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Exploring the Causal Relationship Between Interest Rate Differential and Exchange Rates of China and The U.S.: Frequency Domain Approach

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Abstract. In recent years, China has been actively opening up and internationalizing its financial markets, so it is meaningful to study the relationship between the interest rate differential and exchange rate between China and the United States. This study uses the data from January 1996 to September 2015 to investigate the linkage between the interest rate differential and the exchange rate of the RMB between China and the United States using frequency causality test. Theoretically, interest rate differential and exchange rates should have Granger causality, but the empirical results show that there is no long-run relationship of cointegration between the China-U.S. interest rate differential and the RMB exchange rates in the cointegration test. In the frequency causality test, it is found that the RMB exchange rate has a long-run and medium-run unidirectional causality on the China-US interest rate differential, while the China-U.S. interest rate differential does not have long-run, medium-run and short-run frequency causality on the RMB exchange rate.

Keywords: Interest rate differential; exchange rate; cointegration test; frequency causality test.

1. Introduction

The exchange rate is the ratio of currency exchange between countries, and its changes have a significant impact on imports and exports as well as on the financial market. The interest rate is regarded as the price in the market for borrowing and lending funds, and with the increase in the openness of the financial market and the international foreign exchange market, the exchange rate and the interest rate play an important role in the internal and external equilibrium of the country's economy, and they are important factors affecting the country's financial and economic system. Interest rate policy is one of the important tools used by the government to stabilize prices and regulate the stock and currency markets. With the changes of economic situation, China's foreign exchange management system has evolved continuously, with a fixed exchange rate system and a dual-track exchange rate system before 1994; in 1994, a single and managed floating exchange rate policy was adopted, which led to a major reform of the exchange rate system; from 1994 to 1996, the RMB exchange rate was under tremendous pressure due to massive capital inflows and severe inflation. After the outbreak of the Asian financial crisis, the RMB was under even greater pressure, and after 1997 the exchange rate was kept within 120 basis points, all within a small range. Since July 21, 2005, the floating exchange rate system of staring at the U.S. dollar, which had been implemented for many years, was abandoned and a basket of currencies exchange rate system was adopted instead. It has been nearly 20 years since the exchange rate reform in 2005, which was also a period of rapid economic development in China, and the RMB exchange rate has had a very important impact on China's overall economy. At the same time, China's international financial position has also improved significantly. China has become the second largest economy in the world and has actively signed currency exchange agreements with other countries and opened up offshore RMB clearing operations.

In October 2016, the International Monetary Fund (IMF) has included the RMB in the Special Drawing Rights (SDR) basket. The performance of China's economic growth in recent years and its determination to open up its capital policy are the main reasons for the inclusion of the RMB in the SDR, which is also a necessary process for the RMB exchange rate to move toward liberalization; on

the other hand, it also demonstrates that China's influence on the global economy is increasing day by day. In the future, there will be more free market mechanisms, and the unilateral strategy of maintaining a stable appreciation of the currency before 2014 may not be feasible. In the medium to long term, in the process of promoting the internationalization of the RMB, China has successively opened up the control of the capital account, and if we want to improve the autonomy of China's monetary policy in the future, the first thing we need to do is to make the exchange rate fluctuation more flexible.

With the gradual recovery of the U.S. economy, the U.S. Federal Reserve (Fed) has raised interest rates at the end of 2015. But on the contrary, China has to keep easing its monetary policy to stimulate the economy in the midst of economic slowdown. It is foreseeable that the monetary policies of the world's two largest economies may begin to diverge, and in the future, if the Chinese government further reduces interest rates while the Fed begins to raise interest rates, the interest rate differential between China and the U.S. will converge significantly. Dornbusch modified the PPP theory by pointing out that the exchange rate is affected by the relative prices of the two currencies, and argued that through the carry trade, foreign capital will flow in to make the country's currency appreciate [1]. In the past, when discussing the outlook for the RMB exchange rate, the market did not have pricing power, because most of them were based on exchange rate policy considerations or speculated from an official perspective, which was largely determined by the central bank's control, but the exchange rate reform in 2015 was an important watershed in the process of the RMB exchange rate's market-oriented evolution, which meant that the old way of thinking about RMB analysis will be explored and corrected. In addition, from a structural point of view, more attention is paid to the RMB versus the US dollar, which is still the most important currency in the global currency market. Based on the above considerations, this paper collects data on China-U.S. interest rate spreads and the spot exchange rate of the RMB against the U.S. dollar, and employs Granger causality test to examine the causal relationship between the exchange rate and interest rate spreads, and to explore what kind of interactive relationship between the exchange rate and interest rate spreads in China, which has gone through a number of economic reforms and has a large number of variables; then explore whether there is a reciprocal relationship between the exchange rate of the RMB and the interest rate spreads of the U.S. and China.

2. Literature Review

Generally speaking, when there is a difference in interest rates between two countries, funds will flow from the country with the lower interest rate to the country with the higher interest rate in order to make a profit. Arbitrage traders in comparing the rate of return on investment assets, not only to assess the two currencies due to interest rates brought about by the rate of return, but also to assess the two currencies because of changes in exchange rates on the earnings of the impact, which is the foreign exchange risk. Fama found that there is an overpayment in carry trades, and that high-interest rate currencies do not depreciate as much for low-interest rate currencies as the difference in interest rates between the two [2]. Interest rate parity theory is that the difference in interest rates between the two countries will be equal to the difference between the forward exchange rate and the spot exchange rate, that is, there is a relationship between the forward exchange rate of foreign currencies and the spread between the two countries. However, Meredith and Chinn found that in short-term investments, high-interest rate currencies will appreciate relative to low-interest rate currencies, and that the interest rate parity theory does not hold in shorter-term investments [3]. Hetemi & Irandoust used cointegration analysis, Grangernon-causalitytest, and the analysis of Sweden as an example to observe the extent of changes in capital movements internationally before and after the adjustment of the exchange rate regime, and found that the causal relationship between the exchange rate and the interest rate was in the opposite direction in the case of the floating exchange rate regime, but showed a unidimensional causal relationship between the exchange rate and interest rates in the case of a fixed exchange rate regime [4]. Gyntelberg & Remolona argued that when the interest rate parity theory does not hold, investors can switch from low to high-interest rate currencies without any risk

and obtain excess compensation, i.e., carry trades are essentially betting against the interest rate parity theory [5]. Jiang & Kim used SVAR model to study the influence of exchange rate changes on China's domestic monetary policy. They found that the stable development of the exchange rate plays a unique and significant role in Chinese prices, and the domestic inflation rate may affect the direct impact of exchange rate changes on domestic prices. Thus, policymakers should not use depreciation as an instrument to promote economic growth because it can significantly increase domestic inflation [6]. Si et.al used wavelet analysis to investigate the causal relationship between nominal exchange rates and interest rate spreads in BRICS (China, Russia, Brazil, South Africa, and India) for the period from January 1996 to September 2015 and found that there is a causal relationship between nominal exchange rates and short-run interest rate spreads [7]. Dhamotharan & Ismail also used wavelet analysis to explore the relationship between China's exchange rate and interest rate spreads from 2005-2013 and pointed out that there is a long-run causality between China's exchange rate and interest rate spreads, which means that the banks can stabilize the RMB exchange rate through the interest rate spreads [8]. Summarizing the above literature, it can be found that most of the academics use the time series causality method, and there is little literature on the frequency-based causality test. This paper adopts the frequency causality method to determine the causality between the US-China rate differential and the exchange rate, which is somewhat innovative.

3. Research Methodology

3.1. Sample Data

The data of this study is obtained from the statistics database of WIBS, and the information on the spot exchange rate of RMB against US dollar and the short-term interest rate spread between China and the US from January 1996 to September 2015 is selected, and a total of 474 pieces of data are taken as samples in order to carry out the research on the correlation between each other.

3.2. Research Methods and Hypotheses

In this study, ADF single root test, PP single root test, cointegration test and causality test were used. Firstly, the data are examined to confirm the stability of the series, secondly, the cointegration analysis proposed by Johansen is utilized [9], and finally, the dynamics between the RMB exchange rate and the China-US interest rate differential are examined according to the Granger causality test to check whether there is a causal relationship between the variables [10]. The null hypotheses and opposing hypotheses in the research hypotheses are set as follows:

3.2.1. The null hypothesis of China-US interest rate differential on RMB exchange rate and the opposing hypotheses

H0: There is no long-term causality of the China-US interest rate differential on the RMB exchange rate.

Ha: There is long-term causality of the China-US interest rate differential on the RMB exchange rate.

H0: There is no medium-term causality of the China-US interest rate differential on the RMB exchange rate.

Ha: There is medium-term causality of the China-US interest rate differential on the RMB exchange rate.

H0: There is no short-term causality of the China-US interest rate differential on the RMB exchange rate.

Ha: There is short -term causality of the China-US interest rate differential on the RMB exchange rate.

3.2.2. The null hypothesis of the RMB exchange rate on the US-China interest rate differential and the opposing hypothesis

H0: There is no long-term causality of the RMB exchange rate on the China-US interest rate differential.

Ha: There is long-term causality of the RMB exchange rate on the China-US interest rate differential.

H0: There is no medium-term causality of the RMB exchange rate on the China-US interest rate differential.

Ha: There is medium-term causality of the RMB exchange rate on the China-US interest rate differential.

H0: There is no short-term causality of the RMB exchange rate on the China-US interest rate differential.

Ha: There is short -term causality of the RMB exchange rate on the China-US interest rate differential.

4. Findings and Analysis

4.1. Analysis of Single-root Results

The ADF and PP single-root tests are applied to determine whether the two variables, the RMB exchange rate and the China-US interest rate differential, are single-rooted. If the t-values of the time series data fail to reject the null hypothesis (H0: there is a single-root) at the significant levels of 1%, 5%, and 10%, the time series is said to be single-rooted, and vice versa. The time series data is not a stable series if there is a single root, but if both significantly reject the single root test after first order differencing, that is, the data is a stable series, which can be written as I(1) series.

Table 1 shows that the ADF value is -0.6920, at 1% significant level (>-3.4582), 5% significant level (>-2.8737) and 10% significant level (>-2.5733) cannot be rejected the null hypothesis of a single root, indicating that there is a single root and the RMB exchange rate is an unstable series. After the first-order difference treatment, the ADF value is -4.3554, at 1% significant level (<-3.4582), 5% significant level (<-2.8737) and 10% significant level (<-2.5733) can be rejected the null hypothesis of a single root, indicating that there is no single root and the RMB exchange rate becomes a stabilizing series after the first-order difference treatment.

Table 1. ADF Test for RMB Exchange Rate

	Level			1st-difference		
	optimal lag order	t-values	Prob.	optimal lag order	t-values	Prob.
RMB Exchange Rate	2	-0.6920	0.8454	1	-4.3554***	0.0005

Note: 1. Null hypothesis (H_0): the time series has a single root; 2. **** indicates that the null hypothesis of the existence of a single root is rejected at the 1% significant level (-3.4582).

Table 2 shows that the PP value is 0.0736, at 1% significant level (>-3.4580), 5% significant level (>-2.8736) and 10% significant level (>-2.5733) cannot be rejected the null hypothesis of a single root, indicating that there is a single root and the RMB exchange rate is an unstable series. After the first-order difference treatment, the PP value is -9.0960, at 1% significant level (<-3.4581), 5% significant level (<-2.8736) and 10% significant level (<-2.5733) can be rejected the null hypothesis of a single root, indicating that there is no single root and the RMB exchange rate becomes a stabilizing series after the first-order difference treatment.

Table 2. PP Test for RMB Exchange Rate

	Level			1st-difference		
	Bandwidth	Adj. t-values	Prob.	Bandwidth	Adj. t-values	Prob.
RMB Exchange Rate	9	0.0736	0.9631	7	-9.0960***	0.000

Note: 1. Null hypothesis (H_0): the time series has a single root; 2. **** indicates that the null hypothesis of the existence of a single root is rejected at the 1% significant level (-3.4581).

Table 3 shows that the ADF value is -2.2799, at 1% significant level (>-3.4580), 5% significant level (>-2.8736) and 10% significant level (>-2.5733) cannot be rejected the null hypothesis of a single root, indicating that there is a single root, and the China-US interest rate differential is an unstable series. After the first-order difference treatment, the ADF value is -17.5117, at 1% significant level (<-3.45811), 5% significant level (<-2.8736) and 10% significant level (<-2.5733) can be rejected the null hypothesis of a single root, indicating that there is no single root, and the China-US interest rate differential becomes a stabilizing series after the first-order difference treatment.

Table 3. ADF Test for China-US Interest Rate Differential

	Level			1st-difference		
	optimal lag order	t-values	Prob.	optimal lag order	t-values	Prob.
China-US interest rate differential	0	-2.2799	0.1794	0	-17.5117***	0.000

Note: 1. Null hypothesis (H_0): the time series has a single root; 2. **** indicates that the null hypothesis of the existence of a single root is rejected at the 1% significant level (-3.4580).

Table 4 shows that the PP value is -2.1733, at 1% significant level (>-3.4580), 5% significant level (>-2.8736) and 10% significant level (>-2.5733) cannot be rejected the null hypothesis of a single root, indicating that there is a single root, and the China-US interest rate differential is an unstable series. After the first-order difference treatment, the PP value is -17.6552, at 1% significant level (<-3.4581), 5% significant level (<-2.8736) and 10% significant level (<-2.5733) can be rejected the null hypothesis of a single root, indicating that there is no single root, and the China-US interest rate differential becomes a stabilizing series after the first-order difference treatment.

Table4. PP Test for China-US Interest Rate Differential

	Level			1st-difference		
	Bandwidth	Adj. t-values	Prob.	Bandwidth	Adj. t-values	Prob.
China-US interest rate differential	5	-2.1733	0.2167	5	-17.6552***	0.000

Note: 1. Null hypothesis (H_0): the time series has a single root; 2. **** indicates that the null hypothesis of the existence of a single root is rejected at the 1% significant level (-3.4581).

4.2. Optimal Lag Order Selection for Vector Autoregressive Model

Table 5 shows the VAR model with the RMB exchange rate and the China-US interest rate differential as variables and determines the optimal lag order of the VAR model (the maximum of the optimal

lag order is 18) by the LR criterion, the FPE criterion, the AIC criterion, the SC criterion, and the HQ criterion. When choosing a lag order too long, the number of degrees of freedom will be reduced, the consistency will be low, and the degree of interpretation will be relatively lower due to over-parametrization; on the contrary, if the number of lag order is too short, the residuals will not be recognized as a white noise. In this study, LR, FPE and AIC all fall in the 8th period, but SC falls in the 2nd period, and HQ falls in the 3rd period. Since SC is more powerful in data validation for data with smaller samples, the 2nd period is chosen as the optimal lag order, and then the results are used for further cointegration validation.

Table 5. Optimal Lag Order Selection for Vector Autoregressive Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-778.8048	NA	3.352713	6.937820	6.968185	6.950076
1	304.9888	2138.094	0.000240	-2.657679	-2.566583	-2.620912
2	339.8066	68.08801	0.000183	-2.931614	-2.779787*	-2.870336
3	348.9805	17.77699	0.000175	-2.977604	-2.765047	-2.891815*
4	351.1350	4.136774	0.000177	-2.961200	-2.687912	-2.850900
5	355.8443	8.957970	0.000176	-2.967505	-2.633486	-2.832693
6	357.5381	3.191998	0.000180	-2.947006	-2.552256	-2.787683
7	362.2600	8.814225	0.000179	-2.953422	-2.497942	-2.766589
8	370.8245	15.83480*	0.000172*	-2.993996*	-2.477785	-2.785651
9	374.3982	6.543877	0.000172	-2.990207	-2.413265	-2.757351
10	375.4719	1.946833	0.000177	-2.964194	-2.326522	-2.706827
11	379.5760	7.369240	0.000177	-2.965120	-2.266717	-2.683242
12	381.6245	3.641725	0.000180	-2.947773	-2.188640	-2.641384

Note: * indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

4.3. Cointegration Test and Time Series Causality Verification

Table 6 shows the cointegration test of China-US interest rate differential (CUID) and RMB exchange rate (CE), and the results show that the Trace and Max-Eigen values of CUID and CE are less than the Trace (5%) and Max-Eigen (5%) values, and fall in the range of 0.05 to 0.05, which is the same as the Trace and Max-Eigen values. Outside the confidence interval of 0.05, the test result shows that the null hypothesis cannot be rejected at the 5% level of significance for the CUID and the CE, so there is no cointegrated long-run equilibrium relationship between the CUID and the CE.

Table 6. Cointegration Test of RMB Exchange Rate and China-US Interest Rate Differential

CUID and CE (VAR lag=2)	Trace	Max-Eigen	Trace (5%) Critical value (Prob.)	L-max (5%) Critical value (Prob.)
None	8.4804	7.5933	15.4947	14.2646
			(0.4155)	(0.4216)
At most 1	0.8871	0.8870	3.8415	3.8415
			(0.3463)	(0.3463)

Because the cointegration test shows that there is no cointegrated long-run relationship between the RMB exchange rate (CE) and the China-US interest rate differential (CUID), the causality analysis is conducted using the data after differencing. Table 7 time series checking results show that the optimal lag order is 2. For the null hypothesis: the interest rate differential between China and the United States does not affect the RMB exchange rate, the P-value 0.8698> 0.05, and the null hypothesis cannot be rejected, so the interest rate differential between China and the United States does not affect the RMB exchange rate. For the other null hypothesis: the RMB exchange rate does not affect the China-US interest rate, the P-value 0.0141<0.05, which rejects the null hypothesis, so the RMB exchange rate affects the China-US interest rate differential. Next, we adopt the frequency causality of Brietung & Candelon [11] to further examine the relationship between the China-US interest rate differential and the RMB exchange rate.

Table 7. Granger Time Series Test

Null Hypothesis	Obs	F-Statistic	Prob.
DCUID does not Granger Cause DCE	237	0.1394	0.8698
DCE does not Granger Cause DCUID		4.3407	0.0141

4.4. Frequency Causality Test

According to Breitung & Candelon [11], Fig. 1 presents the results of the Granger frequency causality test: the dotted line parallel to the frequency axis in the figure is the critical value of the statistic 0.05. Since the curve of the China-US interest rate differential affecting the RMB exchange rate falls below the critical value of the statistic, it shows that there is no significant relationship between the two in the long, medium and short term. The curve of the RMB exchange rate affecting the China-US interest rate differential falls above the critical value of 0.05 and shows that the RMB exchange rate and the China-US interest rate differential has a significant effect in the long term, medium term, and there is a frequency causality, while in the short term, there is no significant effect. To sum, the RMB exchange rate affects the China-US interest rate differential and has a significant predictive ability on the China-US interest rate differential in the long and medium term.

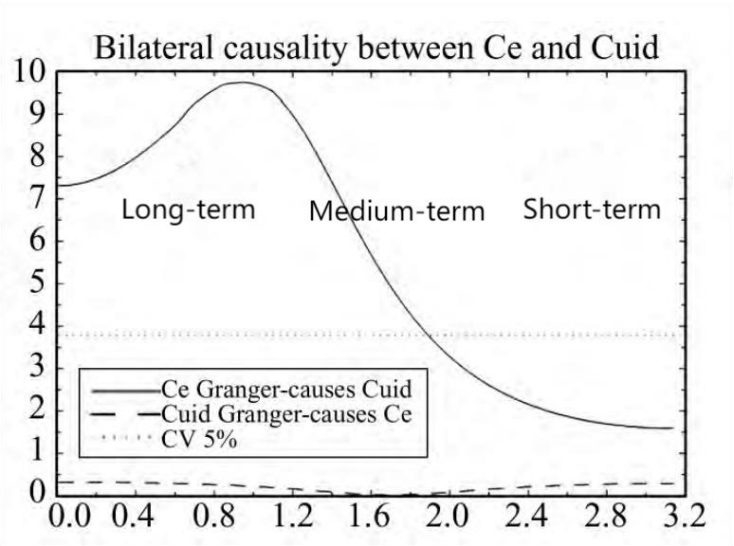

Fig. 1 Frequency Causality Test on the China-US Interest Rate Differential and the RMB Exchange Rate

5. Summary

In the cointegration test, the null hypothesis cannot be rejected at the 0.05 level of significance for the China-US interest rate differential and the RMB exchange rate, so there is no cointegrated long-

run equilibrium relationship between the China US interest rate differential and the RMB exchange rate. Then, the Granger frequency causality test is used to analyze the causal relationship between the two variables. Using the first-order differenced data as the causality test, it is found that in the Granger frequency causality test, the curves showing that the China-US interest rate differential affects the RMB exchange rate fall below the critical value of 0.05, and therefore there is no significant effect in the long run, medium run, and short run. The curve of the RMB exchange rate affecting the China-US interest rate differential falls above the critical value of 0.05, which indicates that the RMB exchange rate and the China-US interest rate differential have a significant effect in the long term and medium term, while there is no significant effect in the short term.

China's total foreign trade ranks first in the world, fluctuations in the RMB exchange rate have a great impact on export-oriented China, changes in the exchange rate affect the export industry, and probably also affect the Chinese economy as a whole, so the government will adjust the interest rate policy in response, and carefully maintain a balance between attempting to avoid causing instability in the financial market, but also through the exchange rate adjustment in order to help the economic growth. Based on past experience, the convergence of interest rate differentials between the US and China will lead to increased expectations of RMB depreciation, which may lead to larger short-term capital outflows. However, empirical results show that the China-US interest rate differential does not affect the RMB exchange rate. The phenomenon of inverted China-US interest rate differential has occurred three times before and after 2002-2003, 2005-2007 and 2009. During this period, China should have experienced capital outflows, however, during the above three times of inverted spreads, China's capital inflows were massive, and the RMB continued to appreciate until the second half of 2014. However, with the addition of the RMB to the SDR, the exchange rate of the RMB has a mechanism to form a basket of currencies, through the market demand and supply of the floating, and the abandonment of the normal intervention, the linkage between the spreads and the exchange rate will be more subtle. Currently facing a shift in the general environment, the dollar has the opportunity to begin to move towards the interest rate cycle, but the RMB is facing a number of issues of depreciation pressure, but also about to become an international currency to the international arena. How to maintain a certain posture between the RMB and the dollar, it is well worth exploring.

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