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ANALYSIS OF GLOBAL ECONOMIC UNCERTAINTY IMPACT ON INDONESIA'S FINANCIAL AND TRADE VOLATILITY USING VECTOR ERROR CORRECTION MODEL WITH EXOGENOUS VARIABLES

Dita Amelia[1*], **Suliyanto**[2], **Galuh Cahya Nugraha**[3], **Billy Christandy Suyono**[4]

[1,2,3,4]*Department of Mathematics, Faculty of Science and Technology, Universitas Airlangga*
Jln. Dr. Ir. Soekarno, Surabaya, 60115, Indonesia

*Corresponding author's e-mail: * **dita.amelia@fst.unair.ac.id***

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ABSTRACT

Increasing global economic uncertainty due to the influence of geopolitical dynamics and monetary policy adjustments from major countries has significantly impacted financial and trade stability in Indonesia. This research examines the relationship between global economic uncertainty and the volatility of Indonesia's financial and trade indicators using the Vector Error Correction Model with Exogenous Variables (VECM-X) approach. The model incorporates external factors such as the US Dollar Index (DXY), Volatility Index (VIX), and Trade Policy Uncertainty (TPU), using monthly data from January 2019 to December 2024. The results of the analysis show that each variable has different volatility with patterns that tend to fluctuate, and there is a cointegration relationship between the variables of the Rupiah exchange rate (USD/IDR), Jakarta Composite Index (JCI), interest rates, export, and imports. The causality test results show that exports, JCI, and imports affect interest rates without a reverse relationship, while there is a one-way relationship between exports and imports and JCI and the exchange rate. In addition, imports and JCI have a two-way relationship that affects each other. Impulse Response Function (IRF) results indicate dynamic short-term interactions among endogenous variables, which gradually stabilize over the medium to long term. In addition, the variance decomposition results show that most of the variability of each variable is explained by itself in the short term, with contributions from other variables increasing over time. This research contributes to Sustainable Development Goals (SDGs) point 8: Decent Work and Economic Growth, by providing insight to strengthen Indonesia's macroeconomic resilience. Integrating exogenous global indicators into the VECM-X model offers a more comprehensive understanding of how global shocks affect domestic stability. However, this study is limited to a macro-level analysis using secondary data and does not account for microeconomic or sectoral variations.

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1. INTRODUCTION

Global economic uncertainty is increasing due to geopolitical factors, changes, and adjustments in monetary policy by countries with the largest economies in the world [1]. The trade war between the United States (US) and China has escalated in recent years, causing US policy propaganda to disrupt various countries' political and economic stability worldwide [2]. As a global trade leader with the world's largest economy, the US plays an important role in shaping international trade policy and contributes around 24% of global GDP, and is a major import-export destination for countries such as Indonesia [3]. Consequently, changes in US trade policies, including protectionism, trade restrictions, and high export tariffs, have significantly impacted Indonesia's economy and other nations. Indonesia has felt the effects of this uncertainty, which has influenced its financial markets, Rupiah exchange rate, and national trade balance [4]. In fact, the Jakarta Composite Index (JCI) dropped by more than 5% on March 18, 2025, so JCI temporarily stopped trading, and the JCI experienced a trading halt. This worst phenomenon repeats itself after the 2020 crisis due to the COVID-19 pandemic [5].

Five endogenous variables have been selected in this research: exchange rate (USD/IDR), JCI, interest rate, exports, and imports, which are widely recognized as key indicators of macroeconomic and financial stability in developing countries. The strengthening of the US Dollar (USD) due to tight monetary policy in the US often leads to depreciation of the Rupiah, resulting in increased import costs, inflation, and widening the trade deficit [6]. Meanwhile, the condition of Indonesia's stock market, as reflected in the JCI, also experiences high volatility as foreign investors tend to withdraw their capital from developing countries and shift their assets to safer instruments, such as gold and bonds [7]. Moreover, interest rates are crucial in maintaining Indonesia's economic stability. Bank Indonesia (BI) frequently adjusts its benchmark interest rate to control inflation, stabilize the Rupiah, and manage foreign capital flows. However, excessively aggressive interest rate hikes can slow economic growth by suppressing domestic investment and consumption [8]. Thus, the exchange rate, JCI, interest rates, exports, and imports are key indicators of how global economic uncertainty impacts the Indonesian economy.

This research examines the impact of global economic uncertainty on Indonesia's financial and trade volatility using the Vector Error Correction Model with Exogenous variables (VECM-X). This method provides several advantages over other econometric techniques, as it facilitates the analysis of short-term and long-term relationships among non-stationary economic variables. Therefore, VECM-X is particularly well-suited for assessing the influence of external shocks on the Indonesian economy [9]. The effectiveness of VECM-X has been proven in a previous empirical study that applied the VECM-X model to analyze the interaction between energy and economic variables in Indonesia, with findings showing that incorporating exogenous variables into the model is able to improve the model's ability to explain the dynamics between domestic and external variables [10].

Previous research found that exchange rates, inflation, and interest rates significantly influence JCI movements, particularly over the long term, based on an analysis using the VECM for the 2008–2018 [11]. Depreciation of the Rupiah tends to hurt the JCI, while an increase in interest rates can trigger an outflow of foreign capital, thereby increasing stock market volatility. Although this provided useful insights into the role of domestic factors in maintaining capital market stability, it did not account for external influences such as global economic uncertainty and international market dynamics, which can also play a critical role in shaping Indonesia's financial and trade conditions. To address this gap, this research introduces two critical novelties. First, this VECM-X model incorporates indicators of global economic uncertainty as exogenous variables, namely the US Dollar Index (DXY) which reflects the strength of the USD against global currencies, the Volatility Index (VIX) which measures the volatility of the US stock market, and Trade Policy Uncertainty (TPU) which describes global trade policy uncertainty [12]. This study can provide a deeper understanding of how trade policy, global exchange rate movements, and world financial market volatility affect the Indonesian economy by including these external variables. Second, this study not only explores the relationship between exchange rates, interest rates, JCI, exports, and imports, but also the strength and direction of their dynamic interactions through variance decomposition analysis, which highlights the relative influence of each variable in the system.

This research also contributes to the Sustainable Development Goals (SDGs) point 8 (Decent Work and Economic Growth) by providing insights into the impact of global economic uncertainty on the Indonesian economy. The findings of this research are expected to provide more accurate information to investors and businesses when making investment decisions and trading strategies. By understanding the factors that affect national economic stability, the findings of this study are expected to provide a basis for economic policymakers to formulate more adaptive policies to face global challenges and provide more accurate information for investors and businesspeople in making investment decisions and trade strategies. Thus, this study aims to strengthen the resilience of the national economy to external shocks and promote more stable and sustainable economic growth.

2. RESEARCH METHODS

2.1 Research Data

This study uses data related to indicators of Indonesian financial and trade volatility and indicators of global economic uncertainty. The data sources include Investing.com, Statistics Indonesia - BPS, Bank Indonesia (BI), and Federal Reserve Economic Data (FRED). The dataset used consists of monthly time-series data from January 2019 to December 2024, totaling 72 observations for each variable. The data sources for each variable are presented in **Table 1** below.

Table 1. Data Source for Each Variable

Data Source	Variable
Investing.com	Jakarta Composite Index (JCI), US Dollar Index (DXY), and Volatility Index (VIX)
Statistics Indonesia - BPS	Export (EXPO) and Import (IMP)
Bank Indonesia (BI)	Exchange Rate (EXR) and Interest Rate (INT)
Federal Reserve Economic Data (FRED)	Trade Policy Uncertainty Index (TPU)

2.2 Research Variables

This research uses five endogenous variables, namely Exchange Rate (EXR) (Y_1), Jakarta Composite Index (JCI) (Y_2), Interest Rate (INT) (Y_3), Export (EXPO) (Y_4), Import (IMP) (Y_5), as well as three exogenous variables, namely US Dollar Index (DXY) (X_1), Volatility Index (VIX) (X_2), and Trade Policy Uncertainty Index (TPU) (X_3).

2.3 Research Procedure

The analysis steps in this research are shown in **Figure 1** below.

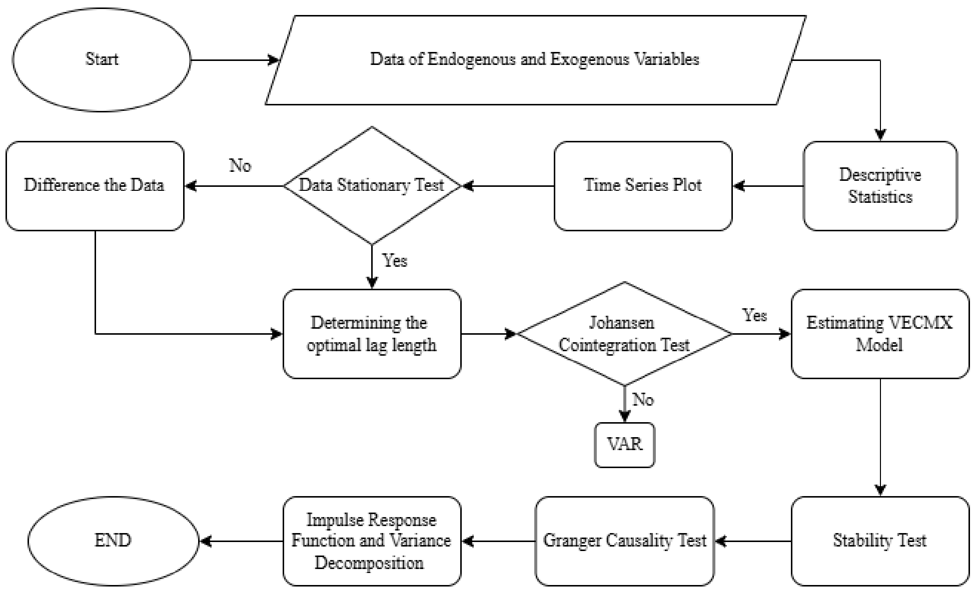


Figure 1. Research Flowchart

2.3.1 Stationary Test

Data stationarity testing is performed to assess whether the research data is already stationary before proceeding with further analysis. Stationarity tests are conducted generally by using the p-value of the unit roots through the Augmented Dicky Fuller (ADF) test. If the data is non-stationary, it must be transformed or differenced to achieve stationarity [13]. The equation of differencing 1 is explained in **Equation (1)** as follows.

$$\Delta \boldsymbol{y_t} = \boldsymbol{y_t} - \boldsymbol{y_{t-1}} \tag{1}$$

The unit root test, developed using the ADF test, follows the model presented in **Equation (2)** [14][15].

$$\Delta \boldsymbol{y_t} = \mu \mathbf{j} + \delta \boldsymbol{y_{t-1}} + \sum_{i=1}^{p} \beta_i \, \Delta \boldsymbol{y_{t-i}} + \boldsymbol{v_t} \tag{2}$$

where,

$\Delta \boldsymbol{y_t}$: the difference of endogenous variables between time t and $t-1$ with a dimension of $q \times 1$

$\Delta \boldsymbol{y_{t-i}}$: the difference of endogenous variables between time $t-1$ and $t-i-1$ with a dimension of $q \times 1$

μ : the intercept term (a constant)

δ : first lag parameter

$\mathbf{j}$: a unit vector of dimension $q \times 1$

p : the optimal lag length

q : the number of variables

$\boldsymbol{\beta_i}$: the autoregressive coefficients of the differenced lag terms up to lag

$\boldsymbol{v_t}$: error vector of dimension $q \times 1$

Based on **Equation (2)**, the hypothesis testing is formulated as follows:

$\mathrm{H_0}: \delta = 0$, the series contains unit roots (non-stationary)

$\mathrm{H_1}: \delta < 0$, the series does not contain unit roots (stationary)

The equation for the ADF test is expressed in **Equation (3)** as follows.

$$\tau = \frac{\hat{\delta}}{Se(\hat{\delta})} \tag{3}$$

Where $\hat{\delta} = \hat{p} - 1$ and $Se(\hat{\delta})$ represents the standard error of $\hat{\delta}$. The τ statistic is then compared to the critical value of $\tau_{(\boldsymbol{\alpha},\boldsymbol{n-1})}$ to determine whether the null hypothesis should be accepted or rejected. If the τ statistic is lower than the critical value, H_0 is accepted, indicating that $\boldsymbol{y_t}$ has a unit root and is non-stationary, whereas if the τ statistic is greater than the critical value, H_0 is rejected, suggesting that $\boldsymbol{y_t}$ does not have a unit root and is stationary. Additionally, if the p-value is less than the significance level $\alpha = 0.05$, it confirms that the data or research variables are stationary [16].

2.3.2 Optimal Lag Determination

The optimal lag length is determined based on criteria such as the Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwartz Criterion (SC), and Hannan Quinn Criterion (HQ), with the optimal choice being the lag that corresponds to the minimum value of these criteria [17]. Choosing the appropriate lag length helps determine how much a variable is influenced by its past values or other endogenous variables in the model. If the selected lag is too short, the model may fail to capture all the dynamics of the relationships between variables. Conversely, if the lag is too long, estimation efficiency decreases due to reduced degrees of freedom, particularly in small samples [18]. Therefore, optimal lag selection is important in model estimation to ensure more accurate analysis results.

2.3.3 Johansen's Cointegration Test

In understanding the long-term relationship between research variables, cointegration testing is needed to ensure an equilibrium between the variables being analyzed. One of the cointegration tests that can be carried out is Johansen's cointegration test, which can identify the existence of a cointegration relationship or a stationary linear combination among variables that are non-stationary at the level [19]. The Johansen cointegration test involves the following hypothesis testing.

H_0: there is cointegration between endogenous variables (cointegration value $\leq q$)

H_1: there is no cointegration between endogenous variables (cointegration value $> q$)

This test statistic uses trace statistics analysis with the Equation (4) as follows [20].

$$\lambda_{trace}(r) = -n \sum_{i=r+1}^{q} \ln\left(1 - \hat{\lambda}_i\right) \tag{4}$$

where,

r : cointegration rank

n : number of periods or observations observed

q : number of endogenous variables

$\hat{\lambda}_i$: estimated i-th largest eigenvalue

With the critical region of the test, if $\lambda_{trace}(0) > \lambda_{trace,5\%}$ and $\lambda_{max}(0) > \lambda_{trace,5\%}$ then the decision taken is to reject H_0 with the interpretation that there is one cointegrating vector among the endogenous variables. The Johansen test indicates the presence of a long-term equilibrium relationship when the test statistic exceeds the p-value.

2.3.4 Vector Error Correction Model with Exogenous Variables (VECM-X)

The Vector Error Correction Model (VECM) is developed from the Vector Autoregressive model (VAR). VECM aims to explain the long-term and short-term relationships in a non-stationary and cointegrated time series data. Meanwhile, VECM-X is a development of VECM with external factors referred to as exogenous variables [10]. In VECM-X, the exogenous variables are not cointegrated with the variables in the main system. Still, they can impact the short-term relationship, so this model is more flexible in capturing policy influences or external factors. In general, the model equation of VECM-X is written in Equation (5) [9].

$$\Delta Y_t = C(t) + \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Phi_1 \Delta Y_{t-i} + \sum_{i=0}^{s} \Theta_{t-i} X_{t-i} + \varepsilon_t \tag{5}$$

Here, ΔY_t denotes the first difference of the endogenous variables, with ensures stationarity. The term $C(t)$ denotes a constant or time trend in the system. The long-term equilibrium relationship between the endogenous variables is captured by the error correction term, which is denoted by ΠY_{t-1}. Meanwhile, the summation $\sum_{i=1}^{p-1} \Phi_1 \Delta Y_{t-i}$ is for short-term dynamics by incorporating lagged differences of endogenous variables and $\sum_{i=0}^{s} \Theta_{t-i} X_{t-i}$ represents the effect of exogenous variables X_t on the endogenous variables, influencing only the short-term relationships since exogenous variables are not cointegrated with the main system. Finally, ε_t represents the error term, which captures external influences not explicitly included in the model, and is assumed to follow a multivariate normal distribution. The statistical test employed to assess the normality of the residuals is the Jarque-Bera test with the null hypothesis that the residuals have a normal distribution, with the formula written in Equation (6) as follows [21].

$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(k-3)^2\right) \tag{6}$$

where n is the number of all observations, S is the skewness of the sample, and k is the kurtosis of the sample with the calculation formula as in Equation (7) and Equation (8) as follows.

$$S = \frac{\mu_3}{\sigma^3} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{\frac{3}{2}}} \tag{7}$$

$$K = \frac{\mu_4}{\sigma^4} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{2}} \tag{8}$$

Where μ_3 and μ_4 are the estimates of third and fourth central moments respectively, $\bar{x}$ is the sample mean, and σ^2 is the variance sample.

2.3.5 Model Stability Test

The model stability test is carried out to ensure that the model used has met the stability assumption by evaluating whether the characteristic root value of the coefficient matrix does not exceed the unit circle or has a value of no more than 1. The model stability test is essential because unstable VAR estimation results can lead to invalid Impulse Response Function (IRF) and Variance Decomposition (VD) analyses. The model is said to be stable if all of its roots have a modulus value < 1 [22].

2.3.6 Granger Causality Test

The Granger Causality test determines whether an endogenous variable can be considered exogenous. This test helps determine the dependency between endogenous variables in the model. If there are two variables Y_1 and Y_2, then the possibilities that can occur are Y_1 affects Y_2, Y_2 affects Y_1, both affect each other, or there is no relationship at all between the two. Y_1 is said to affect Y_2 if the current value of Y_2 can be explained by the value of Y_2 in the previous period and the value of Y_1 in the previous period. The equations used for the Granger causality test are represented in **Equation (9)** and **Equation (10)** [23].

$$Y_{1,t} = \sum_{i=1}^{m} a_i\, Y_{1,t-i} + \sum_{j=1}^{n} b_j\, Y_{2,t-i} + \mu_t \tag{9}$$

$$Y_{2,t} = \sum_{i=1}^{r} c_i\, Y_{1,t-i} + \sum_{j=1}^{s} d_j\, Y_{2,t-i} + v_t \tag{10}$$

Detection of the presence or absence of a causal relationship is tested using the F test. The formula for the F value is shown in **Equation (11)** as follows.

$$F = \frac{\left(\frac{RSS_R - RSS_{UR}}{p}\right)}{\left(\frac{RSS_{UR}}{n-b}\right)} \tag{11}$$

In this context, RSS_R represents the residual sum of squares from conditional regression, while RSS_{UR} refers to the residual sum of squares from unconditional regression. The parameter p indicates the lag length, n indicates the number of data observations, and b indicates the number of parameters estimated in the model [16].

2.3.7 Impulse Response Function (IRF)

The IRF testing algorithm maps the response of endogenous variables to shocks or changes in exogenous variables or the variables themselves over time. IRF aims to determine how long and how much influence these shocks have on other system variables [24]. The IRF helps isolate and understand a particular shock so that it can be more specific in explaining its effects. The appearance of the IRF graph is that the horizontal axis will display the time in the next period after the shock. Meanwhile, the vertical axis will display the response value. This analysis provides insight into how a variable will respond in the future when exposed to shocks from other variables. The response can be either positive or negative, often showing significant fluctuations in the short term. However, the response typically stabilizes over time and diminishes in the long term [25]. The shock will have a positive effect if the response line is above the 0.00 horizontal axis, but it will have a negative impact if it is below the 0.00 horizontal axis. Thus, IRF analysis shows how the system variables interact and react to changes in the system.

2.3.8 Variance Decomposition

Variance Decomposition (VD) analysis is used to decompose the overall variance in other variables to determine how much a particular variable contributes to the total variance. Variance Decomposition separates the total variance based on the variance of different variables. VD for y is a tool used to analyze VAR and VECM models equations to examine the components that make up the predicted variance [26].

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

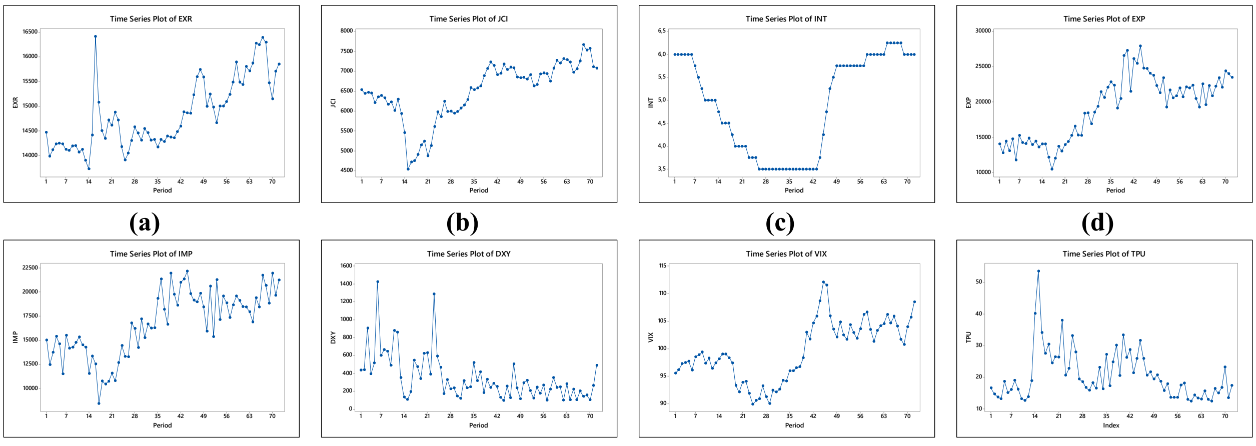
Descriptive statistics summarize the characteristics of each variable used in the study. The descriptive statistics for each variable are presented in Table 2 below.

Table 2. Descriptive Statistics

Variable	Mean	St Dev	Min	Max
EXR (Y_1)	14380	700	13726	16413
JCI (Y_2)	6478.2	739.3	4538.9	7670.7
INT (Y_3)	4.885	1.074	3.500	6.250
EXPO (Y_4)	19137	4479	10453	27929
IMP (Y_5)	16695	3370	8439	22151
DXY (X_1)	352.6	259	96.6	1425.2
VIX (X_2)	99.598	5.410	89.940	112.120
TPU (X_3)	20.628	7.727	12.440	53.540

Based on Table 2, the economic variables in this study have varying volatility. The Rupiah exchange rate against the USD and JCI experienced significant fluctuations, while interest rates were relatively stable. In foreign trade, the average of exports is higher than imports. Meanwhile, global economic factors such as DXY, VIX, and TPU also show high volatility, reflecting the dynamics of global economic uncertainty.

Furthermore, the following visualization represents the time series plot of each variable employed in this study.



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 2. Time Series Plot of (a) EXR, (b) JCI, (c) INT, (d) EXPO, (e) IMP, (f) DXY, (g) VIX, and (h) TPU

Based on Figure 2, each research variable exhibits a fluctuating and distinct data pattern. Therefore, a stationarity test must assess whether the data is stationary before further analysis.

3.2 Stationarity Test

In this analysis, the stationarity test is conducted using the p-value of the unit roots test and the ADF statistical value. The result of the unit root test is presented in Table 3 below.

Table 3. Unit Root Test Results with Augmented Dicky Fuller (ADF) Method

Variable	Original Data		1st Differencing Data	
	ADF Statistical Value	*P-Value*	ADF Statistical Value	*P-Value*
EXR (Y_1)	-2.247987	0.1917	-8.206290	0.0000
JCI (Y_2)	-1.175962	0.6806	-7.463641	0.0000
INT (Y_3)	-1.324496	0.6138	-3.844816	0.0040
EXPO (Y_4)	-1.389659	0.5826	-8.701079	0.0000
IMP (Y_5)	-0.944323	0.7682	-10.43230	0.0001
DXY (X_1)	-1.138162	0.6963	-7.162852	0.0000
VIX (X_2)	-3.886246	0.0035	-10.59969	0.0001
TPU (X_3)	-5.047015	0.0001	-13.04151	0.0001

Based on Table 3, all variables have a p-value less than $\alpha = 0.05$ at the first difference level. This indicates that the data is stationary at the first level of differentiation.

3.3 Optimal Lag Determination

The optimal lag test aims to identify the most suitable number of lags for data analysis and assess its impact on model estimation. The results of the optimal lag test are presented in Table 4 below.

Table 4. Optimal Lag Determination Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2277.414	NA	7.50×10^{20}	69.16407	69.32995	69.22962
1	-2009.728	486.7018	4.81×10^{20}	61.80995	62.80524*	62.20324*
2	-1976.974	54.59013*	3.86×10^{20}*	61.57498*	63.39969	62.29601
3	-1955.555	32.45266	4.44×10^{20}	61.68350	64.33762	62.73227
4	-1933.657	29.86154	5.21×10^{20}	61.77748	65.26103	63.15400
5	-1905.666	33.92792	5.32×10^{20}	61.68686	65.99982	63.39112
6	-1879.981	27.24249	6.20×10^{20}	61.66608	66.80845	63.69808

Table 4 shows that lag 2 is selected as the optimal lag based on the criteria of the highest LR value, the lowest FPE value, and the lowest AIC value. Therefore, lag 2 will be used to model the relationship between the variables in this study.

3.4 Johansen's Cointegration Test

The Johansen cointegration test is used to determine the existence of a cointegration relationship or a stationary linear combination among non-stationary variables at the initial data level. This test is critical in the VAR model because if a cointegration relationship is found, then the more appropriate model to use is the VECM model, which can capture long-term and short-term balance. The Johansen's cointegration test results for the variables in this study are presented in Table 5 below.

Table 5. Results of Johansen Cointegration Test

Hypothesized No. of CE(s)	Eigen Value	Trace Statistic	0.05 Critical Value	Prob.
None*	0.469994	89.14544	69.81889	0.0007
At most 1	0.260542	44.70472	47.85613	0.0959
At most 2	0.163441	23.57611	29.79707	0.2189
At most 3	0.120193	11.08400	15.49471	0.2064
At most 4	0.029836	2.120279	3.841465	0.1454

Table 5 shows that the probability value in the "None" row is lower than the significance level $\alpha = 0{,}05$ which indicates a cointegration relationship between the variables. Therefore, the VECM method is appropriate for modeling this study.

3.5 VECM Model Estimation

The following is the VECM model estimation of Indonesia's financial and trade volatility variables with three global economic variables as exogenous variables.

$$D(EXR) = -0.0759 * (EXR_{t-1} - 2.9742 * JCI_{t-1} - 489.7449 * INT_{t-1} - 0.5707 * EXPO_{t-1} + 1.2485 * IMP_{t-1} - 3110.7338) - 0.1006 * \Delta EXR_{t-1} - 0.2147 * \Delta EXR_{t-2} - 1.0331 * \Delta JCI_{t-1} - 0.3383 * \Delta JCI_{t-2} + 447.2602 * \Delta INT_{t-1} - 518.0298 * \Delta INT_{t-2} + 0.0096 * \Delta EXPO_{t-1} + 0.0239 * \Delta EXPO_{t-2} + 0.0396 * \Delta IMP_{t-1} - 0.0253 * \Delta IMP_{t-2} + 253.5126 - 2.0679 * DXY + 2.7572 * VIX - 0.1943 * TPU$$

$$D(JCI) = 0.1272 * (EXR_{t-1} - 2.9742 * JCI_{t-1} - 489.7449 * INT_{t-1} - 0.5707 * EXP_{t-1} + 1.2485 * IMP_{t-1} - 3110.7339) - 0.0402 * \Delta EXR_{t-1} - 0.0632 * \Delta EXR_{t-2} + 0.105 * \Delta JCI_{t-1} + 0.2903 * \Delta JCI_{t-2} - 106.4189 * \Delta INT_{t-1} + 541.0307 * \Delta INT_{t-2} + 0.0582 * \Delta EXPO_{t-1} + 0.0419 * \Delta EXPO_{t-2} - 0.0901 * \Delta IMP_{t-1} - 0.0402 * \Delta IMP_{t-2} + 484.7666 - 2.7866 * DXY - 12.9426 * VIX + 0.1929 * TPU$$

$$D(INT) = 7.4543 \times 10^{-6} * (EXR_{t-1} - 2.9742 * JCI_{t-1} - 489.7449 * INT_{t-1} - 0.5707 * EXPO_{t-1} + 1.2485 * IMP_{t-1} - 3110.7339) + 7.4373 \times 10^{-5} * \Delta EXR_{t-1} - 9.7203 \times 10^{-6} * \Delta EXR_{t-2} + 7.2249 \times 10^{-5} * \Delta JCI_{t-1} + 7.7356 \times 10^{-5} * \Delta JCI_{t-2} + 0.4726 * \Delta INT_{t-1} + 0.0511 * \Delta INT_{t-2} + 1.1142 \times 10^{-5} * \Delta EXPO_{t-1} + 7.0203 \times 10^{-6} * \Delta EXPO_{t-2} - 4.4601 \times 10^{-6} * \Delta IMP_{t-1} - 5.1899 \times 10^{-6} * \Delta IMP_{t-2} - 0.9388 + 0.0092 * DXY + 0.001 * VIX - 1.2397 \times 10^{-5} * TPU$$

$$D(EXPO) = -0.0924 * (EXR_{t-1} - 2.9742 * JCI_{t-1} - 489.7449 * INT_{t-1} - 0.5707 * EXPO_{t-1} + 1.2485 * IMP_{t-1} - 3110.7340) + 0.4230 * \Delta EXR_{t-1} + 0.1477 * \Delta EXR_{t-2} + 1.9272 * \Delta JCI_{t-1} + 0.6371 * \Delta JCI_{t-2} - 2046.3973 * \Delta INT_{t-1} - 585.7620 * \Delta INT_{t-2} - 0.4251 * \Delta EXPO_{t-1} + 0.0187 * \Delta EXPO_{t-2} - 0.2386 * \Delta IMP_{t-1} - 0.4905 * \Delta IMP_{t-2} + 5588.6733 - 47.9339 * DXY - 10.9455 * VIX - 1.0195 * TPU$$

$$D(IMP) = -0.8177 * (EXR_{t-1} - 2.9742 * JCI_{t-1} - 489.7449 * INT_{t-1} - 0.5707 * EXPO_{t-1} + 1.2485 * IMP_{t-1} - 3110.7339) + 0.4350 * \Delta EXR_{t-1} + 0.8670 * \Delta EXR_{t-2} + 0.0155 * \Delta JCI_{t-1} - 0.8807 * \Delta JCI_{t-2} - 2680.7572 * \Delta INT_{t-1} - 408.7578 * \Delta INT_{t-2} - 0.2136 * \Delta EXPO_{t-1} + 0.0799 * \Delta EXPO_{t-2} - 0.2014 * \Delta IMP_{t-1} - 0.2896 * \Delta IMP_{t-2} + 9695.7547 - 86.4704 * DXY - 23.4888 * VIX - 1.1875 * TPU$$

The estimation results of the VECM model for the exchange rate variable (EXR) show that the error correction term of -0.0759 is significant and negative, indicating a correction mechanism for long-term imbalances. This means that about 7.59% of the deviation in the long-run relationship between EXR and other macroeconomic variables, namely JCI, interest rate (INT), exports (EXPO), and imports (IMP), will be adjusted in one period towards equilibrium. In the short term, changes in JCI have a negative effect on EXR, indicating that an increase in JCI tends to strengthen the Rupiah. Interest rate changes show a significant but inconsistent effect, reflecting the dynamics of monetary policy adjustments. Changes in exports and imports have a relatively small impact on the exchange rate. Exogenous variables such as DXY and VIX also exhibit significant influence, where DXY harms EXR. At the same time, VIX has a positive effect, reflecting the sensitivity of the exchange rate to global pressures. Overall, the model indicates that a combination of domestic and global factors in the short and long term influences the exchange rate.

Furthermore, to assess the adequacy of the VECM specification, especially related to the assumption of multivariate normality of residuals, a residual normality test is conducted based on the Jarque-Bera multivariate approach, with the results presented in **Table 6** below.

Table 6. Residual Normality Test Results

Component	Jarque-Bera	df	Prob.
1	12.91813	2	0.0016
2	0.639220	2	0.7264
3	0.615559	2	0.7351
4	1.785309	2	0.4096
5	0.448202	2	0.7992
Joint	104.9250	105	0.4837

Based on Table 6, the residuals of the VECM model satisfy the assumption of multivariate normality, with the joint Jarque-Bera statistic yielding a p-value of 0.4837, greater than the 5% significance level. This indicates insufficient evidence to reject the null hypothesis of multivariate normality, and thus the residuals can be considered normally distributed.

3.6 Model Stability Test

The stability test results of the VECM model are presented in Table 7 below.

Table 7. Model Stability Test Results

Root	Modulus
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
0.457470 – 0.516461i	0.689935
0.457470 + 0.516461i	0.689935
-0.514901 – 0.437094i	0.675407
-0.514901 + 0.437094i	0.675407
-0.619646	0.619646
-0.308394 – 0.469438i	0.561675
-0.308394 + 0.469438i	0.561675
0.0088429 – 0.451041i	0.459627
0.0088429 + 0.451041i	0.459627
0.2999510 – 0.216090i	0.369325
0.2999510 + 0.216090i	0.369325

Based on Table 7, the modulus values for each root are found to be less than 1. This indicates that the VECM model formed has met the assumptions of model stability. In addition, the results of the stability analysis can also be presented in the form of a plot of inverse roots of the AR characteristics polynomial below.

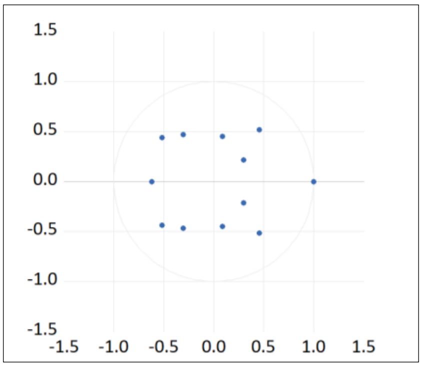


Figure 3. Inverse Roots of AR Characteristics Polynomial

Figure 3, shows that none of the roots and modulus values points are outside the circle or have a value greater than 1, so it can be concluded that the model used in this study has reached a stable condition.

3.7 Granger Causality Test

In this study, the Granger causality test is conducted to examine the causal relationship among endogenous variables. The results of the test are shown in Table 8 below.

Table 8. Granger Causality Test Result

Null Hypothesis:	*Obs.*	*F-Statistic*	*Prob.*
EXPO does not Granger Cause INT	70	5.55044	0.0060
INT does not Granger Cause EXPO		1.23635	0.2972
JCI does not Granger Cause INT	70	3.48140	0.0366
INT does not Granger Cause JCI		0.35053	0.7056
IMP does not Granger Cause INT	70	4.57551	0.0138
INT does not Granger Cause IMP		0.83095	0.4402

Null Hypothesis:	*Obs.*	*F-Statistic*	*Prob.*
EXR does not Granger Cause INT	70	1.29051	0.2821
INT does not Granger Cause EXR		1.37863	0.2592
JCI does not Granger Cause EXPO	70	2.43333	0.0957
EXPO does not Granger Cause JCI		2.40419	0.0983
IMP does not Granger Cause EXPO	70	0.47637	0.6232
EXPO does not Granger Cause IMP		4.21638	0.0190
EXR does not Granger Cause EXPO	70	0.97364	0.3831
EXPO does not Granger Cause EXR		1.68915	0.1927
IMP does not Granger Cause JCI	70	3.50147	0.0360
JCI does not Granger Cause IMP		6.37082	0.0030
EXR does not Granger Cause JCI	70	1.91259	0.1559
JCI does not Granger Cause EXR		20.2653	0.0000
EXR does not Granger Cause IMP	70	1.18529	0.3122
IMP does not Granger Cause EXR		1.53867	0.2224

Based on **Table 8**, there are several $p-values$ that are less than $\alpha = 0.05$ and indicate a causal relationship between the endogenous variables. The export, JCI, and import variables affect the interest rate without a reverse relationship. Then, there is a one-way causality relationship between the export variable that affects imports and the JCI variable that affects the Rupiah exchange rate. Meanwhile, there is a two-way relationship between the import variable and the JCI, where the import variable affects the JCI, and the JCI also affects the import value.

3.8 Impulse Response Function Analysis

The IRF analysis is conducted to assess the impact of shocks on a variable caused by changes and fluctuations in other endogenous variables. The results of the IRF relationship between macroeconomic variables related to Indonesia's financial and trade volatility throughout ten periods are shown in **Figure 4** below.

Figure 4. The IRF Result

Based on **Figure 4**, the following is an interpretation of some of the relationships between variables based on the IRF test chart.

1. Response of EXR to JCI

   In the early period, the Rupiah exchange rate experienced a very sharp decline in response to the JCI until the 3rd period. It slowly began to recover until it finally reached a stable condition. This shows that the direct effect of the JCI on the exchange rate is short-lived and the exchange rate returns to a stable condition within a few periods afterwards. This condition shows the importance of stabilization policies, such as Bank Indonesia intervention or strengthening foreign exchange reserves, to maintain exchange rate stability amidst financial market dynamics.

2. Response of JCI to INT

   The JCI responded to the interest rate hike with a brief decline in the 2nd period. However, it surged to its highest level in the 3rd period before fluctuating and gradually stabilizing near zero. This suggests that interest rates strongly impacted the JCI at the beginning of the period, but over time, the stock market began to adapt to the effect, which gradually subsided. In addition, this also relates to the impact of rising interest rates on increasing the cost of borrowing and can reduce the attractiveness or incentive to the stock market.

3. Response of INT to EXR

   The rise immediately follows the increase in the Rupiah exchange rate against the US dollar, in interest rates, until it reaches a stable point in the 5th period. After that, the interest rate response tends to stabilize and last until the 10th period. This pattern shows that changes in Rupiah exchange rates gradually impact interest rates, where currency depreciation can encourage tighter monetary policy to maintain economic stability. This also aligns with the central bank's strategy of adjusting interest rates in response to inflationary pressures and capital flows due to exchange rate fluctuations.

4. Response of EXPO to EXR

   In the early period, exports experienced a significant decline in response to exchange rate changes, highlighting the direct impact of Rupiah exchange rate fluctuations on export performance. However, the response is volatile with several peaks and declines over several periods. In the 6th period to the 8th period, the value of exports tends to decrease, increasing in the 9th period and decreasing again in the 10th period, with fluctuations that tend to weaken. This indicates that the exchange rate affects exports in the long run with a diminishing impact as time increases.

5. Response of IMP to EXPO

   The effect of changes in export values on imports is a sharp decline at the beginning of the period. Then the value of imports increases and stabilizes at a higher range, although it continues to experience small fluctuations. This pattern indicates that export changes directly influence imports through raw material demand mechanisms or global supply chain linkages. Overall, the relationship between exports and imports shows a fairly close dependency, where an increase in exports can boost import activity in the medium to long term.

3.9 Variance Decomposition Analysis

Variance decomposition analysis is used to measure the extent to which changes in a variable are affected by shocks from the variable itself and to compare it with the impact caused by other variables in a model. The variance decomposition analysis results for each endogenous variable in this study are presented in **Figure 5** below.

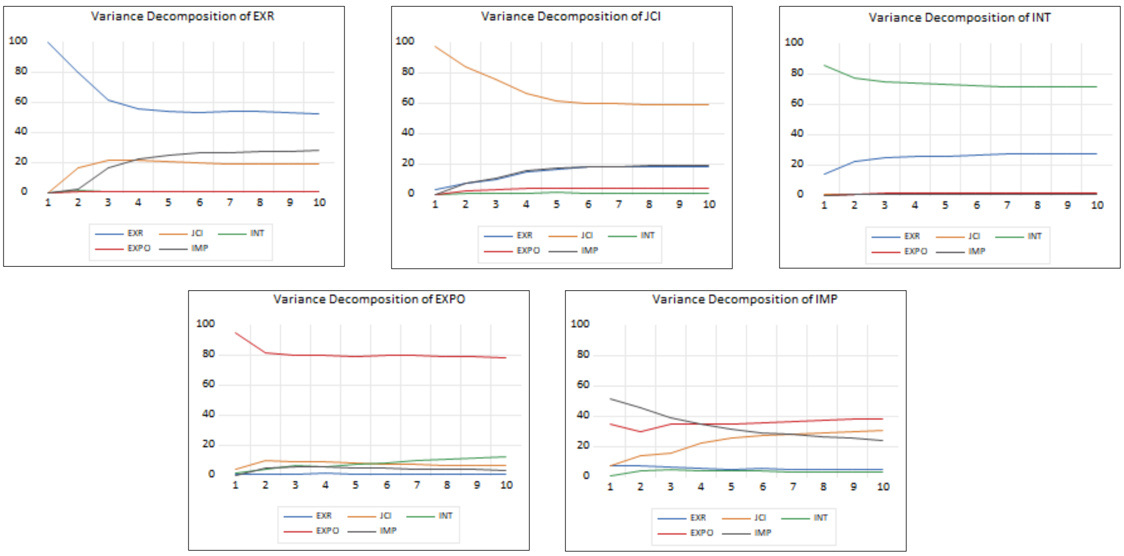


Figure 5. Variance Decomposition of Endogenous Variables

Based on **Figure 5**, it is visible that most of the variability of each variable is explained by the variable itself throughout the analysis period. However, other variables also contribute to a variable's variability.

Table 9. Variance Decomposition of EXR

Period	S.E.	EXR	JCI	INT	EXPO	IMP
1	301.1516	100.0000	0.000000	0.000000	0.000000	0.000000
2	423.6247	79.49455	16.60606	1.067503	0.658626	2.173262
3	502.8826	61.21972	21.30923	0.795016	0.494230	16.18179
4	551.7846	55.56588	21.19212	0.823077	0.711031	21.70790
5	584.0636	53.53383	20.41456	0.770828	0.673011	24.60777
6	615.3504	53.08251	19.59183	0.707645	0.609329	26.00868
7	648.4635	53.34078	18.97076	0.641790	0.549756	26.49692
8	681.7684	53.34126	18.84023	0.593069	0.497356	26.72808
9	713.9605	52.96783	18.82651	0.546324	0.455566	27.20377
10	744.6382	52.46884	18.83274	0.502535	0.424181	27.77171

Based on **Table 9**, the results of the variance decomposition analysis on the EXR variable show that the EXR variable explains its variability throughout the analysis period. In the first period, the exchange rate plays a 100% role in the variation of the exchange rate value itself, while other variables only have a minimal contribution. Over time, the contribution of the exchange rate remained very dominant, although it then decreased to 52.47% in the tenth period. However, EXR remains the dominant factor in explaining the movement of its value. Over time, the contribution of other variables starts to increase. The JCI has the most significant influence after a few periods, contributing around 18.83% in the tenth period. Then the IMP also substantially affects the variability of EXR, reaching 27.77% in the tenth period. Meanwhile, EXR and EXPO have a relatively small influence on the exchange rate movement.

Table 10. Variance Decomposition of JCI

Period	S.E.	EXR	JCI	INT	EXPO	IMP
1	206.2238	2.740271	97.25973	0.000000	0.000000	0.000000
2	291.6868	7.085123	83.68406	0.203878	1.906614	7.120325
3	374.7354	9.860272	75.44840	0.729721	3.192822	10.76878
4	438.0677	14.37518	66.19852	0.736553	3.393635	15.29611
5	481.6821	16.62350	61.66053	0.856801	3.758496	17.10067
6	512.4538	17.76849	59.53490	0.782108	3.881945	18.03255
7	538.5830	18.06028	59.17711	0.708771	3.877027	18.17681
8	565.5116	18.08265	59.02052	0.644305	3.875980	18.37655
9	593.4066	18.01843	59.02430	0.585154	3.860178	18.51194
10	621.3378	18.10304	58.75508	0.534557	3.868728	18.73860

Based on **Table 10**, the result of the variance decomposition analysis on the JCI variable shows that most of the variability of JCI is explained by the variable itself, especially in the early period, with a contribution of 97.26%. However, the influential rate of EXR started to increase from 2.74% to 18.10% in the tenth period, followed by the contribution of IMP from 0% to 18.74%. In addition, INT and EXPO have a fairly small influence on the movement of the JCI value.

Table 11. Variance Decomposition of INT

Period	S.E.	EXR	JCI	INT	EXPO	IMP
1	0.124245	14.16057	0.131729	85.70770	0.000000	0.000000
2	0.231606	22.01384	0.150683	77.32681	0.452473	0.056195

Period	S.E.	EXR	JCI	INT	EXPO	IMP
3	0.328685	24.19508	0.235539	74.68240	0.855210	0.031770
4	0.413167	25.04803	0.252793	73.58768	1.090504	0.020989
5	0.489541	25.75636	0.270066	72.68187	1.233330	0.058377
6	0.557511	26.29991	0.254333	72.01445	1.320448	0.110857
7	0.618300	26.69897	0.224510	71.55303	1.382714	0.140785
8	0.672927	26.94336	0.197359	71.29533	1.413447	0.150502
9	0.722517	27.07096	0.177257	71.17407	1.428595	0.149124
10	0.768506	27.14946	0.164220	71.10000	1.439266	0.147061

Based on Table 11, it is visible that the amount of INT is strongly influenced by itself, with a contribution of 85.71% at the beginning of the period. However, in the long run, it is shown that the effect of EXR on INT significantly increases from 14.16% in the first period to 27.15% in the 10th period. Meanwhile, JCI, EXPO, and IMP have minimal contribution values.

Table 12. Variance Decomposition of EXPO

Period	S.E.	EXR	JCI	INT	EXPO	IMP
1	1659.061	0.820998	3.675699	1.025206	94.47810	0.000000
2	1941.315	0.619398	9.546231	4.098667	81.47069	4.265014
3	2210.595	0.486486	8.337622	6.150001	79.79347	5.232418
4	2512.811	0.869420	8.375002	5.468690	79.86322	5.423664
5	2687.904	0.766407	8.103335	7.266760	78.96867	4.894832
6	2891.742	0.808017	7.169130	8.287134	79.49353	4.242190
7	3055.461	0.727280	6.733653	9.168233	79.49727	3.873564
8	3220.818	0.694064	6.365285	10.53437	78.59942	3.806860
9	3383.068	0.630537	6.229663	11.26609	78.37042	3.503297
10	3533.195	0.585629	6.158311	11.93005	78.03211	3.293908

Based on Table 12, throughout the analysis period, the value change in the EXPO variable is mainly influenced by the variable itself, with an influence of 94.47% at the beginning of the period and becoming 78.03% in the tenth period. Then, INT became the variable with the second most significant influence, with a contribution of 11.93% in the tenth period, followed by JCI, with a relatively small influence and stabilized at around 6.15%. Meanwhile, EXR has a minimal influence with a value of only 0.59% in the 10th period.

Table 13. Variance Decomposition of IMP

Period	S.E.	EXR	JCI	INT	EXPO	IMP
1	1577.424	7.050134	7.022758	0.124646	34.22129	51.58117
2	1725.261	7.149861	14.12388	3.483963	29.99180	45.25049
3	1872.120	6.500605	15.56288	4.665233	34.75084	38.52044
4	2073.156	5.386250	21.89683	3.808457	34.48408	34.42438
5	2206.297	4.828721	25.53618	4.059634	34.59175	30.98372
6	2390.308	5.134468	26.73243	3.510824	35.60756	29.01471
7	2510.597	4.990446	27.87942	3.270613	36.26222	27.59730
8	2618.980	4.867132	28.59136	3.183061	37.21577	26.14267
9	2731.021	4.728020	29.35744	3.052181	37.78409	25.07827
10	2831.658	4.528353	30.24431	3.018828	38.21555	23.99297

Based on **Table 13**, the IMP variable is strongly influenced by the value of IMP itself, with a contribution of 51.58% at the beginning of the period, then decreasing to 23.99% in the tenth period. Meanwhile, the role of JCI tends to increase. It becomes the second most significant factor in explaining the variability of IMP with a contribution value of 30.24%, followed by the EXPO variable, which contributes 38.22%. In addition, EXR has the least influence and tends to decrease in explaining the IMP variable.

The results of the variance decomposition analysis show that its shocks initially dominate the exchange rate (USD/IDR). Still, import values and JCI increasingly contribute to its variability over time, indicating strengthening linkages between trade and financial markets. Similarly, the JCI was mainly self-driven in the early period, yet gradually became more influenced by shocks in the exchange rate and import values, suggesting interdependence between currency fluctuations and equity markets. The interest rate shows a rising sensitivity to exchange rate shocks over time, reflecting potential monetary policy responses to currency volatility. Export values are primarily influenced by their past values, but over time, interest rates and JCI begin to play a moderate role. Meanwhile, imports are influenced not only by their past values but increasingly by exports and JCI, highlighting the dynamic and reciprocal nature of Indonesia's trade and financial systems.

These study results align with previous empirical studies that emphasize the interconnectedness of macroeconomic variables over time. The exchange rate, interest rates, stock index (JCI), exports, and imports do not move independently, but show a dynamic relationship that develops along with changes in economic conditions. Specifically, fluctuations in exchange rates significantly affect the JCI, especially in the context of investor sentiment and capital flows **[27]**. Moreover, interest and exchange rates are also important determinants of stock market performance, especially in the short term **[28]**. Regarding trade, exports and imports are also closely linked to exchange rate movements. Previous studies employing the ARDL model suggest that export volumes rise when the exchange rate depreciates, as domestic goods become cheaper for foreign buyers. Conversely, an appreciation of the exchange rate can reduce export competitiveness while simultaneously making imports more affordable **[29]**. However, the relationship can become more complex in countries like Indonesia, which rely heavily on imported inputs for their exports. These interdependencies were also observed in the current study, where exports and imports were shown to have a growing contribution to the exchange rate variability over time based on variance decomposition results. Furthermore, global economic factors such as DXY, VIX, and TPU affect domestic macroeconomic stability. DXY and VIX increase tends to trigger capital outflows and depreciate emerging market currencies, including the Rupiah, amplifying trade and financial market volatility. These external shocks help explain the increased impact of global uncertainty on domestic variables as observed in the variance decomposition results.

4. CONCLUSION

The analysis results show that each data variable has different volatility with patterns that tend to fluctuate and reach stationary conditions at the first differencing level. By selecting lag 2 as the optimal lag length, a cointegration relationship was identified among the variables of the Rupiah exchange rate against the dollar, JCI, interest rates, export values, and imports. Therefore, the research variables were modeled using the VECM-X method by including three indicators of global economic uncertainty, namely DXY, VIX, and TPU, as exogenous variables. The VECM-X model obtained has reached a stable condition based on the stability test results. The causality test results show several causal relationships among the endogenous variables, where exports, JCI, and imports affect the interest rate without the reverse relationship, as well as a one-way relationship between exports and imports and JCI and the Rupiah exchange rate. Moreover, there is a two-way relationship between imports and JCI, which influence each other. Furthermore, the IRF test results show that the relationship between endogenous variables is dynamic with a fluctuating pattern in the short term, but tends to reach equilibrium in the medium to long term. Meanwhile, the variance decomposition test reveals that most of the variability of each variable is explained by the variable itself, with other variables also contributing to the variability over the analysis period. However, this research is limited by using historical data up to December 2024 and excluding domestic factors such as fiscal and political policies, which may also influence economic dynamics. Future studies are encouraged to use updated and longer-term data, consider domestic factors, and apply advanced statistical methods such as SVAR, Bayesian VAR, or time-varying models. Complementary qualitative approaches may also be used to gain a more comprehensive understanding of Indonesia's economic dynamics.

AUTHOR CONTRIBUTIONS

Dita Amelia: Conceptualization, Funding Acquisition, Supervision, Writing - Original Draft. Suliyanto: Methodology, Investigation, Resources, Validation. Galuh Cahya Nugraha: Formal Analysis, Project Administration, Software. Billy Christandy Suyono: Data Curation, Visualization, Writing - Review and Editing. All authors discussed the results and contributed to the final manuscript.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest to report.

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