Role of Institution in FDI and Energy Consumption Relationship in Developing Economies: A Case of Nigeria

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Abstract: *This study examines the moderating effect of institutional quality on the relationship between FDI and energy consumption in Nigeria from 1996 to 2022 using the novel dynamic autoregressive distribution lag (dynardl) simulation model and Kernel-based regularised least squares (KRLS). The results of the dynardl simulation show that FDI increases energy consumption in the short run, but reduces energy consumption in the long run. The results also validate the existence of an inverted U-shaped relationship between FDI and energy consumption. More importantly, it was revealed that the interactive relationship between FDI and institutional quality was found to reduce energy consumption within the period under study. This indicates that while the benefits of FDI are indisputable, they cannot be fully realised without the appropriate institutional framework. Therefore, the institutional quality of the host country plays a pivotal role in harnessing the absorptive capacity of FDI to effectively curtail energy consumption, especially in the context of fossil fuels, and in promoting the adoption of energy-efficient technologies.*

Keywords: Foreign direct investment; Energy consumption; Environmental Kuznets curve; Kernel-based regularised least squares; Dynamic ARDL simulation

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1.   Introduction

The pressing need to embrace energy-efficient technologies to mitigate greenhouse gas emissions stemming from energy consumption has taken centre stage in the priorities of developing nations. According to a report published by the International Energy Agency (IEA, 2019), there will be an expected annual increase in energy demand of 1.8% from 2005 to 2030. Notably, this report underscores that developing economies are poised to shoulder a substantial 74% of the total energy demand. Global fuel consumption surged by 237% between 1965 and 2019, with Africa notably recording a growth of 665% within the same timeframe. As indicated by a report from the World Energy Council (WEC, 2019), it is anticipated that fossil fuels will continue to dominate the global primary energy landscape, making up over two-thirds of the total by 2040.

Muhammad et al. (2021) propose that a more feasible method of minimising energy consumption might be achieved via channels such as optimising energy policy, developing more energy-efficient technology, and tightening controls on the use of energy. However, because of the exorbitant nature of research and development in the field of energy-saving technologies, the majority of developing countries that require more energy may not have the skill and knowledge to produce such feats. For instance, Nigeria is abundantly endowed with a diverse array of renewable energy sources, including biomass, solar, wind, and hydropower, which have regrettably remained largely underutilised. A significant impediment to the growth of renewable energy in Nigeria is the high operational costs associated with the emerging renewable energy sector.

Consequently, developing economies like Nigeria are increasingly turning to foreign direct investment (FDI) as an alternative solution to address this challenge. One of the driving factors behind the implementation of investor-friendly policies aimed at attracting FDI is the desire to acquire and operate energy-saving technologies. The investment policy initiative implemented recorded a 40% increase in 2020 from the year prior. In 2020, 67 countries approved 152 national policies promoting FDI, representing a nearly 42% increase over the same period in the previous year (UNCTAD, 2020).

Based on past studies (e.g., Muhammad et al., 2021; Munir & Ameer, 2020), it is evident that developing nations have a critical need for FDI to support the financing of advanced clean energy projects. This perspective is

primarily rooted in the potential positive externalities associated with FDI inflows, including the facilitation of knowledge spillover and the transfer of foreign technology. On the other hand, there are researchers (e.g., Zeeshan, 2021; Muhammad et al., 2021) who believe that an increase in FDI could lead to an increase in the consumption of non-renewable energy, which has a great deal of adverse effects on the environment, in addition to putting huge pressure on energy consumption in developing nations that are currently struggling with issues related to the supply of energy and environmental issues. This argument lends credence to the pollution haven hypothesis, which contends that FDI may be a means of outsourcing 'dirty sectors' to developing nations because of laxer environmental rules as a result of weak institutions. Thus, with more FDI entering into developing economies, there is a higher likelihood that energy consumption will be exacerbated.

While the advantages of FDI are undeniable, they do not occur spontaneously; the quality of institutions in the host country plays a vital role in ensuring that it is able to harness the benefits associated with FDI (Hayat, 2019). Furthermore, recent analyses have emphasised the need for an appropriate institutional environment to maximise the benefits of FDI (Sabir et al., 2019). Hence, this study aims to ascertain the role of institutional quality on the relationship between FDI and energy consumption in Nigeria.

This study contributes to the literature by concentrating on Nigeria, a region that has seen limited empirical investigations on this matter. Moreover, most existing studies focus more on the direct impact of FDI on energy consumption. Given the importance of institutional quality as a deciding element in harnessing the benefits of FDI, this study aims to address this void by introducing institutional quality as a moderating variable in the relationship between FDI and energy consumption. This will help to create conceptual arguments by examining the routes through which institutional quality affect energy consumption, as well as complement previous studies by elucidating the root cause of increased energy consumption and providing evidence-based results that will be useful for policy implementation.

Secondly, to account for the non-linear impact of FDI on energy consumption, this study's model will incorporate a second FDI variable, thus validating the U-shaped environmental Kuznets curve (EKC) hypothesis. To the best of our knowledge, this particular approach has not been explored in prior research, especially within the context of Nigeria. By taking this

innovative step, our study is poised to contribute significantly to the existing body of knowledge, offering a more comprehensive insight into the intricate relationship between FDI and energy consumption. Furthermore, it stands to validate the applicability of the EKC hypothesis in the specific case of Nigeria, shedding new light on the potential environmental implications of foreign investments in the country's energy sector, and paving the way for more effective policy recommendations in this domain. Ultimately, these findings can inform policymaking, helping other developing nations navigate the complex interplay between investment, energy consumption, and institutional quality to foster economic growth and environmental sustainability.

Finally, this study seeks to broaden the scope of the current body of knowledge by conducting a detailed analysis of the subject matter using the combination of novel dynamic ARDL simulation (dynardl) approach developed by Jordan and Philips (2018) and the kernel-based regularised least squares developed (KRLS) by Hainmueller and Hazlett (2014). Thus, it is expected that the combination of these two approaches will enhance the outcome of this study as well as resolve the ambiguity in the relationship between FDI and energy consumption.

The rest of the paper is organised as follows: Section 2 contains the literature review, Section 3 incorporates a detailed explanation of the methodological approach, Section 4 discusses the empirical results, while the findings and analyses of the policy implications are summarised in Section 5.

2. Literature Review

The analysis of the influence of FDI on energy consumption usually revolves around two contradictory ideas. The pollution haven hypothesis asserts that firms from higher-income countries, facing strict environmental regulations, may relocate their operations to developing countries with more lenient environmental standards to minimise compliance costs and boost profitability. This shift can lead to increased environmental degradation in the host countries, as multinational corporations (MNCs) engage in pollution-intensive activities that would be restricted in their home nations due to regulatory constraints (Copeland & Helpman, 1994). Consequently, FDI can cause a rise in the use of non-renewable energy sources in the host country, which worsens pollution by increasing carbon emissions (Mert &

Caglar, 2020; Sarkodie & Strezov, 2019; Sun et al., 2017). The pollution halo hypothesis offers an intriguing alternative to the pollution haven hypothesis. It posits that FDI, mostly from MNCs, may substantially improve environmental performance in host nations, particularly in developing nations. The theory asserts that MNCs introduce sophisticated technology, enhanced management practices, and rigorous ecological standards, resulting in a 'halo' effect that promotes greener and more environmentally friendly utilisation of energy. This investment reduces pollutants and enhances overall environmental quality. Thus, FDI could help facilitate the transfer of ecologically beneficial technology, such as renewable energy solutions, therefore promoting sustainable development in the host country (Xu, et al., 2021; Sung et al.,2018; Seker et al., 2015).

It is important to highlight that there is no agreement on the overall influence of FDI on energy consumption, as supported by empirical investigations. Consequently, this topic continues to be a subject of continuing discussion. For instance, Islam et al. (2022) studied the impact of FDI on energy consumption in Bangladesh from 1990 to 2019 using the ARDL estimation technique, and find that FDI acts as a catalyst for the adoption of energy-saving technologies. Concurrently, Tiwari et al. (2022) conducted research in a broader context, encompassing a group of low-income nations in comparison to their high-income counterparts. They conclude that FDI plays a pivotal role in fostering renewable energy consumption in low-income countries. This was largely attributed to the economic constraints faced by these nations, which created a favourable environment for FDI to drive investments in renewable energy infrastructure. However, the narrative shifts when examining European Union countries with data from 2001 to 2015. Camacho et al. (2022) find that, in this context, FDI negatively affected renewable energy consumption. This striking contrast underscores the complex and context-dependent nature of the impact of FDI on renewable energy adoption. This intriguing contrast highlights the complexity and context-specific nature of how FDI impacts renewable energy adoption.

Tan and Uprasen's (2022) study on the effect of FDI on energy consumption of BRICS countries from 1990 to 2015 using panel threshold analysis reveals a noteworthy trend. Specifically, when the regulatory stringency level falls below a certain threshold, FDI is associated with a reduction in renewable energy consumption. However, an intriguing shift occurs when the regulatory stringency surpasses this threshold. At higher

levels of stringency, FDI was observed to promote renewable energy consumption. In a similar vein, Kang et al. (2021) employed fully modified ordinary least squares (FMOLS) regression and dynamic ordinary least squares (DOLS) to empirically investigate the relationship between FDI and energy consumption in South Asian countries over the period spanning from 1990 to 2019. Their findings reveal the negative impact of FDI on renewable energy consumption in this region, suggesting a potential crowding-out effect where FDI discourages the adoption of renewable energy sources. Zhang et al. (2021) extended this observation to the context of 35 OECD countries, examining data from 1999 to 2018, and find that FDI negatively influences renewable energy consumption, pointing to a trend that transcends geographical boundaries and indicating a broader challenge in aligning FDI with sustainable energy practices. Concurrently, Alsagr and Van Hemmen's (2021) study encompassing 19 emerging countries from 1996 to 2015 corroborates the notion that FDI does not incentivise the adoption of energy-saving technologies, further emphasising the nuanced nature of the relationship between FDI and sustainable energy practices.

In the context of 25 European Union countries, Apergis and Pinar (2021) harnessed the general method of moments (GMM) and the pooled common correlated effects (PCCE) methods to demonstrate the positive impact of FDI on the promotion of energy-saving technology. Samour et al. (2020), employing a time series dataset spanning from 1989 to 2019, arrive at a comparable conclusion. Their findings echo the beneficial effect of FDI in driving the adoption of energy-saving technology, reinforcing the notion that it can play a pivotal role in promoting energy efficiency across various temporal dimensions. However, Amoako and Insaidoo (2021), using fully modified ordinary least squares (FM-OLS), find that the energy savings benefits of FDI are yet to be realised in Ghana over the period of 1981 to 2014.

In a study by Adom et al. (2019) on the FDI-energy consumption nexus in 27 African countries from 2000 to 2014, it is shown that there exists an inverted U-shaped relationship between FDI and energy consumption, which is contingent on the level of technology absorptive capacity. In a quest to ascertain the impact of FDI in China between 2002 to 2015, Dong et al. (2019) find that it has an energy-saving spillover effect in high-income regions. Conversely, their analysis did not provide any compelling evidence to support the notion that FDI led to increased energy consumption in low- or middle-income regions. Adom et al. (2018) applied the stochastic fixed

effect, true fixed effect and the Kumbhakar-Heshmati (K-H) models using panel data from 22 countries for the period 1988 to 2014 to examine the relationship between FDI and energy consumption, and find that FDI does not promote energy efficiency.

Kutan et al. (2018) utilise FM-OLS to confirm that FDI led to increased energy consumption in Brazil, China, India, and South Africa from 1990 to 2012. This finding aligns with the results of Adom and Amuakwa-Mensah (2016), who observe that FDI reduced energy consumption in specific African economies. In contrast, Doytch and Narayan (2016) adopted the Blundell-Bond dynamic panel estimator to establish a positive relationship between FDI and non-renewable energy consumption in high- and upper-middle-income nations from 1985 to 2012.

Wang (2017) delves into the intricate relationship between FDI and energy efficiency in China using a dynamic panel model spanning from 2001 to 2013. The study reveals that FDI plays a significant role in enhancing energy efficiency, showcasing a dominant pollution halo effect, surpassing the pollution haven effect. Technical progress emerged as the primary driver for TFEE improvement, while technical efficiency stood out as the primary factor contributing to its decline. These findings were corroborated by Salim et al. (2017), who similarly find that FDI in China bolstered energy-efficient technologies, thereby reducing energy intensity.

FDI, institutional quality, and economic development have consistently been the subjects of extensive research, especially on their influence on energy and environmental sustainability. El Fakiri and Cherkaoui (2022), Patel (2024), and Asghar et al. (2024) highlight the significant role of institutional quality in FDI inflows, economic and environmental sustainability. El Fakiri and Cherkaoui (2022) assert that institutional quality significantly impacts FDI in high-income countries, but its effect is insignificant in middle- and low-income countries. Patel (2024) demonstrates that in India, institutional quality influences the relationship between economic growth, renewable energy utilisation, and FDI, thereby lending credence to the EKC hypothesis and emphasising the vital role of strong institutions in fostering environmental and energy sustainability. Asghar et al. (2024) extend this study by investigating the interplay between innovation, energy consumption, and trade, revealing that innovation inputs have more influence in developing countries, whilst innovation outputs have greater significance in advanced nations.

Collectively, these studies underscore the need for improved institutional quality, and sustainable governance to promote FDI and attain both economic, energy and environmental sustainability, especially in developing countries.

3.   Data and Methods

3.1 Data source

This study analyses secondary annual time series data over the period 1996 to 2022 for Nigeria based on the research requirements and the data availability. Data on energy consumption is measured by the proportion of energy derived from fossil fuels as a percentage of the total energy consumption; FDI as inflow as a percentage of host country GDP; economic growth as GDP per capita (constant 2010 US$); institutional quality as good governance percentile; financial development as the ratio of private sector credit to GDP; and human capital development as a percentage of gross primary school enrolment. All data is sourced from the World Bank database.

3.2 Model specification

The objective of this study is to evaluate the influence of FDI on energy consumption in Nigeria. The foundation of our technique is based on Azam et al. (2015) and Murshed et al. (2022). We utilise a linear econometric model to represent the link between FDI and energy consumption, along with other significant variables that are believed to impact this relationship. The baseline model is as follows:

$$lnEC_t = \beta_0 + \beta_1 lnFDI_t + \beta_2 lnGDPpc_t + \beta_3 lnGOV_t + \beta_4 lnFD_t + \beta_5 lnHC_t + \varepsilon_t \qquad (1)$$

where *EC* represents the dependent variable in the equation is energy consumption, *FDI* is foreign direct investment, *GDPPC* is GDP per capita (constant 2010 US$, as a proxy for economic growth), *GOV* is good governance index (as a proxy for institutional quality), *FD* is financial development, and *HC* is human capital, t the time period, ε the error term, β_0 the intercept or constant, and $\beta_1 - \beta_5$ the coefficient of independent variables. All the variables are transformed into their natural logarithms for ease of estimating the conditional bivariate elasticities.

Consistent with the application of the energy-EKC framework as demonstrated by Wang and Jiayu (2019) and Aruga (2019), equation (1) is extended by introducing the quadratic terms of GDPPC and FDI. The energy-EKC suggests that energy consumption initially increases with economic growth, but then declines as more energy-efficient technologies are adopted, reaching a turning point in economic development (Shahbaz et al., 2018). The modified energy-EKC equation can be formulated as follows:

$$lnEC_t = \gamma_0 + \gamma_1 lnGDPPC_t + \gamma_2 lnGDPPC_t^2 + \gamma_3 ln\,FDI_t + \gamma_4 ln\,FDI_t^2 + \gamma_5 lnGOV_t \\ + \gamma_6 lnFD_t + \gamma_7 lnHC_t + \varepsilon_t \tag{2}$$

where $\gamma_1 > 0$ and $\gamma_2 < 0$ shows the EKC phenomenon between economic growth and energy consumption, and $\gamma_3 > 0$ and $\gamma_4 < 0$ the EKC phenomenon between FDI and energy consumption. Equation (2) is further modified to incorporate the interaction between FDI and institutional quality. Thus, the equation becomes:

$$lnEC_t = \chi_0 + \chi_1 lnGDPpc_t + \chi_2 lnGDPpc_t^2 + \chi_3 lnFDI_t + \chi_4 lnFDI_t^2 + \chi_5 lnGOV_t \\ + \chi_6 ln(FDI * GOV)_t + \chi_7 lnFD_t + \chi_8 lnHC_t + \varepsilon_t \tag{3}$$

In equation (3), the interaction term $\chi_6 ln\,(FDI * GOV)_t$ is included to capture how the impact of FDI on energy consumption is influenced by institutional quality in the host country. Essentially, this interaction term measures the conditional effect of FDI on energy consumption, meaning that the effect of FDI is not uniform, but varies depending on the level of institutional quality.

To address potential issues of multicollinearity between the interaction term and the main term, we employ a novel approach for renormalising the interaction term (χ_6), as recommended by Balli and Sørensen (2013):

$$lnEC_{it} = \chi_0 + \chi_1 lnGDPpc_t + \chi_2 lnGDPpc_{it}^2 + \chi_3 lnFDI_t + \chi_4 lnFDI_{it}^2 \\ + \chi_5 lnFDI_{it}^3 + \chi_6 lnGOV_{it} + \chi_7 ln(FDI - \overline{FDI})(GOV - \overline{GOV})_t \tag{4} \\ + \chi_8 lnFD_t + \chi_9 lnHC_t + \varepsilon_t$$

where $\overline{FDI}$ and $\overline{GOV}$ represent the means of FDI and good governance, and λ_7 the coefficient of the interactive term between FDI and good governance. Specifically, both the FDI and GOV variables were mean-centred before their interaction. Mean centring involves subtracting the mean of a variable

from each of its data points. By mean centring the FDI and GOV variables before their interaction, potential issues related to multicollinearity and misinterpretation of coefficients are mitigated. This is particularly important when examining interaction terms, as it helps prevent inflated standard errors and aids in the proper interpretation of the main effects.

3.3   Estimation techniques

In this study, we employ the dynamic autoregressive distributed lag (dynardl) simulation method proposed by Jordan and Philips (2018) and the kernel-based regularized least squares developed (KRLS) by Hainmueller and Hazlett (2014) to investigate the impact of FDI on energy consumption in Nigeria. The dynardl simulations offer a distinct advantage with its graphical interface, enabling users to explore the potential effects of counterfactual variations in the targeted parameter, all while adhering to the principle of *ceteris paribus*. Moreover, the dynardl simulation can accurately predict the signs and magnitude of variations of the determinants coupled with their short-run and long-run linkages. Additionally, the KRLS is a sophisticated machine learning technique that has strong interpretability and accounts for additivity, heterogeneity, and non-linear impacts. Our analytical approach aligns with the methodologies outlined by Kartal et al. (2023) and Adedoyin et al. (2021). The analysis unfolds in several stages.

First, to safeguard against obtaining spurious results in the autoregressive distributed lag (ARDL) model, we diligently examined the stationarity (constant mean and variance of series) of the variables using the Dickey-Fuller (1979), Phillips and Perron (1988), and Kwiatkowski et al. (1992) unit root tests. The second stage involved testing for cointegration among the variables by employing the ARDL bound testing technique introduced by Pesaran et al. (2001) and the cointegration test by Bayer and Hanck (2013). Subsequently, we determined the optimal lag length for the ARDL estimation. Thereafter, the dynardl simulation was estimated to assess the long-run and short-run effects of FDI on energy consumption. In the fifth stage, a causal relationship between the variables was determined using KRLS.

To ensure the stability of the ARDL model, we conducted a series of diagnostic and stability tests, including the Breusch-Godfrey Lagrange multiplier (LM) test for residual serial correlation, Cameron and Trivedi's

decomposition of the IM-test for heteroskedasticity, and skewness/kurtosis tests for normality. To evaluate structural stability, the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of recursive residual squares (CUSUMSQ) were employed.

3.3.1 Dynamic ARDL simulation model

Jordan and Philips (2018) introduced the dynardl simulation, offering an advanced solution to address the intricacies of the conventional ARDL model. The dynardl simulation serves as a valuable tool for estimating, simulating, and predicting the real variations in the regressors and their corresponding influence on the outcome variable. In this methodology, a counterfactual analysis is conducted to discern the response of the dependent variable to changes in one explanatory variable while keeping all other explanatory variables constant. This allows for a comprehensive understanding of the isolated impact of each explanatory variable on the explained variable, enhancing our ability to dissect and forecast economic relationships. The dynardl simulation is represented by equation (5):

$$
\begin{aligned}
\Delta lnEC_{it} = {} & \emptyset_0 + \emptyset_1 \Delta lnEC_{t-1} + \emptyset_2 \Delta lnGDPpc_{t-1} + \emptyset_3 \Delta lnGDPpc_{t-1}^2 + \emptyset_4 \Delta lnFDI_{t-1} \\
& + \emptyset_5 \Delta lnFDI_{t-1}^2 + \emptyset_6 \Delta lnGOV_{t-1} + \emptyset_7 \Delta ln(FDI * GOV)_{t-1} \\
& + \emptyset_8 lnFD_{t-1} + \emptyset_9 \Delta lnHC_{t-1} + \gamma_1 lnEC_{t-1} + \gamma_2 lnGDPpc_{t-1} \\
& + \gamma_3 lnGDPpc_{t-1}^2 + \gamma_4 lnFDI_{t-1} + \gamma_5 lnFDI_{t-1}^2 + \gamma_6 lnGOV_{t-1} \\
& + \gamma_7 ln(FDI * GOV)_{t-1} + \gamma_8 lnFD_{t-1} + \gamma_9 \Delta lnHC_{t-1} + \varepsilon_{it}
\end{aligned} \tag{5}
$$

where $\emptyset_0$ is the intercept, $\emptyset_i$ the short-run coefficients and γ_i the long-run coefficients of the ARDL model.

3.3.2 Kernel-based regularised least squares (KRLS)

For each data point, the KRLS model yields a closed-form estimation of pointwise marginal derivatives and quantifies the marginal impacts of covariates. These marginal effects are akin to the coefficients derived from conventional regression analysis, enhancing the interpretability of the results (Hainmueller & Hazlett, 2014). Consequently, the KRLS analysis furnishes detailed insights into the pointwise marginal effects of independent

variables. Furthermore, this approach unveils the interplay among variables by examining the correlations between a variable's pointwise marginal derivatives and those of other variables, shedding light on the complex economic relationships.

4. Result Interpretation

4.1 Test for stationarity

The unit root tests for all variables have been conducted and the results are presented in Table 1. According to the empirical data, none of the series exhibited stationarity at the 1(2) level across the selected countries. However, the null hypothesis of non-stationarity cannot be rejected at the level for both the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Still, it is rejected at the first difference, where the t-statistic falls below the critical value of -3.00 at a 5% significance level.

Furthermore, in the case of the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, the null hypothesis of stationarity cannot be conclusively rejected at the level for all variables. However, all the variables do attain a stationary status at the first difference, where the critical value surpasses the t-statistics. This confirms that all the variables exhibit stationarity at the first difference. As a result, the ARDL model can be evaluated using these integrated variables. Following the confirmation of the stationary series, the next step is to determine the optimal number of lags for estimating the ARDL model.

Table 1: Unit root test

Variable	ADF test		PP test		KPSS	
	Level	Diff.	Level	Diff.	Level	Diff.
	-3.00	*-3.00*	*-3.00*	*-3.00*	*0.15*	*0.15*
EC	-1.61	-5.43	-1.72	-5.41	0.15	0.06
FDI	-1.77	-7.63	-1.55	-7.86	0.49	0.07
GDPPC	-1.57	-3.48	-1.38	-3.46	0.48	0.04
GOV	-2.47	-6.38	-2.45	-6.47	0.09	0.03
FD	-2.09	-3.48	-2.25	-3.48	0.24	0.05
HC	-2.21	-3.78	-2.34	-3.77	0.24	0.14

Notes: Critical value for ADF test and PP test is -3.00. Critical value for KPPS is 0.146.

4.2   Lag selection criteria

Before delving into the assessment of long-run equilibrium, we initially conducted a lag length analysis to determine the most suitable model. The results of various lag selection criteria are presented in Table 2. Interestingly, the findings unanimously favour a lag of one, as the majority of the criteria point to lag one as the optimal choice. Additionally, we opted to use the Akaike information criterion (AIC) in this study, as it yielded the lowest value among the selected criteria for a lag of one.

Table 2: Lag selection criteria

Lag	LL	LR	FPE	AIC	SC	HQ
0	-207.97	-38.09	-	0.94	3.67	3.97
1	-108.48	-34.25	5.45*	0.63*	3.44*	3.78*
1	-61.94	-34.15	0.13	0.69	3.51	3.91

Notes: * Symbolises lag order selected by the criterion. LR = sequential modified LR test statistic, FPE = final prediction error, AIC = Akaike information criterion, SIC = Schwarz information criterion, HQ = Hannan-Quinn information criterion.

4.3   Cointegration test

Table 3 presents the results regarding the cointegration status of the variables in our study. The ARDL bounds test has established the presence of a long-term equilibrium relationship among these variables, affirming the existence of cointegration. This inference is further substantiated by the estimated *F*-statistics, which significantly exceed the upper limit critical value at a 5% significance level, indicating a strong likelihood of cointegration. To further validate the long-term relationship between the variables, a confirmatory test was conducted using the Bayer-Hanck test. The results from the Bayer-Hanck test reveal that both the EG-j statistics and EG-J-Ba-Bo values exceed their respective critical values at a 5% significance level, reinforcing the evidence of cointegration among the variables.

Table 3: Cointegration test

	ARDL bounds test		Bayer-Hanck	
			Fisher type	
	F-statistic	**K**	EG-J	EG-J-Ba-Bo
	4.639	5	56.069276	74.588337
Pesaran et al. (2001) critical value bounds			**5% critical value**	
Significance	I(0) Bounds	I(1) Bounds	EG-J	10.419
5%	2.62	3.79	EG-J-BaBo	19.888

4.4   Results and Discussion of Findings

The results of the dynardl simulations are presented in Table 4. The result of the analysis reveal that the linear FDI has a significant positive short-run effect on energy consumption while having a significant negative effect on energy consumption in the long run. This means that a percentage increase in FDI inflow in Nigeria will lead to about 0.860% increase in energy consumption in the short run while having a 0.293% decrease in energy consumption in the long run. This result is consistent with Olaoye et al. (2020), who also find that FDI promotes energy-saving technology in the long run. Furthermore, the negative coefficient of the squared FDI in both the short run and long run confirm that a U-shaped relationship only exists between FDI and energy consumption in the short run. Similarly, the results also confirm a U-shaped relationship between economic growth and energy consumption given the positive and negative coefficients of the linear and squared. This implies that economic growth increases energy consumption until a certain level of income is reached, with further economic expansion promoting energy-saving technology. This empirical finding is in line with Khan and Ozturk (2020).

Good governance which is used as a proxy for institutional quality has a significant negative coefficient of -0.179 and -0.376 in the short and long run respectively. This implies that institutional quality is a major contributor to energy consumption reduction in Nigeria. Furthermore, the results reveal that financial development has a non-significant negative effect on energy consumption in the short run while having a non-positive effect in the long run. The short-run coefficient of human capital development has a significant negative value of -0.0287, thus implying that human capital in Nigeria reduces energy consumption within the period under study. The negative

significance of the ECT value suggests that the rate of change in the previous equilibrium is around 0.94% per year.

Most notably, the estimated short-run and long-run coefficients of the interaction between FDI and good governance consistently exhibit a significant negative sign. This outcome aligns with our *a priori* expectations, affirming that an enhancement in institutional quality exerts a significant impact on mitigating energy consumption in Nigeria by fostering the adoption of energy-efficient technologies. Consequently, the amelioration of institutional quality plays a pivotal role, not only in attenuating the adverse consequences of energy consumption, but also in aiding developing economies, such as Nigeria, in harnessing the advantages of FDI to promote the adoption of efficient and eco-friendly energy-saving technologies. This result is in tandem with the findings of Muhammad et al. (2021), Sarkodie et al. (2020), and Kumaran et al. (2020) who opine that for developing economies to promote the inflow of clean and energy-efficient MNCs, there is need to improve the quality of their institutions.

The dynardl simulation automatically generates forecasts for changes in the actual regressor while holding other explanatory variables constant. It predicts that the impact of FDI on energy consumption will fluctuate by 10%. The impulse response plot as depicted in Figure 1 elucidate the connection between FDI and energy consumption, particularly regarding the 10% increase and decrease in FDI. The dots in the graphs represent the mean predicted values, while the shaded regions, ranging from dark blue to light blue, depict the 75%, 90%, and 95% confidence intervals, respectively.

Table 4: Dynamic ARDL simulations

Variable	Model without an interaction term	Full model
ΔFDI	0.860** (0.022)	0.822*** (0.001)
FDI	-0.293** (0.031)	-0.263** (0.041)
ΔFDI^2	-0.349** (0.031)	-0.347** (0.031)
FDI2	-0.453** (0.036)	-0.482** (0.036)
ΔGDPPC	0.0013** (0.032)	-0.0199 (0.211)
GDPPC	0.0212*** (0.001)	0.0257*** (0.004)

Variable	Model without an interaction term	Full model
$\Delta GDPPC^2$	-0.0523** (0.032)	-0.0528** (0.031)
$GDPPC^2$	-0.0162 (0.152)	-0.0346 (0.511)
ΔGOV	-0.179*** (0.001)	-0.128*** (0.007)
GOV	-0.376** (0.022)	-0.306** (0.081)
ΔFD	-0.313 (0.273)	-0.365 (0.193)
FD	0.0524 (0.199)	0.0583 (0.218)
ΔHC	-0.0287*** (0.007)	-0.0216*** (0.002)
HC	0.136* (0.086)	0.109* (0.688)
$\Delta FDI*GOV$	-	-0.7749** (0.032)
FDI*GOV	-	-0.3166** (0.021)
ECT (-1)	-0.947** (0.041)	-0.617** (0.046)
Obs	25	25
R-squared	0.76	0.73

Notes: p-values in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. FDI = foreign direct investment, GDPPC = GDP per capita, GOV = good governance, FD = financial development, HC = human capital.

Figure 1: The impulse response plot for FDI and energy consumption

(a)   (b)
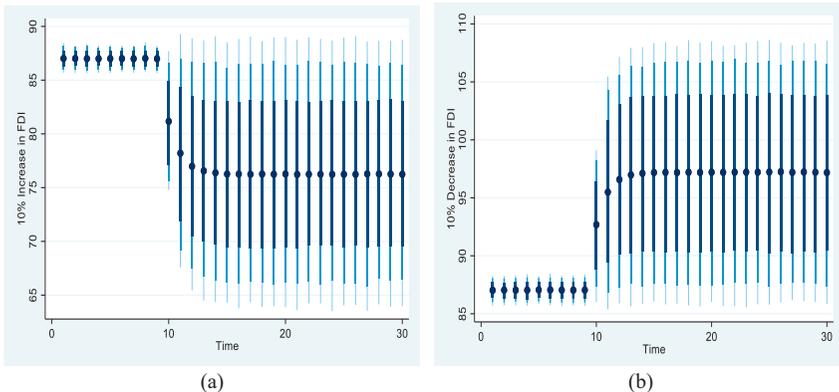
4.5 *Kernel-based regularised least squares (KRLS)*

To further our analysis of the impact of FDI and energy consumption, a machine learning methodology is adopted to assess and establish causal relationships among the variables. An assessment of heterogeneous marginal effects using derivatives of regressors is reported as 25th, 50th, and 75th percentiles. The result of the estimated KRLS as presented in Table 5 shows no evidence of heterogeneous marginal effects across sampled variables, thus, confirming the robustness of the pointwise derivatives. Moreover, the overall predicting power of the model is 0.9335 indicating that explanatory variables explained 97.3% of the variation in energy consumption. Reporting the average marginal effect, it is observed the mean pairwise marginal effects of FDI, FDI^2, GDPPC, $GDPPC^2$, GOV, FD, HC, and the interactive term are 0.31%, -0.04%, -0.0011%, -0.089%, -0.068%, 0.044%, 0.022% and -0.110% respectively. The probability value of each variable at a 5% significance level means that only GDPPC and FD are not significant.

Table 5: Pointwise derivatives using KRLS

EC	Avg.	SE	t	P > t	P25	P50	P75
FDI	-0.3158	0.0842	-3.7520	0.0010	-0.7745	-0.1401	0.1274
FDI^2	-0.0402	0.0172	-2.3300	0.0320	-0.1682	-0.0431	0.0394
GDPPC	-0.0011	0.0001	-0.9300	0.3650	-0.0010	0.0002	0.0005
$GDPPC^2$	-0.0892	0.0037	-2.4650	0.0240	-0.0036	0.0054	0.0028
GOV	-0.0686	0.0377	-1.8190	0.0260	-0.1578	-0.0776	0.0291
FD	-0.0444	0.0313	-1.4180	0.1730	-0.0662	-0.0273	0.0204
HC	0.0220	0.0122	1.8090	0.0370	-0.0176	0.0033	0.0692
FDI*GOV	-0.1103	0.0598	-1.8450	0.0210	-0.3594	-0.0782	0.1338
Diagnostics							
Lambda	0.12	Sigma	8.00	R2	0.93	Obs.	26.00
Tolerance	0.03	Eff. Df	15.80	Looloss	22.67		

Notes: Where Avg. is the average marginal effect; SE is the standard error. P-25, P-50, and P-75 represent 25th, 50th, and 75th percentile. FDI = foreign direct investment, GDPPC = GDP per capita, GOV = good governance, FD = financial development, HC = human capital, FDI*GOV = interactive term between FDI and GOV.

4.6   ARDL post estimation diagnostics tests

Several tests were performed to deal with possible concerns such as serial correlation (the link between variables and their lagged values), autocorrelation, heteroscedasticity, and violation of the normality assumption to ascertain the appropriateness of the dynamic autoregressive lag model. The diagnostic tests, which included the Breusch-Godfrey LM test, Cameron and Trivedi's decomposition of the IM-test, and the skewness/kurtosis tests, were carried out.

The outcomes of the autocorrelation test that was carried out using the Breusch-Godfrey LM test are detailed in Table 6. According to the findings, the p-value is less than the significance threshold of 5% ($p > 0.05$), thus, allowing us to reject the hypothesis that there is no serial correlation between variables and their lagged values. As a result, one may get the conclusion that the approximated ARDL residuals for all of the countries that were chosen do not exhibit any autocorrelation. The decomposition of the IM-test developed by Cameron and Trivedi was utilised to determine whether or not the residuals had heteroskedastic behaviour. Given that the calculated p-value is greater than the significance level of 0.05, it is clear that we are unable to refute the hypothesis of homoscedasticity (H_0). As a result, one might conclude that there is no evidence of heteroskedasticity in the residuals.

Furthermore, to test the model's structural stability, the CUSUM and CUSUMSQ) are employed in this study. The CUSUM and CUSUMSQ visual analyses are depicted in Figure1. The dimensions of the model are considered to be stable if the plots continue to remain within a critical limits range of 5%. The CUSUM and CUSUMSQ data are provided below. Both are less than 5%, which indicates that the parameters have remained the same for the selected countries during all sample periods.

Table 6: Model diagnostic test

Diagnostic test	Null hypothesis (H_0)	X^2 (P-value)
Breusch-Godfrey LM	No serial correlation	0.03
Cameron & Trivedi's decomposition of IM-test	Homoskedasticity	0.38
Skewness/kurtosis tests for normality	Residuals are normally distributed	0.35

Figure 2: CUSUM and CUSUMSQ test

(a)   (b)
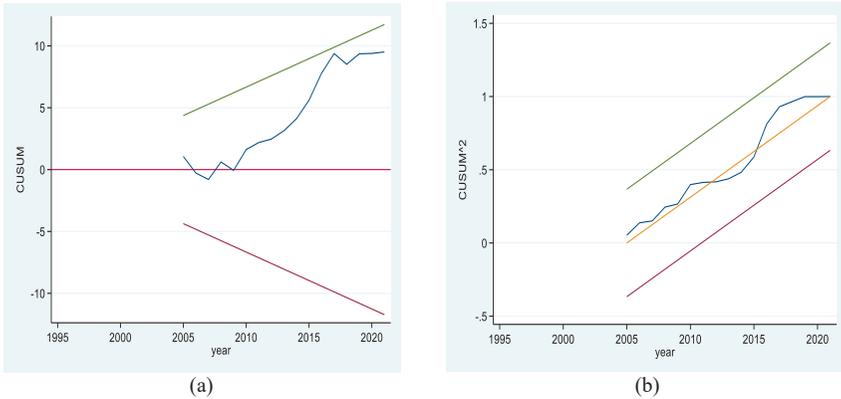
5.   Conclusion and Policy Recommendations

This study explores the moderating impact of institutional quality on the relationship between FDI and energy consumption in Nigeria from 1996 to 2022. Findings from the dynardl simulation technique revealed that FDI increases energy consumption in the short run, and reduces energy consumption in the long run. Additionally, the report confirms the presence of an inverted EKC, signifying a U-shaped relationship between FDI and energy consumption. More importantly, the coefficient of the interaction between FDI and institutional quality is negative in both the short and long run, suggesting that the extent to which FDI contributes to reducing energy consumption and promoting energy-efficient technologies in Nigeria is contingent upon the quality of the country's institutions. Strong institutions act as a catalyst for long-term economic progress by fostering a stable environment that mitigates economic, social, and political uncertainties.

Therefore, the Nigerian government should create an Energy Efficiency Regulatory Commission to ensure adherence to rigorous energy efficiency requirements across several sectors, especially in energy-intensive industries, therefore maximising the advantages of FDI for energy efficiency. The government can also establish a Green Investment Certification Programme that incentivises overseas investors to adopt sustainable practices and technology, together with tax benefits and subsidies for investments in renewable energy and energy-efficient infrastructure. Enhancing public-private partnerships (PPPs) to advance renewable energy initiatives,

especially in rural regions, would attract FDI and provide access to clean energy. Moreover, instituting capacity-building activities for local enterprises to embrace energy-efficient technology and practices will cultivate a more sustainable industrial environment. Ultimately, improving governance via the assurance of openness and accountability in the execution of energy policies will bolster investor trust and encourage responsible investing practices. As a result, it is possible that some components of the United Nations' Sustainable Development Goals (SDGs), in particular SDG7 (cheap and clean energy) and SDG13 (climate action), might be achieved simultaneously.

Although this research yields significant empirical findings, it is limited to the period of 1996 to 2022, owing to data availability. Future studies might broaden their focus to encompass more recent periods and integrate new inventive approaches and methodologies. By doing so, researchers can further enrich the literature and enhance our understanding of the dynamics between FDI and energy consumption.

Credit author statement

Ilemobola Solomon Oyefabi: Conceptualisation, Data Collection, Design of methodology, Formal analysis, Writing - original draft. **W. N. W. Azman-Saini**: Conceptualisation, Design of methodology, Supervision. **Mohamad Khair Afham Bin Muhamad Senan**: Conceptualisation, Supervision. **Yasmin Bani**: Conceptualisation, Editing, Supervision

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