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FOREIGN EXCHANGE RATE PREDICTION OF INDONESIA'S LARGEST TRADING PARTNER BASED ON VECTOR ERROR CORRECTION MODEL

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ABSTRACT

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Foreign exchange rates from trading partners' currencies are critical in developing Indonesia's economic landscape. As an active country in international trade, Indonesia's economic health is highly dependent on trade partnerships, movements, and interactions of foreign exchange rates from Indonesia's main trading partners. To achieve economic stability, Bank Indonesia intervenes in the foreign exchange market to keep the Rupiah exchange rate within a reasonable range. Indonesia is committed to attaining several points in the Sustainable Development Goals (SDGs), such as point 17, which emphasizes partnerships, and point 8, which underlines inclusive and sustainable economic growth. This commitment is an important factor in Indonesia's economic development. Therefore, it is necessary to predict the exchange rate value of Indonesia's largest trading partners considering these SDG aspects. In this study, the Vector Error Correction Model (VECM) was used to predict the foreign exchange rate of Indonesia's largest trading partners. The data used in this study is secondary data obtained from the investing.com webpage, comprising weekly data from January 2021 to November 2023. The foreign exchange rates of Indonesia's largest trading partners have a cointegration relationship, indicating long-term relationships and similarities in movements. The best model identified is VECM (1), with a very accurate MAPE value of 3.29%. The Impulse Response Function (IRF) analysis shows that the Chinese Yuan responds variably to different currencies, stabilizing over time. Variance Decomposition reveals that short-term fluctuations in the Chinese Yuan are primarily influenced by itself (87.89%) and significantly by the Singapore Dollar, South Korean Won, and Taiwan Dollar. The Granger Causality Test indicates that the Philippine Peso influences 11 other exchange rates, refining the VECM model and improving prediction accuracy. Indonesia is expected to build economic collaborations that can help achieve economic stability.

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1. INTRODUCTION

Indonesia as a country with an open and globally integrated economy is strongly influenced by the performance of its main trading partners. Foreign exchange rates from trading partners' currencies are critical in the development of Indonesia's economic landscape. As an active country in international trade, Indonesia's economic health is highly dependent on trade partnerships, movements, and interactions of foreign exchange rates from Indonesia's main trading partners. Indonesia's export value reached USD 22 billion in August 2023, an increase from the previous month of 5.47% [1] changes in export value can be influenced by exchange rate movements from the country's trading partners. According to Indonesia's Foreign Trade Statistics (as known as *Statistik Perdagangan Luar Negeri Indonesia* in Indonesia) 2022 [2], 12 Indonesian trading partner countries have significant export values, i.e. China, India, United States, Netherlands, Japan, South Korea, Malaysia, Singapore, Thailand, Philippines, Vietnam, and Taiwan.

Foreign exchange rates with trading partners have a central role in determining the competitiveness of Indonesian products in the international market. When the exchange rate of trading partner currencies strengthens against the Rupiah, Indonesian export products become more affordable and competitive. This can result in increased revenues from exports that contribute positively to the country's economic growth. Foreign exchange rates also affect import costs and inflation within the country. When the value of the Rupiah weakens against the currencies of trading partners, import costs increase, which can have an impact on increasing the price of imported goods in the domestic market [3]. This can be one of the drivers of inflation and affect people's purchasing power and price stability in the country.

To achieve economic stability, Bank Indonesia is often involved in foreign exchange market interventions to keep the Rupiah exchange rate within a reasonable range. This policy aims to avoid excessive turmoil and maintain Indonesia's export competitiveness. Therefore, a deep understanding of foreign exchange rates from trading partners is key in designing effective monetary policy. In addition to the trade sector, foreign exchange rates also have an impact on the real sector of the economy, including industry, agriculture, and manufacturing. Changes in exchange rates can affect production costs and company profits and can shape investment decisions and business strategies. Therefore, domestic economic stakeholders need to continue to monitor and understand the dynamics of foreign exchange rates to respond appropriately to changes in global economic conditions. This research is related to the eighth indicator and seventeenth indicator of Sustainable Development Goals (SDGs), Decent Work and Economic Growth, and Partnerships for The Goals, respectively [4]. the growth of Indonesia's trade export value is influenced by government decision-making in making decisions related to bilateral cooperation with other countries that are Indonesia's trading partners.

In this research, the researcher used the Vector Error Correction Model (VECM) which is a simultaneous equation model, because this analysis considers several endogenous variables with cointegration properties together in a model. The VECM was chosen because it has several advantages, such as its ability to capture cause-and-effect relationships in the short-term and long-term balance simultaneously. By combining autoregressive elements from the model Vector Autoregressive (VAR) with error correction, VECM is able to respond to changes in endogenous and exogenous variables, allowing researchers to understand market dynamics more comprehensively. In addition, VECM can also handle non-stationarity in data, an important advantage in econometric analysis. In circumstances, the variables have trends or structural changes over time [5].

In this research, VECM is used to predict the foreign exchange rate of Indonesia's largest trading partner country against the rupiah and to see the relationship between variables as an effort to achieve stability in currency exchange rate movements. It is hoped that this research can help the government to take appropriate and effective policies to maintain the stability of the country's currency. In addition, it is expected that market players will gain a better view of the risks and opportunities associated with international trade, which can help market players make more informed decisions.

2. RESEARCH METHODS

2.1 Research Data and Variable

This research uses secondary data which is obtained from the Investing webpage [6]. The data used in this research is weekly data from the foreign exchange rates of Indonesia's largest trading partners from the first week of January 2021 to the second week of November 2023. There are 150 data which are split into training dataset and testing dataset with a ratio of 90 to 10, so that the training dataset and testing dataset obtained are 135 and 15, respectively. The variables in this research are 12 currency exchange rates from Indonesia's largest trading partners which are given in Table 1 as follows.

Table 1. Research Variables

Variable	Definition	Unit
CNY	Chinese currency (Yuan) exchange rate against Rupiah	Rupiah
EUR	European Union currency (Euro) exchange rate against Rupiah	Rupiah
INR	Indian currency (Rupee) exchange rate against Rupiah	Rupiah
JPY	Japanese currency (Yen) exchange rate against Rupiah	Rupiah
KRW	South Korean currency (Won) exchange rate against Rupiah	Rupiah
MYR	Malaysian currency (Ringgit) exchange rate against Rupiah	Rupiah
PHP	Philippines currency (Peso) exchange rate against Rupiah	Rupiah
SGD	Singaporean currency (Singaporean Dollar) exchange rate against Rupiah	Rupiah
THB	Thai currency exchange rate (Baht) against Rupiah	Rupiah
TWD	Taiwan currency (Taiwan Dollar) exchange rate against Rupiah	Rupiah
USD	United States currency (United States Dollar) exchange rate against the Rupiah	Rupiah
VND	Vietnamese currency (Dong) exchange rate against the Rupiah	Rupiah

***Data source**: Indonesia's Foreign Trade Statistics, 2022*

2.2 Data Analysis Technique

In conducting research, steps are needed to carry out data analysis. The stages of analysis in this study can be visualized through the flowchart presented in Figure 1 as follows.

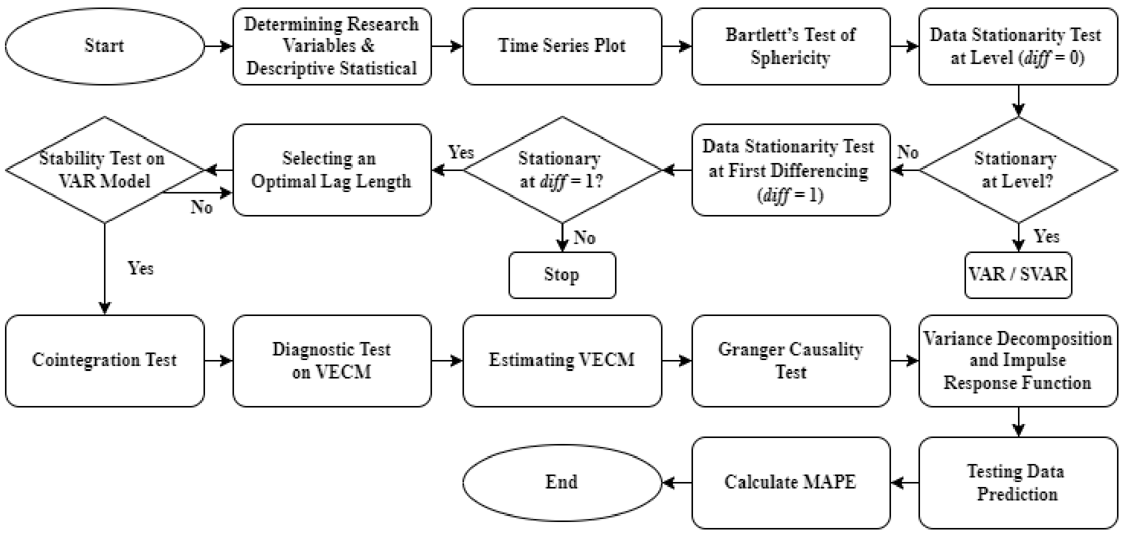


Figure 1. Research Flowchart

The steps taken to carry out data analysis in this research are as follows.

1. Determine research variables and perform descriptive statistical interpretation from the obtained data.
2. Time series plotting on foreign exchange rate data.
3. Perform Bartlett's Test of Sphericity on the training dataset.
4. Perform a stationarity test on the training dataset, if it's not stationary at level then do a differencing on the training dataset and repeat the stationarity test.
5. Selecting an optimal lag on the training dataset.
6. Perform a stability test on the VAR model on the training dataset.

7. Perform a cointegration test on the training dataset.
8. Perform a diagnostic test on VECM.
9. Estimating VECM.
10. Perform Granger Causality Test.
11. Perform Variance Decomposition and Impulse Response Function.
12. Predicting foreign exchange rate and calculating the Mean Absolute Percentage Error (MAPE).

2.2.1. Bartlett's Test of Sphericity

Bartlett's test of Sphericity is a statistical method used to test the hypothesis that the correlation matrix in a data set is an identity matrix, which indicates the uncorrelation between variables. Significant results from Bartlett's test indicate the existence of at least one significant relationship between variables in the dataset. The Bartlett's test hypothesis is $H_0: \boldsymbol{R} = \boldsymbol{I}$ (the data does not have a significant correlation between variables) against $H_1: \boldsymbol{R} \neq \boldsymbol{I}$ (the data has a significant correlation between variables), with Bartlett's test statistics are shown in **Equation (1)** as follows.

$$\chi^2 = -\left(T - 1 - \frac{2M - 5}{6}\right) \ln|\boldsymbol{R}| \tag{1}$$

If Bartlett's test is significant as indicated by the p-value (p-value less than the significance level) or $\chi^2 > \chi^2_{\alpha;\frac{1}{2}M(M-1)}$, where M is the number of variables used, then it indicates that the null hypothesis is rejected so it can be seen that the data has a significant correlation between variables **[7].**

2.2.2. Stationarity Time Series

The Augmented Dickey-Fuller (ADF) test is commonly used to test stationarity in time series analysis. The goal of the ADF test is to determine whether a time series has a unit root, which indicates non-stationarity behavior. If the time series is not stationary, then it may require transformation or differentiation to make it stationary. The equation differencing one is denoted by **Equation (2)**,

$$\Delta Y_t = Y_t - Y_{t-1} \tag{2}$$

Statistically significant ADF test results can indicate the stationarity in the time series, allowing further analysis of the behavior of the data for modeling and prediction purposes **[8].** The equation in the ADF test is formed from the addition of the lag value of the dependent variable ΔY_t, which is denoted by **Equation (3)**,

$$\Delta Y_t = \alpha_0 + \delta Y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \varepsilon_t \tag{3}$$

where ε_t are the residual value of the ADF equation, and δ is the first lag parameter (Y_{t-1}) **[9], [10].** The ADF test hypothesis is $H_0: \delta = 0$ (non-stationary data) against $H_1: \delta < 0$ (stationary data), with the test statistic used in the **Equation (4)**, where $SE(\hat{\delta})$ is the standard error. The test criteria are if the $\tau_{statistic} < \tau_{0.05}$ of the Mackinnon table or when the $p-$ value $< \alpha = 0.05$ then reject H_0 which indicates the data is stationary **[11].**

$$\tau_{statistic} = \frac{\hat{\delta}}{SE(\hat{\delta})} \tag{4}$$

2.2.3. Selecting Optimal Lag

The number of lags used in the VAR model can be determined by several criteria, such as Hanan Quinon (HQ), Schwarz Information Criterion (SC), Akaike Information Criterion (AIC), and Likelihood Ratio (LR) **[12].** The optimal lag is determined to eliminate the autocorrelation problem in the VAR model since it will be used to analyze the VAR stability. In addition, this step is carried out because the optimal lag of the endogenous variable is the independent variable used in the VAR model **[13].**

2.2.4. VAR Stability Test

The stability of the VAR model can be seen in the modulus value that each variable has. The VAR model is said to be stable if the modulus value is at a radius < 1, and unstable if the modulus value > 1. If the largest modulus value is less than one and is at the optimal point, then the composition is already in the optimal position and the VAR model is stable. However, modulus values close to 1 indicate fluctuations or instability in the model. By carrying out a thorough stability test, the results of the analysis will be more accurate [12].

2.2.5. Cointegration Test

The cointegration test in VECM is used to identify long-term relationships between two or more time series that may be correlated. Cointegration testing uses the Johansen Cointegration method with the following hypothesis [14], [15], [16]: H_0: rank cointegration $\leq k$ (there is cointegration at the rank k) against H_1: rank cointegration $> k$ (there is no cointegration in the rank k) with test statistics using the feature root test (trace statistic) in Equation (5) [17].

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{k} \ln\left(1 - \hat{\lambda}_i\right) \tag{5}$$

Where k is the number of variables, T is the number of observations, $\hat{\lambda}_i$ is estimated eigenvalues, r is rank cointegration, with the possible sum r is from $r = 0$ to $r = k - 1$. The test criteria is if the value $\lambda_{trace}(r) > \lambda_{trace\ (0.05)}$ then reject H_0, It means there is a cointegration rank k.

2.2.6. Vector Error Correction Model (VECM)

Vector Error Correction Model (VECM) is a multivariate time series data analysis model that can facilitate data that is not stationary at level, but stationary at differencing first and shows the existence of cointegration [18]. VECM is an extension of the VAR model by considering the long-term balance between the variables. The VECM estimate is considered significant if the t-statistic value exceeds the t-table value with a significance level of 5%. This VECM estimate is useful for identifying effects and variables that have significance in both the long and short term [11]. In general, VECM is written in Equation (6),

$$\nabla Y_t = \alpha\beta' Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \nabla Y_{t-1} + \varepsilon_t \tag{6}$$

Where ∇ is the differencing operator, Y_t is a vector of response variables, Y_{t-1} is a vector of response variables with lag 1 of size $n \times 1$, $\alpha\beta'$ is the coefficient matrix, $p - 1$ is the VECM lag, Γ_i is the coefficient matrix of the i −th endogenous variables with $n \times n$ size, and ε_t is a residual vector of size $n \times 1$ [19].

2.2.7. Granger Causality Test

The Granger Causality Test is used to evaluate the causal influence of a variable on other variables in a time series. This testing process involves comparing the performance of the model with and without the inclusion of certain variables, to assess whether there is a significant improvement in predictive ability. Positive results from this test indicate the causal relationship between these variables in VECM [20].

2.2.8. *Mean Absolute Percentage Error*

MAPE is the average of the overall percentage error (difference) between actual data and forecast data. MAPE is calculated by using the absolute error for each period divided by the actual observed value for that period, then averaging the absolute percentage errors [21]. This approach is useful when the size of the forecast variable is important in evaluating forecast accuracy. The formula for MAPE calculation is written in Equation (7), where y_i is actual data and $\hat{y}_i$ is forecast data.

$$\text{MAPE} = \frac{1}{n}\left[\sum_{i=1}^{n} \left|\frac{y_i - \hat{y}_i}{y_i}\right| \times 100\right] \tag{7}$$

3. RESULTS AND DISCUSSION

3.1 Data Characteristic

The initial step in carrying out the analysis is to carry out a descriptive statistical evaluation of the foreign exchange rate data given in Table 2 as follows.

Table 2. Data Characteristics

Variable	Minimum		Maximum	
	Rate	Date	Rate	Date
CNY	2,066.65	06/25/2023	2,285.09	01/01/2023
USD	13,970	02/07/2021	15,935	10/22/2023
JPY	102.9	11/12/2023	135.07	01/17/2021
INR	179.32	05/07/2023	198.83	03/14/2021
MYR	3,203.68	06/18/2023	3,547.44	01/01/2023
SGD	10,425.78	11/21/2021	11,705.23	01/01/2023
PHP	255.87	09/18/2022	301.2	04/11/2021
KRW	10.56	09/18/2022	13.04	04/11/2021
TWD	472.61	09/18/2022	520.47	06/27/2021
VND	0.606033	01/03/2021	0.665994	01/01/2023
THB	400.399	09/18/2023	469.21	01/24/2021
EUR	14,568.9	09/18/2022	17,567.8	04/18/2021

***Data source**: Investing.com, 2023*

Based on Table 2, the European Euro is the currency with the highest value in Indonesia's exchange rate ranging between Rp14,568.9 and Rp17,567.8, meanwhile Vietnamese Dong is the lowest ranging between Rp0.606 and Rp0.665. The value of the currency exchange rate is constructed in a time series plot to see the data pattern. A time series plot of exchange rate data is given in Figure 2 as follows.

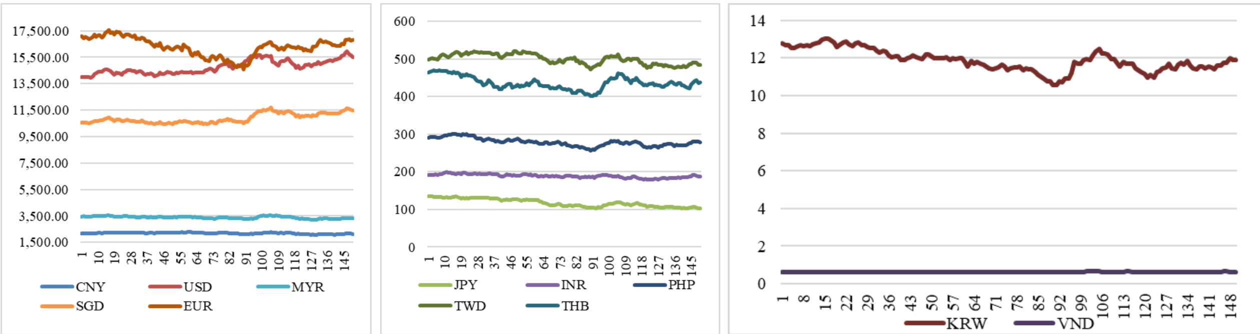


Figure 2. Time Series Plot of Foreign Exchange Rate: CNY, USD, MYR, SGD, EUR on the Left, JPY, INR, PHP, TWD, THB on the Center, and KRW, VND on the Right

Figure 2 shows a time series plot of foreign currency exchange rate data against the Indonesian rupiah, showing that a unit of foreign currency has a fluctuating exchange rate. The foreign currency rates are plotted in several separate graphs so that the fluctuations of each foreign currency against the rupiah can be seen.

3.2 Bartlett's Test of Sphericity

Bartlett's test is used to test whether the correlation matrix is an identity matrix, which indicates the uncorrelation between variables. The Bartlett's test results are given in Table 3.

Table 3. Bartlett's Test of Sphericity Results

Bartlett's Test of Sphericity	Approx. Chi-Square	2,992.301
	df	66
	Sig.	0.000

Based on Table 3, it can be seen that the significance value is 0.000, where this value is less than the significance level of 0.05. Thus, it can be concluded that there is a correlation in the exchange rate data of Indonesia's largest trading partners and the analysis can be continued using the Vector Autoregressive model.

3.3 Stationarity Test

One of the requirements for analysis using the Vector Autoregressive (VAR) method means that the data must be stationary so that a unit root test is carried out simultaneously with the aim of testing the stationarity of the data. The results of the unit root test (ADF Test) on exchange rate data are given in Table 4 as follows.

Table 4. Augmented Dickey-Fuller (ADF) Test Results

Variable	Significance Level	Level		1st Difference	
		Stat. ADF	p-value	Stat. ADF	p-value
CNY	5%	-1.894476	0.3342	-12.73626	0.000
USD	5%	-1.410610	0.5757	-12.26743	0.000
JPY	5%	-0.990381	0.7759	-11.25886	0.000
INR	5%	-2.016569	0.2796	-12.94867	0.000
MYR	5%	-1.820805	0.3693	-6.787142	0.000
SGD	5%	-0.876877	0.7933	-12.10415	0.000
PHP	5%	-1.631192	0.4642	-11.60268	0.000
KRW	5%	-1.896333	0.3334	-12.17145	0.000
TWD	5%	-1.547437	0.5069	-12.79174	0.000
VND	5%	-3.647524	0.0590	-13.17726	0.000
THB	5%	-2.058565	0.2619	-11.60063	0.000
EUR	5%	-1.542683	0.5093	-13.01012	0.000

Based on Table 4, the twelve-exchange rate is not stationary at the level which is indicated by a p-value of 0.1603 which is more than the significance level of 0.05 so it is necessary to make a difference. After making a difference on the first level, the p-value of the data is 0.000 which means the data is stationary at the first differencing.

3.4 Selecting Optimal Lag

Vector Autoregressive (VAR) model identification is related to the selection of the optimal lag. Optimal lag selection can be based on several criteria, that is Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ) [22]. The optimal lag test results are given in Table 5 as follows.

Table 5. Optimal Lag Selection

Lag	Log L	FPE	AIC	SC	HQ
1	**-3800.598**	**7.16×10^{11}**	**61.34261**	**64.80098**	**62.74782**
2	-3700.524	1.49×10^{12}	62.02363	68.67435	64.72595
3	-3579.519	2.44×10^{12}	62.38014	72.22321	66.37958

In Vector Autoregressive (VAR) lag is said to be optimal if it produces the lowest value [23]. Based on Table 5, it is known that the lag that produces the lowest value in each criterion is lag 1.

3.5 VAR Stability Test

Stability tests are carried out to identify the stability of parameters over a certain period. The stability test is determined based on the modulus value. The VAR model is said to be stable if the modulus values are at various root points less than one or at a unit circle [24]. The stability test results are given in Table 6.

Table 6. VAR Stability Test

Root	Modulus	Root	Modulus	Root	Modulus
0.365297 - 0.154375i	0.396578	-0.253180	0.253180	-0.048179 - 0.138724i	0.146852

Root	Modulus	Root	Modulus	Root	Modulus
0.365297 + 0.154375i	0.396578	0.125083 - 0.182563i	0.221303	-0.048179 + 0.138724i	0.146852
-0.096554 - 0.236311i	0.255276	0.125083 + 0.182563i	0.221303	0.101276	0.101276
-0.096554 + 0.236311i	0.255276	-0.178050	0.178050	-0.044265	0.044265

Based on Table 6, the modulus value for each root is less than one, so it can be concluded that the VAR model at lag 1 or VAR (1) is stable.

3.6 Cointegration Test

The cointegration test is used to determine the choice of time series method to be used, where if there is cointegration the analysis continues with the VECM, and if there is no cointegration then the analysis continues with the VAR method. The results of the cointegration test are given in Table 7 as follows.

Table 7. Cointegration Test

Methods	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0,05 Critical Value	Prob
Trace	None *	0.573518	778.8385	334.9837	0.0000
	At most 1 *	0.557295	666.3500	285.1425	0.0000
	At most 2 *	0.492035	558.7897	239.2354	0.0000
	At most 3 *	0.478661	469.3805	197.3709	0.0001
	At most 4 *	0.430111	383.4016	159.5297	0.0000
	At most 5 *	0.371424	309.1763	125.6154	0.0000
	At most 6 *	0.362919	247.8888	95.75366	0.0000
	At most 7 *	0.326225	188.3755	69.81889	0.0000
	At most 8 *	0.293871	136.2541	47.85613	0.0000
	At most 9 *	0.226985	90.32368	29.79707	0.0000
	At most 10 *	0.196555	56.33946	15.49471	0.0000
	At most 11 *	0.187766	27.45166	3.841466	0.0000
Maximum Eigenvalue	None *	0.573518	112.4885	76.57843	0.0000
	At most 1 *	0.557295	107.5604	70.53513	0.0000
	At most 2 *	0.492035	89.40919	64.50472	0.0001
	At most 3 *	0.478661	85.97892	58.43354	0.0000
	At most 4 *	0.430111	74.22531	52.36261	0.0001
	At most 5 *	0.371424	61.28743	46.23142	0.0007
	At most 6 *	0.362919	59.51331	40.07757	0.0001
	At most 7 *	0.326225	52.12141	33.87687	0.0001
	At most 8 *	0.293871	45.93043	27.58434	0.0001
	At most 9 *	0.226985	33.98423	21.13162	0.0005
	At most 10 *	0.196555	28.88780	14.26460	0.0001
	At most 11 *	0.187766	27.45166	3.841466	0.0000

The cointegration test in VECM is used to identify long-term relationships between two or more time series that may be correlated. If the probability value is less than the significance level (0.05), the data are said to have cointegration conditions. Based on the results of the cointegration test using the trace and maximum eigenvalue methods, the probability value was found to be less than the significance level (0.05), so this indicates the occurrence of cointegration in the exchange rate data. Cointegration is confirmed up to $r = 4$ based on the Maximum Eigenvalue Test and up to $r = 11$ based on the Trace Test. Considering that the optimal and stable lag in the VAR model is VAR (1), the analysis will continue with the Vector Error Correction Model using VECM (1).

3.7 Diagnostic Test

There are two diagnostic tests on VECM that need to be fulfilled, that is the Portmanteau Test and the White Test for Heteroscedasticity. The Portmanteau test is used to test whether the VECM (1) residuals have autocorrelation [25]. Autocorrelation in the residuals can indicate that the model has not fully captured the pattern in the data and that there is still information remaining in the residuals. The results of the Portmanteau Test are given in **Table 8** as follows.

Table 8. Portmanteau Test

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob	df
1	73.55125	-	74.11271	-	-
2	300.1253	0.1523	304.1725	0.1173	276

Based on **Table 8**, the results of the Portmanteau test show that there is no residual serial correlation in the VECM (1), this is shown in the p-value of 0.1523 which is more than the significance level of 0.05. Next, a residual heteroscedasticity test was carried out using White Test for Heteroscedasticity which is given in **Table 9**.

Table 9. White Test for Heteroscedasticity

Lags	Chi-sq	df	Prob.
1	2108.003	2028	0.1056

Table 9 shows that there is no heteroscedasticity in the VECM (1), this is shown in the p-value of 0.1056 which is more than the significance level of 0.05. Thus, it can be concluded that the VECM (1) has fulfilled the diagnostic test.

3.8 Estimating VECM

The following are the estimation results of the VECM (1) for the foreign exchange rates of Indonesia's largest trading partners which are presented in **Table 10** and **Table 11** where the variable is said to be significant if the t-statistics value is more than the t-table where in this study the t-table value is 1.977 with a significance level 0.05.

Table 10. VECM Estimation

Variable	Estimation					
	D (CNY,2)	D (EUR,2)	D (INR,2)	D (JPY,2)	D (KRW,2)	D (MYR,2)
D(CNY(-1),2)	-0.05873	0.324093	-0.00022	0.013477	-0.00025	-0.12334
	-0.15989	-1.59587	-0.0148	-0.0143	-0.00133	-0.24163
	[-0.36732]	[0.20308]	[-0.01512]	[0.94217]	[-0.18570]	[-0.51044]
D(EUR(-1),2)	-0.02137	-0.05979	-0.00192	-0.00091	-3.50E-05	-0.00972
	-0.01634	-0.16307	-0.00151	-0.00146	-0.00014	-0.02469
	[-1.30801]	[-0.36664]	[-1.26931]	[-0.62205]	[-0.25781]	[-0.39374]
D(INR(-1),2)	1.104767	22.74804	0.114562	-0.01611	0.012552	-0.95679
	-1.49958	-14.9675	-0.13877	-0.13416	-0.01247	-2.2662
	[0.73672]	[1.51983]	[0.82556]	[-0.12006]	[1.00651]	[-0.42220]
D(JPY(-1),2)	-0.76973	-9.60581	0.112086	-0.01114	-0.01352	-1.01262
	-1.40663	-14.0397	-0.13017	-0.12584	-0.0117	-2.12572
	[-0.54722]	[-0.68419]	[0.86110]	[-0.08850]	[-1.15557]	[-0.47636]
D(KRW(-1),2)	-26.558	-360.955	0.263752	-0.6692	-0.1581	-55.9147
	-20.6864	-206.474	-1.91428	-1.85069	-0.17203	-31.2618
	[-1.28384]	[-1.74819]	[0.13778]	[-0.36160]	[-0.91901]	[-1.78860]
D(MYR(-1),2)	-0.25511	-1.22308	0.000406	-0.00667	-0.0013	-0.36791
	-0.08775	-0.87587	-0.00812	-0.00785	-0.00073	-0.13261
	[-2.90714]	[-1.39642]	[0.05004]	[-0.84998]	[-1.78666]	[-2.77430]
D(PHP(-1),2)	0.519604	-5.36932	0.048543	0.031183	-0.00012	1.499216
	-0.85927	-8.57648	-0.07952	-0.07687	-0.00715	-1.29855
	[0.60470]	[-0.62605]	[0.61048]	[0.40564]	[-0.01662]	[1.15453]
D(SGD(-1),2)	0.093688	0.416559	0.000803	-4.45E-05	0.000141	0.120376
	-0.05794	-0.57832	-0.00536	-0.00518	-0.00048	-0.08756
	[1.61695]	[0.72029]	[0.14980]	[-0.00858]	[0.29176]	[1.37475]
D(THB(-1),2)	0.659053	5.346937	0.016087	0.000134	0.003646	-1.01695
	-0.52278	-5.21793	-0.04838	-0.04677	-0.00435	-0.79004

Variable	Estimation					
	D (CNY,2)	D (EUR,2)	D (INR,2)	D (JPY,2)	D (KRW,2)	D (MYR,2)
	[1.26067]	[1.02472]	[0.33253]	[0.00287]	[0.83873]	[-1.28722]
D(TWD(-1),2)	0.434435	9.952739	-0.07597	-0.01581	0.0082	1.250999
	-0.7346	-7.33209	-0.06798	-0.06572	-0.00611	-1.11014
	[0.59139]	[1.35742]	[-1.11749]	[-0.24062]	[1.34221]	[1.12689]
D(USD(-1),2)	-0.06082	-0.18124	-0.00207	0.002277	-6.34E-05	-0.00665
	-0.03517	-0.35107	-0.00325	-0.00315	-0.00029	-0.05316
	[-1.72907]	[-0.51624]	[-0.63593]	[0.72357]	[-0.21691]	[-0.12511]
D(VND(-1),2)	663.1634	-6519.92	10.79275	-95.7534	-7.55089	-478.803
	-571.78	-5707	-52.9114	-51.1536	-4.7551	-864.086
	[1.15982]	[-1.14244]	[0.20398]	[-1.87188]	[-1.58796]	[-0.55411]

Table 11. VECM Estimation

Variable	Estimation					
	D (PHP,2)	D (SGD,2)	D (THB,2)	D (TWD,2)	D (USD,2)	D (VND,2)
D(CNY(-1),2)	0.052817	0.120581	0.023055	0.051197	1.300397	0.000104
	-0.0226	-0.73319	-0.04099	-0.03822	-1.04081	-4.7×10^{-5}
	[2.33736]	[0.16446]	[0.56246]	[1.33966]	[1.24941]	[2.20278]
D(EUR(-1),2)	0.000275	-0.05042	-0.00408	-0.00022	-0.01112	1.62×10^{-6}
	-0.00231	-0.07492	-0.00419	-0.0039	-0.10635	-4.8×10^{-6}
	[0.11893]	[-0.67296]	[-0.97376]	[-0.05653]	[-0.10457]	[0.33651]
D(INR(-1),2)	-0.056	7.815022	0.133354	0.202984	4.057384	-0.00024
	-0.21193	-6.87647	-0.38443	-0.35842	-9.76158	-0.00044
	[-0.26424]	[1.13649]	[0.34689]	[0.56632]	[0.41565]	[-0.54767]
D(JPY(-1),2)	0.025569	-4.95816	-0.69415	-0.41837	5.811684	0.000219
	-0.1988	-6.45021	-0.3606	-0.33621	-9.15648	-0.00042
	[0.12862]	[-0.76868]	[-1.92496]	[-1.24437]	[0.63471]	[0.52771]
D(KRW(-1),2)	-4.55777	-134.191	-5.21348	-5.90741	-202.239	-0.00395
	-2.9236	-94.8595	-5.30316	-4.94439	-134.659	-0.00611
	[-1.55896]	[-1.41463]	[-0.98309]	[-1.19477]	[-1.50186]	[-0.64571]
D(MYR(-1),2)	-0.01318	-0.54941	-0.02213	-0.00844	0.100707	-3.3×10^{-5}
	-0.0124	-0.4024	-0.0225	-0.02097	-0.57123	-2.6×10^{-5}
	[-1.06281]	[-1.36535]	[-0.98364]	[-0.40247]	[0.17630]	[-1.26087]
D(PHP(-1),2)	0.222024	-0.59155	0.206693	0.064722	2.678888	0.0002
	-0.12144	-3.94026	-0.22028	-0.20538	-5.59345	-0.00025
	[1.82826]	[-0.15013]	[0.93831]	[0.31513]	[0.47893]	[0.78598]
D(SGD(-1),2)	-0.00522	0.270193	-0.00593	0.003126	0.353878	2.66E-06
	-0.00819	-0.26569	-0.01485	-0.01385	-0.37717	-1.70E-05
	[-0.63679]	[1.01693]	[-0.39945]	[0.22574]	[0.93825]	[0.15528]
D(THB(-1),2)	0.033695	1.71265	0.114079	-0.01744	-2.23421	2.2×10^{-5}
	-0.07388	-2.39726	-0.13402	-0.12495	-3.40306	-0.00015
	[0.45606]	[0.71442]	[0.85121]	[-0.13958]	[-0.65653]	[0.14474]
D(TWD(-1),2)	-0.13394	1.548307	0.202644	-0.03278	-4.72437	-0.00021
	-0.10382	-3.36856	-0.18832	-0.17558	-4.78188	-0.00022
	[-1.29015]	[0.45964]	[1.07606]	[-0.18670]	[-0.98797]	[-0.97849]
D(USD(-1),2)	0.002509	-0.19265	-0.00361	-0.00757	-0.36619	-9.19E-06
	-0.00497	-0.16129	-0.00902	-0.00841	-0.22896	-1×10^{-5}
	[0.50475]	[-1.19441]	[-0.40006]	[-0.90079]	[-1.59934]	[-0.88435]
D(VND(-1),2)	-131.104	-659.746	-132.039	9.566042	1882.45	0.002179
	-80.8093	-2621.95	-146.581	-136.665	-3722.02	-0.16893
	[-1.62239]	[-0.25162]	[-0.90079]	[0.07000]	[0.50576]	[0.01290]

3.9 Granger Causality Test

The Granger Causality Test is used to evaluate the causal influence of a variable on other variables in a time series. If the p-value is less than the significance level then there is a causality between variables. By using degrees of freedom of 11, which indicates the number of variables used in this research is reduced by 1, the results of the Granger causality test on foreign exchange rate data are presented in Table 12 as follows.

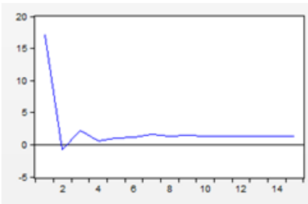
Table 12. Granger Causality Test

Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.
CNY	15.25448	0.1711	KRW	17.0858	0.1054	THB	19.52885	0.0522
EUR	13.55237	0.2588	MYR	10.45561	0.4899	TWD	6.693362	0.8233
INR	6.669073	0.8252	PHP	21.48157	0.0287	USD	9.069432	0.6155
JPY	7.525472	0.7551	SGD	8.953434	0.6262	VND	11.03593	0.4403

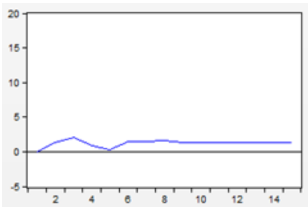
Based on Table 12, it can be seen that the Philippine Peso exchange rate has a causal relationship with 11 other exchange rates simultaneously, while the Chinese Yuan, South Korean Won, European Euro, Indian Rupee, Japanese Yen, Malaysian Ringgit, Singapore Dollar, Thai Baht, Dollar Taiwan, American Dollar, and Vietnamese Dong do not have a causal relationship with other exchange rates simultaneously. The Granger Causality Test helps identify the directional influence between exchange rates, refining the VECM model by highlighting significant variables that improve prediction accuracy [26].

3.10 Variance Decomposition and Impulse Response Function Analysis

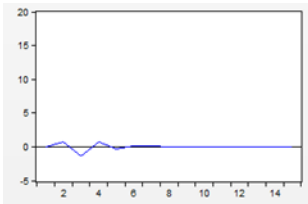
Impulse Response Function (IRF) is used to understand how much of a shock on one variable can influence other variables within a certain period. Variance Decomposition helps identify how much each variable in the system contributes to the variability of a particular variable [27]. Analysis will be carried out at each foreign exchange rate used. The Chinese Yuan exchange rate is chosen for IRF analysis because, according to Indonesia's Foreign Trade Statistics, China is Indonesia's largest trade partner. The IRF for the Chinese Yuan exchange rate is given in Figure 3 as follows.



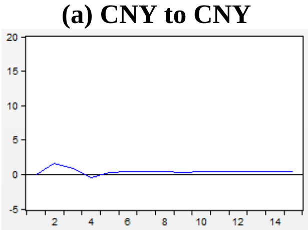
(a) CNY to CNY



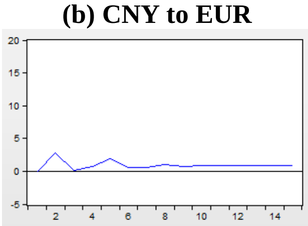
(b) CNY to EUR



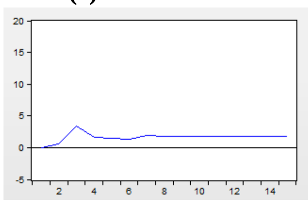
(c) CNY to INR



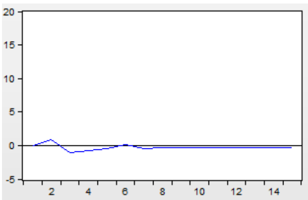
(d) CNY to JPY



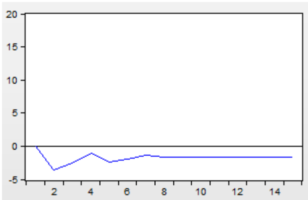
(e) CNY to KRW



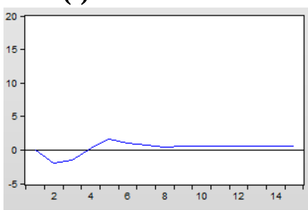
(f) CNY to MYR



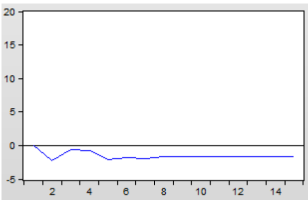
(g) CNY to PHP



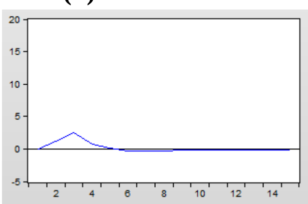
(h) CNY to SGD



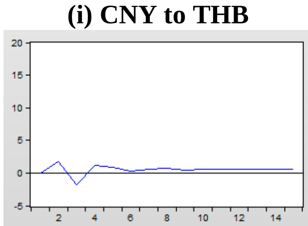
(i) CNY to THB



(j) CNY to TWD



(k) CNY to USD



(l) CNY to VND

Figure 3. Impulse Reaction on Chinese Yuan (CNY)

Based on Figure 3, the Chinese Yuan exchange rate responds negatively to changes in the value of the Taiwan Dollar and Singapore Dollar, for the response of the Chinese Yuan to the European Euro, South Korean Won, and Malaysian Ringgit tends to stagnate above the equilibrium point, while the response of the

Chinese Yuan to the Indian Rupee, The Japanese Yen, Philippine Peso, Thai Bath, United States Dollar, and Vietnamese Dong fluctuate at the beginning and then tend to reach an equilibrium point. The Chinese Yuan's response to itself decreased sharply and then stagnated above the equilibrium point. The value of Variance Decomposition on the Chinese Yuan values which presented in Table 13.

Table 13. Variance Decomposition on Chinese Yuan (CNY)

T	S.E.	D (CNY)	D (EUR)	D (INR)	D (JPY)	D (KRW)	D (MYR)	D (PHP)	D (SGD)	D (THB)	D (TWD)	D (USD)	D (VND)
1	17.04	100.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	18.19	87.89	0.577	0.149	0.790	2.344	0.104	0.256	3.956	1.121	1.501	0.431	0.879
3	19.34	79.03	1.600	0.641	0.926	2.078	3.110	0.508	5.332	1.617	1.422	2.136	1.597
4	19.60	77.10	1.786	0.790	0.967	2.174	3.748	0.672	5.462	1.602	1.541	2.233	1.929
5	20.12	73.39	1.722	0.782	0.941	3.006	4.042	0.676	6.606	2.143	2.562	2.121	2.014
6	20.46	71.29	2.173	0.757	0.956	2.981	4.315	0.657	7.255	2.352	3.214	2.078	1.974
7	20.85	69.28	2.572	0.731	0.974	2.964	5.024	0.669	7.425	2.374	3.978	2.029	1.980
8	21.19	67.40	3.026	0.708	0.996	3.094	5.534	0.666	7.749	2.339	4.494	1.979	2.013
9	21.52	65.78	3.320	0.686	0.992	3.128	6.055	0.660	8.148	2.342	4.962	1.924	2.004
10	21.84	64.24	3.593	0.667	0.998	3.187	6.527	0.653	8.493	2.346	5.402	1.877	2.020
11	22.16	62.74	3.864	0.647	1.009	3.255	6.958	0.654	8.834	2.363	5.828	1.831	2.017
12	22.48	61.35	4.133	0.629	1.018	3.306	7.367	0.650	9.137	2.376	6.230	1.789	2.019
13	22.79	60.02	4.381	0.612	1.026	3.353	7.752	0.646	9.420	2.388	6.627	1.748	2.021
14	23.10	58.77	4.622	0.596	1.034	3.402	8.116	0.643	9.691	2.397	6.991	1.710	2.025
15	23.41	57.59	4.846	0.581	1.041	3.446	8.467	0.639	9.949	2.404	7.338	1.673	2.027

Based on Table 13, in the short term specifically in the second period, the shock of the Chinese Yuan exchange rate against itself caused value the biggest fluctuation in the amount of 87.89%, for other exchange rates that caused significant shocks were the Singapore Dollar, South Korean Won, and The Taiwan dollar respectively caused shocks of 3.956%, 2.344%, and 1.501%.

3.11 Foreign Exchange Rate Prediction

The final analysis stage is to predict the exchange rates of Indonesia's largest trading partners using the VECM (1) for the next 15 periods. In this case, the researcher uses Mean Absolute Percentage Error (MAPE) to measure the precision of model prediction. The results of the predicted exchange rates for Indonesia's largest trading partners for the next 15 periods are presented in Table 14 as follows.

Table 14. MAPE Rate

Currency	MAPE	Currency	MAPE	Currency	MAPE	Currency	MAPE
CNY	1.65%	JPY	1.96%	PHP	1.90%	TWD	1.13%
EUR	1.76%	KRW	2.04%	SGD	0.84%	USD	2.60%
INR	2.43%	MYR	4.10%	THB	2.75%	VND	1.16%
Mean						**2.03%**	

MAPE categorization is for MAPE value criteria of less than 10% the forecasting ability is categorized as very good, for values of 10-20% the forecast is categorized as good, for values of 20-50% the forecast is categorized as feasible, and for values above 50% the forecast is categorized as poor [28]. Based on Table 14, the MAPE value is obtained for each exchange rate in the testing dataset individually it is less than 10% and for simultaneous predictions, the MAPE value is 2.03%. This value is less than 10% so the foreign exchange rate forecasting category using the VECM (1) can be categorized as very accurate.

4. CONCLUSIONS

Based on the data analysis results, the foreign exchange rates of Indonesia's largest trading partners have a cointegration relationship so that predictions of foreign exchange rates from Indonesia's largest trading partners can be made using the Vector Error Correction Model (VECM). It was found that the best model for modeling the foreign exchange rates of Indonesia's largest trading partners is VECM (1) which produces a MAPE value of 3.29% in predicting exchange rates so that predictions using the VECM can be categorized as very accurate. The IRF analysis on the Chinese Yuan as Indonesia's largest trading partner shows that it responds variably to different currencies, stabilizing over time. Variance Decomposition indicates that short-term fluctuations in the Chinese Yuan are mostly influenced by itself and significantly by the Singapore Dollar, South Korean Won, and Taiwan Dollar. The Granger Causality Test reveals that the Philippine Peso influences 11 other exchange rates, refining the VECM model and improving prediction accuracy. There are several recommendations or suggestions for stabilizing the value of the currency that can be taken into consideration by the government, such as increasing transparency and efficiency of the money market to reduce risks and increase investor confidence in investing in domestic companies, investing in the industrial sector in the form of infrastructure and capital to increase effectiveness. and production that can compete in international markets, exercising capital control so that there are no fluctuations that can affect the value of the currency, diversifying the economy so that it can reduce dependence on certain sectors so that the economy can withstand shocks that affect the value of the currency and building economic cooperation with countries. other things that can help create economic stability between countries in cooperation agreements.

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