


Autocorrelation Regression Model Analysis and Selection of Cross-Border RMB Settlement From 2011 to 2020

Cheng Zhang, Yangtze Normal University, China*

 <https://orcid.org/0000-0002-2003-4174>

Ni Hu, Southwest University of Science and Technology, China

Qiang Yan, Hezhou University, China

ABSTRACT

With China's continuous opening to the outside world, changes in the international environment and the operation of the cross-border RMB settlement system (CIPS), the scale of cross-border RMB settlement has fluctuated continuously. In response to this phenomenon, the authors collected and sorted out the total amount of RMB cross-border settlement and payments from 2011 to 2020 time sequence data in China, then use five AR models including ARMA, GARCH(1.1), EGARCH(1.1), PARCH(1.1), and CARCH(1.1) to fit. The experimental results show that the four autocorrelation models all prove that the cross-border RMB settlement has autocorrelation relationship, and the long-term trend continues to grow up. According to the precision and accuracy of the five models, the ARMA model equation is one optimal prediction equation. On the basis of the ARMA model equation, and the establishment of the VENSIM system dynamics simulation model, the scale of China's cross-border RMB settlement in the next 10 years is predicted.

KEYWORDS

Autocorrelation Regression Model, Cross-Border RMB, Simulation Prediction

RESEARCH BACKGROUND

Since China underwent reform and opened up in the 1980s, especially after its entry into the World Trade Organization (WTO) in the early 21st century, China's economic growth and GDP have grown quickly under the pull of the troika. The pulling effect of exports was particularly obvious. China's foreign trade dependence was once as high as 65.2%, but now China is the world's leading import and export trading country and the largest trading partner (it has trade partnerships with more than 120 countries). However, in the international trade settlement, China's import and export enterprises have long relied on U.S. dollars and euros for settlement. In the settlement process, China must pay high

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*Corresponding Author

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currency exchanges and other related fees, as well as the seigniorage of the relevant currency. This financial situation is very inconsistent with China's global international trade "buy the world and sell the world" situation, which embarrassingly becomes selling Chinese goods, but using other countries' currencies. This kind of situation is similar to a little daughter-in-law living under the in-laws' roof, and it makes the majority of Chinese people and foreign friends with a sense of justice feel sad.

The road to renminbi (RMB) internationalization in China is quite tortuous and difficult. On November 30, 2015, the RMB was delayed in obtaining the special drawing rights (SDR) of the International Monetary Fund. This right would accelerate the process of the internationalization of the RMB and make it a real international currency. Russia, Israel, Iran, and other countries have used RMB as a foreign exchange reserve currency, and kept increasing their holdings to resolve various economic crises under special conditions. The RMB reserves also played a role in defusing the economic crisis in Russia during the Russian-Ukrainian War when the dollar reserves were frozen. At the same time, in the process of international trade settlement activities, the willingness of people in various countries to use RMB has been increasing. At present, the use of RMB in cross-border settlement is expanding year by year, but its market use ratio is only about 2% to 3%, and the U.S. dollar and euro generally account for 30% to 70%. There is a lot of room for development and resistance, and the future development trend of the RMB needs to be studied in depth.

LITERATURE REVIEW

The reports and research results of scholars and media on the cross-border settlement of the RMB in the past three years mainly focus on the following aspects:

- The main factors of cross-border settlement of the RMB.
- The use of cross-border RMB settlement in some key countries and regions such as East Asian countries, Association of Southeast Asian Nations (ASEAN) countries, and China's Belt and Road Initiative (formerly One Belt, One Road).

Main Influencing Factors of Cross-Border RMB Settlements

In international trade and settlement practices, cross-border RMB settlement is affected by various internal and external factors. Bilateral currency swap agreements between China and different countries can promote the expansion of RMB cross-border settlement business (Fuhua Deng et al., 2020; Shanshan & Xiaoqian, 2019), whereas RMB money supply and foreign exchange reserve structures are constraints for the cross-border RMB settlement (Sui & Xinyu, 2021). The exchange rate factors have a two-way impact on cross-border RMB settlements (Guangming & Feng, 2021; Weicheng et al., 2021; Yu & Qinwen, 2021.). Institutional, legal, and cultural influences on RMB internationalization have a positive effect (Jinkai, 2019; Yi & Guozheng, 2021; Yixin & Jingyi, 2021).

The Use of Cross-Border RMB Settlements in Key Regions

Under the direction of the Belt and Road Initiative (One Belt, One Road), China has carried out economic and trade exchanges with more than 100 countries. The financial depth, trade breadth, investment intensity, and other factors of mutual cooperation drive the development of cross-border RMB settlement (Changshan, 2020; Hongying, 2021; Lixin, 2020; Qingjun & Xinyue, 2020; Xiaofen et al., 2018). The five Central Asian countries are friendly neighbors in the western border area of China. Since ancient times, border trade exchanges have been formed. Through infrastructure construction, technical exchanges, trade scale, medical resource sharing, and other measures, the main role of the cross-border RMB settlement has been gradually expanded (Xianzheng, 2018; Yanhong & Lizhen, 2022). The ASEAN became China's largest trading partner in 2020. A bilateral local

currency settlement is the common wish of both parties, and the cross-border RMB settlement will be promoted based on the principle of mutual benefit and win-win (Tian, 2021; Yixing et al, 2018).

The Dynamics of Cross-Border RMB Settlements in Border, Coastal, and Inland Highlands

The provinces and cities along the borders, coastal areas, and inland highlands are the pioneers in China's reform projects, taking the lead in developing their cross-border RMB business and becoming a model force for all parts of the country to learn from. Shanghai has made some innovative achievements in exploring cross-border RMB settlement policies and measures and has improved the mechanism design of cross-border settlement (Jie & Jing, 2020). Chongqing is oriented to serve the real economy and promote trade facilitation (Peisi & Yiping, 2022). Shenzhen, Qingdao, and other cities have made great efforts in cross-border RMB settlement services, improving electronics and intelligence, reducing settlement costs, and greatly improving settlement efficiency (Jun, 2022; Liyun & Na, 2022). About a quarter of the national cross-border RMB settlement volume comes from the Guangdong-Hong Kong-Macao Greater Bay Area (Siyi, 2021). Guangxi, Yunnan, and Xinjiang have exploited their geographical advantages along the borders, continuously carried out financial innovations, simplified the approval of the cross-border RMB settlement, and promoted cross-border settlement business by market-oriented means (Geping, 2021; Xiang, 2021; Yongfei, 2022).

In general, scholars have produced rich research results on the cross-border RMB settlement, but they mainly focus their research on the external location environment and influencing factors of cross-border RMB settlements, especially the research on China's border neighboring provinces, cities, and countries. There are few research results on the internal development of the RMB. From the perspective of multiple methods, this paper describes the autoregressive equation of cross-border RMB through models such as ARMA, GARCH (1, 1), EGARCH(1, 1), PARCH(1, 1), and CARCH(1, 1). Through the simulation analysis of VENSIM, the development trend of cross-border RMB settlements can be judged for the future.

MODEL ESTABLISHMENT AND SELECTION

The data in this article was mainly obtained from the official data of the People's Bank of China, and the starting year of the data is the financial statistics for a total of eight years from 2012 to 2020. According to the statistical data, the authors established a variety of autoregressive correlation models and chose the best of the best. The authors also chose the model with the highest fit and lowest error.

Establishment and Analysis of the ARMA Model

ARMA Regression Analysis

For the variable CNY regression equation part, using the ARMA model for regression, note that the CNY(-1) coefficient after regression is 1.211043, and its standard error is 0.117074, which is much smaller than one. The z-Statistic value is 10.34429, which is much larger than one. The accompanying probability is zero, less than 0.05. In addition, R-squared = 0.684476, adjusted R-squared = 0.684476, and the Durbin-Watson statistic is 2.15670, which value is approximately two. The above indicators show that the ARMA regression equation is well fitted. You can use the following regression equation representation: ARMA equation:

$$\text{CNY} = 1.211043\text{CNY}(-1) + \xi(0) \quad (1)$$

Here $\xi(0)$ - Random error varies close to zero for Std. Error = 0.117074.

Residual Test

As can be seen from Figure 1, the autocorrelation and partial correlation of the time series are both within the standard deviation two times, indicating the residual test can be passed. Also combined with the following P values, each P value is greater than 0.1, and even 4 P values are greater than 0.5. Consequently, the results are not significant, which cannot pass the primary hypothesis. Only a few errors exist, so function 1 can be accepted.

To further explore whether there is autocorrelation in this time series, a second-order autocorrelation test was performed by employing the Lagrange multiplier test method. The results are shown in Table 2. According to the results of the Lagrange multiplier test, the F value is 1.96608, the P value is 0.2343 > 0.5, and Prob. Chi-Square(2) is 0.1826 > 0.005, so there is no second-order autocorrelation.

Residuals, Actual, and Estimated Distributions

As shown in Figure 2, both the actual value and the predicted value show a clear upward trend over time; the cross-border RMB settlement volume in China shows a gradual upward trend. At the same

Table 1. ARMA Regression Model Parameter Values

Dependent Variable: CNY			Method: Least Squares	
Variable	Coefficient	Std. Error	t-Statistic	Prob.
CNY(-1)	1.211043	0.117074	10.34429	0.0000
R-squared	0.684476	Mean dependent var		10.33700
Adjusted R-squared	0.684476	S.D. dependent var		5.431964
S.E. of regression	3.051218	Akaike info criterion		5.185427
Sum squared resid	65.16950	Schwarz criterion		5.195357
Log likelihood	-19.74171	Hannan-Quinn criter.		5.118452
Durbin-Watson stat	2.152939	Date: 2022		

Figure 1. Residual Test Report

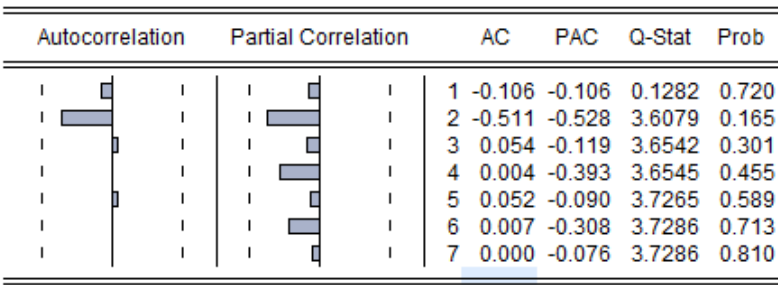


Table 2. Autocorrelation Tests

Breusch-Godfrey Serial Correlation LM Test			
F-statistic	1.966908	Prob. F (2,5)	0.2343
Obs*R-squared	3.400563	Prob. Chi-Square(2)	0.1826

time, note that the actual value and the predicted lines go hand in hand. The residual value is stable between 0 and 4 in most years. From 2012 to 2015, the residual curve shows a slow upward trend. It turned downward in 2015, turned upward again in 2016, and turned downward again in 2018. The residual distribution fluctuates very little, but frequently, the population fluctuates up and down around the $x = 0$ axis, indicating that the residual distribution falls within an acceptable range.

ARMA Heteroscedasticity Test

In the results of the heteroscedasticity test shown in Table 3, the F-statistic value is 0.033918, which is much smaller than the critical value of 6.61 (at the 5% significance level). Note that the P value Prob. $F(1,5) = 0.8611$ and Prob. Chi-Square (1) = 0.8281. Both values are far greater than 0.05. On the whole, this data indicates there is no heteroscedasticity. In addition, in the test equation, the P value of the constant C and the P values of $RESID^2(-1)$ are also much larger than 0.05, while R-squared = 0.006738. These two test values indicate that the variables of the equation are not significant; therefore, the goodness of fit is not high.

ARMA Dynamic and Static Error Prediction

From the dynamic forecast chart shown in Figure 3, the 2S.E double-standard error deviates from $x = 0$ increasingly over time and shows a divergent trend. The error increases with the passage of time, and the forecast value CNYF is increasingly more deviated.

From the statistical point of view, the Theil coefficient value is 0.310956, the root mean square error is 5.507639, the average absolute error is 4.646563, and the average relative error absolute value is 41.13473. The values of these four indicators are too large, indicating that the prediction error is large. Additionally, the covariance ratio is only 0.059235, which is much less than one, so this prediction was inaccurate.

From the static forecast shown in Figure 4, the 2S.E double-standard error first deviates from the x axis increasingly over time, showing a divergent trend. The error decreases over time and turns downward in 2016. The error then decreases over time, showing a convergence trend. The predicted value CNYF is getting farther and farther apart, and it turns up again in 2018. The error increases over time, showing a divergent trend. The predicted value CNYF is getting closer and closer together, and the overall variance trend is first. It would rise, and then fall, and rise again.

According to the static prediction statistics, the root mean square error is 2.854153, the average absolute error is 2.350569, the average relative error absolute value is 24.31958, and the Theil coefficient value is 0.125859. Compared with the dynamic prediction results, the index values are

Figure 2. Distribution of Residual, Actual, and Predicted Values

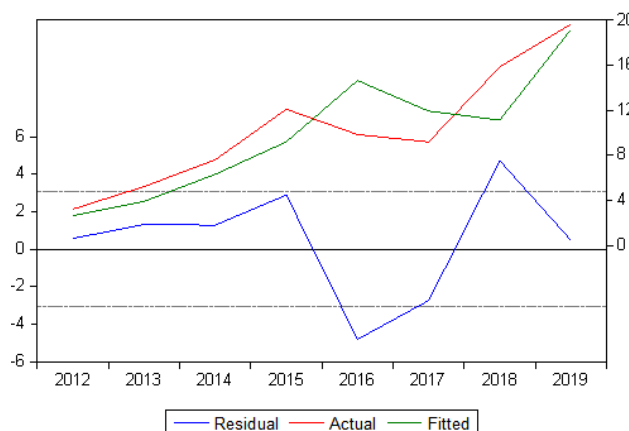


Table 3. Heteroscedasticity Test Parameter Values

Heteroscedasticity Test		ARCH		
F-statistic	0.033918	Prob. F(1,5)		0.8611
Obs*R-squared	0.047166	Prob. Chi-Square(1)		0.8281
Dependent Variable: RESID^2		Method: Least Squares		
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.02634	5.749564	1.743844	0.1416
RESID^2(-1)	-0.082216	0.446414	-0.184169	0.8611
R-squared	0.006738	Mean dependent var		9.263569
Adjusted R-squared	-0.191914	S.D. dependent var		9.664461
S.E. of regression	10.55116	Akaike info criterion		7.785305
Sum squared resid	556.6348	Schwarz criterion		7.769851
Log likelihood	-25.24857	Hannan-Quinn criter.		7.594293
F-statistic	0.033918	Durbin-Watson stat		1.977617
Prob(F-statistic)	0.861117	Date: 2022		

Figure 3. Dynamic Error Prediction Trend Graph

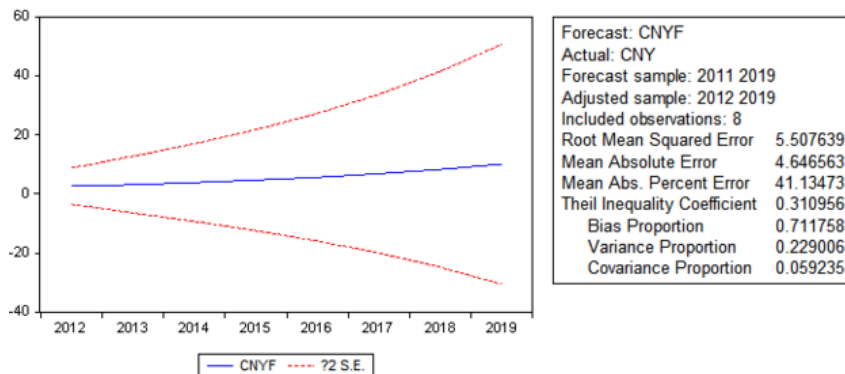
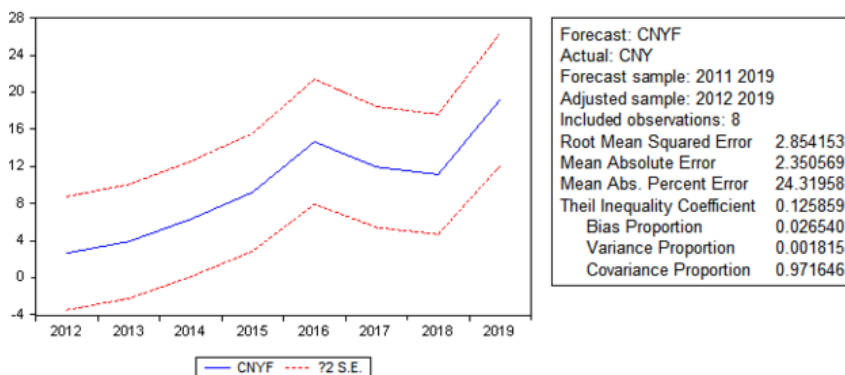


Figure 4. Static Error Forecast Trend Graph



almost reduced by half. The covariance ratio is also as high as 0.971646. On the whole, the accuracy of the static prediction is higher and more in line with the actual situation. This result can also be obtained by observing the previous sample data.

GARCH (1, 1) Model Establishment and Analysis

GARCH (1, 1) Regression Analysis

For the variable CNY regression equation, the GARCH(1, 1) model was used for regression. The values are shown in Table 4. Note that the CNY(-1) coefficient after regression is 1.253784, and its standard error is 0.207168, which is much smaller than one. The z-Statistic value is 6.052023, which is far greater than one, and the associated probability is zero, less than 0.05. The above indicators indicate that the CARCH(1, 1) regression equation is well fitted and that it can be expressed by the following regression equation: GARCH(1, 1) equation:

$$\text{CNY} = 1.253784\text{CNY}(-1) + \xi(0) \quad (2)$$

For the Variance Equation part of the variance equation, it is shown in Table 4 that R-squared = 0.678468, adjusted R-squared = 0.678468, and the Durbin-Watson statistic is 2.202354, approximately two, which makes it seem that the fit is better. However, from the GARCH(1, 1) variance equation C, RESID(-1)^2, GARCH(-1) of the accompanying probability p values are 0.8862, 0.7089, 0.6975, which are bigger than 0.05, and the t values are all small (-0.143116, -0.373296, and 0.388749, respectively) indicating that C, RESID(-1)^2, GARCH(-1) values are not significant. The standard error S.E. after regression is 3.080129, and the residual variance sum is 66.41036; thus, the error is too large. In addition, the coefficient of RESID(-1)^2 is -0.720382 < 0, the coefficient of GARCH(-1) is 2.182676 > 0, and only one coefficient is positive, which also means that the regression result is not long-term and is unreliable. Therefore, the corresponding GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1) equation does not hold.

Table 4. GARCH (1, 1) Regression Model Parameter Values

Dependent Variable: CNY			Sample (Adjusted): 2012 2019	
Method: ML - ARCH (Marquardt) - Normal Distribution				
Convergence Achieved After 13 Iterations, Pre-Sample Variance: Backcast (Parameter = 0.7)				
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
CNY(-1)	1.253784	0.207168	6.052023	0.0000
Variance Equation				
C	-3.279069	22.91194	-0.143116	0.8862
RESID(-1)^2	-0.720382	1.929788	-0.373296	0.7089
GARCH(-1)	2.182676	5.614613	0.388749	0.6975
R-squared	0.678468	Mean dependent var		10.33700
Adjusted R-squared	0.678468	S.D. dependent var		5.431964
S.E. of regression	3.080129	Akaike info criterion		5.158571
Sum squared resid	66.41036	Schwarz criterion		5.198292
Log likelihood	-16.63428	Hannan-Quinn criterion		4.890670
Durbin-Watson stat	2.202354	Date: 2022		

GARCH (1, 1) Residual Analysis

Figure 5 indicates that the autocorrelation and partial correlation of the time series are both within two times of the multiple standard deviation. When these values are combined with the following P values, each P value is greater than 0.3, and even four P values are greater than 0.5, which means that the results are not significant and the residual sequence has no autocorrelation relationship. This data indicates that if other factors are not considered, the error can be ignored and the equation(2) is correct.

GARCH (1, 1) Residual Analysis

According to Figure 6, both the actual value and the predicted value show a clear upward trend; that is, with the passage of time, the cross-border RMB settlement volume shows a gradual upward trend in China. At the same time, it can be seen that the actual value and the predicted value go hand in hand. The residual value is stable between zero and four in most years. From 2012 to 2015, the residual curve shows a slow upward trend. It turned downward in 2015, turned upward again in 2016, and turned downward again in 2018. The residual distribution fluctuates very little, but frequently, the population fluctuates up and down around the $x = 0$ axis, indicating that the residual distribution falls within an acceptable range.

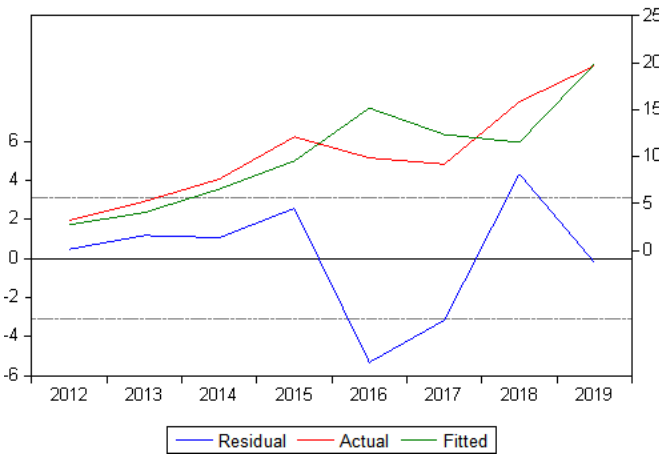
GARCH (1, 1) Heteroscedasticity Test

In the heteroscedasticity test results shown in Table 5, the F-statistic = 1.093586 < 6.61 (at the 5% level of significance). In addition, Prob. F(1,5) = 0.3436, and Prob. Chi-Square(1) = 0. 0.2624, which

Figure 5. Residual Test Report

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 -0.292 -0.292	0.9758	0.323	
		2 -0.243 -0.360	1.7659	0.414	
		3 0.222 0.026	2.5555	0.465	
		4 -0.144 -0.169	2.9674	0.563	
		5 0.014 -0.012	2.9729	0.704	
		6 -0.024 -0.146	2.9956	0.809	
		7 -0.034 -0.068	3.0857	0.877	

Figure 6. Distribution of Residual, Actual, and Predicted Values



cannot pass the heteroscedasticity test. Consequently, the null hypothesis of is accepted. There is no heteroscedasticity. In addition, in the test equation, the P value of the constant C is 0.1732, and the P value of $RESID^2(-1)$ is 0.3436. Both these values are greater than 0.05, indicating that the coefficients of each variable in the test equation are still insignificant. Moreover, $R\text{-squared}=0.179465$, indicating that the goodness of fit of the equation is not high. Overall, although the improved GARCH(1,1) is better than the ARMA model, there is still no ARCH effect In the GARCH(1, 1) model.

GARCH (1, 1) Error Prediction

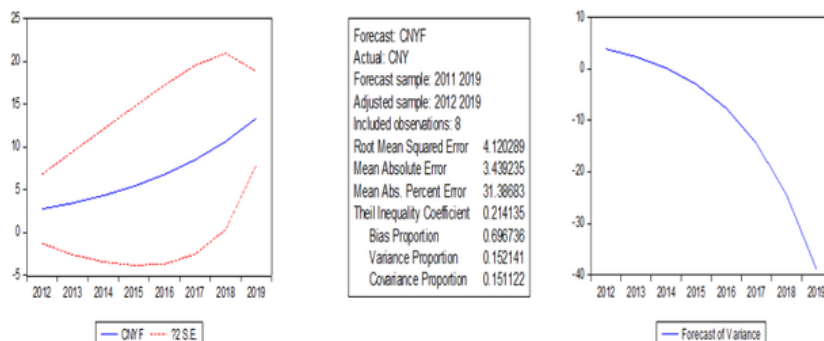
From the left side of Figure 7, the 2S.E double-standard error deviated from $x = 0$ with the passage of time, and showed a trend of first divergence and then convergence. The error first increased and then decreased with the passage of time. The degree of deviation from the predicted value CNYF also increased gradually. Note also in the right side of Figure 7 that the predicted value variance curve gradually deviates downward, and the variance gradually decreases, almost approaching zero.

From the statistical value, the Theil coefficient value was 0.214135, the root mean square error was 4.120289, the average absolute error was 3.439235, and the average relative error absolute value

Table 5. Heteroscedasticity Test Parameter Values

Heteroscedasticity Test: ARCH				
F-statistic	1.093586	Prob. F(1,5)	0.3436	
Obs*R-squared	1.256255	Prob. Chi-Square(1)	0.2624	
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.748811	0.471654	1.587629	0.1732
WGT_RESID^2(-1)	0.383214	0.366450	1.045746	0.3436
R-squared	0.179465	Mean dependent var		1.115838
Adjusted R-squared	0.015358	S.D. dependent var		0.840102
S.E. of regression	0.833626	Akaike info criterion		2.708893
Sum squared resid	3.474662	Schwarz criterion		2.693439
Log likelihood	-7.481125	Hannan-Quinn criterion		2.517881
F-statistic	1.093586	Durbin-Watson stat		2.409255
Prob(F-statistic)	0.343576	Date: 2022		

Figure 7. Dynamic Error Prediction Trend Graph



was 31.38683. The values of these four indicators were too large, indicating that the prediction error was large. Additionally, the covariance ratio is only 0.151122, which is much less than one, so this prediction is not very accurate.

From the static prediction on the left side of Figure 8, the 2S.E double-standard error first deviates from the x axis increasingly with the passage of time, showing a divergent trend. The error increases with the passage of time, but after the curve reaches the apex, turning down, the error increases over time, showing a convergence trend. the upper end is getting closer and closer to the predicted value CNYF, and then continues to deviate upward; the lower end deviation gradually increases, and the overall variance trend first increases and then decreases. From the right side of Figure 8, note that the variance curve of the predicted value gradually deviates upward, and then turns downward after reaching the peak value, and the overall variance trend first increases and then decreases.

According to the static prediction statistics, the root mean square error is 2.881197, the average absolute error is 2.287320, the average relative error absolute value is 23.67060, and the Theil coefficient value is 0.124883. Compared with the dynamic prediction results, the index values have dropped significantly. In addition, the covariance ratio is also as high as 0.987142. On the whole, the accuracy of static prediction is higher and more in line with the actual situation. This result can also be obtained by observing the previous sample data.

EGARCH (1, 1) Model Establishment and Analysis

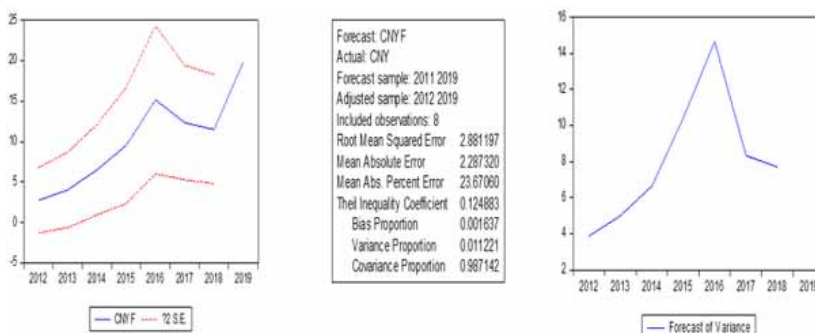
EGARCH (1, 1) Regression Analysis

For the variable CNY regression equation, the EGAHCH(1, 1) model was used for regression. Note that the CNY(-1) coefficient after regression is 1.242350, and its standard error is 0.182438, which is much smaller than one. The z-Statistic value is 6.809719, which is far more than one. The associated probability is zero, less than 0.05. The above indicators show that the EGAHCH(1, 1) regression equation fits well and that it can be expressed by the following regression equation: EGAHCH(1, 1) equation:

$$\text{CNY} = 1.242350\text{CNY}(-1) + \xi(0) \quad (3)$$

For the Variance Equation part of the variance equation, Table 6 shows that R-squared = 0.681253, adjusted R-squared = 0.681253, and the Durbin-Watson statistic 2.196962, was approximately two, which indicates that the fit was better. However, from the GARCH(1,1) variance equations C(2), C(3), C(4), and C(5), the accompanying probabilities p-values are 0.9842, 0.8206, 0.9974, and 0.5990, respectively, and the t values are all too small, indicating that the coefficients C(2), C(3), C(4), and C(5) are not significant. The standard error S.E. after regression is 3.051272, and the residual variance sum is 65.17181, which shows that the error is too large. Therefore, in its corresponding equation

Figure 8. Static Error Forecast Trend Graph



$\text{LOG}(\text{GARCH}) = C(2) + C(3) * \text{ABS}(\text{RESID}(-1) / @ \text{SQRT}(\text{GARCH}(-1))) + C(4) * \text{RESID}(-1) / @$, the equation $\text{SQRT}(\text{GARCH}(-1)) + C(5) * \text{LOG}(\text{GARCH}(-1))$ does not correct.

EGARCH (1, 1) Residual Analysis

According to Figure 9, both the actual value and the predicted value show a clear upward trend; that is, with the passage of time, the cross-border RMB settlement volume in China shows a gradual upward trend. At the same time, it can be seen that the actual value and the predicted value go hand in hand, so the function seems to be accurate. The residual value is stable between zero and four in most years. From 2012 to 2015, the residual curve shows a slow upward trend. It turned downward in 2015, turned upward again in 2016, and turned downward again in 2018. The residual distribution fluctuates very little, but frequently, the population fluctuates up and down around the $x=0$ axis, indicating that the residual distribution falls within an acceptable range.

The residual analysis chart in Figure 10 shows that although the residual shows a left-biased trend, it cannot be seen whether the residual histogram falls within the normal distribution area. However, from the residual statistical values, note that the mean is 0.152214, which is close to zero; the Median is 0.330366, which is close to zero; the standard error is 0.994637, the null hypothesis of the distribution. Therefore, the regression model estimated above is shown to be meaningful.

EGARCH (1, 1) Error Prediction

From the left side of Figure 11, the double-standard error of 2S.E deviates from $x=0$ increasingly over time, and it shows a divergent trend. The error increases with the passage of time. On the other hand, CNYF variance is obviously a slope. The deviation of the variance curve of the predicted value gradually deviates downward, and the variance gradually decreases, and it is almost approaching zero in 2019, indicating the forecast is not too bad.

Table 6. EGARCH(1, 1) regression model parameter values

Dependent Variable: CNY,Method: ML - ARCH (Marquardt) - Normal Distribution				
Convergence Achieved After 39 Iterations				
Pre-Sample Variance: Backcast (Parameter = 0.7)				
$\text{LOG}(\text{GARCH}) = C(2) + C(3) * \text{ABS}(\text{RESID}(-1) / @ \text{SQRT}(\text{GARCH}(-1))) + C(4)$				
$* \text{RESID}(-1) / @ \text{SQRT}(\text{GARCH}(-1)) + C(5) * \text{LOG}(\text{GARCH}(-1))$				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
CNY(-1)	1.242350	0.182438	6.809719	0.0000
Variance Equation				
C(2)	0.112129	5.652313	0.019838	0.9842
C(3)	-1.159321	5.113338	-0.226725	0.8206
C(4)	0.009222	2.851061	0.003235	0.9974
C(5)	1.395563	2.654326	0.525769	0.5990
R-squared	0.681253	Mean dependent var		10.33700
Adjusted R-squared	0.681253	S.D. dependent var		5.431964
S.E. of regression	3.066763	Akaike info criterion		5.856162
Sum squared resid	65.83525	Schwarz criterion		5.905813
Log likelihood	-18.42465	Hannan-Quinn criterion		5.521286
Durbin-Watson stat	2.196962	Date: 2022		

Figure 9. Distribution of Residuals, Actuals, and Predictions

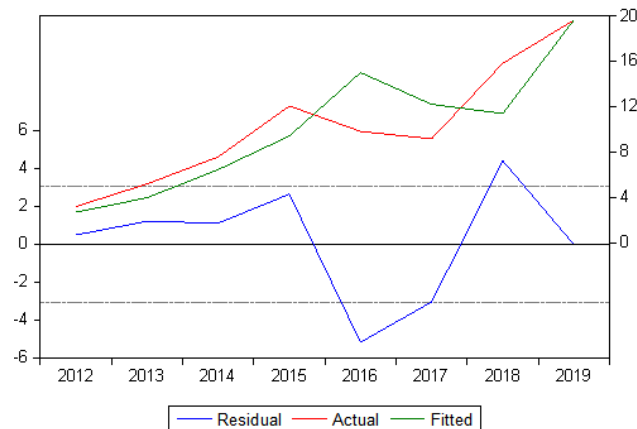


Figure 10. Residual Test Report

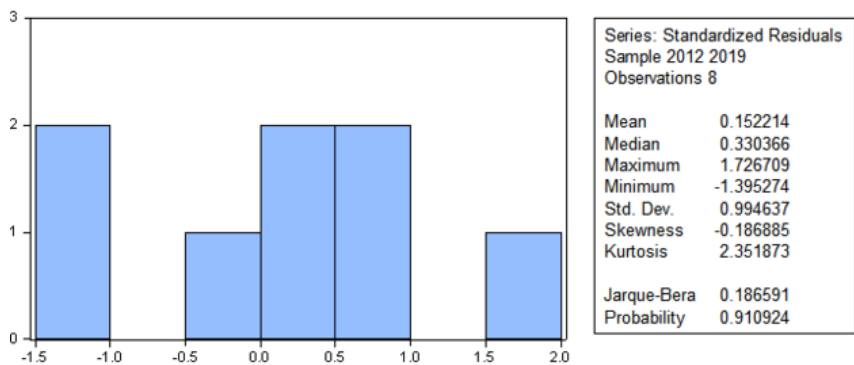
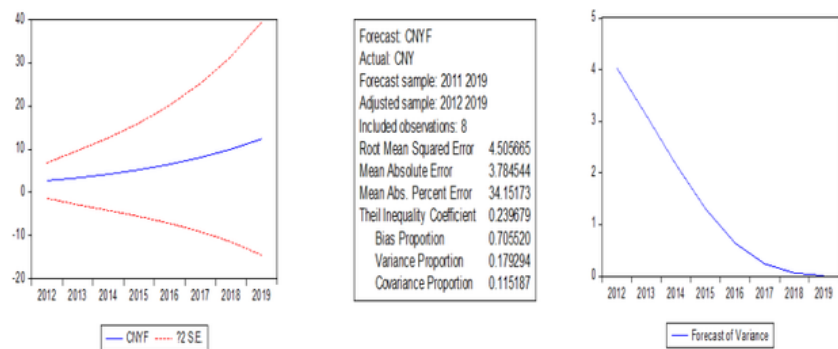


Figure 11. Dynamic Error Prediction Trend Graph



From the statistical value, the Theil coefficient value is 0.239679, the root mean square error is 4.505665, the average absolute error is 3.784544, and the average relative error absolute value is 34.15173. The values of these four indicators are too large, indicating that the prediction error

is large. Additionally, the covariance ratio is only 0.115187, which was much less than one, so this prediction is obviously not accurate.

From the static prediction on the left side of Figure 12, the 2S.E double-standard error first deviates from the x axis increasingly over time, showing a divergent trend, and the error increases with the passage of time, but after the curve reaches the apex, turning down, the error increases with time, showing a convergence trend. The upper end is getting closer and closer to the predicted value CNYF, and then it continues to deviate upward, and the lower end deviates gradually. The overall variance trend first increases and then decreases. In the right side of Figure 12, note that the variance curve of the predicted value gradually deviates upward and then turns downward after reaching the peak value. The overall variance trend first increases and then decreases.

According to the static prediction statistics, the root mean square error is 2.868694, the average absolute error is 2.272474, the average relative error absolute value is 23.68272, and the Theil coefficient value is 0.124911. Compared with the dynamic prediction results, the index values dropped significantly. In addition, the covariance ratio is also as high as 0.986684. On the whole, the accuracy of static prediction is higher and more in line with the actual situation. This result can also be accepted rationally.

PARCH (1, 1) Model Establishment and Analysis

PARCH (1, 1) Regression Analysis

For the variable CNY regression equation, using the PARCH(1, 1) model for regression shown in Table 7, note that the CNY(-1) coefficient after regression was 1.175888, and its standard error was 0.404774, which was much smaller than one. The z-statistic value is 2.905046, which is far from one. The associated probability is 0.0037, less than 0.05. The above indicators indicate that the PARCH(1, 1) regression equation is well fitted and that it can be represented by the following regression equation: PARCH(1, 1) equation:

$$\text{CNY} = 1.175888\text{CNY}(-1) + \xi(0) \quad (4)$$

For the Variance Equation part of the variance equation, note that in Table 7 R-squared = 0.680411, adjusted R-squared = 0.680411, and the Durbin-Watson statistic is 2.054731, approximately two thus, the fit appears to be better. However, from the PARCH(1,1) variance equations C(2), C(3), C(4), C(5), and C(6), the accompanying probabilities p-values are 0.9930, 0.9894, 0.9884, 0.8522, 0.9595, respectively. The t values are also all small, indicating that the coefficients C(2), C(3), C(4), C(5), and C(6) are not significant. The standard error S.E. after regression is 3.070807, and the residual variance is 3.070807. The sum is 66.00899, so the error is obvious, and therefore, its corresponding

Figure 12. Static Error Forecast Trend Graph

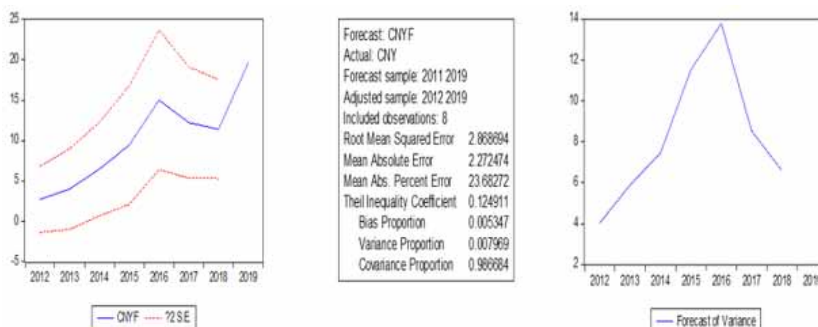


Table 7. PARCH (1, 1) Regression Model Parameter Value

Dependent Variable: CNY,Method: ML – ARCH (Marquardt) – Normal distribution				
Failure to Improve Likelihood After 14 Iterations				
WARNING: Singular covariance – coefficients are not unique				
Pre-Sample Variance: Backcast (Parameter = 0.7)				
@SQRT(GARCH)^C(6) = C(2) + C(3)*(ABS(RESID(-1)) – C(4)*				
RESID(-1))^C(6) + C(5)*@SQRT(GARCH(-1))^C(6)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
CNY(-1)	1.175888	0.404774	2.905046	0.0037
Variance Equation				
C(2)	3.962555	452.1672	0.008763	0.9930
C(3)	-0.123520	9.335894	-0.013231	0.9894
C(4)	-0.996699	68.68544	-0.014511	0.9884
C(5)	1.344084	7.215729	0.186271	0.8522
C(6)	2.840131	55.86525	0.050839	0.9595
R-squared	0.680411	Mean dependent var		10.33700
Adjusted R-squared	0.680411	S.D. dependent var		5.431964
S.E. of regression	3.070807	Akaike info criterion		6.146290
Sum squared resid	66.00899	Schwarz criterion		6.205871
Log likelihood	-18.58516	Hannan-Quinn criterion.		5.744439
Durbin-Watson stat	2.054731	Date: 2022		

@SQRT(GARCH)^C(6) = C(2) + C(3)*(ABS(RESID(-1)) – C(4)*RESID(-1))^C(6) + C(5)*@SQRT(GARCH(-1))^C(6) equation does not run.

PARCH (1, 1) Residual Analysis

According to the three-line chart shown in Figure 13, both the actual value and the predicted value show a clear upward trend; that is, with the passage of time, the cross-border RMB settlement volume in China shows a gradual upward trend. At the same time, it can be seen that the actual value and the predicted value go hand in hand. The residual value is stable between zero and four in most years. From 2012 to 2015, the residual curve shows a slow upward trend. It turned downward in 2015, turned upward again in 2016, and turned downward again in 2018. The residual distribution fluctuates very little, but frequently, the population fluctuates up and down around the $x=0$ axis, indicating that the residual distribution falls within an acceptable range.

The residual analysis chart in Figure 14 shows that although the residual shows a right-biased trend, whether the residual histogram falls within the normal distribution area cannot be seen. However, the residual statistical values shown in Figure 14 indicate that the mean is 0.294437, which is close to zero; the median is 0.490841, which is close to zero; and the standard error is 0.860463, the null hypothesis of the distribution. Thus, there is reason to think that the regression model estimated above is meaningful.

Figure 13. Distribution of Residuals, Actual, and Predicted Values

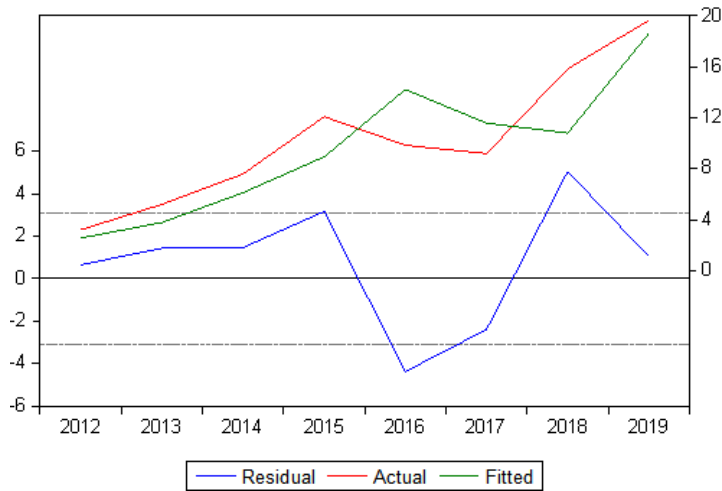
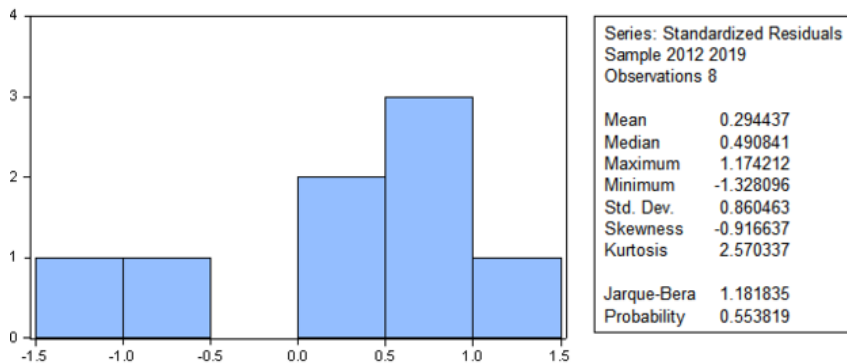


Figure 14. Residual Test Report



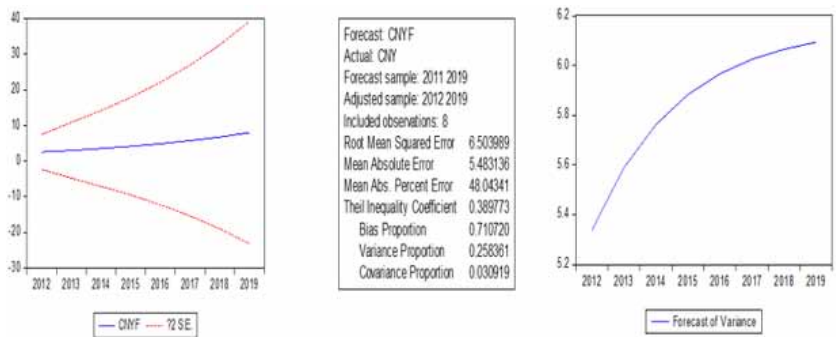
PARCH (1, 1) Error Prediction

From the left side of the dynamic forecast shown in Figure 15, the double- standard error of 2S.E deviates from $x = 0$ increasingly over time and shows a divergent trend. The error increases with the passage of time, and moves closer to the predicted value CNYF. Note also from the right side of Figure 15 that the variance curve of the predicted value deviates gradually upward, and the variance gradually increases.

From the statistical value, the Theil coefficient value is 0.389773, the root mean square error is 6.503989, the average absolute error is 5.483136, and the average relative error absolute value is 48.04341. The values of these four indicators are too large, indicating that the prediction error is large, and the covariance ratio is only 0.030919, which is much less than one, so this prediction is not too good.

From the static forecast on the left side of Figure 16, the 2S.E double-standard error deviates from the x axis increasingly over time, showing a divergent trend, and the error increases over time, but after the curve reaches the peak, it turns downward. The error increases with time, showing a convergence trend, and the upper end gets closer to the predicted value CNYF. The lower end deviates, and the overall variance trend first increases and then decreases. Note that the right side of Figure 16 shows

Figure 15. Dynamic Error Prediction Trend Graph



that the predicted value variance curve gradually changes. It deviates upward, turns downward, and then continues to rise after a small drop. The overall variance trend rises, falls, and then rises again.

According to the static prediction statistics, the root mean square error is 2.872477, the average absolute error is 2.444229, the average relative error absolute value is 25.06506, and the Theil coefficient value is 0.128503. Compared with the dynamic prediction results, the index values are almost reduced by half. The covariance ratio was also as high as 0.931441. On the whole, the accuracy of static prediction is higher and more in line with the actual situation. This result can also be obtained by observing the previous sample data.

Establishment and Analysis of the CARCH (1, 1) Model

CARCH (1, 1) Regression Analysis

For the variable CNY regression equation part, using the CARCH(1, 1) model for regression shown in Table 8, note that the CNY(-1) coefficient after regression is 1.212886, and its standard error is 0.280095, which is much smaller than one. The z-statistic value is 4.330266, which is far greater than one. The associated probability is zero, less than 0.05. The above indicators indicate that the CARCH(1, 1) regression equation is well fitted and can be represented by the following regression equation: CARCH(1, 1) equation:

$$\text{CNY} = 1.212886\text{CNY}(-1) + \text{Error}(0) \quad (5)$$

Figure 16. Static Error Forecast Trend Graph

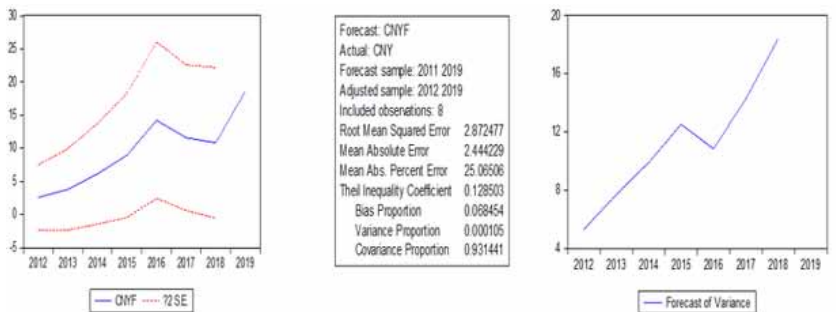


Table 8. CARCH (1, 1) Regression Model Parameter Values

Dependent Variable: CNY,Method: ML – ARCH (Marquardt) – Normal Distribution				
Failure to Improve Likelihood After 11 Iterations				
Pre-Sample Variance: Backcast (Parameter = 0.7)				
$Q = C(2) + C(3)*(Q(-1) - C(2)) + C(4)*(RESID(-1)^2 - GARCH(-1))$				
$GARCH = Q + C(5) * (RESID(-1)^2 - Q(-1)) + C(6)*(GARCH(-1) - Q(-1))$				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
CNY(-1)	1.212886	0.280095	4.330266	0.0000
Variance Equation				
C(2)	8.788148	114.9538	0.076449	0.9391
C(3)	0.841747	5.913124	0.142352	0.8868
C(4)	-0.064454	1.328616	-0.048513	0.9613
C(5)	0.013557	0.009447	1.434973	0.1513
C(6)	-2.261807	8.049645	-0.280982	0.7787
R-squared	0.684465	Mean dependent var		10.33700
Adjusted R-squared	0.684465	S.D. dependent var		5.431964
S.E. of regression	3.051272	Akaike info criterion		5.968300
Sum squared resid	65.17181	Schwarz criterion		6.027881
Log likelihood	-17.87320	Hannan-Quinn criterion.		5.566449
Durbin-Watson stat	2.156706			

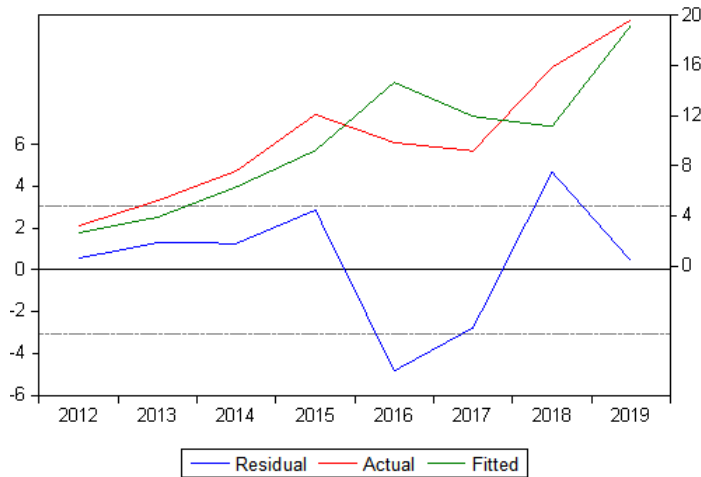
For the variance equation part of the variance equation, Table 8 indicates that R-squared = 0.684465, adjusted R-squared = 0.684465, and the Durbin-Watson statistic is 2.15670, approximately two, which suggests that the fit is better. However, from the GARCH(1,1) variance equations C(2), C(3), C(4), C(5), and C(6), the accompanying probabilities p-values are 0.9391, 0.9613, 0.9613, 0.1513, and 0.7787, respectively. The t values are also all small, indicating that the coefficients C(2), C(3), C(4), C(5), and C(6) are not significant. The standard error S.E. after regression is 3.051272, and the residual variance is 3.051272. The sum is 65.17181, indicating that the error is too large; therefore, its corresponding $GARCH = Q + C(5) * (RESID(-1)^2 - Q(-1)) + C(6)*(GARCH(-1) - Q(-1))$ equation does not hold water.

CARCH (1, 1) Residual Analysis

According to Figure 17, both the actual value and the predicted value show a clear upward trend; that is, over time, the cross-border RMB settlement volume shows a gradual upward trend. At the same time, the actual value and the predicted value trend are hand in hand. The residual value is stable, between zero and four in most years. From 2012 to 2015, the residual curve shows a slow upward trend. It turned downward in 2015, turned upward again in 2016, and turned downward again in 2018. The residual distribution fluctuates very little, but frequently, the population fluctuates up and down around the $x = 0$ axis, indicating that the residual distribution falls within an acceptable range.

The residual analysis chart shown in Figure 18, indicates that although the residual shows a right-biased trend, whether the residual histogram falls within the normal distribution area clearly cannot be seen. However, the residual statistical values in Figure 18, indicate that the mean is 0.243938, which is close to zero. The median is 0.501133, which is close to zero. The standard error is 1.0998879, the

Figure 17. Distribution of Residuals, Actuals, and Predictions



null hypothesis of the distribution, so there is reason to believe that the regression model estimated above is meaningful.

CARCH (1, 1) Error Prediction

From the left side of the dynamic forecast shown in Figure 19, the double-standard error of 2S.E deviates from $x=0$ increasingly over time and shows a divergent trend. The error increases with the passage of time and moves closer to the predicted value CNYF. Note also in the right side of Figure 19 that the variance curve of the predicted value deviates gradually upward, and the variance gradually increases.

From the statistical value, the Theil coefficient value is 0.306760, the root mean square error is 5.451467, the average absolute error is 4.599042, and the average relative error absolute value is 40.74647. The values of these four indicators are too large, showing that the prediction error is large. Additionally, the covariance ratio is only 0.061343, which is much less than one, so this prediction is inaccurate.

From the static prediction on the left side of Figure 20, the 2S.E double-standard error first deviates from the x axis increasingly over time, showing a divergent trend. The error increases over time, but after the curve reaches the apex, it then turns down. The error increases over time, showing

Figure 18. Residual Test Report

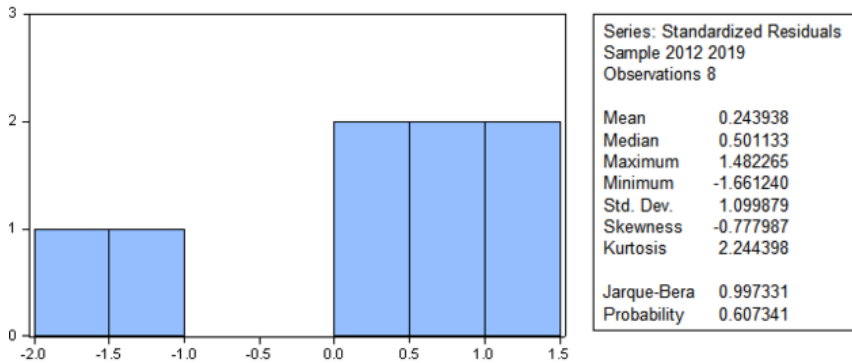
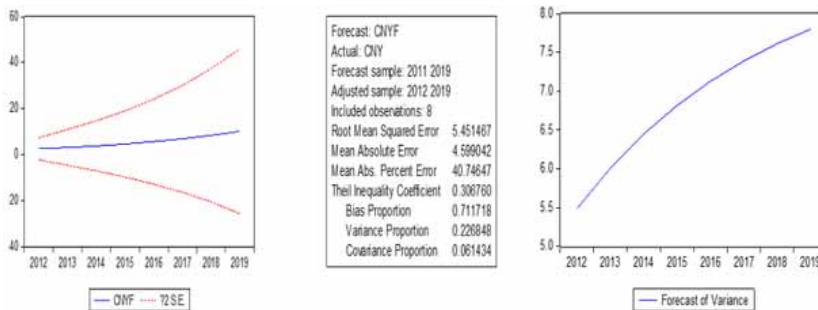


Figure 19. Static Error Forecast Trend Graph



a convergence trend. The upper end moves closer and closer to the predicted value CNYF, the lower end deviates, and the overall variance trend first increases and then decreases. Note also in the right side of Figure 20 that the predicted value variance curve gradually deviates upward, turns downward, and also falls, and then rises repeatedly.

According to the static prediction statistics, the root mean square error is 2.854203, the average absolute error is 2.345661, the average relative error absolute value is 24.28052, and the Theil coefficient value is 0.125767. Compared with the dynamic prediction results, the index values are almost reduced by half. The covariance ratio is also as high as 0.973089. On the whole, the accuracy of static prediction is higher and more in line with the actual situation. This result can also be obtained by observing the previous sample data.

MODEL SELECTION

Different econometric models have different algorithms, different advantages and disadvantages, and different fitting effects and errors. The five econometric models constructed in this paper are shown in Table 9. From Table 9, the authors can easily and intuitively select the appropriate regression equation model and make a mathematical game of choosing one from five according to the different effects.

Note in Table 9 that the ARMA, GARCH(1, 1), EGAHCH(1, 1), PARCH(1, 1), and CARCH(1, 1) models provide “accurate analysis”: (1). Std. Error is different. The ARMA model is 0.117074 and the GARCH(1, 1) model is 0.207168. EGAHCH(1, 1) is 0.182438, PARCH(1, 1) is 0.404774, and

Figure 20. Static Error Forecast Trend Graph

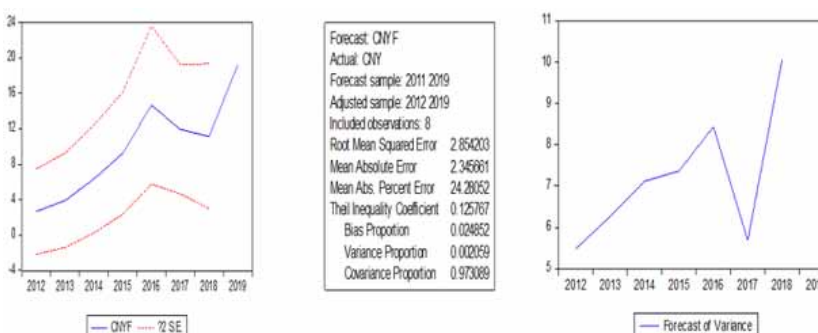


Table 9. Five Model Selection Analysis

		ARMA	GARCH(1, 1)	EGARCH(1, 1)	PARCH(1, 1)	CARCH(1, 1)
Accurate analysis	Std. Error	0.117074	0.207168	0.182438	0.404774	0.280095
	z-Statistic	10.34429	6.052023	6.809719	2.905046	4.330266
	P value	0.0000	0.0000	0.0000	0.0037	0.0000
	JB with P	Null	Null	0.910924	0.553819	0.607341
The error estimation of CNY static prediction	Root Mean Squared Error	2.854153	2.881197	2.868694	2.872477	2.854203
	Mean Absolute Error	2.350969	2.287320	2.272474	2.444229	2.345661
	Mean Abs. Percent Error	24.31958	23.67060	23.68272	25.06506	24.28052
	Theil Inequality Coefficient	0.125859	0.124883	0.124911	0.128503	0.125767
	Covariance Proportion	0.971646	0.987142	0.986684	0.931441	0.973089

CARCH(1, 1) is 0.280095, so the ARMA model must be selected; (2). As the (1) analysis method, from z-statistic and so on, the ARMA model must be selected.

Note also in Table 9 that the ARMA, GARCH(1, 1), EGARCH(1, 1), PARCH(1, 1), and CARCH(1, 1) models “The error estimation of CNY static prediction”: (1). The Root Mean Squared Error is different. The ARMA model is 2.854153, the GARCH(1, 1) model is 2.881197, the EGARCH(1, 1) is 2.868694, the PARCH(1, 1) model is 2.872477, and the CARCH(1, 1) is 2.854203, so the GARCH(1, 1) model must be selected; (2). as the (1) analysis method, from z-statistic and so on, the GARCH(1, 1) model must be selected.

Through the above selection process, research requirements can be selected. When you are considering the “accurate analysis,” the ARMA model will be the choice. When you are considering “The error estimation of CNY static prediction,” it would be proper to select the GARCH(1, 1) model for the comprehensive understanding of absolute error, the Theil coefficient value and the other parameters.

CONCLUSION

There are many complex factors that affect cross-border RMB settlement, and the common factors can be divided into political factors, economic factors, cultural factors, military factors, diplomatic factors, and so on. The influences of these factors are complicated and difficult to analyze quantitatively, but total amounts of cross-border RMB settlement can be achieved by the central bank reports. Therefore, this paper takes a different approach and perspective, which avoids the complex external factors that cannot be quantitatively dealt with, seeks the internal regularity of cross-border RMB settlement, conducts research from the autocorrelation regression of cross-border RMB receipts and payments, and conducts ARMA, GARCH (1, 1), EGARCH (1, 1), PARCH (1, 1), and CARCH (1, 1), in addition to other models to analyze in parallel.

Through the above selection process, it can be decided by the different situations:(1) When considering the “accurate analysis,” the ARMA model will be the choice. (2) When considering “The error estimation of CNY static prediction,” it would be proper to select the GARCH(1.1) model. Through the research results, people can further recognize its past, present, and future characteristics of cross-border RMB payment and settlement services, so as to formulate and introduce relevant policies, systems, and measures to promote the positive and healthy development of China’s cross-border RMB settlement.

AUTHORS' NOTE

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Correspondence concerning this article should be addressed to Ni Hu, Southwest University of Science and Technology, 59 Qinglong Road, Mianyang, Sichuan, P.R. China, 621010; Email: 1125064348@qq.com.

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Zhang Cheng (<https://orcid.org/0000-0002-2003-4174>) completed his postdoctoral training at the School of Finance at the Shanghai University of Finance and Economics and received his doctoral degree at Tongji University's School of Economics and Management. Currently, he is a professor of finance at the Department of Economics and Finance, Yangtze Normal University.

Ni Hu finished his postgraduate studying in 2022 and received a master's degree in from Southwest University of Science and technology.

Yan Qiang finished his postgraduate studies at the Shanghai Social Science Institute and received a doctoral degree in 2013. He now is an associated professor at Hezhou University.