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Dependency of The Exchange Rate with The Volume of Indonesian Aluminum Exports Using Copula

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ABSTRACT

The downstreaming of bauxite, which is one of the raw materials for aluminum, indicates that the Indonesian government is serious about managing these mining resources. As one of the leading commodities, aluminum export activities not only affect investment but also strengthen the IDR-USD exchange rate. The increasing circulation of the rupiah has a positive impact on Indonesia in the international trade market. This study models the dependence between the IDR-USD exchange rate and Indonesia's aluminum export volume using copula. Copula doesn't require the assumption of data normality, so it is very good for measuring the dependence of economic data that is often not normally distributed. The results of the study concluded that there is a positive correlation between the two variables, although it is not significant and is very small. This positive correlation indicates that the rupiah will strengthen along with the increasing volume of Indonesia's aluminum exports.

Keywords: Aluminum; Copula; Correlation; Export Volume

INTRODUCTION

The wealth of Indonesia's mineral resources is something that must be utilized properly. These resources can be a source of income, raw materials, and can strengthen Indonesia's influence in the international market. One of the mining resources that is the focus of management is alumina and bauxite. Both minerals are raw materials for making aluminum. Indonesia has bauxite reserves of 4% of the world's total reserves with a production rate of 4.3% of the world's total bauxite production [1].

Currently the government has banned the export of bauxite and is focusing on domestic processing, then exporting in the form of aluminum [2]. This downstream program is very important to carry out considering the national aluminum needs are very large with a total need reaching 1.024 million tons in various industries [3]. Indonesia's aluminum export volume reached more than 3 million tons from 2010 to August 2023 [4]. This large number shows that investment opportunities for aluminum commodities in Indonesia are very large. One aspect that is influenced by Indonesia's export activities is the fluctuation of the rupiah exchange rate.

Export activities are generally directly proportional to changes in exchange rates [5]. Export activities increase the circulation of the rupiah in the international market and have a positive impact on strengthening the value of the rupiah. Recently, the rupiah has continued to weaken due to various market turmoil and global economic conditions [6]. Therefore, aluminum as a superior resource is seen in relation to changes in the exchange

rate (which in this study chooses IDR-USD) and how the form of dependence between the two.

The dependency analysis in this study uses the copula model. Copula is very good at modeling dependencies on economic data that are very volatile and tend to be asymmetrical and abnormal. Some of the previous literature has also used copulas in modeling data dependencies. Ignatieva [7] modeled spot price dependence in the Australian electricity market and the results led to recommendations in the form of price series considerations for each region using a copula model. To extend the use of the model in describing dependence, a mixed copula model was used. Hu's research [8] shows the superiority of the mixed copula model in being able to empirically construct various patterns of market data dependency structure.

METHODS

Indonesian aluminum export volume is taken from the monthly Indonesian export foreign trade statistics bulletin published by the Indonesian Central Bureau of Statistics (BPS). Exchange rate data uses monthly IDR-USD data taken from the Yahoo Finance website. Both data are monthly data for the period January 2010 to August 2023.

First, the aluminum export volume and exchange rate data were tested for autocorrelation using the Ljung-Box test. Data that do not contain autocorrelation effects are then selected for the best distribution used for copula analysis. If the data has an autocorrelation effect, then the data will go through the time series analysis stage. Time series analysis begins with testing the stationarity of the data in terms of variance and mean. Data whose variances are not stationary are subjected to Box-Cox transformation. Then the data is tested for stationarity against the mean using the Dickey Fuller test. Data whose mean is not stationary will be differenced. Then the order identification and parameter estimation of the ARIMA model are continued. Next, the model errors are tested for white noise assumptions and the best distribution is selected using the Anderson-Darling test.

After that, the error distribution will be converted into a uniform distribution to form a copula model. The best model selection is based on Akaike's Information Criterion (AIC) measure. Single copula parameter estimation uses the maximum likelihood method and mixed copula uses the maximum pseudo likelihood method.

The copulas used are the Archimedean copula family, namely the Frank, Clayton, and Gumbel copulas, which are defined as follows,

$$C_{\theta}^{Fr}(u, v) = -\frac{1}{\theta} \ln \left(1 + \frac{(e^{-\theta u} - 1)(e^{-\theta v} - 1)}{e^{\theta} - 1} \right), \quad \theta > 0 \quad (1)$$

$$C_{\theta}^{Cl}(u, v) = (u^{-\theta} + v^{-\theta} - 1)^{-\frac{1}{\theta}}, \quad 0 < \theta < \infty \quad (2)$$

$$C_{\theta}^{Gu}(u, v) = \exp \left(-[(-\ln u)^{\theta} + (-\ln v)^{\theta}]^{\frac{1}{\theta}} \right), \quad 1 \leq \theta < \infty \quad (3)$$

The Frank copula is defined by equation (1), the Clayton copula by equation (2), while equation (3) defines the Gumbel copula [9]–[11]. The copula models are then combined in the form of a mixed copula to obtain a model that better captures data dependence. Mixed Copula in this study uses a linear combination of 2 copulas. The Mixed copula model is defined as follows,

$$C(u; \theta) = \sum_{k=1}^n w_k C_k(u; \theta_k) = \sum_{k=1}^n w_k C_k(F_1(x_1; \alpha_1), \dots, F_p(x_p; \alpha_1); \theta_k) \quad (4)$$

RESULTS AND DISCUSSION

Data Description

The graphical visualization of the data is designed to provide an overall picture of the characteristics of the data used in this study. This display also aims to provide a visual understanding of the data.

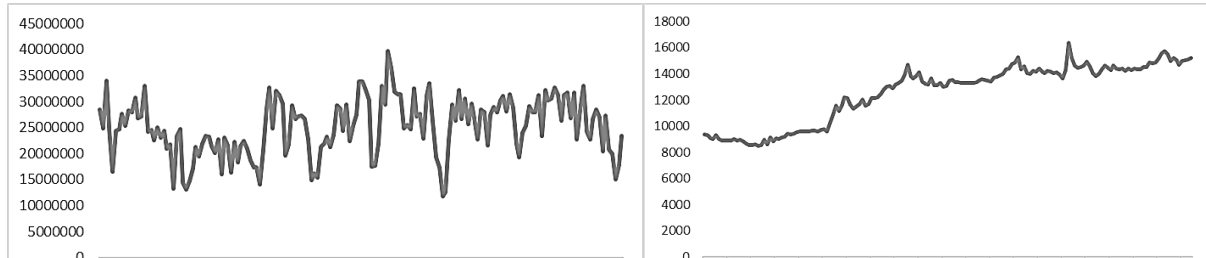


Figure 1. Graph of aluminum export volume (left) and IDR-USD exchange rate (right)

Figure 1 shows the graphical presentation of the two data sets used. Visually, the data fluctuates greatly and tends to be asymmetrical and non-normalized. Furthermore, the descriptive statistics of the data are presented in Table 1 below,

Table 1. Statistics Descriptive

Data	Mean	St. Deviation	Skewness	Kurtosis	Exchange Rate Correlation
Aluminum	20865990	7043408	0.44	0.29	-0.30
Exchange Rate	12583	2249	-0.63	-1.11	1.00

Skewness is a statistical measure used to describe the degree of asymmetry in data distribution. Skewness indicates the degree to which the data tends to be skewed to one side of the mean [12]. Aluminum has a positive skewness value, meaning that most of the data is distributed to the left of the average. Meanwhile, the skewness value of the exchange rate is negative, meaning that most of the data is distributed to the right of the average. Skewness values that stretch away from 0 also indicate that the data tends to be asymmetrical. Kurtosis is a statistical measure used to describe the peak shape and tail weight of a data distribution [13]. A kurtosis value that is far from 3 indicates that the data tends to be abnormal.

Autocorrelation Effect

Data freedom through checking the presence of autocorrelation effects is necessary to avoid errors in decision making [14]. The Ljung-Box test was chosen because it can check for autocorrelation at multiple lags and is suitable for time series data [15]. Testing is done by hypothesis:

H_0 : There is no autocorrelation effect

H_1 : There is an autocorrelation effect

with H_0 rejected when $p\text{-value} < \alpha = 0.05$.

Table 2. Ljung-Box Test Result

Data	χ^2 Statistics	$p\text{-value}$
Aluminum	55.89	1.23e-07
Exchange Rate	298.35	2.2e-16

The Ljung-Box test on both data obtained a $p\text{-value} < 0.05$ so that H_0 is rejected and this means that there is an autocorrelation effect on the data. Therefore, the aluminum export volume and exchange rate data should be subjected to time series analysis [16]. The first step in time series analysis is to test the stationarity of the data.

Stationarity of Variability Data

This test uses the Box-Cox test by optimizing the lambda value. A lambda value close to 1 or a lambda confidence interval containing a value of 1 indicates that the data has a stationary variety.

Table 3. Box-Cox Test Result

Data	Lambda (λ_1)	Confidense Interval
Aluminum	0.93	0.65 – 1.21
Exchange Rate	2.00	1.88 – 2.00

The Box-Cox test results in Table 3 show that the aluminum data (A_t) has a stationary variety. The exchange rate data (z) needs to be Box-Cox transformed to overcome its non-stationary variance. The transformation is done with the formula:

$$z^\lambda = \begin{cases} \frac{z^\lambda - 1}{\lambda}, & \lambda \neq 0 \\ \log z, & \lambda = 0 \end{cases} \quad (5)$$

The exchange rate data (z) is transformed $n - 1$ times until it meets the stationarity requirements. Table 4 shows the results of the Box-Cox test after transformation.

Table 4. Box-Cox Transformation Result

Data	Transformation Data	Lambda (λ_n)	Confidense Interval
Exchange Rate (z)	z^λ	$\lambda_4 = 0.97$	0.78 – 1.51

The lambda value (λ_4) is close to 1, so it can be concluded that the variance of the z^λ transformed data is stationary.

Data Stationarity with Respect to the Mean

Next we will test the stationarity of the data against the mean using the Dickey-Fuller test with the hypothesis:

H_0 : Data is not stationary with respect to the mean

H_1 : Data is stationary with respect to the mean

with H_0 rejected when $p\text{-value} < \alpha = 0.05$.

Table 5. Dickey-Fuller Test Result

Data	$p\text{-value}$
A_t	0.03
z^λ	0.37

Based on Table 5, it can be seen that the A_t data has a $p\text{-value} < 0.05$ so that the data is stationary to the mean. While the z^λ data has a $p\text{-value} > 0.05$ which means that the average data is not stationary, so it is necessary to do differencing using the formula:

$$Z_t = z_t^{\lambda_2} - z_{t-1}^{\lambda_2} \quad (6)$$

Data that has been differentiated is then checked again using the Dickey-Fuller test,

Table 6. Dickey-Fuller Test Result After Differencing

Differencing Data	p-value
Z_t	0.01

the p-value of the Z_t data shows that the mean of the data is stationary. Figure 2 below shows the visualization plot of Z_t and supports that the data is stationary with respect to the mean.

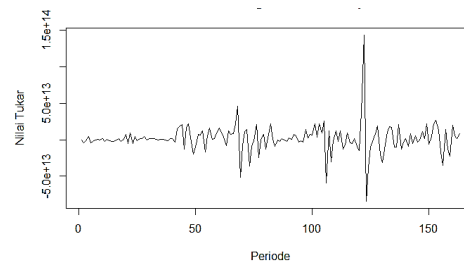


Figure 2. Plot Data of Z_t

Order Identification and ARIMA Model Estimation

Next, the best ARIMA (p,d,q) model will be selected from the two data. The p and q orders are obtained from the initial estimation of the visualization results of the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots, while q states the differencing order on the data. [17].

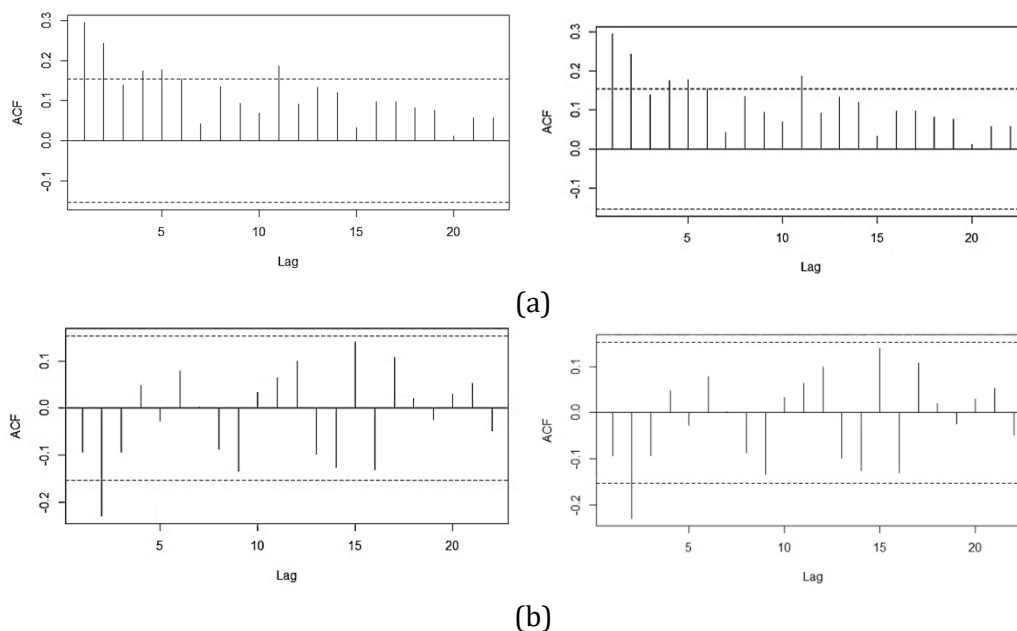


Figure 3. ACF and PACF Plot of A_t (a) and Z_t (b)

The initial estimation results obtained from Figure 3 are then overfitted to measure the minimum AIC value as the best model to be selected. Table 7 below shows the results of overfitting the selected ARIMA model.

Table 7. Overfitting Selected of ARIMA Model

Data	ARIMA Model	Parameter	Coefficient
A_t	ARIMA (1,0,1)	Intercept	20839970
		AR(1)	0.8780
		MA(1)	-0.6990
Z_t	ARIMA (1,1,2)	AR(1)	0.6232
		MA(1)	-1.8577
		MA(2)	0.8576

Based on Table 7, the ARIMA model is obtained as follows:

$$A_t = 20839970 + 0.8780 A_{t-1} - 0.6990 \varepsilon_{t-1} + \varepsilon_t \quad (7)$$

$$Z_t = 0.6232 Z_{t-1} - 1.8577 \varepsilon_{t-1} + 0.8576 \varepsilon_{t-2} + \varepsilon_t \quad (8)$$

White Noise Error Assumption

Furthermore, the error model will be checked for autocorrelation called the white noise error assumption using the Ljung-Box test with the hypothesis:

H_0 : Independent errors

H_1 : Dependent errors

with H_0 rejected when $p\text{-value} < \alpha = 0.05$.

Table 8. Ljung-Box Test Resul White Noise Assumption

Model Error	χ^2 Statistics	$p\text{-value}$
A_t	0.2308	0.6309
Z_t	0.4476	0.5034

Table 8 shows that the errors in both models are independent. The next step is to choose the best distribution for the copula model.

Selection of the Best Error Distribution

The best error distribution was chosen based on two reasons. First, by matching the histogram visualization with the empirical distribution. After that, statistical testing to ascertain the most suitable distribution uses the Anderson-Darling test with the hypothesis:

H_0 : The distribution fits empirical distribution

H_1 : The distribution doesn't fit the empirical distribution

with H_0 rejected when $p\text{-value} < \alpha = 0.05$.

Table 9. Appropriate Distribution

Data Error	Distribution	Parameter	$p\text{-value}$
Aluminum (A_t)	Normal	$\mu = -24677$ $\sigma = 6583070$	0.1848
Exchange Rate (Z_t)	Laplace	$\theta = 279273833355$ $s = 3.2649e+12$	0.7486

In Table 9, it can be seen that the normal distribution is the best fit distribution for the aluminum error distribution and the Laplace distribution is the best fit distribution for the exchange rate error distribution.

Copula

The copula definition area is a uniform distribution so the previous two error distributions must be converted into,

$$A \sim \mathcal{N}(\mu, \sigma^2) \rightarrow U = F_A(a) \sim U(0,1) \quad (9)$$

$$Z \sim \text{Laplace}(\theta, s) \rightarrow V = F_Z(z) \sim U(0,1) \quad (10)$$

This transformation states that the data errors are uniformly distributed (0,1). Then, based on the results of the goodness-of-fit test for the copula, it was found that the appropriate copula to use for fitting the dependencies of the two data was the Archimedean copula (Frank, Clayton, and Gumbel copula). This study was conducted by fitting single copula and mixed copula models. The best copula model was selected based on the lowest AIC value with single copula parameter estimation using the maximum likelihood method.

Table 10. Single Copula Fitting Model

Copula	Parameter	Loglikelihood	AIC
Frank	0.0015	2.7e-06	1.9999
Clayton	0.0324	-0.2043	2.4085
Gumbel	1.0000	-2.7e-07	2.0000

For the time being, the single copula model fitting results in Table 10 show that the best copula to model the dependence between aluminum export volume and exchange rate is the Frank copula with an AIC value of 1.999. The Frank copula shows no dependence on the tails of any part of the distribution. We then fit a mixed copula model to find a model that better captures the dependence with a minimum AIC.

Table 11. Mixed Copula Fitting Model

Parameter	Frank - Clayton	Frank - Gumbel	Clayton - Gumbel
$\hat{\theta}_1$	6.7168	0.0038	-0.6523
$\hat{\theta}_2$	-0.3504	1.0000	1.0000
w_1	0.3266	0.5725	0.0631
w_2	0.6734	0.4274	0.9368
loglikelihood	4.1790	3.7e-06	2.3260
AIC	-0.3578	7.9999	3.3489

Table 11 shows the results of fitting a mixed copula model using a combination of 3 Archimedean copulas. The comparison of single copula and mixed copula model fitting results shows that the Frank - Clayton mixed copula model is the best model in measuring the dependency between aluminum export volume and exchange rate with a minimum AIC value of -0.3578. When combining the Frank and Clayton copulas, the result is usually a copula that can capture the dependence properties of both, taking into account the symmetry of dependence across the distribution (from Frank) and the sensitivity to dependence at the bottom (from Clayton). Based on the framework equations of the Frank copula model in equation (1), the Clayton copula in equation (2) and the mixed copula model in equation (4), the best copula model is written as follows,

$$\begin{aligned}
 (A_t, Z_t) \sim C(u, v; \theta) &= 0.3266 C^{Fr}(u, v; \hat{\theta}_1) + 0.6734 C^{Cl}(u, v; \hat{\theta}_2) \\
 &= 0.3266 \left[-\frac{1}{6.7168} \ln \left(1 + \frac{(e^{-6.7168u} - 1)(e^{-6.7168v} - 1)}{e^{-6.7168} - 1} \right) \right] + \\
 &\quad 0.6734 \left[(u^{0.3504} + v^{0.3504} - 1)^{\frac{1}{0.3504}} \right]
 \end{aligned} \quad (11)$$

where $\theta = (\hat{\theta}_1, \hat{\theta}_2)$ is the joint association parameter vector representing the degree of dependence and (A_t, Z_t) is the Aluminum - Exchange Rate model.

The degree of copula dependence was measured using Kendall's Tau correlation (τ). The results of the construction of the τ correlation values are presented in Table 12.

Table 12. Selected Copula

Data	Copula	AIC	τ
Aluminum – Exchange Rate	Frank – Clayton	-0.3578	0.04

A positive τ value means that when the IDR-USD exchange rate increases (rupiah weakens), the export volume also tends to increase and vice versa when the IDR-USD exchange rate decreases (rupiah strengthens), the export volume also tends to decrease. Based on Table 12, a very small τ value of 0.04 and close to 0 indicates a very weak dependency of each pair of data. Therefore, the dependence on changes in each variable has no significant effect and almost no effect at all.

The weak dependence between the exchange rate and the volume of aluminum exports may have several reasons. The export volume selected in this study may only be a small fraction of the overall export volume that affects the exchange rate. Another reason is that the commodities selected may not cover all the variations that could significantly affect the exchange rate. Furthermore, exchange rates are influenced by many other economic factors besides export volumes, such as monetary policy, inflation rates, interest rates, and global economic conditions. These factors may have a more dominant influence than export volume on exchange rate fluctuations. And interventions from the government or monetary institutions outside the discussion in this study that can directly affect the exchange rate may not be reflected in the export volume, thus disguising the existing relationship.

CONCLUSIONS

Based on the results of this study, it can be concluded that there is no significant relationship between the IDR-USD exchange rate and the volume of aluminum exports. Aluminum volume and exchange rate have a positive correlation of $\tau = 0.04$ and is classified as very weak to measure the dependence between the two. The results of this copula model can be a recommendation regarding considerations for Indonesia's export activities, especially for aluminum commodities, namely there is no need to pay attention to the exchange rate as a key factor in export policy. On the other hand, fluctuations in the volume of aluminum exports also do not have a significant effect on the strengthening/weakening of the exchange rate.

Future research can consider other things such as commodity prices, inflation, taxes, and the effect of production availability in measuring dependency to find a significant effect on exchange rate changes.

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