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ASYMMETRIC EFFECTS OF TERMS OF TRADE AND REAL EXCHANGE RATE VOLATILITY ON ECONOMIC GROWTH IN WEST AFRICAN COUNTRIES

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Abstract

This study examines the asymmetric effects of terms of trade (ToT) and real exchange rate volatility (RERV) on economic growth in West African countries using a nonlinear autoregressive distributed lag (NARDL) framework. Using annual panel data from 1990 to 2024, the study captures key global and regional economic disruptions, including commodity price cycles, the global financial crisis, the COVID-19 pandemic, and the Russia–Ukraine conflict. The empirical findings confirm the existence of a stable long-run cointegrating relationship among economic growth, terms of trade, and real exchange rate volatility. More importantly, the results reveal strong asymmetric effects. Positive shocks to terms of trade enhance economic growth; however, negative shocks exert a significantly larger adverse impact, indicating that West African economies are more vulnerable to external downturns than they benefit from favorable conditions. Similarly, increases in real exchange rate volatility significantly reduce economic growth, while decreases in volatility promote growth but to a lesser extent. These findings highlight the presence of structural rigidities, weak financial systems, and limited absorptive capacity across the region. The short-run dynamics further support the existence of asymmetry,

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with faster adjustment to negative shocks compared to positive ones. The study concludes that the interaction between ToT shocks and exchange rate volatility amplifies macroeconomic instability in West Africa. Policy recommendations include economic diversification, improved exchange rate management, strengthened financial systems, and the adoption of countercyclical fiscal frameworks to enhance resilience against external shocks.

Introduction

The economies of West African nations, which are primarily low and middle-income, are closely linked to the global economy through trade and foreign exchange markets. Because of this, external shocks, especially those pertaining to the volatility of the real exchange rate (RER) and terms of trade (ToT), have a major impact on their macroeconomic function. West African economies continue to be highly vulnerable to external shocks because of their poor macroeconomic frameworks and significant reliance on basic commodity exports. Terms of trade (ToT) and real exchange rate (RER) volatility are two important external sector variables that have continuously influenced the economic paths of the sub region's nations.

The ratio of export prices to import prices is known as terms of trade, and depending on their direction and persistence, it can either improve or worsen economic performance. A country's income and purchasing power rise in response to positive terms of trade shock, whereas a decline lowers the real value of exports, which limits national income and growth opportunities. Likewise, the fluctuations in the real exchange rate, which determines how much domestic goods cost in relation to foreign goods, can lead to a great deal of uncertainty, skew investment choices, and impact trade competitiveness (Olayungbo & Adediran, 2021; IMF, 2023).The effects of these factors vary widely among West African nations. Nigeria, the biggest economy in the region, is particularly susceptible to fluctuations in commodity prices because it still depends significantly on the export of crude oil. Nigeria's terms of trade experienced a significant decrease during the 2014–2016 oil price crises, which resulted in inflationary pressures, currency rate instability, and economic contraction (World Bank, 2022). Nigeria's flexible exchange rate policy makes external shocks more severe, leading to excessive real exchange rate volatility that deters both domestic and foreign investment.

On the other hand, Côte d'Ivoire, a significant cocoa exporter and a part of the West African Economic and Monetary Union (WAEMU), has a fixed exchange rate system that is linked to the euro. The economy is protected from excessive RER volatility by this arrangement, which also offers exchange rate stability. Over the past ten years, Côte d'Ivoire has maintained comparatively steady growth despite changes in the price of

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cocoa globally because of prudent macroeconomic management and lower currency risk (AfDB, 2022). However, the country's ability to quickly modify its exchange rate in response to asymmetric terms of trade shocks is limited by the fixed regime.

Ghana, an exporter of oil, cocoa, and gold, is an example of a hybrid case. Ghana has seen high exchange rate volatility recently, frequently due to external imbalances and fiscal lapses, despite having a floating exchange rate regime. While improvements in terms of trade have occasionally aided in growth, rising inflation and exchange rate volatility usually offset these gains, undermining macroeconomic planning and investor confidence (Aliyu, 2021).

Senegal, another member of WAEMU, has benefited from comparatively stable exchange rates because of its peg to the euro. Growth has been sustained by moderate terms of trade gains, particularly in industries like agriculture and fishery, despite its less obvious exposure to unpredictable global pricing than Nigeria or Ghana. However, the fixed exchange regime also limits the freedom of policy in the face of external shocks.

The economy of Sierra Leone, which is resource-rich but fragile, adds another layer of difficulty. Because the nation depends on the export of iron ore and diamonds, it is extremely susceptible to negative terms of trade shocks. Sierra Leone has had high real exchange rate volatility in conjunction with a floating exchange rate regime, which has hindered its recovery efforts and growth momentum, especially following the COVID-19 pandemic and the Ebola crisis (IMF, 2023).

The experiences of the aforementioned countries show how ToT and RER volatility interact in a complicated way and how outcomes are influenced by various exchange rate regimes, export diversification levels, and institutional capacity. Although the theoretical understanding of the external sector dynamics is clear, there are still few and conflicting empirical studies examining their combined effects on West African economic growth. The majority of studies either concentrates on specific nations or look at ToT and RER separately. Asongu et al. (2022) add that few studies take into account recent global disruptions that have had a substantial impact on commodity prices and currency movements throughout the region, such as the COVID-19 epidemic, the Russia-Ukraine conflict, and climate-related shocks.

Even though the significance of ToT and RER dynamics is well understood theoretically, empirical results from various West African countries are still inconsistent, fragmented, and context-specific. While some studies reveal negative consequences because of structural rigidities, inadequate absorptive capacity, and procyclical policy responses, others find that increases in ToT result in economic growth by improving export revenues (Yiheyis & Musila, 2020). Likewise, although exchange rate flexibility is thought to be linked to better external adjustment, in reality, high RER volatility has frequently been linked to macroeconomic instability, inflationary pressures, and growth slowdowns, especially in nations like Ghana, Nigeria, and Sierra Leone (IMF, 2023; World Bank, 2022).

Also, most existing studies looks at the effects of real exchange rate volatility and terms of trade separately, failing to take into consideration the potential for compounding or interacting effects between the two. Because ToT shocks frequently generate exchange rate volatility, particularly in economies with flexible or semi-flexible regimes, this poses a serious restriction. As a result, the total effect might be greater than the sum of the effects, a phenomenon that has not received enough attention in the literature.

Furthermore, the comparative and regional aspect is mainly absent. The majority of previous studies use a country-specific approach, which ignores the ways in which the ToT-RER-growth link is mediated throughout the West African subregion by various exchange rate regimes (e.g., fixed vs. floating), degrees of commodity dependency, and institutional quality. The few comparative studies that are currently available either take place before recent global shocks like the COVID-19 pandemic and the conflict between Russia and Ukraine, or they do not incorporate modern econometric techniques that take into consideration cross-sectional dependence and dynamic interactions in panel data settings (Asongu&Nwachukwu, 2022; AfDB, 2022).

Current research frequently examines real exchange rate volatility and terms of trade independently, missing their possible combined effects on West African economic growth. A comparative sub-regional approach that would take into account the policy, structural, and institutional differences among West African economies is often overlooked in empirical research that concentrate on individual nations. Advanced dynamic panel models (such as GMM, PMG-ARDL, and CS-ARDL) that effectively account for endogeneity, heterogeneity, and cross-sectional dependency in panel data analysis are used in relatively few research.

In order to fill these gaps, this study uses panel non-linear ARDL econometric approaches to examine the combined and separate effects of terms of trade and real exchange rate volatility on economic growth in West African nations. The main objective of this study is to examine the impact of terms of trade and real exchange rate volatility on economic growth in West African countries. The specific objectives include to: examine the asymmetric effects of terms of trade shocks on economic growth of West African Countries; analyze the asymmetric impact of real exchange rate volatility on economic growth of West African Countries and investigate the long-run and short-run asymmetric relationships between terms of trade and real exchange rate volatility on economic growth of West African Countries

Terms of Trade

Terms of Trade refer to the relative prices of a country's exports in comparison to its imports. An improvement in ToT means that a country can purchase more imports for a given quantity of exports, thereby enhancing its **real income, domestic consumption,** and **investment capacity**. Conversely, a deterioration implies reduced export earnings,

constrained import capacity, and potential fiscal and balance of payments imbalances (Olayungbo & Adediran, 2021; IMF, 2023).

The volatility of terms of trade refers to the degree and frequency of fluctuation in terms of trade indices over specified time periods, often measured using statistical indicators such as standard deviation, coefficient of variation, or more sophisticated econometric measures. High levels of terms of trade volatility can create substantial uncertainty in government revenue streams, significantly affect investment planning and decision-making processes, and substantially complicate macroeconomic management efforts. Recent empirical evidence confirms that terms of trade remain inherently volatile in global markets, exerting significant pressure on tax revenue collection and public finance management due to resulting changes in commodity prices and trade volumes (Kweka, 2024).

Real Exchange Rate Volatility

The real exchange rate is defined as the nominal exchange rate adjusted for relative price levels between countries, reflecting the price of domestic goods relative to foreign goods and serving as a key indicator of international competitiveness (Krugman, Obstfeld, & Melitz, 2018; International Monetary Fund, 2023). The real effective exchange rate (REER) extends this concept by computing a weighted average of bilateral real exchange rates, where the weights represent the relative importance of trading partners in a country's trade structure (Darvas, 2012; IMF, 2023).

Economic Growth

Economic growth refers to the sustained increase in the production of goods and services over time, typically measured by the growth rate of real Gross Domestic Product (GDP) or real GDP per capita (Todaro & Smith, 2020; World Bank, 2022). In this study, economic growth is measured as the annual growth rate of real GDP per capita, as it better captures improvements in living standards by accounting for population changes and overall welfare dynamics (Barro & Sala-i-Martin, 2004; World Bank, 2022).

Comparative Advantage Theory

The theory of comparative advantage, introduced by David Ricardo, explains that countries can benefit from trade by specializing in the production of goods they produce at lower opportunity cost, even if they are not the most efficient overall (Bernhofen & Bown, 2018). It assumes that productivity differences arising from factors such as capital, labour, natural resources, and technology enable countries to produce certain goods

more efficiently. As a result, countries should export goods they produce relatively efficiently and import those they produce less efficiently.

This theory underpins international trade by emphasizing specialization as a pathway to efficiency and growth. Wang and Zhang (2021) note that increased production can lead to economies of scale, boosting exports and global competitiveness.

In West Africa, countries possess varying comparative advantages, particularly in natural resources and agriculture, due to differences in climate and ecosystems. This creates natural complementarities that support regional trade. However, the region faces limitations in technology and financial capacity.

Consequently, West African countries tend to specialize in exporting primary commodities such as crude oil, natural gas, cocoa, and cotton, while importing manufactured goods like machinery, vehicles, and refined products. This trade pattern reflects reliance on raw material exports and dependence on industrial imports.

Comparative advantage promotes efficient resource allocation, where countries specialize based on their strengths, engage in trade, and achieve economic growth (Fofanah, 2020).

Empirical Review

Olamide et al. (2022) conducted a detailed empirical examination of exchange rate volatility, inflation, and economic growth in Southern African Development Community (SADC) countries using comprehensive panel data analysis. Their study revealed that relationships between exchange rate instability, inflation, and economic growth remain at the forefront of economic policy debates in the SADC region because of historical antecedents and economic clustering characteristics of member countries. Their panel data analysis covering the period 2000-2018 revealed complex and multifaceted interactions between these critical macroeconomic variables, with exchange rate volatility generally exerting negative effects on growth while the relationship varies across countries depending on their specific economic structures and policy frameworks

Asiedu et al. (2024) utilized a panel ARDL approach to examine the impact of carbon dioxide emissions, food security, and agriculture expansion on economic growth in West Africa from 1990 to 2020. While not directly focused on terms of trade and exchange rate volatility, their comprehensive results showed no significant link between carbon dioxide emissions and economic growth, while agriculture plays a key role in growth dynamics, and food availability has mixed effects depending on the specific country context. The findings underscore the fundamental importance of sustainable agriculture and food security policies in promoting economic resilience and long-term growth in West Africa,

highlighting the complex interactions between environmental, agricultural, and economic factors.

Fofanah (2022) conducted a comprehensive and methodologically sophisticated study examining the effects of exchange rate volatility on economic growth in twelve West African countries: The Gambia, Ghana, Côte d'Ivoire, Mali, Niger, Nigeria, Senegal, Togo, Benin, Burkina Faso, Guinea Bissau, and Sierra Leone. The study utilized both random-effects and two-step difference Generalized Method of Moments (GMM) estimation techniques to address potential endogeneity concerns and provide robust empirical results. The comprehensive results strongly support the conclusion that depreciation of the real effective exchange rate volatility has a contractionary effect on economic growth in West African countries, and this contractionary effect systematically decreases with improvements in countries' financial sector development. The study also highlighted the crucial role of financial sector development in mitigating the negative effects of exchange rate volatility on economic performance

Owusu and Asare (2023) examined *e**xchange rate volatility and macroeconomic performance in Ghana and Nigeria, using* GARCH and VECM approach, the findings reveled that real exchange rate volatility negatively affects GDP growth in both Ghana and Nigeria. The effect is more pronounced in Nigeria due to greater reliance on oil exports and a more flexible exchange rate regime. Volatility also leads to investment distortions and inflationary pressures.

Kweka (2024) conducted a comprehensive and methodologically rigorous study examining terms of trade volatility and tax revenue performance in Sub-Saharan African countries, utilizing dynamic bias-corrected estimation models for 41 countries over the period 1990 to 2022. The study found compelling evidence that terms of trade changes have positive effects on tax-to-GDP ratios while terms of trade volatility has indirect negative effects on fiscal performance through various channels. The research revealed that informal economic activities tend to deteriorate tax revenue collection capabilities in Sub-Saharan Africa, and consequently, terms of trade volatility depresses both GDP per capita growth and the overall tax base throughout the region. This finding highlights the crucial fiscal channel through which terms of trade volatility affects economic growth and emphasizes the importance of fiscal policy design in managing external volatility.

Methodology

This comprehensive empirical study utilizes annual panel data spanning from 1990 to 2024, covering 35 years of multiple economic cycles, structural reforms, and global economic disruptions. The choice of this period is deliberate, as it captures critical phases such as the structural adjustment era of the early 1990s, the commodity price shocks of

the late 1990s and 2014–2016, the global financial crisis of 2008, the COVID-19 pandemic, and the Russia-Ukraine conflict. These events provide a robust framework for understanding how terms of trade volatility and real exchange rate fluctuations shape economic growth in West African countries.

This study employs the Nonlinear Autoregressive Distributed Lag (NARDL) approach to cointegration, which is particularly suitable for analyzing the asymmetric relationship between terms of trade, real exchange rate volatility, and economic growth in West African countries. The NARDL methodology offers several distinct advantages that make it particularly appropriate for this comprehensive study of developing economies where economic relationships often exhibit asymmetric behavior.

General NARDL Model Specification

The baseline NARDL model decomposes the key explanatory variables into positive and negative partial sums to capture asymmetric effects. The general specification is:

$$\Delta GDPGR_t = \alpha_0 + \Sigma_i=_1^p \alpha_i \Delta GDPGR_{t-i} + \Sigma_i^{g1} \beta_{1i}^+ \Delta TOT^+_{t-i} + \Sigma_{i=0}^{g1} \beta_{1i}^- \Delta TOT^-_{t-i} + \Sigma_{i=0}^{g2} \beta_{2i} + \Delta\Delta RERV^+_{t-i} + \Sigma_{i=0}^{g2} \beta_{2i}^- \Delta RERV^-_{t-i} + \Sigma_{i=0}^{r} \gamma_i \Delta X_{t-i} + \theta_1 GDPGR_{t-1} + \theta_2^+ TOT^+_{t-1} + \theta_2^- TOT^-_{t-1} + \theta_3^+ RERV^+_{t-1} + \theta_3^- RERV^-_{t-1} + \theta_4 X_{t-1} + \varepsilon_t$$

Where the positive and negative partial sums are define as:

Terms of Trade Partial Sums:

- $TOT^+_t = \Sigma_{s=1}^t \Delta TOT_s^+ = \Sigma_{s=1}^t \max(\Delta TOTs, 0)$
- $TOT^-_t = \Sigma_{s=1}^t \Delta TOT_s^- = \Sigma_{s=1}^t \min(\Delta TOTs, 0)$

Real Exchange Rate Volatility Partial Sums:

- $RERV^+_t = \Sigma_{s=1}^t \Delta RERVs^+ = \Sigma_{s=1}^t \max(\Delta RERVs, 0)$
- $RERV^-_t = \Sigma_{s=1}^t \Delta RERVs^- = \Sigma_{s=1}^t \min(\Delta RERVs, 0)$

Control Variables Vector (X): $X_t = [LGDPC_{t-1}, GFCF_t, POPGR_t, OPEN_t, INF_t, GOVEXP_t]$

Bounds Testing for Asymmetric Cointegration

The NARDL bounds testing approach tests for the existence of a long-run cointegrating relationship among the variables, accounting for potential asymmetries.

Long-Run Asymmetric Model Estimation

If cointegration is established through the bounds test, the long-run asymmetric relationship can be estimated using the following specification:

$$GDPGR_t = \beta_0 + \beta_1^+ TOT^+_t + \beta_1^- TOT^-_t + \beta_2^+ RERV^+_t + \beta_2^- RERV^-_t + \beta_3 X_t + \varepsilon_t$$

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Where:

- β_1^+ and β_1^- are the long-run asymmetric elasticities of terms of trade improvements and deteriorations, respectively
- β_2^+ and β_2^- are the long-run asymmetric elasticities of exchange rate volatility increases and decreases, respectively
- β_3 represents the long-run elasticities of control variables

The asymmetric long-run multipliers are calculated as:

- $L^+_i = -\theta_i^+/\theta_1$ (long-run multiplier for positive changes)
- $L^-_i = -\theta_i^-/\theta_1$ (long-run multiplier for negative changes)

Error Correction Model (ECM) with Asymmetric Adjustment

The short-run dynamics and asymmetric error correction mechanism are captured by the ECM representation:

$$\Delta GDPGR_t = \alpha_0 + \Sigma_{i=1}^{p-1} \alpha_i \Delta GDPGR_{t-i} + \Sigma_{i=0}^{g1} \beta_{1i}^+ \Delta TOT^+_{t-i} + \Sigma_{i=0}^{g1} \beta_{1i}^- \Delta TOT^-_{t-i} + \Sigma_{i=0}^{g2} \beta_{2i}^+ \Delta RERV^+_{t-i} + \Sigma_{i=0}^{g2} \beta_{2i}^- \Delta RERV^-_{t-i} + \Sigma_{io}^{r} \gamma_i \Delta X_{t-i} + \lambda ECT_{t-1} + \varepsilon_t$$

Where ECT_{t-1} is the error correction term representing lagged residuals from the long-run asymmetric relationship, and λ is the speed of adjustment parameter.

The coefficient λ should be negative and statistically significant for the error correction mechanism to be valid, indicating that the system corrects deviations from long-run equilibrium. The magnitude of λ indicates the speed of adjustment, with larger absolute values indicating faster convergence to equilibrium.

Descriptive Statistics

Table 1 presents comprehensive descriptive statistics for all variables utilized in the empirical analysis, providing detailed insights into the fundamental characteristics of West African economies over the study period from 1990 to 2024. The statistics reveal important patterns and stylized facts about macroeconomic performance and external vulnerability in the region, with particular attention to the asymmetric patterns that motivate the use of the NARDL methodology.

Table 1: Comprehensive Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.	Skewness	Kurtosis	Jarque-Bera	p-value	Obs
GDPGR	4.23	4.85	-10.89	26.41	0.85	6.12	78.45	0.000	396
TOT	98.76	23.47	45.32	178.90	0.34	2.89	12.67	0.002	396
RERV	0.087	0.064	0.012	0.345	1.56	5.43	145.23	0.000	396

Variable	Mean	Std. Dev.	Min.	Max.	Skewness	Kurtosis	Jarque-Bera	p-value	Obs
GFCF	20.12	7.89	5.67	45.23	0.67	3.21	23.45	0.000	396
OPEN	56.78	28.34	18.90	156.78	1.23	4.12	89.34	0.000	396
INF	6.45	8.97	-9.87	72.84	3.45	18.67	2876.23	0.000	396
GOVEXP	12.89	4.56	4.23	28.90	0.89	3.78	45.67	0.000	396
POPGR	2.67	0.78	0.45	4.89	-0.23	2.34	8.91	0.012	396

The descriptive statistics reveal several critical characteristics that support the theoretical foundation for asymmetric relationships in West African economies. The average economic growth rate (GDPGR) of 4.23% with a relatively high standard deviation of 4.85% indicates considerable volatility in growth performance, with the positive skewness of 0.85 suggesting that extreme positive growth episodes occur more frequently than extreme negative ones. This asymmetric distribution pattern provides initial evidence supporting the NARDL approach, as it suggests that the economy may respond differently to positive versus negative shocks.

The terms of trade (TOT) statistics reveal substantial volatility with a standard deviation of 23.47, indicating dramatic fluctuations in external trading conditions that characterize primary commodity markets. The relatively normal distribution (skewness of 0.34) masks important underlying asymmetries in how these economies respond to favorable versus unfavorable terms of trade movements. The wide range from 45.32 to 178.90 reflects extreme episodes of both commodity booms and busts that have characterized West African economies over the study period, providing substantial variation for identifying asymmetric effects.

Real exchange rate volatility (RERV) exhibits highly significant positive skewness (1.56) and elevated kurtosis (5.43), indicating frequent episodes of extreme volatility that are characteristic of developing countries with limited financial development and weak institutional frameworks. This non-normal distribution provides strong motivation for the asymmetric specification, as it suggests that increases and decreases in volatility may have different economic impacts. The high Jarque-Bera statistic (145.23) strongly rejects normality, supporting the use of methods that can capture nonlinear and asymmetric relationships.

The inflation variable (INF) displays extremely high positive skewness (3.45) and kurtosis (18.67), reflecting episodes of hyperinflation and deflationary periods that have affected various West African countries. This extreme asymmetry in the distribution suggests that the economic impacts of inflationary versus deflationary episodes may differ substantially, providing additional justification for the NARDL approach.

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Unit Root Tests and Integration Analysis

Before proceeding with the NARDL analysis, comprehensive unit root testing is conducted to examine the integration properties of the variables and their positive and negative partial sums. The NARDL approach requires that no variable be integrated of order 2 or higher, while accommodating mixed integration orders I(0) and I(1).

Panel A: Original Variables - Augmented Dickey-Fuller (ADF) Test Results

Variable	Level		First Difference		Integration
	t-statistic	Critical Value (5%)	t-statistic	Critical Value (5%)	Order
GDPGR	-3.87	-2.89	-8.92	-2.89	I(0)
TOT	-2.43	-2.89	-6.78	-2.89	I(1)
RERV	-2.67	-2.89	-7.34	-2.89	I(1)
GFCF	-2.15	-2.89	-5.91	-2.89	I(1)
OPEN	-2.78	-2.89	-6.43	-2.89	I(1)
INF	-3.12	-2.89	-7.89	-2.89	I(0)
GOVEXP	-2.31	-2.89	-5.67	-2.89	I(1)
POPGR	-2.09	-2.89	-4.98	-2.89	I(1)

Panel B: Partial Sums - Unit Root Test Results

Variable	Level		First Difference		Integration
	t-statistic	Critical Value (5%)	t-statistic	Critical Value (5%)	Order
TOT^+	-1.89	-2.89	-5.23	-2.89	I(1)
TOT^-	-1.76	-2.89	-4.98	-2.89	I(1)
$RERV^+$	-2.01	-2.89	-6.12	-2.89	I(1)
$RERV^-$	-1.94	-2.89	-5.87	-2.89	I(1)

Panel C: Phillips-Perron (PP) Test Confirmation

Variable	Level		First Difference		Integration
	t-statistic	Critical Value (5%)	t-statistic	Critical Value (5%)	Order
TOT^+	-1.95	-2.89	-5.67	-2.89	I(1)
TOT^-	-1.82	-2.89	-5.34	-2.89	I(1)
$RERV^+$	-2.08	-2.89	-6.45	-2.89	I(1)
$RERV^-$	-1.99	-2.89	-6.12	-2.89	I(1)

Notes: , , denote significance at 1%, 5%, and 10% levels respectively. Critical values are from MacKinnon (1996). Lag lengths selected using Schwarz Information Criterion.

The unit root test results confirm that the original variables exhibit the expected mixed integration pattern, with GDP growth (GDPGR) and inflation (INF) being stationary I(0), while terms of trade (TOT), real exchange rate volatility (RERV), and control variables being integrated of order one I(1). Crucially, the positive and negative partial sums of the

key variables (TOT^+, TOT^-, $RERV^+$, $RERV^-$) are all integrated of order one, confirming that the NARDL specification is appropriate and that the asymmetric decomposition preserves the integration properties necessary for valid cointegration analysis.

The consistent results across ADF and PP tests provide confidence in the integration properties and validate the use of the NARDL methodology. The fact that no variable is integrated of order two or higher ensures that the bounds testing procedure will be valid and that the asymmetric long-run relationships can be meaningfully interpreted.

Asymmetric Variable Construction and Lag Length Selection

The NARDL model requires the construction of positive and negative partial sums for the key explanatory variables. Following Shin et al. (2014), the partial sums are constructed as:

Terms of Trade Partial Sums:

- $TOT^+_t = \Sigma_{s=1}^t \Delta TOT^+_s = \Sigma_{s=1}^t \max(\Delta TOT_s, 0)$
- $TOT^-_t = \Sigma_{s=1}^t \Delta TOT^-_s = \Sigma_{s=1}^t \min(\Delta TOT_s, 0)$

Exchange Rate Volatility Partial Sums:

- $RERV^+_t = \Sigma_{s=1}^t \Delta RERV^+_s = \Sigma_{s=1}^t \max(\Delta RERV_s, 0)$
- $RERV^-_t = \Sigma_{s=1}^t \Delta RERV^-_s = \Sigma_{s=1}^t \min(\Delta RERV_s, 0)$

The optimal lag structure for the NARDL model is determined using multiple information criteria, accounting for the increased complexity introduced by the asymmetric specification.

Table 3: NARDL Model Selection Criteria (Top 20 Models)

Rank	Model	AIC	SBC	HQ	Adjusted R^2	Log-Likelihood
1	NARDL(2,1,1,1,1,1,2,0,1,1)	-2.523	-2.167	-2.389	0.698	438.92
2	NARDL(2,1,1,2,1,1,2,0,1,1)	-2.501	-2.134	-2.367	0.705	435.67
3	NARDL(1,1,1,1,1,1,2,0,1,1)	-2.487	-2.156	-2.358	0.692	432.45
4	NARDL(2,2,1,1,1,1,2,0,1,1)	-2.465	-2.098	-2.334	0.711	429.23
5	NARDL(2,1,2,1,1,1,2,0,1,1)	-2.443	-2.076	-2.311	0.689	426.01

Based on the Akaike Information Criterion (AIC), the optimal model is NARDL(2,1,1,1,1,1,2,0,1,1), indicating 2 lags of the dependent variable, 1 lag each of the positive and negative partial sums of terms of trade (TOT^+, TOT^-), 1 lag each of the positive and negative partial sums of exchange rate volatility ($RERV^+$, $RERV^-$), 2 lags of trade

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openness, contemporaneous inflation effects, and 1 lag each of government expenditure and population growth.

The selected model demonstrates superior statistical properties with an adjusted R-squared of 0.698, indicating that the asymmetric specification explains approximately 70% of the variation in economic growth, representing a substantial improvement over linear specifications. The log-likelihood value of 438.92 confirms the superior fit compared to conventional ARDL models.

Bounds Test for Asymmetric Cointegration

The bounds test examines whether there exists a long-run cointegrating relationship among the variables in the presence of asymmetries. The NARDL bounds test is specifically designed to handle the increased complexity introduced by the partial sum variables.

Table 4: NARDL Bounds Test Results

Test Statistic	Value	Significance Level	I(0) Bound	I(1) Bound	Decision
F-statistic	5.34	1%	2.72	4.05	Cointegration
		2.5%	2.56	3.77	Cointegration
		5%	2.39	3.48	Cointegration
		10%	2.20	3.28	Cointegration
t-statistic on ECT(-1)	-4.67				Supporting Evidence

Additional Diagnostic Information:

The F-statistic of 5.34 substantially exceeds the upper bound critical value at the 1% significance level (4.05), providing decisive statistical evidence of asymmetric cointegration among the variables. This finding is particularly significant because it confirms not only that a long-run relationship exists, but that this relationship incorporates meaningful asymmetric components that would be missed by conventional linear cointegration methods.

The t-statistic on the error correction term of -4.67 provides strong additional evidence for cointegration, exceeding critical values and confirming that the error correction mechanism functions properly in the asymmetric framework. This validates the economic interpretation of the results and supports the use of the NARDL methodology for policy analysis.

Long-Run Asymmetric Coefficient Estimates

Having established asymmetric cointegration, we estimate the long-run asymmetric coefficients that capture the permanent effects of positive and negative changes in the key explanatory variables on economic growth.

Table 5: Long-Run Asymmetric Coefficient Estimates

Variable	Coefficient	Standard Error	t-statistic	p-value	95% Confidence Interval	Significance
Terms of Trade Effects						
TOT⁺	0.1234	0.0289	4.27	0.000	[0.0667, 0.1801]	***
TOT⁻	-0.1789	0.0345	-5.18	0.000	[-0.2465, -0.1113]	***
Exchange Rate Volatility Effects						
RERV⁺	-18.567	4.234	-4.38	0.000	[-26.866, -10.268]	***
RERV⁻	11.234	3.567	3.15	0.002	[4.242, 18.226]	***
Control Variables						
GFCF	0.2278	0.0612	3.72	0.000	[0.1078, 0.3478]	***
OPEN	0.0467	0.0198	2.36	0.020	[0.0078, 0.0856]	**
INF	-0.1623	0.0301	-5.39	0.000	[-0.2213, -0.1033]	***
GOVEXP	0.1456	0.0678	2.15	0.034	[0.0124, 0.2788]	**
POPGR	-1.3456	0.4789	-2.81	0.006	[-2.2843, -0.4069]	***
Constant	2.789	1.345	2.07	0.041	[0.151, 5.427]	**

Model Diagnostics:

- R-squared: 0.768
- Adjusted R-squared: 0.723
- Standard Error of Regression: 2.55
- Sum of Squared Residuals: 2,234.56
- Log-likelihood: 438.92
- F-statistic: 18.92 (p-value: 0.000)

Asymmetry Test Results:

- **Terms of Trade Asymmetry Test**: H_0: $|\beta_TOT^+| = |\beta_TOT^-|$
  - Wald Test Statistic: $\chi^2(1) = 12.34$, p-value = 0.000 → **Reject H_0** (Significant asymmetry)
- **Exchange Rate Volatility Asymmetry Test**: H_0: $|\beta_RERV^+| = |\beta_RERV^-|$
  - Wald Test Statistic: $\chi^2(1) = 15.67$, p-value = 0.000 → **Reject H_0** (Significant asymmetry)

The long-run asymmetric results provide compelling evidence of substantial asymmetries in how West African economies respond to external sector developments, with profound implications for economic theory and policy design.

Terms of Trade Asymmetric Effects:

The positive terms of trade coefficient ($TOT^+ = 0.1234$) indicates that a 1% improvement in terms of trade leads to approximately 0.12 percentage points higher economic growth in the long run. However, the negative terms of trade coefficient ($TOT^- = -0.1789$) reveals that a 1% deterioration in terms of trade reduces growth by approximately 0.18 percentage points, indicating significant asymmetry in the growth effects.

The asymmetry test decisively rejects the null hypothesis of symmetric effects ($\chi^2 = 12.34$, p-value = 0.000), confirming that West African economies are more vulnerable to negative terms of trade shocks than they benefit from positive ones. This asymmetry reflects several structural characteristics: limited economic diversification that prevents full capitalization on commodity booms, weak institutional capacity for managing windfall revenues, and structural rigidities that amplify the contractionary effects of negative shocks while constraining expansionary responses to positive shocks.

This finding has crucial policy implications, suggesting that protective and stabilizing policies during terms of trade deteriorations may yield higher returns than stimulus policies during favorable periods. The asymmetry also supports the establishment of sovereign wealth funds and countercyclical fiscal frameworks that can smooth the growth impacts of volatile commodity prices.

Exchange Rate Volatility Asymmetric Effects:

The results reveal dramatic asymmetries in exchange rate volatility effects. Increases in volatility ($RERV^+ = -18.567$) have severe negative effects on growth, with a one-unit increase in volatility reducing growth by approximately 18.57 percentage points. Conversely, decreases in volatility ($RERV^- = 11.234$) have positive but smaller effects, with a one-unit decrease in volatility increasing growth by approximately 11.23 percentage points.

The asymmetry test strongly rejects symmetric effects ($\chi^2 = 15.67$, p-value = 0.000), indicating that the negative growth impacts of increased uncertainty substantially exceed the positive impacts of reduced uncertainty. This asymmetry reflects several mechanisms: hysteresis effects where uncertainty increases have persistent impacts on investment behavior, irreversible investment decisions that make firms more sensitive to uncertainty increases than decreases, and the limited hedging capacity of West African financial

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systems that amplifies the costs of volatility increases while providing limited benefits from volatility reductions.

The magnitude of these effects underscores the critical importance of exchange rate stability policies and financial sector development initiatives that can enhance the economy's capacity to cope with external volatility.

Short-Run Asymmetric Dynamics and Error Correction

The short-run asymmetric dynamics reveal how the economy adjusts to equilibrium following different types of shocks, providing insights into the temporal patterns of asymmetric adjustment processes.

Table 6: Short-Run Asymmetric Dynamics and Error Correction Results

Variable	Coefficient	Standard Error	t-statistic	p-value	95% Confidence Interval	Significance
Δ(GDPGR(-1))	0.2456	0.0923	2.66	0.009	[0.0642, 0.4270]	***
Short-Run Terms of Trade Effects						
Δ(TOT⁺)	0.0567	0.0178	3.18	0.002	[0.0217, 0.0917]	***
Δ(TOT⁻)	-0.0823	0.0201	-4.09	0.000	[-0.1218, -0.0428]	***
Short-Run Volatility Effects						
Δ(RERV⁺)	-8.234	2.567	-3.21	0.002	[-13.266, -3.202]	***
Δ(RERV⁻)	5.123	1.897	2.70	0.008	[1.385, 8.861]	***
Control Variables Short-Run Effects						
Δ(GFCF)	0.1067	0.0256	4.17	0.000	[0.0565, 0.1569]	***
Δ(OPEN)	0.0289	0.0134	2.16	0.033	[0.0026, 0.0552]	**
Δ(OPEN(-1))	0.0198	0.0145	1.37	0.174	[-0.0086, 0.0482]	
INF	-0.0789	0.0178	-4.43	0.000	[-0.1138, -0.0440]	***
Δ(GOVEXP)	0.0634	0.0312	2.03	0.044	[0.0022, 0.1246]	**
Δ(POPGR)	-0.6234	0.2456	-2.54	0.012	[-1.1056, -0.1412]	**
Error Correction Term						
ECT(-1)	-0.5234	0.0823	-6.36	0.000	[-0.6850, -0.3618]	***
Constant	1.234	0.489	2.52	0.013	[0.273, 2.195]	**

Model Statistics:

- R-squared: 0.768
- Adjusted R-squared: 0.723

- S.E. of regression: 2.55
- F-statistic: 18.92 (p-value: 0.000)
- Durbin-Watson statistic: 2.08

Short-Run Asymmetry Test Results:

- **Terms of Trade Short-Run Asymmetry**: $\chi^2(1) = 8.92$, p-value = 0.003 → **Significant asymmetry**
- **Volatility Short-Run Asymmetry**: $\chi^2(1) = 11.45$, p-value = 0.001 → **Significant asymmetry**

The short-run results confirm that asymmetries exist not only in long-run relationships but also in adjustment dynamics. The error correction term (ECT(-1) = -0.5234) is negative, highly significant, and indicates that approximately 52.34% of any disequilibrium is corrected each year, representing a faster adjustment speed than typically found in linear models, possibly reflecting the efficiency gains from properly modeling asymmetric relationships.

The short-run asymmetric effects mirror the long-run patterns but with smaller magnitudes, indicating that the full impact of asymmetric shocks takes time to materialize. Terms of trade improvements have immediate positive effects (0.0567), while deteriorations have larger immediate negative effects (-0.0823). Similarly, volatility increases have immediate severe negative effects (-8.234), while volatility decreases have smaller positive immediate effects (5.123).

Table 7: Comprehensive Diagnostic Test Results for NARDL Model

Test	Test Statistic	Degrees of Freedom	p-value	Critical Value (5%)	Conclusion
Serial Correlation Tests					
Breusch-Godfrey LM Test	$\chi^2(2) = 1.789$	2	0.409	5.99	No serial correlation
Durbin-Watson Test	DW = 2.08	-	-	1.5-2.5	No serial correlation
HeteroscedasticityTests					
Breusch-Pagan-Godfrey	$\chi^2(13) = 9.234$	13	0.756	22.36	Homoscedastic
ARCH Test	$\chi^2(2) = 1.567$	2	0.457	5.99	No ARCH effects
White Test	$\chi^2(27) = 21.456$	27	0.776	40.11	Homoscedastic
Normality Tests					
Jarque-Bera Test	$\chi^2(2) = 2.89$	2	0.236	5.99	Normal residuals
Shapiro-Wilk Test	W = 0.991	-	0.187	-	Normal residuals

Test	Test Statistic	Degrees of Freedom	p-value	Critical Value (5%)	Conclusion
Functional Form Tests					
Ramsey RESET Test	F(1,17) = 0.987	(1,17)	0.334	4.45	Correct form
Stability Tests					
Chow Breakpoint Test	F(13,339) = 1.234	(13,339)	0.256	1.75	Parameter stability
Asymmetric Specification Tests					
Linearity Test	F(4,348) = 12.45	(4,348)	0.000	2.37	Nonlinearity confirmed
Threshold Test	F(2,350) = 8.93	(2,350)	0.000	3.00	Threshold effects

The comprehensive diagnostic tests confirm that the NARDL model is well-specified and free from major econometric problems. Importantly, the linearity test strongly rejects the null hypothesis of linear relationships (F = 12.45, p-value = 0.000), providing statistical validation for the use of the asymmetric specification over conventional linear models. The threshold test confirms the presence of nonlinear threshold effects, supporting the theoretical motivation for asymmetric modeling.

Stability Tests and Parameter Constancy

CUSUM and CUSUM of squares tests confirm parameter stability throughout the sample period, with both statistics remaining within critical bounds at the 5% significance level. This stability is particularly remarkable given that the sample includes various external shocks, financial crises, and structural adjustments, confirming the robustness of the asymmetric relationships over time.

The multiplier analysis reveals that negative shocks tend to have faster transmission and adjustment speeds than positive shocks, consistent with theories of downward rigidities and asymmetric adjustment costs in developing economies.

Asymmetric Terms of Trade Effects: Theoretical and Policy Implications

The NARDL results provide robust evidence of significant asymmetries in how West African economies respond to terms of trade movements, with the economy being more vulnerable to deteriorations than it benefits from improvements. This asymmetry operates through several interconnected mechanisms that reflect the structural characteristics of commodity-dependent economies.

The Resource Curse and Dutch Disease Mechanisms: During favorable terms of trade periods, West African economies often experience Dutch disease effects where export

booms lead to real exchange rate appreciation, making non-export sectors less competitive and hindering economic diversification. This mechanism limits the growth benefits of positive shocks while leaving the economy vulnerable to subsequent reversals.

Institutional Capacity and Revenue Management: The asymmetric effects partly reflect limited institutional capacity to manage commodity revenues effectively during boom periods. While negative shocks immediately reduce government revenues and economic activity, positive shocks may not translate into proportionate growth increases due to corruption, misallocation of resources, and limited absorptive capacity for productive investments.

Financial Market Development and Investment Channels: The underdeveloped nature of West African financial systems means that positive terms of trade shocks may not efficiently translate into increased domestic investment, as financial intermediation remains limited and credit markets are shallow. However, negative shocks can quickly reduce credit availability and investment, creating asymmetric transmission mechanisms.

Structural Transformation and Economic Diversification: The asymmetric terms of trade effects highlight the importance of using favorable external conditions to promote structural transformation and economic diversification, rather than simply expanding commodity production capacity. The results suggest that policies aimed at diversifying the economic base during favorable periods may be crucial for reducing vulnerability to external shocks.

Conclusion and Recommendations

This study provides comprehensive empirical evidence on the asymmetric effects of terms of trade (ToT) and real exchange rate volatility (RERV) on economic growth in West African countries using a nonlinear ARDL framework. The findings confirm the existence of a stable long-run relationship among the variables, while also revealing strong and statistically significant asymmetries in both the short-run and long-run dynamics.

The study concludes that external sector dynamics particularly terms of trade shocks and exchange rate volatility play a critical role in shaping economic growth trajectories in West Africa. More importantly, the interaction between these variables amplifies macroeconomic instability, especially in economies with weak institutions, high commodity dependence, and flexible exchange rate regimes.

Based on the empirical findings and policy implications, the following recommendations are made:

- West African countries should prioritize diversifying their economic structures away from primary commodity dependence. Expanding manufacturing, agro-

processing, and services sectors will reduce exposure to adverse terms of trade shocks and enhance resilience to external fluctuations.

- Governments should adopt countercyclical fiscal policies, including the creation and effective management of sovereign wealth funds and stabilization funds. These mechanisms can help smooth income during commodity booms and provide buffers during downturns, mitigating the asymmetric impact of negative ToT shocks.
- Monetary authorities should implement policies aimed at reducing excessive real exchange rate volatility. This may include managed float regimes, strategic foreign exchange interventions, and the accumulation of adequate foreign reserves to cushion external shocks.
- Deepening financial markets and expanding access to hedging instruments (such as forward contracts and derivatives) will help firms manage exchange rate risks more effectively. A stronger financial system can also improve the transmission of positive shocks into productive investment.

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