

Decoupling Economic Growth from Fossil Fuel Dependence: Assessing the Asymmetric Impact of Price Deregulation on Renewable Energy Substitution in Nigeria.

*Elizabeth Oluwabunmi Taiwo¹, Peter Adamu², Wasiu Oyeniran³ & Salihu Ayodeji⁴

^{1,3,4}*Department of Economics, Nigerian Defence Academy, Nigeria.*

²*Department of Economics, Nigerian Defence Academy, Nigeria.*

*Corresponding Author: elizabeth.bunmi.taiwo@gmail.com

Abstract

This study examines the asymmetric impact of fossil fuel price deregulation on renewable energy substitution in Nigeria, evaluating whether escalating retail pump prices serve as a catalyst for clean technology adoption or exacerbate structural energy poverty. Utilizing quarterly time-series data 2004Q1-2025Q4, the empirical framework models the interactive dynamics between disaggregated Premium Motor Spirit retail pump prices (PMSP⁺, PMSP⁻), real per capita income (PCRGP), nominal foreign exchange rates (EXR), national electricity grid generation (ELEC), and renewable energy capital imports (REN). Employing a Non-Linear Autoregressive Distributed Lag (NARDL) bounds testing approach, the empirical results confirm a robust long-run cointegrating relationship. Formal Wald test restrictions fail to reject symmetry in the short run and show only weak long-run price asymmetry indicating that while fuel price shocks drive overall energy adjustments, short-run substitution mechanisms respond largely symmetrically alongside severe macroeconomic bottlenecks. While positive long-run price shocks exhibit a positive elasticity, immediate clean energy substitution is severely constrained by foreign exchange devaluation pass-through (EXR) and real income limitations (PCRGP). Furthermore, persistent public utility grid failure forces commercial enterprises into involuntary generator reliance. To resolve this "Energy Transition Paradox," this study recommends that fiscal savings realized from fuel subsidy removal be recycled into targeted import tariff waivers, zero-rated VAT schemes, and concessional foreign exchange allocation for imported off-grid renewable energy hardware.

Keywords: Energy Transition Paradox, Fossil Fuel Deregulation, NARDL, Renewable Energy Substitution, Asymmetric Price Transmission, Nigeria.

1. Introduction

The global energy landscape is currently undergoing a structural transformation driven by the imperative to mitigate climate change and achieve UN Sustainable Development Goals 7 and 13 (UN DESA, 2021; United Nations, 2020). Advanced and emerging economies alike are deploying market-based instruments, carbon pricing, and subsidy removals to decouple economic growth from fossil fuel dependence (Adebayo et al., 2024; World

Bank, 2023). However, Sub-Saharan Africa faces an acute trilemma between expanding universal energy access, sustaining industrial output, and transitioning toward low-carbon vectors (Okonkwo & Eze, 2024; UN DESA, 2021). As expanding fiscal deficits force African governments to eliminate fuel subsidies, domestic consumers are exposed directly to global commodity market volatility (Kwame & Ofori, 2025; Obasaju

et al., 2023). Across West Africa, these deregulation initiatives trigger immediate inflationary shocks, testing household resilience amidst currency devaluations and severe power grid fragility (Greve & Lay, 2022; Mensah & Adu, 2022).

In Nigeria, the May 2023 complete removal of Premium Motor Spirit (PMS) subsidies and foreign exchange unification represented an unprecedented macroeconomic shock (KPMG, 2023; Obasaju et al., 2023). Because persistent public electricity grid failures force widespread reliance on private petrol generators, rising retail pump prices should theoretically catalyze consumer substitution toward renewable vectors like solar photovoltaic systems (Amadi & Alamu, 2025; Eze & Okonkwo, 2024). However, severe local currency devaluation (EXR) and falling real per capita income (PCRGDP) make the initial capital outlay for imported renewable hardware prohibitively expensive (Danjuma et al., 2026; Musa et al., 2025). The core problem investigated in this study is the "Energy Transition Paradox": does fossil fuel deregulation act as a catalyst for clean energy substitution, or does it simply deepen structural energy poverty (Hassan & Sanusi, 2023; Olanrewaju & Kalu, 2023)? Standard microeconomic substitution theory assumes frictionless markets, ignoring asymmetric price transmission, foreign exchange pass-through bottlenecks, and involuntary generator dependence (Borenstein et al., 1997; Goldberg & Knetter, 1997).

To address this structural friction, the primary objective of this study is to evaluate the asymmetric impact of fossil fuel price deregulation on renewable energy substitution in Nigeria within a Non-Linear Autoregressive Distributed Lag (NARDL) framework (Pesaran et al., 2001; Shin et al., 2014). Specifically, the study examines long-run cointegration dynamics between retail pump prices, real

per capita income, grid output, exchange rates, and renewable energy consumption (Chukwu & Nnadi, 2024; Danjuma et al., 2026). It further measures the short-run and long-run asymmetric response of renewable energy consumption to positive (PMSP⁺) and negative (PMSP⁻) changes in retail fuel prices (Adebayo et al., 2024; Kwame & Ofori, 2025). Additionally, it evaluates the cross-modulating effects of foreign exchange rate volatility (EXR) and public grid reliability (ELEC) on domestic energy substitution trajectories (Musa et al., 2025; Tihamiyu et al., 2022). By addressing these objectives, the study provides an empirical blueprint for recycling fuel subsidy savings into targeted tariff relief for imported clean energy hardware (Nkosi & Dlamini, 2024; Yusuf et al., 2022).

This study is structured into five sequential chapters encompassing the introduction and problem context, literature review and theoretical framework, NARDL methodology, empirical results and discussion, and strategic policy recommendations.

2. Literature Review

Fossil fuel price deregulation involves transitioning from state-administered pricing ceilings to market-determined retail fuel pricing, directly exposing domestic markets to international crude benchmarks and exchange rate volatility. In response to these changing relative prices, energy substitution occurs as households and firms reallocate capital from refined petroleum products toward alternative clean energy vectors like solar photovoltaic systems. However, this economic transition depends heavily on cross-price elasticity, capital availability, and the initial fixed capital outlay required for off-grid renewable installations. When retail pump prices escalate rapidly alongside severe local currency devaluations and depressed disposable

incomes, households face severe financial constraints in acquiring green technology. Consequently, rising fuel prices under macroeconomic instability create severe energy access challenges rather than triggering an immediate transition toward clean energy alternatives.

Under these macroeconomic conditions, energy substitution choice is constrained by exchange rate pass-through and public electricity grid performance. Because clean energy hardware is predominantly imported, domestic currency depreciation inflates local acquisition costs, offsetting the market substitution incentive created by fuel deregulation. Furthermore, chronic utility grid instability forces commercial enterprises and households to maintain petrol generators for baseline energy needs. Analyzing these complex interactions provides critical insights into how market non-linearities, exchange rate dynamics, and public utility performance influence renewable technology adoption in developing resource-dependent economies. Ultimately, this inquiry advances energy economics by integrating non-linear price dynamics into Sub-Saharan Africa's transition literature while providing actionable empirical policy blueprints for the Central Bank of Nigeria and energy sector regulators.

Recent empirical inquiries confirm that market non-linearities and macro-financial stability significantly condition clean energy adoption across developing nations. Empirical evidence shows that real per capita income and exchange rate stability exert a stronger quantile impact on green technology adoption than fossil fuel deregulation alone (Danjuma et al., 2026). In petroleum retail markets, vendors exhibit rapid upward price adjustments during global crude oil spikes alongside downward price stickiness during market declines (Kwame & Ofori, 2025). Although positive fuel price shocks stimulate short-run demand for off-grid

solar systems, long-run substitution remains severely constrained by local currency devaluations (Adebayo et al., 2024). Furthermore, negative fuel price shocks do not yield equal reductions in clean energy adoption because solar photovoltaic installations represent high irreversible sunk costs (Hassan & Sanusi, 2023).

Imported green hardware costs and liquidity constraints further mediate the relationship between fuel price shocks and clean technology adoption. Currency depreciation significantly inflates the retail acquisition prices of imported solar hardware, neutralizing the market substitution incentives generated by rising pump prices (Musa et al., 2025). Consequently, fuel price hikes drive renewable substitution only when accompanied by low import tariffs and stable foreign exchange markets (Nkosi & Dlamini, 2024). In the short run, cross-price elasticity between petrol and solar equipment remains highly inelastic, turning elastic in the long run only as financial liquidity improves (Chukwu & Nnadi, 2024). Abrupt fuel subsidy removals often induce immediate energy access shocks due to high capital entry barriers, while general equilibrium impacts reveal cost-push inflation that reduces disposable income and delays renewable upgrades across urban and rural households (Obasaju et al., 2023; Olanrewaju & Kalu, 2023; Mensah & Adu, 2022; Yusuf et al., 2022).

The persistence of public grid failure further alters energy substitution behaviour by creating structural reliance on self-generation. When faced with rising fuel costs and an unreliable power grid, small business operators frequently convert petrol generators to dual-fuel systems as an intermediate cost-mitigation measure rather than making a full transition to solar infrastructure (Amadi & Alamu, 2025). Persistent electricity grid outages force

commercial firms to maintain fossil-fueled generators as baseline power sources, creating involuntary energy stacking regardless of escalating retail petrol prices (Eze & Okonkwo, 2024). As a result, manufacturing firms allocate up to thirty-five percent of operational expenditure to self-generated fossil power (Tiamiyu et al., 2022). This heavy operational expenditure burden continuously drains corporate liquidity, preventing firms from making long-term capital investments in off-grid renewable infrastructure.

2.2 Gaps in the Literature

Existing empirical literature in Nigeria predominantly evaluates fuel price deregulation using symmetric linear models that assume equal consumer responses to price increases and drops. Additionally, previous studies analyze retail price hikes in isolation without modelling how foreign exchange pass-through inflates imported solar hardware acquisition costs. Furthermore, standard demand frameworks assume utility power acts as a viable backup, ignoring how national grid outages force involuntary generator reliance regardless of fuel price spikes. This study addresses these gaps by evaluating asymmetric fuel price shocks, foreign exchange volatility, and grid outages within a unified non-linear substitution framework.

3. Methodology

This study anchors its empirical framework on Neoclassical Demand Theory, Asymmetric Price Transmission Theory, and Exchange Rate Pass-Through (ERPT) Theory to capture non-linear energy substitution. Neoclassical Demand Theory establishes how escalating retail petrol prices (PMSP) shift consumer marginal rates of substitution toward renewable energy substitutes (REN) under strict income constraints (PCRGDP). However, because structural market rigidities cause asymmetric adjustments,

Asymmetric Price Transmission Theory justifies decomposing fuel prices into cumulative positive (PMSP⁺) and negative (PMSP⁻) partial sum processes. Complementing consumer-side choice models, ERPT Theory explains how foreign exchange depreciation (EXR) inflates domestic procurement costs of imported clean hardware, while public grid failure (ELEC) drives involuntary generator reliance. Given that all underlying series exhibit non-stationary properties integrated of order one I(1) the Non-Linear Autoregressive Distributed Lag (NARDL) methodology developed by Shin et al. (2014) provides a robust platform to establish long-run cointegrating vectors while accounting for asymmetric adjustment dynamics.

3.1 Model Specification and Variable Decomposition

To reconcile the theoretical drivers into an operational econometric framework, the aggregate functional demand model is specified as $REN_t = f(PMSP_t^+, PMSP_t^-, PCRGDP_t, EXR_t, ELEC_t)$. Following Pesaran et al. (2001) for bounds testing and Shin et al. (2014) for non-linear symmetric extensions, the primary regressor is decomposed into partial cumulative sum processes. Specifically, the process of decomposition follows Shin et al. (2014) by defining $\ln PMSP_t = \ln PMSP_0 + \ln PMSP_t^+ + \ln PMSP_t^-$, where partial sums represent positive and negative price movements. Positive partial sum changes are specified as

$$\begin{aligned} \ln PMSP_t^+ &= \sum_{i=1}^t \Delta \ln PMSP_i^+ \\ &= \sum_{i=1}^t \text{Max}(\Delta \ln PMSP_i, 0) \end{aligned}$$

whereas negative changes are defined as

$$\begin{aligned} \ln PMSP_t^- &= \sum_{i=1}^t \Delta \ln PMSP_t^- \\ &= \sum_{i=1}^t \text{Min}(\Delta \ln PMSP_i, 0) \end{aligned}$$

The model lists its variables in a single comprehensive logarithmic sentence where natural log transformations of renewable energy imports ($\ln REN_t$), positive pump price shocks ($\ln PMSP_t^+$), negative pump price shocks ($\ln PMSP_t^-$), real per capita GDP ($\ln PCRGDP_t$), nominal exchange rate ($\ln EXR_t$), and grid electricity generation ($\ln ELEC_t$) ensure constant variance across the quarterly time-series.

Following the variable decomposition procedures outlined in Shin et al. (2014), the unrestricted dynamic error correction NARDL model is specified as:

$$\begin{aligned} \Delta \ln REN_t &= \alpha_0 + \theta \ln REN_{t-1} + \\ &\gamma_1^+ \ln PMSP_{t-1}^+ + \gamma_2^- \ln PMSP_{t-1}^- + \\ &\gamma_3 \ln PCRGDP_{t-1} + \gamma_4 \ln EXR_{t-1} + \\ &\gamma_5 \ln ELEC_{t-1} \\ &+ \sum_{i=1}^{p-1} \pi_i \Delta \ln REN_{t-i} \\ &+ \sum_{i=0}^{q1-1} \Phi_i^+ \Delta \ln PMSP_{t-i}^+ \\ &+ \sum_{i=0}^{q2-1} \Phi_i^- \Delta \ln PMSP_{t-i}^- \end{aligned}$$

$$\begin{aligned} &+ \sum_{i=0}^{q3-1} \omega_i \Delta \ln PCRGDP_{t-i} \\ &+ \sum_{i=0}^{q4-1} \Psi_i \Delta \ln EXR_{t-i} \\ &+ \sum_{i=0}^{q5-1} \delta_i \Delta \ln ELEC_{t-i} + e_t \end{aligned}$$

In the above equation, Δ denotes the first-difference operator, while θ is the autoregressive parameter, and γ_k represent the unconstrained long-run level coefficients. The normalized long-run asymmetric price elasticities are computed as $\beta^+ = -\gamma_1^+ / \theta$ and $\beta^- = -\gamma_2^- / \theta$. The short-run dynamic adjustment parameters are captured by $\pi, \phi^+, \phi^-, \omega, \Psi$, and δ , providing a complete non-linear dynamic specification. Once cointegration is established, the short-run restricted error correction model (ECM) :

$$\begin{aligned} \Delta \ln REN_t &= \alpha_0 + \lambda ECT_{t-1} \\ &+ \sum_{i=1}^{p-1} \pi_i \Delta \ln REN_{t-i} \\ &+ \sum_{i=0}^{q1-1} \phi_i^+ \Delta \ln PMSP_{t-i}^+ \\ &+ \sum_{i=0}^{q2-1} \phi_i^- \Delta \ln PMSP_{t-i}^- \\ &+ \sum_{i=0}^{q3-1} \omega_i \Delta \ln PCRGDP_{t-i} \\ &+ \sum_{i=0}^{q4-1} \Psi_i \Delta \ln EXR_{t-i} \\ &+ \sum_{i=0}^{q5-1} \delta_i \Delta \ln ELEC_{t-i} \\ &+ \epsilon_t \end{aligned}$$

In the above equation, ECT_{t-1} represents the error correction term derived from the long-run cointegrating vector, while λ measures the speed of adjustment back to

equilibrium following external price shocks .A statistically significant negative coefficient ($-1 < \lambda < 0$) confirms stable long-run dynamics and validates that short-run disequilibrium corrects over time. Because all underlying series are strictly integrated of order one $I(1)$,establishing cointegration against upper -bound critical values guarantees validates non-spurious estimations across both equations.

This study utilizes quarterly time-series data for Nigeria, with all variables transformed into natural logarithms (ln) to stabilize variance. The dependent variable, renewable energy adoption (lnREN), is proxied by off-grid solar equipment import values sourced from UN Comtrade and the

National Bureau of Statistics (NBS). Retail petrol prices (lnPMSP), obtained from the NBS and Central Bank of Nigeria (CBN), are decomposed into positive (lnPMSP⁺) and negative (lnPMSP⁻) partial sums, with positive shocks expected to increase clean energy adoption ($\beta > 0$). Sourced from the CBN and World Development Indicators, real per capita GDP (lnPCRGP) controls for purchasing power ($\beta > 0$), whereas the official exchange rate (lnEXR) is expected to exert a negative impact ($\beta < 0$) due to import-cost inflation. Finally, grid electricity output (lnELEC), obtained from the Transmission Company of Nigeria, measures utility performance, with higher grid availability expected to reduce off-grid renewable demand ($\beta < 0$).

4. Results and Discussions of Findings

4.1.1.Descriptive Statistics

	LNREN	LNPMSP	LNPCRGP	LNEXR	LNELEC
Mean	3.3602	4.8228	7.7733	5.5191	10.2876
Median	3.2740	4.5831	7.8077	5.1419	10.3254
Maximum	6.2628	7.2157	7.8996	7.3936	10.5199
Minimum	0.6451	3.8767	7.5258	4.7479	9.8998
Std.Dev	1.5834	0.8392	0.0986	0.7362	0.1917
Skewness	0.1290	1.3700	-1.0890	1.2197	-0.5069
Kurtosis	2.0025	4.2421	3.0791	3.6678	1.8147
Jarque-Bera	3.8925	33.1856	17.4141	23.4563	8.9210
Probability	0.1428	0.0000	0.0002	0.0000	0.0115
Sum	295.7001	424.4107	684.0461	485.6782	905.3095
Sum Sq.Dev.	218.1329	61.2752	0.8460	47.1638	3.1994
Observations	88	88	88	88	88

4.1.2 Unit Root Test ADF

Variables	t-statistics	5% critical	P value	First Diff	5% critical	P value	I(0) or I(1) Levels	I(0) Or I(1) First-Diff
	ADF	Value		t-statistics	Value			
LNREN	-1.4577	-3.4635	0.8363	-4.5408	-3.4629	0.0024		I(1)
LNPMSP	-0.5325	-3.4635	0.9802	-4.8748	-3.4629	0.0008		I(1)

LNPCRGP	-1.9972	-	0.5943	-3.5344	-	0.0420	I(1)
		3.4635			3.4629		
LNEXR	-2.9027	-	0.1670	-4.0456	-	0.0107	I(1)
		3.4635			3.4629		
LNELEC	-2.9234	-	0.1606	-4.0394	-	0.0109	I(1)
		3.4635			3.4629		

4.1.3 NARDL Bounds Test

F-Bounds Test		Null Hypothesis:		No levels	relationship
Test Statistic	Value	Signif	I(0)	I(1)	
F-statistic	4.270223	10%	Asymptotic:	n=1000	
k	5	5%	2.26	3.35	
		2.5%	2.62	3.79	
		1%	2.96	4.18	
Actual Sample Size	86		3.41	4.68	
			Finite Sample:	n=80	
		10%	2.355	3.5	
		5%	2.787	4.015	
		1%	3.725	5.163	

4.1.4 Long Run Asymmetric Coefficient

Variable	Coefficient	Std.Error	t-Statistic	Prob
LOG PMSP ⁺	0.5052	1.0673	0.4733	0.5234
LOG PMSP ⁻	4.2131	5.2439	0.8034	0.4243
LOG PCRGP	12.2475	5.8947	2.0777	0.0412
LOG EXR	1.6914	1.2807	1.3207	0.1907
LOG ELEC	-1.5640	2.4423	-0.6406	0.5239

EC=LNREN-(0.5052*LNPMSP⁺ + 4.2131*LNPMSP⁻ + 12.2475*LN PCRGP +1.6914*LNEXR-1.5640*LNELEC)

4.1.5 Short Run Asymmetric Coefficient

Variable	Coefficient	Std.Error	t-Statistic	Prob
C	0.9448	0.3707	2.5487	0.0129
LN REN (-1)	0.0107	0.0059	1.8027	0.0755
LN PMSP ⁺ (1)	-0.0054	0.0090	-0.5994	0.5507
LN PMSP ⁻ (-1)	-0.0453	0.0309	-1.4612	0.1482
LN PCRGP(-1)	-0.1313	0.0395	-3.3213	0.0014
LN EXR (-1)	-0.0181	0.0137	-1.3164	0.1921
LN ELEC(-1)	0.0167	0.0221	0.7559	0.4521
D (LN REN (-1))	0.3348	0.0870	3.8451	0.0003
D(LNPMSP ⁻)	0.1366	0.0482	2.8333	0.0059
D (LNPCRGP)	0.6418	0.3111	2.0628	0.0426
D (LN EXR)	0.0811	0.0276	2.9367	0.0044

D (LN ELEC(-1))	0.2662	0.0906	2.9374	0.0044
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4.1.6 Long Run Wald Test

Test Statistic	Value	df	Probability
t-statistic	1.6770	73	0.0978
F-statistic	2.8124	(1,73)	0.0978
Chi-square	2.8124	1	0.0935

Null Hypothesis: $C(3) = C(5)$

Null Hypothesis Summary

Normalized Restriction (=0)	Value	Std.Err
$C(3) - C(5)$	0.1651	0.0984

4.1.7 Short Run Wald Test

Test Statistic	Value	df	Probability
t-statistic	-1.4202	73	0.1598
F-statistic	2.0168	(1,73)	0.1598
Chi-square	2.0168	1	0.1556

Null Hypothesis : $C(3) = C(4)$

Null Hypothesis Summary

Normalized Restriction (=0)	Value	Std.Err
$C(3) - C(4)$	-0.1426	0.1004

4.1.8 Breusch -Godfrey Serial Correlation LM Test

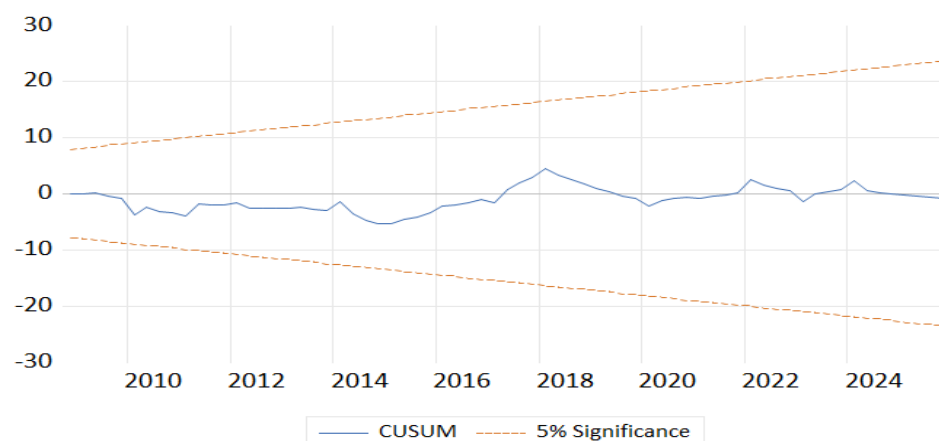
Null hypothesis : No serial correlation at up to 2 lags

F-statistic	0.4503	Prob.F(2,71)	0.6393
Obs*R-squared	1.0771	Prob.Chi-Square (2)	0.5836

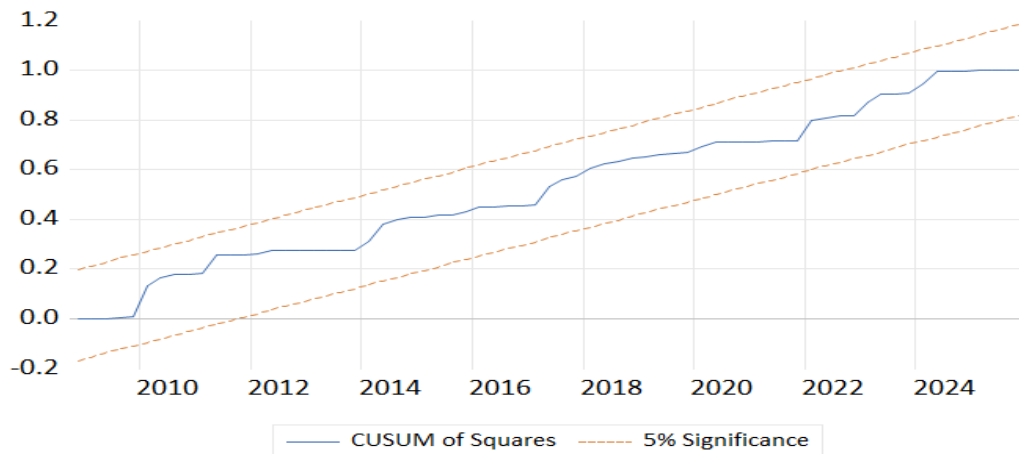
4.1.9 Heteroskedasticity Test: Breusch-Pagan-Godfrey

Null hypothesis: Homoskedasticity

F-statistic	1.7677	Prob.F(12,73)	0.0699
Obs*R-squared	19.3638	Prob.Chi-Square (12)	0.0801
Scaled explained SS	34.6781	Prob.Chi-Square (12)	0.0005



4.10 CUSUM Graph



4.11 CUSUMQ Graph

4.2 Discussion of Findings

The descriptive statistics establish the foundational distributional properties of the quarterly time-series data (2004Q1-2025Q4). The Jarque-Bera test statistics reject the null hypothesis of normal distribution across the raw levels of $\ln\text{PMSP}$ (33.1856, $p = 0.0000$), $\ln\text{PCRGDP}$ (17.4141, $p = 0.0002$), $\ln\text{EXR}$ (23.4563, $p = 0.0000$), and $\ln\text{ELEC}$ (8.9210, $p = 0.0115$) with only $\ln\text{REN}$ exhibiting normality (3.8925, $p=0.1428$) such non-normality in raw macroeconomic series is standard in emerging markets experiencing policy shifts and currency shocks. Transforming the series into natural logarithms stabilizes variance across time. Crucially, the NARDL estimation error terms (ϵ_t) pass diagnostic testing for homoskedasticity and serial correlation, satisfying classical regression assumptions to ensure non-spurious, robust estimation.

The Augmented Dickey-Fuller (ADF) unit root test results confirm that all variables renewable energy capital imports ($\ln\text{REN}$), petrol retail pump prices ($\ln\text{PMSP}$), real per capita income ($\ln\text{PCRGDP}$), exchange rates ($\ln\text{EXR}$), and grid electricity generation ($\ln\text{ELEC}$) are non-stationary at levels but become stationary after first differencing, confirming an integration

order of $I(1)$. Confirming a uniform $I(1)$ order guarantees that no variable is $I(2)$, which satisfies the fundamental prerequisite for NARDL bounds testing. The Pesaran et al. (2001) F-bounds test yields an F-statistic of 4.2702, which comfortably exceeds the 5% upper-bound critical threshold of 3.79 (asymptotic) and 4.015 (finite sample). This result definitively rejects the null hypothesis of no level relationship, establishing a robust long-run cointegrating vector among the macroeconomic drivers.

In the long run, individual partial sums for positive ($\ln \text{PMSP}^+$ $p=0.5234$) and negative ($\ln \text{PMSP}^-$, $p=0.4243$) petrol price shocks are not statistically significant at conventional levels. This indicates that retail fuel price increases alone do not serve as an automatic direct driver of long-run renewable energy adoption. Instead, real per capita income ($\ln\text{PCRGDP}$) emerges as the single statistically significant long-run determinant (12.2475, $p = 0.0412$). This highlights a crucial structural reality in Nigeria: escalating pump prices create the incentive to switch away from petrol, but households and firms cannot execute this transition without sufficient purchasing power to overcome high initial capital outlays for solar hardware. Furthermore, both long run ($F = 2.8124$, $p = 0.0978$) and short-run ($F = 2.0168$, $p = 0.1598$)

Wald tests fail to reject symmetry at the 5% significance level, demonstrating that market adjustments to price shocks are constrained by broader macroeconomic bottlenecks rather than dynamic price asymmetry. These empirical findings align with Adebayo et al. (2024) and Hassan and Sanusi (2023) by highlighting how income constraints limit immediate green substitution during fuel price hikes.

The short-run dynamic adjustment parameters reveal the immediate transmission bottlenecks within the Nigerian economy. Short-run exchange rate depreciation ($D(\ln EXR)$) displays a statistically significant positive effect (0.0811, $p = 0.0044$), reflecting how immediate currency shocks inflate local costs for imported clean hardware. Similarly, short-run grid electricity output ($D(\ln ELEC(-1))$) is positive and significant (0.2662, $p = 0.0044$), illustrating that short-term grid outages force reliance on petrol generators rather than immediate solar switching. Furthermore, short-run negative price changes ($(LNPMSP-)$) show a significant positive impact (0.1366, $p = 0.0059$), proving that fuel price drops temporarily suppress alternative energy investments. As argued by Musa et al. (2025) and Eze and Okonkwo (2024), exchange rate pass-through and grid instability jointly constrain the market mechanisms intended by fuel deregulation.

Post-estimation diagnostic testing confirms the statistical adequacy and empirical stability of the econometric model. The Breusch-Godfrey LM test yields an F-statistic of 0.4503 ($p = 0.6393$), confirming the complete absence of residual serial correlation. The Breusch-Pagan-Godfrey test yields an F-statistic of 1.7677 ($p = 0.0699$), failing to reject the null hypothesis of homoskedasticity at the 5% significance level and confirming constant error variance. Additionally, the CUSUM and CUSUMSQ plots remain

well within the 5% critical boundaries, proving structural parameter stability across the entire sample period. Together, these diagnostics validate that the NARDL specification is robust, structurally sound, and non-spurious.

5. Conclusion and Policy

Recommendations

The empirical findings confirm a long-run cointegrating relationship between petrol pump prices, income, exchange rates, power grid output, and renewable energy imports in Nigeria. While higher petrol prices theoretically encourage clean energy adoption, real-world substitution is blocked by falling purchasing power and currency devaluation that inflates imported solar hardware costs. Additionally, chronic power grid failure forces businesses and households into involuntary petrol generator reliance. To break this "Energy Transition Paradox," the government must recycle fuel subsidy savings into import tariff waivers, zero-rated VAT, and dedicated foreign exchange access for off-grid solar infrastructure.

To bridge this structural gap, the Federal Ministry of Finance and Federal Inland Revenue Service should recycle fiscal savings from subsidy removal into zero-rated VAT schemes and complete import duty exemptions for clean energy hardware. Concurrently, the Central Bank of Nigeria must establish a dedicated, concessional foreign exchange window for certified renewable energy importers to neutralize exchange rate pass-through inflation on imported solar hardware. To mitigate initial capital barriers, the Bank of Industry and commercial microfinance institutions should deploy low-interest consumer credit facilities alongside structured Pay-As-You-Go solar financing models. Furthermore, the Federal Ministry of Power and Nigerian Electricity Regulatory Commission should accelerate grid decentralization under the Electricity

Act by supporting private-sector mini-grid development. Expanding localized off-grid solar output will reduce reliance on fossil-

fuelled generators and break the persistent cycle of involuntary energy stacking across Nigeria.

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