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Research Article

Forecasting the Price of Shallots and Red Chilies Using the Autoregressive Integrated Moving Average with Exogenous Variable (ARIMAX) Model

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Abstract: Shallots and red chilies are superior vegetable crops and make a significant contribution to national economic development. The prices of these two commodities fluctuate almost every year and in certain phenomena they increase. Therefore, given these conditions, researchers want to estimate the prices of shallots and red chilies by involving this phenomenon in their forecasting. The method used in this research is ARIMAX with exogenous variables, namely monthly dummy variables and various religious holiday calendars such as Chinese New Year, Eid al-Fitr and Eid al-Adha. Based on the ARIMAX model, the price of shallots shows that in January, February, March, April, May, June, July, August, September, October, November, December, and one month before Eid al-Fitr, and one month after Chinese New Year has a significant effect on monthly prices for shallots. The effect given one month after the Chinese New Year is 1920, meaning that from this figure one month after the Chinese New Year arrives, the price of shallots will increase by Rp1.920. Meanwhile, the ARIMAX model for red chilies shows that January to December, then one month before Chinese New Year, during Chinese New Year, one month before Eid al-Fitr, during Eid al-Fitr, one month before Eid al-Adha, and during Eid al-Adha has a significant effect on Indonesian monthly prices for red chilies. for example, the effect given by the Eid al-Adha holiday is 5037, meaning that during Eid al-Adha, the price of red chilies will increase by Rp5.037.

Keywords: ARIMAX, Red Chilies, Religious Holidays, Shallots

Introduction

The agricultural sector plays an important role in the national economy both as a source of livelihood and as a support for development. This is supported because most of the Indonesian population who live in rural areas have a livelihood as farmers and Indonesia has fertile soil which is one of the main reasons suitable for farming. Agriculture is the sector that absorbs the most labor in Indonesia. According to the Central Bureau of Statistics, the absorption of labor in the agricultural sector has increased from year to year in February 2022, reaching 29.96% of a total of 135.6 million working people. This is the highest figure out of a total of 17 labor-absorbing sectors in Indonesia [1].

The agricultural sector is divided into five sub-sectors, namely food crops and horticulture, plantations, forestry, fisheries and livestock sub-sectors. The sub-sector that plays a major role in the progress of agriculture in Indonesia is the food crops and horticulture sub-sector, the types of which include vegetables, fruits, ornamental plants, and flowers [2]. In 2010-2014 the Ministry of Agriculture of the Republic of Indonesia stated that the horticultural strategic commodities that became the national superior commodities in the category of vegetable plants were chilies and shallots [3]. Onion and chili plants are included in the group of agricultural products that have sharp price fluctuations. This condition occurs when supply in the market is lacking, causing prices to be higher than normal prices. Meanwhile, when the supply is abundant, the price will fall below the normal price [4].

Based on information from the National Strategic Food Price Information Center (PIHPS) the price of red chilies and shallots experienced a sharp increase in July 2022, this was due to the impact of the La Nina

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phenomenon, which increased rainfall so that in May 2022 it still had high rain intensity and had a negative impact on the main harvest season which falls in July 2022 [13]. The high prices of these two commodities triggered an increase in inflation in July 2022, namely reaching 0.64% (mtm), where red chili and shallots were the main contributors to inflation each of 0. 15% and 0.09% on an annual basis, which is 4.94% (yty), the highest since October 2015 [5]. Efforts to create price stabilization are also important because it involves people's ability to meet household food needs. In order to avoid the negative impacts of fluctuations in the prices of these two commodities which can cause inflation to rise and affect people's purchasing power to meet their needs, it is necessary to forecast the prices of shallots and red chilies in Indonesia. Forecasting results can be used in determining the right strategy and policy regarding the price of shallots and red chilies. In addition, this forecasting can provide benefits to consumers so that they do not only assume but can decide the right time to stock up or not.

ARIMAX is a development of ARIMA. ARIMA is a model that ignores independent variables [16]. whereas in some cases of time series that are influenced by variables other than the observed variables, the ARIMA model is not good enough for modeling. The way to capture input X outside the data series used is ARIMAX. Input X such as phenomena that occur based on the Hijri Celendar and the main data series are modeled based on the Gregorian calendar, so calendar variations will occur [8]. Then Lee, Suhartono, and Hamzah [10] carried out forecasts for sales of Muslim fashion products based on the effects of Ramadan. After explaining that there is previous research that modified the ARIMA model to become ARIMAX using other variables as explanatory variables model.

So, based on the explanation above, this study uses the ARIMAX modeling to predict the price data for shallots and red chilies in Indonesia using other variables (independent) in the form of dummy monthly and the effects of calendar variations (Chinese New Year, Eid al-Fitr, and Eid al-Adha).

Materials and Methods

Materials

In research using quantitative forecasting which uses a mathematical model to predict future events, namely the ARIMAX method (Autogressive Integrated Moving Average Exogenous). The analysis was carried out with the aim of obtaining predictions for the commodity prices of shallots and red chilies for 2023. This research uses assistance software Microsoft Excel, Eviews, and SAS to get forecasting results.

Method

a) Research variables

1. Y_{Bt} = Shallot price data in Indonesia from July 2017 to January 2023 as many as 67 data.
2. Y_{Ct} = There are 67 data on the price of red chilies in Indonesia from July 2017 to January 2023.
3. Variable dummy calendar effect as many as 21 variables dummy displayed on **Table 1**.

Table 1. The results of the parameter significance test of the shallot ARIMAX model

No	Calender Variation Effect Variable	Variabel Description	Coef
1.	Calendar effect in one year	$M_{1,t}$: January	α_1
		$M_{2,t}$: February	α_2
		$M_{3,t}$: March	α_3
		$M_{4,t}$: April	α_4
		$M_{5,t}$: Bulan Mei	α_5
		$M_{6,t}$: June	α_6
		$M_{7,t}$: July	α_7
		$M_{8,t}$: August	α_8
		$M_{9,t}$: September	α_9
		$M_{10,t}$: October	α_{10}
		$M_{11,t}$: November	α_{11}
		$M_{12,t}$: December	α_{12}
2.	Chinese New Year Effect	L_{t-1} : One month before Chinese New Year	β_1
		L_t : During Chinese New Year	β_2
		L_{t-1} : One month after Chinese New Year	β_3
3.	Effect of Eid al-Fitr	D_{t-1} : One month before Eid	γ_1

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No	Calender Variation Effect Variable	Variabel Description	Coef
4.	Effect of Eid al-Adha	D_t : At the time of Eid	γ_2
		D_{t-1} : One month after Eid	γ_3
		A_{t-1} : One month before Eid al-Adha	δ_1
		A_t : At the time of Eid al-Adha	δ_2
		A_{t+1} : One month after Eid al-Adha	δ_3

b) Reasearch steps

The steps of analysis carried out in this study are as follows:

1. Data exploration aims to find out the phenomena that affect the increase in the price of shallots and red chilies where these are the independent variables (X).
2. Dividing data into in-sample and out-sample data.
3. Performing stationary checks on data can use tests Augmented Dickey Fuller Test (ADF).
4. Determine the ARIMAX forecasting model with the ACF plot (Autocorrelation Function) and PACF (Partial Autocorrelation Function) the lag is outside the significance limit. ARIMAX model equation with variable input X includes monthly dummy and calendar variations as follows:

   $Y_t = \alpha_1 M_{1,t} + \cdots + \alpha_m M_{m,t} + \beta_1 L_{t-1} + \beta_2 L_t + \beta_3 L_{t+1} + \gamma_1 D_{t-1} + \gamma_2 D_t + \gamma_3 D_{t+1} + \delta_1 A_{t-1} + \delta_2 A_t + \delta_3 A_{t+1} + \frac{\theta_q(B)}{\phi_p(B)} \varepsilon_t$

   Where t is observation data, $t = 1,2,3,\ldots,n$ being influenced by a collection of independent series, p is ordo Autoregressive (AR), q is ordo Moving Average (MA), $\theta_q(B)$ *and* B is the backshift operator so stand for $1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q$, $\phi_p(B)$ is $1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$, and ε_t is error component which is usually sequence of noise process. Calendar variation also be modeled by using regression where the variables for ϕ is coefficient Autoregressive (AR), θ is coefficient Moving Average (MA), α_m is month coefficient, $m = 1,2,3,\ldots,12$, $M_{m,t}$ is monthly dummy variables. The remaining variables and coefficients of calendar variation in the equation have been explained above attached **Table 1**.
5. Identifying the parameters of the ARIMAX model can be found from the p-value and Q tables. The following is a test of the significance of the AR model parameters [6].

   $t = \frac{\hat{\phi}_i}{SE(\hat{\phi}_i)}$

   Where $\hat{\phi}_i$ is estimated value of the AR model parameters where i = 1,2,3…,n and $SE(\hat{\phi}_i)$is standard error of the AR model parameters.

   If the statistics show $|t| > t_{table}$or p-value < α (0.05), then reject H_0 the conclusion is significant model parameters.
6. Identify the ARIMAX model that meets the white noise assumption with the aim of seeing residual autocorrelation in the error analysis [7].

   $Q = n(n+2)\sum_{k=1}^{K} \frac{\rho_k^2}{n-k}$

   Where for Q is distributed parameter chi-square, K is lag which tested, ρ_k is autocorrelation for lag to-k, $k = 1,2,3,\ldots,k$, and n is amount of observation data Y
7. Calculating the forecasting accuracy obtained with MAPE.

   $MAPE = \frac{1}{n}\sum_{t=1}^{n} \left|\frac{Y_t - \hat{Y}_t}{Y_t}\right| \times 100\%$

   Where Y_t is actual value in periode-t, $\hat{Y}_t$ is forecast value in periode-t, and n is number of observations.

Results and Discussions

Prices of shallots and red chilies in Indonesia fluctuate almost every year. From July 2017 to January 2023 the prices of the two food commodities experienced sharp increases and decreases in prices.

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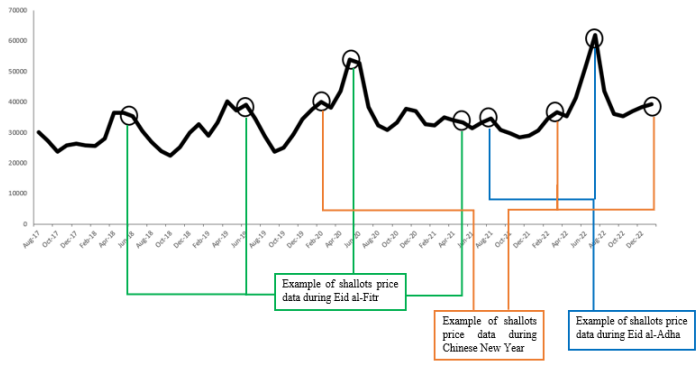
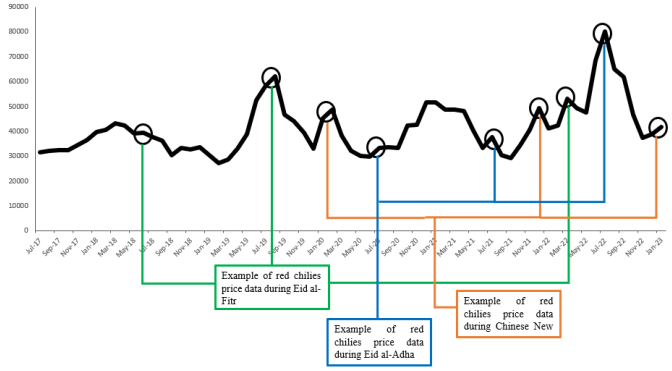


(a)



(b)

Figure 1. The price development of shallots (a) and red chilies (b) in Indonesia period July 2017-January 2023

From the description of these conditions over the past six years **Figure 1**, the price increases for shallots and red chilies have occurred in January, February, March, May, June and July. These months there are phenomena of religious holidays such as Chinese New Year, Eid al-Fitr, and Eid al-Adha. After knowing that there are other factors, namely national religious holidays that affect the prices of the two food commodities, then the first stage of ARIMAX analysis is to identify data stationarity, determine the order p and q through ACF and PACF plots ro create ARIMAX model, check the significance of the model formed, test white noise assumptions, and calculate price predictions.

a) Identify data stationarity

The stationarity of the data is that the data fluctuates around the mean and the constant variance of the data can be seen using Augmented Dickey Fuller Test (ADF) if p-value <α (0,05) then the data has been stationary, the following is a hypothesis test Augmented Dickey Fuller data on shallots and red chilies. The p-value of red chilies and shallots is known 0,0160 and 0,0037 which is smaller than significance level 0,05 the conclusions is rejects H_0 meaning that the data for the two commodities is stationary.

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b) Forming the ARIMAX model

The process of identifying the ARIMA model by looking at the ACF and PACF plots on **Figure 2**.

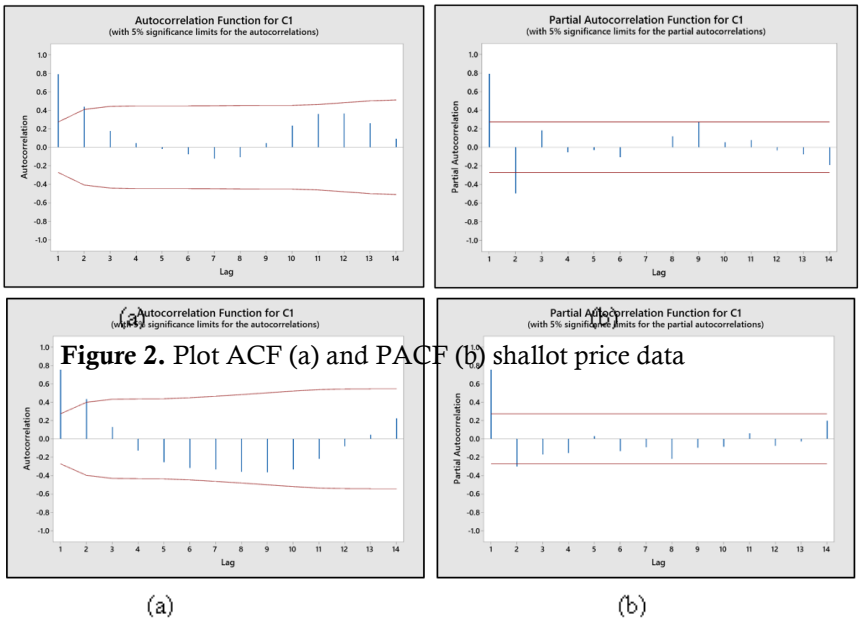

Figure 2. Plot ACF (a) and PACF (b) shallot price data

Figure 3. Plot ACF (a) and PACF (b) red chili price data

On **Figure 2** and **Figure 3** shows there is lag which is out of significant limits lag 1st and 2nd on the ACF plot. Then on PACF there is cut-off on lag to 1 and lag 2nd, in order to obtain a temporary model formed from the order AR(p) and MA(q). The ARIMA(2,0,2) model is then executed overfitting models namely ARIMA (2,0,1), ARIMA (2,0,0), ARIMA (1,0,2), ARIMA (0,0,2), ARIMA (1,0,1), ARIMA (0 ,0,1) and ARIMA (1,0,0). Furthermore, the model that is formed is tested for significance by adding variables dummy to the ARIMA model until the ARIMAX model is formed.

Test the significance of the ARIMAX model parameters

Table 2. The results of the parameter significance test of the shallot ARIMAX model

Model ARIMAX	P-value			
	AR(1)	AR(2)	MA(1)	MA(2)
(2,0,2)	<0,0001*	0,0049*	0,9949	0,0182*
(2,0,1)	0,0064*	0,9757	<0,0001*	-
(2,0,0)	<0,0001*	0,0164*	-	-
(1,0,2)	0,0032*	-	0,0024*	0,9152
(0,0,2)	-	-	<0,0001*	<0,0001*
(1,0,1)	<0,0001*	-	<0,0001*	-
(0,0,1)	-	-	<0,0001*	-
(1,0,0)	<0,0001*	-	-	-

Results on **Table 2** namely the parameter significance test for the shallot ARIMAX model shows that there are model parameters with p-valur smaller than the significance level of 0.05 (5%) namely, ARIMAX (2,0,0), ARIMAX (0,0,2), ARIMAX (1,0,1), ARIMAX (0,0,1) and ARIMAX (1,0,0).

Table 3. The results of the parameter significance test of the red chili ARIMAX model

Model ARIMAX	P-value			
	AR(1)	AR(2)	MA(1)	MA(2)
(2,0,2)	<0,0001*	<0,0001*	0,6793	0,1463
(2,0,1)	<0,0001*	<0,0001*	0,2094	-

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Model ARIMAX	P-value			
	AR(1)	AR(2)	MA(1)	MA(2)
(2,0,0)	<0,0001*	<0,0001*	-	-
(1,0,0)	<0,0001*	-	-	-
(1,0,2)	<0,0001*	-	<0,0001*	<0,0001*
(0,0,2)	-	-	<0,0001*	0,0002*
(1,0,1)	0,0081*	-	<0,0001*	-
(0,0,1)	-	-	<0,0001*	-

Based on **Table 3** shows that in the red chili price data there are six models that have significant parameters with p-value less than the significant level (5%) consists of models, ARIMAX (2,0,0), ARIMAX (1,0,0), ARIMAX (1,0,2), ARIMAX (0,0,2), ARIMAX (1,0,1), and ARIMAX (0,0,1). The parameter significance test for the six red chili ARIMAX models is statistically as follows.

c) MAPE

After finding a suitable model for forecasting the two commodity prices, the next step is to calculate the MAPE value to find out the average percentage error, namely the difference from the data actual with forecast results.

$$MAPE_{Red\ Chili} = \frac{1}{13}\sum_{t=1}^{13}\left(\left|\frac{Y_1-\hat{Y}_1}{Y_1}\right| \times 100\%\right) + \cdots + \left(\left|\frac{Y_{13}-\hat{Y}_{13}}{Y_{13}}\right| \times 100\%\right)$$

$$= \frac{1}{13}\left(\left|\frac{41300-50145}{41300}\right| \times 100\%\right) + \cdots + \left(\left|\frac{41850-40563}{41850}\right| \times 100\%\right) = 25.62\%$$

$$MAPE_{Shallot} = \frac{1}{13}\sum_{t=1}^{13}\left(\left|\frac{Y_1-\hat{Y}_1}{Y_1}\right| \times 100\%\right) + \cdots + \left(\left|\frac{Y_{13}-\hat{Y}_{13}}{Y_{13}}\right| \times 100\%\right)$$

$$= \frac{1}{13}\left(\left|\frac{30750-31620}{30750}\right| \times 100\%\right) + \cdots + \left(\left|\frac{39250-32257}{39250}\right| \times 100\%\right) = 17.36\%$$

d) Forecasting

Based on the data processing that has been done, the best forecasting model for each commodity is obtained, namely shallot ARIMAX (1,0,1) the model equation is $Y_{Bt} = 32258{,}7M_1 + 31353{,}7M_2 + 32364{,}3M_3 + 39717{,}6M_4 + 41552{,}8M_5 + 40526{,}6M_6 + 34683{,}4M_7 + 30997{,}2M_8 + 27556{,}8M_9 + 27021{,}2M_{10} + 29462{,}2M_{11} + 31454M_{12} - 1704{,}0D_{t-1} + 1920{,}5L_{t+1} + \frac{1+1{,}00000B}{1-0{,}60503B}\varepsilon_t$ and commodity namely red chili has best forecasting model ARIMAX (1,0,2) the equation is $Y_{Ct} = 54177{,}3M_{1,t} + 51926{,}0M_{2,t} + 41470{,}9M_{3,t} + 35316{,}4M_{4,t} + 30737{,}9M_{5,t} + 31856{,}4M_{6,t} + 33934{,}3M_{7,t} + 33956{,}9M_{8,t} + 31337{,}8M_{9,t} + 35376{,}3M_{10,t} + 36158{,}5M_{11,t} + 41443{,}8M_{12,t} - 12379{,}5L_{t-1} - 13699{,}6L_t + 3027{,}3D_{t-1} + 4561{,}2D_t + 2943{,}1A_{t-1} + 5037{,}3A_t + \frac{(1+1{,}01055B+1{,}00000B^2)}{1-0{,}66045B}\varepsilon_t$.

Price forecasting for shallots and red chilies in Indonesia for 2023 is carried out with the results **Table 5**.

Table 5. Forecasting results in 2023

Month	Shallot	Red chili
January	32.257	40.563
February	33.273	47.729
March	30.660	44.536
April	39.717	39.902
May	41.553	33.697
June	40.526	36.904
July	34.683	33.941
August	30.997	33.962
September	27.557	31.341
October	27.021	35.378
November	29.462	36.160
December	31.454	41.445

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Based on the results, **Table 5** shows the predicted Shallot prices for January experienced an increase of Rp32.257/Kg compared to the predicted price December 2022, namely Rp31.450/Kg and in accordance with the set price PIHPS (National Strategic Food Price Information Center) [13]. Shallot prices continued to increase until April and May. In April 2023 the predicted price shows an increase of Rp39.717/Kg. The price increase is due to high demand just before Eid Fitri. This is in line with the previous IKAPPI 2022 statement and before Eid, the price of shallots is predicted to reach approx Rp40.000/Kg. In May 2023 the predicted price will experience an increase of Rp41.553/Kg due to the still high needs of the community one month after Eid or before Eid al-Adha and predicted price increases follows the previous year's pattern in May 2022 which coincides with Hari Eid al-Fitr. The price of shallots was the highest in a year in May 2023.

Predictions red chili price for January 2023 will increase, namely Rp40.563/Kg compared to the prediction for December 2022, namely Rp29.194/Kg, and in line with data set by PIHPS for red chili prices in January 2023 amounting to Rp41.850/Kg shows that the predicted value is not much different from the price actual, and this month there is Chinese New Year. In February 2023 shows an increase in price, namely Rp47.729/Kg, compared to last month January 2023, the price of red chilies is Rp41.850/Kg. Predicted price increase red chilies in 2023 follow the pattern of previous years where one month after Chinese New Year the price of red chilies increased. That matter because farmers choose to postpone picking red chilies in the middle The harvest season is full of rain and it is predicted that the rainy season will end in March [12]. In October 2023, based on the prediction results, it is estimated that the price will continues to increase until December 2023 reaching Rp41.445/Kg.

Price increases on red chilies which occurs towards the end of the year also has an impact on price of shallots. Caused by bad weather changes viz entering the beginning of the rainy season so that it can cause the planting season backwards and not all of the chili plants can be harvested because of this plant very risky for high rainfall according to the Chili Agribusiness Association Indonesia [11]. If this happens it can cause reduced supply of red chilies and shallots in the market and causes price increases.

Conclusion

The conclusions that can be given from the analysis that has been carried out are as follows. The best model for forecasting the price of shallots and red chilies is:

1) On shallot the ARIMAX model (1,0,1) obtains MAPE data out-sample of 17.36% and based on the criteria of the goodness of the model shows that the forecasting results are good. The best model for ARIMAX is obtained as follows:
$$Y_{Bt} = 32258{,}7M_1 + 31353{,}7M_2 + 32364{,}3M_3 + 39717{,}6M_4 + 41552{,}8M_5 + 40526{,}6M_6 + 34683{,}4M_7 + 30997{,}2M_8 + 27556{,}8M_9 + 27021{,}2M_{10} + 29462{,}2M_{11} + 31454M_{12} - 1704{,}0D_{t-1} + 1920{,}5L_{t+1} + \frac{1+1{,}00000B}{1-0{,}60503B}\varepsilon_t$$
Forecasting results show the highest shallot price in 2023 starting in April-May. There is a phenomenon that has a major impact on rising shallot prices in Indonesia, namely one month after Chinese New Year.
2) In forecasting the price of red chili, the best model is ARIMAX (1,0,2) with MAPE data out-sample of 25.62% according to the criteria of goodness shows the forecasting results are quite good. The following is the form of the mathematical model:
$$Y_{Ct} = 54177{,}3M_{1,t} + 51926{,}0M_{2,t} + 41470{,}9M_{3,t} + 35316{,}4M_{4,t} + 30737{,}9M_{5,t} + 31856{,}4M_{6,t} + 33934{,}3M_{7,t} + 33956{,}9M_{8,t} + 31337{,}8M_{9,t} + 35376{,}3M_{10,t} + 36158{,}5M_{11,t} + 41443{,}8M_{12,t} - 12379{,}5L_{t-1} - 13699{,}6L_t + 3027{,}3D_{t-1} + 4561{,}2D_t + 2943{,}1A_{t-1} + 5037{,}3A_t + \frac{(1+1{,}01055B+1{,}00000B^2)}{1-0{,}66045B}\varepsilon_t$$
Forecasting the price of red chilies in 2023 shows the highest price increases starting in January-February. There is a phenomenon that has a major impact on increasing the price of red chilies, namely during Eid al-Adha due to the soaring demand for red chilies on this religious holiday.

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