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Research on House Price Forecasting in Guiyang City Based on ARIMA and GARCH Models

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Abstract: The purpose of this study is to forecast and analyze the house price of Guiyang city through ARIMA model and GARCH model, in order to improve the accuracy and reliability of house price prediction, and to provide references for real estate market analysis and policy formulation. As the capital city of Guizhou Province, Guiyang city's real estate market shows certain volatility in the context of economic recovery after the epidemic, and in-depth study of its house price trend is of great practical significance. This study will use the average residential transaction price data of Guiyang city from 2019 to 2024 to firstly analyze the smoothness and autocorrelation of the house price data by ARIMA model to capture the trend and seasonal changes in the time series; secondly, analyze the volatility of house price by GARCH model to capture the conditional heteroskedasticity phenomenon in the market. On this basis, a hybrid model is constructed by combining the advantages of ARIMA and GARCH models, and the performance of single model and hybrid model in house price forecasting is comparatively analyzed. The key issues of the study include how to effectively handle non-stationary data, capture house price volatility, assess the forecasting accuracy of the model, and the feasibility of constructing a hybrid model. Through ADF test, ACF and PACF test, ARCH test and other methods, this study will gradually build and optimize the ARIMA, GARCH and hybrid models, and finally forecast the house price trend in the coming year, and put forward the corresponding market analyses and policy recommendations. The innovation of this study lies in the application of ARIMA and GARCH models to the prediction of house prices in Guiyang City, and the enhancement of the prediction accuracy by the hybrid model, which provides a new analysis perspective for the real estate market.

Keywords: ARIMA Model; ARCH Test; GARCH Model; Mixed Model; Residential Transaction Average Price.

1. Introduction

As an important part of the national economy, price fluctuations in the real estate market are not only related to the quality of life and wealth allocation of residents, but also have a far-reaching impact on the stability and development of the macro-economy. As the capital city of Guizhou Province, Guiyang City occupies an important position in regional economic development. Against the backdrop of economic recovery after the epidemic, the real estate market still faces challenges. Especially after the epidemic, housing prices everywhere have been on a downward trend. With the recovery of the tourism industry, Guiyang's real estate has had a favorable tendency in the past year. However, Guiyang's housing prices in the past five years have been somewhat volatile with the impact of the epidemic, which makes an in-depth study of Guiyang's housing price trends of great practical significance.

1.1. Introduction to the ARIMA Model

The ARIMA model captures the trend and seasonal changes in the time series through autoregressive, differential and moving average components, with smoothness and flexibility, and is widely used in forecasting and analyzing in the fields of economy, finance, marketing, meteorology, manufacturing, healthcare and energy, etc. It can also be based on ARIMA to integrate other models or add exogenous variables (Exogenous Variables). For example, the ARIMAX model makes it possible to take into account the effects of external factors on the time series, thus improving the accuracy and reliability of forecasts. Shuxian Zhang analyzed the private car ownership by using Lasso software and grey correlation and established ARIMAX comparison analysis based on ARIMA (1,0,2) model, which is more suitable for predicting the national private car ownership than ARIMA model. SARIMA (Seasonal Autoregressive Integral Sliding Average) model is a kind of model used for processing and forecasting time series data with seasonal characteristics [1]. powerful tool for processing and forecasting time series data with seasonal characteristics. It adds seasonal parameters to the ARIMA model to better capture cyclical variations in the data. Divisekara et al. chose to use the Seasonal Autoregressive Integral Sliding Average (SARIMA) model to predict the market price of red lentils in Saskatchewan, Canada. Because the market price of red lentils is characterized by significant seasonal fluctuations, the SARIMA (2,1,2)(0,1,1) model performs best in predicting red lentil prices [2].

1.2. Introduction to the GARCH Model

In the financial world, volatility and volatility reflect a risk indicator often used in the study of financial market uncertainty. GARCH model focuses on the conditional heteroskedasticity and volatility of the time series, so the GARCH model has been used many times in the study of financial risk research. Especially in the stock market, Sun Lijun and Wang Jing have analyzed the volatility returns of the stock price returns of Poly Real Estate and Greenland Holdings by building a GARCH model and its variants, TGARCH and EGARCH, and found that the two stocks have financial characteristics and corrected volatility returns can be used to capture the market information [3]. Aras, by building a GARCH model for Bitcoin volatility test and found that the use of higher order GARCH models can effectively improve the accuracy of volatility prediction for Bitcoin [4]. In the financial world, the volatility of financial time series, also known as volatility aggregation, not only affects the variance but also affects higher-order moments such as skewness and sharpness. Based on the GARCH (1, 1) model, Li Wanjie has investigated that the higher-order moments outperform the traditional model in terms of risk management and return enhancement [5].

1.3. Introduction to Hybrid Models

Compared with a single model, hybrid models can better combine the advantages of different models to cope with the nonlinear characteristics in financial markets. For example, the mixture of ARIMA model and GARCH model, which can reflect both the ARIMA model is good at capturing the seasonality and trend in the data as well as the study of volatility aggregation phenomenon by GARCH model. Wang Yiliu improves the accuracy of the ARIMA model in forecasting the short-term RMB exchange rate by mixing the ARIMA and GARCH models and also summarizes the volatility pattern of the RMB since its accession to the SDR [6]. Xiong Zheng and Che Wengang established an ARIMA-GARCH-M model on the basis of a hybrid ARIMA and GARCH model, which successfully solved the problem of the inconspicuous distribution of "sharp peaks and fat tails", and judged the model's performance in short-term forecasting of the stock of "Ping An Bank" [7]. By forecasting the stock of Ping An Bank, the model is judged to be more accurate than the traditional ARIMA, GARCH and GARCH-M models in short-term forecasting.

1.4. Current Status of Time Series Modeling of House Prices

Based on the stable mean and constant variance, the ARIMA model can effectively predict the future price trend in the analysis of commercial residential sales price index and help analyze the market dynamics. Hu Xianqin had predicted the real estate prices in Hefei after 2022 by building an ARIMA model, and determined that the real estate prices in Hefei will rise steadily in the future [8]. Fu Qiwei et al. also predicted the house price of Hengyang city by building an ARIMA model [9]. Chen Lei based on ARIMA and SARIMA to compare and analyze the price of commercial housing in Nanjing between 2014 and 2021, because the predicted value of ARIMA (1, 1, 4) is higher thus inferring the direction of the price of the commercial housing in the coming year to make predictions [10]. While abroad, Jadevicius and Huston effectively applied the ARIMA model to analyze and forecast the Lithuanian house price index, proving its utility in capturing real estate market dynamics and providing reliable short-term forecasts [11]. Zamri et al. analyzed the AIC and the BIC by building an ARIMA model to determine that ARIMA (1, 1 1) is more suitable for predicting future house prices in Malaysia and discussed the factors that affect house prices [12]. Compared to the ARIMA model, the GARCH model also has a constant mean, but the variance changes over time. And the real estate industry is inextricably linked with finance, especially in the environment of economic downturn as house prices increase year by year, the financial burden of home buyers will increase. By building a GRACH model,Cui Yinsheng and Jia Liu comparatively studied the returns of the real estate industry in China and the United States from a financial perspective, which led to the conclusion that the returns of real estate in the two countries have volatility [13]. Suleiman and Othman studied the use of a variety of GARCH models, such as GARCH (1,1), EGARCH, etc., on the processed residential real estate price time series data in Malaysia and estimate the parameters by great likelihood estimation to predict house price volatility [14]. Philipp Otto and Schmid investigate the importance of spatial versus GARCH models by improving the second-order moments in GARCH models. The framework effectively allows the GARCH model to analyze the relationship between real estate prices and geographic factors. These studies show that both ARIMA and GARCH models provide effective real estate price forecasts across different regions and market conditions, helping to analyze market dynamics and volatility [15].

This paper firstly introduces the prospect of house price research and explains the importance of house price research in Guiyang. Then it introduces the characteristics of smoothness and seasonality of ARIMA model and briefly illustrates the use of SARIMA and ARIMAX, the variants of ARIMA model, in the research. The use of GARCH models in volatility studies and the benefits of improving the order moments of GARCH models are then summarized. On the basis of ARIMA and GARCH models, the advantages of hybrid models that can integrate the advantages of multiple models and improve the accuracy are introduced and their applications in various fields. Finally, the use of time series models in house prices is presented.

2. Proposed Research Methodology

2.1. Modeling Principles

2.1.1. ARIMA Modeling

ARIMA model is a time series forecasting method proposed by Box and Jenkins in the early 1970s is known as differential autoregressive moving average model, also known as Box_Jenkins model.ARIMA model is a time series model based on the autoregressive moving average study, in the reality of the study most of the data has a non-stationary nature, so we need to non-stationary treatment of the data. In order to convert the non-stationary time series data into differential stationary series, the differential autoregressive moving average model ARIMA can be realized by difference operation. The model consists of three parts: autoregressive (AR), difference (I) and moving average (MA). The expression of ARIMA model is usually expressed as ARIMA (p, d, q), where p is the order of the autoregressive term, d is the number of differences, and q is the order of the moving average term.

The mathematical expression of the ARIMA model is as follows:

$$\varphi(B)(1-B)^d y_t = \theta(B)\varepsilon_t$$
$$E(\varepsilon_t)=0, Var(\varepsilon_t)=\sigma_i^2, E(\varepsilon_t\varepsilon_s)=0, s\neq t, E(\varepsilon_t\varepsilon_s)=0, \forall s<t \quad (1)$$

The autoregressive polynomial part (AR) is expressed in formula, $\varphi(B)=1-\varphi_1 B-\varphi_2 B^2-\cdots-\varphi_p B^p$, where $\varphi_i, i=1,2,3,\ldots,p$ is the autoregressive coefficient. The polynomial expression for the sliding average (MA) is$\theta(B) = 1 + \theta_1 B + \theta_2 B^2 + \cdots + \theta_q B^q$, the moving average coefficient in formula is$\theta_j, j = 1,2,3,\ldots,q$,$y_t$is the value of the time series at time t, andε_t is the error term (white noise).

2.1.2. GARCH Model

The GARCH model (Generalized Autoregressive Conditional Heteroskedasticity Model) was developed by Bollerslev in 1986 based on the ARCH model (Autoregressive Conditional Heteroskedasticity Model) proposed by Engle. The GARCH model extends the ARCH model by introducing lagged terms to better capture volatility clustering phenomena in the time-series data. GARCH models are widely used in The GARCH model is widely used in financial time series analysis, especially for modeling and forecasting the volatility of asset prices. The mathematical expression of the GARCH model is usually denoted as GARCH(m, s), where m is the order of the ARCH term and s is the order of the GARCH term.

The mathematical expression of the GARCH model is given below:

$$\sigma_t^2 = c + \sum_{i=1}^{m} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{s} \beta_j \, \sigma_{t-j}^2$$
$$c > 0, \alpha_i \geq 0, \beta_j \geq 0, \sum_{i=1}^{m} \alpha_i + \sum_{j=1}^{s} \beta_j < 1 \quad (2)$$

σ_t^2denotes the conditional variance at time t also known as the volatility coefficient,$c$is constant and not less than 0.$\alpha_i$is the coefficient of the ARCH term, which denotes the effect of the past error term ε_{t-i}^2 on the current volatility. is the coefficient of the GARCH term,$\beta_j$represents the effect of past volatilityσ_{t-j}^2on current volatility.

2.1.3. ARIMA-GARCH Mixed Models

The ARIMA-GARCH model is based on is a combination of the ARIMA model and the GARCH model that works on data with linear time dependence as well as volatility changes. The expression of the model is:

$$\sigma_t^2 = c + \sum_{i=1}^{m} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{s} \beta_j \, \sigma_{t-j}^2$$
$$dX_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i \, dX_{t-i} + u_t + \sum_{j=1}^{q} \theta_j \, u_{t-j} \quad (3)$$

$0 < \sum_{i=1}^{m} \alpha_i + \sum_{j=1}^{s} \beta_j < 1, \varepsilon_t$ denotes the random error term, while$u, v$is the GARCH model and the order of the ARCH model. The conditional variance ofσ_t, ε_tcharacterizes the volatility in the current time series.

2.2. Feasibility Analysis

2.2.1. ADF Test

After processing the property data, the ADF test is performed on the property data using the packet in the tseries function in R language. In this test, if the p-value value is less than 0.05 it indicates that the data value is less than the set level of significance and the data is smooth. Conversely, it indicates that the data is a non-stationary series. If in the test the data is non-smooth, then the data needs to be differenced.

2.2.2. Tests for Non-stationary Data

After determining whether the data is smooth or not, the data can be subjected to the ACF test aka autocorrelation function and the PACF test aka bias off function. The ACF demonstrates the overall correlation between the observations in the time series and the past. Whereas the PACF test demonstrates the direct correlation between observations and a specific lagged posterior term by removing the effect of the intermediate term. For the ARIMA model, the model fits the data better when appropriate values of p (autoregressive order) and q (moving average order) are determined by the ACF and PACF tests. For example, if the ACF is trailing and the PACF is truncated after a certain order, the p value can be determined accordingly; conversely, if the PACF is trailing and the ACF is truncated after a certain order, it helps to determine the q value.

2.2.3. ARIMA Modeling

The smoothness of the data needs to be taken care of while building the ARIMA model. If the data is determined to be smooth data before the difference is performed, the data can be directly ARIMA modeling in the establishment. If the data is determined to be non-stationary data, it is necessary to build an ARIMA model based on the differenced data after the data is differenced. After determining the ARIMA model use the Ljing-Box test to perform a white noise test on the residual values. If the white noise test is passed, that is, the p-value is greater than 0.05, it means that there is no autocorrelation in the residual values, and the construction of ARIMA model is effective. On the contrary, the ARIMA model needs to be improved. In constructing ARIMA model, the best ARIMA model can be determined by AIC and BIC.

2.2.4. ARCH Test

The ARCH test is an autoregressive heteroskedasticity test performed before constructing the GARCH model, which tests the residuals of the ARIMA model on the basis of the best ARIMA model. If the p-value is less than the significant level, it means that there is ARCH effect and it is suitable for constructing GARCH model.

2.2.5. GARCH Modeling

Before establishing the GARCH model, it is necessary to establish the ARMA mean model to get the residual value and on this basis based on the judgment of ARCH test passed, the establishment of the GARCH model is feasible. If the ARCH test does not pass then it proves that the established ARMA model or ARIMA model does not have heteroskedasticity, and the GARCH model is not feasible. After constructing the GARCH model it is necessary to conduct Box-test test on the GARCH model. If the residual values pass the test it indicates that the model has adequately captured the volatility characteristics of the data and the GARCH model is reliable.

3. Experimental Results

3.1. Data Preparation

The collected average price of residential transactions in Guiyang from January 2019 to December 2024 was viewed by plotting the icon through R software to see its changes as in Figure 1. Initially, it is judged that the data may have seasonal factors.

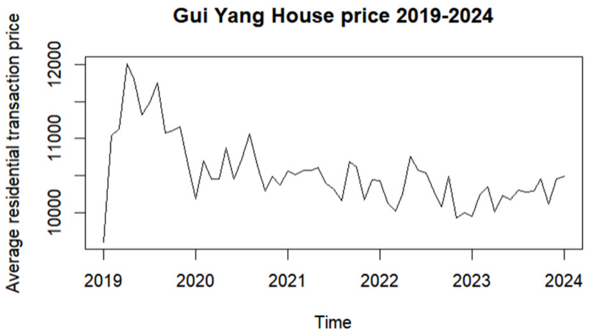

Figure 1. Average price of residential units sold in Guiyang

3.2. Autocorrelation Test

Before conducting the autocorrelation test, the original hypothesis needs to be established that the time series is a non-stationary time series. Based on the results of the ADF test on the original data the p-value is greater than 0.05, therefore the original hypothesis cannot be rejected and the data is non-stationary. After doing first-order differencing on the original data, the result of ADF test on the differenced data p-value is less than 0.05, so the original hypothesis needs to be rejected and the differenced data is determined as a smooth time series based on unit root test. At the same time the original data and first-order difference data for randomness test can be known that the original data for non-white noise data and difference data for white noise data, so the data has the value of research.

Table 1. ADF test

difference in order	DF statistics	P-value
0	-2.8612	0.2265
1	-5.9963	0.01

Table 2. Ljung-Box Tests.

difference in order	X-Squared	P-value
0	29.429	5.799e-08
1	1.7777	0.1824

3.3. ARIMA Model

Based on the fact that the differential data are white noise and smooth data, the ARMA model should be built on the basis of the differential data, and at the same time, this ARIMA model can be identified as ARIMA (0,1,0). In order to further determine the order of the model, autocorrelation plot test and bias off plot test are carried out on the original data and differential data, as shown in Fig. 2, Fig. 3, Fig. 4 and Fig. 5. Through observation, it can be found that the autocorrelation plot of the original data, whose ACF characteristics show a slow decreasing proves that the data need to be further differenced and the judgment based on the results of the ADF test is the same. And by observing the autocorrelation plot of the first-order differenced data, its ACF feature truncates at lag 1. This indicates that the MA part of the ARIMA model based on the first-order difference data is 1. By observing the first-order difference bias plot, it can be learned that the PACF coefficients are out of the confidence interval near lag=1, except that the PACF coefficients are all in the confidence interval. This suggests that the ARIMA model may be better suited to have an AR component of 1.

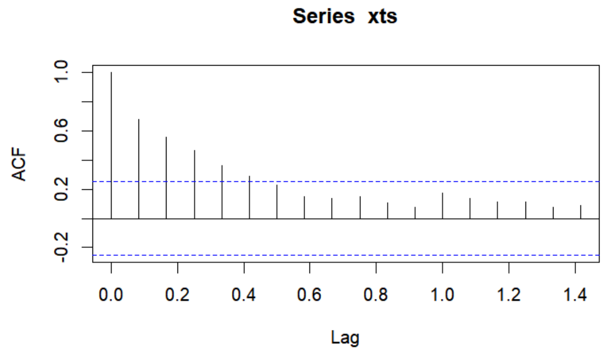

Figure 2. autocorrelation plot

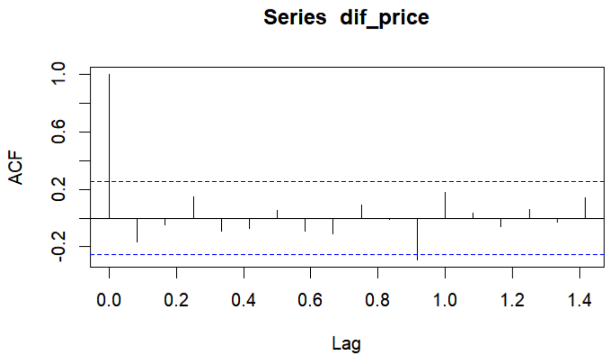

Figure 3. autocorrelation plot

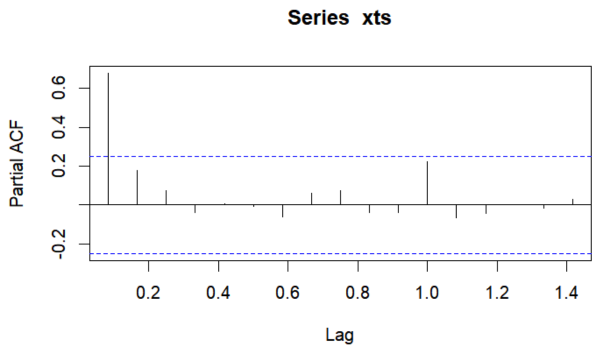

Figure 4. Biased autocorrelation plot

As shown in Table 3, according to the principle of minimizing the AIC value of ARIMA model fitting can surface ARIMA(1,1,1) as the best ARINMA model.

3.4. SARIMA Monthly Modeling

Based on the fact that the original data has some quarterly number of factors, the autocorrelation and partial autocorrelation tests were re-examined on the original data and produced Figure 6 based on the month of the year to set up lag=12 has corresponded to a year of monthly data.

According to the observation ACF and PACF in the lag=12 place its value in the interval of -0.25 to 0.25 has significant characteristics. Based on ARIMA(1,1,1) several SARIMA models are established and white noise test and AIC test are performed as in Table 4, all models are tested to prove that these models are effective. Also based on the comparison of AIC values, the best SARIMA model is ARIMA (1,1,1)(0,1,0)[12].

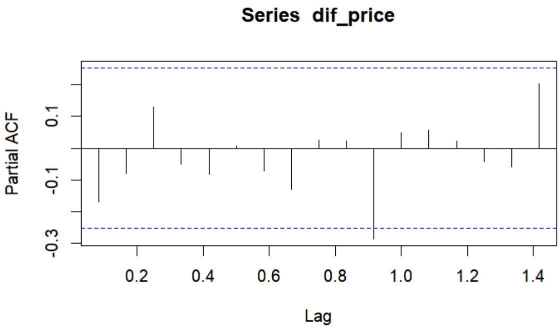

Figure 5. Partial autocorrelation plot

Table 3. Ljung-Box Tests.

ARIMA model	AIC value
ARIMA(0,1,0)	877.49
ARIMA(0,1,1)	879.50
ARIMA(1,1,0)	879.07
ARIMA(1,1,1)	875.92

Table 4. Effect of SARIMA fitting

SARIMA model	Residual Ljung-Box test	AIC value
ARIMA(1,1,1)(0,0,1)[12]	0.4462	873.37
ARIMA(1,1,1)(0,1,0)[12]	0.4765	711.73
ARIMA(1,1,1)(0,1,1)[12]	0.8535	712.36
ARIMA(1,1,1)(1,0,1)[12]	0.4525	875.36
ARIMA(1,1,1)(1,1,0)[12]	0.7795	712.49
ARIMA(1,1,1)(1,1,1)[12]	0.8060	714.35

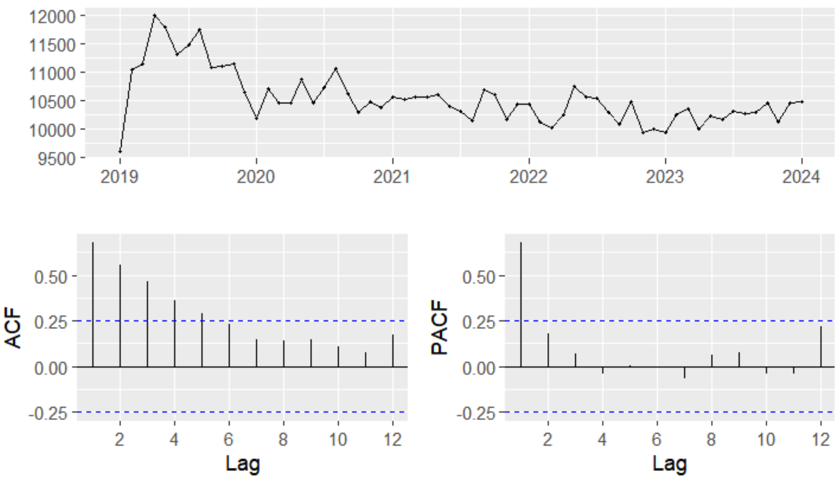

Figure 6. significance test of SARIMA

3.5. ARCH Test

The ARCH test is a prerequisite for building a GARCH model, and in building the ARCH test it is necessary to ensure that the data is a smooth time series and white noise data. Therefore based on the original data being non-smooth and non-white noise data, it is not suitable to build a GARCH model. The best ARIMA model is built on the basis that the data has been differenced and remains smooth. After establishing the residuals for this best ARIMA model as shown in Table 5, the P-value of the ARCH test is less than 0.05 indicating that this current ARIMA model does not capture the change in conditional variance. The LB test combined with its residuals all indicate that we can mix the GARCH model for this model.

Table 5. ARCH test

mould	ARCH test value	Residual Ljung-Box test
ARIMA (1,1,1)	8.344e-05	0.4309

3.6. ARIMA-GARCH Mixed Models

By building the ARIMA (1,1,1)-GARCH (1,1) model and checking the multinomial test of the model, it can be seen that the model has a better prediction effect as shown in Table 6, in which so the residuals of the LB test (the graph is only intercepted at the minimum value) are all passed by the surface of the model successfully eliminated the problem of fluctuating heteroskedasticity. The residuals of the model are consistent with the normal distribution by the Shapiro-Wilk test. normal distribution. The JB test shows that the residuals of the model have no skewness and sharpness. Based on the multinomial test, it is known that the hybrid model can solve the volatility problem more effectively.

Table 6. ARIMA-GARCH fitting effects

inspect	P-value
R^2 Ljung-Box	0.3487
Shapiro-Wilk Test	0.6668
Jarque-Bera Test	0.9643

4. Conclusion

Based on the fact that the original house price data is a non-stationary time series, the data is differenced to make it stationary and the stochasticity test determines that the differenced data is white noise data. Based on the observation of autocorrelation and partial autocorrelation plots and using its AIC value to determine its best ARIMA model ARIMA(1,1,1). After citing its monthly data, observing its autocorrelation and partial autocorrelation plots and combining them with the LB test, it is concluded that SARIMA monthly data is suitable to be applied in forecasting house prices in Guiyang. More AIC values can identify SARIMA(1,1,1)(0,1,0) [12] as the best SARIMA model. According to its ARCH test, the current ARIMA model does not capture the volatility heteroskedasticity well. Since the original house price data is not a smooth time series and is non-white noise data, it is not meaningful to build a GARCH model for the original house price data. The volatility heteroskedasticity is successfully eliminated by building a hybrid model ARIMA(1,1,1)-GARCH(1,1). The ARIMA, SARIMA and ARIMA-GARCH hybrid models are compared and analyzed in Fig. 7, Fig. 8 and Fig. 9, and it is known that the ARIMA model is suitable for predicting the future trend of the average price of residential transactions in Guiyang City by comparing the model prediction charts. However, according to its AIC test, the SARIMA model is more suitable for predicting the house price data, and the prediction is more realistic. After building its ARIMA-GARCH hybrid model, its AIC is only 14.2. Observing its hybrid model, it can be accurately judged that the value of the house price fluctuates in the range of -600 to 450. According to the three forecast charts, it can be concluded that the average price of residential transactions in Guiyang City will have a small drop in the coming year and then stabilize.

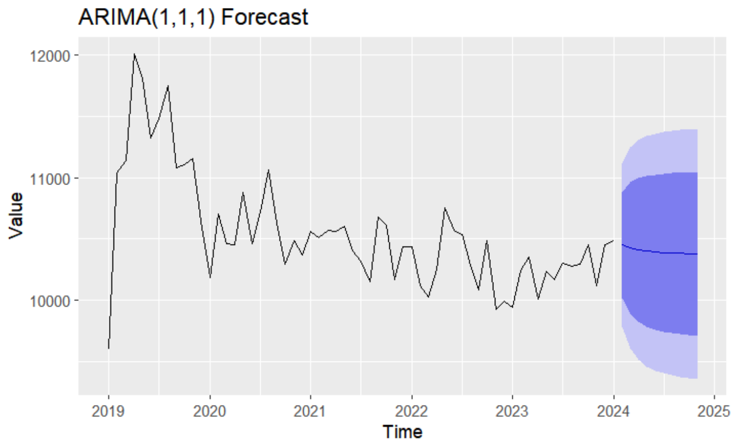

Figure 7. ARIMA(1,1,1) prediction plot

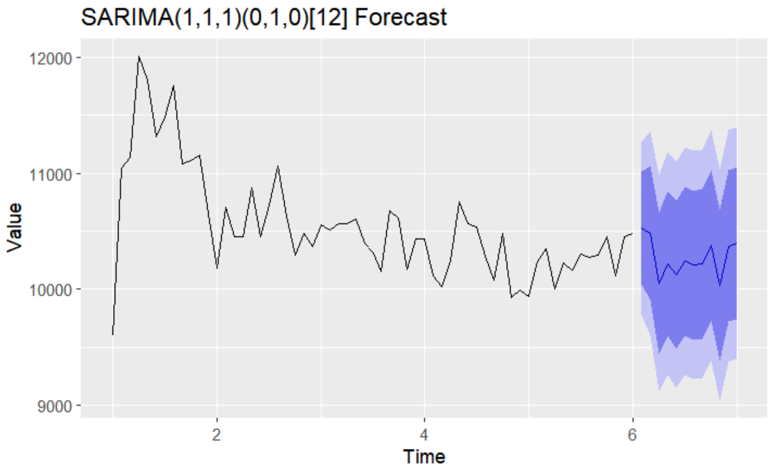

Figure 8. SARIMA(1,1,1)(0,1,0)[12] prediction plot

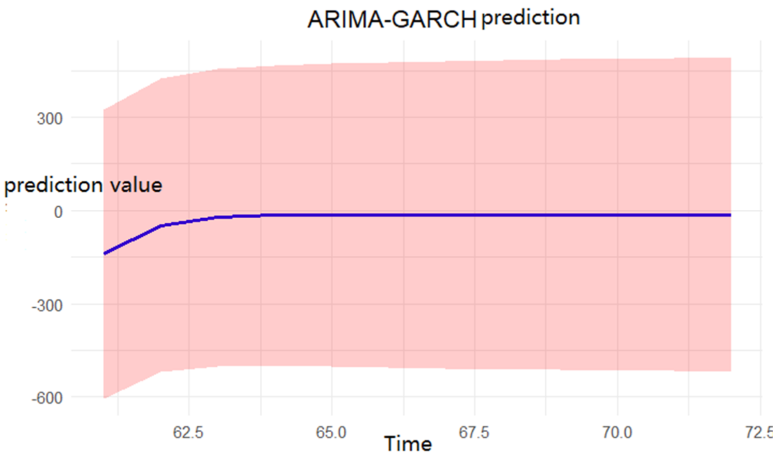

Figure 9. ARIMA-GARCH hybrid model

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