A G D I Working Paper

WP/23/077

Energy Efficiency Investment in a Developing Economy: Financial Development and Debt Status Implication

Forthcoming: International Journal of Energy Sector Management

Chukwunonso Ekesiobi
Department of Economics, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.
E-mail: cs.ekesiobi@coou.edu.ng

Stephen O. Ogwu
Department of Economics, Dennis Osadebay University, Asaba, Delta State, Nigeria
(Corresponding author)
E-mail**:**: Stephen.ogwu@dou.edu.ng

Joshua C. Onwe
School of Financial and Business Management Studies, Federal Polytechnic Ohodo, Enugu State, Nigeria
E-mail: onwejoshuaa@gmail.com

Ogonna Ifebi
Department of Economics, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.
(E-mail**:**: lordnuel@yahoo.com)

Precious M. Emmanuel
MGIG Global Services, Ikeja, Lagos, Nigeria.
Centre for Petroleum Energy Economics and Law (CPEEL), University of Ibadan, Nigeria.
E-mail:: preciousemmanuel202@gmail.com

Kingsley N. Ashibogwu
Department of Accounting, Delta State University of Science and Technology, Ozoro, Delta State, Nigeria
(E-mail:ashibogwukings@gmail.com)

Research Department

Energy Efficiency Investment in a Developing Economy: Financial Development and Debt Status Implication

Chukwunonso Ekesiobi, Stephen O. Ogwu, Joshua C. Onwe, Ogonna Ifebi, Precious M. Emmanuel & Kingsley N. Ashibogwu

Abstract

Purpose: *Our study assesses financial development and debt status impact on energy efficiency in Nigeria as a developing economy.*

Methodology: *We combined the Autoregressive Distributed Lag (ARDL), FMOLS, and CCR analytical methods to estimate the parameters for energy efficiency policy recommendations. Secondary data between 1990 and 2020 were used for the analysis.*

Findings: *The result confirms the long-run nexus between energy efficiency, financial development and total debt stock. Furthermore, the ARDL estimates for our key variables show that financial development promotes energy efficiency in the short run but hinders long-run energy efficiency. Total debt stock limits energy efficiency in Nigeria in short and long-run periods.*

Originality: *The environmental consequences of energy intensity are being felt globally, with the developing countries most vulnerable. The cheapest way to curb these consequences is to promote energy efficiency to reduce the disastrous effect. Driving energy efficiency requires investment in energy-efficient technology, but the challenge for developing economies i.e. Nigeria's funding, remains challenging amid a blotted debt profile. This becomes crucial to investigate how financial sector development and debt management can accelerate energy-efficient investments in Nigeria.*

Practical Implication: *The financial sector must ensure the availability of long-term credit facilities to clean energy investors. The government must maintain a sustainable debt profile to pave the way for capital expenditure on clean energy projects that promote energy efficiency.*

Limitation: *The limitation of this study is that the scope is limited to Nigeria as a developing economy. The need to support energy efficiency projects is a global call requiring cross-country analysis. Despite our study focusing on Nigeria, it provides useful insights that can guide energy efficiency policy through the financial sector and debt management.*

Keywords: Financial Development, Public Debt, Energy Efficiency, Environment, Nigeria.

JEL: E22, E44, E62

1. Introduction

Energy efficiency has become a crucial tool for implementing policy to attain decarbonised growth and to lessen environmental change (Akram et al., 2020). In this respect, energy efficiency entails the ability to produce the same result while using less energy. Energy efficiency in developing nations is crucial for achieving sustainable energy use and also cogent for resolving climate change issues (Özcan & Özkan, 2018). Energy efficiency is the cheapest and most reliable approach toward achieving net-zero and sustainable development goals by 2030 because it involves lowering energy consumption without compromising living standards, productivity, and profitability (Huseyin, 2021; Saleem Jabari et al., 2022). Aside from the potential pollution abatement impact of energy efficiency, it reduces the cost associated with energy use and insecurity.

Furthermore, The United Nations Sustainable Development Goals (SDGs) emphasis the significance of tripling energy efficiency efforts to fulfil SDG 7, which calls for ensuring that everyone has access to modern, affordable, dependable, and sustainable energy. However, Nigeria is still far from meeting the projected improvement in energy intensity of 2.7% by 2030, despite the fact that most economies have made strong attempts to enhance their energy efficiency (United Nations, 2018).According to UNIDO (2016), the average energy intensity in Nigeria is 8.2 MJ/USD, which is much higher than the global average of 5.2 MJ/USD. Lowering this intensity is crucial for improving energy efficiency in Nigeria, which is paramount in promoting sustainability, energy access and security. Reiterating this argument, Hanley et al. (2009) pointed energy efficiency improvement promotes decarbonisation which is incredibly beneficial for the environment. Moreover, achieving energy efficiency requires massive investment (Akram et al., 2020; Hashemizadeh et al., 2021).

On the foregoing, debt financing is one channels through which energy efficiency projects can be financed. Africa has recently shown a larger appetite for debt to finance social and infrastructural sectors (Africa Development Bank, 2018). Although this has repercussions for the burden of debt on African countries, government spending backed by debt can support environmentally friendly products like energy efficiency. Given that, among other things, inadequate financing greatly hinders the advancement of energy efficiency in Nigeria

(Lyakurwa & Mkuna, 2018; Katrina, 2015), investment in energy efficiency initiatives may be discouraged by increased taxes on citizens to fund government services.

Given the above, Nigeria has continued accumulating debt over the years to meet her developmental needs. For instance, available records show that at the end of 2018, the nation's total debt was ₦24.387 trillion or $79.4 billion, with domestic debt representing 68.18% of the overall debt stock while external debt accounted for 31.82% (DMO, 2018). Similarly, as of March 31, 2021, total public debt increased to ₦33.107 trillion or USD87.239 billion, with domestic debt representing 62.33% of the overall debt stock while external debt accounted for 37.67%. The total public debt stock includes debt held by the federal government of Nigeria (FGN), 36 state governments, and the Federal Capital Territory (FCT).

A number of empirical studies demonstrate the crucial role of the financial sector in stimulating investment energy efficient projects with the purview of promoting environmental quality and reducing energy poverty (Dimwobi et al., 2022).Nigeria's financial industry has expanded significantly to become the continent's leading financial market. The Nigerian economy's expansion and the energy sector's development are critical, and the banking sector plays an essential role in the development process. The National Development Plan 2021–2025 (NDP) report shows that between 2017 and 2020, the financial sector contributed about N44.2 trillion to Nigeria's GDP. Moreso, the report shows that the financial services industry's overall size was N78.10 trillion in 2017 but increased to N122.30 trillion by 2020. This shows the potential of the Nigerian financial sector to stimulate clean energy technology, which can promote national energy efficiency and lowers the intensity of energy use. In addition, The bulk of Nigeria's financial sector is made up of the banking sector, which accounted for about N42.7 trillion in 2019, an upward trajectory from N37.8 trillion in 2018 and N34.6 trillion in 2017,respectively.

It is also well recognised that a nation's public borrowing and nature play a significant role in determining its economic performance. Furthermore, scholarly and policy circles have given considerable emphasis to the wider economic effects of public debt. With the recent instability of the global financial system, the occurrence of public debt, and worries about environmental sustainability, such analysis becomes even more pertinent. This debt concern makes it critical to evaluate how public debt has translated to investment in the energy sector to promote energy efficiency. Owing to the rising debt profile, debt servicing and repayment mount pressure on government revenue for possible financial energy-efficient projects (Hashemizadeh et al., 2021).

Therefore, our study evaluates the impact of financial development and debt status on energy efficiency in Nigeria. This study presents novelty in threefold. First, we consider the connection between financial development and energy efficiency. We capture financial development with the IMF financial development index proposed by Svirydzenka (2016). The index is a broad-based indicator that captures the financial market and the financial institutions. Unlike Fu (2020), Latif et al. (2022), Xu et al. (2022), and Zhao et al.(2022), which capture financial development with the private to credit sector, our study presents a more encompassing analysis. Secondly, we consider debt holistically by considering total debt stock, debt servicing, banking and the non-banking sector debt. This holistic view is crucial to prescription policy options for energy-efficient project debt financing. This represents a foremost study taking this holistic approach. Thirdly, unlike existing studies in the literature, especially for Nigeria, we adopted an unconventional unit root developed by Lee & Strazicich (2003). This unit root accounts for Structural breakpoints against the traditional unit root test. Also, we employed the ARDL technique of data analysis proposed by Pesearan et al. (2001) and to ensure the robustness of our estimate, and we utilise the FMOLS and the CCR analytical method to strengthen policy recommendations that can drive energy efficiency in Nigeria via financial development and debt financing.

Therefore, for the organisation of the study, After the introduction, an empirical review follows, then the model and methodology, results, and the conclusion and recommendation of our study.

2. Empirical Reviews

Research on various economies and areas regarding financial development (FD), debt status (DS) and energy efficiency (EF) has been conducted employing different approaches, which produced varied outcomes necessitating appropriate policy prescription in line with findings. This review section is demarcated into three strands to include firstly, the impact of financial development (FD) on energy efficiency (EE); secondly, the impact of debt status (DS) on energy efficiency (EE); and finally, the impact of financial development (FD) and debt status (DS) on energy efficiency (EE). Below is a list of literature on the first strand.

Sadorsky(2010) examined FD as a critical driver of economic growth in the presence of energy demand for 22 developing countries employing the heterogeneous panel estimation from 1990 to

2006; findings show that FD is a good determinant of energy demand. In a related study, Ma, Zhao et al.(2022) considered the role played by FD and energy consumption (EC) on climate change for 67 emerging countries from 1995 to 2018; findings from the panel GMM showed that these emerging economies' energy intensity is significantly reduced by their FD. Again, Ma & Fu (2020)found that FD positively impacts EC for 120-panel countries when GMM is applied. Finally, Rakpho et al.(2021) investigated the asymmetric effects of FD on energy security for 16 Asian countries between the periods of 2000 to 2016. By applying the smooth panel transition model for trend, the study found that FD reduces energy inefficiency in the economy and goes hand in hand with energy accessibility and the share of renewable energy sources. Similarly, Mills et al. (2021) concluded that FD improves energy efficiency for 58 Belt & Road nations.

Latif et al. (2022) employed the panel quantile estimation to examine the FD, EE and climate change issues caused by Co2 emissions from 1990 to 2020 from RCEP countries. They found that FD contributes to climate change issues while EE tends to reduce the detrimental effects of climate change on the environment. Similarly, for China's economy Xu (2012) found that FD impedes the climate and EC in China when GMM is applied from 1999 to 2009. Ah(2017) examined the link between FD and energy in the presence of growth for BRICS countries findings from the study suggest that EE increases after a certain income level due to FD and capital accumulation. While exploring the effects of FD on energy use for UAE from 1989 to 2019 using the Bootstrap ARDL (Samour, Mine, & Tursoy, 2022), found that FD significantly improves the consumption of clean energy sources in UAE.

In a related study, Shahbaz & Lean (2021) andLu et al. (2021)agrees that FD significantly promotes EC in Tunisia and a selected panel of Belt and Road Initiative (BRI) countries, respectively. Once more, the causality test reveals that FD has a unidirectional causality for Tunisia and bidirectional causation for BRI countries regarding EC. For Sub-Saharan African countries, Nkalu et al.(2021) examined the direct effects on FD and energy use from 1975 to 2019. By employing the VECM method, the study found that FD positively drives EC in SSA while a unidirectional causality exists between FD and energy use. The effect of FD and EE was examined by Zhang et al.(2021) during the Covid-19 period for China and Pakistan economies findings revealed that FD impacts positively in both economies in the presence of EE. Huseyin(2021)also found that FD significantly improved clean energy use in Nigeria from 1960to 2019 when ARDL was applied.

On the second strand, which considers the linkage between debt status and energy efficiency, Hashemizadeh et al. (2021) explored the connection between public debt and renewable energy use in 20 emerging nations with high debt profiles and renewable energy demand. Panel dataset ranging from 1990 to 2016 was collected and analysed using regression which employed the Driscoll-Kraay standard errors, in line with the stated object. The regression outcome shows that the sampled countries' debt status deteriorates renewable energy consumption. A further test of causality using the Dumitrescu and Hurlin granger causality test revealed that a two-way causality exists between public debt and renewable energy consumption in the sampled countries. Similarly, Sun & Liu (2020) examined how debt can influence the energy consumption of private sectors and public agencies by changing their fiscal budget constraints in China. In this study, the extended LMDI model was used to test the impact of debt on China's energy consumption using a dataset ranging from 1996 to 2016. The study found that debt-related factors and private debt per capita contribute the most to China's energy use, while the impact on the population was moderate. Specifically, debt structure adjustment and output efficiency of public debt, amongst others, were potent mitigating forces of energy use in China. The study, therefore, recommended a holistic approach to dealing with pollution.

Finally, on the third strand is a single study by Saleem Jabari et al. (2022), who investigated the link between renewable energy consumption, financial development, and external debts in Turkey. The study employed the bootstrap ARDL to ascertain the impact relationship between the explanatory variables and renewable energy consumption, duo its numerous advantages. The findings from the ARDL regression show that a positive relationship exists between financial development and energy consumption. Furthermore, the findings revealed that external debt impact significantly on renewable energy consumption in a negative manner. The study thus recommends increased investment in energy and production as they are potent in mitigating environmental degradation in Turkey. Furthermore, the outcomes illustrate that the coefficient of external debt is negative and significant. The study equally suggested modifying policies on external debt to reduce its negative impact on sustainable energy development in Turkey.

Overall, most literature on financial development and debt status was linked to energy utilisation rather than energy efficiency. In terms of abundance, less than three studies examined the link between financial development and energy efficiency, while no known study has investigated the impact of debt status on energy efficiency across countries and regions. As a result, this current study has found a vast gap in the literature in this area. Hence the study sought to unravel the impact of financial development and debt status on energy efficiency with a particular interest in the Nigerian economy, given the risen concern invigorated by the increasing debt status and the burden servicing in the country.

3. Model Specification, Data and Methodology

3.1 Model Specification

The theoretical linkage between financial development and energy utilisation is well documented in Sadorsky (2011) and Dimnwobi et al. (2022). The theory shows how the financial system connects energy use intensity via promoting business, direct investment in energy projects and the wealth effect. This shows that a well-developed financial system can affect energy efficiency. Similalry, Hashemizadeh et al. (2021) and Jianhua (2022) document that a country's public debt stock can also impact its investment in energy resources. The argument is that as a nation's debt stock increases, the burden of debt servicing and outright payment rises, reducing investment in energy infrastructures and consequently lowering energy efficiency. On the contrary, countries with a low debt profile are buoyant to invest in the energy sector, thereby enhancing energy efficiency (Jianhua, 2022). Therefore, in modelling the connection between financial development, debt status and energy efficiency, we rely on the argument of Sadorsky (2011) and Dimwobi et al. (2022) that the financial sector can impact energy use and Hashemizadeh et al. (2021) and Jianhua (2022) that shows that nations' debt profile affects energy consumption. However, our study diverges from Sadorsky (2011), Hashemizadeh et al. (2021), Dimwobi et al. (2022), and Jianhua (2022) by using hypothesising that energy efficiency (EE) is a function of financial development (FD), Debt status (TDS) and other potential explanatory covariates includes Debt servicing (DS), bank debt (BD), and non-bank debt (NBD), foreign direct investment (FDI), income per person (Y), and consumer price index (CPI).

$$EE_t = f(FD_t, TDS_t, DS_t, BD_t, NBD_t, FDI_t, Y_t) \qquad (1)$$

Eq. (1) X_t represent potential control covariates which include; Debt servicing (DS), bank debt (BD), and non-bank debt (NBD), foreign direct investment (FDI), income per person (Y), and consumer price index (CPI), while *t* indicates the time factor. The study now presents Eq.(1) econometrically as thus;

$$EE_t = \psi_0 + \psi_1 FD_t + \psi_2 TDS_t + \psi_3 DS_t + \psi_4 BD_t + \psi_5 NBD_t + \psi_6 FDI_t + \psi_7 Y_t + \varepsilon_t$$

(2)

ψ_0 is the constant term, ψ_{1-7} represent the elasticities of FD and TDS, DS, BD, NBD, FDI, and Yand ε is the disturbance error.

3.2 Data

We employ secondary data spanning between 1990 and 2020 for this study. The time frame and variables selected for analysis are primarily due to data availability and existing literature. Energy efficiency (EE) is the dependent variable. EE is the utilisation of lesser energy resources in producing per unit of output (Mahapatra & Irfan, 2021). Consistent with the literature, we capture energy efficiency with energy intensity, which is the energy consumption ratio to GDP (Akram et al., 2019; Mahapatra & Irfan, 2021). It is believed that lower energy intensity implies an efficient energy system. Concerning financial development, we employ the financial development index following the studies of Svirydzenka (2016) and Dimwobi et al. (2022). The financial development index is a broad-based indicator that captures financial development with the depth, accessibility and efficiency of the financial institutions and financial market (Svirydzenka, 2016). This index is more robust because it takes into account the efficiency of the financial institutions, which is often neglected in similar studies, i.e. Ahmed (2017), Rakpho et al. (2021), and Samour et al. (2022). Therefore, Svirydzenka's (2016) broad-based financial development computation follows thus;

$$FD_i = FI_i + FM_i \tag{3}$$

FD represent the broad-based financial development, FI and FM capture the financial institution's dept, access and efficiency, which is computed using the principal component analysis (PCA).

Regarding debt status, we capture the total debt stock to measure the debt status, which is consistent with the studies of Hashemizadeh et al. (2021) and Jianhua (2022). It is believed that an increase in debt status can hinder investment in energy-efficient projects, which can trigger energy inefficiency and insecurity. The reverse is the case for nations with low debt profiles. The rest variables, i.e. debt servicing, bank and non-bank debt, FDI, and income per head, are other covariates that can influence energy efficiency. In this respect, this study captures debt servicing with debt servicing to the ratio of GDP following the studies of Mohsin et al. (2021). According to Moshine et al. (2021), as debt servicing rises, public spending on energy declines due to revenue shortages. This means that as debt servicing rises, spending on energy-efficient projects thereby lowers energy efficiency. However, Bank debt is the loans and credit products corporate banks offer. Therefore, the level of loans banks issue to individuals and organisations can influence the choice of energy resources and the kind of energy-efficient appliances they can acquire (Allinger et al., 2021).

On the other hand, non-bank debt is debt obligations issued to individuals and firms by non-bank financial institutions. Therefore, the level of non-bank debt can influence energy efficiency. Furthermore, The relationship between FDI and energy efficiency is well established in the literature. For example,Yao et al. (2021) and Gao et al. (2022) emphasised that FDI facilitates the inflow of technologies that will drive energy efficiency utilisation. Concerning the income per head, it is believed that an individual's wealth influences their consumption choice following the energy ladder hypothesis. Therefore, as revenue per head rises, people purchase energy-efficient appliances, thereby improving energy efficiency (Adom et al., 2021). For this purpose, this study captures income per head with GDP per capita to assess the connection between income per person and energy efficiency. In the preceding, we present tabular summary and measurement units of all the variables in Table 1.

Table 1: Tabular Summary and Measurement Units of Variables

Variables	Measurement Unit	Reference	Source
Energy Efficiency (EE)	This is calculated by obtaining the ratio of GDP to total primary energy consumption	Akram et al. (2019), Mahapatra & Irfan (2021)	Authors Derived
Financial Development (FD)	It is measured with the broad-based financial development index	Svirydzenka (2016), Dimwobi et al. (2022)	AuthorsDerived
Debt Status (TDS)	It is measured with total debt stock, which is the sum of external and domestic debt	Hashemizadeh et al. (2021)	Central Bank of Nigeria, Statistical Bulletin
Debt Servicing (DS)	This is measured with debt servicing in % of GDP	Mohsin et al. (2021)	World Development Indicator
Bank Debt (BD)	This is captured with total commercial bank loans and liabilities	Allinger et al. (2021)	Central Bank of Nigeria, Statistical Bulletin
Non-bank Debt (NBD)		Allinger et al. (2021)	World Development Indicator
Foreign Direct Investment (FDI)	This is measured with FDI net inflows % of GDP	Gao et al. (2022)	World Development Indicator
Income Per Head (Y)	This reflects the individual wealth, and it is captured withGDP per capita	Adom et al., 2021	World Development Indicator

Source: Compiled by authors

3.3 Estimation Technique

3.3.1 Unit Root and Cointegration Test

Before continuing with the analysis, it is crucial to look at the series order of integration by testing for the time series unit root. We adopt both conventional and unconventional unit root tests for this study. We employ the Augmented Dickey-Fuller (ADF) for the traditional unit root test. For the event of structural breaks, the conventional test is handicappedin identifying structural breaks instead; they treat breaks as unitroots (Dimwobi et al., 2022; Kirikkaleli et al., 2022). To account for structural breaks, we employ the Lee and Strazicich (L-S) minimum Lagrange multiplier (LM) unit root test proposed by Lee & Strazicich (2003). The test improves on the traditional test by revealing various breakpoints through observation. In addition, the L-S unit root can more accurately detect break dates and has enhanced size and power features, unlike the Lumsdaine and Papell (1997),Clemente et al. (1998), and Zivot & Andrews (2002) tests. Hence, L-S unit root adoption will help to prevent selecting biased order of integration. Regarding cointegration, We employ the bound cointegration test to check for the cointegration. The bound test follows the framework of the Autoregressive distributed lag (ARDL) suggested by Pesaran et al. (2001). The test is necessary to check if the variables move together in the long run.

3.3.2 Analytical Method

This study employs the Autoregressive distributed lag (ARDL) analytical technique proposed by Pesaran et al. (2001). The ARDL has recently gained prominence among scholars due to its numerous merits over the traditional time series methodology. First, the ARDL is flexible by allowing mixed order of integration among variables. In contrast to the conventional cointegration strategy, the bond test generates more reliable estimates despite a tiny sample, demonstrating the method's suitability for small-size observations (Pesaran et al., 2001; Dimwobi et al., 2022). Also, In order to adjust for misalignment, the method takes into account an unrestricted error correction model (ECM). And lastly, ARDL avoids the endogeneity issue in a single-regression equation paradigm by distinguishing between endogenous variables and regressors. The numerous suitability of ARDL is highlighted in Pesaran et al. (2001). We specify the ARDL equation as thus:

$$\Delta LNEE_t = \chi_0 + \sum_{i=1}^{n} \chi_{1i} \Delta LNEE_{t-i} + \sum_{i=0}^{n} \chi_{2i} \Delta LNFD_{t-i} + \sum_{i=0}^{n} \chi_{3i} \Delta LNTDS_{t-i} + \sum_{i=0}^{n} \chi_{4i} \Delta LNDS_{t-i} + \sum_{i=0}^{n} \chi_{5i} \Delta LNBD_{t-i} + \sum_{i=0}^{n} \chi_{6i} \Delta LNNBD_{t-i} +$$

$$\sum_{i=0}^{n} \chi_{7i} \Delta LNFDI_{t-i} + \sum_{i=0}^{n} \chi_{8i} \Delta LNY_{t-i}$$

$$+ \gamma_1 LNEE_t + \gamma_2 LNFD_t + \gamma_3 LNTDS_t + \gamma_4 LNDS_t + \gamma_5 LNBD_t + \gamma_6 LNNBD_t + \gamma_7 LNFDI_t + \gamma_8 LNY_t + \varepsilon_t$$

(6)

The long-run and short-run elements of the ARDL model are captured by equation (6). The variables remain as identified but χ_0 is the ARDL intercept, $\chi_1 - \chi_8$ are the elasticities of the lagged regressand, financial development and total debt stock whereas and other control variates included in the model. More so $\gamma_1 - \gamma_8$ are the elasticities of the long-run ARDL.

Furthermore, we employ the Fully Modified Ordinary Least Squares (FMOLS) and Carconical Cointegration Regression (CCR) analytical methods based on the framework of cointegration regression to check for the robustness of the ARDL model. This method has an inherent flexibility to generate consistent estimates for both panel and time series observations (Mesagan et al., 2022). Also, the FMOLS and CCR consider potential endogeneity and serial correlation. Moreover, Hossain et al. (2022) pointed out that FMOLS and CCR can provide an efficient robustness check for ARDL estimates.

4. Results

4.1 Preliminary Estimation Check

We present the summary statistics describing the nature of the data we employ for the analysis in Table 2. The evidence shows that energy efficiency (LNEE) has the highest mean values and standard deviation. However, the mean value and standard deviation disparity are minimal. Also, for the remaining variables, the standard deviation is small, which implies a weaker deviation from the average Moreover, the Jarque-P for all the variables is insignificant at a 0.05 critical value. The implication is that all the variables are normally distributed. Since our variables are distributed normally, we proceed to check for unit root and present the results in Tables 3-4

Table 2: Descriptive Statistics

	LNEE		**LNDS**	**LNFDI**	**LNNBD**	**LNTDS**	**LNY**	**LNBD**
Mean	7.3176	0.4529	0.1366	1.6706	0.4075	3.5693	3.2852	3.1724
Median	8.8596	0.4898	0.2185	1.7880	0.0000	3.6225	3.2896	3.2959
Maximum	9.5347	0.5075	0.8143	2.4813	1.5711	4.4583	3.4294	4.3090
Minimum	0.0000	0.2536	-0.9892	0.3827	0.0000	2.5828	3.1504	1.4149
Std. Dev.	3.6511	0.0795	0.5339	0.5782	0.5014	0.5094	0.1051	0.9332
Skewness	-1.5366	-1.5350	-0.4910	-0.7100	0.7179	-0.1561	0.0063	-0.4467
Kurtosis	3.3863	3.8598	2.1182	2.7339	2.1385	2.1720	1.3421	1.8522
Jarque-B	2.3921	3.1129	2.2497	2.6961	3.6219	1.0113	3.5503	2.7328
Jarque-P	0.2037	0.1414	0.3246	0.2597	0.1634	0.6030	0.1694	0.2550

Note: The Authors compile the summary statistics; Jarque-B and Jarque-P represent Jarque Bera statistics and probabilities, respectively.

Table 3 presents the conventional unit root test based on the Augmented Dickey-Fuller (ADF) test. The evidence shows that all the variables are stationary at first difference except non-bank debt (LNNBD) and foreign direct investment (LNFDI), rejecting the null hypothesis at levels. This implies that our variables have a mixed order of integration based on the ADF without structural breaks.

Table 3: ADF Unit Root

HO: Absence of stationarity			
Variables	ADF Stat		Status
	I(0)	I(1)	
LNEE	-1.5254	-5.5261***	1st diffe
LNFD	-1.9047	-6.1345***	1st diff
LNTDS	-2.7199	-3.9486***	1st diff
LNDS	-2.2445	-7.3345***	1st diff
LNBD	-0.8912	-4.0515**	1st diff
LNNBD	-3.4848***	-	Level
LNFDI	-3.4717**	-	Level
LNY	-1.8153	-4.9535***	1st diff

Note: ** is P< 5%, *** represent P<1%, I(0) is stationarity at level and I(1) represent stationarity after differencing ones

Table 4 shows the L-S LM unit root result, which is an unconventional unit root that accounts for structural breaks along the trend line. The result is somewhat similar to the ADF result in Table 3. Except that debt servicing is stationary at I(1) in the ADF, the result is now stationary at I(0). Similarly, the L-S unit root shows that non-bank debt is stationary at I(1) as against I(0) in the ADF result. The break dates identified by the L-S test reveal and reflect practical structural changes in the energy and financial sectors. For instance, the energy sector witnessed a serious unbundling in 2005, known as the power sector reform act. Similarly, the banking sector in 2004 also witnessed restructuring through the recapitalisation policy. As the L-S reveals, the changes in the structure of the bank financial institutions and the power sector account for the structural breaks.

Table 4: L-S LM Unit Root

HO: Presence of unit root with a break					
Variables	**LM Stat I(0)**	**Breakpoints**	**LM Stat I(1)**	**Breakpoints**	**Status**
LNEE	-3.1057	2004, 2015	-90.057***	2007, 2013	1st diff
LNFD	-1.9318	2005, 2017	-6.0514***	2004, 2008	1st diff
LNTDS	-2.5729	2004, 2007	-11.110***	2004, 2015	1st diff
LNDS	-8.8462***	2003, 2013	-	-	Level
LNBD	-9.2600***	2004, 2014	-	-	Level
LNNBD	-2.5385	2006, 2010	-148.53***	2006, 2009	1st diff
LNFDI	-7.1061***	2001, 2006	-	-	Level
LNY	-2.1528	2000, 2008	-8.1826***	2001, 2013	1st diff

Note: *** represent P<1%

Therefore, since the unit root conditions are satisfactory, the study tests for cointegration among the series and present the result in Table 5

Table 5: Bound Cointegration Result

HO: No Cointegration		**Model: ARDL(1,1,1,1,1,1,1)**	
F-statistic	Lower bound	Upper bound	K
3.6312**	2.32	3.5	**7**

Note: ARDL (1,1,1,1,1,1,1) represent the lag length of order one selected based on the Akaike Information Criteria (AIC), K stand for the parameters, and ** means P<5% level of significance

We provide the bound cointegration test result in Table 5and at 5% critical value, it indicates that energy efficiency, financial development, and total debt stock, alongside other covariates, move together in the long run. This shows the presence of cointegration among the variables, thereby accepting H1. After rejecting the no cointegration hypothesis, the study proceeds to analyse the correlation between the variables in Table 6.

Table 6: Correlation Matrix

LNEE	**1**							
LNDS	0.1280	1						
LNFDI	-0.5403	-0.7024	1					
LNNBD	-0.4814	-0.7372	0.6896	1				
LNTDS	-0.6474	-0.5811	0.7321	0.6025	1			
LNY	-0.5085	-0.7730	0.7227	0.7976	0.7809	1		
LNBD	-0.5037	-0.7831	0.6768	0.7752	0.7026	0.7022	1	
LNFD	-0.2278	0.7181	0.4127	-0.5506	0.7612	0.4446	0.3210	1

Note: Correlation matrix compiled by Authors Using STATA 15

We present a correlation matrix in Table 6 to ascertain the degree of association between the variables. Strongly correlated variables can lead to inefficient and inconsistent regression estimates, which may lead to wrong policy implementation. From Table 7, the coefficients of association between the variable are moderate since coefficients are not more than 0.8, which indicate a very strong association. This shows that our model is well specified.

4.2 Regression Results

This study presents the regression results in this section. Specifically, Table 7 indicates the ARDL estimates, and Table 8 shows the FMOL and CCR estimates which we employ for robustness. In this respect, Financial development exerts a positive and significant influence on energy efficiency in Nigeria in the short run, whereas, in the long run, it has a negative but significant effect on energy efficiency. Therefore, the interpretation is that the financial sector promotes short-run energy efficiency in Nigeria, but in the long run, the financial sector is unable to drive energy efficiency in the nation significantly. In both short and long-run periods, the total debt stock has a negative but significant impact on energy efficiency in Nigeria. The meaning is that Nigeria's total debt stock hinders the growth of energy efficiency in short and long-term periods. Similarly, debt servicing and non-bank debt negatively affect short- and long-run energy efficiency. However, non-bank debt is significant in both periods, while debt servicing becomes significant in the long run. This implies that non-bank debt and debt servicing substantially slow down energy efficiency in the nation.

More so, bank debt has a positive but insignificant impact on energy efficiency in Nigeria. This indicates that bank debt has the potential to enhance energy efficiency development. Furthermore, regarding foreign direct investment, the inflows of FDI reduce energy efficiency in Nigeria in the short run, but over the long run, the FDI inflows positively engender energy efficiency. Lastly, the estimate shows that income per head exerts a positive and significant effect on energy efficiency. As a result, as individual income improves, their choice of energy-efficient appliances and equipment increases, thereby promoting overall national energy efficiency.

Table 7: ARDL Regression Result

Regressors	Regresssand: ΔLNEE		ARDL (1,1,1,1,1,1,1)	
	Coefficient	**Std. error**	**t-Stat**	**Prob.**
		Long-run		
LNFD	-22.629	12.923	-1.7510	0.0961
LNTDS	-5.0014	1.7133	-2.9190	0.0088
LNDS	-5.2874	1.3082	-4.0416	0.0007
LNBD	4.4031	3.4206	1.2872	0.2135
LNNBD	-2.7722	1.2392	-2.2369	0.0375
LNFDI	0.3056	4.0236	0.0759	0.9402
LNY	-0.0088	0.0034	-2.5731	0.0186
C	40.774	6.6820	6.1021	0.0000
		Short-run		
ΔLNFD	18.841	10.133	1.8593	0.0785
ΔLNTDS	-4.1643	1.7337	-2.4018	0.0267
ΔLNDS	-0.8482	1.1030	-0.7690	0.4513
ΔLNBD	3.6661	2.8274	1.2966	0.2103
ΔLNNBD	-2.3082	1.2670	-1.8216	0.0843
ΔLNFDI	-0.2544	3.3544	-0.0758	0.9403
ΔLNY	0.0127	0.0061	2.0662	0.0527
ECM(-1)	-0.8326	0.1927	-4.3200	0.0004

Note: ARDL(1,1,1,1,1,1,1) is the lag length selected based on the AIC, and ECM is the error correction mechanism which accounts for the speed of adjustment from the short run to the long run.

On the forgoing, the ECM value obtained in the short-run is negative and statistically significant with about 83% speed of discrepancy adjustment from the short-run to the long-run. The high convergence speed from the short to the long period further substantiates the cointegration evidence in Tables 5 and 6. The study proceeds to check the robustness of the ARDL regression estimates using the FMOLS and CCR in Table 8 to guide robust policy recommendations.

Table 8: Robustness Check

Regressors	Regressand: LNEE			
	FMOL		CCR	
	Cof	t-stat	Cof	t-stat
LNFD	-8.6162	-1.0405	-14.075	-1.0117
LNTDS	-0.2627	-0.1607	-0.7423	-0.2972
LNDS	-1.7957**	-2.1003	-1.4241	-0.9583
LNBD	10.647***	4.4533	12.451***	2.8585
LNNBD	-2.9503***	-3.4367	-3.4162**	-2.8890
LNFDI	0.5599	0.1771	0.5471	0.1536
Y	0.0024	0.9579	0.0013	0.3498
C	-5.2957	-0.6941	-4.0171	-0.3155
Trend	-1.3656***	-5.1202	-1.3997***	-2.9471
R-squared	0.8103		0.8046	
Adj R-squared	0.7380		0.7301	

Note: FMOL means fully modified least squares, CCR represent carnonical cointegrating regression, Cof indicates the regressions elasticities, t-stat denotes t-statistics, **and *** represents P< 5% and 1%, respectively.

The FMOLS and CCR robustness estimates turn out similar and show that Nigeria's financial sector and total debt stock lower energy efficiency. The sign obtained from this calculation is identical to the evidence we obtained in the long run result of the ARDL result in Table 7. This shows that our estimate in Table 7 is efficient and unbiased to guide policy formulation to fast-track energy efficiency in Nigeria via the financial sector and public debt.

4.3 Diagnostic Check

We proceed in this section to diagnose the time series estimates to verify the soundness of our calculation further. For this purpose, we use the Breusch-Godfrey (BG) LM for serial correlation, the Breusch-Pagan-Godfrey test to check for heteroscedasticity, Ramsey RESET and Jarque–Bera (JB) normality test for normality check, and F-statistic to diagnose the collective significance of our regressors. We report the F-values of these tests in Table 9.In addition, the study conducts a stability check on the model using the CUSUM and CUSUM-square test and presents the results in Figures 1-2.

Table 9. Diagnostics

Diagnostic tests	F-values	HO	Conclusion
BG LM	1.4086	Absence of serial correlation	HO accepted
BPG	1.7508	Homoscedastic	HO accepted
Ramsey RESET	2.0861	The model is well specified	HO accepted
JB Normality	0.3181	Errors follow normal distributed	HO accepted
F-statistic	8.4986***	Regressors not significant	HO rejected

Note: HO represent the null hypothesis for the diagnostic tests, and *** indicates significance at a 1% critical value.

The calculated diagnostic test in Table 9 indicates that our model is suitable, and the parameter estimates of the variables are satisfactory and robust for policy analysis. In the same manner, the recursive diagnostic based on CUSUM and CUSUM of the square also aligns with the rest evidence and shows that our model is stable.

Figure 1: CUSUM

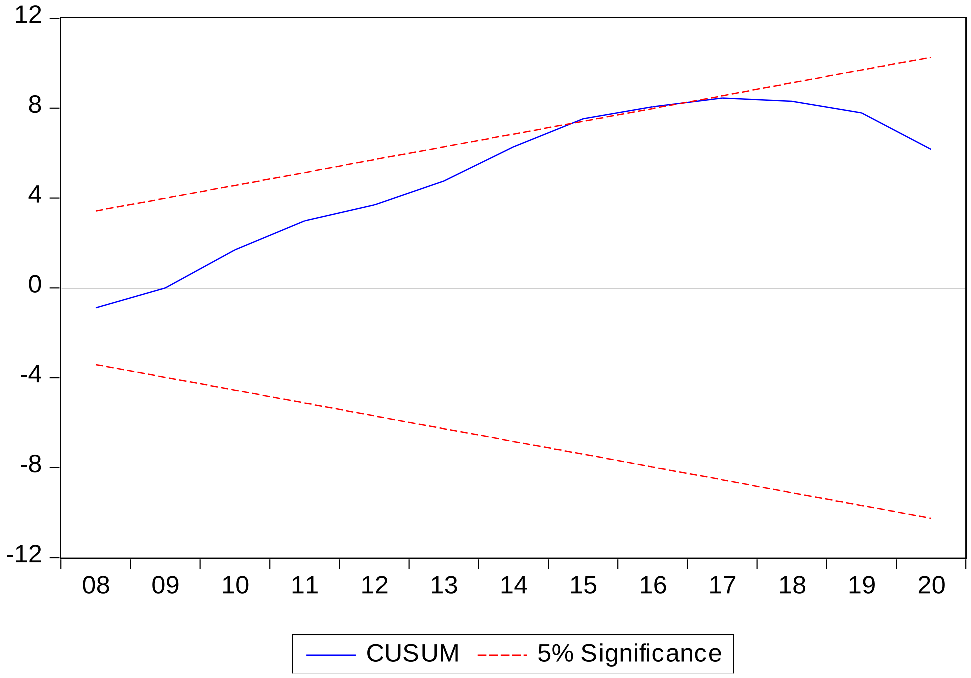
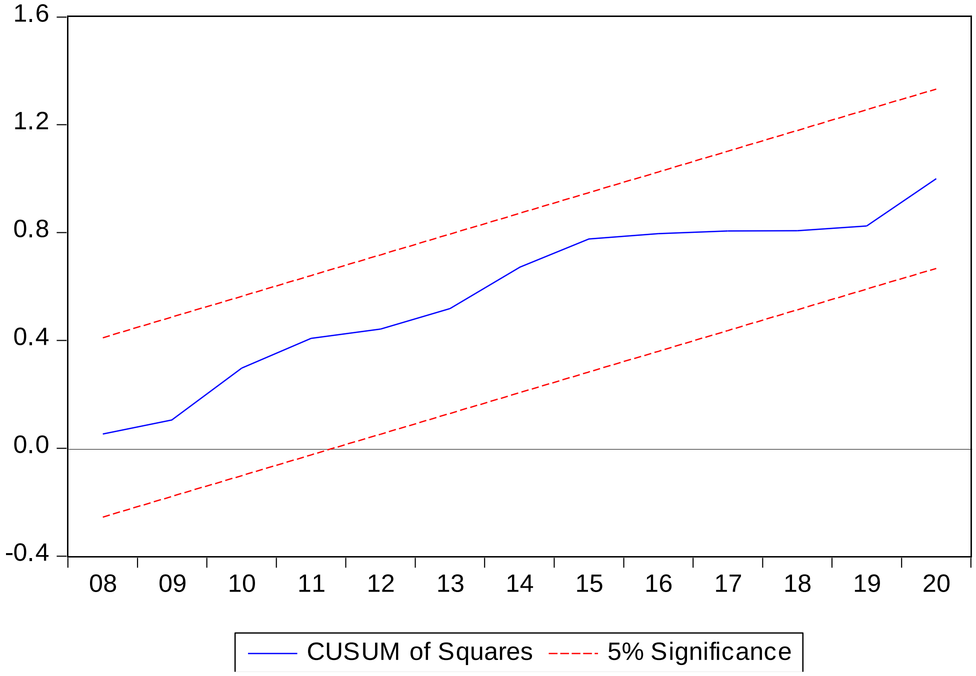


Figure 2: CUSUM of Square



4.4 Discussion of Result

The empirical results are indicative of practical intuition. For instance, the result shows that financial development promotes energy efficiency in the shortrun but, in the long run, deters energy efficiency in Nigeria. This evidence reflects the nature of credit that the Nigerian financial sector creates. The short-run result conforms to the fact the sector gives short-term credit facilities to investors for short-term investment as against long-term credit, which is crucial for long-term investment. This is because financial institutions are keen to profit short-term on credit facilities. However, achieving a long-lasting national energy efficiency requires serious financing of clean energy technology investment. The pessimistic attitude of the Nigerian financial system toward long-run investment financing informs the evidence. The short-run evidence is synonymous with the results of Zhang et al.(2021) and Huseyin(2021), while Mills et al. (2021) finding is similar to our long-run calculation. Regarding the debt status, In both the short and long run, total debt stock inhibits energy efficiency. The result represents a practical reality. For instance, the nation's external and internal debt obligation has risen from about N298.6billion and N89.04 billion in 1990 to about N12,705.62 billion and N16,023.89 billion, respectively (Central Bank of Nigeria, 2021). Over these years, this increase in debt status has not significantly translated to massive capital investment in the energy sector, as about 45% of the total population cannot access electricity (World Bank, 2022). Moreover, as the debt rises, debt servicing will continue to rise as a result and consequently pivot in public spending on energy-efficient technologies that can propel national energy efficiency. For example, Nigeria's debt servicing to % revenue has increased astronomically from 21.6% in 2012 to over 80% in 2020 (Debt Management Office, 2021). The servicing of this debt hinders real-time capital expenditure, especially in the energy sector, consequently lowering energy efficiency development. This debt scenario accounts for the negative nexus between total debt stock and debt servicing on energy efficiency in Nigeria. This result resembles the findings of Hashemizadeh et al. (2021), which found that public debts deteriorate renewable energy use in 20 emerging countries.

Concerning Bank debt and non-bank debt, bank debt encourages energy efficiency while non-bank debt discourages energy efficiency. The meaning is that the banking sector is driving clean energy technology investment in the nation. On the contrary, the non-bank credit instruments are not energy sector supportive. This is connected to the fact that the Nigerian banking system makes credit available to all productive sectors and is effectively regulated by the government, but the non-banking financial system is sector-specialised institutions that direct credit toward a particular sector. Moreover, informality has a huge presence in non-banking institutions. Also, foreign direct investment lowers energy efficiency in the short run but promotes energy efficiency in the long run in Nigeria. Net inflows of FDI have moved from about $0.5billion in 1990 to around $2.13billion in 2020 (Macrotrend, 2022). These inflows of net FDI must have been the driver of long-run energy efficiency. Moreover, FDI stimulates technological progress in the host economy, reducing energy intensity and promoting energy efficiency. Zhang & Zhang (2022) found a similar result for China. Lastly, income per head reduces energy intensity and increases energy efficiency. This shows that as individual income increases and energy consumption behaviour changes by consuming more energy-saving appliances such as lighting bulbs, refrigerators, and other energy-efficient labelled apparatus. Similarly, as income increases, the tendency to consume wood fuel and biomass for lightening and cooking declines, thereby lowering energy intensity. This evidence supports the energy ladder hypothesis.

5. Conclusion and Policy Recommendation

Energy efficiency is the cheapest and most flexible method for achieving decarbonisation and net-zero by 2030. However, supporting energy efficiency practices and investment is crucial for it to be a potent mitigator of climate change. In this respect, our study focuses on the impact of financial development and debt status on energy efficiency in Nigeria using periodic data from 1990 to 2020. The study adopts the ARDL methodology and applies the FMOLS and CCR to check for robustness. The study shows that the FMOLS and CCR obtained similar estimates and their signs are consistent with the ARDL estimates. Therefore, the ARDL result indicates that financial development enhances energy efficiency in the short run but significantly stifles energy efficiency in the long run. Total debt stock exerts a negative impact on energy efficiency. This implies that total debt hinders technology investments that accelerate energy efficiency. In like manner, debt servicing and non-bank debt hamper energy efficiency; bank debt positively affects energy efficiency, although not statistically significant. For FDI, the study shows that FDI reduces energy efficiency in the short term but enhances it in the long term. The income per person promotes energy efficiency. This shows that as income per capita improves, individuals change to the consumption of cleaner and efficient energy, thereby supporting the energy ladder hypothesis.

Based on the empirical revelation, the financial sector should ensure long-term credit facilities are available for energy sector development, especially investment in clean energy sources. Secondly, with the rising nature of the debt, the government may have nothing left to spend on critical sectors to drive productivity and improve the quality of life. Therefore, the study recommends that the government take a quick response to the country's deteriorating debt and debt servicing to ensure the debts are sustainable without compromising core fiscal responsibility. Furthermore, since foreign direct investment supports energy investment in the long run via technology stimulation, the government should focus on attracting FDI into the energy sector with investment interest in renewable energy. Lastly, the government should mandate that energy-dependent equipment be energy efficient and labelled to promote energy-efficient appliances.

Since there is a worldwide demand for energy efficiency, we advise that more research spanning several nations will be useful in determining the degree of energy efficiency attained in each and providing guidance to nations in need of ideas on how to do so through the growth of the financial sector. Therefore, cross-country and regional research should be done in this area to provide workable policy solutions, particularly for developing nations in the sub-Saharan Africa who are witnessing rising debt status and incurring huge cost of servicing such debts.

References

Adom, P. K., Agradi, M., & Vezzulli, A. (2021). Energy efficiency-economic growth nexus: What is the role of income inequality?. *Journal of Cleaner Production*, *310*, 127382.

Adeola, O., & Evans, O. (2017). The impact of microfinance on financial inclusion in Nigeria. *The Journal of Developing Areas*, *51*(4), 193-206.

Ahmed, K. (2017). Revisiting the role of financial development for energy-growth-trade nexus in BRICS economies. *Energy, Elsevier,128(C),* 487-495. DOI: 10.1016/j.energy.2017.04.055.

Akram, R., Chen, F., Khalid, F., Ye, Z., & Majeed, M. T. (2020). Heterogeneous effects of energy efficiency and renewable energy on carbon emissions: Evidence from developing countries. *Journal of cleaner production*, *247*, 119122.

Allinger, K., Beckmann, E., & Nationalbank, O. (2021). Not all debt is bank debt: Nonbank borrowing in Central, Eastern and Southeastern Europe.

Banerjee, A., Dolado, J., & Mestre, R. (1998). Error‐correction mechanism tests for cointegration in a single‐equation framework. *Journal of time series analysis*, *19*(3), 267-283.

Bayer, C., & Hanck, C. (2013). Combining non‐cointegration tests. *Journal of Time series analysis*, *34*(1), 83-95.

Boswijk, H. P. (1994). Testing for an unstable root in conditional and structural error correction models. *Journal of econometrics*, *63*(1), 37-60.

Chen, Y., Wang, M., Feng, C., Zhou, H., & Wang, K. (2021). Total factor energy efficiency in Chinese manufacturing industry under industry and regional heterogeneities. *Resources, Conservation and Recycling*, *168*, 105255.

Central Bank of Nigeria, (2022). Annual Statistical Bulletin. Available at: https://www.cbn.gov.ng/documents/Statbulletin.asp. Accessed on August 11 2022.

Dimnwobi, S. K., Madichie, C. V., Ekesiobi, C., & Asongu, S. A. (2022). Financial development and renewable energy consumption in Nigeria. *Renewable Energy*, *192*, 668-677.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251-276.

Eregha, P. B., & Mesagan, E. P. (2017). Energy consumption, oil price and macroeconomic performance in energy dependent African countries. *Прикладная эконометрика*, (2 (46)), 74-89.

Gao, D., Li, G., Li, Y., & Gao, K. (2022). Does FDI improve green total factor energy efficiency under heterogeneous environmental regulation? Evidence from China. *Environmental Science and Pollution Research*, *29*(17), 25665-25678.

Hashemizadeh A, Bui Q. & Kongbuamai N. (2021)Unpacking the role of public debt in renewable energy consumption: New insights from the emerging countries, *energy*, 224,120187. https://doi.org/10.1016/j.energy.2021.120187.

Huseyin, O. A. (2021). The impact of financial development on energy consumption in Nigeria. . *OPEC Review, 45 (2) ,* , 240-256. https://doi.org/10.1111/opec.12198.

Khalid, A. (2017). Revisiting the role of financial development for energy-growth-trade nexus in BRICS economies. *Energy, Elsevier,128(C),* , 487-495. DOI: 10.1016/j.energy.2017.04.055.

Latif, Y., Shunqi, G., Fareed, Z., Ali, S., & Bashir, M. A. (2022). Do financial development and energy efficiency ensure green environment? Evidence from RCEP economies. *Economic Research-Ekonomska Istraživanja,*, 1-22, doi.org/10.1080/1331677X.2022.2066555.

Lu, J., Imran, M., Haseeb, A., Saud, S., Wu, M., Siddiqui, F., & Khan, M. (2021). Nexus Between Financial Development, FDI, Globalization, Energy Consumption and Environment: Evidence From BRI Countries. *Front. Energy Res. 9:707590.* , doi: 10.3389/fenrg.2021.707590.

Lyakurwa, F. S., & Mkuna, E. (2018). Political-institutional barriers to energy access and efficiency in Tanzania: a case study of Mvomero District. *Afrika Focus*, *31*(1), 173-186.

Ma, X., & Fu, Q. (2020). The Influence of Financial Development on Energy Consumption: Worldwide Evidence. *Int J Environ Res Public Health. 17(4):1428.* , Ma X, Fu Q. (2020) "The Influence of Financial Development on Energy Consumption: Worldwide Evidence". Int J Environ Res Public Health. 17(4):1428. doi: 10.3390/ijerph17041428. PMID: 32102179; PMCID: PMC7068304.

Ma, Y., Zhao, Y., Jia, R., Wang, W., & Zhang, B. (2022). Impact of Financial Development on the Energy Intensity of Developing Countries. *Heliyon*, https://doi.org/10.1016/j.heliyon.2022.e09904.

Nkalu, C. N., Ugwu, S., Asogwa, F., Kuma, M., & Onyeke, Q. (2021). Financial Development and Energy Consumption in Sub-Saharan Africa: Evidence From Panel Vector Error Correction Model. . *SAGE Open* , 1–12. DOI: 10.1177/2158244020935432.

Özcan, K. M., & Özkan, A. U. (2018). The relationship between energy efficiency and economic performance in G20 countries. *Topics in Middle Eastern and African Economies Proceedings of Middle East Economic Association*, *20*(1), 1-20.

Rakpho, P., Yamaka, W., Puttachai, W., & Maneejuk, P. (2021). Role Of Financial Development For Solving The Energy Insecurity In Asia. . *The Singapore Economic Review. 66(02*, 413-434. https://doi.org/10.1142/S0217590820430018.

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy, 38 (5):* , 2528-2535 https://doi.org/10.1016/j.enpol.2009.12.048.

Samour, A., Mine, B. M., & Tursoy, T. (2022). The Impact of Financial Development and FDI on Renewable Energy in the UAE: A Path towards Sustainable Development. . *sustainability, 14, 1208.* , https://doi.org/10.3390/su14031208.

Shahbaz, M., & Lean, H. H. (2021). Does financial development increase energy consumption? The role of industrialisation and urbanisation in Tunisia. *Energy Policy, 40,*, 473-479.https://doi.org/10.1016/j.enpol.2011.10.050},.

United Nations, (2018), Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for allArticle available at : https://unstats.un.org/sdgs/report/2018/goal-07/. Accessed on August 12 2022.

Xu, S. J. (2012). The Impact of Financial Development on Energy Consumption in China: Based on SYS-GMM Estimation. . *Advanced Materials Research*, , 524–527, https://doi.org/10.4028/www.scientific.net/amr.524-527.2977.

Zhang, L., Huang, F., Lu, L., & Ni, X. (2021). *Green financial development improving energy efficiency and economic growth: A study of CPEC area in COVID-19 era, IRTG 1792 Discussion Paper, No. 2021-017,* . Berlin: Humboldt-Universität zu Berlin, Internanational research training group 1792.

.