Biomedical Industry in China under the Long-term Uncertain Situation: an Empirical Research Based on Time Series Model

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Abstract. According to the stock price of biomedical industry in China, the outbreak of COVID-19 has had a significant positive impact on the biomedical industry. This paper based on the data on stock price of biomedical industry in China, and both the numbers of daily increased cases in China and overseas the since the outbreak of Covid-19, analyze the long-term relationship between the increased cases and the fluctuation of the biomedical industry. Different from prediction of many studies in the early days of Covid-19, this paper finds that after more than two years of instability, the newly diagnosed cases of Covid-19 in China still have a significant positive impact on the yield of stock price of Chinese biomedical industry, but the extent of the impact is lower and the rate of decay is faster compared to the beginning of Covid-19. The volatility of the yield of Chinese biomedical industry is also significantly affected by the newly increased cases in China. A larger number of daily Chinese increased cases is related to the higher volatility of Chinese biomedical industry. Meanwhile, new cases abroad have had no significant long-term impact on China's biomedical industry.

Keywords: Covid-19; biomedical industry; stock price; China.

1. Introduction

The outbreak of Covid-19 began in Wuhan, China, in early 2020 and it has gradually spread to other Chinese cities and other foreign countries. This highly contagious disease caused a large number of infected cases and deaths because people and governments did not pay attention to it at first. The lifestyles of citizens have been forced to change and many industries and companies have been severely influenced. The coronavirus pandemic has caused significant uncertainty in the market. The outbreak of COVID-19 in early 2020 led to turmoil in global financial markets. The rapid spread of the coronavirus caused investors to panic in the Chinese, U.S., and European markets in the short term, causing a large amount of capital to flee the financial markets, and leading to a precipitous drop in financial market indexes. By comparing the research data of McKinsey and some GPS on the industry, Yang argues that the pandemic has hit different industries with different levels of severity, and the energy, retail, and transportation sectors have been most negatively affected [1]. However, some industries perform better in the short term because of their special nature, such as the biomedical industries. The coronavirus pandemic has had a huge impact on markets around the world, and that has been reflected in stock markets [2]. China's biomedical sector bucked the trend, while shares in most industry groups continued to fall, which shows that Covid-19 has a positive impact on the biomedical industry [3].

From the data on China's biomedical stocks, it can be found that since February 3, 2020, China's biomedical stocks rose from 1700 to 1900. Yang believes that the outbreak of COVID-19, both in China and overseas, had a positive and significant impact on the market returns of China's biomedical industry [4]. The sudden epidemic made investors enhance their expectations of the biomedical industry. The COVID-19 epidemic had a significant positive impact on the earnings of the biomedical industry, causing the rise in stock prices (Please see Figure 1).

Figure 1. China's Biomedical Index from 2020-02-03 to 2022-08-01

From March 4 to March 24, the biomedical stocks began to fall to the original level, about 1700, as the spread of the Covid-19 in China has been greatly controlled, the number of new patients has been reduced, and the number of cured patients has increased, and the situation has improved [5]. At this time, many papers judge that the positive effect of the epidemic on Chinese medicine is only short-term. Duan indicates that the market hype sentiment on the biomedical industry has cooled rapidly, and the impact of COVID-19 on the earnings of the biomedical industry is short-term [6]. According to the Shanghai and Shenzhen 300 index fluctuation variance decomposition results, the whole outbreak of Covid-19 did not highly contribute to the stock market volatility [7]. The main reason is the short-term effect of the pandemic on stock market volatility [7]. At the beginning of the outbreak, the uncertainty in the market increased, and investors had negative sentiment towards the market such as fear, but with the positive news that the epidemic was under control and the reduction of negative investor emotion, the impact of Covid-19 on stock market volatility also declined.

Since the end of March, Chinese biomedical stocks began to rise sharply and reaching a peak of around 2,750 in August 2020. Based on data before April 30, 2020, Ren, Wang, and Yan's research shows that, from the experimental results, the COVID-19 epidemic has had a long impact on China's biomedical industry, with strong sustainability, and a greater positive impact on China's biomedical industry due to the outbreak of Covid-19 overseas [5]. The impact of the epidemic on China's biomedical industry will not end in a short period.

Chinese biomedical stocks then fluctuated between 2,200 and 2,800 for nearly a year. However, as time goes by, the development of treatment of Covid-19, the stability of the epidemic domestically and abroad, the recovery of stock market in China, and a series of good news have increased the confidence of investors, the impact of Covid-19 on the financial market is considered to decrease. Starting around July 2021, Chinese biomedical stocks continued to fall sharply and gradually returned to the level at the beginning of the pandemic, around 1700 to 2100 points. Investors' enthusiasm for the biomedical sector appears to have waned as people's knowledge of the coronavirus pandemic has deepened and governments have improved their response to Covid-19. In the long run, as people's perception of COVID-19 deepens, whether behavior returns to rationality and whether this effect still exists need to be empirically tested.

The above studies show that the analysis of effect of Covid-19 on the medical industry in China is complex and more research is needed. This article further explores the impact of Covid-19 on the biomedical industry under the situation of the normalization of the epidemic and tries to make a comparison of it with the early stage of the epidemic. This paper chooses Chinese biomedical stock as the main case to be analyzed.

This paper is written to analyze the performance of the Chinese biomedical industry under the long-term uncertain situation of Covid-19. First, this paper builds a VAR model consisting of 3 variables of Chinese biomedical stock price, and daily new cases in China and overseas. This model

is built to analyze and forecasts three time series variables simultaneously. An impulse response graph is drawn to this reflects the amount of change in Chinese biomedical industry caused by the shock of new cases in China and overseas respectively. Finally, this paper pays attention to the volatility of stock price of the Chinese biomedical industry. In this research, autoregressive conditional heteroskedasticity is used to forecast variance. At the same time, based on this ARCH system, GARCH model is introduced to further improve this model. This paper makes conclusion based on the results of these empirical researches.

2. Research Design

2.1 Data Source

The data of daily cumulative number of COVID-19 cases in China and overseas are collected from WHO. On 20 January 2020, the Chinese government began to publish information on the COVID-19 epidemic. This was followed by the Chinese Lunar New Year holiday, when the market was closed and did not officially open until February 3, 2020. This paper mainly studies the long-term performance of the biomedical industry stock market under the COVID-19 pandemic, so this paper selects the data of stock prices of biomedical industry in China from February 3, 2020 to August 1, 2022. This paper calculates the daily number of new coronavirus cases in both China and world by subtracting the previous day's data from the current day's data.

The data of Chinese biomedical industry price Index (daily index, closing price) is collected from Eastmoney.com [8]. This paper chooses the daily index and closing price.

This paper matches the daily new confirmed cases with the daily closing price of the biomedical biological industry price index. Since the stock only trades in trading dates and the price index records the index during the trading dates, this paper omits the daily new confirmed cases both in China and overseas in no trading dates to better match and compare the daily data of new confirmed cases of the COVID-19 pandemic and price index of biomedical industry. The study included 609 data sets.

2.2 Unit Root Test

Unit root test aims to check whether the sequence has a unit root, that is, whether the sequence is stationary. Before conducting the following series of studies, it is necessary to confirm whether these data are stationary. If they are stationary, it is reasonable to establish a series of models to make analysis. If the stationarity test of these series is not satisfied, it is necessary to process these data to make further analysis.

The unit root test assumes that the time series can be satisfied:

$$y_t = \alpha_t + \beta y_{t-1} + \sum_{i=1}^{p-1} \phi_i \Delta y_{t-i} + e_i \quad (1)$$

The null hypothesis is $\beta = 1$, that is the examined time series is nonstationary. The alternative hypothesis is $\beta < 1$, which indicates that the time series is stationary.

The unit root test results of some processed data are displayed in Table 1.

Table 1. ADF test

Variables	t-statistic	p-value
	Price	
Biomedical index	-2.207	0.4857
	Yield	
Biomedical index	-17.521	0.0000***
	New confirmed cases	
China	-4.450	0.0018***
Overseas	-7.036	0.0000***

Note that ***, **, and * present the significance level of 1%, 5%, and 10%, respectively.

From the output of Stata, the p-value of logarithmic price index of Biomedical data is 0.4857 and it is much larger than 0.05. The logarithmic original data of price index does not perform well in the stationary test.

When it is found that the logarithmic data of original data has a unit root, that is, it is not stationary, it is unable to construct the time series model. The way to solve this problem is to find the difference between logarithmic price index of biomedical data.

The sequence after difference is the logarithmic yield of biomedical index. From the output of Stata, the p-value of logarithmic yield of the price index is approximately zero, which is less than 1%. It is evident to reject the null hypothesis test at 1% significance level. Thus, the series of logarithmic yields of the price index is stationary.

Additionally, the p values of logarithmic data of newly confirmed cases in both China and overseas are less than 0.01, which means these time series can reject the null hypothesis, which indicates that they are stationary.

2.3 VAR Model Specification

Sims develops the Vector Autoregression Model [9] and this model can be used to explore the prediction of several time series variables simultaneously. It puts these variables together and forecasts them as a system so that the forecasts are mutually consistent.

This model assumes that there are two variables $\{z_{1t},\ z_{2t}\}$, which are respectively the explained variables of the two regression equations. The P-order lag values of these two variables would be the explanatory variables, which constitute a binary VAR(p) system. The system is:

$$z_{1t} = \alpha_{10} + \alpha_{11}z_{1,t-1} + \ldots + \alpha_{1p}z_{1,t-p} + \gamma_{11}z_{2,t-1} + \cdots + \gamma_{1p}z_{2,t-p} + \varepsilon_{1t} \tag{2}$$

$$z_{2t} = \alpha_{20} + \alpha_{21}z_{1,t-1} + \ldots + \alpha_{2p}z_{1,t-p} + \gamma_{21}z_{2,t-1} + \cdots + \gamma_{2p}z_{2,t-p} + \varepsilon_{2t} \tag{3}$$

It can be written as:

$$Z_t = \mathrm{M}_0 + \mathrm{M}_1 Z_{t-1} + \cdots + \mathrm{M}_p Z_{t-p} + \mathrm{E}_t \tag{4}$$

where $Z_t = \begin{bmatrix} z_{1t} \\ z_{2t} \end{bmatrix}, \mathrm{M}_0 = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \end{bmatrix}, \mathrm{M}_1 = \begin{bmatrix} \alpha_{11} & \gamma_{11} \\ \alpha_{21} & \gamma_{21} \end{bmatrix} \ldots, \mathrm{M}_p = \begin{bmatrix} \alpha_{1p} & \gamma_{1p} \\ \alpha_{2p} & \gamma_{2p} \end{bmatrix},\ \mathrm{E}_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$.

E_t represents the matrix of the error term, and M_i represents the matrix of coefficient terms for Z_{t-i}.

2.4 ARMA-GARCH Model Specification

2.4.1 ARCH Model Specification

In theory, when the variance in one period is large, the volatility in some future periods is likely to be large, which is called volatility clustering. Autoregressive Conditional Heteroskedasticity (ARCH) considers the volatility of the variance, so it improves the prediction of the variance and has major application value in the finance industry.

The ARCH model considers a general linear regression model: $y_t = x_t'\beta + \varepsilon_t$. The error term's conditional variance in period t (σ_t^2) can change over time. Suppose it depends on square of error term for p periods before the period t $(\varepsilon_{t-1}^2, \ldots, \varepsilon_{t-p}^2)$.

Therefore, an ARCH(p) model is:

$$\sigma_t^2 = \delta_0 + \delta_1\varepsilon_{t-1}^2 + \cdots + \delta_p\varepsilon_{t-p}^2 \tag{5}$$

2.4.2 GARCH Model Specification

If p is large in an ARCH(p) model, there will be a large number of parameters that need to be estimated, which will diminish the sample size. The GARCH model, which Bollerslev introduced,

reduced the number of parameters that needed to be estimated and increased the precision of forecasting future conditional variance [10]. Its fundamental concept is to add the autoregressive part of σ_t^2 based on ARCH model. The model of GARCH (p, q) can be written as:

$$\sigma_t^2 = \delta_0 + \delta_1 \varepsilon_{t-1}^2 + \cdots + \delta_p \varepsilon_{t-p}^2 + \theta_1 \sigma_{t-1}^2 + \ldots + \theta_q \sigma_{t-q}^2 + \gamma x \quad (6)$$

Where x represents an exogenous explanatory variable, which is the daily increased cases in period t.

3. Empirical results

3.1 VAR model result

3.1.1 VAR Order Selection

This paper puts three time series data-logarithmic return rate of Chinese biomedical industry stock price, logarithmic daily increased cases in China and overseas are put in a VAR model. It is convenient to select the reasonable order of the VAR model through Stata's VARSOC command. The output from Stata is shown in Table 2, which represents that VAR (7) model is suitable.

Table 2. VAR model identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-381.762				.000855	1.4492	1.45865	1.47335
1	219.984	1203.5	9	0.000	.000092	-.783369	-.74556	-.686764
2	316.471	192.97	9	0.000	.000066	-1.11288	-1.04672	-.943826
3	349.524	66.107	9	0.000	.00006	-1.20348	-1.10896	-.961969*
4	364.364	29.68	9	0.000	.000059	-1.22548	-1.1026	-.911512
5	383.481	38.234	9	0.000	.000057	-1.26358	-1.11235*	-.877165
6	392.663	18.364	9	0.000	.000057	-1.26427	-1.08467	-.805396
7	403.393	21.438*	9	0.000	.000056*	-1.27078*	-1.06283	-.739456
8	408.67	10.555	9	0.000	.000057	-1.25676	-1.02045	-.652981
9	414.991	12.641	9	0.000	.000058	-1.24667	-.982002	-.570435
10	422.01	14.039	9	0.000	.000058	-1.23921	-.946185	-.490522
11	424.924	5.8277	9	0.000	.00006	-1.21629	-.894905	-.395145
12	427.416	4.9839	9	0.000	.000061	-1.19177	-.842035	-.298179

3.1.2 Stability Condition of VAR Estimates

After the selection of a suitable order of the VAR model, the research checks whether the VAR system is a stationary process through Stata's "varstable, graph" command. It is a stationary process if all the eigenvalues, that is, all the points on the graph, are inside the unit circle. From Figure 2, all dots are inside the unit circle, it is reasonable to say that the VAR model is stable.

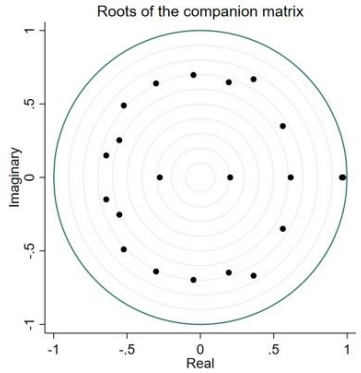


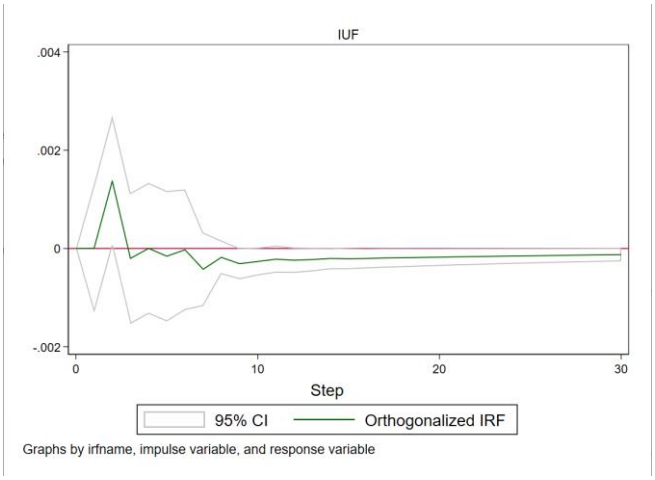
Figure 2. VAR stability

3.2 Impulse Response Graph of the VAR model

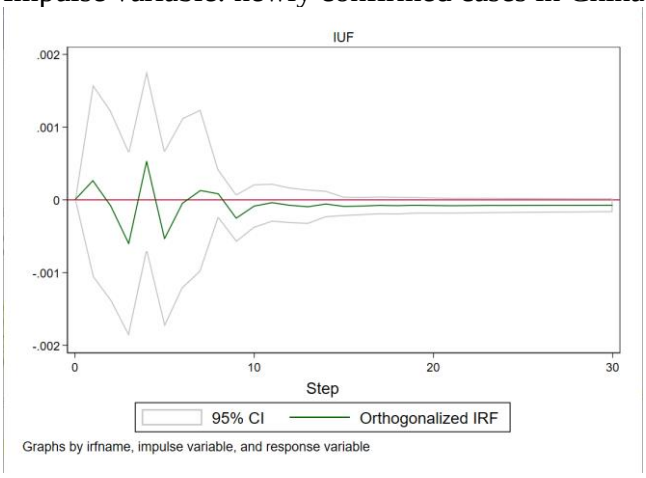
From the estimated results of impulse and response (Figure 3), when the number of newly diagnosed patients in China increases by 1% in the period t=0, the impact on the return rate of the biomedical industry is positive. The influence reaches the peak in the period t=2, which is slightly greater than 0.1%. After t=3, the effect of the current shock on the yield becomes negative. In terms of time effect, the effect gradually decays to 0.

From the above results, it seems that Chinese investors do not "learn a lesson" from experience. The return rate of the biomedical industry has almost repeated the history that the stocks index grows quickly and then decays to its normal level, nothing but this procedure happens in a shorter time frame. However, this research finds that as Covid-19 becomes more normal, investors become less panicked, and the impact of Chinese new cases on the Chinese biomedical industry's returns is not quantitatively significant.

The impact of the shock of overseas confirmed cases on the yield of the biomedical industry is not significant and it will not be further analyzed.



Impulse variable: newly confirmed cases in China



Impulse variable: newly confirmed cases overseas

Figure 3. Impulse and response

3.3 ARMA Order Selection

The research needs to identify the suitable order of AR part and MA part of the logarithmic return series of biological industry. The plot of PACF and ACF produced from Stata are shown in Figure 4. 23 is a suitable selection of orders of AR model from the PACF plot. According to the ACF plot, a good choice for the order of MA part is also 23. Therefore, the reasonable orders for ARMA model are (23, 23).

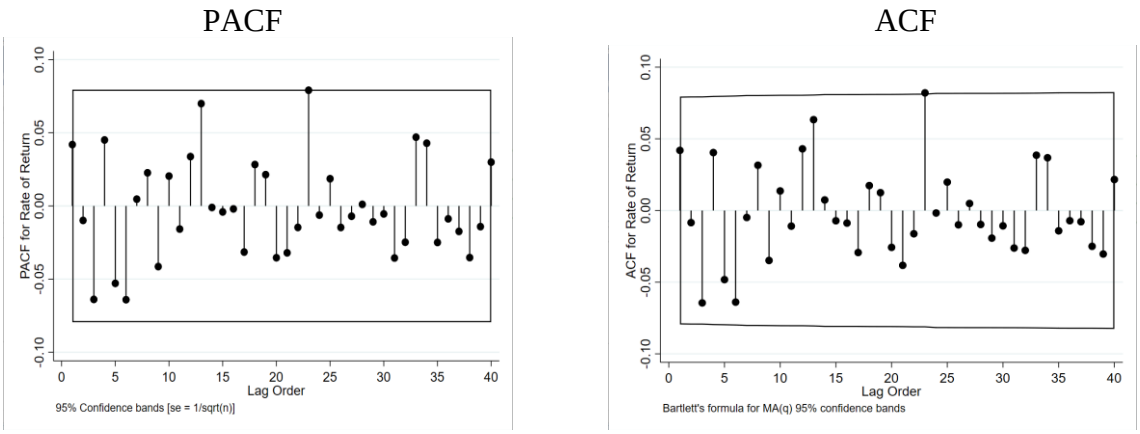


Figure 4. PACF and ACF

3.4 ARMA-GARCH Model Result

From the estimated results of the ARMA-GARCH model (Table 3), the ARCH term of the model in column (1) is significant, and the ARCH term and GARCH term of the model in column (2) are both significant, indicating that the return rate of the biomedical industry has significant conditional heteroscedastic property, which can be used for GARCH modeling.

In addition, from the coefficient of the number of new diagnoses, new cases in China continue to influence significantly the volatility of the biomedical industry. When the number of newly diagnosed cases in China increased by 1%, the daily volatility of the biomedical industry increased by 0.0665 units, while the number of newly diagnosed cases overseas had no similar impact.

Table 3. ARMA-GARCH estimation results

Variables	(1)		(2)	
	Coefficient	Std. err	Coefficient	Std. err
Mean equation				
AR (-23)	-0.5867*	0.3108	-0.5951**	0.2769
MA (-23)	0.6610**	0.2897	0.6696***	0.2564
Constant	0.0002	0.0007	0.0001	0.0006
Variance equation				
New confirmed cases				
China	0.0665**	0.0299		
Overseas			0.0051	0.1118
GARCH (1, 1)				
ARCH (-1)	-0.2660***	0.0338	0.0691**	0.0269
GARCH (-1)	-0.1767	0.6226	0.8680***	0.0616
Constant	-8.2875***	0.6081	-11.0751***	1.5740

Note that ***, **, and * present the significance level of 1%, 5%, and 10%, respectively.

4. Discussion

Chinese investors still have a lot of irrational investment behaviors. The influence of irrational investment behavior on the stock market fluctuation is very significant, which affects the stable development of Chinese stock market [11]. In a mature stock market, the investment ideas of investors should be mature and rational, and the stock market will be less volatile. The Chinese government could play a very important role in establishing a mature stock market [12]. The government should pay attention to the investor's understanding and belief of financial investment, to guarantee the faster and better development of Chinese stock market.

Additionally, the new cases in China still significantly affect the volatility of the earnings of the biomedical industry. In order to stabilize the biomedical industry, the Chinese government still needs to continue to make efforts to control the development of the epidemic and try to avoid another large-scale outbreak.

Investors, should try to avoid irrational investment behaviors and blindly follow the trend. The shock of new cases has had less impact on the yields of biomedical industry. Facing new information about Covid-19, investors should collect a large amount of relevant market information, fully assess their risk tolerance, and make rational investments.

5. Conclusion

In conclusion, from the empirical results, unlike in the early stage of the epidemic, increased cases overseas do not make a significant impact on the biomedical industry in China, which indicates that the new overseas cases did not have a long-term impact on China's biomedical industry. Different from many studies in the early days of the pandemic concluded that the effects of Covid-19 on the biomedical industry were very short-term, this paper finds that, in the long term, the confirmed cases in China still had a significant positive impact on the return of Chinese biomedical stock market, although the impact was weaker and the effect decayed to zero faster than at the beginning of the pandemic. This reflects that the irrational investment behaviors of investors still exist, but the quantity and degree of irrational behaviors have decreased, compared to the beginning of Covid-19. Additionally, new cases in China still significantly influence the volatility of biomedical industry return rate.

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