Price volatility of staple food using ARCH-GARCH model

I Setiawati\textsuperscript{1*}, Ardiansyah\textsuperscript{1} and R Taufikurohman\textsuperscript{2}

\textsuperscript{1} Faculty of Agriculture, Jenderal Soedirman University, Indonesia
\textsuperscript{2} Faculty of Bioindustry, Trilogi University, Indonesia

Corresponding author: iindahs@unsoed.ac.id

Abstract. Staple goods are vulnerable to inflation. The fluctuating of the price of staple food is an interesting study for regions wishing to control the inflation rate. The purpose of this study is to analyze the price volatility of several food commodities and to find out the best model as alternative forecasting model that is suitable for the phenomenon of price volatility. This study uses time series data, namely the weekly prices of staple food for the last two years. The econometric model used in this study is the Autoregressive Conditional Heteroscedasticity-Generalized Autoregressive Conditional Heteroscedasticity (ARCH-GARCH) model. The ARCH-GARCH model is used to estimate the volatility of the price of the community groups. Staple food studied in this study included 3 commodities, namely rice, chicken, and sugar. The results showed that the prices of the three goods were volatile. Therefore, it is important for local governments to know how to maintain the weekly price of staple foods so that inflation can be controlled.

1. Background
Staple foods are volatile goods so that they have the high inflation rate compared to other sectors [1]. Staple goods have very fast price changes in a matter of days. The nature of the goods depends on the season, fresh products from agriculture, and is a daily food requirement. Low elasticity and seasonal production are the determinants of price variations for staple foods [2]. The most of staple foods are agricultural products. Production tends to respond less quickly when prices change, this is because production decisions such as input spending are made before the harvest price occurs. Cultural and natural factors also determine agricultural production activities. This causes the supply of staple foodstuffs from farming activities to have low elasticity.

Changes in the price of staple foods stem from changes in supply and demand. In general, it is assumed that the price volatility of agricultural products staple food is due more to supply shocks, while the volatility for agro-industrial commodities is mainly driven by demand shocks. This price shock can intensify and contribute to broader social risks in terms of food security, human development, and political stability may undermine the resilience of poor people and low-income countries and thus exacerbate economic insecurity, often eroding societal cohesion [3]. Staple foods are vulnerable to inflation, especially in poor areas and it is important to study. The study of price volatility on staple foods is important because price variations over time can be identified and subsequently become the basis for policy to anticipate large price variations so that risks for producers, consumers and the government can be reduced.

Kebumen Regency is the region with the highest percentage of poverty in Central Java. The figure reached 16.82%, far above the average poverty rate of Central Java Province of 10.8% [1]. Kebumen...
Regency is the highest poor population than the surrounding area such as Wonosobo, Banjarnegara and Banyumas. Wonosobo is the closest district in terms of poverty ranking. Different from previous years, Kebumen currently has a higher poverty rate than Wonosobo. One of the efforts to alleviate poverty is to reduce the burden of spending and get health. The burden of spending on staple food is of course the main thing that must be fulfilled in alleviating poverty, therefore, stability of prices and purchasing power of the poor towards staple foods must be achieved. but in fact, the price of staple foods fluctuates, changing every day. it is necessary to conduct a study to anticipate so that price fluctuations can be identified and then controlled.

The price of staple goods in Kebumen Regency shows price volatility during the first semester of 2020. More than fifty percent of total expenditure is used for food expenditure [1]. There are several commodities that dominantly contributed to inflation in Kebumen throughout 2019 (rice, sugar, meat, chilli, shallot, garlic, eggs, etc). Rice productivity in Kebumen shown that surplus production. This condition must be argued that Kebumen will be stable on its daily prices. In fact, the price of rice in Kebumen is similar with the other regency that has volatility price. The chain of distribution and also characteristic the product that seasonal product is the main reason for the changes of daily prices. Likewise, for other food products, the seasonal nature of the product and long distribution channels can be a factor in price fluctuations. Fluctuations will still occur at staple foods.

So that the analysis of the volatility of food prices is very important for price stability policies in Kebumen. The aim of this research is to increase the effectiveness of price stabilization policies, this study aims to analyze the price volatility of several food commodities and to find out the best model that is suitable for the phenomenon of price volatility.

2. Methods

2.1. Data collection
This research has been conducted in Kebumen Regency. Determination of location conducted purposively (purposive) by considering that Kebumen is the poorest area in Central Java, so it requires a price stabilization policy to meet the basic needs of its people. The type of data that used in this research is secondary data of weekly time series data from January 2018 to August 2020, including price data of local market in Kebumen Regency. Data was obtained from several sources such as Central Java Province Trade and Industry Office and Kebumen Regency Trade and Industry Office.

Data analysis methods were used descriptive analysis methods and quantitative analysis methods. Descriptive analysis method was used to provide an overview food balance which includes production data and consumption data in Kebumen Regency in 2019. Meanwhile the quantitative analysis method with ARCH/GARCH model by the help of Eviews 10 was used to figure out the volatility of Kebumen staple foods prices.

![Figure 1. ARCH GARCH estimation procedure flow chart for data analysis](chart)

Analysis of the ARCH-GARCH model is available several steps that must be done, namely: (1) data stationarity test using unit root test, (2) ARMA-ARIMA test, (3) ARCH-LM test, (4) selecting the best model and forecasting volatility using ARCH-GARCH model [4]. Descriptive statistical analysis is carried out as a first step to determine whether the price of these commodities has heterogeneity scedasticity. Using statistic descriptive variable: Mean, Standard Deviation, Skewness,
Kurtosis, Max and Min. If the data shows value of kurtosis more than 3, it is indicated that data has a heteroskedasticity and then analysis using ARCH/GARCH Model needs to be done. ARMA/ARIMA Model be obtained precise prediction results when the variance of the errors is constant, it is called homoscedasticity.

2.2. ARCH-GARCH model

The volatility of staple foods price can be seen with the use of Autoregressive Conditional Heteroscedasticity (ARCH) and Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models to analyze development. The ARCH model was first developed by Engle which assumes residual variants for inconstant of time series data or contain heteroscedasticity. The basic form of the ARCH model can be explained as follows [5]:

\[ Y_t = \beta_0 + \beta_1 X_t + e \]

Where, \( Y_t \) is the dependent variable; \( X_t \) is an independent variable; and \( e \) are interference or error variable. In general, the type of time series data tends to have a variant of error term which is constant over time or homoscedastic. However, the high volatility in time series data can cause the residual variants of the data to be inconstant and change from one period to another period, or contain an element of heteroscedasticity. Heteroscedasticity occurs because the time series data shows the element of volatility, the variance of the disturbance variable from the model will depend on disturbance variable volatility of previous period or in other words, the variance of disturbance variable is strongly influenced by disturbance variable in previous period.

GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model is an improvement of the ARCH model which was developed by Bollerslev in 1986. The GARCH model states that the variance of the disturbance variable is not only influenced by the disturbance variable in the previous period, but it’s also influenced by variance of interruption variable of previous period. Then, the equation for variance of interference variable with GARCH model can generally be written as follows:

\[ h_t = K + \delta_1 h_{t-1} + \delta_2 h_{t-2} + \ldots + \delta_r h_{t-r} + \alpha_1 \epsilon_{2t-1} + \alpha_2 \epsilon_{2t-2} + \ldots + \alpha_m \epsilon_{2t-m} \]

Where, \( h_t \) is the price variable of garlic at time \( t \), or the variance at time \( t \); \( K \) is a constant variance; \( \epsilon_{2t-m} \) is the ARCH term or volatility in the previous period; \( \alpha_1, \alpha_2, \alpha_m \) are estimated order \( m \) coefficients; \( \delta_1, \delta_2, \delta_m \) are estimated order \( r \) coefficients; and \( h_{t-r} \) is the GARCH term or variance in the previous period.

3. Results and discussion

3.1. Descriptive statistics

Descriptive statistics were performed to identify the ARCH-GARCH effect, whether the data contained heteroscedasticity or not [4]. This can be found by observing some summary statistical data (descriptive statistics). If the data has a kurtosis value of more than 3, it shows early symptoms of heteroscedasticity [6] (Harjanto, 2014). In addition, testing the presence of ARCH effects on one data set can be done by observing the autocorrelation coefficient value of the squared data. The arch effect is indicated by the significant quadratic autocorrelation value for the first 15 lags examined for their ACF and PACF behavior.

At this stage, tests were also carried out on the existence of the ARCH effect on a group by observing autocorrelation function (ACF) and partial autocorrelation function (PACF). The presence of the ARCH effect is indicated by the value of the autocorrelation coefficient from the data that is squared significantly for the first 15 lags. The next step is to estimate the model with the Box-Jenkins methodology to find the best ARIMA model.

The data analyzed in the volatility of food prices are rice price data, chilies, onions, chicken, garlic, beef, sugar, cooking oil and eggs. The development of price data for the three food commodities
described descriptively Table 1 below. Food price data has quite diverse variations as shown in Table 1.

Table 1. Descriptive statistics of rice, chilies, chicken, garlic, beef, sugar, cooking oil and eggs price variables

|      | Mean   | Std. deviations | Skewness   | Kurtosis      |
|------|--------|-----------------|------------|---------------|
| Rice | 9018.150 | 570.5062        | 0.402175   | 6.144363*     |
| Chilies | 27547.34  | 11996.42       | 0.969654   | 3.190966      |
| Chicken | 30536.11  | 2816.024       | 0.648890   | 3.977845*     |
| Garlic | 29832.66  | 7969.546       | 1.067816   | 3.819801      |
| Beef   | 110903.6 | 4602.933       | -0.216365  | 2.307618      |
| Sugar  | 12295.57  | 1778.611       | 1.755616   | 5.459698*     |
| Cooking oil | 10551.35  | 886.5079      | 0.414452   | 2.430427      |
| Eggs   | 22792.56  | 1872.566       | 0.329352   | 2.608796      |

Based on Table 1, the kurtosis value for the three variables (rice, chicken, and sugar) is more than three. This value indicates that the analyzed data has problems heteroscedasticity. A kurtosis value of more than three means that the distribution is variable economies analyzed have a tail that is denser than the distribution normal. The skewness value of all staple food price (except beef) data is greater than zero. This means that the distribution of existing data has data distribution sloping to the right which means data tends to pile up on low value.

3.2. Unit root test

The next step is to test the stationarity of the data using the unit root test using both price data at the level and the first difference. Stationary data were obtained using the Augmented Dickey Fuller (ADF) Test. Stationarity test can be performed on data level, first difference and second difference. Based on Table 2, it can be seen that the variable price of rice and sugar is stationary at the first different, while the variable price of chicken meat is stationary at the data level. This matter because the ADF t-statistic value is smaller than the critical value of MacKinnon at the 5 percent level. If the data shows the ADF Test is smaller than the Mc Kinnon value, the data is stationary (predictable and unbiased). If not, then change the data to its first different data.

Table 2. The results of the root test of the weekly unit prices for rice, chicken meat and period sugar January 2018-August 2020

| Variable | ADF Tstatistic | Mc Kinnon Value (5%) | Test unit root in |
|----------|----------------|----------------------|-------------------|
| Rice     | -5.775,897     | -1.943,157           | First different   |
| Chicken  | -9.976,181     | -1.943,193           | Level             |
| Sugar    | -1.323,482     | -1.943,157           | First different   |

3.3. ARMA-ARIMA model and ARCH LM test

The Box-Jenkins model was determined after the stationarity test was carried out. Some Box-Jenkins models are Auto Regressive (AR), Moving Average (MA), Auto Regressive Moving Average (ARMA) and Auto Regressive Integrated Moving Average (ARIMA). If the data is stationary at the level, then the estimation model uses ARMA, but if the data is stationary, it is first difference using ARIMA. The best ARMA model estimation results for price data of rice, chicken meat and sugar can be seen in Table 3. The best model is selected after perform some ARMA model simulations. The criteria for selecting the ARMA model is based on a significant coefficient of estimation, has R-Squared and the largest adjusted R-Squared, the smallest AIC and SIC values, and the Standard values Relatively small Error of Regression and Sum Square Residual [7].
Table 3. Best ARMA/ARIMA model

| Variable | ARMA/ARIMA Model | Probability of ARCH LM Test |
|----------|------------------|-----------------------------|
| Rice     | ARIMA (2,1,0)    | 0.0000                      |
| Chicken  | ARMA (1,4)       | 0.0065                      |
| Sugar    | ARIMA (1,1,3)    | 0.0078                      |

The best of ARMA-ARIMA Model Then perform the ARCH LM test to determine the best arima model. the best arima model for rice prices is ARIMA 2-1-0, The best arima model for sugar prices is ARIMA 1-1-3, while the best arima model for chicken meat price is ARIMA 1-4.

3.4. ARCH-GARCH model

Based on Table 3, all staple food commodity prices have an ARCH effect, so it can volatility analysis was performed using ARCH-GARCH. The best ARCH-GARCH model is selected based on the criteria that is, all coefficients are significant in the variance equation, have the largest Log-Likelihood value, the smallest AIC and SIC values, and have positive values for all coefficients in the variance equation. Based on the existing criteria, the ARCH-GARCH model selected for each food price variable is shown in the Table 4.

Table 4. The best ARCH-GARCH model on commodity prices for rice, chicken, and sugar

| Variable | ARCH/GARCH | Probability of ARCH-GARCH model | Jarque Bera | Probability |
|----------|------------|---------------------------------|-------------|-------------|
| rice,    | ARCH(1)    | 0.0000                          | 32.658      | 0.0000      |
| chicken  | ARCH(1)    | 0.0001                          | 157.435     | 0.0000      |
| sugar    | ARCH(1)    | 0.0001                          | 121.85      | 0.0000      |

Based on Table 4, the ARCH model is the best model for the three the food commodity studied. After selecting the best ARCH-GARCH model, the next thing to do is evaluate the model. Model evaluation can be done through the normality test by paying attention to the Jarque-Bera statistical value. The results of the Jarque-Bera statistical test can be seen in Table 4. The results of the normality test show that the Jarque-Bera value statistically significant, which means the model error is not normally distributed. All ARCH-GARCH models on each variable were tested for normality and shows that the errors in all ARCH-GARCH models are distributed abnormal, so the ARCH-GARCH model is shown in Table 4 still the best model.

3.5. Price volatility

Based on the estimation results of the ARCH-GARCH model that has been done, it can be concluded that the volatility of the three food commodities can be analyzed. This is because the three ARCH-GARCH models built have an effect ARCH. The volatility value obtained from the three commodities varies. The presentation of the estimated value of food price volatility is displayed in graphic form.

3.5.1. Volatility in rice prices. The volatility of rice prices in Figure 2 starts in the first week of January 2018 until the fourth week of August 2020. Rice price volatility always moves under its average (April & October in 2018 & 2019). The highest price volatility occurred in April – May in 2018 and 2019.

During this period, the volatility of the rice price reached more than four standard deviations. After this period, the volatility started to decline up to end of March 2018. In October 2018, volatility again increased with value reached four standard deviations, but fell back to below the mean in December 2018. In the following year, namely at the end of March 2019, volatility again peaked with a value of more than four standard deviations. The peak of volatility in 2019 occurred for 5 weeks until volatility fell below the mean again. Volatility rose again above its four standard deviations from August to October 2019. then decreased to below the mean and increased again in early 2020 to more than four standard deviations. throughout 2020, price volatility fluctuated quite a bit and reached its highest point in February and April 2020.
Price volatility from the beginning of the year to March 2018 occurred due to the effect of the transition from the harvest period and the next planting period. This is thought to have occurred in the rice stock fluctuation in the market. The peak of such volatility occurred in the following year, in March 2019. This shows that while waiting for the next harvest period, there was very high volatility. It was caused mainly by seasons and yearly routine cycles [8]. This is a concern for the government to improve price stability policy through the rice stock mechanism in the market [9].

Figure 2. Volatility in rice price

3.5.2. Volatility in chicken price. The volatility of sugar prices in Figure 3 starts in the first week of January 2018 until the fourth week of August 2020. Volatility price occurs at the average price. Highest volatility occurs at June 2018, June 2019, June 2020. The national average price of live-birds at the farmer level is often below the reference price, due to excess production of the live-birds at the farmer level [10]. The frequent fluctuation of chicken prices on a daily basis indicates that a market is not integrated [11]. Four contributing factors change in chicken prices, namely: (1) oversupply from broilers, (2) oversupply from day old chicken (DOC), (3) decreasing public purchasing power, and (4) mafia issues chicken cartel. This paper aims to examine the factors causing the decline broiler prices and government efforts to stabilize them [12].
3.5.3. Volatility in sugar price. The volatility of sugar prices in Figure 4 starts in the first week of January 2018 until the fourth week of August 2020. Figure 4 shows that volatility in sugar price occurs above mean price. Highest volatility occurs at April 2020, the high volatility of sugar prices in April indicates that the pandemic period played a role in the volatility of sugar prices. The Ministry of Trade said that the impact of the spread of the Corona virus made a number of countries temporarily close their trade access. One of the impacts is trade access to trading partner countries that usually supply refined sugar and raw sugar to Indonesia. Low elasticity implies that small shocks to production can have a large impact on prices [13].
Sugar prices still show fluctuations indicating that the government’s efforts to provide affordable white crystal sugar at the consumer level by setting a sales reference price have not been effective. Volatility in sugar price occurs influence, significantly, by consumption of sugar, import of industrial sugar, world sugar prices, rice prices at the consumer level, and retail prices of plantation white sugar in the previous periods [14].

4. Conclusion
The volatility of the three staple food commodities can be analyzed. Analysis using the ARCH GARCH method shows that the best model for assessing the price volatility of staple food in Kebumen Regency is the ARCH model with the order 1-0. Volatility occurs due to supply and demand factors and the accompanying policies, resulting in shocks in the availability of staple food goods in the market.

The study of prices on staple foods shows that there has been high volatility in the past two years. This shows that price stability has not yet occurred in Kebumen Regency, so there needs to be government efforts to maintain the purchasing power of its people so that poverty can be reduced.

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