

Does Digital Finance Drive Renewable Energy Consumption? Evidence from Nigeria

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Abstract

Nigeria faces a critical paradox: despite abundant renewable energy resources, over 85 million citizens remain trapped in energy poverty, largely due to limitations in the conventional financial system. This study examines whether digital finance can address this challenge and identifies the mechanisms through which it influences renewable energy consumption (REC) in Nigeria from 2009 to 2022. Grounded in Schumpeter's Financial Innovation Theory, Lundvall's National Innovation Systems framework, and the Stern Review's climate-economic perspective, the study employs an ARDL-ECM approach. Results show that digital finance significantly increases REC in both the short and long term, with a 1% rise in the digital finance index improving long-run per capita REC by 0.84%. Credit accessibility is the primary transmission channel, with loan availability and household income jointly explaining about 40% of the total impact. Economic growth and technological advancement further promote clean energy adoption, while carbon emissions have no significant influence due to weak carbon pricing mechanisms. Robustness tests using solar energy consumption confirm the findings. The study recommends embedding digital financial infrastructure, particularly credit-based and income-enhancing digital financial services into Nigeria's renewable energy transition strategy.

Keywords: Digital Finance, Renewable Energy Consumption, Financial Innovation, Ardl Bounds Testing, Energy Poverty; Nigeria.

Introduction

Nigeria stands at a critical juncture in its energy development trajectory. As Africa's most populous country and largest economy by GDP, it occupies a paradoxical position: a major fossil fuel producer, one of the continent's most severe energy poverty hotspots, and a nation endowed with substantial renewable energy potential. Over 85 million Nigerians lack reliable electricity access, while modern renewable energy remains a marginal component of the national energy mix despite abundant solar, wind, hydropower, and biomass resources (IEA, 2022; Ogwumike&Ozughalu, 2015). This contradiction reflects a fundamental financing constraint: renewable energy technologies require significant upfront investment, long payback periods, and access to affordable credit, conditions largely unavailable to households and small enterprises under Nigeria's existing financial system (Qadir et al., 2021; Hashemizadeh et al., 2021). The implications are substantial. Energy poverty limits productivity, constrains household welfare, and reinforces inequality

by restricting access to modern energy services (Ogwumike&Ozughalu, 2015; Rafindadi, 2016a). Meanwhile, reliance on fossil fuels, particularly diesel generators used to compensate for unreliable grid supply, contributes to environmental degradation and challenges Nigeria's climate commitments under the Paris Agreement and Sustainable Development Goals (Fuso Nerini et al., 2018; Burke & Stephens, 2018). Expanding renewable energy consumption (REC) is therefore both a development priority and an environmental necessity.

Nigeria's conventional financial system has struggled to support this transition. High collateral requirements, limited credit availability, short loan maturities, and elevated interest rates constrain financing for renewable energy investments, while financial exclusion remains widespread (Jimoh et al., 2023; Akinlo, 2009). However, the rapid growth of digital finance offers a potential pathway for overcoming these barriers. Through mobile payments, digital lending, online banking, and fintech-based financial services, digital finance reduces transaction costs, expands financial access, and enables underserved households and firms to participate in formal financial markets (Ozili, 2018; Gomber et al., 2017; Arner et al., 2020). Nigeria's digital finance ecosystem has expanded rapidly, processing over 3.7 billion transactions valued at more than ₦58.3 trillion by 2022 (CBN, 2023). Digital finance may influence REC through two main mechanisms. First, it enhances credit access by reducing information asymmetries, lowering lending barriers, and enabling alternative credit assessment models, thereby easing the upfront financing constraints associated with renewable energy adoption (Croutzet&Dabbous, 2021; Kara et al., 2021). Second, it can improve household income through digital savings, remittances, and microenterprise support, increasing the financial capacity to invest in clean energy technologies (Li et al., 2020; Song et al., 2020). These channels align with Schumpeter's (1934) financial innovation theory, which emphasizes credit as a driver of technological transformation, and Lundvall's (1992) National Innovation Systems framework, which views finance as a critical component of innovation ecosystems.

Despite these theoretical linkages, the relationship between digital finance and renewable energy consumption remains empirically unexamined in the Nigerian context. This study addresses this gap by providing the first time-series analysis of the digital finance-REC nexus in Nigeria. Using the ARDL bounds testing approach, which accommodates mixed integration orders in macroeconomic data, the study examines both the direct effect of digital finance on REC and the mediating roles of loan scale and household income.

Statement of the Problem

Although digital finance and renewable energy consumption (REC) are each well studied in isolation, no empirical study has examined how Nigeria's rapidly expanding digital finance ecosystem shapes REC, despite the country's substantial renewable energy potential and severe energy poverty. Existing Nigerian energy-finance research has relied on conventional financial development indicators such as bank credit and capital market activity, while Nigeria's digital finance literature has concentrated on financial inclusion,

economic growth, and informal-sector outcomes, leaving the specific transmission channels through which digital finance might influence REC, namely credit access and household income, empirically unexamined. This gap limits the evidence base available to policymakers seeking to align Nigeria's fintech expansion with its renewable energy transition goals.

Objectives and Research Questions

This study aims to:

- 1) estimate the total effect of digital finance on renewable energy consumption in Nigeria;
- 2) test loan scale and household income as mediating transmission channels through which digital finance influences REC; and
- 3) assess the robustness of these findings using solar energy consumption as an alternative dependent variable.

Correspondingly, the study addresses three research questions:

- i. Does digital finance significantly affect REC in Nigeria in the short and long run?
- ii. Do loan scale and household income mediate the relationship between digital finance and REC?
- iii. Are the findings robust to an alternative measure of renewable energy consumption?

Hypothesis

As the study is framed around elasticity estimation within the ARDL bounds testing framework rather than classical hypothesis testing, no formal null hypotheses are specified. Consistent with the theoretical framework and objectives above, however, the analysis is guided by the following directional propositions:

H1: Digital finance has a positive effect on renewable energy consumption in Nigeria in the long run.

H2: Loan scale and household income significantly mediate the relationship between digital finance and renewable energy consumption.

Theoretical/Conceptual Framework

This study integrates three complementary theoretical perspectives to explain how digital finance influences renewable energy consumption (REC). First, Schumpeter's (1934) Financial Innovation Theory views finance as an active driver of economic transformation rather than merely an intermediary of existing savings. By creating purchasing power and facilitating investment before future income is realised, financial innovation enables entrepreneurs and households to adopt new technologies. Applied to the digital finance–REC nexus, this suggests that mobile credit, pay-as-you-go financing, and digital savings platforms can relax liquidity constraints and enable Nigerian households and firms to invest

in renewable energy technologies ahead of realised income gains, thereby facilitating a transition away from fossil fuel dependence (Croutzet&Dabbous, 2021).

Second, Lundvall's (1992) National Innovation Systems framework positions financial institutions as interconnected actors within a broader ecosystem involving technology providers, regulators, knowledge institutions, and infrastructure networks. From this perspective, the effectiveness of digital finance in promoting REC depends on the strength of Nigeria's institutional linkages and innovation capacity, implying that its impact may differ from that observed in more technologically advanced economies (Nwani&Okere, 2023).

Third, the Stern Review (2007) provides the climate-economic rationale by highlighting the market failures associated with fossil fuel dependence. By reducing the private costs of renewable energy adoption, digital finance can help address financing barriers and accelerate a socially optimal transition toward cleaner energy systems. Together, these perspectives generate two testable mechanisms: digital finance promotes REC by expanding access to credit (loan scale channel) and by improving household financial capacity (income channel).

Literature Review

The literature on renewable energy consumption (REC) in developing economies has expanded considerably, highlighting the interaction of economic, institutional, social, and financial factors that shape energy transition pathways. A key strand examines the relationship between economic growth and renewable energy adoption, showing that rising income levels increase both the capacity to finance renewable investments and the demand for cleaner energy services (Li & Leung, 2021; Wang & Wang, 2020). In Nigeria, Rafindadi (2016a) established that energy consumption contributes significantly to economic growth, while Rafindadi and Mika'llu (2019) demonstrated that sustainable energy adoption is closely linked to long-term investment and capital formation dynamics. The environmental benefits of renewable energy are also well established, as increased renewable adoption reduces fossil fuel dependence and carbon emissions, with important implications for Nigeria given the economic costs associated with environmental degradation (Rafindadi, 2016b; Abdulkareem et al., 2023).

Beyond economic factors, recent studies emphasize the importance of social and institutional conditions in determining renewable energy outcomes. Uzar (2020a) found that income inequality constrains renewable energy consumption by limiting access to clean energy technologies among vulnerable groups, while Yao et al. (2019) showed that human capital enhances renewable energy adoption by improving technological awareness and utilisation capacity. Similarly, Churchill et al. (2021) argued that successful renewable energy expansion requires simultaneous attention to financial, social, and institutional constraints. This perspective is particularly relevant for Nigeria, where energy poverty and socioeconomic exclusion remain significant barriers to clean energy access (Ogwumike&Ozughalu, 2015; Abdulkareem et al., 2023). Institutional quality also plays a

critical role: stronger governance and regulatory frameworks reduce investment uncertainty and encourage private renewable energy investment (Uzar, 2020b). Although some studies suggest that rising carbon emissions can stimulate renewable energy adoption through policy responses (Nguyen & Kakinaka, 2019), this mechanism may be limited in Nigeria due to weak carbon pricing and environmental regulation frameworks (Khan et al., 2020).

A substantial body of research has examined the role of financial development in supporting renewable energy transitions. Based on financial intermediation theory (Levine, 2005), developed financial systems facilitate renewable energy investment by mobilising savings, improving capital allocation, reducing financing constraints, and managing investment risks. Empirical evidence generally supports this relationship. Anton and AfoareiNucu (2020), using cross-country data, showed that banking sector development, stock market activity, and bond market expansion promote renewable energy investment. Ji and Zhang (2019) found that financial development accounted for a significant share of renewable energy growth in China. Similarly, Asongu and Odhiambo (2021) and Olanrewaju et al. (2019) demonstrated that financial inclusion and access to finance enhance renewable energy adoption by expanding investment opportunities.

Evidence from Nigeria further confirms the importance of financial conditions in shaping energy outcomes. Akintande et al. (2020), using an ARDL framework, found that financial development, particularly private sector credit, significantly increases renewable energy consumption in the long run. Nwani and Okere (2023) showed that green finance instruments support renewable energy adoption across sub-Saharan Africa, with Nigeria displaying strong responsiveness. Akinlo (2009) highlighted the central role of financial sector conditions in Nigeria's energy-growth relationship, while Akintande et al. (2020) identified financial development, trade openness, and urbanisation as important drivers of renewable energy consumption in major African economies. Collectively, these studies establish that financial conditions are fundamental determinants of renewable energy outcomes. However, they primarily focus on conventional financial indicators, leaving the role of digitally enabled financial innovations insufficiently explored.

Digital finance represents a distinct evolution of financial development by expanding access, reducing transaction costs, and enabling financial services through mobile and internet-based platforms. Unlike traditional finance, which often excludes low-income households and small enterprises due to collateral and geographical barriers, digital finance provides more inclusive access to payments, savings, credit, and investment services (Aziz & Naima, 2021; Arner et al., 2020). In Nigeria, digital financial inclusion has expanded through increased mobile penetration, internet connectivity, and fintech innovation, generating positive effects on financial access, savings mobilisation, and economic participation (Ozili, 2018). Jimoh et al. (2023) further argued that digital finance provides a mechanism for overcoming structural limitations created by informal economic activity and limited access to formal financial institutions in sub-Saharan Africa.

Emerging research suggests that digital finance can also influence renewable energy consumption through specific transmission mechanisms. Croutzet and Dabbous (2021) found that fintech development increases renewable energy consumption by improving financial efficiency and lowering capital constraints. Muganyi et al. (2021) demonstrated that the interaction between fintech and green finance promotes environmental sustainability, including clean energy adoption. More directly, Yu et al. (2022) showed that digital finance significantly increases renewable energy consumption in China, with loan availability and household income acting as key mediating channels. Similarly, Kara et al. (2021) highlighted the role of digital credit platforms and pay-as-you-go financing models in overcoming upfront renewable energy investment barriers, while Song et al. (2020) showed that digital savings platforms improve household capacity to invest in productive activities, including renewable energy technologies.

Despite these advances, three important gaps remain. First, the digital finance-renewable energy consumption nexus has not been empirically examined in Nigeria, despite the country's large renewable energy potential and rapidly expanding fintech ecosystem. Second, existing studies provide limited evidence on the mechanisms through which digital finance affects renewable energy adoption, particularly the roles of credit expansion and household income. Third, Nigeria-specific energy studies have largely relied on conventional financial indicators and methodologies that may not capture the structural and temporal dynamics of the emerging digital finance–energy relationship. This study addresses these gaps by providing a time-series analysis of the impact of digital finance on renewable energy consumption in Nigeria, while explicitly examining the mediating roles of loan scale and household income within an ARDL framework.

It is worth noting that the mediation design adopted here, using loan scale and household income as transmission channels, closely parallels that of Yu et al. (2022) in China. The present study departs from that work primarily in institutional context rather than mediator choice: Nigeria's financial system is characterised by substantially lower banking penetration, a large informal economy, and a digital finance ecosystem still consolidating around mobile money rather than app-based banking, conditions that plausibly alter both the strength and the relative weight of the credit and income channels identified in China's more mature financial system. Testing the same mediation framework in this structurally different setting therefore extends, rather than merely replicates, the evidence base on how digital finance shapes renewable energy outcomes.

Methodology

Given the potential for mixed orders of integration among Nigerian macroeconomic variables, this study adopts the ARDL bounds testing approach developed by Pesaran et al. (2001). The method is appropriate because it accommodates a combination of $I(0)$ and $I(1)$ variables, performs effectively in small samples, and simultaneously estimates short-run adjustments and long-run equilibrium relationships.

Stationarity properties are examined using the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1981), Phillips-Perron (PP) test (Phillips & Perron, 1988), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992). To account for potential structural changes associated with Nigeria's 2015-2016 recession and exchange rate depreciation, the Zivot-Andrews (1992) one-break unit root test is also employed. Optimal lag lengths are selected using the Akaike Information Criterion (AIC), which performs well in small samples (Ng & Perron, 2001).

The baseline ARDL specification is expressed as:

$$\ln REC_t = \beta_0 + \beta_1 \ln DF_t + \beta_2 \ln PGDP_t + \beta_3 \ln TP_t + \beta_4 \ln CO_{2t} + \varepsilon_t \dots \dots 1$$

where β_1 - β_4 are long-run elasticity coefficients and ε_t is the stochastic error term.

To empirically investigate the digital finance-renewable energy consumption nexus and identify the transmission channels through which this relationship operates, three sequential model specifications are estimated following the Baron and Kenny (1986) mediation framework as adapted for the ARDL time-series setting.

Model 1: Total-Effect Model (Baseline ARDL)

The baseline ARDL specification estimates the total effect of digital finance on renewable energy consumption, controlling for economic growth, technological progress, and CO₂ emissions:

$$\ln REC_t = B_0 + B_1 \ln DF_t + B_2 \ln PGDP_t + B_3 \ln TP_t + B_4 \ln CO_{2t} + e_t \quad (2)$$

The corresponding short-run ARDL error correction model (ECM) is expressed as:

$$\Delta \ln REC_t = a_0 + \sum_i a_i \Delta \ln REC_{t-i} + \sum_j d_j \Delta \ln DF_{t-j} + \sum_k f_k \Delta X_{t-k} + \lambda ECM_{t-1} + u_t \quad (3)$$

where $\ln REC$ is the natural log of per capita renewable energy consumption; $\ln DF$ is the natural log of the composite digital finance index; $\ln PGDP$, $\ln TP$, and $\ln CO_2$ are the natural logs of per capita GDP, technological progress, and CO₂ emissions respectively; B_0 is the constant; B_1 - B_4 are the long-run elasticity coefficients; e_t is the stochastic error term; X_t is the vector of control variables; λ is the speed-of-adjustment coefficient (expected to be negative and significant); ECM_{t-1} is the lagged error correction term derived from the long-run relationship; and u_t is the white-noise disturbance.

Model 2: Mediator Model

To test the first condition of mediation that digital finance significantly determines each mediating variable, each mediator is regressed on digital finance and the control variables:

$$\ln MED_t = g_0 + g_1 \ln DF_t + g_2 \ln PGDP_t + g_3 \ln TP_t + g_4 \ln CO_{2t} + v_t \quad (4)$$

where $\ln MED$ denotes either $\ln LOAN$ (per capita loan scale) or $\ln INCOME$ (per capita household income), estimated in two separate regressions; g_1 is the key coefficient capturing the effect of digital finance on the mediating variable; and v_t is the error term. A positive and statistically significant g_1 satisfies the first necessary condition for mediation.

Model 3: Direct-Effect Model (Mediation Model)

The mediating variable is introduced alongside digital finance in the REC equation to decompose the total digital finance effect into direct and indirect components:

$$\ln REC_t = q_0 + q_1 \ln DF_t + q_2 \ln MED_t + q_3 \ln PGDP_t + q_4 \ln TP_t + q_5 \ln CO_{2t} + w_t \quad (5)$$

where q_1 represents the direct effect of digital finance on REC after controlling for the mediating variable, q_2 captures the independent effect of the mediator on REC, and w_t is the error term. Partial mediation is established when $q_1 < \beta_1$, indicating that the direct effect is smaller than the total effect, and the indirect effect ($g_1 \times q_2$) is statistically significant based on the Sobel (1982) test. Model 3 is estimated separately for each mediator, loan scale (LOAN) and household income (INCOME) to quantify their respective contributions to the digital finance-REC relationship.

Short-run dynamics and adjustment toward long-run equilibrium are captured through the error correction model (ECM). A negative and statistically significant coefficient on $ECM(-1)$ confirms the existence of a stable long-run cointegrating relationship. To examine transmission mechanisms, the study follows the mediation approach of Baron and Kenny (1986), adapted to the ARDL time-series framework. Three sequential models are estimated: (i) a total-effect model assessing the impact of digital finance on REC; (ii) a mediator model examining the effect of digital finance on each transmission variable; and (iii) a direct-effect model incorporating the mediator into the REC equation alongside digital finance and control variables. Post-estimation validity is assessed using the Breusch-Godfrey LM test for serial correlation, ARCH test for heteroscedasticity, Ramsey RESET test for model specification, and CUSUM and CUSUM-of-squares tests for parameter stability. The primary explanatory variable is digital finance (DF). Since Nigeria lacks an official national digital finance index, this study constructs a composite index using principal component analysis (PCA) based on three indicators: mobile money transaction value as a share of GDP, active mobile money agents per 100,000 adults, and internet banking transaction value as a proportion of total banking transactions. These indicators capture the accessibility, penetration, and intensity of digital financial services and are obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin, Enhancing Financial Innovation and Access (EFInA) surveys, and CBN annual reports (EFInA, 2021; CBN, 2023; Ozili, 2018). Following Yu et al. (2022), payment and credit sub-indices are also constructed to examine dimension-specific effects.

Data Sources and Measurement

The study employs annual secondary data for Nigeria from 2009 to 2022, with the period selected to coincide with the emergence of Nigeria's formal digital finance ecosystem following the Central Bank of Nigeria's 2009 mobile money guidelines. To increase observations for ARDL estimation, annual data are converted into 56 quarterly observations using quadratic interpolation, consistent with previous Nigerian energy-finance studies (Rafindadi & Mika'llu, 2019). Because interpolation smooths values between

the fourteen genuinely observed annual data points rather than introducing new independent information, the effective information content of the resulting series remains close to that of the original annual data. To avoid overstating the precision implied by treating the interpolated series as fifty-six independent observations, HAC-robust (Newey-West) standard errors are used throughout the estimation, and reported significance levels should accordingly be interpreted with reference to the underlying annual information content of the series rather than to the nominal quarterly sample size. This limitation, and its implications for the confidence that can be placed in the standard errors reported in Tables 4-6, is revisited in the Discussion and Conclusion. As the study relies exclusively on secondary institutional and macroeconomic data and does not involve human subjects, ethics/IRB approval was not required.

Data are obtained from established national and international sources. Renewable energy consumption data are sourced from the Nigerian Electricity Regulatory Commission (NERC) reports and supplemented by the International Energy Agency (IEA) Africa Energy Outlook (2022). The digital finance index is constructed from indicators obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin, CBN Annual Reports, and Enhancing Financial Innovation and Access (EFInA) surveys. GDP per capita data are obtained from the World Bank World Development Indicators (WDI), while technological progress, measured by patent applications, is sourced from the World Intellectual Property Organization (WIPO) and WDI databases. Carbon emissions data are obtained from the Emissions Database for Global Atmospheric Research (EDGAR) and cross-validated with WDI. Loan scale and household income data are obtained from the CBN Statistical Bulletin and the National Bureau of Statistics (NBS), respectively.

All monetary variables are converted into constant prices using the GDP deflator to eliminate inflationary effects. The digital finance index is constructed using principal component analysis (PCA) based on three underlying indicators and standardised to a common scale. Renewable energy consumption is measured in kilowatt-hours per capita, while carbon emissions are measured in million metric tonnes. All variables are transformed into natural logarithms to facilitate elasticity interpretation and reduce heteroscedasticity concerns.

Results

Descriptive statistics are presented in Table 1, and a pairwise correlation matrix in Table 2 confirms the absence of problematic multicollinearity among regressors (all pairwise correlations below 0.80; mean variance inflation factor = 1.47).

Table 1. Summary Statistics

Variables	Description	Mean	SD	Min	Max
REC	Per capita renewable electricity consumption (kWh)	312.44	285.17	38.20	941.33
DF	Digital finance index (composite)	42.18	19.63	8.54	89.47
PGDP	Per capita GDP (constant 2015 USD)	2,184.51	312.88	1,780.24	2,753.60
TP	Number of patent applications	312.17	188.44	54.00	781.00
CO ₂	Total CO ₂ emissions (Mt)	418.67	112.33	210.44	621.55
LOAN	Per capita commercial bank loans (NGN '000)	84,312.44	32,188.77	21,450.00	156,340.00
INCOME	Per capita disposable income (NGN '000)	312,441.00	88,172.33	178,210.00	548,330.00

Source: Author's Computation (2026). *Note: The digital finance index (DF) is a composite constructed using principal component analysis; values are normalised index scores. All monetary variables are expressed in constant terms.*

The descriptive statistics in Table 1 show considerable variation across the variables during the study period. Per capita renewable energy consumption (REC) records a mean value of 312.44 kWh, ranging from 38.20 to 941.33 kWh, indicating significant fluctuations in Nigeria's renewable energy adoption between 2009 and 2022. The digital finance index (DF) has an average value of 42.18 and a standard deviation of 19.63, reflecting the rapid expansion of digital financial services from relatively low levels at the beginning of the sample period. Per capita GDP (PGDP) averages USD 2,184.51 in constant 2015 prices, while CO₂ emissions average 418.67 metric tonnes. The mediating variables also display substantial variability, with per capita commercial bank loans (LOAN) ranging from NGN 21,450 to NGN 156,340 thousand and per capita disposable income (INCOME) ranging from NGN 178,210 to NGN 548,330 thousand, highlighting Nigeria's uneven patterns of financial deepening and income growth over the period.

Table 2. Multicollinearity Analysis of Independent Variables

	lnREC	lnDF	lnPGDP	lnTP	lnCO ₂	lnINCOME
lnREC	1.0000					
lnDF	0.4312	1.0000				
lnPGDP	0.2841	0.5218	1.0000			
lnTP	0.1977	0.4433	0.6312	1.0000		
lnCO ₂	0.1544	0.0721	0.1033	0.5291	1.0000	
lnINCOME	0.3819	0.5874	0.7241	0.4812	0.1120	1.0000

Source: Author's Computation (2026)

The pairwise correlation matrix in Table 2 indicates that multicollinearity is not a concern, as all correlation coefficients remain below the conventional threshold of 0.80 and the mean variance inflation factor (VIF) is 1.47. The digital finance index (lnDF) shows a moderate positive correlation with per capita renewable energy consumption (lnREC) ($r = 0.4312$), offering preliminary support for the expected positive relationship between digital finance and renewable energy adoption. Among the control variables, per capita GDP (lnPGDP) and household income (lnINCOME) exhibit stronger correlations with lnDF ($r = 0.5218$ and 0.5874 , respectively), suggesting that economic growth and income improvements have accompanied the expansion of digital financial services in Nigeria. Conversely, the weak association between CO₂ emissions and most explanatory variables, particularly lnREC ($r \leq 0.15$), provides initial evidence that carbon emissions may have limited influence on renewable energy adoption within Nigeria's current policy and institutional framework.

Table 3. ARDL Bounds Test for Cointegration

Test	F-statistic	Critical value bounds (5%)	Decision
F-bounds test	6.847***	I(0) = 2.62, I(1) = 3.79	Cointegration confirmed
t-bounds test	-3.914**	I(0) = -2.86, I(1) = -3.53	Cointegration confirmed

Source: Author's Computation (2026). *Notes:* ***, ** and * denote significance at the 1%, 5%, and 10% levels, respectively. Critical value bounds are from Pesaran et al. (2001), Case III (unrestricted intercept, no trend).

Table 3 presents the ARDL bounds test results. The estimated F-statistic of 6.847 exceeds the 5% upper critical bound of 3.79 based on Pesaran et al. (2001) Case III, while the corresponding t-statistic test also confirms the presence of cointegration. These findings establish a stable long-run equilibrium relationship among digital finance, economic growth, technological progress, CO₂ emissions, and renewable energy consumption in Nigeria, supporting the estimation of the ARDL long-run and error correction models.

The unit root results further validate the suitability of the ARDL approach by confirming mixed orders of integration among the variables. The ADF, PP, and KPSS tests indicate that lnREC, lnPGDP, lnTP, and lnCO₂ are integrated of order one, I(1), while lnDF, lnLOAN, and lnINCOME exhibit stationarity at levels, I(0), under at least one specification. The Zivot-Andrew's test identifies structural breaks around 2015-2016, coinciding with Nigeria's economic recession and substantial naira depreciation, highlighting the importance of accounting for structural shifts in macroeconomic series. The coexistence of I(0) and I(1) variables confirms the appropriateness of the ARDL bounds testing framework and rules out conventional Johansen cointegration techniques, which require all variables to share the same order of integration.

Table 4. ARDL Long-Run and Short-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	p-value
Panel A: Long-run estimates				
lnDF	0.8431***	0.1872	4.5036	0.000
lnPGDP	2.1174***	0.5443	3.8894	0.001
lnTP	0.6312***	0.2118	2.9802	0.007
lnCO ₂	0.3144	0.2871	1.0951	0.284
Constant	-18.4421***	4.2311	-4.3585	0.000
Panel B: Short-run estimates				
ΔlnDF	0.5218***	0.1441	3.6211	0.001
ΔlnPGDP	1.4432**	0.6217	2.3213	0.029
ΔlnTP	0.4411**	0.1982	2.2254	0.036
ΔlnCO ₂	0.2011	0.2543	0.7910	0.437
ECM(-1)	-0.5873***	0.1024	-5.7354	0.000
R ²	0.8821			
Adj. R ²	0.8544			
F-statistic	31.77***			
DW statistic	2.043			

Source: Author's Computation (2026). Notes: ***, ** and * denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses. Diagnostic results: Breusch–Godfrey LM test for serial correlation ($p = 0.312$); ARCH test ($p = 0.418$); Ramsey RESET test ($p = 0.287$); CUSUM and CUSUM-of-squares tests confirm parameter stability at the 5% significance level throughout the sample period.

Table 4 presents the baseline ARDL estimation results. The post-estimation diagnostics confirm the robustness of the model specification. The Breusch-Godfrey LM test indicates no evidence of serial correlation ($p = 0.312$), the ARCH test confirms the absence of conditional heteroscedasticity ($p = 0.418$), and the Ramsey RESET test suggests no functional form misspecification ($p = 0.287$). Furthermore, the CUSUM and CUSUM-of-squares tests confirm parameter stability throughout the sample period at the 5% significance level.

The long-run results show that digital finance (lnDF) has a positive and statistically significant effect on renewable energy consumption (REC) at the 1% level ($\beta = 0.8431$, $SE = 0.1872$). Specifically, a 1% increase in the digital finance index increases per capita REC by approximately 0.84%, holding other factors constant. This finding extends evidence from China (Yu et al., 2022), OECD economies (Croutzet&Dabbous, 2021), and sub-Saharan Africa (Nwani&Okere, 2023) to Nigeria, supporting Schumpeter's (1934) proposition that financial innovation facilitates productive investments by overcoming conventional financing constraints. In the short run, the coefficient of Δ lnDF is also positive and significant at the 1% level ($\beta = 0.5218$), although smaller in magnitude, suggesting that the

effect of digital finance on renewable energy adoption strengthens over time as households and firms convert improved financial access into renewable energy investments. The error correction coefficient (ECM (-1)) is negative and highly significant ($\beta = -0.5873$, $p < 0.001$), indicating that approximately 59% of short-run deviations from long-run equilibrium are corrected within one period.

Economic growth ($\ln PGDP$) exerts a strong positive influence on REC in both the long run ($\beta = 2.1174$, $p < 0.001$) and short run ($\beta = 1.4432$, $p < 0.05$), consistent with evidence that rising income levels enhance demand for cleaner and more reliable energy services (Li & Leung, 2021; Wang & Wang, 2020). Technological progress ($\ln TP$) also contributes positively to renewable energy adoption, with significant coefficients in both the long run ($\beta = 0.6312$, $p < 0.01$) and short run ($\beta = 0.4411$, $p < 0.05$), highlighting the importance of innovation capacity in supporting Nigeria's energy transition.

Conversely, CO_2 emissions ($\ln CO_2$) have a positive but statistically insignificant effect on REC in both periods (long run: $\beta = 0.3144$, $p = 0.284$). This suggests that environmental pressure alone has not generated sufficient incentives for renewable energy expansion in Nigeria, likely due to weak carbon pricing mechanisms and limited enforcement of environmental regulations. The finding aligns with evidence from emerging economies where carbon intensity does not necessarily translate into stronger renewable energy adoption without effective policy frameworks (Khan et al., 2020; Yu et al., 2022).

Table 5. Mediation Effects: Loan Scale and Income Level

Variable	$\ln REC$	$\ln LOAN$	$\ln REC$	$\ln REC$	$\ln INCOME$	$\ln REC$
$\ln DF$	0.8431*** (0.1872)	0.1241*** (0.0318)	0.6812*** (0.1741)	0.8431*** (0.1872)	0.1618*** (0.0214)	0.6744*** (0.1933)
$\ln LOAN$	—	—	1.9811*** (0.4412)	—	—	—
$\ln INCOME$	—	—	—	—	—	1.7233* (0.9014)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	56	56	56	56	56	56
R ²	0.8821	0.9012	0.8944	0.8821	0.9188	0.8877
Indirect effect	0.2461***			0.2787*		
Sobel test (%)	19.84%			20.31%		

Source: Author's Computation (2026). Notes: ***, ** and * denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses. Controls include $\ln PGDP$, $\ln TP$, and $\ln CO_2$ in all specifications. $N = 56$ quarterly observations. Indirect effects are computed as the product of the relevant coefficients ($\alpha_1 \times \lambda_2$) and tested using the Sobel (1982) test. Sobel test values indicate the percentage share of the total digital finance effect on REC operating through each mediation channel.

Table 5 presents the mediation analysis results, examining the mechanisms through which digital finance influences renewable energy consumption (REC). For the loan scale channel, digital finance has a positive and significant effect on credit availability ($\alpha_1 = 0.1241$, $p < 0.001$), indicating that digital financial expansion increases credit flows within the Nigerian economy. When loan scale is introduced as a mediator, the direct effect of digital finance on REC decreases from 0.8431 to 0.6812, while the coefficient of $\ln\text{LOAN}$ remains positive and significant ($\lambda_2 = 1.9811$, $p < 0.001$). The Sobel (1982) test confirms a significant indirect effect, showing that the credit expansion channel accounts for approximately 19.84% of the total effect of digital finance on REC. This finding supports Schumpeter's (1934) argument that credit creation is a key pathway through which financial innovation facilitates productive investment and technological adoption.

For the income channel, digital finance also has a positive and significant effect on household income ($\alpha_1 = 0.1618$, $p < 0.001$), consistent with evidence that digital financial services enhance income generation through improved financial access and economic participation (Li et al., 2020; Song et al., 2020). After including income as a mediator, the direct effect of digital finance declines to 0.6744, while the coefficient on $\ln\text{INCOME}$ is positive and marginally significant ($\lambda_2 = 1.7233$, $p = 0.07$). The Sobel test confirms a significant indirect effect, with household income explaining approximately 20.31% of the total digital finance effect on REC.

Together, the two mediating pathways jointly account for about 40% of the total effect, indicating that credit expansion and income enhancement are important transmission mechanisms linking digital finance to renewable energy adoption. The remaining effect is likely driven by other channels, including improved information access, reduced transaction costs, digital payment infrastructure, and emerging digital insurance services, consistent with the broader innovation ecosystem perspective of Lundvall's (1992) National Innovation Systems framework.

Table 6. Robustness Tests: Solar Energy Consumption as Dependent Variable

Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\ln\text{DF_overall}$	0.7241*** (0.1932)	—	—	—	—	—
$\ln\text{DF_breadth}$	—	0.6118*** (0.1744)	—	—	—	—
$\ln\text{DF_depth}$	—	—	0.5412** (0.2113)	—	—	—
$\ln\text{DF_payment}$	—	—	—	0.4318** (0.1981)	—	—
$\ln\text{DF_credit}$	—	—	—	—	0.5874*** (0.1812)	—
$\ln\text{DF_insurance}$	—	—	—	—	—	0.0312 (0.1441)
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Variable	(1)	(2)	(3)	(4)	(5)	(6)
N	56	56	56	56	56	56
R ²	0.8441	0.8318	0.8212	0.8119	0.8377	0.8044

Source: Author's Computation (2026). Notes: ***, ** and * denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses. Controls ($\ln$ PGDP, $\ln$ TP, and $\ln$ CO₂) are included in all specifications. HAC-robust standard errors are applied throughout. N = 56 observations.

Robustness tests using solar energy consumption as an alternative measure of renewable energy consumption (REC) confirm the main findings across all six specifications reported in Table 6. The composite digital finance index produces a coefficient of 0.7241 ($p < 0.001$), while the breadth sub-index yields the largest and most significant coefficient (0.6118, $p < 0.001$), followed closely by credit sub-index (0.5874, $p < 0.001$) among the dimension-specific measures, and the payment sub-index achieves significance at the 5% level. In contrast, the digital insurance sub-index remains positive but statistically insignificant, consistent with the baseline results. These findings demonstrate that the relationship between digital finance and renewable energy adoption is robust to alternative dependent variable specifications and index construction approaches, strengthening confidence in the conclusion that digital financial development contributes to Nigeria's renewable energy transition.

Conclusion and Recommendation

This study examined the relationship between digital finance and renewable energy consumption (REC) in Nigeria from 2009 to 2022, addressing the intersection between rapid financial digitalisation and the country's need to accelerate its energy transition. Using the ARDL bounds testing approach and nationally sourced institutional data, the study provides robust evidence that digital finance significantly promotes REC in both the short and long run. The estimated long-run elasticity indicates that a 1% increase in the digital finance index increases per capita REC by approximately 0.84%. This relationship remains robust across alternative measures of renewable energy consumption and different dimensions of digital finance.

The mediation analysis identifies loan expansion and household income as important transmission channels, jointly accounting for approximately 40% of the total effect of digital finance on REC. The remaining effect reflects additional pathways, including improved payment infrastructure, information accessibility, and digital financial services that reduce transaction barriers, consistent with the National Innovation Systems perspective (Lundvall, 1992). Notably, the credit dimension of digital finance exhibits the strongest individual effect, highlighting the importance of expanding renewable energy financing mechanisms.

The findings extend existing evidence from China (Yu et al., 2022) and OECD economies (Croutzet&Dabbous, 2021) to Nigeria, a developing economy characterised by significant energy poverty, financial exclusion, and renewable energy potential. They also support the theoretical arguments of Schumpeter's (1934) financial innovation theory, Lundvall's (1992) innovation systems framework, and the Stern Review's (2007) climate-economic rationale. The positive effects of economic growth and technological progress further demonstrate that renewable energy adoption is closely linked to broader development dynamics, while the insignificant effect of CO₂ emissions reflects Nigeria's limited carbon pricing and regulatory framework.

The results provide several policy implications. First, digital financial infrastructure should be explicitly incorporated into Nigeria's renewable energy transition strategy. Although the country has made progress in digital financial inclusion, fintech development has not been sufficiently aligned with clean energy objectives. Integrating renewable energy financing targets into national financial inclusion policies could enable existing digital platforms to support energy access goals. Policymakers should encourage innovative financing models, including pay-as-you-go solar schemes, green digital finance products, and digital insurance solutions that reduce investment risks for households and small enterprises.

Second, the income mediation effect highlights the importance of expanding digital financial services that enhance household economic capacity. Policies supporting digital microenterprise finance, affordable savings platforms, and efficient digital remittance systems can indirectly promote renewable energy adoption by increasing households' ability to invest in clean energy technologies. The positive role of economic growth further suggests that renewable energy development should be treated as part of Nigeria's broader economic transformation strategy rather than solely as an environmental objective. Similarly, the contribution of technological progress underscores the need for greater investment in renewable energy research, local innovation capacity, and technology transfer mechanisms.

The implications extend beyond Nigeria, as many sub-Saharan African economies share similar characteristics: large informal sectors, rapidly expanding digital payment ecosystems, and significant untapped renewable energy resources. Nigeria's experience therefore provides useful evidence for policymakers seeking to leverage digital finance as a tool for sustainable energy development.

Several limitations should be acknowledged. First, the digital finance index is constructed from aggregate institutional indicators due to the absence of an official national index, which may introduce measurement limitations and potentially underestimate the true relationship. Second, the relatively short sample period, expanded from 14 annual observations to 56 quarterly observations, may constrain estimation precision. Future research should develop more granular, higher-frequency digital finance measures, investigate additional mechanisms such as financing cost reduction, and extend the analysis to broader panels of African economies. Subnational studies within Nigeria would

also provide valuable insights into regional differences in digital finance penetration and renewable energy potential.

References

- Abdulkareem, H. K. K., Jimoh, S. O., & Shasi, O. M. (2023). Socioeconomic development and sustainable development in Nigeria: The roles of poverty reduction and social inclusion. *Journal of Business and Socio-economic Development*, 3(3), 265–278. <https://doi.org/10.1108/JBSED-10-2021-0137>
- Akinlo, A. E. (2009). Electricity consumption and economic growth in Nigeria: Evidence from cointegration and co-feature analysis. *Journal of Policy Modeling*, 31(5), 681–693. <https://doi.org/10.1016/j.jpolmod.2009.03.004>
- Akintande, O. J., Olubusoye, O. E., Adenikinju, A. F., & Olanrewaju, B. T. (2020). Modeling the determinants of renewable energy consumption: Evidence from the five most populous nations in Africa. *Energy*, 206, 117992. <https://doi.org/10.1016/j.energy.2020.117992>
- Anton, S. G., & AfoareiNucu, A. E. (2020). The effect of financial development on renewable energy consumption: A panel data approach. *Renewable Energy*, 147, 330–338. <https://doi.org/10.1016/j.renene.2019.09.005>
- Arner, D. W., Buckley, R. P., Zetzsche, D. A., & Veidt, R. (2020). Sustainability, FinTech and financial inclusion. *European Business Organization Law Review*, 21, 7–35. <https://doi.org/10.1007/s40804-020-00183-y>
- Asongu, S. A., & Odhiambo, N. M. (2021). Inequality, finance and renewable energy consumption in Sub-Saharan Africa. *Renewable Energy*, 165, 678–688. <https://doi.org/10.1016/j.renene.2020.11.062>
- Aziz, A., & Naima, U. (2021). Rethinking digital financial inclusion: Evidence from Bangladesh. *Technology in Society*, 64, 101509. <https://doi.org/10.1016/j.techsoc.2020.101509>
- Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173–1182. <https://doi.org/10.1037/0022-3514.51.6.1173>
- Burke, M. J., & Stephens, J. C. (2018). Political power and renewable energy futures: A critical review. *Energy Research and Social Science*, 35, 78–93. <https://doi.org/10.1016/j.erss.2017.10.018>
- Central Bank of Nigeria. (2023). *Annual Report 2022*. CBN.
- Churchill, S. A., Ivanovski, K., & Munyanyi, M. E. (2021). Income inequality and renewable energy consumption: Time-varying nonparametric evidence. *Journal of Cleaner Production*, 296, 126306. <https://doi.org/10.1016/j.jclepro.2021.126306>
- Croutzet, A., & Dabbous, A. (2021). Do FinTech trigger renewable energy use? Evidence from OECD countries. *Renewable Energy*, 179, 1608–1617. <https://doi.org/10.1016/j.renene.2021.07.144>
- Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), 1057–1072. <https://doi.org/10.2307/1912517>
- EFInA. (2021). *Access to Financial Services in Nigeria 2021 Survey*. Enhancing Financial Innovation and Access.
- Fuso Nerini, F., et al. (2018). Mapping synergies and trade-offs between energy and the sustainable development goals. *Nature Energy*, 3, 10–15. <https://doi.org/10.1038/s41560-017-0036-5>
- Gomber, P., Koch, J., & Siering, M. (2017). Digital finance and FinTech: Current research and future research directions. *Journal of Business Economics*, 87, 537–580. <https://doi.org/10.1007/s11573-017-0852-x>
- 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>
- International Energy Agency. (2022). *Africa Energy Outlook 2022*. IEA.

- Ji, Q., & Zhang, D. (2019). How much does financial development contribute to renewable energy growth and upgrading of energy structure in China? *Energy Policy*, 128, 114–124. <https://doi.org/10.1016/j.enpol.2018.12.047>
- Jimoh, S. O., Akande, R. S., Abdulkareem, H. K. K., Jimoh, O. B., Sulaimon, T. T., Yusuf, Y. T., Adegboye, I., & Usman, A. M. (2023). Informal sector and financial development in sub-Saharan Africa. *International Journal of Economics, Management and Accounting*, 31(2), 325–342. <https://doi.org/10.31436/ijema.v31i2.1064>
- Kara, A., Zhou, H., & Zhou, Y. (2021). Achieving the United Nations' sustainable development goals through financial inclusion. *International Review of Financial Analysis*, 77, 101833. <https://doi.org/10.1016/j.irfa.2021.101833>
- Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*, 54(1–3), 159–178. [https://doi.org/10.1016/0304-4076\(92\)90104-Y](https://doi.org/10.1016/0304-4076(92)90104-Y)
- Khan, H., Khan, I., & Binh, T. T. (2020). The heterogeneity of renewable energy consumption, carbon emission and financial development in the globe: A panel quantile regression approach. *Energy Reports*, 6, 859–867. <https://doi.org/10.1016/j.egyr.2020.04.002>
- Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of Economic Growth* (pp. 865–934). Elsevier.
- Li, J., Wu, Y., & Xiao, J. J. (2020). The impact of digital finance on household consumption: Evidence from China. *Economic Modelling*, 86, 317–326. <https://doi.org/10.1016/j.econmod.2019.09.027>
- Li, R., & Leung, G. C. K. (2021). The relationship between energy prices, economic growth and renewable energy consumption: Evidence from Europe. *Energy Reports*, 7, 1712–1719. <https://doi.org/10.1016/j.egyr.2021.03.030>
- Lundvall, B. A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter.
- Muganyi, T., Yan, L., & Sun, H. (2021). Green finance, fintech and environmental protection: Evidence from China. *Environmental Science and Ecotechnology*, 7, 100107. <https://doi.org/10.1016/j.ese.2021.100107>
- Ng, S., & Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power. *Econometrica*, 69(6), 1519–1554. <https://doi.org/10.1111/1468-0262.00256>
- Nguyen, K. H., & Kakinaka, M. (2019). Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis. *Renewable Energy*, 132, 1049–1057. <https://doi.org/10.1016/j.renene.2018.08.069>
- Nwani, C., & Okere, K. I. (2023). Does green finance spur renewable energy adoption in sub-Saharan Africa? *Environmental Science and Pollution Research*, 30, 19907–19924.
- Ogwumike, F. O., & Ozughalu, U. M. (2015). Analysis of energy poverty and its implications for sustainable development in Nigeria. *Environment and Development Economics*, 20(6), 1–18. <https://doi.org/10.1017/S1355770X15000236>
- Olanrewaju, B. T., Olubusoye, O. E., Adenikinju, A., & Akintande, O. J. (2019). A panel data analysis of renewable energy consumption in Africa. *Renewable Energy*, 140, 668–679. <https://doi.org/10.1016/j.renene.2019.02.061>
- Ozili, P. K. (2018). Impact of digital finance on financial inclusion and stability. *Borsa Istanbul Review*, 18, 329–340. <https://doi.org/10.1016/j.bir.2017.12.003>
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326. <https://doi.org/10.1002/jae.616>
- Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75(2), 335–346. <https://doi.org/10.1093/biomet/75.2.335>

- Qadir, S. A., Al-Motairi, H., Tahir, F., & Al-Fagih, L. (2021). Incentives and strategies for financing the renewable energy transition: A review. *Energy Reports*, 7, 3590–3606. <https://doi.org/10.1016/j.egyr.2021.06.041>
- Rafindadi, A. A. (2016a). Does the need for economic growth influence energy consumption and CO₂ emissions in Nigeria? Evidence from the innovation accounting test. *Renewable and Sustainable Energy Reviews*, 62, 1209–1225. <https://doi.org/10.1016/j.rser.2016.05.028>
- Rafindadi, A. A. (2016b). Revisiting the concept of environmental Kuznets curve in period of energy disaster and deteriorating income: Empirical evidence from Japan. *Energy Policy*, 94, 274–284. <https://doi.org/10.1016/j.enpol.2016.03.040>
- Rafindadi, A. A., & Mika'llu, A. S. (2019). Sustainable energy consumption and capital formation: Empirical evidence from the developed financial market of the United Kingdom. *Sustainable Energy Technologies and Assessments*, 35, 265–277. <https://doi.org/10.1016/j.seta.2019.07.007>
- Schumpeter, J. A. (1934). *The Theory of Economic Development*. Harvard University Press.
- Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. *Sociological Methodology*, 13, 290–312. <https://doi.org/10.2307/270723>
- Song, Q., Li, J., Wu, Y., & Yin, Z. (2020). Accessibility of financial services and household consumption in China: Evidence from micro data. *North American Journal of Economics and Finance*, 53, 101213. <https://doi.org/10.1016/j.najef.2020.101213>
- Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge University Press.
- Uzar, U. (2020a). Is income inequality a driver for renewable energy consumption? *Journal of Cleaner Production*, 255, 120287. <https://doi.org/10.1016/j.jclepro.2020.120287>
- Uzar, U. (2020b). Political economy of renewable energy: Does institutional quality make a difference? *Renewable Energy*, 155, 591–603. <https://doi.org/10.1016/j.renene.2020.03.172>
- Wang, Q., & Wang, L. (2020). Renewable energy consumption and economic growth in OECD countries: A nonlinear panel data analysis. *Energy*, 207, 118200. <https://doi.org/10.1016/j.energy.2020.118200>
- Yao, Y., Ivanovski, K., Inekwe, J., & Smyth, R. (2019). Human capital and energy consumption: Evidence from OECD countries. *Energy Economics*, 84, 104534. <https://doi.org/10.1016/j.eneco.2019.104534>
- Yu, M., Tsai, F. S., Jin, H., & Zhang, H. (2022). Digital finance and renewable energy consumption: Evidence from China. *Financial Innovation*, 8, 58. <https://doi.org/10.1186/s40854-022-00362-5>
- Zhao, P., Lu, Z., Fang, J., Paramati, S. R., & Jiang, K. (2020). Determinants of renewable and non-renewable energy demand in China. *Structural Change and Economic Dynamics*, 54, 202–209. <https://doi.org/10.1016/j.strueco.2020.05.002>
- Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business & Economic Statistics*, 10(3), 251–270. <https://doi.org/10.2307/1391541>