analysis, they lack the background for COVID-19 [5]. Chris Bradley and Peter Stumpner say that stock market performance reveals the impact of accelerating trends, growing gaps between the winners and the rest, and a flow of value to mega players [6]. Qing He and Junyi Liu have concluded from the empirical results that COVID-19 has a negative but short-term impact on stock markets of affected countries and that the impact of COVID-19 on stock markets has bidirectional spill-over effects between Asian countries and European and American countries. However, there is no evidence that

COVID-19 negatively affects these countries' stock markets more than it does the global average [7]. Philip Hans Franses and Dick Van Dijk studied the performance of the GARCH model and two of its non-linear modifications to forecast weekly stock market volatility. We find that the QGARCH model is best when the estimation sample does not contain extreme observations such as the 1987 stock market crash [8]. Ning Zhang and Aiqun Wang examined the volatility of China and the most advanced countries of the world stock markets due to the pandemic of COVID-19 using the TGARCH model. Using the sample containing closing stock market returns from 05 January 2015 to 04 April 2020 of sample countries, they found that through the COVID-19, there is no significant impact of returns volatility coming from advanced countries towards the China stock market. (Switzerland, Sweden, Netherlands, and the UK) except the U.S.A. during COVID-19 [9]. Manamba Epaphra examined the behavior of the exchange rate in Tanzania. To capture the symmetry effect of the exchange rate data, the paper applies both ARCH and GARCH models. Also, they employed exponential GARCH (EGARCH) model to capture the asymmetry in volatility clustering and the leverage effect of exchange rate. It revealed that the exchange rate series exhibits the empirical regularities such as no stationary, non-normality and serial correlation that justify the application of the ARCH methodology. The results also suggest that exchange rate behavior is generally influenced by previous information about the exchange rate. This also implies that previous day's volatility in the exchange rate can affect current volatility of the exchange rate [10].

In the paper, we will refer to news about some governmental anti-epidemic measures and analyze the impact of the exchange rate (USD/CNY) on the Chinese stock market by combining the collected data results with the news and draw on the GARCH method to analyze secondary data collected in the form of JCI daily data, stock prices and the exchange rates. Moreover, we will use an AR model to predict the results and compare results with the referenced researches. We will generally analyze the fluctuations for the exchange rate and stock prices according to several time nodes in the background section.

3. DATA SOURCES

3.1 The Exchange Rate and Observation Time

The exchange rate refers to the US dollar to the RMB exchange rate. We find these data from CSMAR with observation time from December 9, 2019, to June 18, 2020. We choose this period because December 9, 2019, is when the first patient of COVID-19 was reported in China and June 18, 2020, is the last Friday before the first patient of Delta variant was reported in China. Additionally, our data is not continuous, but there are no non-working days and holidays.

3.2 Closing Price of SSE 50 Index

Because we need to find data to describe China stock price, we choose the daily closing price of the SSE 50 Index from CSMAR.

3.3 Newly confirmed cases

We know that the data of newly confirmed cases is a big measure of the severity of COVID-19 in China, so we assume that the newly confirmed cases every day in China will influence our model and results. The newly confirmed cases are from China Health Construction Commission.

4. BUILD TIME SERIES

4.1 Original Sequence

The first sequence is the pristine data. The dependent variable is the closing price of the SSE 50 index. The independent variable is the exchange ratio. The observation time is from December 9, 2019, to June 18, 2020.

$$x_1 = \text{exchange ratio (No.1)}$$

$$y_1 = \text{closing price (No.2)}$$

4.2 Logarithmic Sequence

Because the magnitude of the closing price and exchange ratio is different, we take the natural logarithm of both data to estimate the influence of magnitude. Then we get a new time series.

$$x_2 = \ln(1+\text{exchange ratio}) \text{ (No.3)}$$

$$y_2 = \ln(1+\text{closing price}) \text{ (No.4)}$$

4.3 Growth Rate Sequence

We estimate that the original and logarithmic sequences are likely to be unstable, so we also use a growth rate sequence. The growth rate reflects the change of variables in one day time.

x_3 = return of exchange ratio = exchange ratio_t - exchange ratio_{t-1} (No.5)

y_3 = growth rate of closing price = closing price_t - closing price_{t-1} (No.6)

4.4 Logarithmic Growth Rate Sequence

Meanwhile, because of the influence of the magnitude, we also establish a logarithmic growth rate sequence.

return of exchange ratio = exchange ratio_t - exchange ratio_{t-1}

$$x_4 = \ln(1+ \text{return of exchange ratio})$$

the growth rate of closing price = closing price_t - closing price_{t-1} (No.7)

$$y_4 = \ln(1+ \text{growth rate of closing price}) \text{ (No.8)}$$

5. ADF TEST

5.1 Methodology of ADF Test

We use the Augmented Dickey-Fuller Test to check the stationarity of the different time series by assuming the null hypothesis is that the sequence is not stationary. Oppositely, we have an alternative hypothesis that the sequence is stationary. After getting the results from Augmented Dickey-Fuller Test, we can check its Augmented Dickey-Fuller statistics and p-values to ensure whether the test is significant or not. If the Augmented Dickey-Fuller statistics are more negative, there is more confidence to reject the hypothesis. Moreover, if the p-value is less than 0.05, then the result is significant. On the other hand, if the p-value is greater than 0.05, the result is insignificant.

5.2 The Results of All the Variables

Table 1 ADF Test

Variables	***ADF***	***P-value***
The Exchange rate	-1.7615	0.6777
Ln(1+the exchange rate)	-1.7705	0.6738
Return of the exchange rate	-7.1453	<0.0100
Ln(1+ return of the exchange rate)	-7.1469	<0.0100
Closing price	-2.1136	0.5290
Ln(1+closing price)	-2.1426	0.5168
Growth rate of the closing price	-7.3528	<0.0100
Ln(1+growth rate of closing price)	-7.3186	<0.0100
Newly confirmed cases	-3.4862	0.0436
ln(1+newly confirmed cases)	-7.5504	<0.0100

By introducing the null hypothesis that the sequence is not stationary, we use the ADF test to check the stationary of the sequence. After getting the results of P-values, we can see that the sequences including the return of the exchange rate, logarithmic exchange rate, growth rate of the closing price, logarithmic growth rate of the closing price and logarithmic newly confirmed cases have P-values that are smaller than 0.05, which means that these sequences have significant results to reject the null hypothesis. Thus, we can say that those sequences are stationary.

Since our dependent variable is the market closing price in China, we should consider two sequences about the Chinese market closing prices. Based on the graph and statement above, we can conclude that the growth rate sequence and logarithmic growth rate sequence are stationary. In order to find the best sequence as our basic model, we need to check their ADF values. When considering ADF values, we will exclude the logarithmic growth rate sequence since its ADF value is not negatively big enough. As a result, we would use the growth rate sequence as the basic model.

6. GRANGER CAUSALITY TEST

6.1 Basis of Granger Causality Test

Now we know that the time series is stationary. Nest, we are expected to analyze the causal relationship between x and y. So, we make the Granger causality test with different independent and dependent variables.

During the condition that the past information of variables X and Y are included, the predictive effect of variable Y is better than the predictive effect of Y solely based on the past information of Y. The variable X helps explain the future changes of variable Y. It is considered that variable X is the Granger cause of the variable Y.

Table 2 Granger Causality Test

Variables(X~Y)	*F-value*	*P-value*
The exchange rate～Closing price	4.9928	0.0261*
Ln(1+ the exchange rate)～Ln(1+closing price)	5.6497	0.0180*
Return of the exchange rate～Growth rate of the closing price	1.2915	0.2565

Note: * Significant at the 0.05 level(two-tailed).

6.2 Analysis of the results of Granger Causality Test

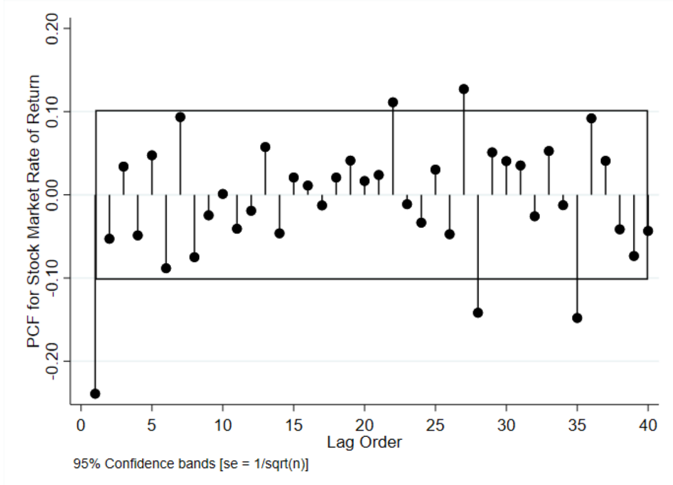
Firstly, suppose the null hypothesis that the lagged X does not show a relationship in Y. After that, we use Granger causality test to check whether the result is significant or not.

Based on the results in the Table 2, the P-value in the Granger causality test between the exchange rate and closing price is 0.0261, which is significant. This shows that the result rejects the null hypothesis that the lagged exchange rate shows a relationship in the market closing price. Also, the P-value in the Granger causality test between Ln(1+the exchange rate) and Ln(1+closing price) is 0.0180, which is significant. Similarly, we have a significant evidence to reject the null hypothesis and there is a causal relationship between the logarithmic exchange rate and logarithmic closing price. However, since the P-value in the Granger causality test between the return of exchange rate and growth rate of the closing price is 0.2565, which is larger than 0.05 and is not significant, we are fail to reject the null hypothesis and there is no significant relationship between the return of exchange rate and growth rate of the closing price. Therefore, we could conclude that the stock market and the forex market are dynamically dependent according to these two values.

7. ARMA-GARCH MODEL

7.1 Determination of Order

We could draw a plot for the Partial Autocorrelation Function (PACF) of different lags to explain the partial correlation between the sequences and lagged itself. From the Figure 2, PACF cuts immediately after the several lags, so we could consider that the Autoregressive Model AR(1) for the stock market return is the best from the graph.



source: group work in R

Figure 2. PACF Test

Then, we consider using the same AR(1) as the current order for the new combination of model ARMA(1,0)-GARCH(1,1), where ARMA is an Autoregressive Moving Average, and GARCH is Generalized AutoRegressive Conditional Heteroskedasticity. First, we use a standard GARCH model with the formula of return of stock price$_t$ = $\gamma\times$return of the exchange rate$_t$ + $\phi\times$return of the exchange rate$_{t-1}$ + $\delta\times$return of the exchange rate$_{t-2}$+ϵ_t as mean function and $\sigma_t^2 = \alpha_0+\alpha_1\times\epsilon_{t-1}^2+\beta_1\times\sigma_{t-1}^2$ as variance equation. Then, we set the current exchange rate return as consistent in the mean equation and use another predictor newly reported cases in China in both mean and variance equations, respectively.

7.2 Results of ARMA-GARCH Model (a)

To examine the stock market's response to the variation on the exchange rate during the COVID-19 period, we reported different mean functions of three models by changing the different lags for the independent variable return of the exchange rate so that we can obtain the best model for forecasting the dependent variable (the return of stock price). In model (1), we use the current return of the exchange rate as the mean function. In model (2), we try the first-period lag to return the exchange rate. In model (3), we create the second period lag for the exchange rate return. All three models use the same variance function, which only contains the terms of Autoregressive Conditional Heteroscedasticity (ARCH) and Generalized AutoRegressive Conditional Heteroskedasticity (GARCH). However, the results show that the changes in the exchange rate are immediately reflected on the Chinese stock market, and there is no lag relationship.

Table 3 ARMA-GARCH Model(a)

Variables	(1)	(2)	(3)
ARCH	0.2294	0.2034	0.1915
	(0.1381)	(0.1256)	(0.1285)

GARCH	-0.1423	-0.1540	-0.1492
	(0.0972)	(0.1165)	(0.1217)
Return of exchange $rate_t$	-2.5771***	-2.6088***	-2.6107***
	(0.2640)	(0.2459)	(0.2478)
Return of exchange $rate_{t-1}$		-0.1977	-0.1892
		(0.1496)	(0.1500)
Return of exchange $rate_{t-2}$			0.1671
			(0.1112)
Constant	0.0005	0.0004	0.0005
	(0.0009)	(0.0009)	(0.0009)
N	369	368	367

* Significant at the 0.05 level(two-tailed).

** Significant at the 0.10 level(two-tailed).

*** Highly significant at the 0.01 level(two-tailed).

7.3 Discussion of ARMA-GARCH Model (a)

The current exchange rate return is negative for all models, which means that the past exchange rate return has a negative influence on the return to stock price during COVID-19. We could use the model 1 as an example. When the return of exchange rate in the current time increases 1 unit, the return of the stock price in the current time will decrease 2.5771 units. As the COVID-19 rapidly spread out the whole of China, the exchange rate between CNY and USD dropped, which caused so many negative effects on business and the economy in China. For example, the imports and exports are canceled and delayed due to the lockdown and suspension of production. Thus, the direct results showed in stock market as investors were not optimistic about investing in Chinese companies and started selling off the stock.

In addition, the parameters for mean equations for our models are strongly significant. All the constants for mean equations are extremely small, which approaches zero. In three models, GARCH terms of the variance equation are quite small, which shows that σ_t is not highly correlated with σ_{t-1} with a short persistence. Since the sums of ARCH and GARCH terms are far from one, we can conclude that the stock market volatility is not persistent during the COVID-19 period. The stock market prediction shows that the Chinese stock market will not fluctuate for a long period. In the optimistic view, as the COVID-19 period ended, the Chinese stock market might be gradually stable. The COVID-19 would not have a consistent and bad influence on the Chinese stock market and even the Chinese economy. We could hold a positive attitude to the Chinese future.

7.4 Results of ARMA-GARCH Model (b)

We create another six models with different mean functions and variances. In model (1)-(3), all variance functions only contain the terms of ARCH and GARCH, while the mean functions are the current exchange rate return with different lags of newly reported cases COVID-19. In model (4)-(6), we set the mean function containing the only current exchange rate return during the COVID-19 and change the functions for variances by combining different lags of newly reported cases with terms of ARCH and GARCH.

Table 4 ARMA-GARCH Model(b)

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
ARCH	0.2384	0.2532	0.2518	0.2450	0.2456	0.2590
	(0.1449)	(0.1435)	(0.1453)	(0.1509)	(0.1697)	(0.1908)
GARCH	-0.1382	-0.1390	-0.1453	-0.1384	-0.1382	-0.1320
	(0.0946)	(0.0955)	(0.0984)	(0.0982)	(0.1032)	(0.0970)
Return of exchange rate$_t$	2.5805***	2.5879***	2.6070***	2.5125***	2.5119***	2.5141***
	(0.2692)	(0.2882)	(0.2796)	(0.2904)	(0.2983)	(0.3088)
Reported cases in China$_t$	0.0004	0.0026	0.0287	0.0371	0.0377	0.0405
	(0.0006)	(0.0015)	(0.0015)	(0.0613)	(0.0872)	(0.1220)
Reported cases in China$_{t-1}$		-0.0026	-0.0018		-0.0011	-0.0018
		(0.0014)	(0.0015)		(0.0958)	(0.1292)
Reported cases in China$_{t-2}$			-0.0011			-0.0041
			(0.0009)			(0.1757)
Constant	-0.0007	0.0002	0.0004	0.0005	0.0005	0.0005
	(0.0019)	(0.0018)	(0.0018)	(0.0009)	(0.0009)	(0.0009)
N	369	369	368	369	369	368

* Significant at the 0.05 level(two-tailed).

** Significant at the 0.10 level(two-tailed).

*** Highly significant at the 0.01 level(two-tailed).

7.5 Discussion of ARMA-GARCH Model (b)

We use model 1 as an example and interpret the model. When the current return of exchange rate increases 1 unit and the current reported cases in China increases 1 number, the current return of exchange rate will decrease 2.5801 units. Then, we can compare all coefficients for the current return of the exchange rate and the newly reported cases in China and find out that the current return of the exchange rate and the newly reported cases in China have negative coefficients in all models from Table 4. This shows that both predictors have negative impacts on our dependent variable (return of stock market). During the COVID-19 period, the Chinese government required every provincial government to report the newly reported cases of COVID-19 and took quarantine measures. The data of newly reported cases were announced and collected on January 23, 2020, in China. As the number of reporting cases for COVID-19 was increasing, people started to be panic and caused the volatility of the stock market indirectly.

Furthermore, our models' coefficients for mean equations (return of the exchange rate) are strongly significant, and all the constants for mean equations are approximately equal to zero. Similarly, with the three models in part(B), the sum of ARCH and GARCH terms are very small, which does not approach one. Thus, the conclusion of the volatility of the stock market is not strong, and the results overstate the fluctuation of the Chinese stock market in the COVID-19 period.

8. CONCLUSION

In conclusion, we could say that the exchange rate is a factor that could significantly influence the Chinese stock market. In the long term, COVID-19 will not impact the return and volatility of the Chinese stock market, which means that China's economic development is resilient. The only limitation is that we only consider two representative variables as our independent variables in the model and there might be other factors or predictors can affect the stock market price in China. For example, the governmental restriction on business during the period of COVID-19 could also be another direct factor that affects the closing price of Chinese market. Since there are plenty of third variables, we could be add more variables for the further study in a comprehensive consideration.

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