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VOLATILITY ANALYSIS AND INFLATION PREDICTION IN PANGKALPINANG USING ARCH GARCH MODEL

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ABSTRACT

One of the concerns of both developed and developing countries, as well as in a region, is the amount of inflation that occurs. Inflation is a serious problem. Inflation is a macroeconomic variable that affects people's welfare and is defined as a complex phenomenon resulting from general and continuous price increases. This research aims to analyze the volatility and projected value of the inflation rate, especially in Pangkalpinang City, using the Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models. This research uses time series data on inflation rate of Pangkalpinang, Bangka Belitung Island Province from January 2014 to May 2024. This data was obtained through publications from the Central Statistics Agency of Bangka Belitung Islands Province. The ARCH model is used to handle heteroscedasticity in data, while the GARCH model is a development of the ARCH model and serves as a generalization of the volatility model. This research shows that the predicted inflation rate in Pangkalpinang City from June 2024 to November 2024 tends to decrease with a MAPE prediction accuracy level of 200.04%. The high MAPE value is caused by actual data moving toward 0.

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1. INTRODUCTION

Inflation is one of the variables in macroeconomics that can affect people's welfare and is defined as a complex phenomenon resulting from general and continuous increases in prices [1]. This is what can have an impact on other economic indicators. The occurrence of inflation can be identified by a spike in prices which will affect other goods in a certain period [2]. Several studies have shown that the previous Covid-19 pandemic had a positive impact on inflation in Indonesia [3]. This also correlates with the issue of a recession which is predicted to occur in Indonesia in 2023. The Pangkalpinang city government, Bangka Belitung Islands Province must also be alert in determining the type of policy that will be taken in response to this matter. When compared with the national inflation rate and the city of Palembang as the closest city to the Bangka Belitung Islands Province, during the 2012-2016 period the inflation rate in Pangkalpinang was always higher. This phenomenon must be of concern to regional leaders when conducting macroeconomic studies for the progress of their region.

This condition must also be accompanied by strong economic resilience in a region. Economic resilience is a strong dynamic condition of a nation's economy in developing national strength in overcoming and facing all threats, obstacles, disruptions, and challenges originating directly or indirectly from within the country and abroad to ensure the survival of the nation's and state's economy [4].

Inflation has a close relationship with economic growth. Low and stable inflation will increase a country's economic growth. Of course, you can't just look at the inflation rate to see the economic growth conditions of a region. This can also be seen through the Gross Regional Domestic Product (GRDP) value produced to determine the level of economic growth and the level of prosperity of society in the region [5]. This economic growth will certainly affect infrastructure in the region. In the Bangka Belitung Islands Province in particular, infrastructure readiness is the main point in developing tourism destinations for the progress of the area [6]. This is also considering that the Bangka Belitung Islands Province as a tourist destination must have adequate infrastructure. Reflecting on Hong Kong, the decline in Gross Domestic Product (GDP) for two consecutive quarters is a technical category for a recession [7]. For Indonesia, the political dynamics and economic recession in Hong Kong and their potential impact on the global crisis must be well anticipated so as not to disrupt national resilience.

Volatility analysis on inflation variables has been examined in previous studies. This is done to measure the level of variation in a certain period. The inflation indicator has a high volatility. This is because this variable often experiences increases and then decreases again significantly. This phenomenon results in a large difference between the lowest and highest values. For example, research by [8] using GARCH to predict inflation and CPI in Aceh Province, demonstrates that the GARCH model can address heteroscedasticity issues in inflation and CPI data. A study using time series data generally tends to have a variance of constant confounding error or homoscedasticity. However, the high volatility in time series data can make the residual variance in the data not constant and always change in each period or contain heteroscedasticity [9]. This phenomenon can be overcome by using ARCH GARCH analysis to overcome the problem of heteroscedasticity as well as being an advantage of the ARCH GARCH method. This research also has a renewal aspect and perfects the research carried out by [10] which only focuses on the GARCH method for analyzing inflation forecasting in North Maluku. Considering the importance of knowing the projected value of the inflation rate, this research will analyze the volatility and how the projected value of the inflation rate is, especially in Pangkalpinang City, which not only uses the Autoregressive Conditional Heteroskedasticity (ARCH) model but is also developed by applying the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. It is hoped that the results of this research can provide an overview for policymakers regarding future predictions, especially in the field of predicting the inflation rate as the main target of monetary policy [11] so that economic resilience can be maintained.

2. RESEARCH METHODS

Time series analysis is a collection of observation values that are measured based on certain time intervals. The time interval for this data can be daily, weekly, monthly, and yearly. Time series analysis can be carried out on numerical data. If the values of events in a time series are given the symbols Z_1, Z_2,..., Z_n, and the times when the events were recorded are given the symbols t_1, t_2,.., t_n, then the time series of events Z is symbolized Zt which means the magnitude of the value of an event at the time the incident occurred [12].

This research uses time series data on the inflation rate of Pangkalpinang City, Bangka Belitung Province from January 2014 to December 2023. This data was obtained through publications from the Central Statistics Agency (BPS) of the Bangka Belitung Islands Province. The models used to predict the inflation rate are the ARCH and GARCH models. This model is used to see predictions of inflation levels from January 2024 to June 2024.

2.1 ARIMA Model

This model is used to predict time series data in the short term. This is because this model has poor accuracy when used in long-term predictions. The ARIMA modeling is as follows:

2.1.1 AR Model

The AR model is a time series data model that describes the relationship between current data and previous period data [13]. The general form of the AR model with orde p (AR(p)) is as follows:

$$X_t = \alpha_0+\theta_1 X_{t-1}+\ldots+\theta_p X_{t-p}+e_t \tag{1}$$

2.1.2 MA Model

The MA model describes the relationship between time series data and previous residuals. The MA equation of orde q (MA(q)) is defined as follows:

$$X_t = \emptyset_0+\emptyset_1 X_{t-1}+\ldots+\emptyset_q e_{t-q} \tag{2}$$

2.1.3 ARMA Model

The ARMA model is a combination of AR and MA models for stationary time series data. ARMA modeling with the orders AR(p) and MA(q) as follows:

$$X_t = \theta_1 X_{t-1}+\theta_2 X_{t-2}+\ldots+\theta_p X_{t-p}+ e_t- \emptyset_1 e_{t-1}-\ldots-\emptyset_q e_{t-q} \tag{3}$$

2.1.4 ARIMA Model

ARIMA is a non-stationary model that uses past data to produce accurate short-term predictions. This model is formed from a combination of $AR(p)$ and $MA(q)$ models which get differencing (d) [14]. The general form of the ARIMA method is shown in **Equation 4** below:

$$X_t = (1+\theta_1)X_{t-1}+(\theta_1-\theta_2)X_{t-2}+\ldots+\left(\theta_p-\theta_{p-1}\right)X_{t-p}+ e_t- \emptyset_q e_{t-1}-\ldots-\emptyset_q e_{t-q} \tag{4}$$

ARIMA model identification is formed from the ACF and PACF plots. The criteria for determining the ARIMA order (p, d, q) are as follows:

a. The AR(p) model is shown by the PACF plot decreasing significantly exponentially and the cut off PACF plot after the p -th lag.

b. The MA(q) model is shown by the cut off ACF plot after the qth lag and the PACF plot decreases significantly exponentially.

c. The ARMA(p, q) model shows that the shape of the ACF and PACF plots decreases significantly exponentially.

2.2 ARCH Model

The ARCH model is a model developed by Engle to handle heteroscedasticity in data. This model consists of two variance components, namely a constant variance and a variance that is dependent on the amount of volatility in the past period [15]. The general form of the p order ARCH model (ARCH(p)) is as follows [16]:

$$h_t = \alpha_0+\alpha_1 \varepsilon^2_{t-1}+\alpha_2 \varepsilon^2_{t-2}+\ldots+\alpha_p \varepsilon^2_{t-p} \tag{5}$$

The general form above illustrates the value of $\alpha_0 > 0$ and $\alpha_1 \geq 0$, so that h_t is a conditional variance that connects the residual variance in the t period with the square of the residual in the previous period.

2.3 GARCH Model

The GARCH model is a development of the ARCH model by Bollerslev in 1986. This model was developed as a generalization of the volatility model [15]. The GARCH (p, q) method assumes that the residual variance h_t is influenced by the residual and residual variance of the previous period. The general form of the GARCH (p, q) method is as follows [16]:

$$h_t = \alpha_0+\alpha_1\varepsilon^2_{t-1}+\ldots+\alpha_p\varepsilon^2_{t-p}+\beta_1 h^2_{t-1}+\beta_q h^2_{t-q} \quad (6)$$

Identification of the GARCH model is carried out by observing the cut-off that occurs in the lag ACF and PACF correlogram of squared residuals of the best ARIMA model. If there is more than one ACF and PACF lag that is cut off, then the best model parameter estimation uses the smallest AIC and SIC values. Apart from that, selecting the best GARCH model requires paying attention to the following things, namely [17]:

a. The model must meet the underlying assumptions.

b. Comparison of methods is carried out by paying attention to the smallest error.

c. Parsimony principle, in this principle the model should be as simple as possible or contain fewer parameters, so that this makes the method more stable.

3. RESULTS AND DISCUSSION

This research describes the level of inflation that occurs in Pangkapinang City, Bangka Belitung Islands Province, which tends to fluctuate. The time series of the inflation rate is shown in Figure 1 below.

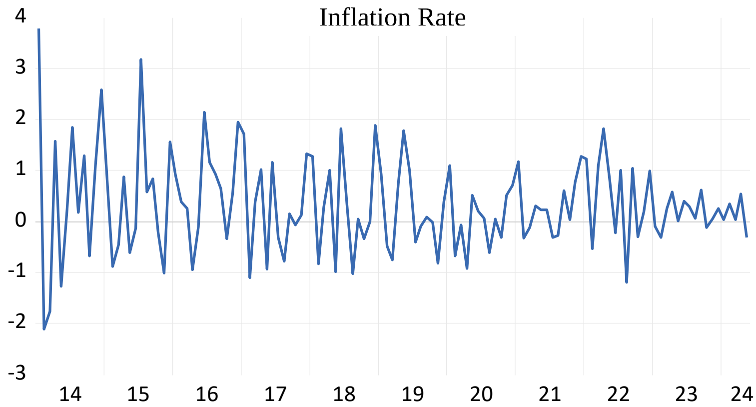


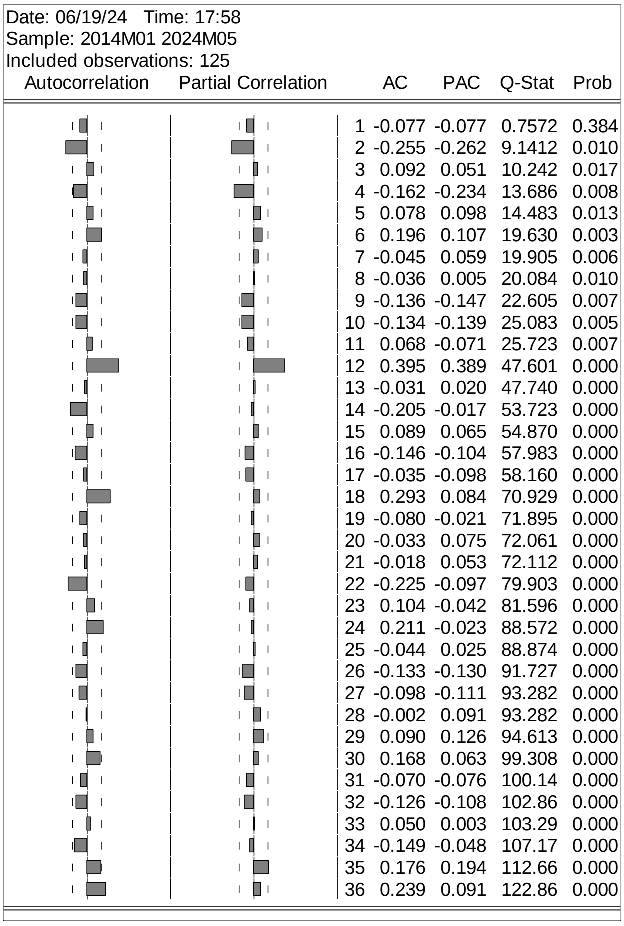
Figure 1. Inflation Rate in Pangkalpinang City

Figure 1 above is a plot of historical data used in this research. Based on this figure, the data is stationary at level so there is no need for a differencing stage. Apart from that, stationarity in the data can be seen through the probability values in the ADF test. The ADF test results for the inflation rate in Pangkalpinang City are as follows:

Table 1. ADF Test of Pangkalpinang Inflation Rate

		t-statistic	Prob
ADF Test		-10.48	0.0000
Test Critical Value	1% level	-3.48	
	5% level	-2.88	
	10% level	-2.57	

Based on Table 1, The probability value in the ADF test is zero (0) or smaller than the 5% significance level so it can be concluded that the data is stationary at the level. This means that the integrated data in orde I(0) or H_0 is rejected, which means that the data does not have a unit root. Inflation data that is already stationary at level d(0) will be continued in the identification of the tentative ARMA method based on the cut-off that occurs in the ACF and PACF correlogram lags. The ACF and PACF correlograms above show the occurrence of cut-off in both correlograms. The ACF correlograms illustrate the occurrence of cut-offs at lags 2, 12, 18, 22, 24, 36, and so on. In line with the ACF correlogram, the PACF correlogram also illustrates the occurrence of cut-offs at lags 2, 4, 12, and 35. This stage produces results like **Figure 2** below:


Date: 06/19/24 Time: 17:58
Sample: 2014M01 2024M05
Included observations: 125

Lag	AC	PAC	Q-Stat	Prob
1	-0.077	-0.077	0.7572	0.384
2	-0.255	-0.262	9.1412	0.010
3	0.092	0.051	10.242	0.017
4	-0.162	-0.234	13.686	0.008
5	0.078	0.098	14.483	0.013
6	0.196	0.107	19.630	0.003
7	-0.045	0.059	19.905	0.006
8	-0.036	0.005	20.084	0.010
9	-0.136	-0.147	22.605	0.007
10	-0.134	-0.139	25.083	0.005
11	0.068	-0.071	25.723	0.007
12	0.395	0.389	47.601	0.000
13	-0.031	0.020	47.740	0.000
14	-0.205	-0.017	53.723	0.000
15	0.089	0.065	54.870	0.000
16	-0.146	-0.104	57.983	0.000
17	-0.035	-0.098	58.160	0.000
18	0.293	0.084	70.929	0.000
19	-0.080	-0.021	71.895	0.000
20	-0.033	0.075	72.061	0.000
21	-0.018	0.053	72.112	0.000
22	-0.225	-0.097	79.903	0.000
23	0.104	-0.042	81.596	0.000
24	0.211	-0.023	88.572	0.000
25	-0.044	0.025	88.874	0.000
26	-0.133	-0.130	91.727	0.000
27	-0.098	-0.111	93.282	0.000
28	-0.002	0.091	93.282	0.000
29	0.090	0.126	94.613	0.000
30	0.168	0.063	99.308	0.000
31	-0.070	-0.076	100.14	0.000
32	-0.126	-0.108	102.86	0.000
33	0.050	0.003	103.29	0.000
34	-0.149	-0.048	107.17	0.000
35	0.176	0.194	112.66	0.000
36	0.239	0.091	122.86	0.000

Figure 2. Correlogram of Residuals Squared Analysis Results

Based on the concept of parsimony and cut-off that occurs in ACF and PACF, tentative ARMA methods can be formed as stated in **Table 2** below:

Table 2. Fitting Model ARMA

ARMA Model	P-Value		AIC
	AR	MA	
2,2	0.954	0.110	2.660
2,6	0.000	0.200	2.669
2,12	0.000	0.000	2.530
4,2	0.165	0.000	2.651
4,6	0.100	0.319	2.723
4,12	0.242	0.000	2.579
12,2	0.000	0.000	2.489
12,6	0.000	0.972	2.537
12,12	0.000	0.006	2.505

In **Table 2**, it can be seen that the ARMA model (12,2) is the best because it has the smallest Akaike Info Criterion (AIC) and p values compared to other models. The results of the ARMA (12,2) model are as follows:

Table 3. ARMA Model Analysis Results

Variable	Coefficient	Std. Error	t-statistic	Prob.
C	0.32	0.08	3.66	0.0014
AR(12)	0.46	0.08	5.37	0.0000
MA (2)	-0.26	0.07	-3.28	0.0013
SIGMASQ	0.64	0.07	8.20	0.0000

Variable	Coefficient	Std. Error	t-statistic	Prob.
R-squared	0.26	Mean dependent var		0.3208
Adjusted R-squared	0.24	S.D. dependent var		0.9405
S.E. of regression	0.81	Akaike info criterion		2.4896

The analysis results in **Table 3** show that the resulting p-value is significant because it is smaller than the alpha value (α = 5%). The next stage of analysis is a diagnostic test to determine the element of heteroscedasticity in the data. This diagnostic test uses Autoregressive Conditional Heteroscedasticity Lagrange Multiplier (ARCH LM) to determine the effect of ARCH (heteroscedasticity) on historical data. The results of the diagnostic test with ARCH LM can be seen in **Table 4** below:

Table 4. Heteroscedasticity Test Result

Heteroskedasticity Test: ARCH			
F-statistic	0.155	Prob. F(1.121)	0.693
Obs*R-Squared	0.158	Prob. Chi_Square (1)	0.690

In **Table 4**, it can be seen that the resulting chi square probability value is significant because it is bigger than the alpha value (α = 5%) thus indicating that there is no ARCH (heteroscedasticity) effect in the historical data. Heteroscedasticity in the data will provide estimation results that have a high error rate **[18]**.

The estimation of the GARCH model parameters on the inflation variable is carried out by considering the AIC value with the following results.

Table 5. GARCH Tentative Model Analysis Results

GARCH Tentative Model	AIC Value
1,0	2.241
1,1	2.182
0,1	2.201

Based on **Table 5**, it is obtained that GARCH (1,1) is the best tentative GARCH model that will be used in the prediction and volatility analysis stages. This GARCH model is a temporary GARCH method. This model still requires parameter estimation. Parameter estimation is carried out to obtain the best GARCH model that will be used in the prediction and volatility analysis stages. The results of the GARCH (1,1) model analysis are as follows:

Table 6. GARCH Model Analysis Results

Variable	Coefficient	Std. Error	t-statistic	Prob.
C	0.33	0.08	3.83	0.0001
AR (12)	0.38	0.07	5.29	0.0000
MA (2)	-0.14	0.09	-1.45	-1.1460
		Variance Equation		
C	0.86	0.17	4.99	0.0000
RESID(-1)^2	-0.09	0.04	-2.13	0.0325
GARCH(-1)	-0.66	0.27	-2.46	0.0136
R-squared	0.24	Mean dependent var		0.2949
Adjusted R-squared	0.23	S.D. dependent var		0.8086
S.E. of regression	0.70	Akaike info criterion		2.1820
Sum square resid	55.05	Schwarz criterion		2.3268
Log likelihood	-117.28	Hannan-Quinn criterion		2.2408
Durbin-Watson stat	2.01			

Table 6 above shows that the resulting p-value is significant because it is smaller than the alpha value (α = 5%). The next stage of analysis is to predict the inflation rate in Pangkalpinang City from January 2024 to June 2024 using the GARCH (1,1) model. Prediction results can be seen in **Figure 3** below:

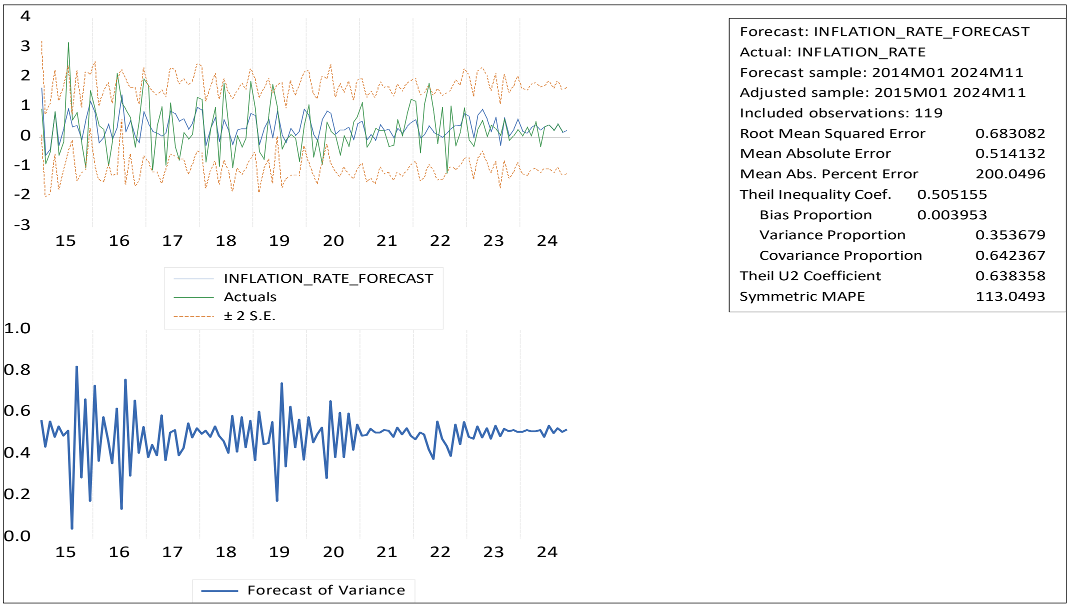


Figure 3. Prediction Results of Inflation Rates in Pangkalpinang City

The predicted values for the inflation rate from June 2024 to November 2024 found that the inflation rate in Pangkalpinang City fluctuated in the period from June to November 2024. This fluctuation will affect the economy, especially the purchasing power of the people in Pangkalpinang. This prediction of inflation is generally presented in Table 7 below:

Table 7. Prediction of Inflation Levels in Pangkalpinang

Period	Inflation Rate Prediction
June	0.33
July	0.39
August	0.22
September	0.43
October	0.15
November	0.22

Based on Table 7 and the figure above, it is found that the predicted inflation rate in Pangkalpinang from June 2024 to November 2024 tends to decrease with a MAPE prediction accuracy level of 200.0496. The MAPE value indicates that the estimation error exceeds 50%, suggesting that the prediction results may be unreliable. The high MAPE accuracy value is caused by the actual data move towards 0 [19]. This is also reinforced by the fact that the MAPE value in the estimation has a sensitivity to numbers approaching 0. Even though inflation in Bangka Belitung is still relatively light, it is still necessary to monitor inflation because its fluctuations are uncertain, especially in the foodstuffs group [20].

4. CONCLUSIONS

Based on the GARCH (1,1) model in Table 6 previously, the volatility value can be determined using the standard deviation value, which is the square root of the variance of the ARCH (α_1) and GARCH (β_1) models of -0.09 and -0.66 respectively. The sum of these two coefficient values gives a value of -0.75, which means that the level of volatility is low or it can be said that prices in Pangkalpinang tend to be stable and financial market conditions tend to be calm. Furthermore, based on the prediction results of the inflation rate in Pangkalpinang, it tends to fluctuate from period to period. On the other hand, the local government must also be prepared to face changes in economic conditions as an anticipatory step in maintaining the regional economy, especially in Pangkalpinang.

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