The TGARCH Supply Chain Management Model of Rice Price Volatility in South Sumatra, Indonesia

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Abstract— **The aim of this study was to build a price model for premium and medium rice in South Sumatra Province, being a major centre for production in Indonesia. This was estimated using the ARCH/GARCH model, based on the weekly data obtained between March 2016 and July 2019. The results showed the occurrence of price volatility for premium and medium variety, despite the polity implementation by government. Therefore, the best volatility model was identified, termed TGARCH (1,1), with a threshold of 1, characterized by futuristic price predictability. In addition, the estimations provide an overview, and also serve as a material for policy evaluation, in order to enhance effectivity and promote the actualization of goals.**

Keywords— *Price volatility, premium and medium rice, TGARCH, supply chain management*

1. Introduction

Food price instability is a major risk faced by agricultural households in developing countries [1]. Furthermore, it is possible to use these variations as a positive signal, and perhaps as a negative indicator where the changes are large enough, based on the fact that the government or economic actors become unable to anticipate accurately. The volatility is ascribed as a statistical method for measuring price fluctuations and not level over a certain period, which serve as a basis for allocating agricultural resources, risk management, and product prices. However, significant changes in prices and the quantity of and agricultural commodities produced lead to high levels of risk and uncertainty [2][3]. [1] Further reported its impact on investment behaviour, farm income, policies, and food security.

Rice is one of the main food commodities in Indonesia, which serves as an indicator of the country's economy, as its price reflects management capability [4]. Furthermore, the government and communities tend to have interest in the relative stability of rice price [5]. Several price and non-price policies have been implemented by the government. This includes the introduction of a basal and the maximum price, intended to protect farmers and consumers, respectively. However, it is assumed that some of these policy instruments have not been effectively conducted in practice, prompting the need for further evaluation [6][7][8].

The latest strategy issued by the government required the determination of highest retail price (HET) as stipulated in the Minister of Trade Regulation of the Republic of Indonesia Number 57/M-DAG/PER/8/2017. This took effect on September 1, 2017, aimed at maintaining stability and certainty, as well as affordability of rice prices to consumers. [8] Concluded the ineffective nature of this policy, as a continuous increase was attained, as medium variety also exceeded the value set in the HET strategy. According to [9], rice policy is loaded with various interests, hence, decisions taken by the government are aimed at satisfying short-term benefits, encompassing the issue of purchase prices (HPP), imports, and other related policies. Hence, weak data accuracy, poor rice farmers, the extent of rice dependency, as well as the price and distribution of rice are the four basic problems encountered in this sector.

Detailed information is needed regarding the behaviour of the commodity concerned, in order to improve the effectiveness of policies and programs that stabilize prices, especially rice. In addition, the scope of data needed includes the trend or direction of change and its volatility. This is highly useful in the formulation of more effective actions, due to the fact that the concept is closely related to the risks and uncertainties faced in decision making [11][12]. [13] reported various reasons affiliated with the volatility of agricultural commodities, encompassing (1) price variability is influenced by external shock or weather, in relation to commodity supply, and (2) price fluctuations are predictable. [14] stated the importance of agricultural commodity price estimation as a tool for market risk management. Therefore, the volatility in food

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prices is observed as a challenge and opportunity to formulate a price model that provides the information needed for rice market stakeholders, and also for the government, as a policyholder [15].

The aim of this study was, therefore, to analyse the price volatility of rice in South Sumatra Province, being one of the food storage areas in Indonesia. [16] grouped the estimation into two methods, encompassing: (1) historical and (2) implied volatility. Several models have been developed previously, due to the importance of the volatility concept, especially in the aspects of economics and finance [17]. Rice price volatility in the current investigation was analysed using the ARCH/GARCH method, as performed by [18-24][13]. Therefore, the knowledge of rice price volatility model is expected to contribute towards policy planning and evaluation.

2. Literature Review

Time series analysis is one of the procedures conducted on time series data, which is applied to predict futuristic conditions, in the decision making context, and some of the methods used include ARIMA, VAR, ARCH, GARCH [25]. In addition, related economic and financial data tend to frequently possess high volatility, with the implication of variance and error (residual), which are not constant. Hence, the data is said to have experienced heteroscedasticity [26].

This manifestation necessitates the creation of an approach model in an attempt to measure the residual volatility problem, involving the inclusion of independent variables that possess the capacity to predict residual volatility. The ARCH/GARCH model treats heteroscedasticity as a variety to be modelled, in order to uncover the predicted results of error diversity. This approach corrects the weakness of the least squares and also calculates each forecast for confounding error variants [27].

[28] compared several symmetrical and asymmetrical GARCH models for the gold price form in Malaysia and identified the best to be TGARCH. [28] also drew conclusions on its ability to provide a better explanation regarding the return volatility, in contrast with the simple GARCH, while asymmetric effects were observed to perform better at explaining conditional volatility. [29] also used the TGARCH model in the composite stock price index return, this was conducted to overcome the problem of financial data generally demonstrating the phenomenon of asymmetry between the value of positive and negative error. Moreover, the ARCH/GARCH model assumes similarity in the effects of positive and negative errors on volatility.

Susanti et al. [30] compared the TGARCH with the EGARCH model in the process of forecasting a composite stock price index, as both are asymmetric, and TGARCH was concluded to be the best model. Also, Winata and Hapsari [31] made a similar conclusion at PT. Gudang Garam.

3. Materials and methods

The analysis of rice price volatility was concentrated in the South Sumatra Province, being a major centre of production in Indonesia. Therefore, secondary data were obtained weekly, in the form of retail prices from the second week of March 2016 to the second week of July 2019 (175 weeks). This was collected from the Price Panel Information System of the Food Security Agency (BKP).

Building a model for rice prices required the simulation of a number of models, using the ARCH/GARCH, in an attempt to choose the best. This is, therefore, to be used for the futuristic selection of premium and medium rice prices in the Province of South Sumatra. Furthermore, the ARCH/GARCH model in the current research was estimated using the EViews 10 SV software.

3.1 The ARCH model

The residual variance equation in the ARCH model, where α is a constant and e^2_{t-1} is the residual square of the previous period, is written as Equation 1 [32].

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2$$

This is called the ARCH (1) because the variance of residuals (σ^2_t) depends only on the residual squared fluctuations that occurred one period ago (e^2_{t-1}). Therefore, dependence on past periods (lag p), leads to the expression of the general form of ARCH (p), as seen in Equation 2.

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \alpha_2 e_{t-2}^2 + \dots + \alpha_p e_{t-p}^2$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \left|\frac{e_{t-1}}{\sigma_{t-1}}\right| + \varphi_1 \left|\frac{e_{t-1}}{\sigma_{t-1}}\right| + \dots + \alpha_p \left|\frac{e_{t-p}}{\sigma_{t-p}}\right| + \varphi_p \frac{e_{t-q}}{\sigma_{t-q}} + \lambda_1 h \sigma_{t-1}^2 + \dots + \lambda_q h \sigma_{t-q}^2$$

3.2 The GARCH model

Bollerslev [33] developed the ARCH model by incorporating past period residual elements and residual variance, termed Generalized Autoregressive Conditional Heteroscedasticity (GARCH), generally expressed in Equation 3.

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \lambda_1 \sigma_{t-1}^2 \quad (3)$$

Equation 3 indicates that the residual variance (σ^2_t) is influenced by the square (e^2_{t-1}), and also the variance (σ^2_{t-1}) of the previous period. Therefore, the model is termed the GARCH (1,1), while the form of (p,q) is stated in Equation 4.

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \dots + \alpha_p e_{t-p}^2 + \lambda_1 \sigma_{t-1}^2 + \dots + \lambda_q \sigma_{t-q}^2 \quad (4)$$

Furthermore, variations in the ARCH and GARCH models have been developed as follows:

3.3 The ARCH-M model

The ARCH-M model (ARCH-in-mean) includes the residual variance element as one of the independent variables in the average equation. Furthermore, the general form is observed to be similar to the GARCH model, as seen in Equation 4, with the ARCH (p) and the GARCH (q) elements.

3.4 The TGARCH model

The general form of TGARCH model is expressed in Equation 5.

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \dots + \alpha_p e_{t-p}^2 + \varphi e_{t-1}^2 d_{t-1} + \lambda_1 \sigma_{t-1}^2 + \dots + \lambda_q \sigma_{t-q}^2 \quad (5)$$

Where d is a dummy variable, $d_{t-1} = 1$ if $e_{t-1} < 0$ and $d_{t-1} = 0$ if $e_{t-1} > 0$. In addition, the characteristics of "good news" in the t-1 period ($e_{t-1} < 0$) and "bad news" in the t-1 period ($e_{t-1} > 0$), are observed to confer different effects on conditional variance. This causes the impact on α and α + φ, respectively. If φ ≠ 0, followed by the occurrence of an asymmetrical effect [34].

3.5 The EGARCH model

The general form of the EGARCH model is expressed in Equation 6.

(6)

The conditional variance uses the natural logarithmic form (ln), indicating that it is exponential and not quadratic, and the use of ln further guarantees that variance is never negative, as an asymmetrical effect occurs on instances where φ ≠ 0. In addition, the ARCH term parameter value in Equation 6 consists of two parts, encompassing (1) the sign effect (e_{t-q}/σ_{t-q}), which shows the difference between positive and negative shocks in period t on the current variance, and (2) Magnitude effect ($|e_{t-p}/\sigma_{t-p}|$), demonstrating the magnitude of the volatility in the t-p period on the current variance [26].

Prior to building the ARCH/GARCH model of rice price volatility, it is necessary to detect the presence or absence of the ARCH element. This identification from time-series models formed through the Box-Jenkins method is possibly conducted via either of two methods: (1) by using a squared residual pattern through a correlogram, and (2) by means of the ARCH-LM test. Therefore, if the count of χ^2 is greater than its critical value at a certain confidence level, H_0 is rejected. Hence ARCH elements are present in the model.

Ermawati et al. [35] outlines the steps adopted to estimate the ARCH/GARCH model, which encompasses: (1) test stationarity of rice price data; (2) model identification; (3) estimation of the best ARIMA Box-Jenkins model; (4) identification of the ARCH effect on ARIMA; (5) estimation and selecting the best; (6) model evaluation; and (7) forecasting.

4. Equations

The TGARCH model of premium rice price

Based on weekly data processing of premium rice prices obtained for 175 weeks, through the Box-Jenkins method, ARIMA (4,1,0) was estimated for the model in the form of an equation: $Y_t = -0.124y_{t-2} + 0.164y_{t-4}$.

The ARIMA (4,1,0) model without constant demonstrates the statistical significance of all coefficients of AR (2) and AR (4). In addition, tests conducted on the residuals with the ACF and PACF correlograms showed the absence of significance, up to lag 36, which was similar to the output of the Ljung-Box test. This drew conclusions on the model capacity to generate random residuals, subsequently making it the best.

The behaviour of premium rice price data was evaluated for ARCH element content, using the ARCH-LM test method , and the following results were obtained:

Table 1. ARCH-LM test of premium rice price

F-statistic	38.68896	Prob. F(1,171)	0.0000
Obs*R-squared	31.91961	Prob. Chi-Square(1)	0.0000

Source: own calculation in EViews 10 SV based on BKP data, 2019

The calculated value for χ^2 (obs*R-squared) = 31.91961, with a probability of 0.0000, while F-statistic was 38.68896, with a probability value of 0.0000, indicative of statistical significance. Thus, H_0 is rejected, stipulating that the residual variance lacks constancy, or the model contains the ARCH element.

Selecting the best model for premium rice pricing required taking into account the significance of the estimated parameters, the largest log-likelihood, as well as the smallest AIC and SIC criteria. Therefore, a summary of the various indicators, based on simulations of various variance equation models is expressed in Table 2.

Table 2. Premium rice price estimation for the ARCH/GARCH model

Model	The significance of the estimated parameter (α = 5%) AR(2)	AR(4)	Log-likelihood	AIC	SIC
ARCH(1)	√	√	-1027.341	12.13342	12.20720
GARCH(1,1)	x	x	-1017.569	12.03022	12.12245
ARCH-LM	√	√	-1027.307	12.14478	12.23701
TGARCH	√	x	-1014.788	12.00927	12.11994
EGARCH	x	x	-1017.306	12.03889	12.14957

Source: personal calculations in EViews 10 SV based on BKP data, 2019

Based on the indicators in Table 2, the best model for estimating the price of premium rice was the TGARCH (1,1), chosen based on the fact that it possesses the largest log-likelihood and the smallest AIC and SIC values, in contrast with other models. This was selected as the best model for premium rice prices can be seen in Table 3.

Table 3. TGARCH (1,1) of premium rice price

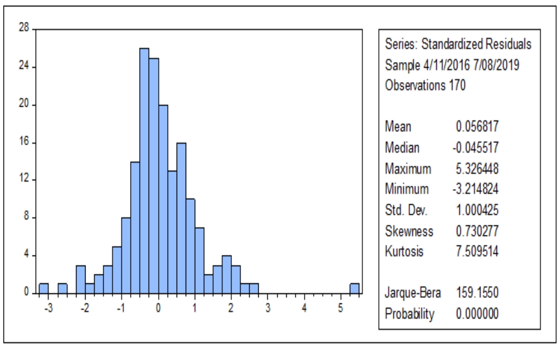
Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(2)	-0.155667	0.076746	-2.028349	0.0425
AR(4)	0.051025	0.069827	0.730732	0.4649
Variance Equation				
C	1998.779	659.1459	3.032377	0.0024
RESID(-1)^2	0.714998	0.252922	2.826951	0.0047
RESID(-1)^2*(RESID(-1)<0)	-0.530039	0.243174	-2.179670	0.0293
GARCH(-1)	0.430611	0.152667	2.820598	0.0048
R-squared	0.038781	Mean dependent var		1.505882
Adjusted R-squared	0.033060	S.D. dependent var		137.1679
S.E. of regression	134.8815	Akaike info criterion		12.00927
Sum squared resid	3056425.	Schwarz criterion		12.11994
Log likelihood	-1014.788	Hannan-Quinn criter.		12.05418
Durbin-Watson stat	2.210560			
Inverted AR Roots	.40	.00-.56i	-.00+.56i	-.40

Source: own calculation in EViews 10 SV based on BKP data, 2019

TGARCH model shows the presence of an asymmetrical effect, while the asymmetric effect is demonstrated in the variance equation, which is the RESID variable (-1)^2 *(RESID(-1)<0). Furthermore, the result is known to be statistically significant at alpha 5%, thus, confirming the asymmetrical effect of the behaviour model.

The TGARCH model of premium rice price was evaluated using the Jarque-Bera model, as shown in Figure 1.

Figure 1. Residual distribution of premium rice price



Source: own calculation in EViews 10 SV based on BKP data, 2019

Figure 1 shows the statistical significance of Jarque-Bera normality test, indicating that the model error distribution is not normal. Meanwhile, the skewness value of 0.73 or $S_k > 0.01$ leads to the formation of a curve that tilted to the left (positive), which is classified as a pointed curve (leptokurtis), based on the kurtosis value > 3. However, Alberg et al. [36] reported the elevating effect of asymmetric GARCH models with fat-tailed densities on the overall estimates for the measuring conditional variance. This, therefore, indicates the enhanced propensity to forecast futuristic premium rice prices, and the results obtained is shown in Figure 2.

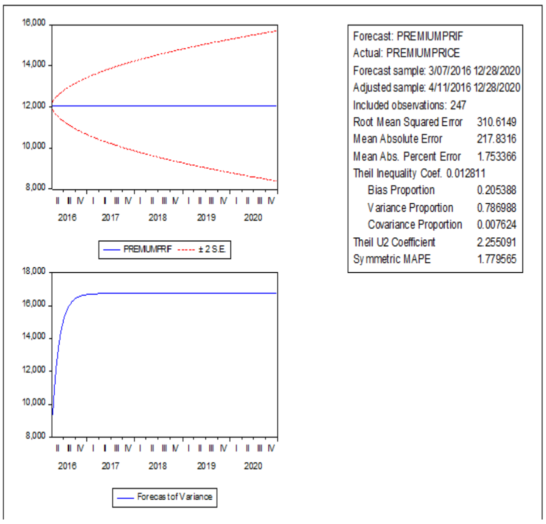
Figure 2 showed the enhanced tendency for prices to raise and move away from the balance line continuously, and information is also provided concerned with the values of RMSE, MAE and MAPE, in an attempt to measure forecasting errors, while the test was only performed on one model, although it is not possible to determine the error size from RMSE and MAE, as they are both dependent on the variable scale. Meanwhile, testing a single model requires more precise error detection through the MAPE size, which indicated a relatively small value of about 1.753 percent.

The TGARCH model of medium rice price

The best ARIMA model for medium rice prices in South Sumatra is the ARIMA (2,1,0), without constants, or: $Y_t = -0.336y_{t-1} - 0.283y_{t-2}$.

ARCH element testing on its behaviour was conducted through the ARCH-LM test, and the results are shown in Table 4.

Figure 2. TGARCH (1,1) dynamic forecast of premium rice price



Source: own calculation in EViews 10 SV based on BKP data, 2019

Table 4. ARCH-LM test of medium rice price.

F-statistic	6.314560	Prob. F(1,171)	0.0129
Obs*R-squared	6.160909	Prob. Chi-Square(1)	0.0131

Source: own calculation in EViews 10 SV based on BKP data, 2019

Furthermore, selecting the best model for medium rice prices required taking into account the estimation results of several models, as summarized in Table 5.

Table 5. Estimation results of the ARCH/GARCH model for medium rice prices.

Model	The significance of the estimated parameter (α = 5%)		Log-likelihood	AIC	SIC
	AR (1)	AR (2)			
ARCH(1)	x	√	-1049.037	12.24462	12.31782
GARCH(1,	√	√	-1018.	11.89881	11.99031

1)			298		
ARCH-M	x	√	-1047.509	12.23847	12.32997
TGARCH	√	√	-1016.549	11.89010	11.99990
EGARCH	√	√	-1017.753	11.90410	12.01390

Source: own calculation in EViews 10 SV based on BKP data, 2019

Based on Table 5, the best model chosen is TGARCH (1,1), and the estimation is seen in Table 6.

Table 6. TGARCH (1,1) of medium rice price.

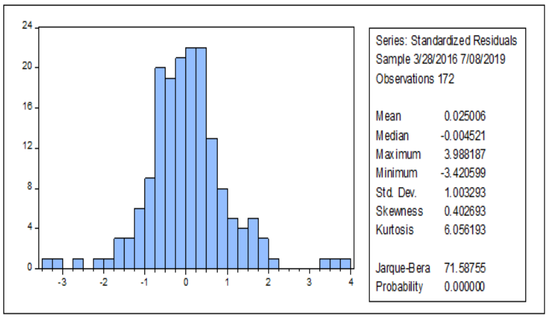
Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.460911	0.094778	-4.863079	0.0000
AR(2)	-0.257348	0.085874	-2.996806	0.0027
Variance Equation				
C	623.4204	175.6287	3.549649	0.0004
RESID(-1)^2	0.603740	0.150196	4.019677	0.0001
RESID(-1)^2*(RESID(-1)<0)	-0.367535	0.139890	-2.627316	0.0086
GARCH(-1)	0.599414	0.068450	8.756950	0.0000
R-squared	0.120192	Mean dependent var		-0.366279
Adjusted R-squared	0.115017	S.D. dependent var		138.9420
S.E. of regression	130.7076	Akaike info criterion		11.89010
Sum squared resid	2904363.	Schwarz criterion		11.99990
Log likelihood	-1016.549	Hannan-Quinn criter.		11.93465
Durbin-Watson stat	1.727680			
Inverted AR Roots	-.23+.45i	-.23-.45i		

Source: own calculation in EViews 10 SV based on BKP data, 2019

The asymmetrical effect in the TGARCH model of medium rice prices is shown in the variance equation, encompassing the RESID variable (-1)^2*(RESID (-1)<0). This is statistically significant at alpha 5%, based on Table 6, hence, it is possible to conclude the presence of an asymmetrical effect in the behaviour model of premium rice prices.

The TGARCH model evaluation of medium rice price using the Jarque-Bera model as shown in Figure 3.

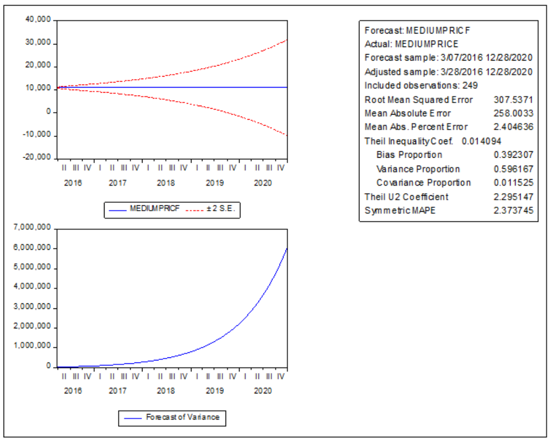
Figure 3. Residual distribution of medium rice price



Source: own calculation in EViews 10 SV based on BKP data, 2019

The residual price of medium rice was also observed not to be distributed normally, as indicated by a significant probability value. Therefore, the curve is classified as leptokurtis, and despite this, there is a possibility of adopting the TGARCH model for forecast, and the results are shown in Figure 4.

Figure 4. TGARCH(1,1) dynamic forecast of medium rice price.



Source: own calculation in EViews 10 SV based on BKP data, 2019

Figure 4 shows the probability of predicting the price for medium rice up to the fifth week of 2020, showing a continuous increase away from the balance line, while the MAPE value portrays a relatively low forecasting error rate in South Sumatra Province, at a value of 2,405 percent.

5. Conclusion

The TGARCH is a development of the ARCH and GARCH models, which is advantageous, due to its ability to overcome variants that are not constant, as well as the asymmetric influence on data. ARIMA (4,1,0) was identified as a suitable model for premium rice, and the TGARCH (1,1) was determined as the best forecasting model, with an order threshold of 1. However, the suitable models for medium rice were ARIMA (2,1,0), with TGARCH (1,1), and order threshold 1, hence, it is possible to conclude that the price of both rice in South Sumatra experienced volatility, despite the stipulated policy. This, therefore, requires a solution from the government, being the policyholder, especially because rice is a staple food commodity in Indonesia, and also that high fluctuations contribute to inflation, which results in unrest, to both producers and consumers.

The proposed recommendation involves making price stabilization policy more effective in both the consumer and producer markets. Despite its actual implementation by the government, the results are evidence of ineffectiveness. In addition, the purchase price policy was set in 2015 on the producer side, and the determination of rice HET for consumers was conducted on September 1, 2017, and has not successfully overcome the occurrence of price volatility. This is due to the long marketing channel, which ensues in an oligopsonistic form, possessing the tendency to increase the power of traders, leading to unsuccessful policies. Furthermore, there is a need for the government also to strengthen the role of BULOG's as an extension of the government in regulating the distribution and also maintaining the availability of rice stocks. This, indicates the need for developing reliable and sustainable partnership institutions, characterized by embarking on practices to improve the area of planting on the producer side, especially in the dry season. In addition, the consequence is that the government also needs to provide facilities and infrastructure, presented in the form of production inputs, alongside the addition and maintenance of irrigation networks, in order to ensure stability.

Overcoming the problems of distribution and stock is necessary to effectively run the regulations related to price policies, leading to a resolution of price volatility problems. Furthermore, there is a possibility that the TGARCH model built beforehand is capable of providing predictions about futuristic price movements. This is followed by the likelihood of utilizing the results as an evaluation material for the government to implement the policies determined.

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