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Empirical analysis of interest rate parity and purchasing power parity

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ABSTRACT

Exchange rate change is a problem that has been bothering economists for a long time. These economists also try to explain the change of exchange rate through many models. But these are theoretical after all. This paper focuses on the relationships between Mainland China, Europe and Hong Kong and tries to verify whether two basic models namely, interest rate parity model and purchasing power parity model are practical or not. In addition, this paper uses the method of covered in the interest rate parity model and fill to calculate the data of the last ten year.

Key word: exchange rate, interest rate parity, purchasing power parity

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Introduction

Exchange rate is a very simple concept, which directly reflects the relative value of the two currencies. In the early days, economists determined the exchange rate between the two countries through the relative price of the same big Mac in Hamburg chain stores of two countries. However, such a model has many defects. For example, it assumes that goods can be freely traded, and it ignores transaction costs such as tariffs, quotas and taxes, and ignores the service industry.

At the same time, the exchange rate is a very complex problem, which has troubled economists for a long time. In fact, there are many factors that affect the exchange rate. One of the most important factors is interest rate. Later, economists established the interest rate parity model to establish the relationship between interest rate and exchange rate. This model explains the effect of interest rate on exchange rate very well, but it also has some defects, for example, it assumes that capital flows freely.

This paper selects three places, the first is mainland China, which adopts floating exchange rate control system, the second is Hong Kong, which has more open capital, and the third is Europe, because the LIBOR as the benchmark is very representative. As the onshore RMB and the offshore RMB are not exactly the same, this paper can test this model to determine whether there is arbitrage opportunity between them and the actual relationship between them and the euro.

Literature review

Recently, the relationship between China, the United States and Hong Kong seems very delicate. Many contradictions are brewing, not only the Sino US trade war, but also the internal political issues in Hong Kong. As long as people talk about trade wars or Hong Kong, which is a city with a very high degree of economic openness, and it will involve the exchange rate. Because trade war is a problem of trade between the two countries, trade must involve currency. Secondly, as a diversified City, Hong Kong carries out a large number of transactions with its banks every day.

Indeed, since 2010, the process of RMB internationalization has accelerated, and the RMB foreign exchange market in Hong Kong has developed rapidly. Hong Kong gradually becomes the main trading place of offshore RMB. (He & Zhang, 2012) As Li, Hui and Chung (2012) said, Hong Kong's foreign exchange market gives investors a new place to invest and use hedging to avoid risks. It also allows Hong Kong to attract more foreign capital. However, Li, Hui and Chung (2012) also pointed out that due to capital control, there is institutional separation between the onshore and offshore forward exchange rate markets, which directly leads to differences in currency prices. In addition, it is not only the institutional differences that lead to the price differences, but also the information asymmetry and Investor's deviation of interest rate estimation. (Li, Hui & Chung, 2012) Although China is gradually promoting the process of integration, the differences between onshore and offshore exchange rates still exist.

There are a bunch of factors that affect the exchange rate. For example, the information asymmetry and government policy system mentioned in the previous paper will have

impacts on the exchange rate. For the exchange rate, economists have built many models to explain the reasons for the exchange rate changes, the most basic of which is the purchasing power parity model, whose main purpose is to find the impact of the inflation rate of the two countries on the exchange rate. However, the purchasing power parity model has defects. Abuaf and Jorion (1990) said that there is a huge deviation between the theoretical value and the actual value of the purchasing power parity model in the short term. According to statistics, this deviation will take about three years to reduce by half. However, Abuaf and Jorion (1990) did not deny the rationality of the purchasing power parity model. They pointed out that the problems existing in the experiment are not the problems of the model itself. If there is a sufficient database, then the purchasing power parity model is reasonable in the long run and the exchange rate changes are relatively stable. After that, some economists improved this model, just like Lehmann and Adler (1983). They tried to explain the exchange rate changes caused by purchasing power parity model from the micro economic phenomenon. They built a martingale model to prove that if the traditional purchasing power parity model follows one martingale, the deviation is really between 3% and 5%.

Although there are defects in the purchasing power parity model, it does not lack economic significance. Economists apply this theory to research. For example, Ashenfelter (2001) used the Big Mac index to compare the wage rates of transnational workers, in which the working hours and types of workers are the same. This also proves the practicability of purchasing power parity model.

In addition to the inflation rate, interest rate is also a very important factor affecting the exchange rate. Economists have also developed a model of interest rate parity to

quantify how interest rates affect exchange rates. However, Like the purchasing power parity model, the interest rate parity model has many defects, many factors will be mixed in this model. Finally, the real exchange rate deviates from the theoretical exchange rate in the model. Chinn and Meredith (2005) tested the rationality of interest rate parity model by studying the interest rates of bonds among seven countries and explained one of the reasons for the deviation of interest rate parity model, that is, the impact of external markets and the synergy of monetary policy. In addition, they found that the real exchange rate can better fit the interest rate parity model in the long run. (Chinn & Meredith, 2005)

Nonetheless, the nominal interest rate is used in this model, and the real interest rate is not considered. As early as 1998, Wu and Chen (1998) improved the interest rate parity model and re-examined the effect of real interest rate on exchange rate. Unfortunately, they found that the real interest rate change did not support the interest rate parity model. In other words, the change of real interest rate does not explain the change of exchange rate very well.

In order to evaluate the persistence of deviations from CIP, Balke and Wohar (1998) employ nonlinear impulse response analysis. They built a dynamic model using interest rate and exchange rate data between the United Kingdom and the United States from 1974 to 1998 and find that deviations from covered interest parity that are outside the transaction costs band are less persistent than those inside the band. (Balke & Wohar, 1998)

In addition to a large number of economists before the twenty-first Century test of interest rate parity model, after twenty-first Century, economists also verify this model.

According to Coffy, Hrung and Sarkar's study (2009) which is after the financial crisis in 2007, in the normal period, the deviation degree of interest rate parity model is relatively low, but after the outbreak of financial crisis, the deviation degree is greatly increased. There are two reasons for the collapse of foreign exchange and arbitrage, one is the increase of credit risk, the other is the lack of capital. The Fed's response was timely, reducing the bias in interest rate parity by providing dollars to foreign countries through reciprocal monetary arrangements.

Different from the common view, interest rate parity may deviate, and Taylar (1987) holds a special view on this issue. He thinks that most economists only use data that real investors cannot encounter in real investment, such as average interest rate and average exchange rate, which leads to errors in model test. Not only that, he also believes that arbitrage does exist, but the time interval is very small, or even less than 10 minutes. Based on this conjecture, Taylar (1987) collects high-frequency real data from the London foreign exchange market.

Methodology

In this paper, linear regression method is used to determine the relationship between forward exchange rate and spot exchange rate. For the theory of interest rate parity, this paper assumes that the spot exchange rate of the next month is the forward exchange rate of the previous month. By calculating another forward exchange rate, the linear regression analysis of the two forward exchange rates is carried out.

For the purchasing power parity model, this paper calculates the forward exchange rate of the next month through the inflation rate and makes regression analysis between the forward exchange rate and the spot exchange rate to determine the relationship between them.

Interest rate parity's formula

Suppose an investor who has two choices.

First, choose to hold foreign currencies and get (1 + i*) units of foreign currencies one year later.

Second, assume exchange foreign currencies for domestic currencies at the current spot exchange rate e. One year later, they can get e (1 + i) units of domestic currency. At the same time, in the forward foreign exchange market, the unit currency e(1+i)/f is sold at the forward interest rate f, and the unit currency e(1+i)/f is obtained.

If these two number are not equal, risk-free arbitrage will exist.

Therefore, the interest rate parity equation e(1+i)/f=1+i* is invariably valid.

And, this formula can be got as below,

$$\rho = \frac{f - e}{e} = i - i^*$$

- F is forward exchange rate
- e is spot exchange rate. (Direct pricing methods)
- I* Represents foreign interest rates
- I represents domestic interest rates
- P is premium rate

Purchasing power parity formula

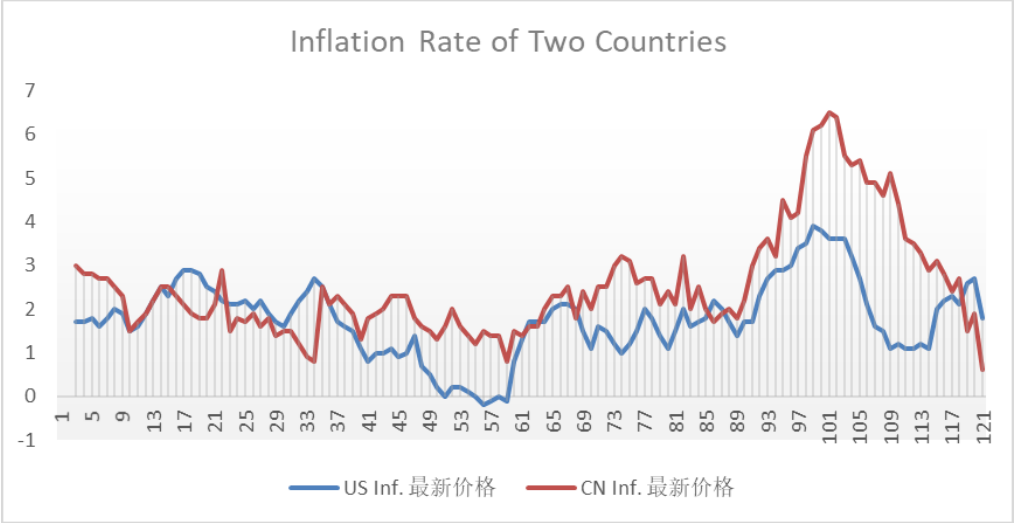
According to the theory of relative purchasing power parity, the change of exchange rate should be equal to the difference of inflation rate between the two countries.

$$\frac{E_t - E_{t-1}}{E_{t-1}} = \pi_{RMB} - \pi_S$$

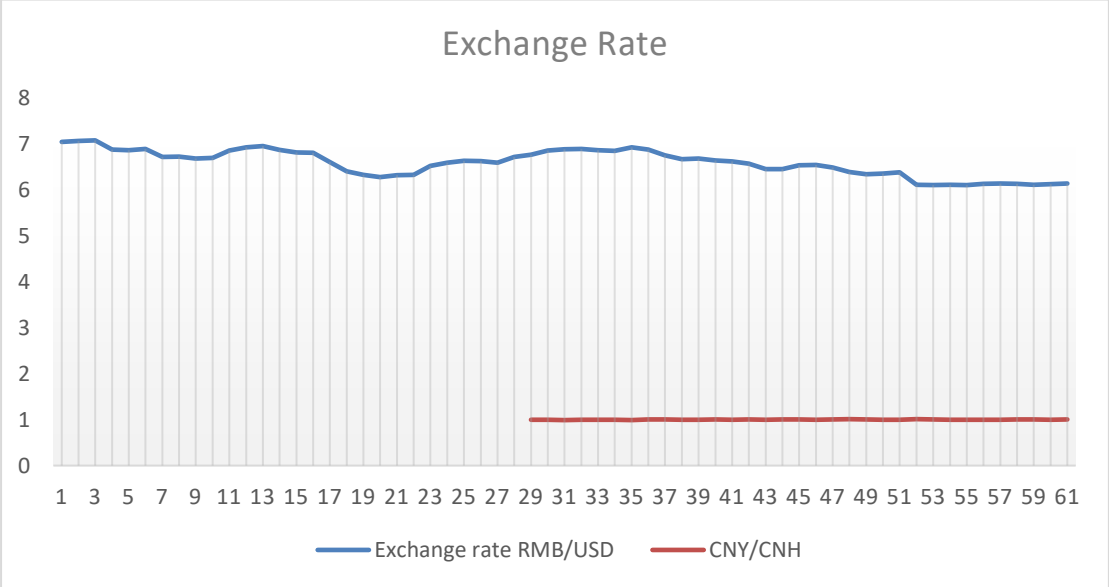
- Et is the spot exchange rate in t period
- πRMB is China's inflation rate
- πs is America's inflation rate

Data

This paper uses the inflation rate of China and the United States over the past decade from 2009 to 2019. The data comes from Bloomberg.



This paper uses the exchange rate of the onshore RMB against the offshore RMB and the exchange rate of the onshore RMB against the US dollar for ten years from 2009 to 2019. Data from investing.com.



This article also uses the one-month interbank offered rate of the Bank of London as the US dollar interest rate, the one-month SIBOR as the onshore RMB interest rate, and the one-month RMB interbank offered rate of the Bank of Hong Kong as the offshore RMB interest rate. Data covers every month from 2015 to 2019. The data comes from Dongfang.fortune.com. (See the appendix)

Date	Sibor	HK	Libor/US	Exchange rate RMB/USD	Actual forward exchange rate RMB/USD	Caculate RMB/USD	CNY/CNH	Actual CNY/CNH forward	Calculate CNY/CNH
2019/10/31	2.775		1.785	7.0533	7.0324	7.559848205			
2019/9/30	2.762		2.016	7.0729	7.0533	7.449354295			
2019/8/31	2.661		2.089	7.0879	7.0729	7.375661999			
2019/7/31	2.606		2.224	6.8841	7.0879	7.068979513			
2019/6/30	2.603		2.388	6.8747	6.8841	6.977428698			
2019/5/31	2.816		2.431	6.8992	6.8747	7.083261534			
2019/4/30	2.856		2.481	6.7286	6.8992	6.902843837			
2019/3/31	2.782		2.493	6.7335	6.7286	6.867770441			
2019/2/28	2.694		2.49	6.6901	6.7335	6.784287743			
2019/1/31	2.839		2.514	6.7025	6.6901	6.85258354			
2018/12/31	3.472		2.503	6.8632	6.7025	7.321756216			
2018/11/30	2.701		2.347	6.9357	6.8632	7.106832488			
2018/10/31	2.663		2.307	6.9646	6.9357	7.137899616			
2018/9/30	2.802		2.265	6.8792	6.9646	7.138164627			
2018/8/31	2.72		2.104	6.8246	6.8792	7.122668179			
2018/7/31	2.965		2.081	6.8165	6.8246	7.244437362			
2018/6/30	4.031		2.09	6.6166	6.8165	7.528084784			
2018/5/31	3.905		2	6.4144	6.6166	7.287216571			
2018/4/30	3.9		1.909	6.3393	6.4144	7.246737364			
2018/3/31	4.288		1.883	6.2881	6.3393	7.377409263			
2018/2/28	4.042		1.67	6.3294	6.2881	7.427668969			
2018/1/31	4.129		1.58	6.3339	6.3294	7.522788888			
2017/12/31	4.935		1.564	6.5342	6.3339	8.158115379			
2017/11/30	4.072		1.372	6.6034	6.5342	7.936721867			
2017/10/31	4.027		1.243	6.6397	6.6034	8.035526082			
2017/9/30	4.069		1.232	6.6369	6.6397	8.059881054			
2017/8/31	3.892		1.232	6.601	6.6369	7.927984583			
2017/7/31	3.889		1.232	6.7283	6.601	8.079349962			
2017/6/30	4.461	4.953	1.224	6.7744	6.7283	8.432652632	1.0001	1.0017	0.971075686
2017/5/31	4.076	5.906	1.051	6.8633	6.7744	8.454096299	1	1.0001	0.89779962
2017/4/30	4.024	5.118	0.995	6.8931	6.8633	8.499810265	0.9907	1	0.927385022
2017/3/31	4.35	4.584	0.983	6.8993	6.8931	8.6885585	1.0006	0.9907	0.986481548
2017/2/28	4.08	4.301	0.789	6.875	6.8993	8.644147314	0.9978	1.0006	0.984272376
2017/1/31	3.876	6.951	0.779	6.8588	6.875	8.521035198	0.9982	0.9978	0.836231502
2016/12/31	3.306	11.856	0.772	6.937	6.8588	8.313319919	0.9921	0.9982	0.636530961
2016/11/30	2.87	4.0785	0.624	6.8865	6.937	8.111712215	1.0041	0.9921	0.92862935
2016/10/31	2.745	3.6	0.534	6.7641	6.8865	7.957288535	1.0043	1.0041	0.949256635
2016/9/30	2.741	3.381	0.531	6.6778	6.7641	7.855514309	1.0003	1.0043	0.958677739
2016/8/31	2.696	2.181	0.525	6.6908	6.6778	7.850538667	1.0004	1.0003	1.036730724
2016/7/31	2.767	2.302	0.494	6.6511	6.6908	7.861116832	1.0017	1.0004	1.034268207
2016/6/30	2.887	2.245	0.465	6.6312	6.6511	7.919669025	0.9988	1.0017	1.043814363
2016/5/31	2.846	2.295	0.469	6.579	6.6312	7.833172989	1.0031	0.9988	1.041764435
2016/4/30	2.853	2.471	0.436	6.4589	6.579	7.714220143	1.0006	1.0031	1.027013461
2016/3/31	2.807	1.847	0.437	6.4612	6.4589	7.692449015	1.0018	1.0006	1.071253889
2016/2/29	2.8	4.556	0.441	6.5452	6.4612	7.786267985	1.0024	1.0018	0.896081179
2016/1/31	3.168	6.148	0.425	6.5516	6.5452	7.997961272	0.9997	1.0024	0.83554384
2015/12/31	3.004	5.647	0.43	6.4936	6.5516	7.838292389	1.0028	0.9997	0.852610143
2015/11/30	2.7	4.61	0.243	6.3962	6.4936	7.679828473	1.0116	1.0028	0.895275135
2015/10/31	2.765	3.351	0.192	6.3495	6.3962	7.689498647	1.0042	1.0116	0.965866263
2015/9/30	3.09	5.268	0.193	6.3613	6.3495	7.872715246	1.0006	1.0042	0.874395066
2015/8/31	3.034	4.589	0.201	6.3893	6.3613	7.872857651	1.001	1.0006	0.90716945
2015/7/31	2.988	3.047	0.192	6.1172	6.3893	7.520061811	1.0104	1.001	1.006438174
2015/6/30	3.521	3.249	0.187	6.1136	6.1172	7.786098761	1.0018	1.0104	1.019669342
2015/5/31	2.29	2.733	0.184	6.1196	6.1136	7.17737065	1.0009	1.0018	0.970804385
2015/4/30	3.465	3.453	0.181	6.1137	6.1196	7.761954725	1.0009	1.0009	1.001677247
2015/3/31	5.009	4.432	0.176	6.1422	6.1137	8.580213518	1.0009	1.0009	1.036046014
2015/2/28	5.083	4.182	0.173	6.1475	6.1422	8.627104452	1.0011	1.0009	1.056840397
2015/1/31	5.01	4.826	0.171	6.137	6.1475	8.576975598	1.0027	1.0011	1.013664983
2014/12/31	5.588	4.042	0.171	6.119	6.137	8.842409991	1.0053	1.0027	1.102182795
2014/11/30	4.178	3.519	0.154	6.1345	6.119	8.165537354	1.0016	1.0053	1.044132019
2014/10/31	3.991	3.295	0.156	6.1461	6.1345	8.085084329	1.0029	1.0016	1.048537032

Data result

Interest rate parity of onshore RMB against USD

This analysis is based on the interbank offered rate of USD of Bank of London and

SIBOR. First, calculate the forward exchange rate of each month through the interest rate parity formula, and then use the exchange rate of the next month as the actual forward exchange rate for regression analysis. The analysis results are as follows

SUMMARY OUTPUT								
回归统计								
Multiple R	0.296087755							
R Square	0.087667959							
Adjusted R Square	0.072204704							
标准误差	0.509800696							
观测值	61							
方差分析								
	df	*SS*	*MS*	*F*	*Significance F*			
回归分析	1	1.473468404	1.473468404	5.669437601	0.020509525			
残差	59	15.33390822	0.259896749					
总计	60	16.80737662						
	Coefficients	*标准误差*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*下限95.0%*	*上限95.0%*
Intercept	11.36170683	1.517972674	7.484790094	4.08098E-10	8.324250529	14.39916314	8.324250529	14.39916314
X Variable 1	-0.546257655	0.22941803	-2.381058084	0.020509525	-1.005322072	-0.087193237	-1.005322072	-0.087193237

It is intuitively found that the actual forward exchange rate is related to the forward exchange rate calculated by the interest rate parity formula. It can be seen from the above table that the actual forward exchange rate is taken as the independent variable and the calculated forward exchange rate is taken as the dependent variable for linear regression analysis. From the above table, it can be seen that the square value of the model R is 0.088, which means that the actual forward exchange rate can explain the 8.8% change reason of the calculated forward exchange rate. It is found that the model passes the F-test ($F = 5.7$, $P < 0.05$), that is to say, the actual forward exchange rate will have an impact on the calculated forward exchange rate, so the impact of independent variables on the dependent variables can be specifically analyzed.

This is a cogent proof that the theory of interest rate parity is reasonable for the actual analysis of the exchange rate of RMB on shore and USD.

Interest rate parity of onshore RMB against offshore RMB

This analysis is based on the interbank offered rate of offshore RMB of Bank of Hong Kong and SIBOR. Similar steps are used, and results are as follows:

SUMMARY OUTPUT								
回归统计								
Multiple R	0.174411585							
R Square	0.030419401							
Adjusted R Square	-0.000857393							
标准误差	0.092677011							
观测值	33							
方差分析								
	df	*SS*	*MS*	*F*	*Significance F*			
回归分析	1	0.008353577	0.008353577	0.972586938	0.331671059			
残差	31	0.266259879	0.008589028					
总计	32	0.274613456						
	Coefficients	*标准误差*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*下限95.0%*	*上限95.0%*
Intercept	-3.236679991	4.26091586	-0.759620724	0.453219561	-11.92687518	5.4535152	-11.92687518	5.4535152
X Variable 1	4.196456827	4.255185948	0.986198225	0.331671059	-4.482052131	12.87496578	-4.482052131	12.87496578

It can be seen from the above table that the actual exchange rate is taken as an independent variable and the calculated exchange rate is taken as a dependent variable for linear regression analysis. From the above table, it can be seen that the square value of the model R is 0.030, which means that the actual exchange rate can explain the 3.0% change reason of the calculated exchange rate. It is found that the model fails to pass the F-test ($F = 0.973$, $P = 0.45 > 0.05$), that is to say, the actual exchange rate does not have an impact on the calculated exchange rate, so the impact of independent variables on the dependent variables cannot be specifically analyzed.

Purchasing power parity of onshore RMB against USD

First, a forward exchange rate is calculated by the model, and the regression analysis is made between the forward exchange rate and the actual forward exchange rate. The results are as follows:

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.171719524							
R Square	0.029487595							
Adjusted R Square	-0.091826456							
Standard Error	0.004105972							
Observations	10							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	4.09789E-06	4.0979E-06	0.243068259	0.635245558			
Residual	8	0.000134872	1.6859E-05					
Total	9	0.00013897						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.001044354	0.00180514	0.57854444	0.578815704	-0.003118307	0.00520701	-0.0031183	0.00520701
X Variable 1	0.000782344	0.001586841	0.49301953	0.635245558	-0.002876919	0.00444161	-0.0028769	0.00444161

From the above table, it can be seen that the square value of the model R is 0.030 and it is found that the model fails to pass the F-test ($F = 0.24$, $P = 0.57 > 0.05$), that is to say, purchasing power parity is not applicable between onshore RMB and US dollar.

Analysis and findings

This paper analyzes interest rate parity and purchasing power parity model by linear regression and finds that the real exchange rate of purchasing power parity model deviates greatly from the theoretical exchange rate. According to the formula of

inflation rate, this paper finds that although the difference of inflation rate between the two countries is very small, it will cause a great change of exchange rate and gradually reflect on the commodity price.

As for the interest rate parity model, this paper finds that the fitting degree of the model between the onshore RMB and the US dollar is relatively good, but the fitting degree of the model between the onshore RMB and the offshore RMB is relatively poor. This is inseparable from the policy system between the two places. The mainland of China adopts the floating management exchange rate system, while Hong Kong is an open range exchange rate system, which changes with the change of the US dollar price. This paper finds out from the metadata that the fluctuation of interest rate of offshore RMB in a single day is very large, which is also a reason for the low fitting degree of the model.

Conclusion

1. In the past five years, the real situation of the exchange rate fluctuation of onshore RMB against US dollar on shore is in line with the interest rate parity model, which can explain the change of the exchange rate. It shows that there

is little arbitrage space between the two currencies.

2. On the contrary, in the past five years, the exchange rate between onshore RMB and offshore RMB is not in line with the interest rate parity model. But it can't be simply said that this model is problematic. After all, the actual situation is very complex, there are many factors affecting the exchange rate change, and Hong Kong is very open to the outside world. It can only be explained here that the interest rate parity model does not conform to the actual situation in Hong Kong.
3. The relationship between the real forward exchange rate of PPP theory and the calculated forward exchange rate is very irrelevant, which shows that PPP theory is not applicable in practice.

Limitation

1. Error caused by interest rate data. This paper uses the closing rate on the last day of each month to represent the interest rate level of the whole month and does not calculate the average value. It is likely that interest rates will suddenly increase on the last day. For example, the interest rate of offshore RMB of Bank of Hong Kong will reach 11% one day.
2. The limitations and defects of the model and the diversification of the actual situation will lead to the deviation of the calculation results from the theoretical results.
3. The limitation of single forward exchange rate. In this paper, only one month's forward exchange rate is used for calculation and comparison, which is short-term. It is likely that these models will perform better in the long run than in the short run.
4. Restrictions on the type of currency. This article uses only three currencies for

analysis.

5. This paper only uses interbank offered rate to verify the interest rate parity model.

Future contribution

In future research, the data in this paper can be expanded, such as increasing the types of currencies and interest rates. More sufficient data can better help explain the reliability of these two models.

Secondly, in fact, every bank is trying to avoid the arbitrage of speculators. They can always integrate various factors to determine the exchange rate between two currencies, such as economic growth, government policies, etc., not only limited to interest rates and inflation rates. So, in the future research, more factors will be taken into consideration and included in a comprehensive model for analysis and more accurate determination of exchange rate changes.

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