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Effectiveness Analysis of Foreign Exchange Intervention by China's Central Bank Based on GARCH Model

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Abstract

This paper examines the effects of the Bank of China's intervention on CHY/USD exchange rate volatility by GARCH Model. The empirical results show that the component GARCH models provide new evidence on the effects of the Bank of China's intervention on the volatility of the CHY/USD exchange rate. The intervention reduces the volatility component from 2008 to 2017. Using the GARCH model to simulate the pattern of rapid appreciation, the pattern of financial crisis, the pattern of devaluation of the RMB, the models are well fitted the trends of exchange rate volatility.

Key words: Foreign exchange intervention; GARCH model; Exchange rate volatility; Scenario simulation; China's Central Bank

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INTRODUCTION

Exchange rate is the core economic variable of a country. Fluctuations in the exchange rate will directly affect the stability and development of the economic. The exchange rate is affected by many factors, which lead to complex and changeable. The frequency and volatility of exchange rates may exceed expectations of the government. In order to safeguard their own economic interests, governments will take varying degrees of foreign exchange intervention measures aperiodically, so that exchange rate and fluctuations return to the expected range. Foreign exchange intervention can temper the short-term fluctuation of exchange rate, correct the serious deviation of exchange rate, guide the exchange rate to new equilibrium level, and realize the macro policy goal.

When China's central bank announced the reform of the RMB exchange rate since July 2005, the CHY/USD exchange rate began to fluctuate. During this period, China's central bank has repeatedly adjusted the floating range of transaction price between CHY and USD. During the financial crisis from 2008 to 2010, China's central bank adopted more stringent control measures about foreign exchange. After 2014, the CHY/USD exchange rate showed a two-way fluctuation. The rate sometimes appreciates, sometimes devaluate. The range of fluctuation is larger, and the exchange rate market trend is very complex. The exchange rate varies with the fluctuation of the financial market, and the exchange rate is becoming more and more complicated and dynamic.

The purpose of foreign exchange intervention is to restrain exchange rate fluctuations and restore back to equilibrium. Therefore, the effectiveness of exchange rate intervention has been discussed and studied by many scholars. In order to assess the effectiveness of foreign exchange intervention, some scholars analyzed the channels of foreign exchange intervention, and studied the intervention process and the effect; some scholars examined the impact of foreign exchange intervention on price, fluctuations and expectations of exchange rate.

1. JOURNALS REVIEWED

The channels for foreign exchange intervention include asset portfolios, signals, and traditional channels based on market microstructure. Diao (2002) used the risk premium model to empirically test the asset portfolio model of foreign exchange intervention, and the results confirmed that foreign exchange intervention through asset portfolio channels is effective. Chen and Huang (2004) used the intervention analysis model to investigate the effect of joint intervention on the JPY/USD exchange rate by the Bank of Japan and FRB. The results showed that the joint intervention has a certain impact on the JPY/USD exchange rate, but there was no significant difference between joint intervention and non-joint intervention, and its impact was very short. Using data from 2004 to 2006 in China, Gui (2008) proved that foreign exchange interventions by China's central bank through portfolio channels are effective. Qin and Bian (2013) used the SVAR model to study the dynamic relationship between the foreign exchange intervention, monetary policy and RMB exchange rate in China after the exchange rate reform in 2005. The empirical analysis showed that foreign exchange intervention has a significant impact on the exchange rate at the same time. The effective channel of foreign exchange intervention was the signal channel.

The research on the effectiveness of foreign exchange intervention also includes examining the impact of foreign exchange intervention on exchange rate levels and fluctuations. The main research methods are event analysis and GARCH models. US, Japan and other countries announced foreign exchange intervention data from the monetary authorities, including the amount and frequency of intervention. So a lot of research on the effectiveness of foreign exchange intervention is about the USD/JPY, the JPY/EUR. Toshiaki and Kimie (2006) examined the effects of the Bank of Japan's (BOJ) intervention on the volatility as well as the level of the yen/dollar exchange rate for the GARCH model. The results showed that the BOJ's intervention only reduces the short-run volatility component from the late 1990s to 2003. The stabilizing effect of the BOJ's intervention in the late 1990s and the first few years of the 2000s are not enhanced by the Fed's coordinated intervention. Suardi (2008) found that interventions by the Bank of Japan and the Federal Reserve are more effective in changing the direction of the exchange rate movements and reducing its volatility level in a regime when the exchange rates are severely misaligned by using a double threshold GARCH model. Gan (2007) analyzed the foreign exchange intervention by China's central bank, using case analysis and non-parametric test. The empirical results showed that the foreign exchange intervention can change the fluctuation of the financial market, to enhance the purpose of monetary policy. Hillebrand (2009) use the GARCH model to establish the relationship between foreign exchange intervention and foreign exchange fluctuations, so as to study the effectiveness of the intervention by the Bank of Japan. The results showed that the foreign exchange intervention from 1995 to 1999 did not achieve the desired effect, the exchange rate fluctuations increased; the foreign exchange intervention from 1999 to 2004 was effective, the exchange rate fluctuations decreased. Wang (2013) adopted the event analysis method to analyze the effectiveness of China's foreign exchange intervention with the data from 2002 to 2011. The results showed that the foreign exchange intervention by the central bank is effective, but the effect is not symmetrical.

According to the previous literature review, there are many researches on foreign exchange intervention using GARCH model, and empirical results are very good. The GARCH model is rarely used in the study of China's central bank's foreign exchange intervention. Therefore, this paper uses the GARCH (1,2) model to verify the effectiveness of China's foreign exchange intervention.

2. TEST MODEL

In the GARCH model of the effectiveness of foreign exchange intervention, the explained variable is the fluctuation of exchange rate, and the explanatory variables are the quantity, frequency, mode of foreign exchange intervention and deviation of exchange rate. Based on the principle of saving, the low order GARCH (1,1) model is adopted to test the effectiveness of China's central bank's foreign exchange intervention.

There are many factors that affect the effectiveness of foreign exchange intervention. By observing the obvious influence of different factors on the foreign exchange intervention strategy, the quantity, frequency, method of intervention and combined intervention are adopted as the factors on the foreign exchange intervention (Fratzscher, 2005; Jun, 2008; Suykena & Vandewalle, 1999). The quantity of foreign exchange intervention is a major factor in the intervention measures taken by the central bank. Excessive intervention leads to excessive fluctuations in exchange rates, while intervention may be too small to achieve the effect of intervention. The frequency of foreign exchange intervention was the ratio of the number of days of intervention to the total number of days within a year. The method of foreign exchange intervention mainly refers to the continuity of intervention. Combined intervention refers to the Fed's currency trading in the foreign exchange market in order to influence the CHY/USD exchange rate.

At present, most countries except the United States and Japan did not publish foreign exchange intervention data. China's central bank also did not publish foreign exchange intervention data. So frequency, method of intervention and combined intervention was not available. We refer to the research of many scholars. Gan (2007) used the daily

trading volume of CHY/USD exchange rate in the foreign exchange market as the intervention variables. Gui (2009) used the monthly data of foreign exchange reserves as the cumulative value of foreign exchange intervention. In order to verify the effectiveness of foreign exchange intervention, the amount of foreign exchange reserves published by the central bank is used to indicate the cumulative intervention, while the other three factors are not taken into consideration.

The standard GARCH (1,1) model is

$$y_t = x_t^T \beta_t + \varepsilon_t, \quad t = 1,2,\cdots,T, \tag{1}$$

$$\varepsilon_t = \sigma_t \nu_t, \tag{2}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2. \tag{3}$$

Here, $\nu_t \sim i.i.d.N(0,1)$, $\alpha_0>0$, $\alpha_1 \geqslant 0$, $\alpha_2 \geqslant 0$.

According to the basic elements chosen in this paper, the GARCH (1,2) model used to examine the effect of foreign exchange intervention is

$$\Delta S_t = \beta_0 + \beta_1 \Delta S_{t-1} + \beta_2 \mathrm{In}t_t + \varepsilon_t, \tag{4}$$

$$\varepsilon_t = \sigma_t \nu_t, \tag{5}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2 + \alpha_3 \sigma_{t-2}^2 + \varphi_1 |\, \mathrm{In}t_t \,|. \tag{6}$$

Here, $\nu_t \sim i.i.d.N(0,1)$, $\alpha_i > 0$, $i=0,1,2$, $\varphi_j \geq 0$, $j=1,2,3$. ΔS_t is the RMB exchange rate return series, which depicts the first order difference of the exchange rate, ΔS_{t-1} is the first-order time delay of ΔS_t, $\mathrm{In}t_t$ is the number of foreign exchange interventions by the central bank.

3. TEST ON THE INHIBITORY EFFECT OF RMB FOREIGN EXCHANGE INTERVENTION ON EXCHANGE RATE FLUCTUATION

In this paper, the change of foreign exchange reserves is used as an alternative variable for foreign exchange intervention. The data is taken from the people's Bank of China website. The daily data of CHY/USD exchange rate is compiled into monthly data to match the foreign exchange intervention data.

3.1 Data Pretreatment

Since the exchange reform, China's foreign exchange reserves showed a rapid growth trend. By June 2014, foreign exchange reserves had increased fourfold. Both aggregate and growth rates are at record highs, as shown in Figure 1. At the same time, the RMB exchange rate is gradually appreciated with minor fluctuations, as shown in Figure 2. On the one hand, the rapid growth of foreign exchange reserves led to the expected appreciation of the CHY; on the other hand, the expected appreciation of the CHY also contributed to the increase in foreign exchange reserves.

Figure 1
Foreign Exchange Reserves From 2005 to 2017

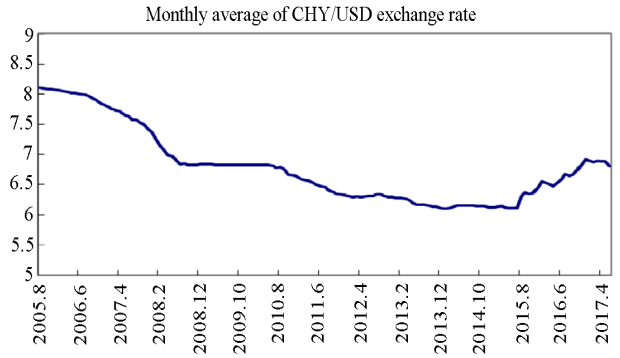

Figure 2
Monthly Average of CHY/USD Exchange Rate From 2005 to 2017

$\mathrm{In}t_t$ is foreign exchange intervention variable. The positive value is the amount of foreign exchange intervention in which the CHY is sold to buy the USD. Negative values indicate the amount of foreign exchange intervention in which the USD is sold to buy the CHY, as shown in Figure 3. As can be seen from the Figure 3, before 2008, the central bank's foreign exchange intervention was to buy dollars, and the number and frequency of foreign exchange intervention were relatively small. Between 2008 and 2010, due to the emergence of the international financial crisis, the frequency and amount of foreign exchange intervention were increasing, and there were also cases of selling dollars. From 2010 to 2014, the continuing impact of financial crisis, exchange rate reform in 2012, and the devaluation of the RMB exchange rate in 2014, the expansion of the floating range

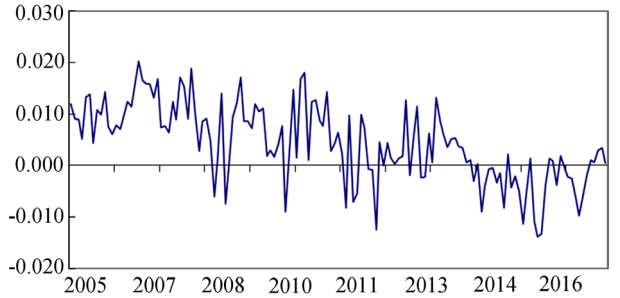

Figure 3
Foreign Exchange Intervention From 2005 to 2017

of exchange rate, all these factors have led to the frequent foreign exchange intervention. From 2014 to 2017, the CHY/USD exchange rate continued to depreciate, foreign exchange reserves declined, foreign exchange intervention appeared reverse intervention.

Exchange rate return series ΔS_t is derived from the daily reference rate for the CHY/USD and processed by logarithmic and differential. Foreign exchange intervention $\mathrm{In}t_t$ is derived from the foreign exchange reserves and processed by logarithmic and differential. Data is from the people's Bank of China website, a total of 143 samples, from September 2005 to June 2017. The data description statistics of ΔS_t and $\mathrm{In}t_t$ are shown in Table 1.

Table 1
Description Statistics of Sample

Statistic	Mean	Standard deviation	Max	Min	Kurtosis	Skewness
ΔS_t	-0.0005	0.0024	0.0132	-0.0071	8.0065	1.6759
$\mathrm{In}t_t$	0.0043	0.0076	0.0202	-0.0139	-0.5055	-0.1683

The kurtosis of exchange rate volatility ΔS_t is greater than 3, the kurtosis of normal distribution. It shows that the fluctuation in the exchange rate is characterized by "peak, thick tail". Therefore, the GARCH model is usually used to study this fluctuation of exchange rate. The exchange rate volatility series is tested by the ARCH-LM effect. The results show that the value is stills less than the significant level 0.05 in the case of 10 order lag. This shows that the residual series has higher order ARCH effects, so the exchange rate volatility series is applicable to the GARCH model. In order to determine the order of the GARCH model, the AIC criterion and the SC criterion are used as the criterion. There is little difference between the standardized residuals in different orders. Finally, GARCH (1,2) model is selected according to the significance.

3.2 Empirical analysis

First, the unit root tests of ΔS_t and $\mathrm{In}t_t$ are used to determine whether the series are stable.

Table 2
ADF Test for ΔS_t and Int_t

	ADF	*p*
ΔS_t	-3.4472	0.0116
$\mathrm{In}t_t$	-8.8517	0.0000

From the test results, the ΔS_t and $\mathrm{In}t_t$ all are stationary series. Next, we estimate the GARCH model.

The GARCH (1,2) model is about foreign exchange intervention strategies and intervention effects. The empirical results are as follows:

Mean equation:

$$\Delta S_t = \underset{(0.21)}{3.56E-05} + \underset{(12.15)}{0.3265}\Delta S_{t-1} \underset{(-4.88)}{-0.0927}\mathrm{In}t_t + \varepsilon_t, \quad (7)$$

$$R^2=0.36,\ DW=1.8$$

Variance equation

$$\sigma_t^2 = \underset{(19.5)}{1.91E-07} + \underset{(9.88)}{0.0081}\varepsilon_{t-1}^2 + \underset{(295.63)}{1.9428}\sigma_{t-1}^2 \underset{(-150.55)}{-0.9955}\sigma_{t-2}^2 \underset{(-10.23)}{-1.01E-05}|\mathrm{In}t_t|. \quad (8)$$

As can be seen from the above results, the coefficients of the GARCH model are significant at the significant level of 0.05. We continue to perform ARCH-LM tests on residual series. The results show that the *p* value is still greater than the significant level 0.05 from the lag 1 order to the lag 10 orders. This shows that the residual series no longer have autoregressive conditional heteroscedasticity, so the residual series has no autocorrelation.

In the mean equation, the coefficient of exchange rate return in delay period ΔS_{t-1} is 0.3265. This means that when the exchange rate return in delay period rises (or falls) by 1%, the exchange rate return in current period will rise (or fall) by 0.3265%. The RMB exchange rate is an asset price, so the demand for foreign exchange assets by foreign exchange market participants depends on the expected rate of asset return. When the RMB exchange rate falls, the foreign exchange market participants expect the CHY to appreciate, thus the participants accelerated the purchase of CHY. As a result, the demand for USD in the foreign exchange market will be reduced, and the RMB exchange rate will continue to decline. This indicates that the RMB will continue to appreciate.

In the mean equation, the coefficient of foreign exchange intervention $\mathrm{In}t_t$ is significantly negative. This means that the direction of exchange rate changes in accordance with the direction of intervention after the intervention event. So it indicates that foreign exchange intervention has effectively affected the exchange rate level. The coefficient of foreign exchange intervention $\mathrm{In}t_t$ is -0.0927. This shows that if China's foreign exchange reserves growth rate increased by 1%, while the growth rate of the RMB exchange rate return will decline by 0.0927%, the appreciation rate is reduced by

0.0927%; on the contrary, if China's foreign exchange reserves growth rate dropped by 1%, the growth rate of the RMB exchange rate return will rise 0.0927%, the appreciation rate increased by 0.0927%. Foreign exchange intervention can reduce the appreciation of the RMB exchange rate to a certain extent, but it cannot completely inhibit the appreciation of the exchange rate.

In the variance equation, the coefficient of foreign exchange intervention is significantly negative, which means that foreign exchange intervention will reduce the exchange rate fluctuations. Although the coefficient is very small, it also shows the effect of leveling the fluctuations.

3.3 Scenario Simulation of Foreign Exchange Intervention

In this section, we make a scenario simulation analysis of the GARCH (1,1) model about the foreign exchange intervention strategy and intervention effect. We suppose three scenarios: the rapid appreciation model of CHY, the model of financial crisis and the devaluation mode of CHY.

Situation 1: The rapid appreciation model of CHY. The period was from September 2005 to May 2008. This period was the initial stage of the exchange rate reform in 2005. The exchange rate of CHY/USD increased rapidly and the intervention rate of foreign exchange was small.

Situation 2: The model of financial crisis. The period was from June 2008 to May 2010. This period coincided with the international financial crisis. In order to protect the CHY from the international financial crisis, the central bank has adopted more stringent foreign exchange intervention measures, the exchange rate of CHY/USD suspended appreciation.

Situation 3: The devaluation mode of CHY. The period was from July 2015 to April 2017. Influenced by the political and economic factors at home and abroad, the RMB depreciated. The central bank adopted more intervention measures, and the amount of foreign exchange intervention was relatively large. Foreign exchange intervention was mainly reverse intervention.

We use the mean Equation (7) of the GARCH model to simulate the above three scenarios, and then compare them with the actual exchange rate volatility series, the results are as follows:

Figures 4, 5, and 6 show that the effect of scenario simulation analysis of the GARCH (1,2) model is very well. The simulation results in three scenarios fit the trend of exchange rate yield very well. In the period of rapid appreciation of the CHY, the direction of foreign exchange intervention was single, all buying foreign exchange.

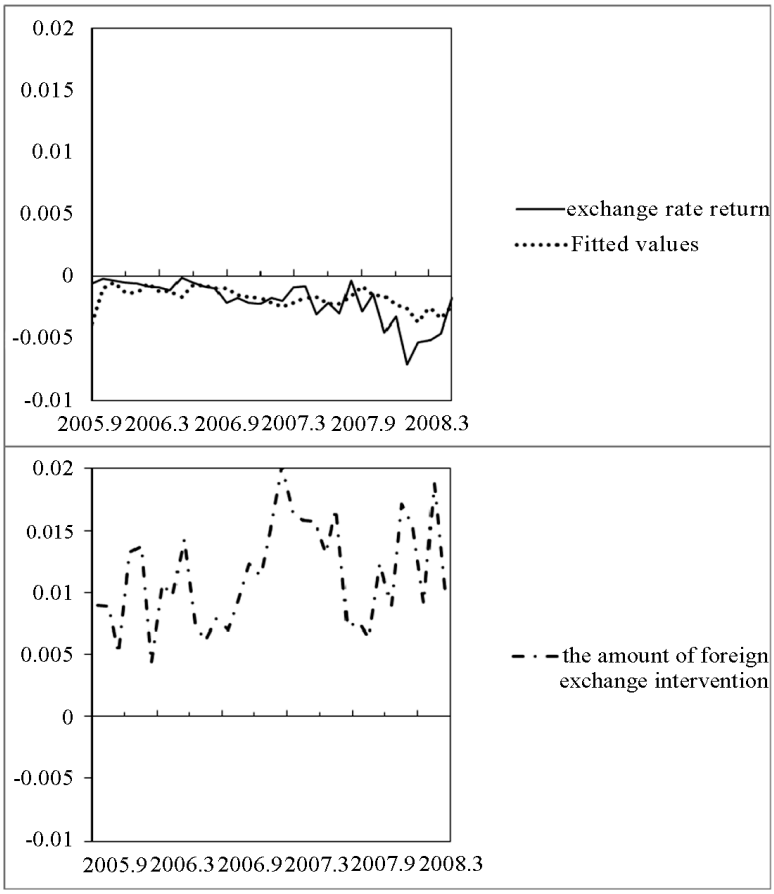

Figure 4
The Fitted Value of Exchange Rate Return From September 2005 to May 2008

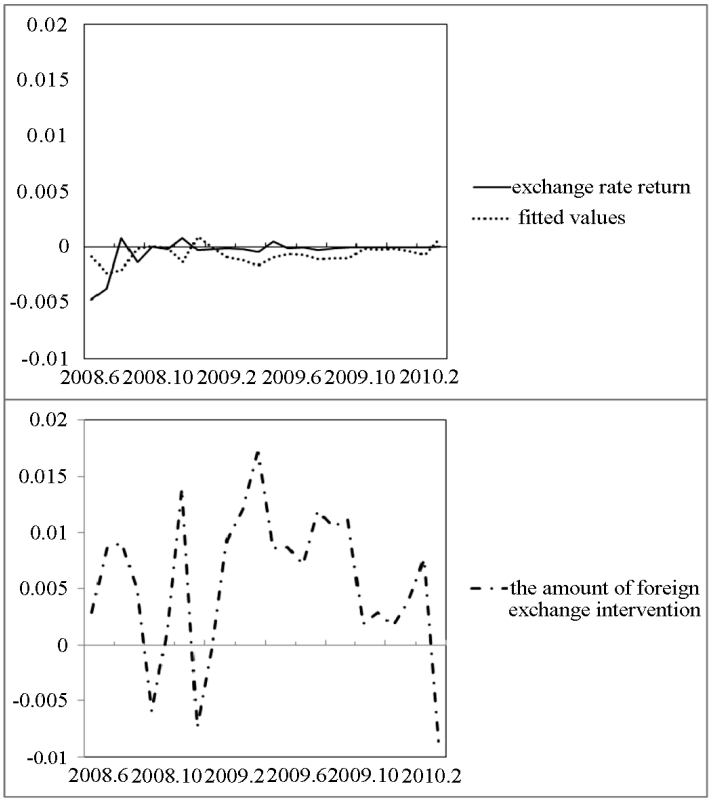

Figure 5
The Fitted Value of Exchange Rate Return From June 2008 to May 2010

During this period, the exchange rate maintained a trend of appreciation and fluctuated considerably. Under foreign exchange intervention, exchange rate fluctuations were moving closer to intervention. During the financial crisis, the intensity of foreign exchange intervention was increasing, and there was also two-way interference. The

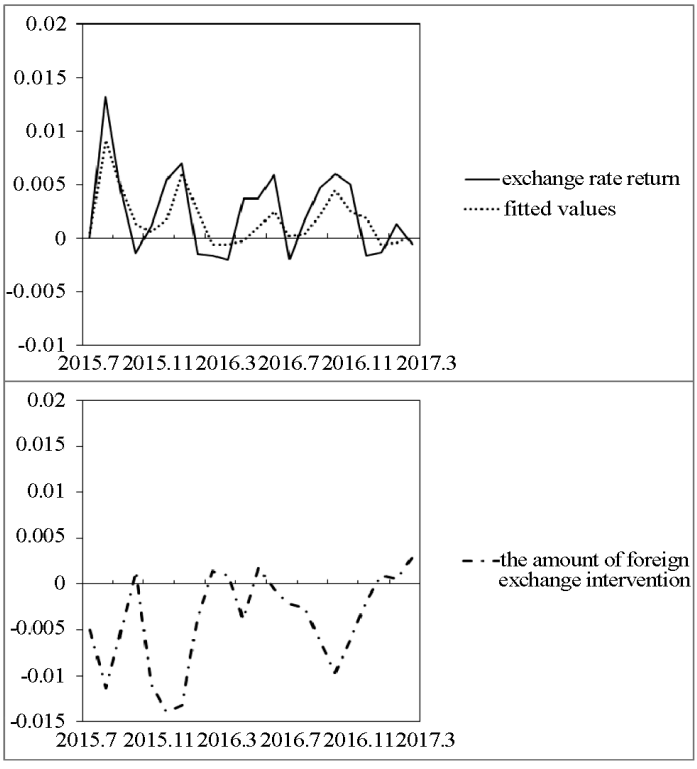

Figure 6
The Fitted Value of Exchange Rate Return From July 2015 to April 2017

exchange rate remained stable and fluctuated very little during this period. Under foreign exchange intervention, the exchange rate changed within a predetermined range.

During the period of the devaluation of the exchange rate, the central bank intervened frequently in 2015. The intensity of foreign exchange intervention is increasing and there is a counter directional intervention. During this period, the exchange rate began to depreciate, and there was a two-way fluctuation. Under the foreign exchange intervention measures, the fluctuation of exchange rate approached the direction of intervention, and the fluctuation gradually decreased.

Our country has managed floating exchange rate system. Since the reform of the exchange rate system, the central bank has made frequent intervention in the foreign exchange market. The central bank directly purchases and sells USD assets in the foreign exchange market, in order to avoid the sharp fluctuation of the exchange rate, maintain the exchange rate at a reasonable level and avoid the appreciation of the CHY. At the same time if the central bank take sterilized intervention in China, use open market operations and other monetary policy tools to offset the effect of the dollar traded on money supply, then the basic money supply will remain unchanged, the demand for the dollar will increase, the CHY will depreciate. On the contrary, when the central bank adopts non sterilized intervention, buys the dollar assets in the foreign exchange market, and the money supply on the market will increase, the CHY will depreciate. After the second exchange rate reform in 2012, the foreign exchange intervention measures by China's central bank were more frequent, and achieved results.

In conclusion, the GARCH (1,2) model is a good indication of the relationship between foreign exchange intervention and intervention effect. At the same time, the model also confirms that foreign exchange intervention has a restraining effect on exchange rate fluctuations. The foreign exchange intervention can effectively change the exchange rate, levels the fluctuations of the exchange rate, and makes exchange rate levels back to the target area.

CONCLUSION

In this article, we discussed the foreign exchange intervention measures taken by the Central Bank of China to the CHY/USD exchange rate. China's exchange rate system adopts a managed floating exchange rate system. The management of exchange rate system is reflected in foreign exchange intervention. China's central bank will adjust the fluctuation range of the exchange rate according to the international balance of payments. This can effectively deal with changes in the international and domestic financial markets, to prevent fluctuations in the exchange rate. In this paper we use the RMB exchange intervention data from 2005 to 2014 to examine the effectiveness of foreign exchange interventions by China's central bank. The foreign exchange intervention variables are introduced into the GARCH model to analyze the fluctuation of exchange rate and the impact of foreign exchange intervention on exchange rate fluctuations. In the mean equation, the coefficient of foreign exchange intervention Int_t is significantly negative. This means that the direction of exchange rate changes in accordance with the direction of intervention after the intervention event. So it indicates that foreign exchange intervention has effectively affected the exchange rate level. The coefficient of foreign exchange intervention Int_t is -0.0552. This shows that if China's foreign exchange reserves growth rate increased by 1%, while the growth rate of the RMB exchange rate return will decline by 0.05%, the appreciation rate is reduced by 0.05%; on the contrary, if China's foreign exchange reserves growth rate dropped by 1%, the growth rate of the RMB exchange rate return will rise 0.05%, the appreciation rate increased by 0.05%. Foreign exchange intervention can reduce the appreciation of the RMB exchange rate to a certain extent, but it cannot completely inhibit the appreciation of the exchange rate. In the variance equation, the coefficient of foreign exchange intervention is significantly negative, which means that foreign exchange intervention will reduce the exchange rate fluctuations. Although the coefficient is very small, it also shows the effect of leveling the fluctuations.

We make a scenario simulation analysis of the GARCH (1,1) model of the foreign exchange intervention strategy and intervention effect in three different scenarios: the CHY quick appreciation model, the financial crisis model and the CHY devaluation model. That effect of scenario simulation analysis of the GARCH (1,1) model is very well. The simulation results in three scenarios fit the trend of exchange rate yield very well. The intervention of foreign exchange intervention in CHY/USD exchange rate market is effective intervention on the exchange rate and the fluctuation of exchange rate.

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