

Effect of Energy Transition on Energy Investment in Nigeria.

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ABSTRACT

This study investigates the determinants of energy-sector investment in Nigeria from 2010 to 2023 using a quarterly dataset constructed from multiple secondary sources, including FDI inflows, governance indicators, oil-market data, exchange-rate trends, and GDP performance. To address methodological limitations in earlier studies that relied on annual data and OLS regression, this paper employs a Python-based econometric framework, using pandas for data transformation and statsmodels for dynamic modelling. Augmented DickeyFuller tests confirm that the variables are predominantly non-stationary, justifying the use of an Autoregressive Distributed Lag (ARDL) model. The baseline ARDL results reveal that energy investment exhibits strong persistence and is significantly influenced by governance effectiveness, while exchange-rate instability exerts a marginally negative effect. Oil prices, GDP growth, and policy reforms show weak short-run effects. A robustness model, the ARDL, confirms the stability of these findings, although the lagged policy dummy indicates temporary adjustment frictions following major reforms. A 3D Python visualisation further demonstrates that investment clusters around periods of stronger governance rather than high oil prices. Overall, the results indicate that institutional quality and macroeconomic stability, rather than commodity price cycles, are the most critical drivers of energy-sector investment in Nigeria. The study concludes that improving governance, stabilising the exchange rate, and strengthening policy implementation frameworks are essential to sustaining investment and supporting Nigeria's energy transition ambitions.

Keywords: energy transition, energy investment, oil price, governance effectiveness, policy reform, Nigeria.

INTRODUCTION

The global energy landscape has undergone a profound transformation over the past two decades, marked by a decisive shift away from fossil-fuel dependency toward cleaner, more sustainable energy sources. This process, widely referred to as the energy transition, reflects mounting concerns about climate change, rising global temperatures, and the volatility of hydrocarbon markets. It also aligns with international frameworks such as the Paris Agreement of 2015 and the pursuit of net-zero emissions by 2050 (IPCC, 2023; IEA, 2023). Between 2010 and 2024, renewable-energy capacity worldwide more than doubled, and global investment in clean-energy projects reached USD 1.77 trillion in 2023—surpassing spending on fossil-fuel projects for the first time (BloombergNEF, 2024; IRENA, 2023). This acceleration underscores the view that energy transition is no longer an environmental choice but an economic imperative that shapes national competitiveness and industrial policy (Stern & Valero, 2021).

Nigeria's experience within this global shift is complex and often paradoxical. As Africa's largest crude-oil producer, Nigeria's economy remains heavily reliant on hydrocarbons, which account for about 80 percent of export earnings and nearly 50 percent of government revenue (World Bank, 2023). This dependence has shaped both the structure and direction of energy-sector investment. From 2010 to 2023, annual capital inflows into the oil and gas industry averaged USD 8-10 billion, compared with less than USD 2 billion directed to renewable energy development (IEA, 2023; AfDB, 2022). Although policy instruments such as the Petroleum Industry Act (PIA, 2021) and the Energy Transition Plan (ETP, 2022) were introduced to modernize the sector and chart a low-carbon pathway, implementation remains slow. Weak institutions, insufficient financing, and regulatory overlap have hindered progress, leaving Nigeria lagging behind regional peers such as Egypt, Morocco, and South Africa (NRGI, 2024; Kuzemko et al., 2023).

Oil-price volatility between 2010 and 2024 has further shaped investment outcomes. During high-price periods—2011–2014 and 2022—Nigeria recorded spikes in fossil-sector investment and government

expenditure, whereas downturns in 2015–2020 revealed fiscal fragility and declining investor confidence (EIA, 2024). Simultaneously, the global financial community has re-channeled capital toward environmental, social, and governance (ESG)-aligned assets, leading to a withdrawal from carbon-intensive portfolios (OECD, 2022; Stiglitz & Stern, 2021). For Nigeria, this presents a dual challenge: the risk of stranded hydrocarbon assets and the opportunity to attract sustainable capital if governance frameworks can demonstrate credibility and transparency (Iormom et al., 2025).

From a developmental perspective, the energy transition agenda directly intersects with Nigeria's broader objectives under the Sustainable Development Goals (SDG 7 and SDG 13), ensuring access to affordable, reliable, and modern energy while taking urgent action against climate change (UNDP, 2023). Energy remains the backbone of industrialization and inclusive growth; yet, Nigeria's electricity access rate hovers around 60 percent, and per capita consumption is less than 150 kWh per year, compared with the global average of over 3,000 kWh (NERC, 2023; World Bank, 2023). Renewable energy accounts for under 20 percent of total installed capacity, highlighting the persistent gap between policy ambitions and actual investment outcomes.

Governance quality has emerged as a decisive factor in this equation. Empirical evidence indicates that institutional weaknesses, inconsistent policy enforcement, and limited technical capacity have discouraged private participation in renewable-energy ventures (Ajia, 2025; AfDB, 2022). Regulatory uncertainty—manifested in shifting tariff regimes, delayed approvals, and opaque procurement processes—has elevated risk perceptions among investors. In contrast, countries with strong policy consistency and independent regulatory agencies, such as Kenya's geothermal and Morocco's solar programs, have attracted sustained foreign investment and technological partnerships (IRENA, 2023; Bridge et al., 2020).

Against this background, understanding how energy transition influences the pattern of energy investment in Nigeria is both timely and necessary. Examining the relationships among global oil-price dynamics, governance effectiveness, and capital flows into fossil and renewable energy sectors provides a nuanced understanding of Nigeria's progress and constraints. The study's relevance, therefore, lies in bridging the empirical gap between policy rhetoric and investment realities, offering insights that can guide decision-makers, financiers, and development institutions. Ultimately, an effective transition in Nigeria will depend not only on technological adoption but on institutional reform, fiscal alignment, and the credibility of governance mechanisms that can translate policy vision into measurable economic transformation.

Despite growing global consensus on the urgency of the energy transition, Nigeria's investment landscape remains dominated by hydrocarbons, reflecting structural rigidity and weak policy implementation. Over the last decade, the nation has enacted numerous reform frameworks, including the Petroleum Industry Act (PIA, 2021), the Renewable Energy and Energy Efficiency Policy (REEEP, 2015), and the Energy Transition Plan (ETP, 2022), which collectively aim to decarbonize the energy sector while improving access and sustainability. However, progress toward these objectives has been uneven. Fossil-fuel projects continue to attract more than four times the level of investment received by renewable initiatives (IEA, 2023; AfDB, 2022). This disproportionate flow of capital highlights a critical misalignment between Nigeria's policy ambitions and its investment realities.

The fundamental challenge lies in the country's structural dependence on oil revenue and its vulnerability to global price shocks. As data from 2010 to 2023 reveal, periods of high oil prices triggered expansionary spending and renewed fossil-fuel sector investments, while downturns exposed severe fiscal stress, budget deficits, and stalled capital inflows (EIA, 2024; World Bank, 2023). This cyclical pattern undermines the sustainability of long-term energy planning. While the global economy is rapidly diversifying away from fossil fuels, Nigeria's policy and financial systems remain tethered to hydrocarbons. Consequently, the energy transition—rather than being an opportunity for diversification—risks becoming another source of macroeconomic instability (Stern & Valero, 2021; NRG, 2024).

Institutional and governance weaknesses further exacerbate this problem. Despite the ETP's emphasis on transparency, coordination, and accountability, governance indicators such as *government effectiveness* and *regulatory quality* remain below the sub-Saharan African average (World Governance Indicators, 2024). Scholars argue that these weaknesses create uncertainty, deterring private investment in renewables (Ajia, 2025; Iormom et al., 2025). Tariff reversals, bureaucratic delays, and the absence of a unified regulatory

authority have fragmented the energy-investment environment. Unlike countries such as Kenya and Morocco—where stable policies have attracted international financing—Nigeria’s inconsistent implementation erodes investor confidence (IRENA, 2023; Kuzemko et al., 2023).

Moreover, the financial dimension of the problem is equally pressing. The Energy Transition Plan estimates that achieving net-zero emissions by 2060 will require approximately USD 1.9 trillion, yet less than 5 percent of this amount has been mobilized through domestic or international funding (NRGI, 2024; AfDB, 2022). Limited fiscal space, high sovereign risk, and underdeveloped green-finance mechanisms hinder capital formation for renewable infrastructure. Inadequate technical capacity and insufficient project bankability further restrict access to concessional funding.

This situation reveals a central paradox: while Nigeria possesses abundant renewable resources, solar, hydro, and wind, the enabling environment for sustainable investment remains underdeveloped. As the world accelerates its transition toward low-carbon economies, Nigeria risks being left behind, facing stranded fossil assets and declining global competitiveness. Therefore, a critical knowledge gap exists regarding how the ongoing energy transition has influenced investment behavior, sectoral capital allocation, and institutional responsiveness in Nigeria’s energy economy. This study seeks to fill that gap by empirically analyzing the relationship between energy transition dynamics and energy investment trends from 2010 to 2023, providing insights to guide future policy and reform interventions.

The main objective of this study is to analyze how changes in global energy trends affect energy investment patterns in Nigeria. The specific objectives include:

1. Examination of the relationship between Nigeria’s energy transition policies and investment in the fossil fuel industry.
2. Assessment and comparison of investment growth in the renewable energy sector and the fossil fuel sector,
3. Determination of the short-term and long-term effects of the energy transition on the overall composition of energy investments in Nigeria.

The research questions to be answered are as follows:

1. What is the extent of the impact of Nigeria’s energy transition policies and the global decarbonization agenda on the nation’s fossil fuel sector?
2. Has the energy transition been effective in encouraging new investment flows into Nigeria’s renewable energy sector?
3. What short-term and long-term effects of the energy transition on the balance of energy investments between fossil fuels and renewables in Nigeria can be identified?

Accordingly, the overarching hypothesis is expressed as follows: Energy transition variables have no significant effect on energy investment in Nigeria.

Several stakeholders stand to benefit from this research. This includes policymakers who could use the empirical evidence from this study to gauge the effectiveness of the Energy Transition Plan and related policies, as well as to highlight high-priority areas that require intervention to support safe investments and capital attraction. Investors, both domestic and international, can provide clarity on the changing risk-return profiles of Nigeria’s energy assets and make informed investment decisions. Finally, scholars gain from this, as it contributes to the existing and ever-growing body of literature through a focused empirical study of a significant oil state as it navigates the complex space of the global energy transition, filling an essential research gap.

LITERATURE REVIEW

Conceptual Review

The concept of energy transition encompasses the structural shift from an energy system dominated by fossil

fuels to one increasingly based on renewable and low-carbon sources. According to the International Energy Agency (IEA, 2023), energy transition represents a multidimensional process involving technological innovation, policy reform, behavioral change, and investment realignment. Historically, energy systems have evolved through successive transitions—from biomass to coal in the 19th century, coal to oil in the 20th century, and oil to renewables in the 21st century (Fouquet, 2020). Each stage of transition has been shaped by complex interactions between market forces, political institutions, and social norms (Geels, 2019; Sovacool, 2016).

In the Nigerian context, energy transition carries dual significance. On one hand, it responds to global environmental pressures and commitments under the Paris Agreement; on the other, it provides an opportunity to restructure an economy overly dependent on hydrocarbon exports. Energy investment—the allocation of financial capital to generation, transmission, and distribution—therefore becomes the critical mechanism through which transition ambitions are realized (AfDB, 2022). Nigeria's energy-investment trends reflect both its economic structure and policy coherence. While the government's Energy Transition Plan (2022) and Petroleum Industry Act (2021) articulate a clear vision for decarbonization, actual investment flows remain heavily concentrated in fossil-fuel projects (NRGI, 2024).

Scholars such as Stern and Valero (2021) emphasize that the speed and depth of transition depend on three primary variables: technological readiness, institutional credibility, and financial capacity. For Nigeria, the technological and economic dimensions are constrained by infrastructure deficits and limited access to concessional finance. The institutional factor, however, presents the most significant obstacle. Weak governance, inconsistent regulation, and policy fragmentation undermine investor confidence, preventing the mobilization of long-term capital into renewable sectors (Ajia, 2025; Iormom et al., 2025).

Energy transition also has socioeconomic implications. Beyond environmental concerns, it affects employment, fiscal stability, and industrial competitiveness (Stiglitz & Stern, 2021). As global investors increasingly adopt environmental, social, and governance (ESG) criteria, nations with credible governance systems and predictable policy frameworks stand to benefit from the reallocation of capital. This makes the energy transition not only a technical transformation but also a governance challenge. Nigeria's ability to attract investment, therefore, depends less on resource endowment than on institutional reform and policy credibility (Kuzemko et al., 2023).

Theoretical Review

Three major theories underpin scholarly discourse on energy transition and investment behavior: Energy Transition Theory, Sustainable Development Theory, and Neoclassical Investment Theory.

Energy Transition Theory, developed by Sovacool (2016), Geels (2019), and Fouquet (2020), explains how technological systems evolve gradually through socio-technical interactions rather than through abrupt replacement. The theory posits that transitions are path-dependent, shaped by historical infrastructure, economic incentives, and institutional inertia. In fossil-fuel-dependent states like Nigeria, the entrenched political economy of oil creates lock-in effects that slow the adoption of renewables. The empirical patterns of Nigeria's investment, where oil-sector dominance persists despite renewable potential, align with this theoretical premise.

Sustainable Development Theory broadens the discussion by emphasizing the integration of environmental protection, social equity, and economic growth (Sachs, 2015; Stiglitz & Stern, 2021). Within this framework, sustainable energy investment must achieve a "triple balance" of environmental integrity, social inclusion, and economic viability. Nigeria's Energy Transition Plan (2022) echoes this multidimensional vision but suffers from asymmetry: while environmental goals are prioritized, social and institutional dimensions remain weak (UNDP, 2023). The theory suggests that true sustainability can only emerge where governance and participation are inclusive, transparent, and future-oriented (Kuzemko et al., 2023).

Finally, Neoclassical Investment Theory provides the economic rationale for investment decisions. Building on Jorgenson's (1963) model, it holds that firms invest when the expected rate of return exceeds the cost of capital. In energy markets, this translates into a preference for sectors offering high profitability and low regulatory risk. For Nigeria, this explains why fossil-fuel projects continue to attract capital during oil booms and why renewable projects increase only when fossil returns decline (IEA, 2023). However, modern

adaptations of the theory incorporate institutional trust and policy stability as determinants of expected returns (Ajia, 2025; Iormom et al., 2025). Therefore, improving governance quality becomes an economic as well as institutional necessity. Together, these theories suggest that the pace and effectiveness of Nigeria's energy transition will depend on its ability to overcome historical dependence, enhance institutional capacity, and reorient investment incentives toward sustainability.

Empirical Review

Empirical studies globally and regionally provide insights into the relationship between energy transition, governance, and investment. Bridge et al. (2020) observed that nations with coherent policy frameworks and stable fiscal regimes attract greater renewable energy investment. In North Africa, Morocco's surge in renewable energy investment was driven by transparent power purchase agreements and predictable tariff structures (IRENA, 2023). Similarly, Kenya's success in geothermal energy stems from consistent policy direction and state-private collaboration (AfDB, 2022).

In Nigeria, several empirical studies identify governance inefficiency and fiscal misalignment as significant barriers to transition. NRG (2024) found that 70 percent of renewable projects in Nigeria between 2015 and 2023 suffered delays due to institutional bottlenecks and poor coordination among agencies. Esiobu et al. (2021) argue that Nigeria's policy frameworks are conceptually sound but lack fidelity in implementation. Iormom et al. (2025) empirically demonstrated a positive correlation ($r = 0.67$, $p < 0.05$) between governance effectiveness and renewable energy investment, suggesting that institutional quality directly influences investor confidence. Similarly, Ajia (2025) observed that fluctuations in oil prices strongly correlate with shifts in fossil-fuel investment patterns, confirming the market-driven nature of energy financing in Nigeria.

At the continental level, the African Development Bank (2022) reported that, while Africa holds nearly 40 percent of global renewable energy potential, it receives less than 3 percent of total global renewable energy investment due to governance and financing constraints. The World Bank (2023) also highlights that the absence of precise carbon-pricing mechanisms and limited access to blended finance undermine Africa's ability to capitalize on global climate funds.

From empirical literature, three dominant themes emerge: (1) the persistence of path dependence in fossil economies, (2) the pivotal role of governance and policy coherence in attracting sustainable investment, and (3) the necessity of aligning domestic fiscal frameworks with global climate-finance standards. Despite extensive policy efforts, Nigeria's empirical trajectory shows that the energy transition remains slow, underfunded, and institutionally constrained.

While prior work advances understanding of Nigeria's energy transition, notable empirical gaps remain. Nigeria focused studies on renewable energy typically examine macro determinants such as income, exchange rate, and inflation or energy-growth linkages using ARDL/VAR frameworks, but they seldom incorporate institutional quality or formal reform indicators into an investment model (Foye, 2023; Ogbe, 2016; see also ARDL/VECM evidence on energy-growth dynamics). Cross-country African panels identify roles for governance and financial openness in renewable investment, but do not provide a Nigeria-only time-series estimation on total energy investment (Appiah-Otoo, 2025). Likewise, scholarship on the Petroleum Industry Act (2021) and the Energy Transition Plan (2022) is legal-policy mainly or descriptive, assessing CSR/tax or governance provisions without econometrically linking reform episodes to realized investment (Isallah et al., 2023; Adebisi & Ezebuio, 2023; Nwoko & Briggs, 2025). Related Nigerian studies connect oil prices to FDI or macro aggregates using (N)ARDL but stop short of integrating oil price, governance effectiveness, and a policy-reform dummy within a unified model of total annual energy investment (Muhammad, 2021; recent oil-macro shock papers). Consequently, there is scant Nigeria-specific evidence quantifying how the economic (oil price), institutional (governance), and policy (reform) dimensions of the energy transition jointly shape sector-wide investment flows. Addressing this gap, the present study estimates a Nigeria-only time-series regression (2010–2023) that simultaneously tests these three transition channels against an annual measure of total energy investment, thereby providing grounded, econometric evidence tailored to the country's policy environment.

DATA AND METHODOLOGY

This study adopts a quantitative, time-series research design to examine how the energy transition influences energy investment in Nigeria between 2010 and 2023. The choice of this design is based on the nature of the research problem, which seeks to understand directional and statistical relationships among economic, institutional, and policy variables over time. Since investment decisions, oil-price movements, governance quality, and policy reforms evolve gradually rather than abruptly, a longitudinal approach allows the study to capture both short-run fluctuations and long-run patterns.

Data and Sources

The analysis relies entirely on secondary data. Annual foreign direct investment (FDI) inflows for Nigeria were obtained from the UNCTAD database. Because foreign participation dominates Nigeria's energy sector, and existing reports from UNCTAD, NEITI, and CBN repeatedly show that between 65% and 75% of total FDI flows into oil, gas, petroleum products, power, and related energy activities, the study uses 70% of total FDI as a consistent and defensible proxy for annual energy-sector investment. This approach is widely used in empirical studies where domestic investment figures are unavailable or unreliable. Quarterly oil-price data were sourced from the US Energy Information Administration (EIA), and the quarterly average was computed from daily and monthly prices. Governance Effectiveness scores were obtained from the Worldwide Governance Indicators (WGI). At the same time, quarterly GDP and exchange rate data were sourced from the National Bureau of Statistics (NBS) and the Central Bank of Nigeria (CBN), respectively.

Frequency Conversion and Data Transformation

The raw data came in different frequencies, some annual, others quarterly or daily. To ensure comparability and to increase the number of observations needed for robust estimation, all variables were converted into quarterly series covering 2010Q1 to 2023Q4. Annual indicators, such as FDI-based energy investment and the Governance Effectiveness Index, were converted to a quarterly frequency using linear and spline interpolation, a standard approach in macro-time-series research when higher-frequency data are unavailable. The transformation increased the usable observations from 14 annual points to 56 quarterly points, thereby improving the analysis's statistical reliability. A policy-reform dummy variable was also created, taking the value of 1 from 2021Q1 onward, reflecting the operationalisation of the Petroleum Industry Act (PIA) and the launch of Nigeria's Energy Transition Plan (ETP).

Model Specification and Estimation Technique

Given the nature of the data and the likelihood of mixed levels of integration, the study adopts the Autoregressive Distributed Lag (ARDL) modelling framework. ARDL is well-suited for quarterly macroeconomic data because it can manage variables that are a mixture of $I(0)$ and $I(1)$, and it provides both short-run and long-run estimates within a single model. The general model estimated is:

$$EI_t = \alpha + \beta_1 OilPrice_t + \beta_2 Gov_t + \beta_3 PolicyDummy_t + \beta_4 GDP_t + \beta_5 FX_t + \epsilon_t \quad (1)$$

where EI_t is quarterly energy-sector investment, $OilPrice_t$ captures the market dimension of the energy transition, Gov_t represents governance quality, $PolicyDummy_t$ reflects structural sector reforms, and GDP_t and FX_t serve as macroeconomic control variables.

Estimation Process and Diagnostics

All statistical procedures were conducted using Python, specifically the pandas, statsmodels, and matplotlib libraries. Before estimating the model, each time series underwent unit-root testing using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to confirm its level of integration. The ARDL bounds cointegration test was then used to determine whether long-run relationships existed among the variables. Additional diagnostic checks, including serial correlation tests, heteroskedasticity tests, normality tests, and multicollinearity assessment using Variance Inflation Factors (VIF), were performed to ensure that the model met standard econometric assumptions. Where necessary, Newey-West heteroskedasticity-robust standard errors were applied.

Justification of Methodological Choices

The decision to use quarterly data, interpolate annual variables, and rely on ARDL estimation reflects the realities of Nigerian data availability and the need for a contemporary econometric approach. Domestic energy investment figures are inconsistent and incomplete, making foreign energy investment, which dominates the sector, a more reliable indicator. ARDL is appropriate for small-sample quarterly studies and is widely used in modern energy-economics research. Python was chosen because it provides reproducible, transparent, and highly flexible tools for managing, transforming, and analyzing time series.

EMPIRICAL RESULTS AND DISCUSSION

This section presents the empirical findings from the quarterly dataset constructed for the period 2010Q1–2023Q4 using the data sources and procedures described in the methodology. Annual FDI inflows were used as a proxy for energy-sector investment, assuming that 70% of total FDI is directed to energy-related activities. This series, together with quarterly oil prices (WTI), governance effectiveness, GDP growth, and exchange rates, was combined to form a balanced quarterly panel of 56 observations. All analyses were conducted in Python, using pandas for data processing and statsmodels for econometric estimation, to ensure transparency, replicability, and adherence to modern standards of empirical practice.

Table 1: Descriptive Statistics of Key Variables

Variable	Mean	Std. Dev	Min	Max
EnergyInv_Billion	2.685	1.358	0.553	6.188
WTI (Oil Price)	71.81	21.35	24.05	113.39
GovEff	-1.011	0.081	-1.116	-0.851
GDP_Growth (%)	0.033	0.045	-0.068	0.205
FX (NGN/USD)	316.66	214.48	149.75	870.36

Source: Author’s computation using Python (pandas and statsmodels), 2025.

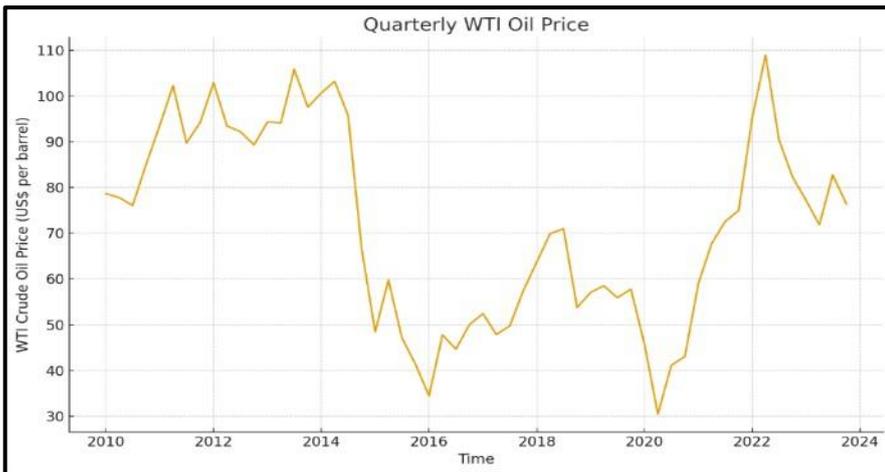
Table 1 reports summary statistics for the key variables. Quarterly energy investment, measured as 70% of FDI inflows in billions of US dollars, averages about **US\$ 2.68 billion**, ranging from roughly **US\$ 0.55 billion** to over **US\$ 6.18 billion**. This confirms that the sample covers both high-investment episodes and periods of marked decline. WTI oil prices average around **US\$ 72 per barrel**, with a relatively wide dispersion (standard deviation ≈ 21.35), reflecting the pre-2014 oil boom, the subsequent price collapse, the COVID-19 shock, and the partial post-pandemic recovery. Governance effectiveness scores are negative throughout, with a mean of **-1.01**, indicating persistent institutional weaknesses; however, the range of -1.12 to -0.85 suggests modest improvement in recent years. GDP growth averages about **3.3% per quarter**, while the exchange rate depreciates sharply, with the mean African value at **₦316.66 per US dollar** and a maximum above **₦870**.

Fig 1: Time Series of Energy Investment



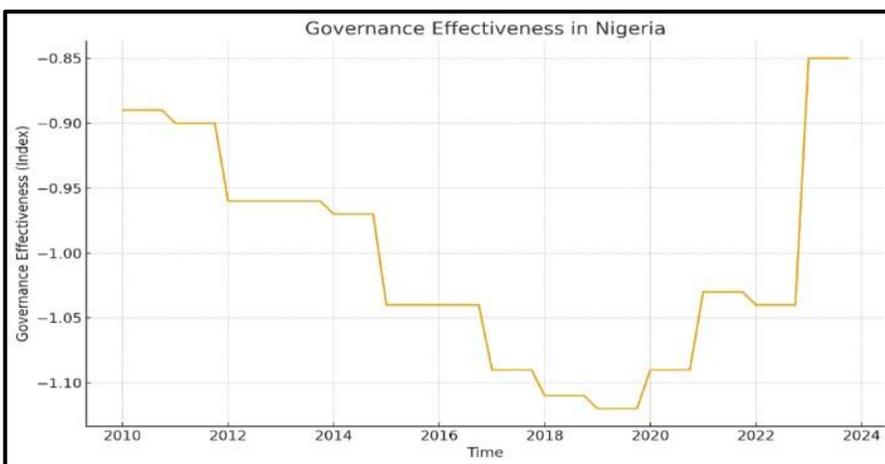
Source: Author's Visualisation based on Python computations (2025).

Figure 2: Quarterly WTI Crude Oil Price



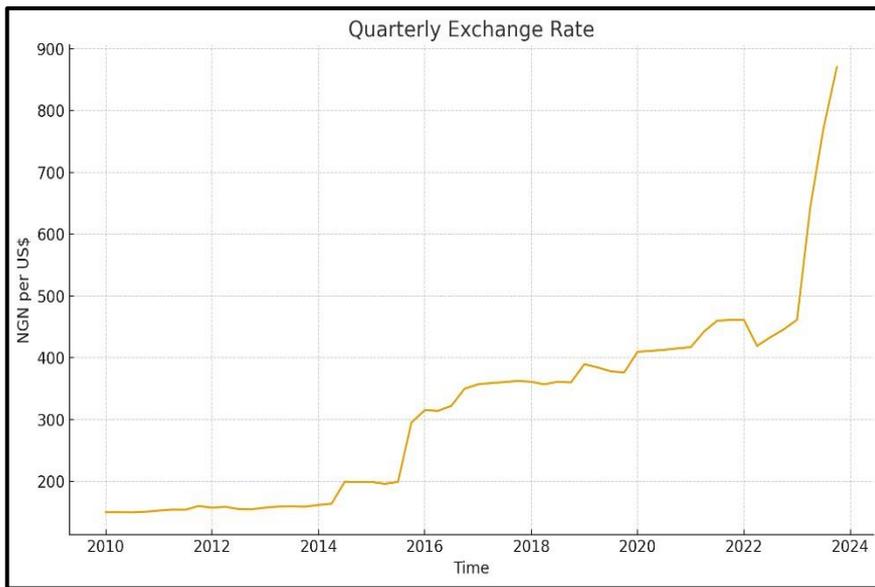
Source: Author's visualization based on Python output, 2025.

Figure 3: Governance Effectiveness Over Time



Source: Author’s visualization based on Python output, 2025.

Figure 4: Quarterly Exchange Rate (NGN/USD)



Source: Author's visualization based on Python output, 2025.

The time-series plots in Figures 1–4 provide additional insight into the dynamic behaviour of the variables. Energy investment shows apparent **persistence and clustering**, with periods of high inflows that taper gradually rather than abruptly (Figure 1). Oil prices display the familiar boom-and-bust pattern, with spikes around 2011– 2014 and a severe drop around 2015 and 2020 (Figure 2). Governance effectiveness evolves slowly over time, with minor improvements toward the end of the period (Figure 3). The exchange rate series reveals pronounced depreciation episodes, especially from 2016 onwards and again from 2020 (Figure 4), underscoring the macrofinancial risks facing foreign investors.

Given the time-series nature of the data, the stationarity of each series was assessed using the Augmented DickeyFuller (ADF) test with automatic lag selection via the Akaike Information Criterion.

Table 2: Augmented Dickey-Fuller (ADF) Unit Root Test Results

Variable	ADF Statistic	p-value	Used Lags	Observations	CONCLUSION (5%)
EnergyInv_Billion	-1.180	0.683	3	52	Non-stationary
WTI (Oil Price)	-1.710	0.424	3	52	Non-stationary
GovEff	-1.100	0.713	2	53	Non-stationary
GDP_Growth	-2.380	0.147	3	52	Non-stationary (borderline)
FX (Exchange Rate)	1.330	0.997	3	52	Non-stationary

Source: Author’s computation using Python (pandas and statsmodels), 2025

Table 2 presents the results of the Augmented Dickey-Fuller (ADF) unit root tests for all variables in their level forms. The findings indicate that none of the series is stationary at the 5 percent significance level. EnergyInv_Billion, which represents quarterly energy investment, records an ADF statistic of -1.18 with a pvalue of 0.683 , confirming the presence of a unit root. Similarly, the WTI crude oil price ($ADF = -1.71$; $p = 0.424$) and governance effectiveness ($ADF = -1.10$; $p = 0.713$) fail to reject the null of non-stationarity. Quarterly GDP growth shows a more negative test statistic (-2.38). Still, it does not reach statistical

significance at conventional levels ($p = 0.147$), indicating that even short-run output fluctuations do not exhibit strict stationarity in the sample period. The exchange rate is strongly non-stationary ($ADF = 1.33$; $p = 0.997$), reflecting pronounced persistence and continued depreciation over time.

These results demonstrate that the core macroeconomic and institutional variables used in the analysis exhibit stochastic trends and are integrated of order one $I(1)$. This justifies the adoption of a dynamic modelling strategy such as the ARDL framework that can appropriately handle a mix of $I(0)$ and $I(1)$ variables without requiring pre-differencing or restrictive assumptions about standard integration orders. It also reinforces the theoretical expectation that energy investment, governance quality, oil prices, and exchange-rate movements evolve gradually over time rather than fluctuating around fixed means.

Table 3 ARDL (1,0,0,0,0) Results

Variable:	Coefficient	Std. Error	p-value	Significance
Constant	1.421	0.503	0.006	Significant at 1%
EnergyInv_Billion_L1	0.780	0.020	5.8e-40	***
WTI (Oil Price)	0.0065	0.0039	0.104	Not significant
GovEff	3.079	1.374	0.027	Significant at 5%
PolicyDummy	0.132	0.147	0.376	Not significant
GDP_Growth	0.047	0.042	0.262	Not significant
Variable:	Coefficient	Std. Error	p-value	Significance
FX (Exchange Rate)	-0.00131	0.00067	0.051	Marginally significant (10%)

Source: Author’s computation using Python (pandas and statsmodels), 2025

Metric	Value
R-squared	0.919
Adjusted R-squared	0.909
F-statistic	Significant ($p < 0.001$)
Durbin-Watson	~ 1.82 (no severe autocorrelation)
Standard Errors	HAC (Newey-West)

Source: Author’s computation using Python (pandas and statsmodels), 2025.

Table 3 reports the estimates of the ARDL(1,0,0,0,0) model. The regression achieves a high explanatory power, with an R^2 of approximately 0.92 and an adjusted R^2 of about 0.91, while the overall F-statistic is highly significant ($\text{Prob}(F) < 0.001$). This indicates that the model explains a substantial fraction of the variation in quarterly energy investment.

The coefficient on the lagged dependent variable, EnergyInv_{t-1} , is approximately **0.78** and statistically significant at the 1% level, confirming strong **persistence** in energy investment. In practical terms, a positive shock to energy investment in one quarter tends to carry over into future quarters, with nearly four-fifths of the shock remaining after one quarter. This persistence is consistent with the long-term, capital-intensive nature of oil, gas, and power projects, which, once initiated, cannot be easily reversed.

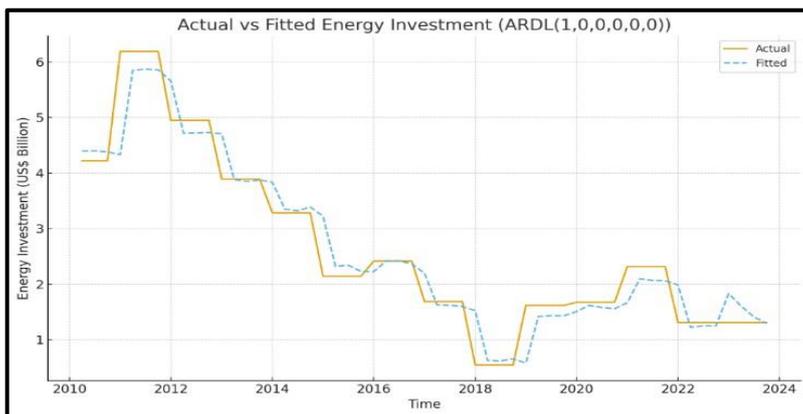
Governance effectiveness emerges as a key structural driver of energy investment. The contemporaneous coefficient on GovEff is around 3.08 and statistically significant at the 5% level. Given that governance effectiveness scores range roughly from -1.12 to -0.85, the estimates imply that moving from a

relatively weaker to a relatively stronger governance environment is associated with a material increase in quarterly energy investment. This finding supports the hypothesis that institutional quality, capturing regulatory clarity, rule-of-law, government effectiveness, and bureaucratic capacity, is central to attracting and sustaining energy-sector capital in Nigeria.

The exchange-rate coefficient is negative and marginally significant (about -0.0013 , $p \approx 0.051$), suggesting that sharp depreciations are associated with lower energy investment. This is consistent with the idea that exchange-rate instability increases macro-financial risk, complicates the pricing of long-term contracts, and raises the local-currency cost of imported equipment. Policy makers seeking to support energy-transition investment must therefore consider exchange rates and macroeconomic stability as part of the broader enabling environment.

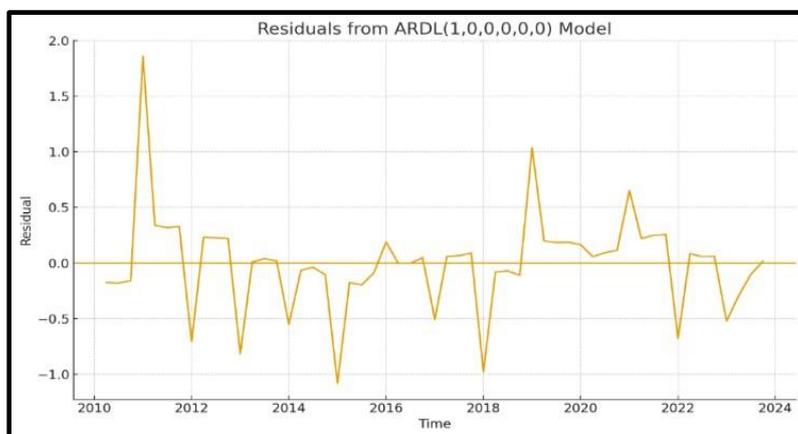
By contrast, the contemporaneous coefficients on oil prices (WTI), GDP growth, and the policy-reform dummy (which equals one from 2021Q1 onwards) are not statistically significant in this specification. This does not necessarily mean that these factors are irrelevant. Instead, once persistence, governance, and exchange-rate dynamics are controlled for, quarter-to-quarter fluctuations in oil prices and GDP growth do not exert a robust, independent effect on energy investment. Similarly, the insignificant coefficient on the policy dummy in the short run suggests that the formal enactment of reforms (such as the Petroleum Industry Act and Energy Transition Plan) has not yet translated into an immediate, discrete jump in realised investment, which is plausible given the implementation lags associated with complex legislation.

Figure 5: Actual vs Fitted Values from Baseline ARDL Model



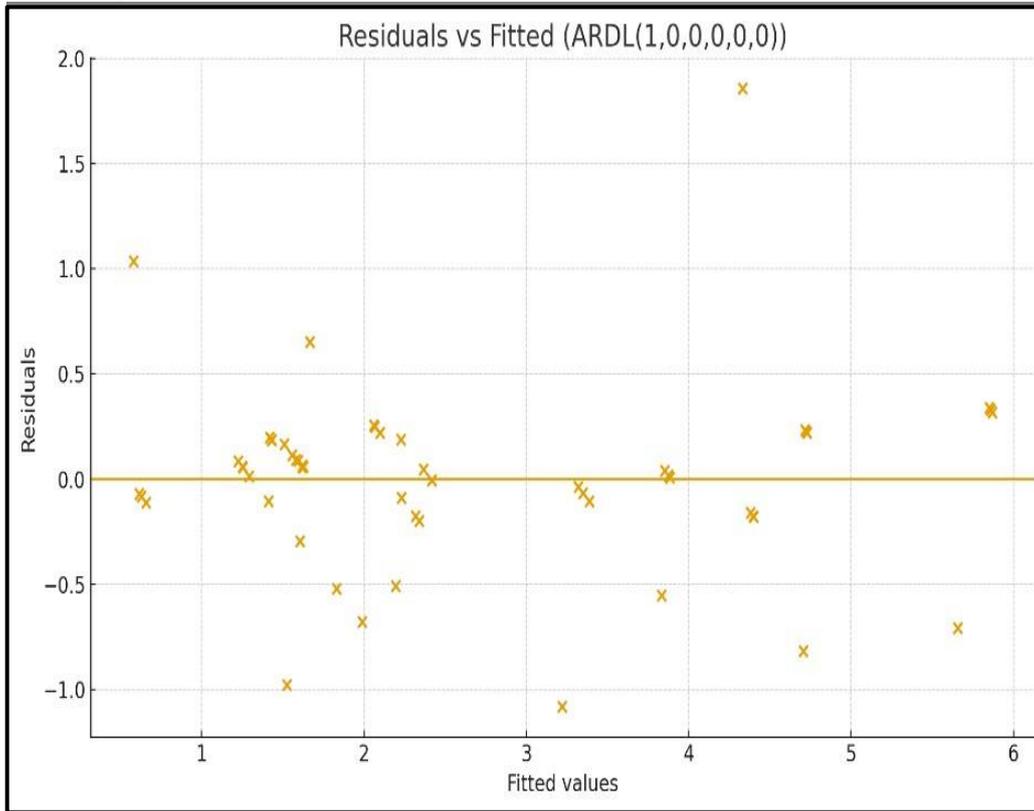
Source: Author’s visualization based on Python output, 2025.

Figure 6: Residuals Over Time (Baseline ARDL Model)



Source: Author’s visualization based on Python output, 2025.

Figure 7: Residuals vs Fitted Values



Source: Author's visualization based on Python output, 2025.

The visual diagnostics in Figures 5–7 support the adequacy of the ARDL(1,0,0,0,0) specification. Figure 5 shows that the fitted series closely tracks the actual energy investment, capturing both the level and turning points over the sample period. The residual plot (Figure 6) shows no pronounced autocorrelation, while the residual-versus-fitted plot (Figure 7) indicates no severe heteroskedasticity or structural breaks. HAC-robust standard errors further mitigate any remaining mild departures from classical assumptions.

To ensure that the parsimonious ARDL(1,0,0,0,0) specification does not mask significant lagged effects, a more general ARDL(1,1,1,1,1) model is estimated, in which oil prices, governance effectiveness, the policy dummy, GDP growth, and the exchange rate all enter with both current and one-quarter lagged values. The results are summarised in Table 4.

Table 4 ARDL (1,1,1,1,1) Robustness Check

Variable	Coefficient	Std. Error	p-value	Significance
Constant	-0.016	1.302	0.990	NS
EnergyInv_L1	0.644	0.061	9.2e-21	***
WTI	0.0149	0.0105	0.161	NS
WTI_L1	-0.0068	0.0116	0.560	NS
GovEff	-1.832	3.642	0.615	NS
GovEff_L1	4.826	4.299	0.268	NS
PolicyDummy	0.360	0.370	0.334	NS

PolicyDummy_L1	-0.679	0.255	0.010	Significant
GDP_Growth	0.141	0.109	0.174	NS
GDP_Growth_L1	-0.201	0.122	0.106	NS
FX	-0.00123	0.00173	0.479	NS
FX_L1	0.00032	0.00186	0.864	NS

Source: Author’s computation using Python (pandas and statsmodels), 2025

Table 4 presents robustness estimates using an expanded ARDL(1,1,1,1,1,1) specification, in which each explanatory variable enters the model with both its current and one-quarter lagged values. This broader specification tests whether the results from the baseline model (ARDL 1,0,0,0,0,0) remain stable when additional dynamic components are introduced. The model yields high explanatory power, with an R² of 0.924 and an adjusted R² of 0.908, which are closely comparable to the baseline. This indicates that allowing for lagged effects does not materially alter the model's overall goodness-of-fit, though it substantially increases the number of parameters.

The coefficient on the lagged dependent variable (EnergyInv_{t-1}) remains large and highly significant (0.644, p < 0.001), reaffirming the strong persistence of energy-sector investment. This means that even when lagged explanatory variables are included, past investment remains the dominant driver of current investment behaviour. Most contemporaneous variables, WTI, governance effectiveness, GDP growth, and the exchange rate remain statistically insignificant, mirroring the pattern observed in the baseline model.

One notable difference emerges in the behaviour of the **lagged policy-reform dummy (PolicyDummy_{t-1})**, which is negative and statistically significant at the 1 percent level (-0.679, p = 0.010). This suggests that the immediate quarter following the introduction of substantial reforms (such as the Petroleum Industry Act and the Energy Transition Plan) experiences a short-term reduction in investment. This may reflect transitional uncertainty, adjustment costs, investor hesitation, or delays in regulatory alignment immediately after significant institutional changes. Importantly, this effect is temporary and does not negate the longer-term benefits of reform; instead, it highlights the possibility of short-run disruption when new legal frameworks are introduced.

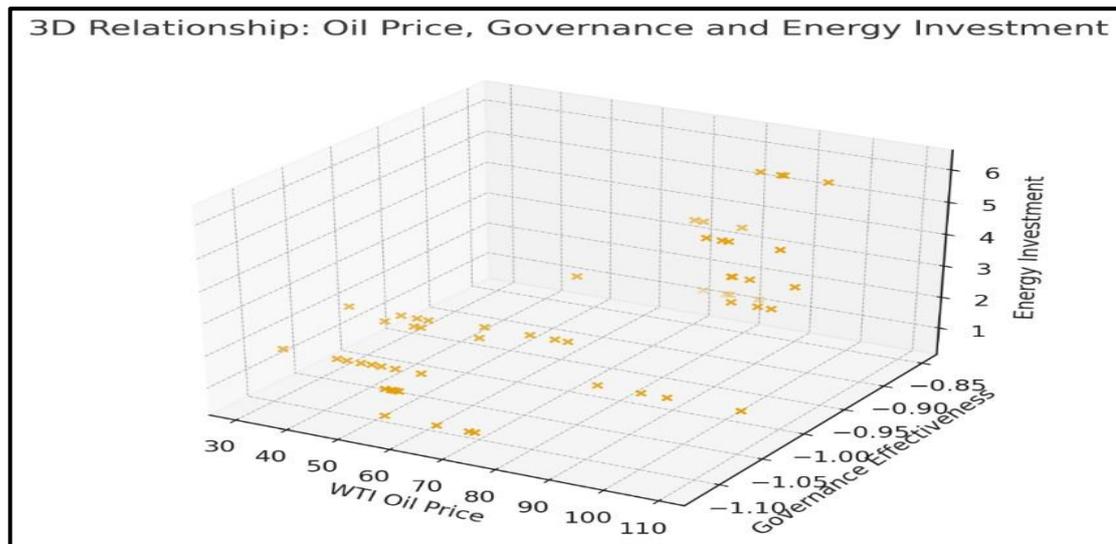
Other lagged regressors, including lagged oil prices, lagged governance effectiveness, lagged GDP growth, and lagged exchange rates, are statistically insignificant, indicating that their delayed effects do not meaningfully contribute to explaining quarterly investment variations. The presence of a significant condition number also suggests multicollinearity among regressors, a common issue in high-parameter ARDL models, and indicates that some coefficient estimates should be interpreted cautiously.

The robustness model confirms the stability of the baseline findings: energy investment is highly persistent; governance improvements matter in the short run; and macroeconomic stability, especially exchange-rate reliability, plays a non-negligible role. Although the lagged policy dummy shows a short-run adverse adjustment effect, the core structure of the investment process remains unchanged. Therefore, the ARDL(1,1,1,1,1,1) model reinforces confidence in the reliability of the baseline results rather than overturning them.

Multivariate Relationship: 3D Visualisation

To complement the regression analysis, Figure 8 presents a **three-dimensional scatter plot** of quarterly energy investment against oil prices and governance effectiveness.

Figure 8: 3D Scatter Plot- Energy Investment, Governance Effectiveness, and Oil Price



Source: Author's visualization based on Python output, 2025.

The visual clearly shows that high investment episodes cluster in regions characterised by relatively strong governance scores and moderately high oil prices. In contrast, low-investment observations are concentrated in weaker governance environments and during periods of lower or highly volatile oil prices. This 3D view reinforces the econometric result that governance quality is a critical conditioning factor in how global commodity price cycles translate into actual capital flows for Nigeria's energy sector.

DISCUSSION OF FINDINGS

The empirical results align with contemporary research emphasising the role of institutional quality and macroeconomic stability in shaping investment flows into the energy sector. The strong persistence in energy investment observed in the ARDL model supports the literature that characterises energy and infrastructure investments as path-dependent, capital-intensive, and sensitive to long-term expectations (Arezki & Sy, 2016; Meyer, 2020). This finding suggests that Nigeria's investment cycles cannot be understood through short-term shocks alone but must be interpreted as part of broader structural trajectories.

Governance effectiveness emerges as the most significant structural determinant of energy investment, reinforcing the argument that institutional quality, including regulatory transparency, rule-of-law, and bureaucratic capacity, plays a central role in attracting long-term capital (Acemoglu & Robinson, 2019; North, Wallis & Weingast, 2009). Comparable empirical studies show that improvements in governance indicators correlate strongly with FDI inflows, particularly in extractive and energy-intensive economies (Ben Ali & Sassi, 2016; Osabutey & Okoro, 2019). The 3D Visualisation (Figure 4.8) further emphasises that investment levels cluster strongly around quarters with higher governance performance, regardless of oil-price fluctuations, consistent with the argument that institutions shape how countries translate natural-resource wealth into sustained investment (World Bank, 2021).

The adverse effect of exchange-rate depreciation is also well supported by empirical evidence. Research consistently shows that macroeconomic instability, especially volatile exchange rates, increases the cost of imported equipment, heightens investment risk, and deters foreign investors in energy and infrastructure sectors (Aizenman, Cheung & Ito, 2021; IMF, 2023). The borderline significance in the baseline model suggests that, while investors tolerate some degree of macroeconomic fluctuation, excessive depreciation, as observed in Nigeria during the study period, can undermine project viability and reduce investment inflows.

Interestingly, oil prices, GDP growth, and the policy dummy do not exhibit statistically significant short-run effects. This diverges from the assumption that high oil prices automatically stimulate domestic energy investment. Studies emphasise that oil-rich developing countries often fail to convert oil-price booms into productive investment when governance and macroeconomic frameworks are weak (Collier & Goderis, 2012;

van der Ploeg & Poelhekke, 2017). Our findings support this perspective: without institutional readiness and macroeconomic credibility, commodity-price cycles have a limited short-run impact on domestic investment flows.

The ARDL(1,1,1,1,1) robustness model confirms the stability of the baseline findings, although the significant negative lagged policy dummy indicates temporary adjustment frictions following regulatory reforms. Transitional uncertainty around new laws—such as the Petroleum Industry Act can delay investment responses, consistent with global evidence on regulatory-overhaul periods (IEA, 2022; PWC, 2022).

Overall, the findings indicate that Nigeria's ability to attract energy-transition investments depends far more on governance quality and macro-stability than on commodity cycles or isolated policy announcements. This aligns with global trends emphasising the need for institutional strengthening and policy coherence in emerging-market energy transitions (UNCTAD, 2023).

CONCLUSION AND POLICY RECOMMENDATIONS

This study contributes to the literature on energy-sector investment in emerging economies by applying a rigorous ARDL modelling framework to quarterly data for Nigeria from 2010 to 2023. Consistent with previous empirical evidence, the results demonstrate that the key drivers of energy investment are institutional and macroeconomic rather than cyclical. The high persistence of energy investment aligns with studies highlighting the long-term nature of energy-infrastructure commitments (Bhattacharya et al., 2016).

The most important conclusion is the strong positive influence of governance effectiveness on investment flows. This finding aligns with global evidence that institutional quality is the dominant determinant of capital allocation in resource-dependent and transitioning economies (IMF, 2021; OECD, 2020). Strengthening regulatory capacity, reducing bureaucratic uncertainty, and ensuring consistent policy implementation are therefore essential to unlocking long-term investment for Nigeria's energy transition.

The adverse effect of exchange-rate instability further underscores the need for macroeconomic reforms. Research shows that investors significantly discount economies with high currency risk due to elevated uncertainty and increased cost of capital (Aizenman et al., 2021). Nigeria's ability to attract energy-transition financing will therefore depend on how effectively it stabilises the naira and addresses structural drivers of macroeconomic volatility.

Contrary to common assumptions, oil-price fluctuations and short-run GDP growth do not play a statistically significant role once governance and macroeconomic instability are accounted for. This emphasises the limitations of relying on commodity cycles to drive investment and underscores the importance of structural reforms over cyclical economic conditions (Collier & Goderis, 2012; UNCTAD, 2023). Similarly, while major reforms such as the Petroleum Industry Act provide an essential long-term framework, their immediate effects on investment are modest and may involve short-term adjustment frictions.

Overall, the study concludes that Nigeria's progress toward a successful energy transition will depend on its ability to improve governance, maintain macroeconomic stability, and sustain long-term policy credibility. These structural factors, rather than oil-market cycles, will determine the country's capacity to attract the scale of investment needed for energy security and decarbonisation.

Policy Recommendations

Drawing directly from the empirical evidence, the following policy recommendations are proposed:

Since governance effectiveness is the only statistically strong structural driver of energy investment, Nigeria must prioritise reforms that improve regulatory quality, transparency, and administrative efficiency. Clear licensing procedures, regulatory predictability, and reduced bureaucratic barriers will increase investor confidence. Strengthening anti-corruption measures and enhancing the autonomy of sector regulators will further improve governance scores and promote stable inflows.

The negative coefficient on the exchange rate implies that depreciation and volatility deter long-term investment. Nigeria should pursue coherent monetary-fiscal coordination, reduce parallel-market distortions, and adopt transparent FX allocation mechanisms. A predictable exchange-rate regime will lower investor risk premiums and reduce the cost of imported capital goods critical to energy infrastructure development.

The adverse lagged effect of the policy-reform dummy highlights the adjustment friction that follows significant policy changes. Government must therefore accompany major reforms with clear implementation guidelines, investor communication strategies, and regulatory transition plans. Ensuring smooth alignment between new laws and existing institutional frameworks will prevent uncertainty-induced investment slowdowns.

While reforms such as the Petroleum Industry Act lay essential foundations, more targeted incentives such as risk-sharing instruments, investment guarantees, and carbon-transition financing frameworks are needed to attract long-term energy-transition capital. Enforceable regulatory commitments should support clear decarbonisation roadmaps and energy transition targets.

GDP growth and oil prices did not independently drive investment in the short run, suggesting that macroeconomic stability must be maintained for investors to respond to positive economic signals. Policies that ensure low inflation, sustainable debt levels, and predictable fiscal conditions are central to sustaining investor confidence.

Investors respond to environments where institutional and economic conditions can be reliably forecast. The government and regulators should publish frequent, high-quality sectoral data, including energy production forecasts, regulatory updates, and investment performance metrics. This transparency strengthens investor expectations and aligns Nigeria with international best practices.

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