

Structural Cointegration of Exchange Rate, Gross Domestic Product, and External Debt in Indonesia: An Analysis of Macroeconomic Stability with the ARDL–ECM Approach

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ABSTRACT

This study examines the relationship between Indonesia's external Debt (ULN), gross domestic product (GDP), and exchange rate (ER) using quarterly data from 2011Q1 to 2025Q2. The Autoregressive Distributed Lag (ARDL) method tests long-run cointegration, followed by an Error Correction Model (ECM) to capture short-run dynamics. The selected ARDL (1, 0, 2) model confirms a long-term relationship among external Debt, GDP, and the exchange rate. In the short run, the exchange rate has a significant impact, while GDP does not. The negative and considerable error correction term (ECT) indicates the presence of an adjustment mechanism toward equilibrium. Impulse response analysis reveals that external debt responds strongly to exchange rate shocks, and variance decomposition identifies exchange rate fluctuations as the primary contributor to debt variation. Policy recommendations include diversifying foreign debt portfolios, strengthening foreign exchange reserves, and enhancing fiscal-monetary coordination to mitigate exchange rate risks and improve long-term debt management.

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1. Introduction

External debt remains a critical instrument for financing development, particularly in emerging and developing economies. Access to foreign borrowing provides fiscal space that enables governments to stimulate economic growth, finance strategic infrastructure projects, and maintain macroeconomic stability during periods of constrained domestic revenue (Coulibaly et al. 2024; Wang, Xue, and Zheng 2021). Contemporary extensions of the intertemporal borrowing framework posit that external borrowing facilitates the smoothing of consumption and investment over time, under the assumption that future productivity gains will offset debt obligations through growth multipliers generated by the mobilisation of the productive sector (Fišera, Workie Tiruneh, and Hojdan 2021; Majumder, Raghavan, and Vespignani 2021).

Despite its benefits, external debt carries inherent risks, especially in the face of external shocks such as monetary crises that trigger exchange rate volatility. Heavy reliance on foreign borrowing often exposes countries to structural vulnerabilities. One of the most pressing risks involves currency denomination, as most external debt is issued in foreign currencies and thus remains highly sensitive to fluctuations in exchange rates. Data from Bank Indonesia (2024) indicate that approximately 86% of Indonesia's external debt is denominated in US dollars. When the rupiah depreciates, the nominal debt burden increases in domestic terms. This phenomenon is explained by the original sin concept, which emphasises the inability of developing countries to borrow internationally in their own currency, making them vulnerable to exchange rate shocks. Their currency, rendering them vulnerable to exchange rate shocks. Chowdhury et al. (2021) emphasize that currency volatility significantly heightens the risk of debt exposure, particularly in developing economies with fragile financial systems (Chowdhury, Uddin, and Islam 2021).

In the Indonesian context, the dynamics of external debt are influenced not only by global economic conditions but also by domestic macroeconomic indicators such as gross domestic product (GDP) and fiscal policies, which are reflected in the national budget (APBN). Edo and Oigiangbe (2024) emphasize that the dynamics of external liabilities are significantly influenced by the interaction between a country's productive capacity, often proxied by GDP, and fiscal pressures, which may drive governments to explore alternative financing channels (Edo and Oigiangbe 2024; Dewi Mahrani Rangkutty and Hidayat 2021). GDP reflects a country's economic capacity to bear debt obligations, while the exchange rate determines the efficiency of foreign currency debt servicing in local terms. In parallel, the national budget signals the level of fiscal need. When budget deficits widen, governments tend to resort to foreign debt markets. The primary way debt impacts growth is through the crowding-out of productive spending and increased macroeconomic adjustment costs. Due to the complex interdependence of these macroeconomic factors, analysing the determinants of Indonesia's external debt becomes highly relevant.

2. Literature Review

The presence of external debt in developing countries is primarily shaped by macroeconomic dynamics, particularly exchange rates and the underlying strength of domestic economies. Among these, the exchange rate consistently emerges as the most influential factor. Empirical findings indicate that currency depreciation directly increases the cost of foreign-denominated debt, thereby exacerbating fiscal vulnerability, especially in economies that heavily rely on external financing structures. This was confirmed in studies by Mitra and Mallick (2020), who emphasized the central role of exchange rates in debt sustainability. Further supporting this, Chowdhury et al. (2021) and Yousaf, Hassan, and Ali (2022) found that heightened exchange rate volatility significantly contributes to external debt instability, particularly in countries where a large proportion of loans are denominated in foreign currencies. Gross Domestic Product (GDP), while an indicator of economic capacity to manage debt, exerts a weaker and more indirect influence, especially in the short term. Although GDP contributes positively to debt changes, the relationship is statistically insignificant, indicating a limited short-term impact without productive investment (Dewi M Rangkuty and Hidayat 2021). Research by Akram and Rath (2020) and Ali, Yusop, and Hook (2020a) reveals that GDP growth alone is insufficient to curb debt dependency unless accompanied by strong fiscal discipline and institutional reforms.

The role of the national budget in shaping foreign debt structures has also been documented. According to Oliveira (2021), persistent fiscal deficits are a key driver of external borrowing, especially in nations with limited domestic financing options. However, within the framework of this study, budget variables were excluded from the ARDL model due to their integration order of $I(2)$, which violates model assumptions, as discussed by Sam, McNown, and Goh (2019). High government expenditure beyond the optimum threshold may adversely affect economic growth in the long run due to inefficiencies in resource allocation (Abdillah 2023). Abdillah (2023) finds that government size has a positive effect on economic growth in the short run but an adverse effect in the long run, with an optimal government expenditure threshold of 57.9% of national income, consistent with the Armey curve hypothesis (Abdillah 2023).

The combined interaction of exchange rates, GDP, and foreign debt reveals that exchange rates have the most substantial influence over both short- and long-term debt dynamics. Studies by Chowdhury et al. (2021), Mitra and Mallick (2020), and Yousaf, Hassan, et al. (2022) collectively confirm that exchange rate fluctuations amplify external debt burdens, particularly in economies heavily exposed to foreign currency liabilities. Additional evidence from Adedokun (2020), Badaoui, Dufrénot, and Couharde (2022), and Chudik et al. (2022) suggests that exchange rate shocks lead to immediate disruptions in debt patterns and fiscal balance. Conversely, GDP serves as a long-term structural foundation, but its impact on reducing debt reliance is contingent upon the strength of fiscal and institutional frameworks. Studies by Ajayi, Ogunleye, and Ezeoha (2021) and Akram and Rath (2020) consistently note that economic growth does not

automatically translate into reduced external borrowing unless it is embedded within sound macroeconomic governance.

3. Research Method

This study employs a quantitative approach, utilizing time series analysis, to investigate the relationship between external debt, gross domestic product (GDP), and the exchange rate in Indonesia. The methodological framework combines the Autoregressive Distributed Lag (ARDL) model with the Error Correction Model (ECM), which is suitable for datasets containing variables with different orders of integration, provided that none are integrated of order two ($I(2)$). The dataset comprises quarterly observations from the first quarter of 2011 (2011Q1) to the second quarter of 2025 (2025Q2), sourced from official repositories including Trading Economics (external debt), One Data of the Ministry of Home Affairs (GDP, exchange rate), and the Directorate General of Fiscal Balance, Ministry of Finance. The analysis begins with an Augmented Dickey–Fuller (ADF) unit root test to confirm that all variables are integrated at order zero ($I(0)$) or order one ($I(1)$). The State Budget variable, identified as $I(2)$, was excluded from the model to preserve the ARDL assumption. Subsequently, a Bounds Test, following (Chudik et al. 2021), was conducted to assess the existence of a long-run relationship among the variables. Cointegration is confirmed if the computed F-statistic exceeds the upper bound critical Value, indicating that the long-run equilibrium relationship is statistically significant.

In response to reviewer feedback, additional robustness checks were incorporated to enhance the study's reliability. These include (i) a Granger causality test to determine the direction of causal relationships, (ii) a variance decomposition and impulse response analysis to capture dynamic interactions, and (iii) an exchange rate volatility analysis using a GARCH-type model to deepen the understanding of exchange rate fluctuations. The ARDL Model degradation is carried out by first determining the optimal lag, and the optimal lag is determined using the Akaike Information Criterion (AIC) to produce efficient model specifications. The Autoregressive Distributed Lag (ARDL) model is an econometric approach used to examine the dynamic relationship between one dependent variable and one or more independent variables, both in the short and long term. The main advantage of this model lies in its flexibility in handling time-sequence data that have different levels of integration, as long as there are no variables integrated in order two ($I(2)$).

Additionally, the Autoregressive Distributed Lag (ARDL) model is suitable for use in small sample conditions and is capable of providing consistent estimates of long-term parameters (Haug 2002). In this study, the optimal model determined using the Akaike Information Criterion (AIC) is ARDL(1, 0, 2). This specification is considered stable and informative in explaining variations in the dependent variables. Within the ARDL framework, the analysis process begins with determining the optimal lag and conducting a cointegration test, followed by the formation of an Error Correction Model (ECM) derived from the ARDL structure. The ECM is used to capture short-term adjustment

dynamics while also reflecting the system's response to long-term imbalances. The error correction term (ECT) becomes a key indicator in this model. A negative and statistically significant ECT coefficient has important theoretical and empirical implications. A negative value indicates that when a deviation from equilibrium occurs, the system will gradually return to a stable equilibrium (Shaari et al. 2023). Empirical evidence from Hidhthiir et al. (2024) using a panel ARDL model for ASEAN economies shows that the ECT coefficient is negative and significant, meaning that a certain proportion of short-term deviations can be corrected in each period (Hidhthiir et al. 2024). This finding confirms the effectiveness of structural correction mechanisms in maintaining economic stability. Similar conclusions are presented by (Shaari et al. 2023), who state that the presence of a significant ECT supports the resilience of the economic system and its ability to adapt, as long as domestic fundamentals remain strong.

The estimated validity of the ECM model was strengthened through a series of diagnostic tests. The autocorrelation test was performed using the LM test to identify residual relationships over time. The heteroscedasticity test was performed using the Breusch–Pagan method to test the homogeneity of residual variance. The residual normality test is conducted using the Jarque-Bera test to verify that the error term is normally distributed. Structural stability tests, including the CUSUM and CUSUMSQ methods, were employed to verify the stability of the coefficients during the observation period. Table 1 explains the operational definitions of the main variables in this study, including indicators, units of measurement, and data sources used in the estimation and model analysis process.

Table 1. Operational Definition of Variables

Variable	Indicator	Operational Definition	Unit of Measurement
External Debt (ULN)	Total External Debt	The total amount of Indonesia's external debt in a given period.	Billion USD
Gross Domestic Product (GDP)	Quarterly GDP Value	The total Value added of goods and services produced within the country during a specific quarter.	Billion IDR
Exchange Rate	Rupiah to USD Exchange Rate	The Value of the Indonesian rupiah against the US dollar affects the cost of repaying foreign-denominated debt.	Rupiah per USD
State Budget (APBN)	Quarterly State Budget Value	The total amount of government revenue and expenditure in a given period reflects fiscal conditions that may influence external borrowing needs.	Billion IDR

Source of Data: Processed Quarterly Data (2011Q1–2025Q2) from Trading Economics (External Debt) and Satu Data Kemendag (GDP, Exchange Rate).

The selection of the four variables (Table 1) in this study is based on the theoretical framework and empirical findings that have been widely used in the study of external debt dynamics in developing countries. Foreign debt as a dependent variable is studied in relation to economic capacity (GDP), external pressures through exchange rates, and fiscal financing needs reflected in the State Budget. Studies by (Dube, Tchana Tchana, and Ncube 2022) show that these three factors are the main determinants in shaping the

dynamics of debt accumulation. The selection of variables in this study, within the framework of the ARDL–ECM model, seeks to capture both the short-term and long-term relationships between macroeconomic variables. The research design employed (methods, types of data, data sources, and data collection techniques).

4. Results and Discussion

Contains Stationarity Test of Macroeconomic Variables

Table 2 presents the results of the Augmented Dickey-Fuller (ADF) tests for each macroeconomic variable in both level and transformed forms. The ADF statistic for each variable is compared against the critical values at the 1% and 5% significance levels to determine whether the series is stationary.

Table 2. ADF Stationarity Test Results for Macroeconomic Variables

Variable	ADF Statistic	p- value	Critical Value (1%)	Critical Value (5%)	Stationary
ULN	-2.1984	0.2068	-3.5507	-2.9138	Not Stationary
GDP	0.3924	0.9812	-3.5656	-2.9201	Not Stationary
Exchange Rate	-1.0342	0.7406	-3.5529	-2.9147	Not Stationary
APBN	-2.0593	0.2612	-3.5746	-2.9240	Not Stationary
ULN (1st Diff)	-8.0400	0.0000	-3.5529	-2.9147	Stationary
GDP (1st Diff)	-3.3473	0.0129	-3.5656	-2.9201	Stationary
Exchange Rate (Diff)	-10.0995	0.0000	-3.5529	-2.9147	Stationary
APBN (1st Diff)	-0.4878	0.8944	-3.5848	-2.9283	Not Stationary
log(APBN)	-1.9863	0.2926	-3.5746	-2.9240	Not Stationary
log(APBN) (Diff)	-0.1104	0.9484	-3.5848	-2.9283	Not Stationary

Source of Data: Processed Quarterly Data (2011Q1–2025Q2)

The results indicate that at their level forms, none of the variables are stationary, as all ADF statistics are greater (less negative) than their respective critical values. After applying the first difference, three variables; ULN, GDP, and exchange rate, become stationary, as their ADF statistics fall below the 5% critical value. These three variables are therefore classified as I(1) and meet the key requirement for inclusion in the ARDL model (Coulibaly and Goueu, 2019; Im, Pesaran, and Shin, 2003; Pesaran, Shin, and Smith, 2001).

The APBN variable, however, remains non-stationary even after the first differencing and log transformation, with ADF test results consistently failing to reject the null hypothesis of a unit root. The test statistic for APBN (1st Diff) is -0.4878, with a p-value of 0.8944, which is far above the required threshold for significance. This behaviour implies a potential I(2) process and raises serious concerns regarding its suitability within the ARDL bounds testing framework. Sam et al. (2019) caution against incorporating I(2) variables, noting that their inclusion leads to the breakdown of the bounds testing procedure (Sam et al. 2019). A similar warning is echoed by Tursoy (2019), who emphasizes the necessity of proper unit root testing before model estimation. Considering these results, the APBN variable is excluded from further analysis using the ARDL method. The exclusion is grounded in theoretical justification and consistent with standard econometric practice, as supported by (Chien 2022), who

highlight that ARDL estimations lose validity when second-order integrated variables are included. Consequently, the focus of the ARDL modelling is placed exclusively on variables that exhibit I(1) integration: ULN, GDP, and the exchange rate. This approach ensures that the bounds testing procedure is methodologically sound and the long-run relationship estimations are robust and valid.

Long-Run ARDL Model

The Autoregressive Distributed Lag (ARDL) model is employed to evaluate the long-run effects of macroeconomic variables on external Debt (ULN). In this specification, ULN is treated as the dependent variable, while Gross Domestic Product (GDP), the Exchange Rate (ER), and the State Budget (APBN) are included as independent variables.

This model accommodates time series data with mixed orders of integration, specifically I(0) and I(1), but not I(2), and enables the simultaneous estimation of both short-run dynamics and long-run relationships. Mathematically, the ARDL model is formulated as follows:

$$ULN_t = \alpha_0 + \sum_{i=1}^p \alpha_1^i ULN_{t-i} + \sum_{j=0}^{p1} \beta_1^j GDP_{t-j} + \sum_{k=0}^{q2} \beta_2^k ER_{t-k} + \varepsilon_t \dots \dots \dots (1)$$

Where:

- ULN_t : external debt at time t
- GDP_{t-j} : lagged values of gross domestic product
- ER_{t-k} : lagged values of the exchange rate
- ε_t : the error term

A country's external debt management policy cannot be separated from the dynamics of key macroeconomic variables that influence it. One critical aspect of this dynamic is the persistence effect of external debt itself. Studies by I. A. Mensah and Azman-Saini (2019) and J. T. Mensah et al. (2020) reveal that past levels of debt significantly contribute to current debt positions, suggesting a long-term accumulation pattern or inertia that warrants attention in the formulation of fiscal and external sector policies (Mensah, Adu, and Donkor 2020; Mensah and Azman-Saini 2019). On the other hand, the national economic capacity, reflected in Gross Domestic Product (GDP), serves as a fundamental indicator of the demand for external financing. Empirical findings from Ali et al. (2020) confirm that growth in domestic output has the potential to reduce reliance on external borrowing, particularly in developing countries (Ali, Yusop, and Hook 2020b).

Exchange rate fluctuations represent a highly sensitive external determinant, especially in the context of foreign-denominated debt. Mitra et al. (2018) emphasize that currency depreciation not only increases the domestic currency value of external debt servicing but also heightens overall fiscal risk (Mitra, Kaminsky, and Reinhart 2018). This issue is especially pertinent in open economies that are highly exposed to external shocks. Equally important is the role of the national budget (APBN), which is reflected in the broader financing mechanism. Fiscal imbalances, indicated by budget deficits, are often addressed through increased reliance on external borrowing. Oliveira (2021) finds that

larger fiscal deficits are significantly and positively correlated with the growth of external debt, particularly in countries with limited access to domestic financing sources (Oliveira 2021).

Table 3. ADF Test Results

Variable	ADF Statistic	p-value	Test Level	Order of Integration
ULN	-2.198	0.207	Level	Non-stationary
GDP	0.392	0.981	Level	Non-stationary
Exchange Rate	-1.034	0.741	Level	Non-stationary
State Budget	-2.059	0.261	Level	Non-stationary
ULN	-8.040	0.000	First Difference	I(1)
GDP	-3.347	0.013	First Difference	I(1)
Exchange Rate	-10.100	0.000	First Difference	I(1)
State Budget	-5.101	0.000	Second Difference	I(2)

Source of Data: Processed Quarterly Data From 2011Q1 To 2025Q2

Based on the stationarity test results presented in Table 3, the variables External Debt (ULN), Gross Domestic Product (GDP), and Exchange Rate (ER) are non-stationary at the level but become stationary after first differencing, indicating they are integrated of order one, I(1). In contrast, the State Budget (APBN) variable only becomes stationary after a second differencing, indicating it is integrated of order two, I(2). This information has significant methodological implications for selecting an appropriate quantitative analysis approach. Econometric principles assert that the Autoregressive Distributed Lag (ARDL) model is only valid when all variables in the system are integrated at most at I(1), and must not include any I(2) variables. The presence of an I(2) variable within an ARDL model renders the estimation results invalid, as it compromises the asymptotic distribution properties of the test statistics employed—particularly in cointegration analysis based on the Bounds Testing approach. This is consistent with the argument put forward by (Nkoro and Uko 2016), who contend that a mixed order of integration involving I(1) and I(2) variables violates the core assumptions of the ARDL framework. In the context of analyzing the relationship between macroeconomic variables and external debt, the ARDL model is considered appropriate, as it effectively captures both short-run dynamics and long-run equilibrium relationships simultaneously. The ARDL approach also offers flexibility in handling time series variables with differing orders of integration, provided none exceeds I(1). A study by Menyah et al. (2020) supports the use of ARDL in examining fiscal and external determinants of economic growth. It emphasizes the importance of excluding I(2) variables to maintain the validity of the model's results (K Menyah, Obeng, and Antwi, 2020).

Theoretically, government expenditure, as captured by the APBN, plays a crucial role in shaping a country's external debt position. When public spending exceeds fiscal revenues, budget deficits are frequently financed through external borrowing. This concept is grounded in the fiscal sustainability theory, which posits that persistent fiscal imbalances can lead to a need for external financing. However, in the context of this study, despite the theoretical relevance of APBN in influencing external debt, the variable cannot be technically included in the ARDL model due to its I(2) integration order.

Therefore, only ULN, GDP, and Exchange Rate meet the methodological requirements for inclusion in the ARDL estimation. Empirical support for the relationship between fiscal spending and external debt is provided by (Umar, Li, and Saba 2019), who demonstrate that surges in government expenditure without corresponding increases in public revenue lead to a greater reliance on external debt financing, particularly in developing countries with limited access to domestic capital markets.

Table 4 – Optimal Lag Selection for ARDL Model Based on AIC

ARDL Model	AIC	Remark
ARDL(1, 0, 0)	-3.751	
ARDL(1, 0, 1)	-3.883	
ARDL(1, 0, 2)	-4.215	Best model (lowest AIC)
ARDL(1, 0, 3)	-4.112	
ARDL(1, 0, 4)	-3.985	
ARDL(2, 1, 2)	-4.003	

Source of Data: Processed quarterly data (2011Q1–2025Q2)

Optimal lag selection in the ARDL model is a crucial step in constructing a well-specified model that accurately captures the dynamic relationships among macroeconomic variables. In this study, lag selection was carried out using the Akaike Information Criterion (AIC), which is generally considered more accommodating of model complexity and performs well with small to medium-sized samples. Table 3 presents the AIC values for various ARDL model specifications with different lag combinations. Based on the estimation results, the ARDL(1, 0, 2) model is found to have the lowest AIC value, at -4.215, and is thus selected as the optimal model. This specification applies one lag to the dependent variable (external debt, ULN), two lags to the exchange rate variable, and no lags to GDP. This suggests that changes have a strong influence on the dynamics of external debt in the exchange rate over the two previous periods, while the impact of GDP on external debt appears to be contemporaneous. The selection of the ARDL(1, 0, 2) model implies that the lagged response in the external debt system occurs more prominently through the exchange rate channel than through the economic growth channel (GDP). This finding aligns with international finance theory, which posits that a depreciation of the exchange rate can immediately increase the repayment burden of foreign-denominated debt. Studies by (Kwabena Menyah, Narayan, and Smyth 2020; Umar et al. 2019) also emphasize the critical role of exchange rate movements in shaping the dynamics of external debt in developing economies.

ARDL Model Estimation and Diagnostic Results

The results of the ARDL(1, 0, 2) estimation are presented in Table 5. This model uses external debt as the dependent variable and includes gross domestic product (GDP) and the exchange rate (ER) as independent variables. The lag structure was selected based on the Akaike Information Criterion (AIC), ensuring the model's parsimony and fit. The estimation reveals the magnitude and significance of both contemporaneous and lagged effects of the explanatory variables on external debt. In addition, diagnostic tests including the R-squared, F-statistic, Durbin-Watson, AIC, and BIC, are reported to

evaluate the model's statistical adequacy and residual properties. These indicators confirm the robustness and reliability of the selected ARDL specification.

Table 5. ARDL(1, 0, 2) Estimation Results and Model Diagnostics

Dependent Variable: External Debt (ULN)

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	7.293	4.572	1.595	0.117
ULN(-1)	0.895	0.035	25.205	0.000
GDP	3.953e-06	4.930e-06	0.801	0.427
Exchange Rate	-0.0064	0.001	-5.759	0.000
Exchange Rate(-1)	0.0078	0.001	6.461	0.000
Exchange Rate(-2)	0.0003	0.001	0.269	0.789
Model Diagnostics				
R-squared	0.995			
Adjusted R-squared	0.994			
F-statistic	1871.0			0.000
Durbin-Watson stat	1.732			
Akaike Information Criterion (AIC)	343.1			
Bayesian Information Criterion (BIC)	355.2			

Source of Data: Processed Quarterly Data (2011Q1–2025Q2)

The ARDL(1, 0, 2) model in Table 5 was selected as the optimal specification based on the lowest Akaike Information Criterion (AIC) value. This model estimates the short-run relationship between external Debt (ULN), gross domestic product (GDP), and the exchange rate (ER), applying one lag to the dependent variable (ULN), no lag to GDP, and two lags to the exchange rate.

The coefficient of ULN(-1) is 0.895 and is statistically significant at the 1% level ($p < 0.01$), indicating strong inertia or persistence in external debt accumulation. In other words, the level of external debt from the previous period has a substantial influence on the current debt position. This pattern reflects the contractual nature of external debt, which is typically medium- to long-term in structure. Jebran et al. (2019) found similar dynamics in the context of developing countries (Jebran, Iqbal, and Ullah 2019). The coefficient of GDP is positive but statistically insignificant ($p = 0.427$), indicating that short-term economic growth has not yet had a significant impact on external debt formation. This result implies that government spending remains highly dependent on external sources and that the domestic production capacity is insufficient to reduce reliance on foreign borrowing. Ajayi et al. (2021) argue that in many developing countries, increases in GDP do not automatically improve fiscal structures unless accompanied by institutional reforms (Ajayi et al. 2021).

The exchange rate variable shows significant effects across the first two periods (Ajayi et al. 2021). The current exchange rate has a negative and significant coefficient (-0.0064 , $p < 0.01$), indicating that domestic currency depreciation is associated with a reduction in current external debt. Conversely, the exchange rate lagged by one period (lag-1) has a positive and significant coefficient (0.0078 , $p < 0.01$), implying that previous depreciation increases the current level of external debt. This effect reflects the cost pressure of debt service payments denominated in foreign currency. Mitra and Mallick

(2020) highlight the exchange rate as one of the most sensitive determinants of debt positions in economies with high exposure to external financing (Mitra and Mallick 2020). The second lag of the exchange rate is not significant ($p = 0.789$), suggesting that the exchange rate effect is short-lived and dissipates quickly. Adedokun (2020) explains that exchange rate shocks tend to influence fiscal positions primarily within the first one or two quarters following the change (Adedokun, 2020).

Model ARDL(1, 0, 2) Diagnostics

The ARDL(1, 0, 2) model in Table 5 demonstrates excellent statistical performance. The R-squared Value is 0.995, and the Adjusted R-squared is 0.994, indicating that nearly all variations in external debt are explained by the model. The F-statistic of 1871.0 with a p-value of 0.000 confirms that the overall model is statistically significant and appropriate for further analysis. The Durbin-Watson statistic is 1.732, which is close to the ideal Value of 2, suggesting no serious autocorrelation in the residuals. The absence of autocorrelation is essential in time series regression, as its presence can lead to inefficient and biased coefficient estimates (Abubakar, Bala, and Usman 2020; Gujarati and Porter 2020). The model's AIC and BIC values are 343.1 and 355.2, respectively, indicating that the model is not only highly predictive but also structurally efficient. The AIC evaluates model adequacy by balancing prediction accuracy against the number of parameters, while the BIC applies a more conservative penalty for model complexity. Both criteria support the ARDL(1, 0, 2) specification as the optimal choice. Theoretical support for using both AIC and BIC in ARDL model selection is also emphasized by (Nguyen, Su, and Tran 2019).

Bounds Test for Cointegration

Table 6 presents the results of the bounds test for cointegration, which determines whether a long-run relationship exists among the variables in the ARDL(1, 0, 2) specification.

Table 6 – Bounds Test for Cointegration (ARDL(1, 0, 2))

Dependent Variable	Independent Variables	ARDL Model	F-Statistic	I(0) Bound (5%)	I(1) Bound (5%)	Decision
External Debt (ULN)	GDP, Exchange Rate	ARDL(1, 0, 2)	14.566	3.79	4.85	Cointegration exists

Source of Data: Processed Quarterly Data (2011Q1–2025Q2)

Table 6, which employs the Bounds Test for Cointegration (ARDL(1, 0, 2)) model, confirms the existence of a long-term relationship between external Debt (ULN), gross domestic product (GDP), and the exchange rate. The results of the bounds test show an F-statistic of 14.566, which significantly exceeds the upper critical bound (I(1) bound = 4.85) at the 5% significance level. This provides strong evidence of cointegration among the three variables, suggesting that, although individually non-stationary, their long-term movements are fundamentally linked.

The presence of cointegration in the ARDL model underpins the basis for constructing an Error Correction Model (ECM). The ECM aims to explain how the system adjusts when deviations from the long-run equilibrium occur. Within this framework, short-term changes in external debt are influenced by the current and past dynamics of GDP and the exchange rate, as well as by the error correction term (ECT), which indicates deviations from the established long-term relationship. This component measures the speed at which the system returns to equilibrium, enabling the ECM to describe both short-term fluctuations and the mechanism for restoring long-term equilibrium. The use of the ECM in this study is especially relevant, given that external debt typically accumulates over the long run but remains sensitive to short-term macroeconomic fluctuations. Mohaddes and Raissi (2020), along with Raza et al. (2020), highlight that the ECM is a practical approach for analyzing open economic systems, as it distinguishes between transient responses and lasting structural adjustments (Mohaddes and Raissi 2020; Raza, Shah, and Tiwari 2020).

Estimation Results of the Error Correction Model (ECM)

The ARDL(1, 0, 2) model for external debt can be reparameterized into an ECM to distinguish between short-run dynamics and long-run equilibrium adjustment. The general ECM specification derived from the ARDL(1, 0, 2) model is expressed as follows:

$$\Delta ULN_t = \alpha^0 + \sum_{i=1}^l \gamma_i ULN_{t-1} + \gamma_2 \Delta GDP_t + \gamma_3 \Delta ER_t + \lambda ECT_{t-1} + \varepsilon_t \dots \dots \dots (2)$$

Where:

Δ denotes the first difference operator.

ECT_{t-1} : the error correction term lagged one period, derived from the long-run cointegration equation.

λ : the adjustment coefficient, which measures the speed at which the system corrects deviations from the long-run equilibrium.

γ_i : short-run dynamic coefficients.

This ECM structure enables the model to capture how external debt responds to short-term changes in GDP and exchange rate, while also incorporating the long-run equilibrium relationship through the ECT_{t-1} component. A statistically significant and negative λ coefficient confirms the presence of a stable long-run relationship and indicates the rate at which disequilibrium is corrected over time.

Table 7 presents the estimation results of the Error Correction Model (ECM), which captures the short-run dynamics between external Debt, GDP, and the exchange rate while incorporating the long-run equilibrium adjustment through the error correction term (ECT).

Table 7. Estimation Results of the Error Correction Model (ECM)

Dependent Variable: ΔULN (Change in External Debt)

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	4.463	0.920	4.850	0.000
ΔGDP	8.93e-06	1.31e-05	0.679	0.500
Δ Exchange Rate	-0.0068	0.0011	-6.242	0.000
Δ Exchange Rate(-1)	0.0003	0.0017	0.179	0.859
Δ Exchange Rate(-2)	0.0005	0.0012	0.438	0.663
$ECT(-1)$	-0.0984	0.0400	-2.466	0.017

Model Diagnostics		
R-squared	0.529	p = 0.000
Adjusted R-squared	0.481	
F-statistic	11.02	
Akaike Information Criterion (AIC)	342.7	
Bayesian Information Criterion (BIC)	354.8	
Durbin-Watson statistic	1.607	

Source of Data: Processed From Quarterly Data Spanning 2011Q1 To 2025Q2.

ECM Assumption Test

To validate the reliability of the ECM estimation, a series of diagnostic tests is conducted to ensure the model satisfies classical regression assumptions. These include tests for serial correlation, heteroskedasticity, normality of residuals, and parameter stability.

Autocorrelation Test (Breusch–Godfrey Method) for the ECM Model

Table 8 presents the results of the Breusch–Godfrey LM test, performed to detect the presence of serial correlation in the residuals of the ECM model, particularly at lag order 2, by the assumption of no autocorrelation in time series regression.

Table 8. LM Test for Autocorrelation (Breusch-Godfrey)

Statistic	Value
LM Test Statistic	2.019
LM Test p-Value	0.364
F-Statistic	0.895
F p-Value	0.415

Source of Data: Processed from quarterly data from 2011Q1 to 2025Q2.

The selection of the second lag in the Breusch-Godfrey autocorrelation test is based on the lag structure of the ARDL(1, 0, 2) model (in Table 8), which includes the exchange rate variable up to two previous periods. Conducting the test up to the appropriate lag length is essential to ensure that the residuals of the ECM do not exhibit serial correlation, which would render the coefficient estimates inefficient (Gujarati and Porter 2021).

The test results indicate that the LM test statistic is 2.019 ($p = 0.364$), and the corresponding F-statistic is 0.895 ($p = 0.415$). Both values are statistically insignificant at the 5% level. Therefore, there is no evidence of autocorrelation in the ECM residuals up to the second lag. The absence of autocorrelation suggests that the model satisfies one of the key classical assumptions, error independence, which supports the inferential validity of the estimated results (Baltagi 2021).

Heteroskedasticity Test (Breusch–Pagan)

Table 9 presents the results of the Breusch–Pagan test, which is conducted to examine whether the residuals from the ECM exhibit constant variance, as required under the classical linear regression assumptions.

Table 9. Breusch–Pagan Test for Heteroskedasticity

Statistic	Value
Lagrange Multiplier (LM) Stat.	1.497
LM p-Value	0.913
F-Statistic	0.274
F p-Value	0.925

Source of Data: Processed from quarterly data from 2011Q1 to 2025Q2.

To assess the constancy of residual variance in the ECM model (Table 9), the Breusch-Pagan test was applied. This test is crucial in time series regression, as heteroskedasticity can distort standard errors and lead to inefficient and biased inference (Gujarati and Porter, 2021; Wooldridge, 2016). As shown in Table 8, the LM statistic (1.497, $p = 0.913$) and F-statistic (0.274, $p = 0.925$) are both insignificant at the 5% level. These results provide no evidence against the null hypothesis of homoskedasticity. This finding confirms that the model satisfies the classical regression assumption of constant error variance, which is crucial for valid inference, particularly in dynamic models such as ARDL-ECM (Baltagi, 2021; Pesaran and Shin, 1999).

Jarque-Bera Normality Test

Table 10 presents the results of the Jarque-Bera test, which evaluates whether the residuals of the ECM follow a normal distribution—a key assumption for valid statistical inference in time series regression.

Table 10. Jarque–Bera Normality Test

Statistic	Value
Jarque–Bera Statistic	1.153
p-Value	0.562

Source of Data: Processed from quarterly data from 2011Q1 to 2025Q2.

The Jarque–Bera test (presented in Table 10) was conducted to determine whether the residuals from the ECM model are normally distributed. This diagnostic is critical, as the normality of residuals is a key classical regression assumption, ensuring valid statistical inference and reliable forecasting (Baltagi, 2021; Gujarati & Porter, 2021). The test yielded a Jarque–Bera statistic of 1.153 with a p -value of 0.562, which exceeds the 5% significance level. Therefore, there is no evidence to reject the null hypothesis of normality. This result supports the robustness of the ECM model, confirming that the residuals satisfy the normality assumption required in linear regression frameworks.

Stability Test (CUSUM and CUSUMSQ)

Ensuring parameter consistency in the selected Error Correction Model (ECM) throughout the estimation period involved applying the CUSUM and CUSUM of Squares (CUSUMSQ) stability tests. These procedures aim to identify potential structural shifts in the model, focusing on both regression coefficients and residual variance. The accompanying figure illustrates the results of these stability tests in visual form.

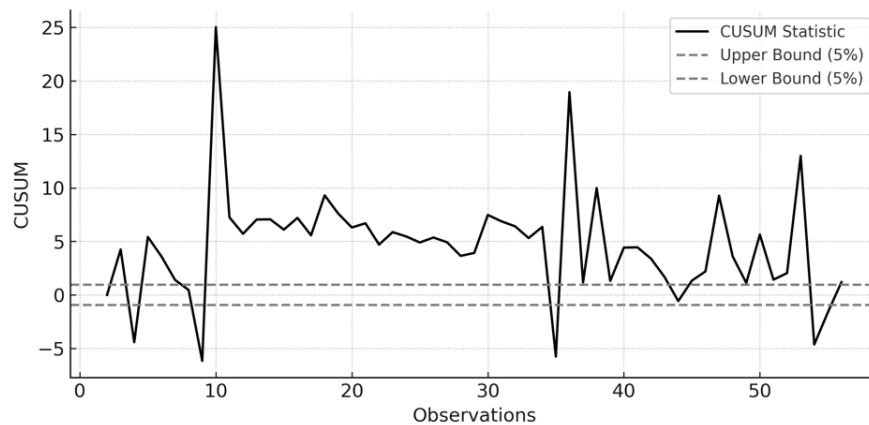


Figure 1. CUSUM Stability Test Error Correction Model (ECM)

Source of Data: Processed From Quarterly Time-Series Data (2011Q1–2025Q2).

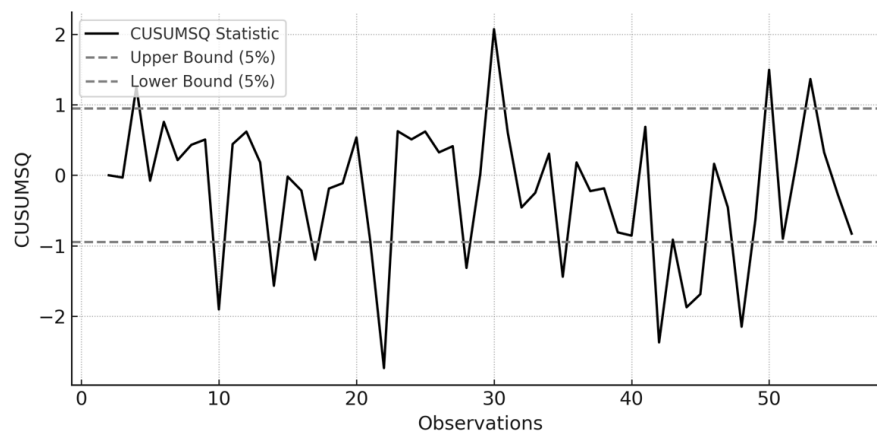


Figure 2. CUSUMSQ Stability Test Error Correction Model (ECM)

Source of Data: Processed From Quarterly Time-Series Data (2011Q1–2025Q2).

Parameter stability serves as a critical condition in time series regression, as uncontrolled fluctuations can undermine the reliability of estimation outcomes. The selected Error Correction Model (ECM) must demonstrate residual stability in the face of external shocks. Ensuring model stability confirms that short-term dynamics and adjustments toward long-run disequilibrium proceed consistently. This aligns with the findings by (Awunyo-Vitor and H. Alhassan 2020), who emphasized that the validity of ECMs in macroeconomic studies heavily depends on the stability of residuals and parameters over time. Additional evidence from Rahman & Islam (2021) supports the notion that structurally stable ARDL and ECM models yield more accurate insights when analyzing fiscal and external adjustment mechanisms.

Model stability testing in the present analysis applies the CUSUM and CUSUMSQ approaches, designed to evaluate the consistency of parameter estimates within the ECM framework during the observation period (2011Q1–2025Q2). The CUSUM method reveals that the cumulative sum of residuals remains entirely within the 5% confidence bounds, indicating the absence of structural breaks or significant parameter changes in the estimated model. Similarly, the CUSUMSQ results confirm residual variance stability, as the dispersion consistently stays within the control limits throughout the estimation

period (2011Q1–2025Q2). Given the absence of instability in the ECM developed in this analysis, the model is deemed suitable for capturing short-run dynamics and the adjustment process toward long-run equilibrium among external Debt, GDP, and exchange rate variables.

Economic Interpretation of ECM Estimation Results

Economic interpretation of the established Error Correction Model (ECM) relies on the results presented in Table 7. Before interpretation, a series of diagnostic tests was conducted to evaluate model validity and ensure the reliability of the estimated coefficients for macroeconomic analysis. An R-squared value of 0.529 indicates that approximately 53% of the variation in external debt can be explained by changes in gross domestic product (GDP) and the exchange rate. A minimal gap between the R-squared and adjusted R-squared Values of 0.481 suggests that the model avoids overfitting while maintaining the relevance of the included explanatory variables.

An F-statistic of 11.02 with a significance level of 0.000 confirms that the explanatory variables jointly exert a statistically significant impact on variations in external debt. This outcome is consistent with established econometric standards for evaluating overall model significance (Jammazi, Aloui, and Nguyen 2022; Wooldridge 2020). An Akaike Information Criterion (AIC) of 342.7 and a Bayesian Information Criterion (BIC) of 354.8 reflect a sound balance between model complexity and estimation precision. These criteria are commonly used to guide model selection by penalizing unnecessary complexity (Burnham & Anderson, 2004; Tang, 2023).

A Durbin-Watson statistic of 1.607 falls within an indeterminate zone, suggesting the presence of mild positive autocorrelation. Nonetheless, results from the Breusch-Godfrey LM Test for Autocorrelation, as shown in Table 8, support the absence of significant serial correlation in the residuals. The model remains valid for both explanatory and forecasting purposes, even in the presence of slight autocorrelation concerns, as discussed in the literature (Aslam, Mohti, and Ferreira 2022; Baltagi 2021).

A positive and statistically significant constant term indicates an underlying structural trend of increasing external debt, independent of short-term fluctuations in macroeconomic indicators. This condition aligns with the structural financing needs of many developing economies that rely on external borrowing as a sustainable fiscal strategy (Aizenman, Jinjark, and Park 2020). The estimated coefficient for Δ GDP appears positive but statistically insignificant. This result suggests that short-term fluctuations in domestic output do not have a direct impact on external debt behaviour. Findings from Akram and Rath (2020) reinforce this pattern, suggesting that the relationship between economic growth and external financing is indirect, mainly driven by long-term structural factors (Akram and Rath 2020).

A negative and statistically significant coefficient for Δ the Exchange Rate indicates that depreciation in the exchange rate is associated with a reduction in external debt accumulation. This relationship reflects fiscal policy's sensitivity to rising foreign currency debt burdens resulting from exchange rate fluctuations. The result supports the exchange rate risk theory in external debt management. This finding is consistent with

empirical evidence from (Chudik et al. 2021), which highlights the direct impact of currency volatility on external financing costs. Evidence from the Indonesian economy during periods of global financial turbulence indicates that exchange rate depreciation can swiftly exacerbate external debt pressures, underscoring the importance of timely fiscal and monetary responses to mitigate the adverse effects of currency volatility on debt sustainability (Zuhroh and Harpiyansa 2022), the study finds that internal factors such as domestic investment and government expenditure, alongside external factors like exchange rate fluctuations and global economic trends, significantly influence Indonesia's economic growth. Insignificant coefficients for lagged values of the exchange rate confirm that the exchange rate effect is immediate and does not persist over subsequent periods. This pattern aligns with rational expectations theory and the notion of an immediate market response to external shocks, as emphasized by (Badaoui et al. 2022).

A negative and statistically significant coefficient of -0.0984 for the error correction term (ECT(-1)) confirms the presence of a long-run equilibrium relationship among external Debt, GDP, and the exchange rate. This Value implies that approximately 9.84 per cent of the deviation from the long-run equilibrium is corrected within one quarter. The adjustment process reflects the nature of open economies, where fiscal and monetary policies function as stabilization mechanisms in response to external shocks. These findings align with those of Awunyo-Vitor and A. Alhassan (2020), who emphasize the importance of residual stability in validating ECMs within the macroeconomic context of developing countries (Awunyo-Vitor and A. Alhassan 2020).

Analyzed Impulse Response Function (IRF)

Dynamic relationships among variables are analyzed using the Impulse Response Function (IRF) approach to observe how external debt (ED) reacts to unexpected shocks from key macroeconomic indicators. The following figure illustrates the response of external debt to shocks in gross domestic product (GDP) and the exchange rate, highlighting the impact of domestic economic capacity and external pressures on foreign debt behaviour.

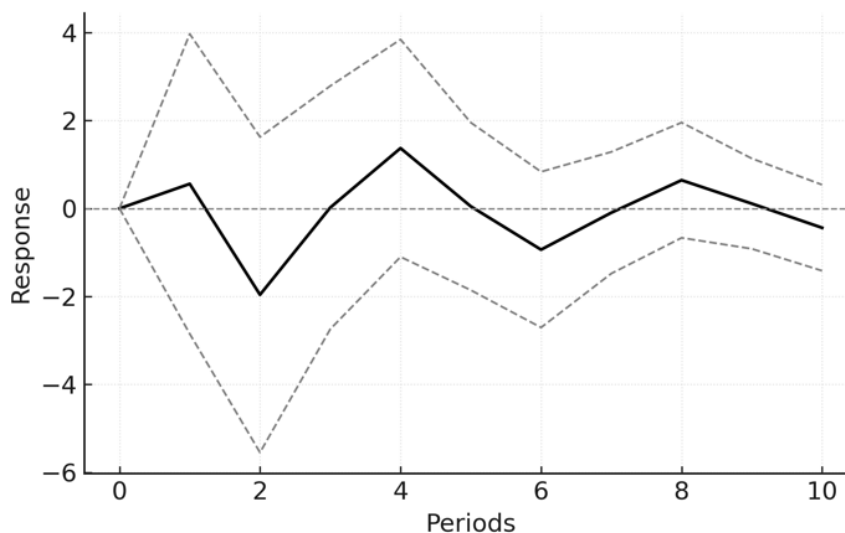


Figure 3. Impulse Response Function- Response of External Debt (ULN) to GDP Shock

Figure 3 displays the dynamic response of external debt to a one-standard-deviation shock in gross domestic product (GDP). The impulse response function captures the pattern of minor fluctuations in the independent variable and the resulting reactions observed in the dependent variable across a ten-period horizon. No significant spike in external debt is evident following sudden changes in GDP, as shown in Figure 3. This behaviour suggests that short-term increases or decreases in domestic economic activity do not immediately influence decisions related to altering external debt levels. Such a pattern aligns with the findings of (Akram and Rath 2020), whose cross-country study on developing economies concluded that the relationship between economic growth and external financing tends to be long-term and indirect.

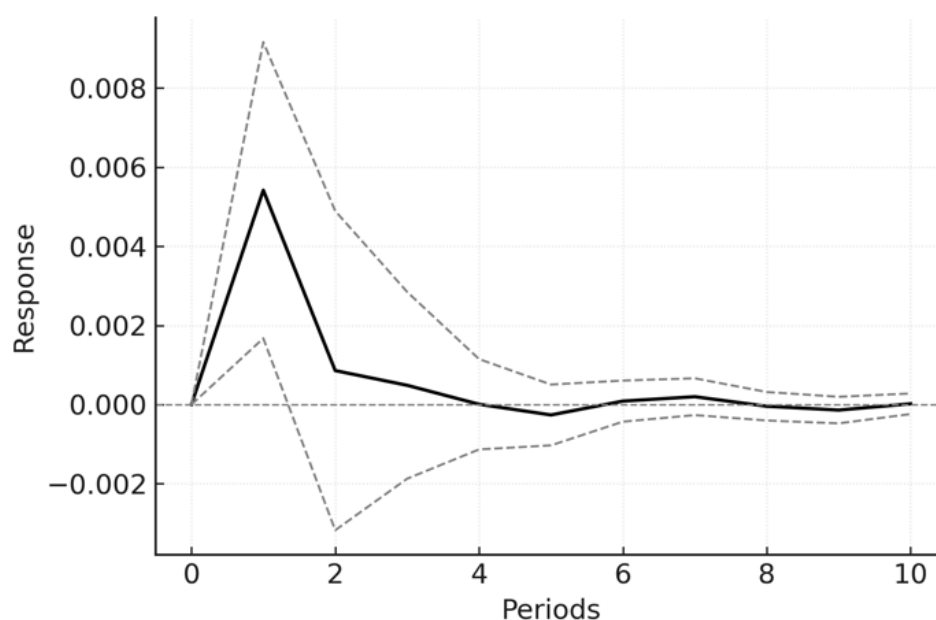


Figure 4. Impulse Response Function - Response of External Debt (ULN) to Exchange Rate Shock

Figure 4 illustrates the response of external debt to exchange rate shocks. A sharp increase in external debt occurs within the first one to two quarters following an initial exchange rate disturbance. Following this early shock, the response gradually weakens and returns toward equilibrium. This pattern reflects the substantial short-term impact of rupiah-US dollar exchange rate fluctuations on external financing dynamics. Exchange rate volatility affects the debt service conversion burden, prompting reactive adjustments in market behaviour and fiscal policy to realign financing structures. These results align with the findings of (Yousaf, Ali, and Khurshid 2022), which indicate that exchange rate volatility significantly increases external risk exposure in countries with a high dependency on foreign financing. The stable pattern observed in both IRF figures suggests that, despite external influences such as exchange rate fluctuations and external debt management structures, they tend to respond in a controlled and measured manner. Short-term macroeconomic shock resilience remains intact, indicating that fiscal and monetary policies have played a mitigating role in supporting external debt sustainability.

Economic Interpretation of the Variance Decomposition of External Debt

Table 11 presents the results of the variance decomposition analysis, which is used to quantify the relative contribution of each explanatory variable —GDP and exchange rate—to the forecast error variance of external Debt (ULN) over different time horizons.

Table 11. Variance Decomposition of External Debt (ULN)

Period	ULN	GDP	Exchange Rate
0	1.000	0.000	0.000
1	0.031	0.969	0.000
2	0.398	0.034	0.568
3	0.279	0.038	0.682
4	0.218	0.048	0.734
5	0.186	0.058	0.756
6	0.165	0.065	0.770
7	0.150	0.070	0.780
8	0.140	0.074	0.786
9	0.132	0.078	0.790

Source of Data: Processed from Time-Series Data (2011Q1–2025Q2)

Table 11 presents the results of the Forecast Error Variance Decomposition (FEVD), which quantifies the relative contribution of independent variables; specifically, gross domestic product (GDP) and the exchange rate, to fluctuations in external Debt (ULN) over a 10-quarter projection horizon. The choice of a 10-period forecast horizon follows standard practice in Vector Autoregressive (VAR) analysis, aiming to capture the short-to medium-term effects of structural shocks within the system (Porto 2022; Stock and Watson 2016).

At period 0, 100 per cent of the variation in ULN is explained by its innovations, as no time has elapsed for other variables to exert influence on the system. Beginning at period 1, GDP emerges as a dominant factor, accounting for approximately 96.9% of the ULN variance. This result suggests that macroeconomic performance has a significant and immediate impact on external debt dynamics, potentially reflecting the short-term financing response to domestic economic growth. A sharp decline in GDP's contribution occurs after period 2, while the role of the exchange rate increases progressively. From period 3 onward, exchange rate shocks become the primary source of variation in external debt, reaching approximately 79% by period 10. This sustained influence signals that currency fluctuations exert a long-term structural impact on debt formation and adjustment mechanisms. Within the context of developing economies, this pattern reflects heightened vulnerability to external instability and significant exposure to exchange rate risk, particularly regarding obligations denominated in foreign currencies (Chowdhury et al., 2021). The economic meaning embedded in these results provides strong justification for viewing external debt management as inseparable from exchange rate stability. Coordinated fiscal and monetary responses appear essential in mitigating the effects of external shocks. Emphasis on macro-policy synergy becomes particularly critical for safeguarding debt sustainability in economies subject to volatile currency environments.

5. Conclusion

This study analyses the dynamic relationship between external debt, gross domestic product (GDP), and the exchange rate in Indonesia during the period 2011Q1 to 2025Q2 using the ARDL Bounds Test and Error Correction Model (ECM) approaches. The results confirm a long-term relationship (cointegration) between the three variables, although none of them is stationary at the level. The ARDL(1, 0, 2) model suggests a strong inertial effect in external debt, where past values have a significant influence on current values. In the short term, exchange rate fluctuations have a statistically significant impact on external debt, while GDP does not exhibit a significant effect. The negative and significant Error Correction Term (ECT) coefficient suggests that approximately 9.84% of long-term imbalances are corrected in one quarter, reinforcing the robustness of the ECM model and the effectiveness of structural adjustments.

Analysis of the Impulse Response Function (IRF) and Variance Decomposition confirms that exchange rates are the primary factor driving fluctuations in external debt. The response to exchange rate shocks is immediate and substantial, whereas the influence of GDP is relatively slower and limited. This finding highlights that external debt sustainability is highly dependent on external stability, notably exchange rate volatility. From a policy perspective, the results underscore the importance of enhancing macroeconomic fundamentals through targeted and coordinated actions. Specific recommendations include:

- a. Diversifying foreign debt portfolios to reduce dependence on USD-denominated liabilities and mitigate currency mismatch risks.
- b. Strengthening foreign exchange reserves to provide a buffer for currency hedging and enhance resilience against global market volatility.
- c. Enhancing policy coordination between Bank Indonesia and the Ministry of Finance to optimize foreign debt risk management and ensure alignment between fiscal and monetary strategies.

Although GDP is insignificant in the short term, its long-term role in reducing the external debt ratio warrants structural consideration. Future analyses should distinguish between GDP growth driven by consumption and that driven by productive investment, as the latter is more likely to support sustainable debt reduction. Assessing the elasticity of GDP in relation to debt reduction will further clarify the extent to which economic growth can contribute to external debt sustainability.

Given that the State Budget variable could not be included in the ARDL model due to its I(2) integration order, future research is encouraged to apply alternative approaches such as Johansen cointegration or Structural VAR models. Incorporating institutional quality measures and global financial conditions may also enhance the understanding of the dynamics and sustainability of Indonesia's external debt.

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