

China and U.S. Stock Market Linkage Analysis

Yue Zhong¹, Yan Zhang²

¹Dongbei University of Finance and Economics, Dalian, 116025, Liaoning, China

²Zhejiang Gongshang University, Hangzhou, 310018, Zhejiang, China

Keywords: Covid-19 epidemic, co-movement, Var

Abstract: We choose four representative indexes in the two stock markets– CSI 300, CSI 500, DJIA and S&P 500 for comparative study and analysis. The period from the outbreak time of COVID-19 in China to May 2021 is used for the study. First, we use the image to combine the COVID-19 data with the stock market return index, and the performance of the Chinese and American stock markets during the COVID-19 epidemic is analyzed intuitively through image comparison, then perform descriptive statistical analysis on the Chinese and American market indices, standardize the calculation of logarithmic rate of return, and then perform stationarity tests and autocorrelation tests, after that, the VAR (4) model is constructed to research the co-movement between Chinese and American stock market through empirical analysis, and the mutual guiding relationship between the two stock markets is judged through Granger causality test. Finally, we study the spillover effect between the two stock markets by impulse response function and analyze the results. Through empirical analysis, the co-movement between Chinese and American stock markets is studied and the following conclusions are drawn based on the empirical analysis results: the American market has a significant impact on the Chinese market, the American stock market has produced great volatility, which has been transmitted to The Chinese stock market in a very short time through risk spillover effect and market contagion effect. However, the risk co-movement exists one-way linkage, that is, one-way transmission from the United States to China.

1. Introduction

In 2020, the COVID-19 epidemic struck the world, and the global capital market was violently shaken. China's Shanghai Composite Index fell by 7.72% on February 3 (the first trading day after the Spring Festival), more than 3,000 stocks in the A-share market fell by the daily limit, and stock indexes around the world have plummeted since March. Many stock markets, including Canada, Brazil, South Korea and the Philippines, triggered circuit breakers. The U.S. stock market had an unprecedented four circuit breakers on March 9, March 12, March 16 and March 18 (local time).

First of all, before analyzing China and U.S. stock market linkage analysis, we collected the epidemic situation on Wind and made an intuitive comparison with the corresponding data about China Stock Markets and America Stock Market, then the plots are as follows:

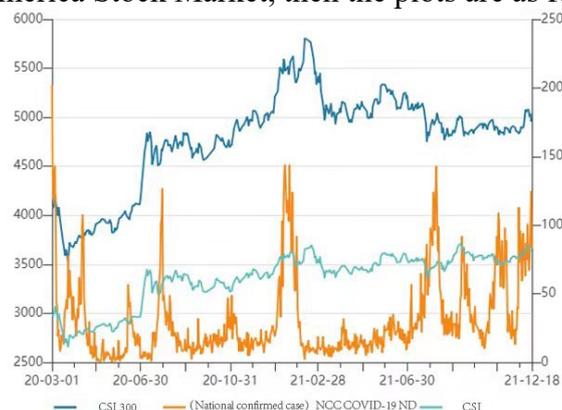


Fig.1 The Number of Daily New Cases and China Stock Market

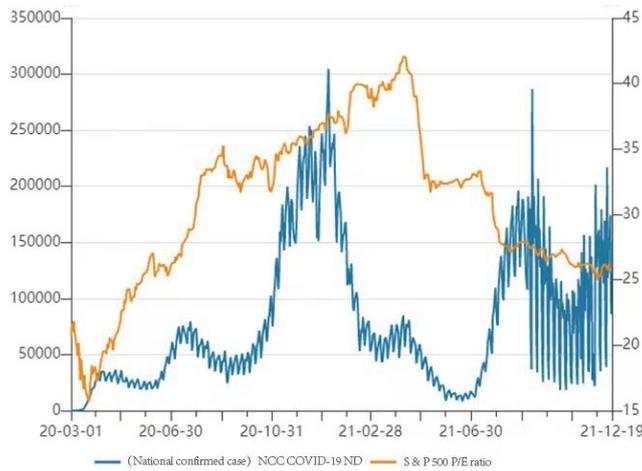


Fig.2 The Number of Daily New Cases and U.s. Stock Market

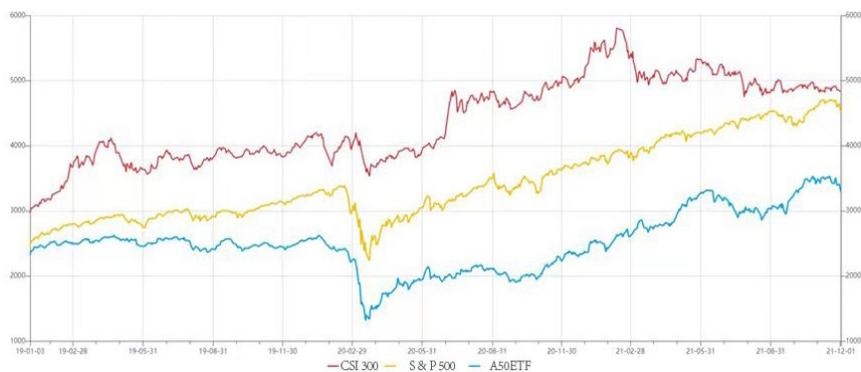


Fig.3 Time Series Chart of China and U.s. Stock Market Indices

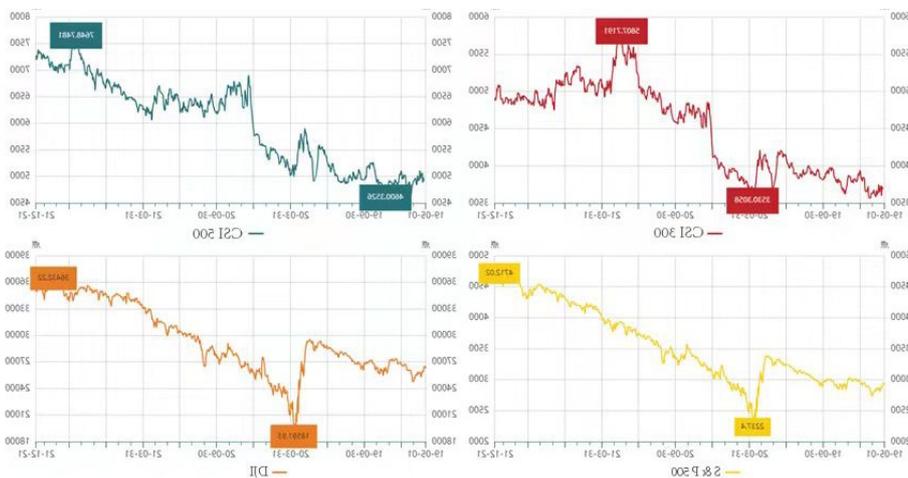


Fig.4 Time Series Chart of China and America Stock Market Indices

It is obvious that both China stock market and America stock market experienced great fluctuations in early March 2020, the CSI300 and the S&P500 in the U.S. has also fell at the same time, as we know from past news, the COVID-19 has been detected in China since the end of 2019, and the Chinese government has taken a series of measures in time, at the moment, the Americans were not paying attention to it, it was not until March 2020 that the U.S. scientists began to catch on, then they began to study the U.S. epidemic data. The COVID-19 has been going on for months in China which has finally woken up America's politicians, thus the COVID-19 broke out, leading to great turmoil in the America stock market. The downward trend in the graph shows how huge the impact of the outbreak has been on the US market, the Chinese market has also been hit and the market indexes also fell. But the COVID-19 has already been taken seriously, the number of the

COVID-19 has peaked and gradually began to fall back, although Chinese people has adjusted to the life, the Chinese stock market was experiencing the same decline as the U.S. stock market, which was not as acute as the U.S. stock market, but it makes us wonder if the reason for the Chinese stock market's volatility is related to the U.S.

2. Literature Review

The stability of capital markets is important for the long-term economic and social development of a country, and there is a large international literature on inter-country stock market linkages. Most studies have focused on developed stock markets (Longin & Solnik, 1995; Jondeau & Rockinger, 2006; Dennis & Voth, 2008)^[6,10,11], and in recent years, the literature has expanded to include studies of linkages between developed and emerging markets (Chiang et al., 2007)^[12]. Studies have shown that the linkages between both developed and emerging markets have significant time-varying characteristics, and the linkages have increased significantly during the financial crisis. However, relatively few domestic scholars have studied the linkages between the US and Chinese markets, which are the first and second stock markets in the world, and there are few studies on the linkage effects between the US and Chinese stock markets before and after the new crown epidemic.

Foreign scholars generally agree that the interdependence structure of the Chinese and U.S. stock markets is increasing during the financial crisis, but both are at a low level of interdependence, showing time-varying characteristics (Hu ,2010; Wang et al., 2011; Hwang ,2012)^[7,9,13]. Domestic scholars Jiaying You and Tingguo Zheng ^[3] (2009) used DCC-GARCH to study the time-varying trajectories of stock market linkages between China and the U.S. and their characteristics from 1991 to 2008, and found that although the stock market linkages between China and the U.S. tend to increase, they are at a low level, and the contagion effect of the financial crisis spread to China. Wu, Jilin and Zhang, Erhua (2010) studied the change in the structure of interdependence between the stock markets of China and the US from January 2005 to March 2009 using the Copula method of mechanism switching dynamics and used this change as a marker to determine whether infection occurred between the two markets ^[1]. It was found that the interdependence between the Chinese and US stock markets declined instead during the subprime crisis and no infection occurred. Using Johansen cointegration tests and measures such as DCC-GARCH, Bing Zhang et al. (2010) investigated that the volatility spillover between the U.S. and Chinese stock markets from December 12, 2001 to January 23, 2009 showed an increasing trend ^[2]; the volatility spillover from the U.S. stock market to the Chinese stock market showed an increasing trend, and the U.S. stock market to the Chinese stock market after the full-blown subprime mortgage crisis The risk contagion of the U.S. stock market to the Chinese stock market has increased sharply after the full outbreak of the subprime crisis. Li Hongquan et al. (2011) studied the interaction between the U.S. and Chinese stock markets from July 26, 2005 to July 7, 2009 based on the information spillover perspective, and found that the correlation between U.S. stocks and A-shares increased significantly after the subprime crisis, indicating that U.S. stocks have a financial contagion effect on China's A-share market ^[4]. Jinlan Zhou (2019) based on BEKK-GARCH model to study the volatility spillover effect of foreign exchange market and stock market in China, comparing the volatility spillover effect of exchange rate and stock index return before and after the exchange rate reform in China as the cut-off point, and analyzing the transmission mechanism of the two markets through single spectrum analysis and and cross spectrum ^[5].

Regarding the linkage mechanism between stock markets of different countries, domestic and foreign scholars have given the following explanations. First, the accelerated process of financial liberalization will cause market linkage. Bekaert & Harvey (2003) point out that financial liberalization policies will deregulate interest rates and exchange rates, lower international financial barriers, and promote domestic and international capital flows, thus strengthening the interconnection between financial markets ^[16], and Beine & Candelon (2011) also reach a similar conclusion ^[14]. Second, the convergence of economic fundamentals enhances market linkages ^[8]. Chen et al. (1986) argue that interest and inflation rates affect the discount rate, which in turn

affects stock prices^[15]. On this basis, Pretorius (2002) showed that the smaller the absolute value of the difference between the interest rate, inflation rate, and economic growth rate of two countries, the stronger the stock market linkage between the two countries, and empirically tested this phenomenon^[17]. Third, market contagion causes stock market correlation. In times of financial crisis, due to the general lack of investor confidence and more pronounced speculative psychology, coupled with the frequent large entry and exit of international lenders, and the herding effect in financial markets will further amplify the behavior of investors, these will intensify the large fluctuations in stock market prices, so that the linkage between stock markets during the crisis is strengthened, defined as “contagion” (Forbes & Rigobon, 2002). Domestic scholars have concluded that the enhanced market linkages between the U.S. and China are the result of a combination of economic fundamentals and market contagion (Zhang, Bing et al., 2010). The macroeconomic factor of structural and abrupt changes in U.S. monetary policy shocks and market contagion are also the main factors contributing to the enhanced market linkages between the U.S. and China (Yang, Xuelai and Zhang, Hongzhi, 2012).

3. The Empirical Analysis of the Linkage about the China and U.s. Stock Market

3.1 Data Processing

In order to analyze the linkage between the China stock market and the US stock market, we choose the following research selects the CSI 300 Index, CSI 500 Index, Dow Jones Industrial Index and S&P 500 Index as the test objects, and the data sources from Wind database from January 2020 to May 2021.

The price fluctuation of the stock index can usually reflect the fluctuation of the stock market. There is a large gap between the closing prices of the two stock markets in China and America, and the data is prone to instability. In order to obtain more accurate analysis results, the relevant data are standardized, and the formula is as follows:

$$\text{Percentage~Rate: } R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \times 100\%$$

$$\text{Logarithmic~Rate: } R_{\{t\}} = \left\{ \log \frac{P_t}{P_{t-1}} \right\} = \log P_t - \log P_{t-1}$$

3.2 Descriptive Analysis of China and America Stock Market Returns

Through the descriptive statistical table, we make a comparison of the fluctuation of return rates of China and America stock markets, and draw the following conclusions:

The average return rate of China and America stock markets was similar and positive, and both had positive returns throughout the duration of COVID-19 pandemic. Although the America stock market has a long history and is more mature than China stock market, in terms of yield, the America stock market and the China stock market are actually similar, and the average yield of the China stock market, CSI 300 and CSI 500 exceeds the Dow Jones Industrial Average. In terms of standard deviation, the US stock market index fluctuates around 0.02, while the standard deviation of the China stock market index fluctuates around 0.15, which shows that the America stock market has more obvious fluctuations and is more affected by the epidemic.

From the perspective of skewness, the skewness of the four stock markets is negative, showing a left-skewness distribution, not a normal distribution. In terms of kurtosis, the kurtosis range of the American market is 13-15, while the kurtosis of the Chinese market is less than 10. The values of skewness and kurtosis both indicate that the distribution is “peak and thick tail”, that is, the stock market is prone to extreme situations, and the daily return rate of the America stock market is higher than that of the China stock market. Chinese investors have more obvious speculative sentiment, and the arbitrage opportunities in China stock market are greater than those in America stock market, which also indicates that China stock market is not mature and perfect, and more attention should be paid to financial risk management in capital market than America stock market.

3.3 Unit Root Test and Autocorrelation Test

Since we have taken the difference and standardized the data before, the return rate R_t of four markets was obtained. Therefore, we conducted Dickey-Fuller test for unit root on the return rate R_t of S&P 500, Dow Jones Industrial Index, CSI 300 and CSI 500 respectively, and obtained the following results:

Table 1 Descriptive Statistical Table of Daily Returns of the Four Index

Variable	S&P500	DIJA	SCI 300	SCI 500
Means	0.0007727	0.0005426	0.0007516	0.000627
Median	0.000645	0.000673	0.000609	0.001052
Maximum	0.0896832	0.1076433	0.074263	0.063926
Minimum	-0.1276521	-0.1384181	-0.0820879	-0.090811
Standard	0.0196464	0.020786	0.0146321	0.0150226
Skewness	-0.92407	-0.9297783	-0.5313542	-1.101346
Kurtosis	13.56081	14.75516	7.8692	7.857745
JB test	23297.24	31704.65	2300.686	1357.619
P value	0.00000	0.00000	0.00000	0.00000

Dickey-Fuller test for unit root:

Table 2 Unit Root Test

Return Volatility Index	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
S&P500 Index	Z(t) -25.316	-3.454	-2.877	-2.570
DIJA	Z(t) -24.335	-3.454	-2.877	-2.570
CSI 300	Z(t) -17.479	-3.454	-2.877	-2.570
CSI 500	Z(t) -17.747	-3.454	-2.877	-2.570

The results of the four indicators Test Statistic are all less than 1% Critical Value, they proves that these four yield indicators are stable. Then the return rate of these four stock markets is $R_{SP500}, R_{DJIA}, R_{CSI300}, R_{CSI500}$.

Next, we take the return rate of CSI 300 as the dependent variable, and the S&P 500, Dow Jones Industrial Index and CSI 500 as the independent variable for regression. The results show that the coefficients of independent variables are not significant, which means that the relationship between the American market and the Chinese market is not significant in the long term and only limited to the long term. Then we perform the autocorrelation test and found that the p-value > 0.05 , indicating that H_0 : no serial correlation cannot be rejected.

Table 3 Autocorrelation Test

Breusch-Godfrey LM test for autocorrelation			
Lags(p)	chi2	df	Prob >chi2
1	0.014	1	0.9068

H_0 : no serial correlation

3.4 Var Optimal Lag Selection

Firstly, determine the lag order of VAR model. When constructing the VAR model, the larger the lag period is, the more complete the dynamic features will be reflected. However, there are more parameters to be estimated in the model, which will reduce the degree of freedom. The lag order was determined by AIC, LL, LR, HQIC and other criteria.

Table 4 The Determination of the Optimal Lag Order of the Model

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	3935.69				3.7e-16	-24.195	-24.1765	-24.1845*
1	3971.42	71.451	16	0.000	3.2e-16	-24.3164	-24.2235*	-24.0836
2	3995.06	47.286	16	0.000	3.1e-16	-24.3635	-24.1962	-23.9443
3	4008.49	26.852	16	0.043	3.1e-16	-24.3476	-24.106	-23.7422
4	4027.57	38.164*	16	0.001	3.1e-16*	-24.3666*	-24.0506	-23.5749
5	4039.74	24.329	16	0.083	3.2e-16	-24.343	-23.9527	-23.365

By observing the above table, we can find that the optimal lag order is 4th order, so the selected model - VAR model with 4th order lag: VAR(4).

3.5 Var Model

The specific formula of the unconstrained VAR model without exogenous variables is:

$$R_t = \phi_0 + \phi_1 R_{t-1} + \dots + \phi_p R_{t-p} + \varepsilon_t, t = 1, 2, \dots, T$$

Therefore, the VAR model established according to the example is as follows:

$$\begin{pmatrix} R_{CSI300,t} \\ R_{SP500,t} \\ R_{DJIA,t} \\ R_{CSI500,t} \end{pmatrix} = \phi_0 + \phi_1 \begin{pmatrix} R_{CSI300,t-1} \\ R_{SP500,t-1} \\ R_{DJIA,t-1} \\ R_{CSI500,t-1} \end{pmatrix} + \phi_2 \begin{pmatrix} R_{CSI300,t-2} \\ R_{SP500,t-2} \\ R_{DJIA,t-2} \\ R_{CSI500,t-2} \end{pmatrix} + \phi_3 \begin{pmatrix} R_{CSI300,t-3} \\ R_{SP500,t-3} \\ R_{DJIA,t-3} \\ R_{CSI500,t-3} \end{pmatrix} + \phi_4 \begin{pmatrix} R_{CSI300,t-4} \\ R_{SP500,t-4} \\ R_{DJIA,t-4} \\ R_{CSI500,t-4} \end{pmatrix} + \varepsilon_t, \quad t = 1, 2, \dots, T$$

The results of the model established by Stata are shown in the following table:

Table 5 Overview of Var Model Results

Equation	Parms	RMSE	R-sq	chi2	p>chi2
R(CSI300)	17	0.014495	0.0753	26.54685	0.0468
R(S&P500Index)	17	0.01842	0.1738	68.56804	0.0000
R(DJIA)	17	0.019655	0.1595	61.85484	0.0000
R(CSI500)	17	0.013947	0.1858	74.38827	0.0000

3.6 Testing for Stationarity

The results of the the eigenvalue stability condition tests for the variables are shown as follows:

Table 6 Test for Stationarity

Eigenvalue	Modulus
0.4865969 + 0.4729039i	0.678539
0.4865969 - 0.4729039i	0.678539
-0.5311825 + 0.4136635i	0.673255
-0.5311825 - 0.4136635i	0.673255
-0.6077055 + 0.2866456i	0.671916
-0.5913114	0.591311
0.4180234 + 0.3578228i	0.550255
0.4180234 - 0.3578228i	0.550255
0.0728956 + 0.5414238i	0.546309
0.0728956 - 0.5414238i	0.546309
0.2706823 + 0.3484143i	0.441205
0.2706823 - 0.3484143i	0.441205
0.3775722	0.377572
-0.1338151 + 0.334169i	0.359966
-0.1338151 - 0.334169i	0.359966

All the eigenvalues lie inside the unit circle.
 VAR satisfies stability condition.

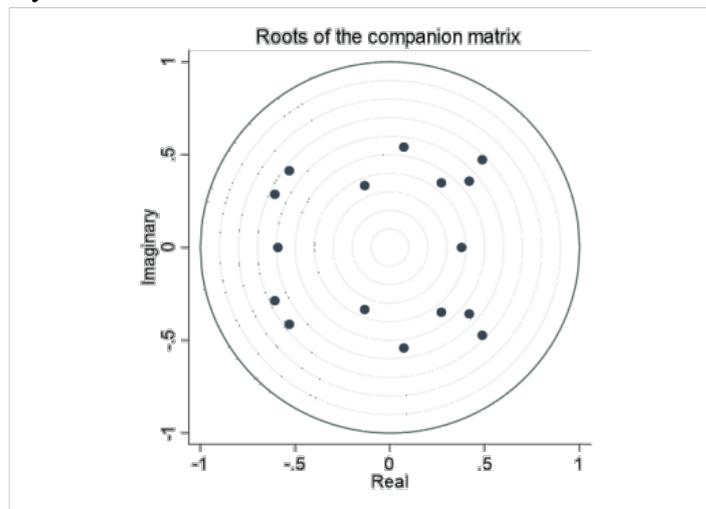


Fig. 5 Ar Unit Root Distribution Chart

It can be seen from the AR unit root distribution chart: the reciprocal absolute values of the characteristic roots are all less than 1 and located in the unit circle, indicating that the established VAR(4) model is stable. It can be interpreted as: when one variable in the model changes (i.e. the impact is formed), other variables will change, but this effect will disappear with time.

3.7 Granger Causality Test

This section, in order to analyze the risk transmission path between Chinese and American stock markets during the epidemic, we conduct the Granger causality test on the logarithmic return sequences of the four markets. Focus on how much the S&P500 and DJIA lag introduced into the US market can explain the CSI300 and CSI500 in the Chinese market and how much the yield index introduced into the Chinese market can affect the yield index in the US market, and then explore the interconnections between The Chinese market and the American market.

The Results of Granger causality test of VAR model are as follows:

Equation	Excluded	chi2	df	Prob > chi2
CSI 300	S&P 500	14.632	4	0.006
CSI 300	DJIA	10.396	4	0.034
CSI 300	CSI 500	2.5371	4	0.638
CSI 300	ALL	22.597	12	0.031
S&P 500	CSI 300	1.0201	4	0.907
S&P 500	DJIA	6.0576	4	0.195
S&P 500	CSI 500	1.3613	4	0.851
S&P 500	ALL	8.6691	12	0.731
DJIA	CSI 300	1.4365	4	0.838
DJIA	S&P 500	3.6087	4	0.462
DJIA	CSI 500	1.1625	4	0.884
DJIA	ALL	6.8635	12	0.866
CSI 500	CSI 300	35.636	4	0.000
CSI 500	S&P 500	7.9667	4	0.093
CSI 500	DJIA	8.7558	4	0.068
CSI 500	ALL	65.355	12	0.000

Fig.6 Granger Causality Wald Tests

From Fig. 6 Granger causality Wald tests, we know that during the COVID-19 period, the Chinese and American stock market have one-way Granger causality, indicating that the fluctuation of the American stock market will have an impact on the changes of the Chinese stock market, but the fluctuation of the Chinese stock market does not significantly transfer to the American stock market. That is, the American stock market leads the Chinese stock market, but the Chinese stock market does not lead the American stock market obviously. Chinese stock market has had little

effect on what happened in the US.

3.8 Impulse Response Function

The first two lines of impulse response diagram show that the impact effect of the fluctuation of The Chinese market on the American market fluctuates around 0, with both positive impact and negative impact, but the fluctuation range is small and can be almost ignored, after reaching the fourth phase, it basically tends to be stable, which shows that the Chinese market has little influence on the American market; in the last two lines of the impulse response diagram, we can see that the volatility of the US market has a very obvious impact on the Chinese market. DJIA has a more obvious negative impact on CSI300, while it has a positive impact on CSI500, but S&P500 has an opposite impact on CSI300 and CSI500. After reaching the sixth phase, the influence of the fluctuation of the American market on the whole VAR model also tends to be stable. It can be seen that the impact of such fluctuation on both the Chinese market and the American market has a short duration of impact, and will eventually reach the equilibrium state and become stable.

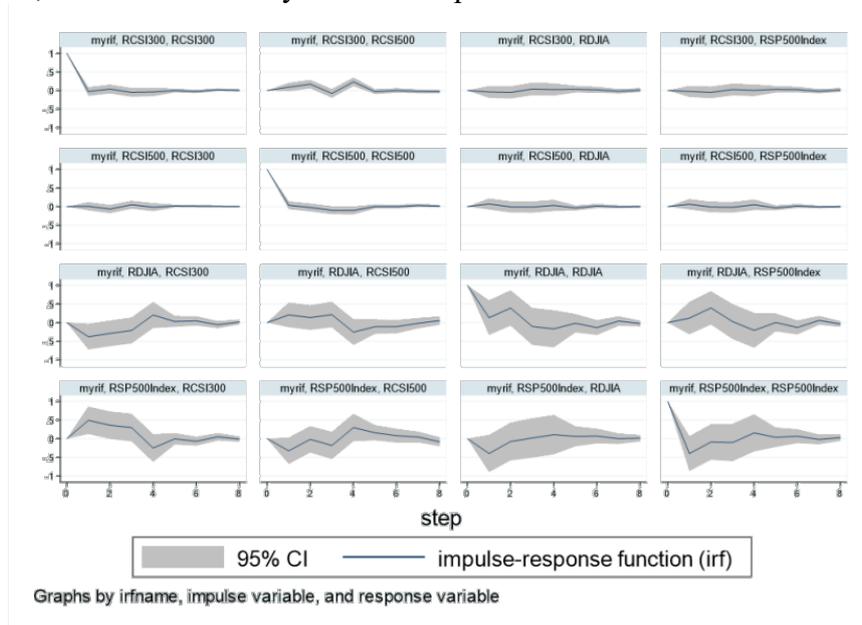


Fig.7 Impulse Response Function Chapters

4. Conclusion

COVID-19 is a large-scale public health crisis worldwide, and its outbreak provides an opportunity to identify exogenous shocks in the linkage of Chinese and US stock markets. In the chapter of studying the linkage between Chinese and American stock markets, we use the CSI 300 and CSI 500 return rate volatility index to represent the risk of Chinese stock market, and the S&P 500 and DJIA return rate volatility index to represent the stock market of the United States, by using VAR model and Granger causality test, we find that in the middle period of the outbreak of COVID-19, especially the large-scale outbreak in the United States, the American stock market will have an obvious one-way impact on our Chinese stock market, which further reflect the linkage effect among global markets. This also shows that with the deepening of the capital market opening strategy, Chinese financial market is becoming more and more integrated into the global financial system, so it will be affected by international economic or financial fluctuations. This is the effect of economic globalization – risk globalization, and the American market is only a part of the globalization. We can also imagine that the Chinese market will be affected by the Asian market, European market and many other foreign markets in a positive or negative way, and the sustainability of this impact is also uncertain. The Chinese market also needs to consider how to deal with these risks. In the long run, this risk linkage effect will gradually weaken, reflecting the ability of Chinese stock market to self-regulate and self-repair.

5. Recommendation

Investors need to improve their risk awareness, we need to know that public health paroxysmal incident have a very large impact on the financial market at the initial stage, and the trend of such emergencies is usually uncertain. In the long run, it will be a slow and time-consuming process for the market to recover to its original level. So investor must raise the risk consciousness, pay attention to the influence of sudden event. Investors should get rid of geographical restrictions, look to the world asset field, carry out a wider range of asset planning, constantly update the investment structure, increase the number of securities products in investment products, and achieve diversification and diversification of investment requirements. At the same time, investors must establish the awareness of the stock market, where is vulnerable to infection. It needs to constantly do a good job in the proportion of assets between the various markets adjustment and allocation. The global stock market has coactivity. When investors find unexpected risks in a country's stock market, they should timely predict the behavior of different markets and quickly adjust the capital proportion of each stock market to avoid self-risks.

References

- [1] Wu Jilin, Zhang Erhua. Subprime mortgage crisis, market risk and interdependence of stock markets[J]. *World Economy*,2010,33(03):95-108.
- [2] Zhang, Bing, Fan, Zhi-Zhen, Li, Xin-Dan. A study of the linkage between the U.S. and Chinese stock markets[J]. *Economic Research*, 2010, 45(11):141-151.
- [3] You Jiaying, Zheng Tingguo. From Segmentation to Integration of China and World Financial Markets - A Test Based on DCC-MGARCH Model [J]. *Quantitative Economic and Technical Economics Research*,2009,26(12):96-108.
- [4] Li Hongquan, Hong Yongmiao and Wang Shouyang. Study on the interaction between China's A-share market and U.S. and Hong Kong stocks: Based on the information spillover perspective[J]. *Economic Research*, 2011 (8): 15-25.
- [5] Zhou Jinlan. An empirical study on the linkage between RMB exchange rate and stock market [D]. Jilin University,2019.
- [6] Longin, F. and Solnik B. Is the Correlation in International Equity Returns Constant:1960-1990[J]. *Journal of International Money and Finance*, 1995 (1): 3-26.
- [7] Hu, J. Dependence Structures in Chinese and US Financial Markets: A Time-varying Conditional Copula Approach [J]. *Applied Financial Economics*, 2010 (7):561-583.
- [8] Hwang, J.K. Dynamic Correlation Analysis of Asian Stock Markets[J]. *International Advances in Economic Research*, 2012 (2):227-237.
- [9] Wang, K., Chen Y.H. and Huang S.W. The Dynamic Dependence between the Chinese Market and Other International Stock Markets:A Time-varying Copula Approach[J]. *International Review of Economics and Finance*, 2011 (4):654-664.
- [10] Jondeau, E. and Rockinger M. The Copula-GARCH Model of Conditional Dependencies:An International Stock Market Application[J]. *Journal of International Money and Finance*, 2006 (5):827-853.
- [11] Dennis P. Q. and Voth H.J. A Century of Global Equity Market Correlation[J]. *American Economic Review*, 2008 (2):535-540.
- [12] Chiang, T.C., Jeon B.N. and Li H. Dynamic Correlation Analysis of Financial Contagion: Evidence from Asian Markets [J]. *Journal of International Money and Finance*, 2007 (7): 1206-1228.
- [13] Yang Xuelai, and Zhang Hongzhi. The financial crisis, macroeconomic factors and stock

market linkages between China and the United States[J]. *World Economic Research*, 2012 (8): 17-21.

[14] Beine M. and Candelon B. Liberalisation and Stock Market Co-movement between Emerging Economies [J]. *Quantitative Finance*, 2011 (2):299-312.

[15] Chen, N.F., Roll R. and Ross S.A. Economic Forces and the Stock Market[J]. *Journal of Business*, 1986 (3):383-403.

[16] Bekaert, G. and Harvey C.R. Emerging Markets Finance[J]. *Journal of Empirical Finance*, 2003 (1):3-55.

[17] Pretorius, E. Economic Determinants of Emerging Stock Market Interdependence [J]. *Emerging Markets Review*, 2002 (1): 84-105.