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Assessing the Effects of Exchange Rate Volatility on Zambia's Economic Growth: Evidence from ARDL and NARDL Models

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Abstract: This study investigated the interplay between exchange rate volatility, inflation rates, and real interest rates on Zambia's economic growth from 1992 to 2022, utilizing annualized time series data. The study was necessitated by the limited published literature and relatively varying findings on the variables' relationships in resource-dependent countries, such as Zambia. Diagnostic tests, including stationarity and co-integration analyses, were employed to determine integration orders and potential long-run relationships. The linear and nonlinear autoregressive distributed lag models were employed to assess short- and long-run dynamics of the variables on economic growth. The results established a positive short-run relationship between inflation rates and Gross Domestic Product (GDP) growth in the linear autoregressive distributive lag model, while an inverse relationship was observed in the nonlinear autoregressive distributive lag model, suggesting that negative shocks in inflation rates had a highly significant positive impact on economic growth. Furthermore, interest rates exhibited a positive relationship with economic growth, further suggesting that positive shocks had a greater significant direct effect on economic growth in comparison to negative shocks in the short and long run, respectively. Finally, exchange rates in both models exhibited an inverse relationship with economic growth irrespective of positive or negative shocks in the long run, highlighting the adverse effect of exchange rate volatility on economic growth prospects in developing countries, such as Zambia. The speed of adjustment to convergence following any disruptions was determined to be 75.18% (ARDL) and 89.19% (NARDL), highlighting relatively fast speeds of adjustments from any short-run disruptions. Notably, some of the policy recommendations included regular assessments of exchange rate volatility influences on import prices, domestic inflation, and production costs in key sectors. Additionally, the implementation of currency hedging options and forwards as well as bulking of foreign exchange reserves will ensure the stability of exchange rates against other major currencies in various economic conditions.

Keywords: ARDL bounds test; exchange rate; GDP growth; NARDL bounds test; Zambia

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1. Introduction

Exchange rate stability is argued to be a fundamental ingredient in ensuring the economic health and financial stability of most nations due to its influence on trade balances, inflation rates, and overall economic sustainability. It is in this regard that exchange rate regime changes have been initiated over the years to address the considerable implications of exchange rate volatilities on economic affairs across the globe. Notably, some of the common types of regime changes implemented include fixed, floating, and hybrid transitions, which significantly help determine how a country's currency value is managed in relation to other currencies. Particularly, fixed exchange rate regimes peg a country's currency to another major currency, such as the US Dollar, the Euro, or to a basket of currencies, providing stability in international prices but necessitating large reserves of the foreign currency (Duttagupta et al. 2006). Floating exchange rate regimes, on the other hand, allow the currency value to be determined by market forces without direct government or central bank intervention (Duttagupta et al. 2006). This flexibility leads to significant volatility, as the currency value adjusts automatically based on economic conditions. Hybrid or managed float regimes combine elements of both fixed and floating regimes, allowing the currency to fluctuate within a set range while enabling occasional central bank interventions to stabilize it. These varieties of exchange rate management regimes come with diverse economic repercussions stemming from rigid monetary policy measures to relatively unstable currency performances.

Notably, in America, the economic impacts of exchange rate regimes are evident in both the United States and Latin America. The US operates a floating exchange rate regime (Eun and Resnick 2021), offering flexibility in monetary policy but also exposing the economy to exchange rate volatility, which can impact inflation and interest rates, ultimately influencing economic growth and stability. In contrast, Latin American countries, such as Argentina and Venezuela, have experienced severe economic crises partly due to their rigid exchange rate policies (Alvarez and De Gregorio 2014). Frequent regime changes from fixed to floating regimes, and vice versa, have led to hyperinflation and economic instability, underscoring the challenges of managing exchange. On the other hand, Europe's integration under the European Monetary Union (EMU) and the adoption of the Euro by 19 of the 27 EU member states (Delivorias 2020) provides a unique perspective into exchange rate regime changes and their subsequent economic impacts. The Euro represents one of the most significant currency regime changes known to eliminate exchange rate volatility among member countries and foster deeper economic integration. However, it also requires member states to give up independent monetary policies, which can be problematic during asymmetric economic shocks.

Nonetheless, outside the Eurozone, European countries, such as the United Kingdom and Switzerland, maintain their currencies and employ floating exchange rate regimes. These countries benefit from the flexibility to adjust monetary policy according to domestic economic conditions, but they also face the challenges of managing exchange rate volatility, particularly in times of global financial instability. In contrast, many sub-Saharan African countries face significant challenges related to exchange rate volatility due to their heavy reliance on commodity exports (Senadza and Diaba 2018). Countries such as Nigeria and Ghana have experimented with various exchange rate regimes, dealing with issues such as inflation, currency depreciation, and economic instability (Kwame et al. 2020). In Nigeria, the shift from a fixed to a more flexible exchange rate regime aimed to address external shocks and improve competitiveness, but it also led to short-term volatility and economic uncertainty. Similarly, Ghana's attempts to stabilize its currency through different regimes have highlighted the difficulties of managing inflation and maintaining investor confidence in a volatile economic environment. Nonetheless, in the realm of state historical economic performance against the backdrop of global economic currents, developing countries across the world continue to face both challenges and opportunities that shape their economic resilience. Scholars have probed the topic in relation to its effect on both developed and developing economies with a primary emphasis on key economic indicators, including GDP and international trade. Some studies, including those conducted by Schnabl (2008) on the analysis of exchange rate volatility on economic growth in Europe and East Asia, provided evidence in favor of a significantly inverse relationship between exchange rate volatility and economic growth. Further studies carried out in Africa, particularly in West African countries, collectively recorded a significant inverse relationship between economic growth and exchange rate volatility (Umaru et al. 2018; Ahiabor and Amoah 2019). However, further research on the individual countries in this region yielded contrary results to those obtained from the collective study, as countries such as Gambia and Sierra Leone recorded insignificant results on the effect that exchange rate volatility has on economic performance. Conversely, empirical evidence found from the examination of the effect of exchange rate volatility in European countries' economies based on time series data from 1998 to 2019 showed a strong positive relationship between volatility and economic growth in the context of export and investments (Ozata 2020). Thus, the implication of these varying findings highlights the variability in conclusive results from state to state given certain economic conditions. As such, to further probe the relationship between exchange rate volatility and economic growth in the context of Zambia, the following hypotheses were developed:

Hypothesis (H_0): *Exchange rate volatility does not affect economic growth.*

Hypothesis (H_A): *Exchange rate volatility has a significant effect on economic growth.*

Therefore, this paper seeks to test the hypotheses and provide valuable insight and policy implications relevant to developing and resource-dependent economies in sub-Saharan Africa and across the world. The outline of this paper comprises of a thorough review of Zambia's exchange rate performance, as well as its economic outlook against other major currencies. This is followed by the methods and measurements section, which highlights the econometric procedure and presentation of the study variables. Finally, the results and discussions sections follow immediately after, highlighting the findings as well as subsequent conclusions and recommendations.

2. Data and Methods

2.1. Study Area

Zambia, a landlocked sub-Saharan country in the southern region of Africa, shares a common narrative of economic challenges with many other developing and resource-dependent nations. In recent years, it has grappled with its fair share of economic instabilities and uncertainties. Notably, developing countries that are primarily resource-dependent are often susceptible to these adverse influences, and more so to effects from elements such as exchange rate volatilities in critical sectors, such as international trade, foreign investment, and trade balances. These sectors, among others, are instrumental in shaping key economic indicators and collectively reflect a nation's economic growth. Although exchange rate stability is a core mandate of central banks, it remains a challenging endeavor, particularly in light of the inherent uncertainties stemming from economic and financial market shocks, including global financial crises and geopolitical tensions.

Exchange rate volatilities introduce a series of challenges that reverberate through various sectors of an economy. Definitively, exchange rates refer to the value of one currency expressed as another (Hamilton 2018) and thus are primary culprits in challenges associated with heightened inflation, as exchange rate depreciation normally leads to increased import costs and lessened purchasing power of individuals (Mbao 2021). The prolonged impact of unmonitored exchange rate fluctuations tends to subsequently erode the affordability of basic necessities and sustainable standards of living. Countries such as Zambia, where a significant portion of debt is denominated in foreign currencies, experience significant increases in the cost of servicing debt due to exchange rate volatilities (International Monetary Fund 2022). Additionally, domestic and foreign investment is normally affected adversely, as investors are often cautious when faced with the prospect of unpredictable currency fluctuations. This consequently leads to hesitancy that tends to impede economic growth, job creation, and disrupts the overall business climate, which is crucial for economic development.

Figure 1 below provides a review of the performance of the Kwacha's (Zambia's currency) performance against the US Dollar over a 30-year period.

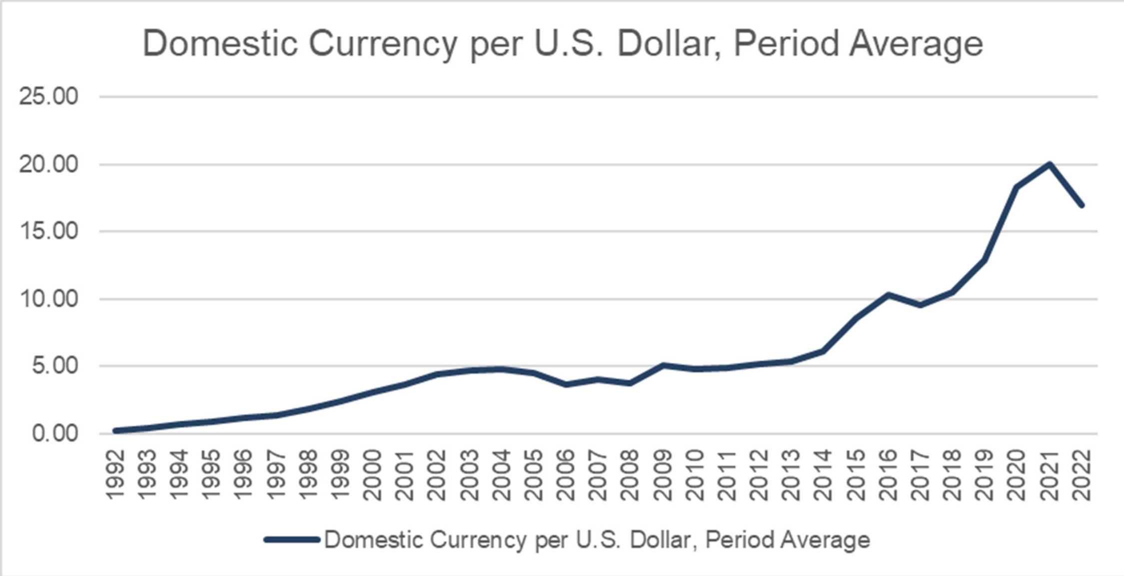


Figure 1. Zambia's Kwacha per US Dollar, from 1992 to 2022. Source: IMF, International Financial Statistics (IFS).

In light of Zambia's economic landscape, factors such as declining copper prices can be ascribed to the Kwacha's value fluctuations against major global currencies. Zambia, as one of the largest producers of copper, plays a vital role in the global mining sector (World Bank 2023). Disruptions in the global mining industry have a great and far-reaching impact on the economic growth as well as exchange rate stability of emerging economies (Luckeneder et al. 2021). A comprehensive review of key sectors in Zambia, with a particular focus on mining, revealed a persistent state of revenue and productivity instability stemming from increased exchange rate volatility experienced over most of the country's productive period (International Monetary Fund 2023). The continued exchange rate instability in Zambia can also be ascribed to factors such as fiscal mismanagement, continual inflation, and market sentiments. The rise of global catastrophes and pandemics, such as COVID-19, dealt considerable negative blows on international trade and economic growth forecasts, as countries grappled to mitigate and cushion the repo-effects on their respective domestic economies (Inegbedion 2021). Although the consequences of exchange rate volatility might seem minor on the surface, they bring forth a range of both favorable and unfavorable implications for an economy's growth. It is imperative to grasp the significant effects of these dynamics to devise effective policies and strategies for economic stability and progress. In essence, exchange rate volatility, when unchecked, can manifest in these adverse outcomes, impacting the economy and the daily livelihoods of Zambian citizens. Recognizing and mitigating these negative effects is essential for fostering economic stability and growth in the nation. However, in recognition of the challenges posed by exchange rate volatility, Zambia has a relatively active monetary policy system aimed at mitigating the effects of these exchange fluctuations and fostering economic stability. Central bank intervention, carried out by the Bank of Zambia (BOZ), involves active participation in the foreign exchange market, where the central bank trades currency reserves as needed to stabilize the Kwacha. Notably, adjustments in monetary policy rates and commercial bank rates have shown to effectively manage the subsequent negative effects stemming from exchange rate instability (Kartal et al. 2023). Nonetheless, the pursuit of Economic Reforms has been a pivotal strategy, encompassing efforts to enhance fiscal management, reduce the national debt burden, and diversify the economy through comprehensive initiatives. These reforms have been aimed at addressing underlying structural issues that contribute to exchange rate instability, as well as management of inflation by adjusting interest rates and money supply (Scarlata 2002). Despite all these measures highlighting Zambia's commitment to addressing the effects of exchange rate volatility, there still remain significant setbacks in achieving a more predictable economic environment, primarily in exchange rate stability, which is pivotal in facilitating growth and prosperity. Thus, this research delves into the dynamics of exchange rate fluctuations and their implications on overall economic growth. Through this exploration, the research endeavors to offer valuable insights that can guide policymakers, businesses, and investors in navigating Zambia's economic landscape, with a specific focus on addressing the effects of exchange rate volatility on the nation's overall economic health.

2.2. Methods and Measurements

The research design employed a quantitative approach, as it is well suited to analyze the relationships between exchange rate volatility and economic growth alongside relevant factors in a linear and nonlinear approach. The research study utilized time series annualized secondary data obtained from data sources provided by entities such as the World Bank, IMF, statistical agencies, and OECD databases. The data obtained covered a period from 1992 to 2022. The variables of interest are indicated in Table 1 below.

Table 1. Variables of interest.

Variables	Description
GDP Growth Rates	GDP based on market prices using constant local currency
Real Interest Rates	Interest rates based on GDP deflator and adjusted for inflation
Inflation Rates	Average consumer's cost basket of goods and services
Exchange Rate Volatility	Annual averaged domestic currency per US Dollar

The GDP growth rate variable was the dependent variable, expressed in percentage form, representing the economy's growth and overall performance. Exchange rate volatility, being the primary independent variable, was expressed as the price of one currency in relation to another and based on the annual averaged domestic currency per US Dollar. The generalized autoregressive conditional heteroscedastic model (GARCH) was used in generating the exchange rate volatility variable. The relevance of the variable in this model stems from the Zambian economy's high sensitivity to fluctuations in exchange rates that pose as a major factor in its copper export markets and the goods import industries (Jonathan 2019). Other support variables included the inflation rate variable, which represented the consumer price index (inflation), expressed as the annual percentage change in the average consumer's cost of purchasing a basket of goods and services. This was justified by its usefulness in capturing the purchasing power of consumers and the effectiveness of Zambia's domestic monetary policies in relation to exchange rate dynamics (Lubinda and Nanchengwa 2016). Finally, the real interest rate variable utilized in this model was determined by the GDP deflator and adjusted for inflation. Inclusion of the variable ensured the factoring in of consumption and investment decisions that influence Zambia's cost of financing for businesses and households (Kabwe and Marvin 2020).

Econometric Procedure

The variables were first examined for stationarity using unit-root tests prior to conducting additional econometric analysis. This step is critical because non-stationary variables or those with a unit root can lead to misleading and spurious results (Engle and Granger 1987; Nelson and Plosser 1982). The augmented Dickey–Fuller (ADF) test, which accounts for serial autocorrelation, as well as the Zivot and Andrews test, which factors in the presence of structural breaks, were primarily employed for this purpose (Dickey and Fuller 1981; Zivot and Andrews 1992). The results could vary from singular to mixed orders of integration. Thus, after assessing stationarity and the levels of integration, the linear and nonlinear autoregressive distributed lag bounds tests were performed, as is necessitated by the integration order requirement, suggesting integration orders I(0), I(1), or a combination of both. As such, the presence of co-integration, noted by an F-statistic value exceeding the upper bound I(1) level (Pesaran et al. 2001; Wooldridge 2018), suggested a long-run relationship among the variables in the model, and vice versa. Furthermore, the Akaike information criterion (AIC) was utilized to determine the optimal lags for the variables, as it is particularly suitable for small sample sizes (Wooldridge 2018). Compared to the sequential modified LR test statistic, the AIC is more effective at identifying the correct lag length and reduces the risk of underestimation. It also incorporates considerations from the Hannan–Quinn information criterion, Schwarz information criterion, and final prediction error (Liew 2004). All the tests and pre-estimation procedures necessitated the estimation of the autoregressive distributive lag model (ARDL), as it accounts for both I(0) and I(1) integration orders in the presence of co-integration among variables and is particularly suitable for capturing short- and long-term dynamics, as was the case in this analysis. Finally, post-estimation analysis included testing for the null hypotheses of no heteroscedasticity (ARCH-LM test), no autocorrelation (Breusch–Godfrey test), and normality (Jacque–Bera test). The model's specification was also verified using the Ramsey Reset test (Ramsey 1969), and the model's stability was assessed with the CUSUM and CUSUM of squares tests.

2.3. Model Specification

The chosen approach for analysis was based on a series of pre-estimation tests to determine the regression model relevant for the research study and well suited for investigating both the time-based relational dynamics between variables. The selection rationale was based on the models' capacity to assess the dynamic nature of the relationships under scrutiny through lag criteria selections, stationarity, and co-integration tests. Thus, ARDL and NARDL models were selected and then econometrically redefined, as follows:

General model representation:

$$\begin{gathered}\text{Economic growth (GDP growth)} = \beta 0 + \beta 1 \text{ (exchange rate volatility)} \\ + \beta 2 \text{ (inflation rates)} + \beta 3 \text{ (interest rates)} + \varepsilon\end{gathered} \tag{1}$$

where $\beta0$ is the intercept, while $\beta1$, $\beta2$, and $\beta3$ represent coefficients for the variables shown in the general formula, and ε is the white noise disturbance term. The formula and the econometric procedures carried out in this paper are similar to those of many other researchers who used similar variables to conduct the analysis (Ali et al. 2020; Fiaz et al. 2021).

ARDL model:

$$\begin{gathered}\Delta GDPG_t = \alpha_0 + \sum_{i=1}^{n1} \alpha_{1i}\Delta GDPG_{t-i} + \sum_{i=1}^{n2} \alpha_{2i}\Delta VOLEX_{t-i} \\ + \sum_{i=1}^{n3} \alpha_{3i}\Delta RIR_{t-i} \\ + \sum_{i=1}^{n4} \alpha_{4i}\Delta INFLR_{t-i} + \lambda_1 GDPG_{t-i} + \lambda_2\Delta VOLEX_{t-i} + \lambda_3\Delta RIR_{t-i} \\ + \lambda_4\Delta INFLR_{t-i} + \varepsilon_t\end{gathered} \tag{2}$$

where the coefficients from λ_1 to λ_4 are the long-run values of the relational interplay among the variables GDP growth rate (GDPG), exchange rate volatility (VOLEX), real interest rates (RIR), and inflation rates (INFLR). Similarly, values α_0 to α_{4i} show the short-term interactions of the model in determining the relationships between the dependent and independent variables, respectively. Additionally, ε_t expresses the white noise disturbance term of the model, and the value represented by Δ shows the first difference operator.

The error correction model was estimated as:

$$\begin{gathered}\Delta GDPG_t = \alpha_0 + \sum_{i=1}^{n1} \alpha_{1i}\Delta GDPG_{t-i} + \sum_{i=1}^{n2} \alpha_{2i}\Delta VOLEX_{t-i} \\ + \sum_{i=1}^{n3} \alpha_{3i}\Delta RIR_{t-i} + \sum_{i=1}^{n4} \alpha_{4i}\Delta INFLR_{t-i} + \varphi ECM_{t-i} + \varepsilon_t\end{gathered} \tag{3}$$

where the values represented by α_0 to α_{4i} and Δ show the short-run dynamics of the variables in the model and first difference operators, respectively. Additionally, the value represented by φ expresses the error correction term, being the speed of adjustment from any short-run disruptions to convergence in the long run.

NARDL model:

$$\begin{aligned}\Delta GDPG_t = \alpha_0 \quad & + \sum_{i=1}^{n1} \alpha_{1i}\Delta GDPG_{t-i} + \sum_{i=1}^{n2} \alpha_{2i}\Delta VOLEX^{+}{}_{t-i} + \sum_{i=1}^{n3} \alpha_{3i}\Delta VOLEX^{-}{}_{t-i} \\ & + \sum_{i=1}^{n3} \alpha_{4i}\Delta RIR^{+}{}_{t-i} + \sum_{i=1}^{n3} \alpha_{5i}\Delta RIR^{-}{}_{t-i} + \sum_{i=1}^{n4} \alpha_{6i}\Delta INFLR^{+}{}_{t-i} \\ & + \sum_{i=1}^{n4} \alpha_{7i}\Delta INFLR^{-}{}_{t-i} + \lambda_8 GDPG_{t-i} + \lambda_9\Delta VOLEX^{+}{}_{t-i} \\ & + \lambda_{10}\Delta VOLEX^{-}{}_{t-i} + \lambda_{11}\Delta RIR^{+}{}_{t-i} + \lambda_{12}\Delta RIR^{-}{}_{t-i} + \lambda_{13}\Delta INFLR^{+}{}_{t-i} \\ & + \lambda_{14}\Delta INFLR^{-}{}_{t-i} + \varepsilon_t\end{aligned} \tag{4}$$

where the coefficients from λ_8 to λ_{14} are the long-run values of the positive and negative relational interplay among the variables GDP growth rate (GDPG), exchange rate volatility ($VOLEX^+, VOLEX^-$), real interest rates (RIR^+, RIR^-), and inflation rates ($INFLR^+, INFLR^-$). Similarly, values α_0 to α_{7i} show the short-term interactions of the model in determining the relationships between the dependent and independent variables, respectively. Additionally, ε_t expresses the white noise disturbance term of the model, and the value represented by Δ shows the first difference operator.

The error correction model was estimated as:

$$\begin{aligned}\Delta GDPG_t = \alpha_0 + \textstyle\sum_{i=1}^{n1} \alpha_{1i}\Delta GDPG_{t-i} + \sum_{i=1}^{n2} \alpha_{2i}\Delta VOLEX^{+}{}_{t-i} + \sum_{i=1}^{n2} \alpha_{3i}\Delta VOLEX^{-}{}_{t-i} + \sum_{i=1}^{n3} \alpha_{4i}\Delta RIR^{+}{}_{t-i} \\ + \textstyle\sum_{i=1}^{n3} \alpha_{5i}\Delta RIR^{-}{}_{t-i} + \sum_{i=1}^{n4} \alpha_{6i}\Delta INFLR^{+}{}_{t-i} + \sum_{i=1}^{n4} \alpha_{7i}\Delta INFLR^{-}{}_{t-i} + \varphi ECM_{t-i} + \varepsilon_t\end{aligned} \tag{5}$$

where the values represented by α_0 to α_{7i} and Δ show the short-run dynamics of the variables in the model and first difference operators, respectively. Additionally, the value represented by φ expresses the error correction term, being the speed of adjustment from any short-run disruptions to convergence in the long run.

3. Results and Discussions

Table 2 below presents the descriptive statistics of the variables used in the analysis, highlighting a summary of the central tendency, dispersion, and overall distribution of the data.

Table 2. Descriptive statistics.

Variable	GDPG	INFLR	RIR	VOLEX
Mean	4.428083	27.94831	5.669922	0.978154
Median	4.697992	17.86973	6.112942	0.982758
Maximum	10.29822	183.3120	23.67049	1.283410
Minimum	−8.625442	6.429397	−41.79024	0.116115
Std. Dev.	3.820367	40.74979	12.07832	0.212876
Skewness	−1.469750	3.146047	−1.855340	−2.027697
Kurtosis	5.873654	11.80868	8.892625	9.807112
Jarque–Bera	21.82729	151.3617	62.63572	81.09471
Probability	0.000018	0.000000	0.000000	0.000000
Sum	137.2706	866.3977	175.7676	30.32277
Sum Sq. Dev.	437.8561	49816.35	4376.575	1.359492
Obs.	31	31	31	31

Source: Authors' computations (2024).

The descriptive statistics for the variables GDP growth rate (GDPG), inflation rate (INFLR), real interest rate (RIR), and exchange rate volatility (VOLEX) revealed the characteristics and distributions of the data utilized in the analysis. The mean GDP growth rate was 4.43%, with a median of 4.70%, indicating a distribution slightly skewed toward higher growth rates. GDPG values ranged from a maximum of 10.30% to a minimum of

−8.63%, with a standard deviation of 3.82%, reflecting moderate variability. The skewness of GDPG was −1.47, indicating a left-skewed distribution, while the kurtosis value of 5.87 suggested a leptokurtic distribution with fat tails. The Jarque–Bera statistic was 21.83, with a probability of 0.000018, rejecting the null hypothesis of normal distribution. Notably, the inflation rate variable showed a high mean of 27.95% and a median of 17.87%, suggesting significant skewness with occasional high inflation spikes, as indicated by the maximum value of 183.31%. The minimum inflation rate was 6.43%, and the standard deviation was 40.75%, indicating substantial volatility. Inflation rates had a skewness of 3.15, indicating a right-skewed distribution, and a kurtosis of 11.81, pointing to a highly leptokurtic distribution. The Jarque–Bera statistic for inflation rates was 151.36, with a probability of 0.000000, confirming non-normality. The real interest rate had a mean of 5.67% and a median of 6.11%, with values ranging widely, from a maximum of 23.67% to a minimum of −41.79%. This large range and the standard deviation of 12.08% highlight considerable fluctuations. The skewness of the real interest rate was −1.86, indicating a left-skewed distribution, and the kurtosis value was 8.89, suggesting a leptokurtic distribution. The Jarque–Bera statistic was 62.64, with a probability of 0.000000, indicating non-normality. Lastly, the exchange rate volatility had a mean of 0.98 and a median of 0.98, suggesting a fairly symmetric distribution. Exchange rate volatility observations varied from a maximum of 1.28 to a minimum of 0.12, with a standard deviation of 0.21, indicating relatively low variability compared to the other variables. Exchange rate volatility exhibited a skewness of −2.03, indicating a left-skewed distribution and a kurtosis of 9.81, which points to a leptokurtic distribution. The Jarque–Bera statistic for exchange rate volatility was 81.09, with a probability of 0.000000, confirming the non-normality of its distribution. Table 2 presents results based on recommended lags suitable for the estimation of the autoregressive models.

Table 3 outlines the lag selection criteria, which recommend suitable lag lengths for regression estimations so as to ensure that the model captures the underlying patterns and addresses model fit concerns and statistical efficiency. As noted in the table, the significant values at the first lag highlighted the selected optimal lag length of 1, supported by the majority of selections, including the Akaike information criteria, which is largely preferred.

Table 3. Lag selection criteria.

Lag	Log L	LR	FPE	AIC	SC	HQ
0	−309.8764	NA	14381.33	20.9251	21.1119	20.9849
1	−251.0852	97.98529 *	839.9965 *	18.0724 *	19.0065 *	18.3712 *

* Denotes the selected lag length information criteria. LR: sequential modified LR test statistic (each test at the 5% level). FPE: final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan–Quinn information criterion. Source: Authors' computations (2024).

Table 4 highlights the results of stationarity tests conducted with the augmented Dickey–Fuller (ADF) and Zivot and Andrews (Z-A) techniques. As noted in the table above, mixed integration orders of stationarity were observed for the Gross Domestic Product growth rate variable. The ADF test reviewed that GDP growth rate was stationary at first difference I(1), while the Zivot and Andrews test noted its stationarity at level I(0). Similarly, inflation rate was stationary at level I(0), highlighted by the ADF test, while the Z-A test noted it to be stationary at first difference I(1). Nonetheless, real interest and exchange rate volatility were found to be stationary at level I(0) in both the ADF and Z-A tests. All test results were subject to a 5% level of significance comparison. Therefore, based on the mixed orders of integration exhibited by the variables, an autoregressive distributive lag bounds test was necessary in order to assess any presence of co-integration among the variables, as can be noted in Table 4 below.

Table 4. Stationarity test.

	Level				1st Difference		
	Test	**T. Stat.**	**5% Critical**		**Test**	**T. Stat.**	**5% Critical**
GDPG	ADF	−2.1978	−2.9678	GDPG	ADF	−7.2396 *	−2.97185
	Z-A	−6.078 (2013) *	−4.8598		Z-A		
INFLR	ADF	−18.448 *	−2.9678	INFLR	ADF		
	Z-A	−3.6034 (2019)	−4.8598		Z-A	−33.367 (1996) *	−4.8598
RIR	ADF	−5.5908 *	−2.9639	RIR	ADF		
	Z-A	−6.725 (1995) *	−4.8598		Z-A		
VOLEX	ADF	−7.4766 *	−2.9639	VOLEX	ADF		
	Z-A	−7.456 (2020) *	−4.8598		Z-A		

* Denotes significant integration order at the 5% level (constant and trend). Source: Authors' computations (2024).

3.1. Linear Autoregressive Distributive Lag Approach (ARDL)

Table 5 highlights the autoregressive bounds test results conducted to detect any long-run relationship among the variables (Pesaran et al. 2001). The results, as outlined above, indicate the presence of any extended time period relationship among the variables (co-integration), indicated here by the F-statistic value of 20.59336 being greater than the 5% upper bound value of 4.35. Prior stationarity and co-integration tests necessitated the estimation of the effect and relationship between the variables using an autoregressive distributed lag model (Pesaran and Shin 1999), whose results are shown below.

Table 5. Results of co-integration test.

	ARDL F-Bounds Test			
	Value	**Significance**	**I(0)**	**I(1)**
F-statistic	20.59336	5%	3.23	4.35
K	3			

Source: Authors' computations.

Table 6 highlights the short- and long-run results obtained from the estimation of a linear autoregressive distributive lag model (ARDL). In terms of short-run dynamics, the error correction term, denoted by ECM (−1), carried an inverse sign and was highly significant at all levels. The implication of this term dictates the rate of adjustment from any disequilibrium in the short run and suggests an eminent convergence and correction in the long run from any short-run disruptions. Therefore, the convergence rate from a state of disequilibrium will take place at a speed of 75.18% in the coming periods, indicating a relatively fast readjustment rate, equivalent to a period of approximately one year and four months. Notably, the inflation rate coefficient (0.13069) indicated a direct and positive relational effect on GDP growth rate in the short run, implying that a marginal increment in the independent variable (inflation rate) will lead to a 0.130639 increase in the GDP growth rate, significant at all levels.

The findings obtained from the computation of the long-run form autoregressive distributive lag model (ARDL) indicated that exchange rates had a significantly negative effect on economic growth in an extended time period, as represented by the proxy of Gross Domestic Product growth rate. This was observed through the significant *p*-value of 0.0002, whose results were in consensus with the majority findings conducted by other researchers, as discussed earlier in the literature review. Additionally, it can also be noted that real interest rates were found to have a positive relational effect on economic growth in the long run, as can be observed through the positive value and significant *p*-value of 0.0144 at the 5% level. Therefore, a marginal increment in exchange rate volatility will lead to a 16.71703 unit decrease in GDP growth rate, while a unit increase in real interest rates will result in a 0.176197 unit increase in GDP growth rate, respectively. Table 6 presents a summary of the diagnostic tests conducted on the estimated ARDL model.

Table 6. ARDL estimation results.

		Short-Run Results		
Variables	**Coefficient**	**Std. Error**	**T. Stat.**	**Prob.**
D(INFLR)	0.1306	0.0138	9.4478	0.0000 *
ECM(−1)	−0.7518	0.0781	−9.6265	0.0000 *
		Long-Run Results		
Variables	**Coefficient**	**Std. Error**	**T. Stat.**	**Prob.**
VOLEX	−16.7170	3.7720	−4.4317	0.0002 *
RIR	0.1761	0.0665	2.6468	0.0144 *
INFLR	0.0303	0.0191	1.5868	0.1256

Source: Authors' computations. * Denotes significance at 5% level.

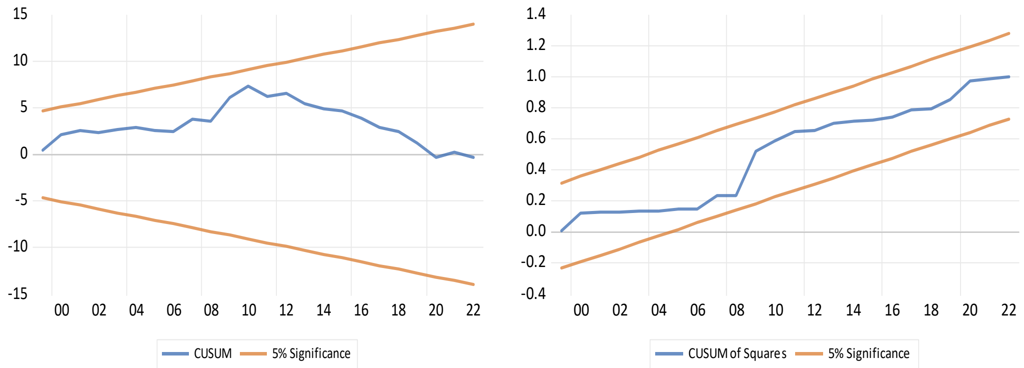
Table 7 highlights the results of several diagnostic tests necessary to ensure reliability and validity of the estimation results. Notably, the ARCH-LM test was conducted to assess any levels of heteroscedasticity present in the model and its corresponding variables. The test null hypothesis was not rejected considering the F-statistical probability of 0.5888, which is larger than the 5% level of significance. The implications of these findings confirmed the absence of heteroscedasticity in the model. Notably, the findings obtained from the serial correlation test confirmed that there was no serial correlation in the model, as can be noted from the F-statistical probability of 0.8240, which is larger than all the relevant levels of significance. The normality test was conducted to assess the model's normality characteristics. The findings indicated the model to be normally distributed, as seen by the probability of 0.318982, which is greater than the 5% level of significance. Finally, the Ramsey Reset test was conducted to ascertain the likelihood of any functional form incompatibility and model misspecifications. The findings indicated by the probability value of 0.7370, greater than the 5% level of significance, implied the failure to reject the assumption of model misspecification and confirmed that the model was well specified and in suitable functional form.

Table 7. Results of diagnostic tests.

Problem	**Diagnostic Test**	**Prob.**
Heteroscedasticity	ARCH-LM	0.5888
Serial Correlation	Breusch–Godfrey LM	0.8240
Normality	Jarque–Bera	0.3189
Misspecification	Ramsey Reset Test	0.7370
Model Stability	CUSUM	Stable
Model Stability	CUSUM of Squares	Stable

Source: Authors' computations.

As can be observed, Figure 2a,b represent the results of the model stability diagnostic tests, which are necessary tools for noting any interference from factors, such as structural breaks. Notably, the model did not exhibit any form of instability. This is noted through the blue margins' fluctuations maintained within the 5% band in the CUSUM test noted in Figure 2a. Additionally, the distribution of the blue margin within the 5% band in the CUSUM of squares test results confirmed that the model was not affected by structural breaks, as noted in Figure 2b.



(**a**) (**b**)

Figure 2. Model stability test: (**a**) CUSUM, and (**b**) CUSUM of Squares.

3.2. Nonlinear Autoregressive Distributive Lag Approach (NARDL)

Table 8 reveals the results of the NARDL bounds test, which was conducted to detect any long-run relationship among the variables (Pesaran et al. 2001). The results, as outlined above, indicated the presence of any extended time period relationship among the variables (co-integration), indicated by the F-statistic value being larger than the upper bound value. Prior stationarity and co-integration tests necessitated the estimation of the effect and relationship between the variables using a nonlinear autoregressive distributed lag model (Pesaran and Shin 1999), whose results are shown Table 9 below.

Table 8. Co-integration test.

NARDL F-Bounds Test				
	Value	**Significance**	**I(0)**	**I(1)**
F-statistic	5.2641	5%	2.27	3.28

Source: Authors' computations.

Table 9. NARDL estimation results.

Short-Run Results				
Variables	**Coefficient**	**Std. Error**	**T. Stat.**	**Prob.**
VOLEX $^{+}$	−4.7381	2.3630	−2.0051	0.0574 *
VOLEX $^{-}$	−24.6627	3.2025	−7.7009	0.0000 *
RIR $^{+}$	0.4317	0.0579	7.4509	0.0000 *
RIR $^{-}$	−0.1245	0.0696	−1.7890	0.0874 ***
INFLR $^{+}$	−0.1046	0.1107	−0.9449	0.3549
INFLR $^{-}$	0.2496	0.0173	14.4006	0.0000 *
ECM(−1)	−0.8919	0.1135	−7.8591	0.0000 *
Long-Run Results				
Variables	**Coefficient**	**Std. Error**	**T. Stat.**	**Prob.**
VOLEX $^{+}$	−19.0866	4.8074	−3.9702	0.0006 *
VOLEX $^{-}$	−20.5785	6.6585	−3.0905	0.0053 *
RIR $^{+}$	0.2604	0.1287	2.0228	0.0554 ***
RIR $^{-}$	0.0788	0.1439	0.5479	0.5892
INFLR $^{+}$	0.1261	0.1412	−0.8928	0.3815
INFLR $^{-}$	0.1669	0.1723	0.9689	0.3431

Source: Authors' computations. * Denotes significance at the 1% level, and *** denotes significance at the 10% level.

Table 9 reveals the short- and long-run estimation results computed on the variables of the nonlinear autoregressive distributive lag model. In terms of short-run dynamics, the error correction term, denoted by ECM (−1), carried an inverse sign and was highly significant at all levels. The implication of this term dictates the rate of adjustment from any disequilibrium in the short run and suggests an eminent convergence and correction in the long run from any short-term disruptions. Therefore, the convergence rate from a state of disequilibrium will take place at a speed of 89.19% in the coming periods, indicating a relatively fast readjustment rate equivalent to a period of approximately one year and two months. The short-run results from the nonlinear autoregressive distributed lag (NARDL) model revealed significant asymmetric impacts of exchange rate volatility, real interest rates, and inflation rates on the economic growth. Thus, positive changes in exchange rate volatility had a negative and marginally significant impact (−4.7381) on the GDP growth rate, suggesting that increases in volatility tend to negatively affect the economic outcome. In contrast, negative shocks in exchange rate volatility exhibited a highly significant and substantial negative impact (−24.6627), indicating that decreases in exchange rate volatility are strongly associated with declines in the economic growth. Notably, regarding real interest rates, positive changes significantly boosted the economic growth, as expressed by the positive coefficient (0.4317), highlighting a positive relationship between increasing real interest rates and economic growth. Conversely, negative changes in real interest rates showed a marginally significant negative impact (−0.1245), suggesting that decreases in real interest rates may adversely affect the economic growth, though this evidence is not as strong. Finally, positive changes in the inflation rate did not significantly influence the dependent variable, as indicated by the high *p*-value. However, negative changes in inflation rates had a highly significant positive impact (0.2496), demonstrating that decreases in inflation rates were strongly associated with improvements in the dependent variable.

The long-run results from the NARDL model provided further insights into the asymmetric effects of exchange rate volatility on economic growth. Positive changes in exchange rate volatility had a significant and negative long-term impact, with a coefficient of −19.0866, suggesting that increased stock market volatility adversely affects the economic variable. Negative changes in exchange rate volatility also had a significant and negative effect, with a coefficient of −20.5785, indicating that reductions in stock market volatility similarly harm the economic outcome. In terms of real interest rates, positive changes were marginally significant and positively related to the economic growth, with a coefficient of 0.2604. This implies that increases in real interest rates may boost the economic outcome in the long run. However, negative changes in real interest rates were not statistically significant, suggesting that decreases in real interest rates do not have a notable impact on the economic variable in the long term. Regarding inflation rates, neither positive nor negative changes were statistically significant in the long run, as indicated by their high *p*-values. This suggests that variations in inflation rates, whether increases or decreases, do not have a significant long-term impact on the economic growth.

Table 10 presents the results of a symmetry test conducted in order to ascertain the presence of linear and nonlinear relationships among the variables. The results indicated varying degrees of asymmetry in these relationships. Specifically, exchange rate volatility showed significant asymmetry, with a coefficient of 0.0284, suggesting that its impact on economic growth differs in the short run depending on the direction of change. Similarly, real interest rates exhibited asymmetry, with a coefficient of 0.0268, indicating that its effect on economic growth varies in the short run depending on whether interest rates are increasing or decreasing. Finally, inflation rates also demonstrated weak but significant asymmetry, with a coefficient of 0.0971, implying that its influence on economic growth fluctuates under different circumstances. Table 10 below presents a summary of the diagnostic tests conducted on the estimated ARDL model.

Table 11 highlights some of the findings from several diagnostic tests conducted on the nonlinear autoregressive lag model (NARDL) so as to assess its reliability. The ARCH-LM test was conducted to assess any levels of heteroscedasticity present in the model and its corresponding variables. The test null hypothesis was not rejected considering the F-statistical probability of 0.4983, which is larger than the 5% level of significance. The implications of these findings confirmed the absence of heteroscedasticity in the model.

Additionally, the findings obtained from the serial correlation test confirmed that there was no serial correlation in the model, as can be noted from the F-statistical probability of 0.3739, which is larger than all the relevant levels of significance. The normality test was conducted to assess the model's normality characteristics. The findings indicated the model to be normally distributed, as be seen by the probability of 0.8296, which is greater than the 5% level of significance. Finally, the Ramsey Reset test was conducted to ascertain the likelihood of any functional form incompatibility and model misspecifications. The findings indicated by the probability value of 0.6503, greater than the 5% level of significance, implied the failure to reject the assumption of model misspecification, and confirmed that the model was well specified and in suitable functional form.

Table 10. Symmetry tests.

Variables	Short Run	Long Run
VOLEX	0.0284 **	0.7381
RIR	0.0268 **	0.1007
INFLR	0.3172	0.0971 ***

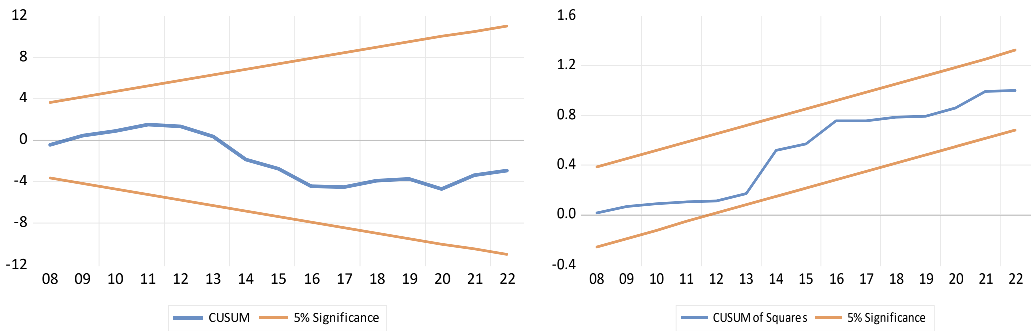
Source: Authors' computations. ** denotes significance at the 5% level, and *** denotes significance at the 10% level.

Table 11. Diagnostic tests.

Problem	Diagnostic Test	Prob.
Heteroscedasticity	ARCH-LM	0.4983
Serial Correlation	Breusch–Godfrey LM	0.3739
Normality	Jarque–Bera	0.8296
Misspecification	Ramsey Reset Test	0.6503
Model Stability	CUSUM	Stable
Model Stability	CUSUM of Squares	Stable

Source: Authors' computations.

As can be observed from the CUSUM test results in Figure 3a, the model did not exhibit any form of instability. This is noted through the blue margin fluctuations maintained within the 5% band. Additionally, the distribution of the blue margin within the 5% band in the CUSUM of squares test in Figure 3b confirms that the model was not affected by structural breaks.



(**a**) (**b**)

Figure 3. Model stability test: (**a**) CUSUM and (**b**) CUSUM of square.

4. Discussion of Findings

The findings derived from the application of the autoregressive distributive lag model (ARDL) shed light on the intricate relationship between key economic variables, providing valuable insights into their long-run and short-run interactions. Notably, the long-run ARDL model revealed a substantive adverse impact of exchange rate volatility on economic growth, a relationship that was not statistically significant in the short-term ARDL estimations. This aligns with studies conducted in countries such as Nigeria (Ehikioya 2019) and Ghana (Adjei 2019), whose findings suggested an inverse relationship between exchange rate volatility and economic growth, largely attributed to various factors, including market dynamics and consumer behavior responses, where economic growth is strongly influenced by the export sector (Emilio 2001). Nonetheless, the short-run results obtained from the nonlinear autoregressive distributive lag model (NARDL) revealed that positive shocks in exchange rate volatility had a marginal yet significant negative impact on the GDP growth rate. Conversely, negative shocks in exchange rate volatility exhibited a highly significant and substantial negative impact in the short run, indicating that increases and decreases in volatility are strongly associated with declines in economic growth. Furthermore, the long-run nonlinear autoregressive distributive lag model (NARDL) results also revealed that both positive and negative shocks in exchange rate volatility had significant negative impacts, implying that variations in volatility, whether increases or decreases, adversely affected the economic outcome in the long term. These findings present a considerably counterintuitive perspective to the conventional expectation that reduced exchange rate volatility will have a significant positive impact on economic growth, as was the case in Yensu et al. (2022) and Barguellil et al. (2018)'s studies. However, exchange rate volatility in this paper revealed relatively contrasting and asymmetric impacts on economic growth, where both positive and negative shocks exhibited negative effects on economic growth. Nonetheless, some studies indicated findings similar to this paper's results. For instance, Magda (2000) highlighted that negative shocks were observed to reduce output growth, without significantly alleviating inflationary pressures, as noted in nations such as Egypt and Nepal. On the other hand, positive shocks to exchange rate volatility also tended to slow economic growth and exacerbate inflation. Thus, irrespective of the direction, exchange rate volatility was observed to have an adverse effect on economic growth. Moreover, the impact of exchange rate volatility on trade flows, a key channel through which economic growth is influenced, also showed considerable asymmetry. Bahmani-Oskooee et al. (2023) revealed that while increased exchange rate volatility boosts exports in some G7 countries, such as France and Italy, it negatively affects others, such as Germany. Similarly, decreased volatility tends to hurt exports and improve imports in several of these economies. Kokken (2019) and Kayani et al. (2023) reinforced these findings, showing that both increases and decreases in volatility can detrimentally affect bilateral trade and subsequently, economic growth, albeit with varying degrees of significance. Conversely, real interest rates did not show any significant effect in the short run but demonstrated a positive effect on economic growth over an extended period within the autoregressive distributive lag model (ARDL). This was also highlighted in the nonlinear autoregressive distributive lag model (NARDL), which revealed that real interest rates showed a positive relationship with economic growth in the short run, as positive changes significantly boosted growth, with negative changes having a marginally significant adverse effect. Notably, in the long run, positive changes were marginally significant and positively related to economic growth, suggesting that increases in real interest rates might boost economic outcomes over time, while negative changes were not statistically significant. This could be attributed to the country's strong dependency on foreign direct investment, which is vital for the country's economic growth. This is strongly supported by a report by the Bank of Zambia on the impact of FDI on economic growth, alongside other key macroeconomic variables (Mudenda et al. 2021). The results highlighted a significantly direct relationship between external investments and economic growth, which are largely attracted to regions of relatively high interest rates and returns on investments, as supported by Suciany et al.'s (2024) study on macroeconomic variable impacts on economic growth. However, other scholars (Bano 2018) countered this conclusion, citing that interest rates will have a negative effect on investments and, subsequently, economic growth, depending on the policy mix implemented.

Furthermore, the autoregressive distributive lag model (ARDL) short-run effect of inflation rates on GDP growth rate was unveiled, showing a positive relationship between the two variables. The statistical significance of this coefficient across all levels of significance further emphasized the relevance of inflation rates in understanding short-term economic dynamics. Notably, the nonlinear autoregressive distributive lag model (NARDL) results highlighted that positive shocks in inflation rates did not significantly influence GDP, but negative shocks in inflation rates had a highly significant positive impact, underscoring that decreases in inflation rates strongly correlated with improvements in economic performance. Additionally, inflation rates in the long run did not show significant long-term impacts on economic growth, regardless of whether they increased or decreased. The relationship derived from the estimations corroborates with postulates of the Philips curve hypothesis, which highlights the short-run tradeoff between inflation and unemployment, which is a key ingredient in enhancing economic growth (Phillips 1958). Additionally, the negative connection between inflation and economic growth can be attributed to individuals' inclination toward shifting from holding money to investing in interest-earning assets, as affirmed by findings from a study in Ethiopia (Ali and Asfaw 2023). This behavior results in heightened capital intensity, ultimately contributing to the promotion of economic growth, as highlighted by Tobin (1965)'s research. Furthermore, Sarel (1996) extended this perspective by emphasizing that maintaining inflation rates below a certain threshold is crucial, as it not only avoids adverse effects but also holds the potential to positively influence economic growth.

Finally, the short-run estimation results, built upon the long-run ARDL variables, revealed the significance of the error correction term, ECM (−1), with an inverse relational sign and high significance across all levels. The term highlighted the speed of adjustment for any short-term disequilibrium, signaling an imminent convergence and correction after an extended period. The calculated rates of adjustment, 75.18% for the ARDL model and 89.19% for the NARDL model, underscored the efficiency with which the system corrects deviations from the extended time period equilibrium.

5. Conclusions and Recommendations

This study was conducted to establish the relational effect of exchange rate volatility alongside control variables (inflation rates and real interest rates) on Zambia's economic growth, with annualized time series data from 1992 to 2022. Diagnostic tests were conducted, including those of stationarity and co-integration, to establish integration orders and potential long-run relationships among the variables used in the study. The linear (ARDL) and nonlinear (NARDL) autoregressive distributive lag models were utilized in modeling and determining the short- and long-run relationships between the dependent and independent variables. The results suggested that inflation rates directly affected the level of economic growth, more specifically, by negative shocks in inflation in the short and long run. This aligned with expectations of economic theories, such as the Philips curve hypothesis, which equally suggested a positive relationship in the form of tradeoffs. Furthermore, it was established that real interests, contrary to most studies, exhibited a positive relationship with respect to economic growth, irrespective of positive or negative shocks in the short and long run. The effect between the two variables in this regard could be attributed to benefits resulting from increases in foreign direct investment and external business ventures in the country. Finally, the relational effect of exchange rate volatility on economic growth was established to be negative, implying an inverse association with economic growth irrespective of positive or negative shocks, highlighting the need for policymakers to keenly monitor the consequential impact of this relationship in sectors such as international trade and sensitive financial markets. Further diagnostic tests, including heteroscedasticity, model stability, misspecification, serial correlation, and normality tests, were conducted to ensure the validity and reliability of the results.

Based on the comprehensive findings of this study, policymakers in Zambia should critically consider and respond to the discerned relationships among exchange rate volatility, inflation rates, real interest rates, and economic growth. The study highlighted the significance of controlling inflation rates for short-term economic growth, which underscores the importance of implementing measures to manage and stabilize inflation rates and ensure economic stability. Some of the measures include upward adjustments in reserve ratios and monetary policy rates as a means of limiting the availability of money in the economy as soon as the relationship between inflation rates and economic growth becomes negative. Additionally, the study brought attention to the negative relational effect of exchange rate volatility on economic growth. In light of this, policymakers in resource-dependent and developing countries should diligently monitor the potential repercussions of this relationship, especially in sectors sensitive to international trade and financial markets. This includes conducting regular assessments of exchange rate volatility influences on import prices, domestic inflation, and production costs in key sectors. The identified negative impact suggests a need for proactive policy interventions aimed at mitigating the adverse effects of exchange rate volatility on the country's economic growth via tools such as currency hedging options/forwards as well as bulk foreign exchange reserves.

Conclusively, Zambia's economy, similar to most resource-dependent economies, is still largely influenced by the effects of fluctuations in key economic variables, including exchange rates, which have been seen to have detrimental effects when left unchecked. Nonetheless, the primary limitation to this study was access to complete and comprehensive data on exchange rates, real interest rates, and inflation rates. However, further research can be conducted on this topic with the aim of assessing the actual sensitivity of Zambia's exchange rates to shocks from financial markets and specific industry variables utilizing GARCH and EGARCH models.

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