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Co-movement Analysis of Foreign Exchange Reserve Volatility in BRICS Countries

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Abstract: Foreign exchange reserves are an important component of a country's official reserve assets and an important indicator of a country's international liquidity. As representatives of emerging market countries and developing countries, the volatility of the foreign exchange reserves of the BRICS countries is crucial to the world. Studying whether there is volatility of foreign exchange reserves among the five countries is conducive to adjusting the direction of foreign exchange reserve management within the country, better exploring ways to promote the development of the foreign exchange reserve market, and is also of great significance to the future economic cooperation among the five countries. This study uses the correlation coefficient method, Granger causality test and cluster analysis to prove that there is indeed co-movement in the volatility of foreign exchange reserves among the BRICS countries.

Keywords: Foreign exchange reserves, Co-movement.

1. Introduction

Since 2008, the global economy has been greatly impacted by the financial crisis, the economic recovery of developed countries have been slow, the global trade and investment situation has become more complex, and trade protectionism has begun to appear. Some countries that had previously argued that they did not need to hold foreign exchange have also begun to actively to accumulate foreign exchange reserves. As an important part of national reserves, abundant foreign exchange reserves greatly strengthen a country's international payment strength, and its foreign trade liquidity can further attract foreign investment, allowing large-scale foreign capital inflows into the country, and promoting the country's economic strength to improve more quickly.

The BRICS countries account for 26.46 per cent of the world's territory and 41.93 per cent of the world's population, and IMF data show that since the establishment of the BRICS countries, developing countries with the BRICS as the core have contributed more than 70 per cent of the world's economic growth, and the BRICS countries have contributed more than 50 per cent of the world's economic growth, much higher than the G7. 50 per cent, much higher than that of the G7. In 2021, the BRICS achieved an economic growth rate of 7.6 per cent, much higher than the world average of 5.5 per cent, and the trade volume among BRICS countries increased by 300 per cent compared with that of 2006, making it the engine that leads the world's economic recovery and, in fact, economic growth. In terms of foreign exchange reserves, the volume of global foreign exchange reserves has surged, jumping from $1.76 trillion in 1998 to $11.79 trillion in 2017, with the share of emerging market countries in total global foreign exchange reserves rising from 36 per cent to 59 per cent. In 2014 the BRICS countries accounted for as much as 61 per cent of the reserve asset share of emerging market economies. It can be seen that today the BRICS countries are playing an increasingly important role in the growth of global foreign exchange reserves.

In recent years, the influence and attractiveness of the BRICS mechanism has continued to grow. The five countries have adhered to fairness and justice, actively promoted the reform of the global governance system, greatly enhanced the international discourse of emerging market countries and developing countries, gradually consolidated the foundation of cooperation, and continuously expanded the areas of cooperation, becoming a constructive force in promoting world economic growth, improving global governance and promoting the democratisation of international relations. As global economic integration continues to strengthen, changes in the world economic environment tend to have a stronger impact on the BRICS countries. For the BRICS countries, having a certain scale of foreign exchange reserves is conducive to maintaining the healthy and stable development of the national economy, and analysing the co-movement of foreign exchange reserve fluctuations among countries is conducive to adjusting the direction of foreign exchange reserve management within the countries, enhancing the stability and sustainability of their own economies, and, at the same time, it has an important significance for the future economic cooperation among the five countries.

2. Literature Review

Foreign exchange reserves as a country's economic regulation, to achieve an important means of internal and external balance, play an increasingly important role, domestic and foreign scholars have conducted relevant research on it. Existing literature mainly focuses on the influence factors of foreign exchange reserves and the moderation of its size analysis.

Regarding the analysis of the factors influencing the size of foreign exchange reserves, most existing studies focus on individual countries. Luo Sumei and Zhou Guangyou constructed a framework for analysing the optimal size based on multilevel dynamic substitution, and the study showed that imports, FDI, external debt, cross-border capital flows, interest rates, and exchange rates have a significant impact on the size of foreign exchange reserves.[1] Liu Yixin and Ma Shaokang built an econometric model from the demand perspective and found that the change in the median price of

the exchange rate of the RMB against the US dollar has the greatest impact on the movement of foreign exchange reserves.[2] Wang Zenglei and Zhang Hengyi constructed a VAR model to conduct an empirical study, and found that the gross domestic product has a long-term impact on foreign exchange reserves, while the foreign investment return rate, the value of net exports, the RMB exchange rate and the RMB interest rate have a short-term impact on foreign exchange reserves.[3] Duan Jiexin and Wang Zhiwen summarised the influencing factors of China's foreign exchange reserve growth into economic scale factors and exchange rate influencing factors through factor analysis, and adopted multiple regression analysis, and the study showed that the economic scale factors are the dominant factors of China's foreign exchange reserve growth.[4] Ding Zhenhui used the method of cointegration test to prove that the net export of foreign trade, FDI inflow and world oil prices are the most important factors affecting Russia's foreign exchange reserves.[5] Yuan Qi establishes a multiple linear regression model, which shows that the main factors affecting China's foreign exchange reserves are gross domestic product, foreign debt balance and current account balance.[6]

For the analysis of the moderateness of China's foreign exchange reserve scale, the views are mainly divided into three views: reserve scale excess, reserve scale moderateness and reserve scale insufficiency. For the reserve scale excess, Ma Dan and Xiong Feng, Xiao Wen et al., Lian Lina, Li Jingyi, Luo Sumei and Zhou Guangyou are all based on the Agarwal model, corrected according to China's national conditions, and the results show that China's current foreign exchange reserves are in a state of excess.[1,7-10] Liu Xinqi comprehensively used the ratio analysis method and demand function analysis method, measured China's foreign exchange reserves since 2001 has always exceeded the moderate range.[11] Lv Xinyang and Zhou Guangyou to the demand for foreign exchange reserves as the perspective of the decision, the establishment of the optimal size of foreign exchange reserves based on multi-level demand measurement model, the study shows that there is an excess of foreign exchange reserves in China.[12] Li Shaokun et al. constructed the representative of the narrow frame and loss aversion characteristics of the Consumer utility function, the study concluded that China's foreign exchange reserve level has been above the moderate size.[13] For the moderate size of reserves, Jiang Xuchao et al. analysed from the perspective of combining quantitative analysis and qualitative analysis that China's foreign exchange reserves are within a reasonable range of 20% on the basis of the basic reserve size, which is also in line with China's national conditions.[14] Wang Guolin concluded that China's foreign exchange reserves are sufficient through descriptive method of qualitative analysis, proportionality analysis, establishment of autoregressive model and multiple regression analysis.[15] Liu Leah and Ren Ruo En constructed a structured equation of the moderate size of foreign exchange reserves, combined with China's actual situation, the study concluded that the trajectory of the movement of the actual size of China's foreign exchange reserves and the trajectory of the movement of the moderate size of the basically the same and coincide with.[16] Li Wei and Zhang Zhichao constructed a systematic analytical framework and simulated the size of China's consensual foreign exchange reserves, and the results show that, under the premise of ensuring the domestic financial stability, China's foreign exchange reserves are sufficient. The results show that, under the premise of ensuring domestic financial stability, China's total foreign exchange reserves are not excessive and are within a reasonable range.[17] For the reserve scale is insufficient, Liu Bin use the international and domestic foreign exchange reserves of historical data, through the proportion analysis method, calculate the broad currency to foreign exchange reserves ratio, prove that China's foreign exchange reserves scale is lower than the normal level.[18] Zhang Jugang and Zhao Zhiqiang use statistical data to compare the foreign exchange reserves of our country and other countries, and concluded that the scale of China's foreign exchange reserves moderately expand is necessary.[19] Huang Ping and Chen Jianyun use the dynamic adjustment model to measure the moderateness of the scale of China's foreign exchange reserves, the study shows that China's foreign exchange reserves relative to the demand is less than adequate.[20]

Existing studies mainly explore the law of foreign exchange reserve size for one country, and do not take into account the co-movement of foreign exchange reserve fluctuations between countries. And the BRICS countries, as the outstanding performance of emerging market countries, the fluctuation of their foreign exchange reserves has a certain co-movement, and it is necessary to study the foreign exchange reserve situation of the BRICS countries as a whole. Tang Lingxiao et al. used factor analysis, cluster analysis and cointegration analysis to confirm that foreign exchange reserve fluctuations among BRICS countries have co-movement, and there is a long-run stable relationship between the country's characteristic factor and the international shock factor.[21]

In summary, most of the existing research mainly focuses on analysing the foreign exchange reserve situation of a single country, ignoring the influence and importance of the BRICS countries on global foreign exchange reserves. At the same time, in the existing research on the foreign exchange reserves of foreign exchange countries, the mutual co-movement is often not taken into account. Therefore, the innovation of this paper is based on the study of the co-movement of foreign exchange reserves between countries, which has a stronger timeliness, and can also better provide national policymakers with more real, reliable and effective information to make the right decision and promote the economic development and cooperation of BRICS countries.

3. Method

3.1. Data Description

In this paper, monthly foreign exchange reserve data for the BRICS countries (China, Brazil, South Africa, Russia, and India) from January 2001 to December 2022 are selected, with 264 data for each country, which are obtained from each country's central bank database. Table 1 presents descriptive statistics of the data. In terms of mean value, China's foreign exchange reserves are much larger than the other four countries, up to about $2284.6 billion; in second place is Russia, the volume of foreign exchange reserves is about $324 billion; India and Brazil's foreign exchange reserves mean value is $297.5 billion and $237.3 billion; South Africa's foreign exchange reserves are the lowest, the mean value is $31.3 billion. Comparing the degree of volatility of the five countries, China's standard deviation is the largest, which can be seen in China's foreign exchange reserves fluctuations are the strongest. Compared to the other four

countries, South Africa's foreign exchange reserve size mean, standard deviation, minimum and maximum values are very low, there is a lot of room for development. Observing Figure 1, China's foreign exchange reserves are significantly more than the other four countries; South Africa's foreign exchange reserves are the smallest in size, but are still rising and developing continuously.

Table 1. Descriptive statistics of foreign exchange reserves data for BRICS countries

	China FERb	Brazil FERc	ZA FERd	Russia FERe	India FERf
Mean	2284596.00	237321.80	31301.42	324081.80	297468.20
Standard Deviation	1245634.00	132074.30	13887.79	151232.60	113900.20
Min	168623.00	31925.13	5584.00	24586.00	123570.00
Max	3993213.00	372627.00	47433.00	582294.00	578411.50
Median	3053333.00	308431.00	39022.50	378684.00	265892.00
Kurtosis	1.71	1.54	2.19	2.35	3.03
Skewness	-0.54	-0.51	-0.84	-0.84	0.80

volume of foreign exchange reserves in millions of United States dollars

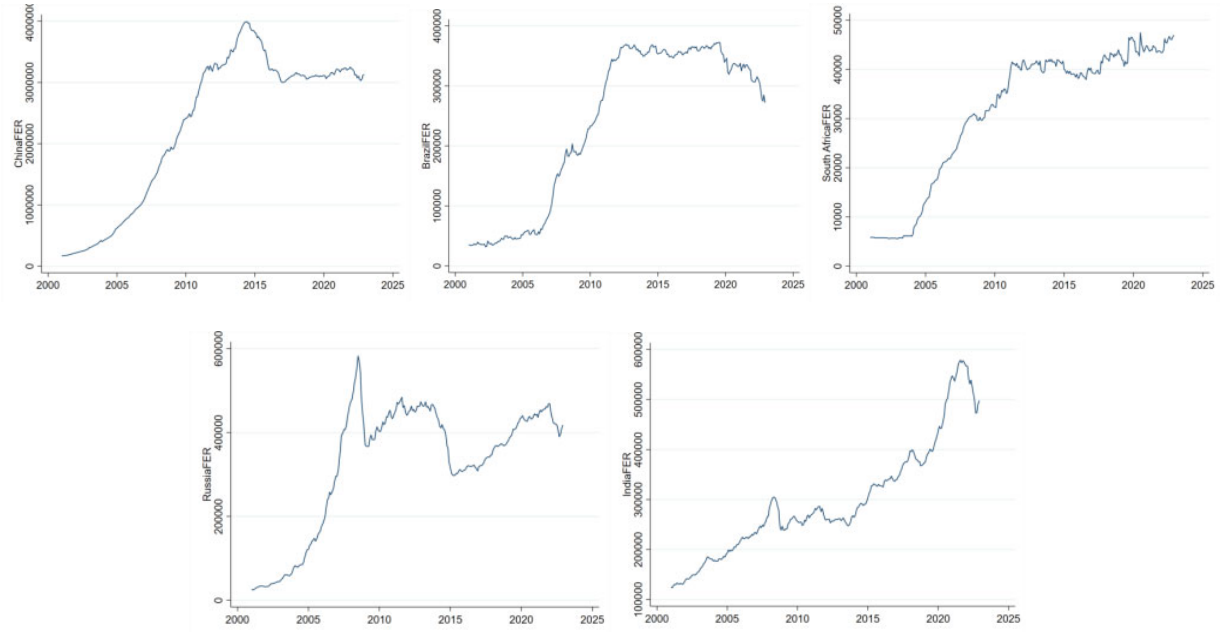

Figure 1. Time series plots of foreign exchange reserves of BRICS countries (2001 - 2022)

3.2. Data Processing

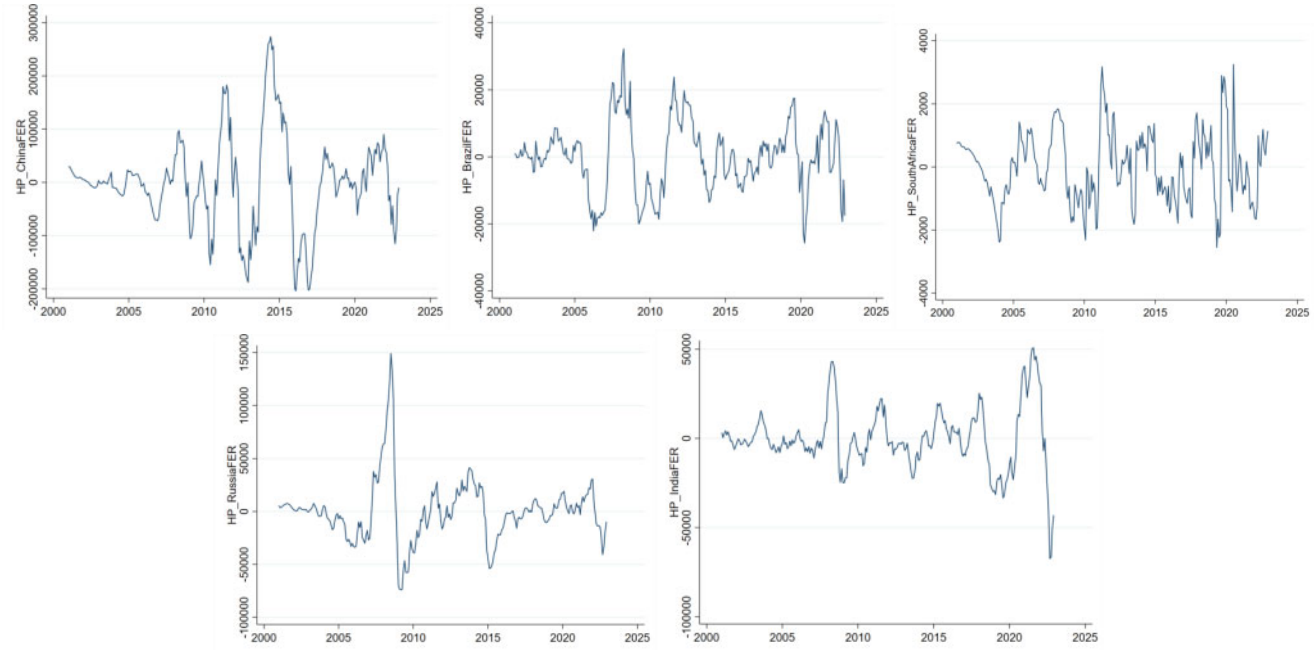

Figure 2. Time-series plots of foreign exchange reserve volatility for BRICS countries

As this paper studies the co-movement of the changes in the size of foreign exchange reserves among the BRICS countries, the data of each country is processed by HP filtering to extract the volatility term of the foreign exchange reserve volume as a measure of the volatility of foreign exchange reserves, and the image is plotted as shown in Figure 2. It can be clearly seen that the foreign exchange reserve volume of almost all five countries develops relatively smoothly before 2006, and fluctuates strongly after 2006; it shows a significant growth trend in 2008, 2012, 2014, and 2021, and a significant decline in 2009 and 2022. Although the degree of change in the volume of foreign exchange reserves varies among the five countries, their trends at some of the same time points are basically the same, and these changes can roughly prove the existence of co-movement in the volume of foreign exchange reserves of the BRICS countries. The ADF unit root test for the volatility terms are all smooth time series.

3.3. Co-movement Test

3.3.1. Static correlation coefficient method test

The matrix of correlation coefficients of foreign exchange reserve fluctuations among BRICS countries can reflect the co-movement of national changes. In order to avoid the loss of important information, this study utilises two types of correlation coefficients, namely the Pearson correlation coefficient and the Spearman correlation coefficient, and Table 2 shows the specific results. It is easy to see that there is a correlation with a significance level of 1 per cent between all the countries except India and South Africa where there is no significant correlation in terms of change in foreign exchange reserves. According to the Pearson correlation coefficient, the correlation between the foreign exchange reserve fluctuations of Brazil and South Africa is low at 0.1966, and the correlation between the foreign exchange reserve fluctuations of Brazil and Russia is the highest at 0.5589; according to the Spearman correlation coefficient, the correlation between the foreign exchange reserve fluctuations of Brazil and South Africa is low at 0.1897, and the correlation between the foreign exchange reserve fluctuations of Brazil and Russia is the highest at 0.514.These data further prove that there is a significant co-movement in the foreign exchange reserve fluctuations of the BRICS countries.

Table 2. Matrix of correlation coefficients of foreign exchange reserve volatility in BRICS countries

	correlation coefficient	China	Brazil	South Africa	Russia	India
China	Pearson	1	0.2450**	0.3636**	0.2682**	0.3701**
	Spearman	1	0.3322**	0.3793**	0.3711**	0.4971**
Brazil	Pearson	0.2450**	1	0.1966**	0.5589**	0.3499**
	Spearman	0.3322**	1	0.1897**	0.5140**	0.2877**
South Africa	Pearson	0.3636**	0.1966**	1	0.3497**	0.0640
	Spearman	0.3793**	0.1897**	1	0.3132**	0.0870
Russia	Pearson	0.2682**	0.5589**	0.3497**	1	0.3796**
	Spearman	0.3711**	0.5140**	0.3132**	1	0.2838**
Russia	Pearson	0.3701**	0.3499**	0.0640	0.3796**	1
	Spearman	0.4971**	0.2877**	0.0870	0.2838**	1

Note:** indicates a significance level of 1 per cent

3.3.2. Rolling correlation coefficient method test

Compared with the static correlation coefficient test, the rolling correlation coefficient method better reflects the dynamic correlation of foreign exchange reserve changes between countries over a fixed period of time. As China plays an important and constructive role in the BRICS co-operation mechanism, this study calculates the rolling correlation coefficient between the five countries from 2001 to 2022 based on the fluctuation cycle of the Chinese economy, with a five-year cycle. By observing Table 3, it can be seen that the foreign exchange reserve fluctuations of the BRICS countries have quite significant correlations, and most of the correlation coefficients are above 70 per cent in absolute value, thus, the foreign exchange reserve fluctuations of the five BRICS countries have obvious co-movement.

Table 3. Matrix of rolling correlation coefficients of changes in foreign exchange reserves of BRICS countries

Time	China and Brazil	China and ZA	China and Russia	China and India	Brazil and ZA	Brazil and Russia	Brazil and India	ZA and Russia	ZA and India	Russia and India
2001-2005	0.4180	0.4416	-0.0346	-0.5360	-0.6210	-0.9142	-0.8122	0.8671	0.2689	0.6712
2002-2006	-0.4556	0.8977	0.9207	0.4125	-0.7911	-0.6077	-0.6609	0.9263	0.5485	0.6181
2003-2007	0.8269	0.8945	0.9822	0.9160	0.4922	0.7416	0.7859	0.9373	0.7662	0.8821
2004-2008	0.9501	0.8575	0.8287	-0.2283	0.8237	0.8572	-0.0808	0.9773	0.2458	0.3119
2005-2009	0.9571	0.7867	0.5965	-0.7078	0.9252	0.7923	-0.4985	0.9643	-0.1914	0.0484
2006-2010	0.9643	0.7073	0.1638	-0.8282	0.8689	0.4186	-0.6747	0.8130	-0.2465	0.3445
2007-2011	0.9426	0.6389	-0.7867	-0.9365	0.8550	-0.6064	-0.8832	-0.1338	-0.5515	0.8917
2008-2012	0.9526	0.8932	-0.2147	-0.8335	0.9782	-0.0470	-0.9439	-0.0403	-0.9098	-0.1800
2009-2013	0.6513	0.5389	-0.3603	-0.9059	0.9758	0.3140	-0.7291	0.3144	-0.5976	0.1794
2010-2014	-0.0370	-0.2892	-0.4719	-0.8548	0.8368	0.4161	-0.3238	0.8164	0.0575	0.3244
2011-2015	0.4176	0.6730	0.4932	-0.7183	0.9484	0.9162	-0.0282	0.9259	-0.2409	-0.2360
2012-2016	0.7306	0.8542	0.6861	-0.7371	0.9593	0.9277	-0.5862	0.9327	-0.7786	-0.7182
2013-2017	0.9836	0.9426	0.7697	-0.7838	0.9324	0.7943	-0.8791	0.8942	-0.7375	-0.6454
2014-2018	0.9678	0.9242	0.5486	-0.3624	0.8456	0.3301	-0.3598	0.7402	-0.3388	-0.2512
2015-2019	0.8656	0.5499	-0.6533	-0.3316	0.2396	-0.9398	-0.6064	0.0077	0.5889	0.6916
2016-2020	0.9441	0.6175	-0.9417	-0.6467	0.7278	-0.9555	-0.8441	-0.4971	-0.8678	0.6949
2017-2021	0.9403	0.8046	-0.9213	-0.7313	0.9133	-0.9064	-0.8935	-0.6592	-0.9006	0.7334
2018-2022	0.9860	0.7376	0.3565	-0.2892	0.8240	0.2176	-0.4412	-0.0433	-0.7456	0.6234

3.3.3. Granger causality test

It has been shown earlier that the volatility term of the foreign exchange reserves volume extracted after the HP filtering process is a smooth time series, and therefore, the series satisfies the prerequisites for conducting the Granger causality test. The basic principle of Granger test is that when one variable changes, the other variable also changes. It can be used to test whether there is a causal relationship between events and thus infer whether one event leads to another. So it can be used to examine whether there is significant co-movement in the volatility of foreign exchange reserves of BRICS countries. Granger test is conducted on the volatility term and the results are shown in Table 4. China's foreign exchange reserve volatility is the cause of the foreign exchange reserve volatility of South Africa, Russia and India, but has no significant effect on the foreign exchange reserve volatility of Brazil; Brazil's foreign exchange reserve volatility is the cause of the foreign exchange reserve volatility of China, South Africa, Russia and India; South Africa's foreign exchange reserve volatility is the cause of the foreign exchange reserve volatility of Russia, but has no significant effect on the foreign exchange reserve volatility of China, Brazil and India; Russia's foreign exchange reserve fluctuations are the cause of foreign exchange reserve fluctuations in Brazil, South Africa, and India, but have no significant impact on China's foreign exchange reserve fluctuations; India's foreign exchange reserve fluctuations are the cause of foreign exchange reserve fluctuations in China, Brazil, and South Africa, but have no significant impact on Russia's foreign exchange reserve fluctuations.

Table 4. Granger causality test for foreign exchange reserve volatility in BRICS countries

Whether fluctuations in country A's foreign exchange reserves are the cause of fluctuations in country B's foreign exchange reserves		P Value	Conclusion
A	B		
China	Brazil	0.120	NO
	South Africa	0.003	YES
	Russia	0.029	YES
	India	0.806	NO
Brazil	China	0.014	YES
	South Africa	0.002	YES
	Russia	0.002	YES
	India	0.004	YES
South Africa	China	0.631	NO
	Brazil	0.088	NO
	Russia	0.010	YES
	India	0.742	NO
Russia	China	0.207	NO
	Brazil	0.012	YES
	South Africa	0.017	YES
	India	0.009	YES
India	China	0.009	YES
	Brazil	0.005	YES
	South Africa	0.036	YES
	Russia	0.078	NO

3.3.4. Cluster analysis

Cluster analysis can be used to study the dependence between data, therefore, clustering the foreign exchange reserve fluctuations of BRICS countries is a necessary method to study their co-movement. In order to make the data comparable with each other and eliminate the influence of the scale between indicators, the volatility terms are first standardised before the cluster analysis. Table 5 and Figure 3 show the results of the cluster analysis. This study uses a systematic clustering method, in which the affinity of measuring the change in the foreign exchange reserves of each country is measured using the squared Euclidean distance. In the first stage, China and Brazil are clustered first, with a distance coefficient of 3.609; in the second stage, South Africa and Russia are clustered, with a distance coefficient of 6.913; in the third stage, China, Brazil, South Africa, and Russia are clustered into one category, with a distance coefficient of 14.202; and in the fourth stage, the five countries are clustered into one category, with a distance coefficient of 62.996.The spectral diagram makes it very intuitive to It can be seen that China, Brazil, South Africa and Russia are aggregated into one category, and their foreign exchange reserve fluctuations tend to be more consistent, and their co-movement is stronger.

Table 5. Clustering results of foreign exchange reserve volatility in BRICS countries

	Combinatorial Clustering		Coefficients	Stages where Clustering First Occurs		Next Stage
Stage	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	1	2	3.609	0	0	3
2	3	4	6.913	0	0	3
3	1	3	14.202	1	2	4
4	1	5	62.996	3	0	0

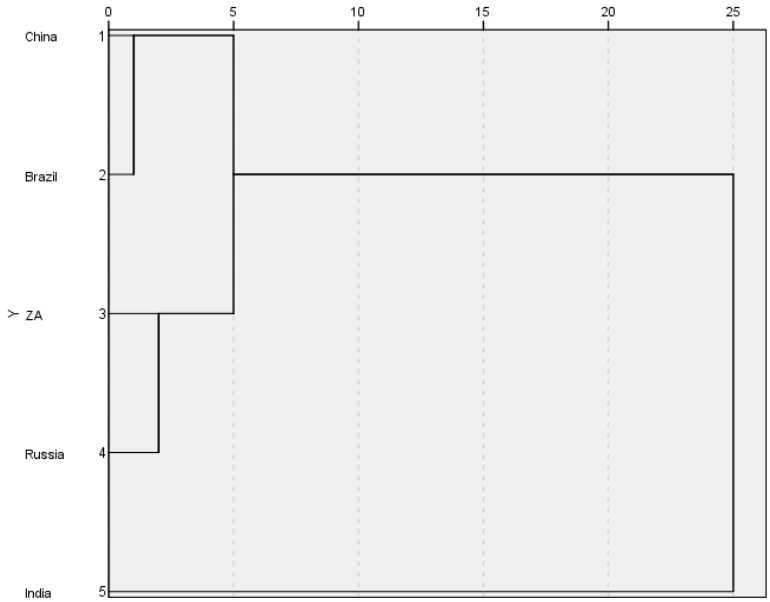

Figure 3. A clustered spectrogram of foreign exchange reserve volatility in the BRICS countries

4. Conclusion

In the era of international pattern change and economic order adjustment, emerging economic powers play a very important role in international affairs, and the BRICS countries, as representatives of emerging economic powers, study the co-movement of their foreign exchange reserve fluctuation is of great significance to the subsequent economic cooperation of the BRICS countries. Using the foreign exchange reserve data of BRICS countries from January 2001 to December 2022 for empirical analysis, it is proved that the foreign exchange reserve fluctuation of BRICS countries does exist co-movement through correlation coefficient method, Granger causality test and cluster analysis. The existence of co-movement provides a basis for the BRICS countries to fully consider the economic fluctuations of the other four countries when they formulate their own economic policies in the future, and also highlights the strategic significance of the BRICS countries to strengthen the adjustment of foreign exchange reserve cooperation.

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