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Article

Asymmetric Crude Oil Pass-Through and Retail Fuel Pricing Dynamics in Nigeria

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Abstract

The Nigerian fuel market dynamics are unique; with high percentage of crude oil export yet lacks the refining capacity to meet its domestic requirements, and therefore exposed to the intricacies of the global oil supply shocks. This study interrogates asymmetric crude oil pass-through and retail fuel pricing dynamics in Nigeria, between 1992 to 2025. Yearly data were used and the following variables were employed: Domestic retail fuel price, Brent crude price, real effective exchange rate, inflation rate and interest rate. Exploring the dynamic non-linear autoregressive distributed lag model approach. The following outcomes emerged: increase in global crude price pushes domestic retail fuel price up, while when there is reduction in global crude price the retail fuel marketers do not respond to the adjustment in price to reflect consumers expectations. Additionally, when the Naira depreciates it automatically increases cost of procurement and landing for refined fuel in the domestic market. The following policy suggestions were made: to dismantle the asymmetric pricing weight on the consumers, the authorities should implement fiscal and regulatory policies directed towards calming the foreign exchange market to regulate landing cost, implement stern competition rules through the relevant regulatory agencies to discourage retail price fixing and put local public refineries in good state to decouple logistics from foreign freight and exchange rate volatility.

Keywords

Asymmetric crude pass-through, Retail fuel pricing, Dynamic non-linear autoregressive distributed lag

JEL Classification Codes

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1. Introduction

For an emerging resource dependent economy, the intersection between global commodity market and domestic retail fuel pricing dynamics represents an important macroeconomic policy relationship. There is a deep macroeconomic wave throughout oil importing and exporting emerging countries, driven by demand, geopolitical disruptions and global oil supply shocks. Nigeria stands out as a reference point in Sub-Saharan Africa, in spite of its position as one of the largest producers of crude oil, yet it imports refined petroleum products due to the bad state of its refineries [1]. Furthermore, the path through which global crude supply shocks transmit into the Nigeria's economy is complicated and unpredictable.

Retail fuel pricing structure in Nigeria has experienced transformational change. Before the 2023 removal of subsidy on premium motor spirit (PMS), the Nigerian government insulated her citizens from the global crude oil volatility through an extensive fiscally demanding subsidy regime for PMS. Nevertheless, following the subsidy removal in 2023 the country transited to a liberalised market framework [2]. As a result, retail fuel pricing market in Nigeria is exposed to the unregulated forces of global supply volatility and macroeconomic instabilities. Comprehending how the worldwide benchmarks interrelate with domestic monetary indicators cannot be considered as a mere theoretical exercise; therefore, it becomes important prerequisite for macroeconomic stability and fiscal sustainability.

There is always a proportional increase in the landing cost of refined petroleum product in Nigeria whenever global supply shocks drive the increase of Brent crude price (BCP). This scenario complicates the domestic currency inevitabilities, especially after the subsidy removal in the country. This happens because about 90% of refined fuel use in Nigeria is imported, a devalued Naira plays the role of a structural multiplier, increasing the landing cost of domestic PMS even when global crude price is moderate [3]. When the fuels stations increase PMS price, it reflects immediately in the cost of transportation and fees for logistics, which also reflects in the supply chain average costs. Furthermore, domestic inflation rate (INFR) increases, as this also translate to increase in prices of commodities and consumables [4]. To curtail the rising prices in the economy and to save the fluctuating Naira from capital flight, the monetary authority raised the standard interest rate (INTR). This automatically increases the cost of capital; and independent oil marketers that depend on bank credit channels for fuel importation will react by increasing PMS price. The end users bear the transferred cost which lead to a secondary upsurge of retail increase in price intensifying the cycle of instability in the domestic economy.

Mixed outcomes were presented by extant literature exploring the intersection between energy disruptions and macro-variables in a nation with abundant natural resources. The domestic subsidy on fuel was seen as key macro-stabiliser by early equilibrium literature, though at a detrimental fiscal cost to the economy. Additionally, a New-Keynesian dynamic stochastic general equilibrium (DSGE) model was used and it shows that subsidised fuel protects customers from instant global price pass-through, automatically persuaded by serious fiscal disturbances and corresponding misalignment in the foreign exchange market [3]. On the other hand, dynamic simulated autoregressive distributed lag (DS-ARDL) model was also employed and outcome showed exclusion of pricing buffer directly translate from international energy shocks to increased cost of living [5]. Additionally, structural vector autoregression (SVAR) was employed for interrogation and outcome showed that oil price fluctuation spill-over, have a different urban-rural asymmetry, indicating urban consumer prices and transport logistics responding with high velocity [4].

The Nigerian retail PMS pricing structure has been exposed to global supply shocks since the removal of subsidy and liberalisation of the foreign exchange market. The local economy does not possess fiscal buffer that absorbs international oil volatility anymore. Furthermore, unpredictable movement in the international oil standard, together with floating exchange rate regime, diffuse straight to the domestic PMS retail price. Cost-push inflation is driven as a result; this also affects business operations planning and welfare of the average consumer. Although, extant literature has extensively interrogated either the isolated macroeconomic effects of global oil volatility or the fiscal consequences of the removal of subsidy; however, an important empirical gap still exist. Precisely, extant studies fall short of an integrated, high frequency empirical interrogation of how global supply shocks pass through to domestic retail prices within a combined liberalised currency and fuel market. However, the existence of inadequate econometric evidence of the exact asymmetric pass-through, cointegrating dynamics between BCP, the unifier real effective exchange rate (REER), INFR and rising INTR in the current policy dispensation calls for attention. To fill this gap, this study examines the asymmetric pass-through effect and also evaluates the effect of exchange rate on domestic fuel price in Nigeria. The modern dynamic non-linear autoregressive distributed lag (D-NARDL) model approach was employed to capture the dynamic, multi directional pass-through of global oil supply shocks to domestic retail fuel pricing in Nigeria.

2. Literature Review

2.1 Empirical Review

2.1.1 Literature on Asymmetric Price Transmission

Positive crude price shocks have stronger and more persistent effect on PMS, automotive gas oil (AGO) and dual-purpose kerosene (DPK) prices than negative shocks, validating the rocket and feather effect. The study is Nigeria specific and recent, but it treats exchange rate and subsidy regime only as control rather than exploring regime dependent asymmetry, leaving a gap on post-subsidy dynamics and explicit retail market structure [6]. Furthermore, survey on asymmetric price

transmission in agricultural and energy markets was carried out. The study synthesized mechanisms like market power, menu costs, and search friction. While not Nigeria specific, their framework is routinely used to interpret asymmetric fuel pricing, yet many Nigerian studies import this theory without empirically testing which mechanism dominates in the current deregulated fuel market [7]. Non-linear autoregressive distributed lag (NARDL) approach was utilised to examined oil prices to gasoline pass-through in several European markets. Outcome indicated mixed result, long and short run asymmetry was identified in some countries but absent in others. Though, the technique was suitable, however the study does not account for subsidy regime or dual exchange rate challenge peculiar to Nigeria [8]. Threshold cointegration to crude gasoline price transmission in the US was examined, indicating regime dependent asymmetry. The outcome suggested that different adjustment regimes matter, however, recent Nigerian studies rarely apply threshold or regime switching formulations, creating scope for modelling asymmetric pass through across pre and post subsidy regimes [9]. Evaluation of asymmetric price adjustment and rent seeking was carried out using NARDL model technique and result showed that, global retail energy market is persistent with problems of rocket and feather effect and the possibilities of retail manipulations. This study did not take the subsidy era into consideration [10]. Employing the new Keynesian dynamic stochastic general equilibrium model to evaluate oil price volatility and macroeconomic outcomes indicated that, oil price volatility coupled with the increasing oil income result in widening the monetary base and leads to growth in liquidity and rising inflation [11]. Asymmetric effect of retail fuel prices and inflation in Nigeria was examined using NARDL and result indicated that, rise in fuel prices wields inflationary pressure especially on food prices; on the other hand, decrease bring muted deflationary effects [12]. Effect of oil price volatility on inflation in Nigeria was evaluated asymmetrically, using NARDL technique and result indicated that, real gross domestic product (RGDP), exchange rate and revenue from oil indicated positive and significant connection with inflation. This study ignores structural breaks pre and post subsidy era [13].

Asymmetric pass-through is indicated in Nigeria's specific case, however, there is scarcity of literature that jointly modelled product level retail prices, explicitly differentiating pre and post subsidy regimes and connects observed asymmetry to exchange rate movements and retail market structure utilising the D-NARDL technique.

2.1.2 Literature on Exchange Rate Pass-Through

Extant literature on Nigeria using NARDL indicated that oil price significantly affects exchange rate and exchange rate shocks feed into domestic prices, but typically treats fuel prices as part of average inflation or macro variables rather than separate retail product. The General theory of pass-through was provided from international perspective, under imperfect competition indicating that costs shocks which includes exchange rate movements, can present asymmetric pass-through depending on demand curvature and ark up behaviour. Although, Nigerian extant literature rarely estimates these pass-through patterns clearly, suggesting a gap between theory of incidence and applied retail fuel pricing [14]. Effect of global oil price on exchange rate, balance of trade and reserve in Nigeria was examined. The study used Granger causality technique and result showed evidence of causality between oil price and reserve in the short run, while in the long run no causation between oil price and balance of trade and exchange rate in Nigeria [15]. Additionally, exchange rate was included as a determinant of petroleum price in Nigeria, the study submitted that, together crude oil and exchange rate shocks contribute to asymmetric pass-through. However, the study did not separate asymmetry for oil price versus exchange rate shocks nor compare pre and post 2023 subsidy removal periods which this study is concern about [6]. Exchange rate pass-through most times interacts with market power and regulation to give asymmetric price transmission. Nevertheless, a lot of Nigerian submissions does not quantify the way exchange rate shocks and crude price shocks combine to drive fuel prices under deregulation and exchange rate challenge, ignoring a numerous shocks pass-through gap [7]. Nigeria's exchange rate, oil price, economic policies, supply chain disturbance and inflation were interrogated using five ensemble learning algorithms: Random Forest, Decision Tree, Bagging, Gradient Boosting regression and AdaBoost. Outcome showed presence of significant connection between foreign currency exchange rate and inflation [16]. Exchange rate pass-through, monetary policy and price stability in Nigeria were examined using Johansson cointegration test and error correction model. Result indicated that, price stability and monetary policies showed a positive correlation with exchange rate pass-through, this implies that exchange rate pass-through effect is not sufficient [17].

Extant literature identified exchange rate as key driver, however, there is limited studies modelling joint asymmetric pass-through from both crude and exchange rate shocks into fuel prices, especially using dynamic nonlinear multipliers for post subsidy era.

2.1.3 Literature on Post Subsidy Fuel Market

The asymmetric link between oil prices and transportation costs in Nigeria was evaluated. The study employed monthly data between January 1995 to December 2023, using Threshold Autoregressive and Momentum Threshold Autoregressive models and Dynamic OLS for evaluating the long run connection. The study found that oil price increase also increases transportation costs, although the upward adjustment is relatively slow and weaker statistically. The study demonstrated that oil price adjustment is nonlinear and threshold dependent in Nigeria's transportation sector, but the study did not examine whether the same process operates at the retail petroleum level [18]. The evaluation of first level cost allocation, transport logistics pass-through and supply chain adjustment in a deregulated volatile petroleum pricing regime was undertaken [19]. The study employed combined micro level panel data of distributional networks with asymmetric vector error correction model (AVECM). Outcome indicated that, downstream distribution of logistics exacerbates the

asymmetry of crude oil pass through. The study focused more attention to the transport sector cost absorption while failing to model upstream crude procurement contracts and price smoothing mechanisms used by bulk importers. On the other hand, a significant contribution was made by evaluating the immediate policy of Nigeria's subsidy removal. The separation of rural and urban inflation is valuable because the impact of fuel price reform is questionable if spatially uniform always. The study employed dynamic simulated ARDL technique which gave a useful way of tracing the consistency of large PMS price volatility over time [20]. Although, the study showed that the policy reform generated consistent and spatial differentiated inflationary effects. Nevertheless, the study ignores whether Nigeria's retailers pass through upward and downward variations in crude oil and import costs differently. This study extends to 2025 and estimates asymmetric retail price adjustment rather than viewing PMS price as an exogenous policy fluctuation. Asymmetric effects of oil pass-through shocks and exchange rate movement on inflation in Nigeria was examined [21]. The study identified exchange rate devaluation among the important transmission mechanism in import dependent petroleum market. The study used average INFR as dependent variable instead of retail fuel price of PMS. Inflation may respond to fuel prices through transport, food, exchange-rate, monetary, and fiscal channels. Furthermore, the study established that oil price exchange rate volatility affects Nigeria asymmetrically, but they do not regulate whether retail fuel price themselves show asymmetric adjustment after the subsidy removal. Energy price dynamic effect on inflation was considered for Nigeria using ARDL cointegration technique and outcome showed a significant positive long run connection between energy prices and inflation with price of petroleum exerting the strongest effect. The methodology of the study remains inadequate as fuel price dynamics in Nigeria has showed to be asymmetric [22]. Effect of subsidy removal and consumption of petroleum on growth of the Nigerian economy and the environment was examined using ARDL. Outcomes indicated that, petroleum consumption showed a significant positive effect on economic growth and carbon emission, furthermore, subsidy is significant in reducing growth of the economy within the period of the study [23].

Extant literature showed that Nigeria's post subsidy fuel price structure is characterised by incomplete, nonlinear and potentially regime dependent transmission. However, the evidence remains indirect. Asymmetric effects of oil pass-through shocks and exchange rate movement on inflation in Nigeria evaluated inflation rather than pump prices; while the immediate policy of Nigeria′s subsidy removal examined inflationary consequences of PMS-price changes rather than the determinants of PMS prices; and the asymmetric link between oil prices and transportation costs in Nigeria examined transportation costs rather than retail petroleum prices.

2.1.4 Literature on Asymmetric Pass-Through

Threshold cointegration was demonstrated for asymmetric pass-through from crude to gasoline. Outcome indicated various cost regimes can present different adjustment paths. Using Threshold or regime switching NARDL to the pre versus post subsidy context for Nigeria could further improve dynamic asymmetry analysis, however this is yet to be done [9]. On the other hand, NARDL can capture both long and short run asymmetry in gasoline markets, with dynamic multiplier for positive and negative shocks. The study is for developed economies, institutional bottlenecks; import dependence, subsidy reforms, exchange rate challenges make the pass-through process potentially more asymmetric and regime dependent in Nigeria [8]. Hidden cointegration was employed to permit asymmetric long run connection between positive and negative components of crude and petroleum prices. The technique was impressive however, it focussed on long run hidden cointegration; short run dynamics and regime specific adjustment speeds are underexplored, therefore the need for Dynamic NARDL with unambiguous multiplier [6]. Evidence from hidden cointegration technique on crude oil pass-through to retail petroleum product prices indicated that, retail petroleum prices in Nigeria respond to asymmetric variations than crude price [24].

NARDL framework and hidden cointegration have been used for Nigeria's inflation and average petroleum prices, however studies are scares on Dynamic NARDL to jointly model asymmetric crude and exchange rate pass through to disaggregate retail fuel prices before and after subsidy removal with explicit dynamic multipliers and specific product adjustment speed.

2.1.5 Novelty

This study identified an existing gap in previous studies regarding the triple effect that has characterised the Nigeria's domestic retail fuel market since 2023: PMS subsidy removal, exchange rate unification and naira floating (though, the policies are still evolving). In filling this gap, this study under these triple policy concerns, employed D-NARDL model approach to product level retail prices, within the pre and post subsidy regimes and interrogates the effect of exchange rate on domestic retail fuel price (DRFP) in Nigeria.

2.2 Theoretical Review

2.2.1 Cost-Push Inflation and International Transmission Theory

Cost-push inflation arises when there is increase in costs of production and distribution especially of imported crude oil and refine petroleum products, transmitted into the local market prices and pushing up the aggregate price level even where average demand is not expanding. The cost-push inflation theory highlights that exogenous increase in prices of

inputs shifts firms marginal cost curve upward, resulting to higher equilibrium prices and inflationary pressures [7,25]. From the perspective of the international transmission, oil price shocks originating in the global markets are transmitted into domestic economies through trade prices, exchange rates and imported input costs, leading to imported inflation or external cost-push pressures. Furthermore, under perfect competition and incomplete exchange rate pass-through, companies may adjust prices asymmetrically to external shocks, intensifying the domestic inflation reaction depending on market structure and policy regimes. For Nigeria, an oil dependent economy positive global oil price volatility can at the same time raise fiscal revenues and costs of product, but the downstream retail fuel market may transmit these shocks unequally across products and time as a result of regulation, subsidies and oligopolistic behaviour [7,25].

2.2.2 Asymmetric Pricing Theory (The Rocket and Feather Hypothesis)

The empirical regularity that prices tend to respond more quickly and fully to costs increases than costs decreases are described by the asymmetric pricing theory (the rockets and feathers effect), that is prices shoot up like rockets with rising costs but fall back like feathers when cost falls. Initial contributions in gasoline markets indicated that retail fuel prices show faster and larger adjustment to crude price increases than to decreases, consistent with market power, menu costs, collusive behaviour and search frictions among retailers [26,27]. Several mechanisms for asymmetric pass-through were offered by theoretical literature. Within the confines of perfect competition, companies offer convex demand and mark-up pricing may change margin differently for positive and negative costs shocks, leading to non-linear pass-through pattern [14,21]. When search is costly according to the consumer search theory, retailers may hurriedly raise prices in response to cost increases but adjust downward more cautiously, exploiting consumer inertia and limited search [28,29]. Additionally, repeated oligopoly models also predict rigid and asymmetric price adjustment when companies coordinate on supra-competitive prices, transmitting positive cost shocks immediately but delaying negative adjustments until demand realisation force them to reduce prices [30,31]. Extant literature indicated that asymmetric transmission is predominant in agricultural and energy markets, especially where market power, regulation and adjustment costs are significant [7]. Recent evidence in Nigeria indicated that petroleum product prices respond asymmetrically to global crude oil prices, with larger effects for positive shocks and confirmation of the rocket-and-feather hypothesis in the retail energy market [6].

The international transmission theory helps in explaining global macro corridor that directs the international shocks into Nigeria's boarder, on the other hand, asymmetric price theory operates as a domestic micro filter that regulate how global shock is analytically spread to retail end users. The international transmission theory prescribes the reason local prices usually increase when global supply contracts, on the other hand it does not explain the reason retail price do not fall instantly when there is recovery at the global level. The asymmetric theory determines the blind spot in this microeconomics. Nigeria's case is exclusive as an oil exporter with a robust term of trade volatility when there are global oil spikes. Therefore, using international transmission theory alone will amount to focusing only on macro remedy, which might include building domestic refineries. While asymmetric pricing theory alone will lead to regulatory reaction which might include anti cartel enforcement. Together, these theories allow this study to provide dual-layered policy prescription that takes care of both structural supply boundary and retail market inadequacies.

3. Methodology

3.1 Nature and Sources of Data

This study used times series data between 1992 to 2025, with DRFP, measured in Nigerian naira and sourced from the Nigerian Bureau of Statistics (NBS), BCP, measure in US dollars and sourced from Organisation of the Petroleum Exporting Countries (OPEC) Annual Statistical Bulletin (ASB). REER, indexed using 2010 as base year and sourced from the world development indicator (WDI). INFR sourced from NBS and INTR sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin 2025.

3.2 Model Specification

D-NARDL model is utilised in analysing the asymmetric crude oil pass-through and retail fuel pricing dynamics in Nigeria. The superiority of the D-NARDL is in desegregating the effect of the independent variables on the dependent variable into their negative and positive components [32]. Furthermore, D-NARDL model is more suitable for asymmetric and dynamic pass-through from a highly unpredictable, potentially nonlinear transmission driver, in this case crude oil, to downstream prices of retail fuel, under realistic integration properties. The lag length selection process was automatic; AIC (=423.9 imposed) is the model selection criteria. Stability and post diagnostic test were also carried out and twenty-eight observations were finally used for estimation. However, DRFP and BCP were logged to give a uniform unit of measurement.

$$DRFP = f(BCP, REER, INFR, INTR) \quad (1)$$

InDRFP = f(InBCP, REER, INFR, INTR)

$$InDRFP_t = \alpha_{0+\alpha 1} InBCP^{+}_t + \alpha_2 InBCP^{-}_t + \alpha_3 REER_t + \alpha_4 IFNR_t + \alpha_5 INTR_t \quad (2)$$

$$InDRFP_t = \alpha_{0+} \alpha_1 InBCP^{+}_t + \alpha_2 InBCP^{-}_t + \alpha_3 REER_t + \alpha_4 INFR_t + \alpha_5 INTR_t + \mu_t \quad (3)$$

To capture the long-run and short-run partial sum

$$\Delta \text{InDRFP}_t = \alpha 0 + \rho\ \text{InDRFP}_{t-1} + \theta^{+}\ \text{InBCP}^{+}_{t-1} + \theta^{-}\ \text{InBCP}^{-}_{t-1} + \beta_1 \text{REER}_{t-1} + \beta_2 \text{INFR}_{t-1} + \beta_3 \text{INTR}_{t-1} + \Sigma p\text{-}1_{i=1\ +}\ \gamma i \Delta\ \text{InDRFP}_{t-i} + \Sigma q1_{i=0}$$
$$(\pi^{+} i \Delta\ \text{InBCP}^{+}_{t-i} + \pi^{-} i \Delta\ \text{InBCP}^{-}_{t-i}) + \Sigma q2_{i=0}\ \varphi i \Delta \text{REER}_{t-I} + \Sigma q3_{i=0}\ \delta i \Delta \text{INFR}_{t-I} + \Sigma q4_{i=0}\ \psi i \Delta \text{INTR}_{t-I} + \mu_t \quad (4)$$

Where: DRFP, Domestic retail fuel price, BCP^{+} and BCP^{-}, Brent crude price, REER for real effective exchange rate, INF for inflation rate and INTR for interest rate, α_0 to α_5 indicates unknown vector parameters and μ_t depicts stochastic term.

Δ represents first difference operator;

p is the lag order of the dependent variable;

q1, q2, q3, q4 are lag orders of the independent variables;

θ^{+} and θ^{-} capture the long-run effects of positive and negative changes in BCP;

π^{+} and π^{-} capture the short-run effects of positive and negative changes in BCP;

ρ is the speed of adjustment parameter; and

μ_t is the error term.

In = log (InBCP; log of BCP)

4. Result and Interpretation

4.1 Preliminary Test

4.1.1 Trend Analysis

For the trend of all the variables in Figure 1, DRFP demonstrates that between 1992 to 2022 there was a stagnant minor step like administrative increase followed by an exponential, vertical spike leading up to 2025 then spiralling past ₦1,200/litre. This display a prolonged era of stagnant, highly subsidised fuel pricing. The swift parabolic surge after 2022 indicates structural deviation, precisely subsidy removal resulting from total deregulation of the downstream petroleum sector. For BCP the trend is highly cyclical, in the 1990s it was low, thriving in the 2000s to a hight near 2008 above $100/barrel, crashing during the Global Financial Crisis (GFC), and gradually rebuilding to 2014 commodity crash, plummeting during Covid-19 in 2020, increased after the pandemic before a little softening near 2025. BCP is the main external shocks variable, but previously DRFP did not vary in consonance with BCP as a result of the subsidy regime. Nevertheless, the post 2022 DRFP exponential increase happened even as BCP was softening, giving internal policy variations which override global market movements.

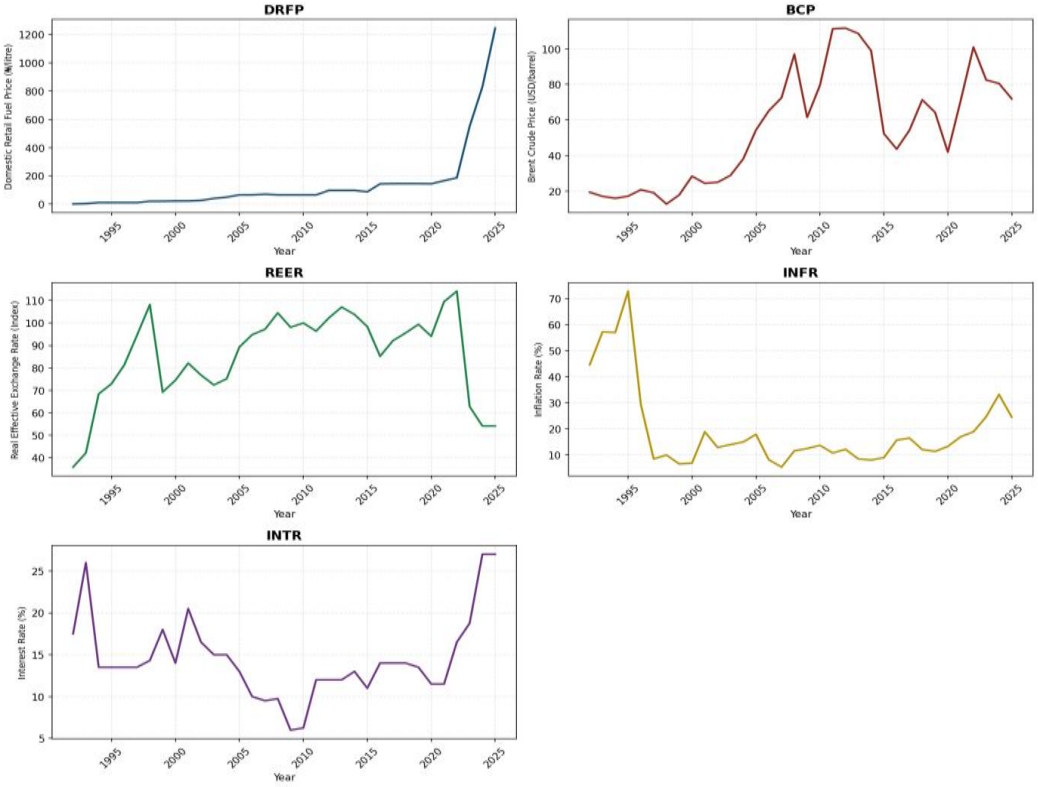


Figure 1. Individual time series plots of study variables (1992-2025).
Source: Extract from STATA 17, 2026.

REER progressively increased with significant volatility from 1992 to a hight around 2022, then an impulsive historic breakdown between 2022 and 2025, flattening out at its lowest level. The immense fall post 2022 indicates a severe real depreciation of the domestic currency. This is an indication of a massive devaluation or floating regime of the exchange rate, coinciding with the subsidy removal era. In the case of INFR early 1990s presented hyperinflation peaking 70% in 1995, a long period of relative stabilisation followed. Importantly, this showed a period of sharp upward resurgence between 2020 to 2024, then in 2025 a minor downward hook. The cost push inflation of recent is driven mainly by the twin shocks of currency devaluation and skyrocketing cost of energy (DRFP spike), which bring about severe domestic instability in price. INTR is volatile, it was high in the early 1990 at 26%, dropping to a low of around 6% in 2009 post 2008 GFC and increasing to a hight of 27% by 2024/2025. Post 2022, the CBN has engaged in aggressive monetary tightening to combat soaring cost push inflation.

In Figure 2, the variations in global BCP explain about 10.2% of the variation in DRFP. This is because the coefficient of determination is low. Distortion in the dashed trend line indicates a slight non-negative linear connection between DRFP and BCP, however at the top right quadrant, it is heavily distorted by a few extreme outliers. Many of the data points sits in a flat, horizontal cluster close to the bottom of the graph where DRFP is at ₦200/litre (two hundred Naira per litre), spread throughout the range of global crude price from $15 to over $110 per barrel. Close grouping of points across the horizontal range of BCP especially when it was $40 and $110, the domestic price hardly moved and this showed a static price control or fuel subsidy mechanism. Instead of permitting the global market shocks pass through to the end users, the Nigerian government absorbed the volatility in price by way of fiscal subsidies. Furthermore, above the trend line lies extreme outliers especially at the point close to $72/barrel where DRFP spikes over to ₦1,200/litre, this represents enormous structural break in the pricing system. For the asymmetric pass-through effect, these showed that domestic prices increase not because of global price spike to historic high, but as a result of policy change domestically like currency devaluation. On the effect of devaluation, because Nigeria imports refined fuel using foreign currency, the enormous increase in DRFP at relatively moderate BCP at $70 to $80 shows that domestic price is severely pushed by exchange rate rather than just the dollar price of crude only.

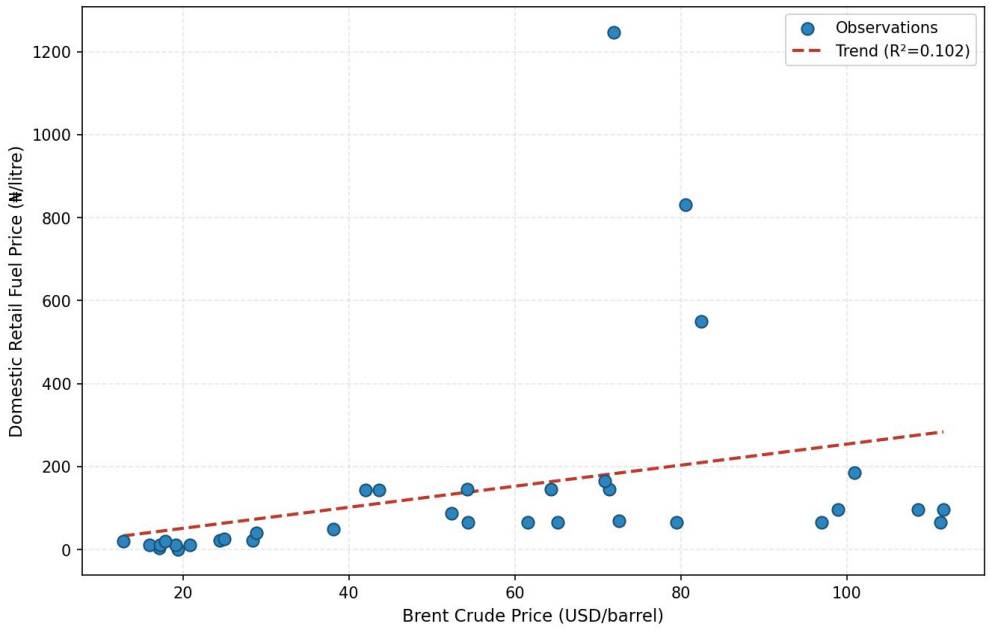


Figure 2. Relationship between BCP and DRFP.
Source: Extract from STATA 17, 2026.

4.1.2 Descriptive Statistics Result

Table 1 presents the descriptive statistics for all study variables over the sample period. The outcome of the descriptive statistics for DRFP in Table 1 indicates that, with the Mean of 140.7250; Std. Dev of 252.87; Min and Max values of 0.70 and 1,245.80 respectively; Skewness of 3.42; Kurtosis of 12.25 and JB p-value of 0.0000. Figures of the standard deviation is almost twice that of the mean, this implies that the DRFP is highly volatile. Having enormous non-negative skewness, with heavy tailed extra kurtosis, showed that the distribution has a long right tail dominated by extreme non-negative values. The Jarque-Bera test strongly negates normality, implying that for the period of the study, 1992 to 2025 fuel price was arbitrarily kept at a lower price of ₦0.70. The huge standard deviation indicates that the hike in price of late is abnormal as indicated by the maximum value of ₦1, 245.80. This showed dismantling of the decade subsidy regime, which represented a historic structural shock. For BCP with a Mean of 55.30; Std. Dev of 31.85; Min and Max values of 12.80 and 111.63 respectively; skewness of 0.28; Kurtosis of -1.17 and JB p-value of 0.3031. Global oil prices are distributed normally with a JB p-value of 0.3031 unlike DRFP that is not significant unable to reject normally. For the skewness that is nearer zero and a negative kurtosis showing a flatter platykurtic distribution, this is in consonance to the

business cycle swings. This descriptive statistics outcome of BCP is in consonance with the cyclical commodity market fluctuations. Furthermore, BCP being normally distributed while DRFP is not statistically, which implies that the domestic fuel market was heavily decouple through policy intervention from global shocks.

Table 1. Descriptive statistics of study variables (1992-2025).

Var	Obs	Mean	Std Dev	Min	Max	Skewness	Kurtosis	JB Stat	JB p-val
DRFP	34	140.7250	252.8703	0.70	1245.80	3.4224	12.2565	212.491	0.0000
BCP	34	55.2965	31.8519	12.80	111.63	0.2851	-1.1725	2.3876	0.3031
REER	34	85.4824	19.7029	35.80	114.20	-0.8459	0.1085	3.7089	0.1565
INFR	34	19.3794	15.9713	5.40	72.80	2.0700	3.8801	36.3160	0.0000
INTR	34	14.5018	4.9120	6.00	27.00	1.1266	1.7030	8.9256	0.0115

Note: Var = Variable, Obs = Observations, Std Dev. = Standard Deviation, Min. = Minimum value, Max = Maximum value, JB Stat = Jarque-Bera Statistic, JB p-val =Jarque-Bera Probability value.
Source: Authors computation with extracts from STATA 17, 2026.

On the other hand, REER has a Mean, and Std. Dev of 85.48 and 19.70 in that order, Min and Max Values of 35.80 and 114.20 respectively, Skewness and Kurtosis of -0.85 and 0.11 in that order and JB p-value of 0.1565. Although, REER is normally distributed, however it shows a Skewness that is negative implying the distributive tail reached towards simple devaluation. The asymmetric risk of currency dependence is captured by the negative skewness. More so, the outcome implies that the currency has long been defended artificially overvalued by the CNB by keeping it close to the maximum value of 114.20. Therefore, forces of the market have over time unconditionally triggered rapid devaluations thereby pulling the index to 35.80 for the minimum value. INFR indicated 19.38% and 15.97% for the Mean and Std. Dev respectively. For Min and Max, it stood at 5.40% and 72.80% respectively, while for Skewness and Kurtosis it is 2.07 and for JB p-value it is 0.0000. Inflation is not normally distributed and highly volatile at a JB p-value of 0.0000 and a high non-negative skewness implying that, sitting at an average of 19% inflation have a high chance of upward spikes. The summation is that the Nigerian economy suffered from structural price instability. Furthermore, the least inflation Nigeria attained over the years is 5.4%, suggesting that low inflation is not normal. Serious cost-push volatility is a reflection of the positive skewness irrespective of fuel price, collapse of exchange rate and inflation increased to all time high of 72.8%.

For INTR, the Mean and Std. Dev. are 14.50% and 4.91% respectively, Min and Max values at 6.00% and 27.00% in that order. Skewness and Kurtosis at 1.13 and 1.70, while JB p-value at 0.0115. INTR is not normally distributed and is skewed positively; this implies policy rate last longer at elevated level. Structurally, Nigeria has high interest on capital at 14.5% pegged to mitigate high INFR. Maximum value of 27% and positive skewness implies aggressive reaction with monetary policy by the monetary authority when macroeconomic volatility ensued, putting aside cheap credit to shield currency and reduce the effect of inflation. In summation, a critical look at the result of the descriptive statistics indicated that, one of the main challenges of the Nigeria's economy is asymmetric policy response. Furthermore, outcome of the Jarque-Bera test indicates that external volatility represented by BCP are absorbed over time till fiscal policy intervention. And when these takes place, it leads to adjustment in; fuel prices, exchange rate and INFR, they occur as non-linear jumps rather than usual market conditions. This motivate the CBN to structurally maintain high INTR to mitigate the effect of inflation in the economy.

4.1.3 Unit Root Test

Table 2 reports the Zivot-Andrews unit root test result at levels and first differences. The null hypothesis is that the series contains a unit root.

Table 2. Zivot-andrews unit root test results.

Var	T. Stat (Level)	p-value (Level)	Break Date	T. Stat (1stDiff)	p-value (1st Diff)	Break Date	Order
DRFP	-0.628607	0.09	2021	-5.177863	0.03	2022	I(1)**
BCP	-4.712117	0.07	2015	-6.272471	0.01	2014	I(1)**
REER	-5.149907	0.02	2022	-6.894773	0.01	2022	I(0)**
INFR	-9.715293	0.01	1995	-6.217942	0.01	1996	I(0)**
INTR	-3.572569	0.64	2023	-10.05789	0.01	2021	I(1)**

Note: Var = Variable, T. Stat (Level) = Test Statistic at level, T. Stat (1st Diff) = Test Statistic at First Difference. *** p<0.01, ** p<0.05, * p<0.10. Lag selection based on AIC criterion. Critical values: -3.646 (1%), -2.954 (5%), -2.614 (10%).
Source: Authors computation with extracts from STATA 17, 2026.

Table 2 indicates the Zivot-Andrews unit root test, which is suitable for this study because Augmented Dickey Fuller (ADF) and Phillips Perron (PP) assumes no structural break under null hypothesis, this biases them towards falsely failing to reject a unit root even when break actually exists. Meanwhile, the fuel market in Nigeria have undergone at least few main regime changes; exchange rate policy change, subsidy removal and deregulation, within the sample period, moderating these breaks implies misclassifying the integration of DRFP and BCP. Meanwhile, outcome of the test indicates that; DRFP, BCP and INTR were stationary at first difference I(1), while REER and INFR were stationary at level I(0). There break dates gathering around meaningful occurrences in Nigeria; 1995 to 1996, 2014 to 2015 global oil price collapse, 2021 to 2023, naira float, exchange rate unification and PMS subsidy removal. This is not by accident; it is an indication of real structural shifts in the crude to pump price transmission mechanism. The outcome supports the use of D-NARDL as it correctly identifies orders of integration which is mixed I(0) and I(1), and also this is the precondition for D-NARDL. The break dates substantively corroborate the asymmetric pass-through incidence the D-NARDL model is intended to test.

4.1.4 NARDL Bounds Test for Co-integration

Table 3 presents NARDL bounds test for the existence of a long-run cointegrating relationship between DRFP and the explanatory variables.

Table 3. NARDL bounds test results.

Test	F-Statistics	10% I(0)/I(1)	5% I(0)/I(1)
F-stat (Bounds Test)	9.9651	2.45 / 3.52	2.86 / 4.01
Decision	Reject H0 (Cointegration)	-	-

Source: Author's computation with extracts from STATA 17, 2026.

Table 3 indicates the result of the ARDL bounds test for co-integration, which implies co-integration between DRFP and the explanatory variables; BCP, REER, INFR and INTR.

4.1.5 Long Run Asymmetric (D-NARDL) Estimates

Table 4 presents the long-run coefficient estimates from the NARDL model incorporating asymmetric partial sum decomposition of BCP (BCP^{+} and BCP^{-}).

Table 4. Wald test results–Asymmetry between positive and negative oil price shocks.

Hypothesis	F-Statistic	p-value	Decision
H0: $\beta(BCP^{+}) = \beta(BCP^{-})$ [Short-run symmetry]	17.7658	0.0003***	Reject H0
H0: $L(BCP^{+}) = L(BCP^{-})$ [Long-run symmetry]	9.8943	0.0041***	Reject H0
H0: No asymmetry (Joint)	13.8300	0.0009***	Reject H0

Note: *** p<0.01, ** p<0.05, * p<0.10.
Source: Authors computation with extracts from STATA 17, 2026.

Wald Test for Asymmetry (Rocket and Feather): Table 5 reports the Wald test results for both short-run and long-run symmetry. The null hypothesis (H0) posits that positive and negative oil price changes exert equal-magnitude effects on DRFP.

Result in Table 4 for Wald Test indicates significant evidence of strong structural statistical asymmetry on how the Nigeria economy respond to global oil price variations. Thus, the null hypothesis stands rejected in favour of the alternate hypothesis. This implies that positive oil price increase and negative oil price decrease do not exhibit equal impact in the short run and in the long run. However, this study is more concern about the long run.

4.2 D-NARDL Test Result

The outcome in Table 5 is a representation of the Nigeria's asymmetric pricing effect in the context of the domestic retail fuel market. The key reason for utilising the D-NARDL model approach is for the testing of the volatile DRFP. reaction to positive versus negative crude oil pass-through experienced within the period of the study precisely 1995-1996 2014 - 2015 and 2021- 2023. The result shows that shocks resulting from the positive and negative InBCP on InDRFP in Nigeria are not the same. Therefore, the positive strand of InBCP has a coefficient of 2.3153 and statistically significant at the normal 5% level with a p-value of 0.028. This indicates that, a unit surge in positive InBCP shocks will lead to a statistically significant increase of about 2.3% in InDRFP in Nigeria in the long run. Thus, retail fuel price increases when there is increase in global oil price. On the other hand, for the negative strand of InBCP, with a coefficient of 0.1915 though insignificant statistically with a p-value of 0.884 at 5% level. This implies that in the long run, a unit contraction in InBCP will have no statistical significance on InDRFP in Nigeria. However, the confidence interval of -2.475, 2.858 at 95% is critical. From econometrics viewpoint, this implies that the negative effect of BCP is not statistically proven by

this estimate. Oil marketers and retailers pass cost surge quickly to consumers to protect their profit margin however, they are reluctant to pass on the cost savings when BCP reduces. This might be because of market power, search cost or rigidities from regulatory agencies.

Table 5. Long-run and short run asymmetric (D-NARDL) coefficient estimates.

Var	Coef.	Std. Err.	t-Stat	p-value	95% CI
Constant	301.6294	320.231	0.942	0.355	[-355.43, 958.69]
InBCP_POS	2.3153	0.996	2.325	0.028**	[0.272, 4.359]
InBCP_NEG	0.1915	1.300	0.147	0.884	[-2.475, 2.858]
REER	-6.1135	2.566	-2.382	0.025**	[-11.379, -0.848]
INFR	-1.6543	1.929	-0.857	0.399	[-5.613, 2.304]
INTR	13.0964	8.340	1.570	0.128	[-4.017, 30.210]
Cointq	-0.5569	0.067	-8.293	2.945	[-0.6885]
D(InBCP_POS)	0.0266	0.172	0.154	0.878	[0.3.3115]

Note: Var = Variable, Coef. = Coefficient, Std. Err. = Standard Error, t.Stat.= Test Statistics, CI = 95 percent Confidence Interval.
*** p<0.01, ** p<0.05, * p<0.10.
Source: Authors computation with extracts from STATA 17, 2026.

A look at REER, it is not asymmetric in the long run, therefore, with the coefficient of -6.1135 and significant statistically at a p-value of 0.025. This implies that a unit decrease in REER will lead to a surge of about 6.1% in InDRFP in Nigeria in the long run. This implies that, lower REER implies depreciation of the Nigerian Naira and higher DRFP, because REER indicates the strength of a currency. Couple with the fact that Nigeria highly relies on importation of refined fuel, a weak Naira considerably increases landing cost thereby increasing domestic retail fuel cost. For INFR, it is not asymmetric in the long run, with a coefficient of -1.6543 an insignificant p-value at 0.399 at the usual 5% level. This is an indication that, a unit surge in INFR will not have statistically significant effect on InDRFP in Nigeria in the long run. This indicates why macroeconomic inflation doesn't directly affect DRFP. variations above the going price determine by REER and InBCP. 13.0964 is the coefficient of INTR with an insignificant p-value at 0.128 at the usual 5% level is not asymmetric in the long run. This also indicates that a unit surge in INTR will not have statistically significant effect on InDRFP in Nigeria in the long run. Cost of financing the importation of refined fuel increases with high INTR, however it's not robust statistically in the long run. Inflation and INTR indicates bidirectional causation, as weak naira indicates increase cost of borrowing and leads to increase in the costs of imported refine PMS in the domestic market. For the constant with 301.6294 as its intercept and insignificant p-value of 0.355, this implies the constant does not differ from zero without these macroeconomic determining factors.

For the positive shock to BCP, it exhibits a large positive and statistically significant effect with coefficient of 2.31, while for the negative strand, the resulting shock is small and a negligible effect that is not statistically significant at 0.19.

On the other hand, in the short run the sign is negative as expected for a stable long run equilibrium and statistically significant at p<0.01, this also indicates existence of long run connection between the variables of interest and with a large coefficient of -0.557. The coefficient implies that approximately 56% of any disequilibrium (deviation from the long run equilibrium) in DRFP is corrected within a single period (within a year) while the remaining 44% is corrected in the succeeding period. The short run positive D (InBCP_POS) with a coefficient of 0.0266 and probability value of 0.878 indicates that the effect of BCP on DRFP is statistically insignificant. This implies in the short run, changes resulting from positive shocks of D (InBCP_POS) have no measurable pass-through to InDRFP in Nigeria. Although, the positive InBCP shocks are the generators of disequilibrium worth correcting, with a statistically significant long run effect at 2.3153, a positive InBCP expansion creates a gap between current equilibrium values and the ECT then works near a 56% per year. While negative BCP shocks contraction doesn't create a significant long run disequilibrium, therefore, the asymmetry is in the source and magnitude of disequilibrium.

4.3 Discussion of Result

The clear contrast between InBCP-positive and InBCP-negative (as shown in Figure 3) gives a better picture of the Nigeria's downstream petroleum market; however, this estimate does not statistically establish the negative effect. Nevertheless, when the marketers are experiencing increasing import costs, they pass this to protect their profit margin, the absence of asymmetric reaction to falling crude prices might indicates imperfect competition, limited consumer price search and pricing discretion that together permit retailers to retain the benefit of cost decline instead of transmitting them to consumers. More so, in Nigeria fuel is an inelastic necessity for both domestic and business use, hence the product cannot easily be ignored. Fuel marketers are aware consumers will only complain but they will eventually pay, this contributes to their reluctance in reducing the retail fuel pump price. This outcome is in tandem with the findings of [6], which supports the asymmetric pricing of fuel pump price in Nigeria, however it treats exchange rate and the subsidy regime as control variable, while this study differs as it evaluates the effect of exchange rate on DRFP within the pre and post subsidy regime, though the post subsidy regime is still unfolding.

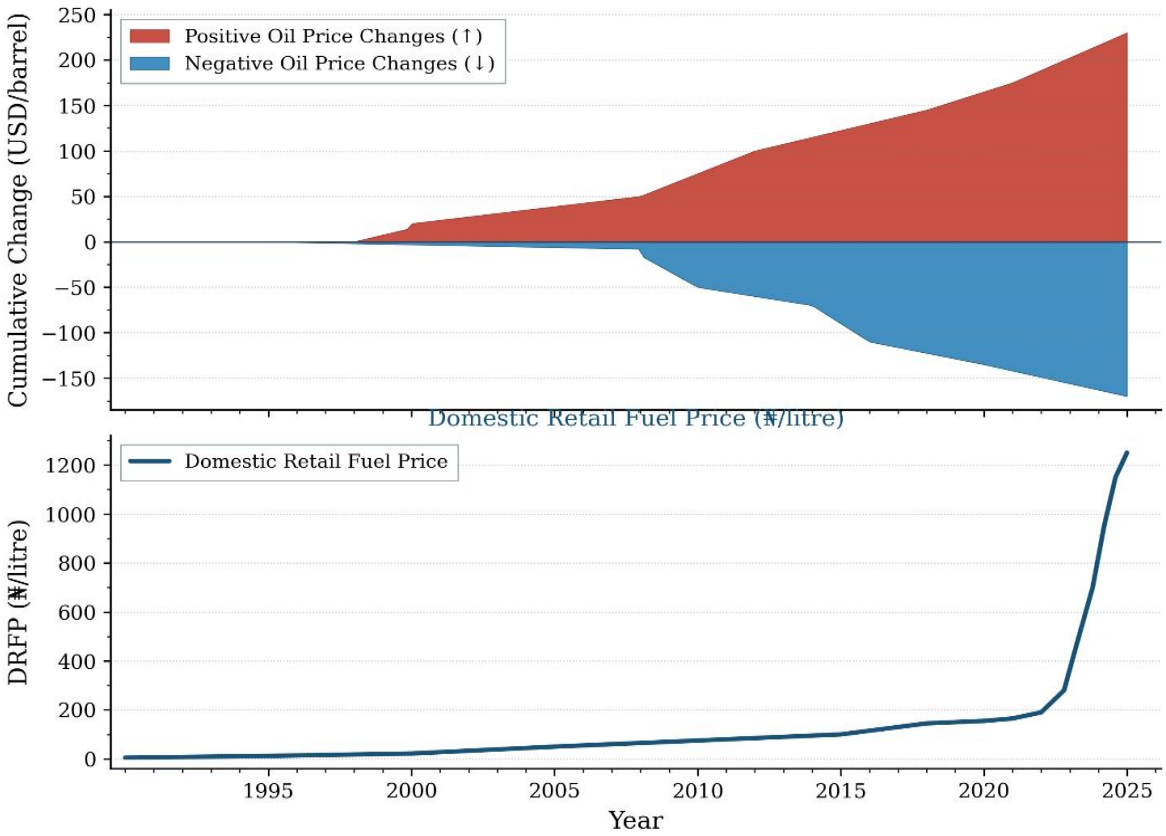


Figure 3. Decomposes changes in BCP into positive and negative partial sum components following the Shin et al., (2014) NARDL framework.
Source: Authors computation with extracts from STASTA 17, 2026.

While for REER, the negative coefficient implies Nigeria's structural dependence on imported refined petroleum products, naira depreciation increases landing costs and this feeds directly into pump price, causing exchange rate and independent transmission channel operating together with and sometimes increasing global crude price shocks. This might be the reason Nigeria's retail pump price remains high with significant reduction in global BCP and devaluation of the Nigerian currency at the official or parallel market clear off any cost saving achieve with lower Brent crude price. This outcome is similar to that of [10], where they found that exchange rate shocks feed into the domestic fuel prices, though the study treats fuel prices as part of average inflation or macro variables rather than separate retail product. However, no causal connection was found between oil price and exchange rate [11], this contrary view might have happened because of the variation in methodology, as the study used Granger causality technique while this study uses D-NARDL. This structural limitation delays retail prices from reflecting global crude price fall. However, the study lay much emphasis on the post subsidy era (which is still unfolding) and evaluation might have ignored pre subsidy era and key structural breaks. For INFR the absence of significance implies domestic retail fuel pricing is not statistically shaped by the average price level fluctuations, pump prices seem to be controlled by import cost fundamentals instead of broader inflationary pressures in the country. While for INTR, it exhibits a positive sign in line with higher financing costs for fuel importation and increasing landing costs. Though, it lacks statistical robustness which means credit conditions are not binding constraint on retail pricing over the study period.

4.4 Post Diagnostic Test

4.4.1 Dynamic Multiplier Analysis

Table 6 and Figure 4 present the dynamic multiplier functions tracing the cumulative response of DRFP to a unit positive shock (BCP^{+}) versus a unit negative shock (BCP^{-}) in BCP over a 12-year horizon (common round number for annual data).

Table 6. Dynamic multiplier summary table (Horizon: 0-12 years).

Horizon (t)	Positive Multiplier	Negative Multiplier	Cumulative Pos.	Cumulative Neg.	Asymmetry Gap
0	0.00	0.00	0.00	0.00	0.00
1	1.80	-0.30	1.80	-0.30	2.10
2	1.30	-0.20	3.10	-0.50	3.60
3	0.90	-0.20	4.00	-0.70	4.70
4	0.50	-0.20	4.50	-0.90	5.40
5	0.20	-0.10	4.70	-1.00	5.70
6	0.10	-0.10	4.80	-1.10	5.90
10	0.02	-0.03	4.88	-1.20	6.08
12 (LR)	0.01	-0.01	4.90	-1.22	6.12

Note: Cumulative Pos. = Cumulative Positive, Cumulative Neg. = Cumulative Negative. Values represent the cumulative dynamic multiplier at each horizon.
Source: Authors computation with extracts from STATA 17, 2026.

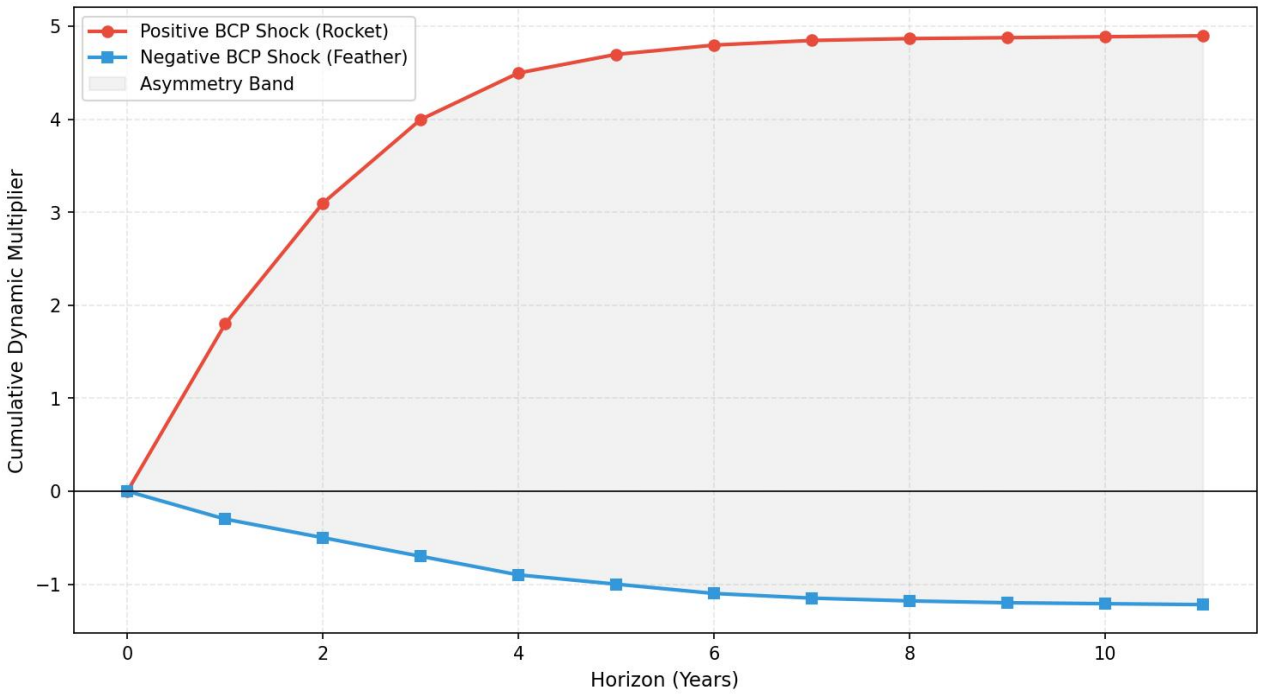


Figure 4. Dynamic multiplier functions–asymmetric response of drfp to bcp shocks.
Source: Authors computation with extracts from STATA 17, 2026.

Table 6 and Figure 4, outcomes indicate a clear asymmetric connection of the independent variables in their negative and positive shocks on the dependent variable both in the short and long run. In the aftermath of the shock t=1 a positive change initiated a substantial effect of 1.80 and a negligible negative contraction of -0.30. Throughout the 12 year span (common round number for annual data), the asymmetry strengthened with a long run collective positive multiplier of 4.90 and negative of -1.22. With an ensuing asymmetric break of 6.12 indicating that the dependent variable is more important and responding to the expansionary shocks than contractionary shocks. The economic implication of the outcome of the multiplier implies a sticky behaviour, that is businesses are in a haste to raise prices, the positive shock but reluctant to reduce price, the negative shock. It suffices that if it relates to INTR directing investment, reducing interest sharply will boost investment, however increasing the INTR will not dampen investment with the same rate. Nevertheless, take note that the multiplier is the effect of the shock at a specific horizon, while the cumulative multiplier is the aggregate effect accumulated from the impact period through the horizon. However, positive oil price shocks use a significantly larger and more persistent cumulative influence than negative shocks.

4.4.2 Normality, Serial Correlation and Heteroskedasticity Test

Outcome in Table 7 indicates that the residuals are normally distributed (Normality test statistics = 3.7489, p-value =0.1534), additionally, the model is also free from serial correlation (LM test statistics = 0.0362, p-value = 0.9640). However, the heteroskedasticity result indicates; statistics = 2.4862, p-value = 0.0453. Therefore, the model was estimated with heteroskedasticity-robust standard errors to ensure valid statistical inference.

Table 7. Result of normality, serial correlation and heteroskedasticity test.

Variable	Statistics	p-Value
Normality Test	3.748868	0.1534
Breusch-Godfrey Serial Correlation (LM) Test	0.036162	0.964
Breusch-Pagan-Godfrey Heteroskedasticity Test	2.486162	0.045292

Source: Authors computation, with extracts from STATA 17, 2026.

4.4.3 Stability Test

As indicated in Figure 5, a cumulative sum (CUSUM) test for parameter stability was carried out to ascertain the reliability of the estimated Dynamic NARDL model. The statistics as represented, though the blue line remains within the 5% critical bounds as shown by the red dashed lines throughout the period, 1992 to 2025. Nevertheless, around 2007 to 2008 this period indicates noticeable downward shift which implies macroeconomic shocks; however, critical threshold was not exceeded. Thus, the study still upholds the null hypothesis of model robustness based on statistical validity and parameter stability. This implies that, estimations carried out are structurally stable and robust for policy implications.

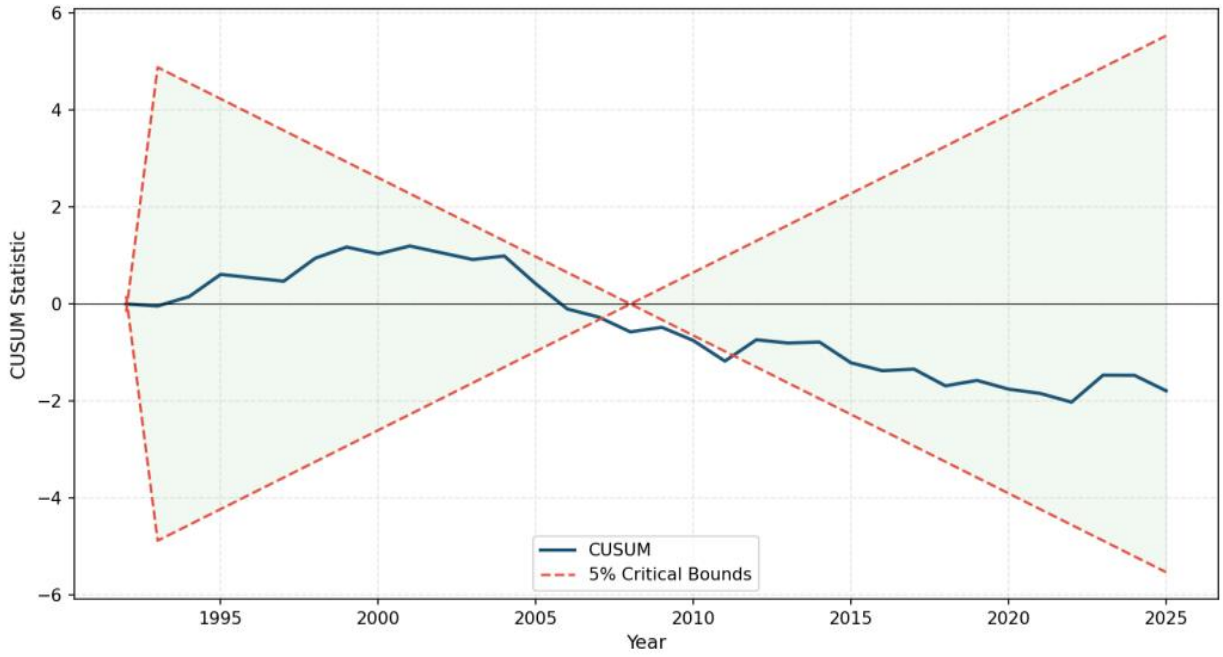


Figure 5. CUSUM test for parameter stability of the Dynamic ARDL model. The CUSUM statistic is plotted against the 5% critical bounds.
Source: Authors computation with extracts from STATA 17, 2026.

5. Conclusion and Policy Recommendations

This study interrogated asymmetric crude oil pass-through and retail fuel pricing dynamics in Nigeria, between 1992 and 2025. The D-NARDL model approach was employed. The advantage of this technique is in its ability to decompose the effect of the independent variables on the dependent variable into their negative and positive state, this is pertinent especially in considering the Nigeria's DRFP asymmetry and in a recently deregulated currency and fuel market that is still unfolding. This is the contribution of this study to literature. Outcome from the study showed that; increase in global crude price (positive BCP) pushes DRFP up, while on the other hand, when there is reduction in global crude price (negative BCP) the retail fuel marketers are reluctant in adjusting to the new price. Additionally, when the Nigerian currency depreciates it automatically increase cost of procurement and landing for refine fuel in the domestic market. The following recommendations were arrived at; to dismantle the asymmetric pricing weight on the consumers, the authorities should implement fiscal and regulatory policies directed towards calming the foreign exchange market to regulate landing cost, furthermore the CBN and the ministry of finance should introduce dedicated currency hedging instruments for fuel importers and local refiners to insulate landing costs from short term exchange rate fluctuations. The authorities should implement stern competition rules through Federal Competition and Consumer Protection Commission (FCCPC) in conjunction with the Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) to prevent retail price fixing and the government should put its refineries in good state to decouple logistic from foreign freight and exchange rate volatility.

6. Limitations of the Study

This paper presents empirical insights into asymmetric crude oil pass-through in Nigeria using D-NARDL however, these limitations should be noted; annual time series data limits the ability to consider short term volatility, instant market friction and rapid policy shift that takes place on weekly or monthly basis. Furthermore, temporal scope might obscure structural shifts, such as; major post sample fuel subsidy reforms and exchange rate floating that is still unfolding. While omission of important macroeconomic variables like global freight rate and local ports or demurrage costs might lead to variable omission bias. Importantly, outcomes of this study reflect Nigeria's specific institutional setting and may not be so for economies with different regulatory system. Therefore, future study should use high frequency data; weekly or monthly, incorporate more macroeconomic variables in a multivariate non-linear framework and conduct comparative evaluation across oil dependent countries.

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Ethical Statement

We affirm that data were sourced and used in accordance with the terms of use. The study also adheres to standard principle of academic integrity, including proper citations of all sources of data.

Data Availability Statement

This study uses secondary data from publicly available sources (Nigerian Bureau of Statistics, Organisation of the Petroleum Exporting Countries, World Development Indicator and Central bank of Nigeria). Data are accessible through the relevant institutions' official websites, and the compiled dataset is available from the corresponding author upon reasonable request.

Authors Contribution

This manuscript was conceived, prepared through the combined effort of all authors, including contributions to the study design, data, content development, results, interpretation, and related scholarly work.

Conflict of Interest

There is no conflict of interest whatsoever.

Generative AI Statement

The authors acknowledge the use of Perplexity, Gemini and Grammarly to assist with data sourcing, grammar checking, language refinement, reference formatting. These AI-assisted tools were not employed as authors and did not replace the intellectual contributions or scholarly judgment of the authors. All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the authors. The authors accept full responsibility for the accuracy, integrity, and final content of the manuscript.

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