Journal of Regional Studies Review (JRSR)
Volume 4, Issue 4 (Fall 2025) | Pages: 146–157
ISSN (Online): 3006-6646
Digital Object Identifier (DOI): 10.62843/jrsr/2025.4d146
Correspondence should be addressed to Wasim Shahid Khawaja: wkhawaja@hotmail.com

RESEARCH ARTICLE

From GDP to Green Energy: Asymmetric Impacts of Environmental, Economic, and Energy on Pakistan's Per-Capita Energy Consumption

Wasim Shahid Khawaja [a] Azam Ali [b] Saleem Raza Bhatti [c] Muhammad Mubashir Khan [d]

Abstract: Developing economies demonstrate nonlinear responses in energy and environmental studies owing to challenges in development and day-to-day economic demands. This study employs asymmetric short- and long-run relationships among per capita energy consumption, energy intensity, open trade, renewable energy, and foreign investment for Pakistan for the period–1970-2023. Using the NARDL framework, regressors are divided into positive and negative observations to enable differential treatment of positive and negative shocks on the dependent variable, per capita energy consumption. The results indicate that energy intensity demonstrates symmetrical long-run effects with a coefficient of −2.05, reducing per-capita energy consumption and confirming the energy conservation hypothesis. Foreign investment inflows and outflows have asymmetric long-run effects. Renewable energy shows significant positive effects only in the short run, indicating that infrastructure development is in its earliest phase, where energy intensity initially increases before declining in later phases. Open trade shows no statistically significant short- or long-term effects. These findings demonstrate that nonlinear analysis approaches contradict the linear modeling methods currently employed. Policy recommendations are provided to address asymmetrical positive and negative economic responses, improve green energy transitions, and optimize FDI allocation for sustainable development in cleaner technologies.

Keywords: Asymmetrical Effects, NARDL, Green Energy, Foreign Investment

Introduction

Asymmetrical effects are the unequal effect of a variable when an increase or decrease in it causes unproportioned effects on the outcome. For example, an increase in causes a strong positive effect, but a decrease in causes weak effects or strong effects in the reverse direction (Ahmed et al., 2023; Mahapatra & Irfan, 2023). This can be seen in many field, such as sports (uneven human limb moments), economics (unproportioned returns on effort), and marketing.

Drivers are the key factors that cause these changes. World ecosystems and climate change are the most important environmental drivers (e.g., pollution and biodiversity loss). Economic indicators such as GDP, inflation, and employment rate are economic states on which available resources are utilized and policies are formed. Energy drivers are concerned with the available energy sources, costs, population, and economic growth. Policy considerations such as government regulations and organizational strategies guide actions for the energy use, environmental concerns, and production (Gershon et al., 2024).

The energy consumption per capita is the average energy used by a person per year. The recent figures for Pakistan are 0.4 tonnes of oil (toe), which is approximately 492 kilowatt-hours per capita in 2023

[a] HOD, Department of Business Administration. Emaan Institute of Management & Sciences, Karachi, Sindh, Pakistan.
[b] Dean, Emaan Institute of Management & Sciences, Karachi, Sindh, Pakistan.
[c] Sr. Lecturer, Department of Business Administration, Emaan Institute of Management & Sciences Karachi, Sindh, Pakistan.
[d] Lecturer, Department of Business Administration, Emaan Institute of Management & Sciences Karachi, Sindh, Pakistan.

Cite this Article: Khawaja, W. S., Ali, A., Bhatti, S. R., & Khan, M. M. (2025). From GDP to Green Energy: Asymmetric Impacts of Environmental, Economic, and Energy on Pakistan's Per-Capita Energy Consumption. *Journal of Regional Studies Review, 4*(4), 146-157. https://doi.org/10.62843/jrsr/2025.4d146

(Enerdata). This is among the lowest in the world and significantly lower than that of developing nations (Tang et al., 2024).

Current energy consumption models are based on linear models, which consider energy economics variables to have symmetrical effects on positive and negative shocks, which does not match the evidence from developing countries. These systems exhibit nonlinear behaviors, where positive changes have different effects than negative changes. The core issues in the energy use in these economies are the continued use of traditional sources, financial problems in the development of large environmentally friendly infrastructure, and the tendency to delay the adoption of newer technologies (Al Irsyad et al., 2017; Alam et al., 2024; Alam et al., 2025).

Pakistan is the best example of asymmetric energy demand behavior, a developing economy with high energy needs to develop its economy. As energy demand increases, the country faces the dual challenges of energy security, costs, and a sustainable path for environmental safety. Currently, its economy is heavily dependent on fossil fuels, despite the huge unexplored potential of renewable sources. Understanding how economic incentive and policy interventions can shape the energy use is essential for meeting energy availability and long term environment protection goals (Gershon et al., 2024; Tang et al., 2024).

Newer studies confirm asymmetrical behavior in developing energy economics. Warsame et al. (2024) emphasized that energy use has nonlinear behavior and employed non-linear ARDL in context of Somalia (Warsame et al., 2024). Ahmed et al. (2023) said that energy use and carbon emissions pattern vary across country to country (Ahmed et al., 2023). It is clear that linear models are too simple to capture the complex relationship between energy variables and driving forces (Ali et al., 2022; Mujtaba et al., 2022).

Expanding on the scholarship of nonlinear energy demand, this research examines per capita energy use in Pakistan from 1970 to 2023. The nonlinear autoregressive distributed lag (NARDL) model is used by the study, this method helps in decomposing the main drivers in to positive and negative shocks. This serves to differentiate between their respective influences. The effects are looked at both short-term and long-term. The emphasis on Pakistan provides conclusions that may also serve other developing economies that confront similar energy transition dilemmas.

Statement of Problem

The problem addressed in this study is that the current linear models do not explain the true dynamics of energy consumption in Pakistan, as they ignore the potential asymmetries of the drivers of per capita energy demand in terms of economic, environmental, and policy drivers. This generates a lack of knowledge in the distinction in positive and negative shocks for factors such as energy intensity, renewable energy, FDI, trade openness and the short and long-run relationships with energy use(Mujtaba et al., 2022; Rahaman et al., 2023), which impair policy homogeneity in energy transition in Pakistan.

Objective of the Study

The aim is to examine and quantify the asymmetric short- and long-run effects of key economic, environmental, energy and policy factors such as — energy intensity, trade openness, renewable energy share and FDI — on per capita energy consumption in Pakistan during the period 1970–2023, where advanced nonlinear econometric methods are applied to guide better context-dependent energy policy designs.

Literature Review

Theoretical Framework

Energy security is a complex issue which includes economic, political, institutional, legal and other aspects peculiar to every country or region. In the academic and policy literature, energy security most often refers to ensuring reliable access to various energy resources through methods such as diversification. In developing economies, energy consumption is driven by a complex interplay of variables that operate through intricate and often reciprocal adjustment mechanisms. Integrating long-standing theoretical perspectives with recent empirical findings, study distills four principal theoretical pathways by which the variables modulate energy demand(Bayramoglu & Yildirim, 2017; Zeraibi et al., 2024).

Economic Growth and Development Theory

According to traditional linear models, open trade brings economic prosperity with access to better technologies and energy supplies, but it also results in a higher use of energy. Mmbage et al (2024) reported short term connection between open trade and energy use in East Africa, confirming that energy consumption is affected by trade with developed nations (Alqaralleh & Hatemi-J, 2024; Ilyas et al. 2024; Mmbaga et al., 2024; Zaman et al.,2024; Zaman et al.,2025).

Energy Efficiency Theory

Both theoretical and empirical research suggest that sustainable practices can delink economic growth and energy consumption, achieved through better technologies and energy resource management. According to Ahmed et al.(2023), a reduction in energy intensity results in improved environmental quality across various developed nations, supporting the idea that efficiency gains can effectively reduce energy demand (Ahmed et al., 2023; Ali et al., 2022; Rahaman et al., 2023).

Renewable Energy Transition Theory

The gradual phasing in of renewable energy can have both positive and negative effects on the energy consumption of a country (Rahaman et al., 2023); While the initial energy consumption may increase for producing renewable supplies, which in return will benefit in lesser fossil fuel requirements and energy security (Markard & Rosenbloom, 2022). Urom et al (2022) found that renewable energy has asymmetric effects due to growth and globalization in G7 countries study (Urom et al., 2022; Ahmed et al., 2024; Ahmed et al., 2025).

Investment-Led Development Theory

This theory explains how foreign direct investment (FDI) is fundamental in increasing energy consumption through three interlinked processes. FDI improves infrastructure, introduces modern technologies, and expands economic sectors. According to Ullah et al. (2022), foreign investments lead to increased energ4y use by expanding industrial developments and better transportation systems in Belt and Road Initiative countries (Ullah et al., 2022).

Empirical Evidence

Nonlinear methods are gaining popularity in energy econometrics. Warsane et al. (2024) studied NARDL in the context of Somalia and stated that positive or negative shocks have a significant impact on the country's growth, with positive shocks providing higher results than negative shocks. These findings support nonlinear studies for computation of economy effect (Warsame et al., 2024).

Ahmed et al (2023) studied NARDL method for tri-country India, China and USA, for energy consumption and CO2 emission, found differences from country to country, and observed that direction and change intensity produced different results (Ahmed et al., 2023; Khan et al., 2024).

Sanli et al (2023) used NARDL methodology to study carbon emissions, using renewable and non-renewable energy as independent variables. They found that addition or reduction of different sources have difference effects on carbon emission, therefore highlighting the need devising the strategy accordingly(Şanlı et al., 2023).

Mmbaga et al. (2024) conducted Panel ARDL for East Africa on energy consumption for inflation, population, trade openness, and FDI, and found asymmetrical effects, calling for according changes in energy policy (Mmbaga et al., 2024).

Data and Methodology

Data Description

In this research we analyzed data from Pakistan 1970-2023 (54 Years), taken from WDI and our world in data(Ritchie et al., 2025; WDI, 2023). the independent variable is Energy use per person in KWh/capita, the features are energy intensity (EI), open trade (TRADE), percent of renewable share (REN) and foreign investments Table 1 provides the descriptive statistics of the study, which show that the variables have significant variations in series volatility. The log of FDI is the most dispersed (Std Dev = 1017), whereas the log of energy intensity is stable (Std Dev = 0.134). All variables had negative skewness, meaning that they tilted towards the left side. The Jarque-Bera test revealed that most variables were not normally distributed, requiring advanced time-series techniques (Thadewald & Büning, 2007) .

Table 1

Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
ln(ECPC)	7.927	8.031	8.401	7.250	0.344	-0.537	1.985	4.917	0.086
ln(EI)	-0.047	-0.014	0.154	-0.671	0.134	-2.026	9.802	141.068	0.000
ln(TRADE)	3.398	3.455	3.651	2.761	0.191	-1.372	4.857	24.711	0.000
ln(REN)	2.535	2.524	2.876	1.383	0.264	-1.473	7.715	69.537	0.000
ln(FDI)	-0.772	-0.584	1.110	-4.670	1.017	-1.213	6.044	33.456	0.000

NARDL Model Specification

Following Shin et al. (2014), the NARDL framework separates each regressor into positive and negative cumulative components, thereby allowing for an asymmetric impact assessment. The model is given by(Shin et al., 2014):

$$\Delta lnECPC_t = \alpha_0 + \sum_{i=1}^{p}\beta_i \Delta lnECPC_{t-i} + \sum_{i=0}^{q}(\gamma_1^+ \Delta lnEI_t^+ + \gamma_1^- \Delta lnEI_t^-) + \sum_{i=0}^{r}(\gamma_2^+ \Delta lnTRADE_t^+ + \gamma_2^- \Delta lnTRADE_t^-) + \sum_{i=0}^{s}(\gamma_3^+ \Delta lnREN_t^+ + \gamma_3^- \Delta lnREN_t^-) + \sum_{i=0}^{u}(\gamma_4^+ \Delta lnFDI_t^+ + \gamma_4^- \Delta lnFDI_t^-) + \theta_1 lnECPC_{t-1} + \theta_2^+ lnEI_t^+ + \theta_2^- lnEI_t^- + \theta_3^+ lnTRADE_t^+ + \theta_3^- lnTRADE_t^- + \theta_4^+ lnREN_t^+ + \theta_4^- lnREN_t^- + \theta_5^+ lnFDI_t^+ + \theta_5^- lnFDI_t^- + \varepsilon_t$$

In this equation, the positive and negative cumulative decompositions are labeled by + and −, respectively.

Dependent Variable

Per-capita Energy Consumption (ECPC): Average energy consumption per capita in a year (kWh).

Independent Variables

Energy Intensity (EI): Energy consumed per unit of GDP.

Trade openness (TRADE): The sum of exports and imports of goods and services as a percentage of GDP.

Renewable Energy Share (REN): The proportion of total energy that is of derived of renewable sources and expressed as a percentage

Foreign direct investment (FDI): Net foreign investment as percent of GDP.

Tests of Healthiness of Data

Various diagnostic tests were imposed to verify the stability and validity of the econometric models employed in the analysis(Ahmed et al., 2023):

1. Portmanteau test: Autocorrelation in the residuals was tested.
2. Heteroscedasticity test by breusch and pagan: It was used to check either the variance of the residuals is the same (homoskedastic).
3. Ramsey test: A test of correct specification (functional form) of the model.
4. The normality of residuals was investigated using Jarque-Bera (JB) normality test.

Unit Root Testing

The series were tested for the order of integration by employing the Augmented Dickey-Fuller (ADF) test. The findings reveal that ln(ECPC), ln(EI), and ln(TRADE) exhibit first-order integration (I(1)), whereas ln(FDI) and ln(REN) are stationary at level (I(0)), thus satisfying the conditions for a Nonlinear Autoregressive Distributed Lags (NARDL) framework.

Table 2

Unit Root Test Results

Variable	Test at Level (Intercept)	Test at Level (Trend & Intercept)	Test at 1st Difference (Intercept)	Order of Integration
ln(ECPC)	-1.171 (0.680)	-0.606 (0.975)	-5.966 (0.000)***	I(1)
ln(EI)	-2.555 (0.110)	-2.960 (0.154)	-10.609 (0.000)***	I(1)
ln(TRADE)	-3.422 (0.014)**	-3.348 (0.070)*	-7.643 (0.000)***	I(1)
ln(REN)	-2.253 (0.191)	-4.838 (0.001)***	-7.988 (0.000)***	I(0)
ln(FDI)	-3.542 (0.011)**	-4.241 (0.008)***	-13.402 (0.000)***	I(0)

Three stars, two stars, one star indicate significance at 1%, 5%, and 10% levels, respectively

Heteroscadesticity

The research examined hetroscedasticity to verify if the residuals of the model (or errors) have constant variance among all observations, which is crucial for statistical inferences. The Breusch-Pagan Test showed the test statistic 0.004 and a p-value 0.948 This high p-value indicates that there is no presence for heteroscedasticity and the residuals are homoskedastic. In other words, the errors are equally and constantly spread – leading to confidence in the estimated coefficients and standard errors by the model(Breusch & Pagan, 1979).

Results and Discussion

NARDL Estimation Results

The estimates from the NARDL analysis are presented after establishing the optimal lag length using selection criteria. The model achieved an R-squared of 0.7820 and met all relevant diagnostic test requirements, indicating a robust specification.

$$\begin{aligned}\Delta\ln ECPC_t = {} & \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta\ln ECPC_{t-i} + \sum_{i=0}^{q} (2.680\,\Delta\ln EI_t^{+} - 2.045\,\Delta\ln EI_t^{-}) + \sum_{i=0}^{r} (0.699\,\Delta\ln TRADE_t^{+} \\ & - 1.269\,\Delta\ln TRADE_t^{-}) + \sum_{i=0}^{s} (1.239\,\Delta\ln REN_t^{+} - 1.398\,\Delta\ln REN_t^{-}) \\ & + \sum_{i=0}^{u} (0.248\,\Delta\ln FDI_t^{+} - 0.024\,\Delta\ln FDI_t^{-}) + \theta_1 \ln ECPC_{t-1} + 2.680\ln EI_t^{+} \\ & - 2.045\ln EI_t^{-} + 0.699\ln TRADE_t^{+} - 1.269\ln TRADE_t^{-} + 1.239\ln REN_t^{+} \\ & - 1.398\ln REN_t^{-} + 0.248\ln FDI_t^{+} - 0.024\ln FDI_t^{-} + \varepsilon_t\end{aligned}$$

The estimated model given in Table 3 shows that positive (+) and negative (-) shocks to each variable have dissimilar effects (“asymmetry”) on the energy consumption of Pakistan.

Table 3

Asymmetry Statistics and Long-Run Effects

Variable	Long-run Effect [+]		Long-run Effect [-]		Long-run Asymmetry		Short-run Asymmetry	
	Coeff.	P>F	Coeff.	P>F	F-stat	P>F	F-stat	P>F
ln(EI)	2.680	0.057*	-2.045	0.047**	1.401	0.249	2.795	0.109
ln(TRADE)	0.699	0.277	-1.269	0.176	1.333	0.261	1.776	0.196
Ln(REN)	-1.398	0.204	1.239	0.166	0.273	0.607	6.171	0.021**
Ln(FDI)	-0.024	0.848	0.248	0.235	3.539	0.073*	0.002	0.965

Positive (+) Shocks

Energy Intensity (+):

A positive shock to energy intensity corresponds with a substantial increase in per-capita energy consumption. The long-run coefficient of 2.680 implies that if there is a 1% increase in energy intensity, then on an average per- capita consumption is increased by 2.68%. This means that waste translates directly into demand.

Trade Openness (+):

The model has a positive coefficient (0.699), but it is not significant. Positive trade shocks exert no significant effect on increased energy consumption in this instance.

Renewable Energy Share (+):

In the short run, the model indicates a significant positive and persistent effect from renewable energy shocks (F-stat = 6.171, p = 0.021). Initial increases in the share of renewable energy may lead to a temporary surge in energy demand, likely due to the energy-intensive process of developing new infrastructure. Nonetheless, the long-term coefficient is observed to be insignificant.

Foreign Direct Investment (+):

The long-run results are insignificantly positive (0.248) for both positive and negative shocks, and asymmetry is significantly positive, indicating that foreign capital increases energy use.

Negative (–) Shocks

Energy Intensity (–):

The results are significant with minus value (-2.045), one percent results in reduction of 2.5% in energy use. Confirming that improvements in technology benefits in in the long term energy consumption.

Trade Openness (–):

The effect is insignificant (-1.269), openness in trade increases the energy consumption.

Renewable Energy Share (–):

The renewable energy effects positive, negative, and symmetrical are insignificant in the long run.

Foreign Direct Investment (–):

The coefficient is -0.024, which is negative and insignificant. The negative sign indicates that inflows and outflows have different effects on the dependent variable. This may be caused by sectoral changes or technological advancements.

Short-Run Dynamic Effects

Most indicators have symmetrical responses in the short run, except for renewable energy in the short run, which has a significant asymmetric response (F-stat = 6.171, p = 0.021), indicating that positive and negative changes have different impacts on energy consumption. The renewable sources are at initial stage of inverted-U shape energy demand curve, these efforts will later beneficial in sustainable benefits in future (Markard & Rosenbloom, 2022). The remaining indicators, energy intensity, trade, and foreign direct investment, have symmetric responses, and no positive or negative shocks are observed in the timeframe.

Long-Run Effects

In the long run, the explanatory variables demonstrate the divergent effects of energy use. Energy intensity had the largest effect size, such that enhancements in efficiency reliably reduced energy demands by 2.05% (p=0.047), whereas setbacks increased consumption by 2.68% (p=0.057). This pattern confirms that efficiency improvement should be the fundamental part of a new energy policy. Furthermore, FDI has the largest observed asymmetry effect (F-stat = 3.539, p=0.073), suggesting that capital addition or removal has a different trajectory for energy consumption. In contrast, open trade and share of renewables do not yield statistically robust long-run consequences, whether symmetrical or otherwise. These differentiated patterns highlight the need for calibrated policy frameworks that recognize the varied temporal and directional signatures of each driver (Ahmed et al., 2023; Mmbaga et al., 2024).

Diagnostic Tests and Key Insights of Model

The diagnostic result show that the model is reliable, with no autocorrelation (Portmanteau, p=0.249), consistent residuals (Breusch/Pagan, p=0.948), correct model specification (Ramsey RESET, p=0.445), and normally distributed residuals (Jarque-Bera, p=0.632) (Baltagi, 2008) , as given in Table 4

Table 4

Diagnostic Test Results

Test / Effect	Statistic / Coefficient	P-value	Interpretation
Portmanteau (lag 22)	26.06	0.249	No autocorrelation
Breusch/Pagan (heteroscedasticity)	0.004	0.948	Homoskedastic residuals
Ramsey RESET	0.932	0.445	Correct specification
Jarque-Bera (normality)	0.919	0.632	Normal residuals
Short-run effect: Renewable energy (asymmetry)	F-stat: 6.171	0.021	Significant asymmetric short-run impact
Long-run effect: Energy intensity (+)	2.680	0.057*	Significant positive effect
Long-run effect: Energy intensity (−)	-2.045	0.047**	Significant negative effect
Long-run asymmetry: FDI	F-stat: 3.539	0.073*	Marginal asymmetric long-run effect

The major findings and key takeaways of this study are as follows.

1. **Asymmetrical Effects are observed:** energy intensity has positive and negative shocks, and FDI has asymmetry observed; policymakers should consider these findings when designing the future energy policy for the country (Ahmed et al., 2023).
2. **Improving Energy Intensity:** will result in reduced energy demand, which will prove to be a key tool for improving long-term policy (Mmbaga et al., 2024).

3. Green energy has effects only in the short run: incrementing the renewable share through green projects will transiently increase energy consumption, but it does not have long-term effects in the studied sample (Ahmed et al., 2023).
4. The open trade impact is not statistically significant for the studied period.

Policy Implications and Conclusions

Policy Implications

The recommendations after this analysis are provided to incorporate in Pakistan's Energy Policy 2030 and relevant energy sector reforms.

Efficiency Criteria Based Policy: Specifically, this study examined year samples with improved energy intensity and found that they behaved differently than years in which energy efficiency deteriorated. Evidently, energy interventions are required to improve efficiency (Mahapatra & Irfan, 2023).

Clean Energy Initiatives: The short-run temporal disparity for green energy development shows that the starting phase will result in a temporary rise in energy demand. The executors of the Pakistan energy sector should be aware of this phenomenon before the later payoff of enhanced capacity in the long run (Rahaman et al., 2023).

FDI with Cleaner Sources: The long-run asymmetry of FDI reveals that new capital generates more carbon pollution. Therefore, the government should incentivize investments based on cleaner fuel technologies and infrastructure(Khawaja et al., 2025; Petrović & Lobanov, 2022).

Adaptive Policy Framework: The asymmetrical results of the explanatory variables demand that the policy driving mechanism should be adaptive rather than based on linear methodology. Policymakers should continuously monitor economic development actions and counterbalance environmental deterioration (Andriamahery & Qamruzzaman, 2022).

Conclusion

The study confirmed asymmetrical results of key energy economic variables, that is, energy consumption per capita, by employing the nonlinear ARDL study method. The investigation finds that the green energy share produces significant short-run imbalances, whereas foreign investment has sustained effects in the long run. Improvement in energy intensity is needed, which is the worst in the region of South Asia, as it has both positive and negative shocks in longer run effects, to enable country transition to energy reduction in an inverted U-shaped pathway towards betterment (Jafri et al., 2021).

These findings endorse the formulation of policies that take advantage of the dynamic nature of energy variable consequences rather than relying on the linear formulation of problems, as it failed to capture the gains from positive shocks and deterioration due to negative actions on energy consumption. Therefore, policy guidelines should recognize and include mechanisms to identify the next corrective actions to achieve economic versus environmental goals (Majeed et al., 2021).

This study adds to the existing body of knowledge on the nonlinear time series response of developing countries facing similar reform challenges. Future research can improve this work by breaking down the analysis by sector and incorporating the role of the institutional framework.

Recommendations

Based on the empirical findings and nonlinear technique discussed in this study, targeted advice is provided for governing bodies and stakeholders. These findings provide insights into the imbalances in energy use factors, which can help achieve sustainable energy goals for Pakistan(Ahmed et al., 2023; Mmbaga et al., 2024).

1. Integrate asymmetry-informed models in policy formation, as evidenced in this study, to improve the evaluation of economic and environmental forces on energy consumption.
2. Harness the long-term, cost-effective benefits of energy efficiency by advancing policy and performance improvements and creating investment policies that encourage a continuing decline in per capita energy use.
3. Policymakers should leverage the evidence of FDI asymmetry to strategically attract investment into sectors that promote long-term sustainability and lower energy intensity, moving beyond one-size-fits-all models.
4. Catalyze expansion of renewables taking into account short-run demand variations noted, forecasting for short-term spikes in demand when building new infrastructure without compromising the long-term goals for clean energy.
5. Adopt NARDL, and other nonlinear econometric, techniques for routine policy surveillance, enabling future energy policy actions to be more flexible in responding to changing economic or policy conditions, as suggested by the methodological innovation in this study.

Future Research Options

Based on the constraints of this research there are other paths which could be explored in future research to improve this understanding(Ahmed et al., 2023; Mmbaga et al., 2024).

1. Subsequent research could focus on analyzing the asymmetric effects in single fields/regions to investigate more detailed regularities of the energy consumptions.
2. A complete picture would also emerge from an analysis that considered changes not only in technology, but in government policy and in the prices of energy.
3. From the practical point of view, the time dependence of the demand would be more accurately modeled through a widely-used panel or time series.
4. Another interesting extension would be to reproduce these results before extending the work with other techniques such as machine learning or other non-linear methods.
5. And it is useful to know how in abstract cutting back on energy use would help the environment (expressed in terms such as carbon emissions), so policy could be based in reality.

References

Ahmed, M., Huan, W., Ali, N., Shafi, A., Ehsan, M., Abdelrahman, K.,…Fnais, M. S. (2023). The effect of energy consumption, income, and population growth on CO2 emissions: evidence from NARDL and machine learning models. *Sustainability*, *15*(15), 11956. https://doi.org/10.3390/su151511956

Ahmed, B., Zaman, S. uz., & Alam, S. H. (2025). Role of AI-Based Marketing Activities in Shaping Brand Experience, Brand Preference, and Brand Loyalty. *Qlantic Journal of Social Sciences and Humanities*, 6(1), 237-253. https://doi.org/10.55737/qjssh.vi-i.25320

Ahmed, S.M.M., Zaman, S.U., & Alam, S. H. (2024). The Effect of Green Branding on Consumer Beliefs and Attitudes Toward Eco-Conscious Purchases. *Journal of Social Sciences Review*, 4(4), 281–299. https://doi.org/10.62843/jssr.v4i4.477

Al Irsyad, M. I., Halog, A. B., Nepal, R., & Koesrindartoto, D. P. (2017). Selecting tools for renewable energy analysis in developing countries: An expanded review. *Frontiers in energy research*, *5*, 34. https://doi.org/10.3389/fenrg.2017.00034

Alam, S. H., Zaman, S. U., & Rajput, A.M. (2025). From Happy Customers to Brand Advocates: The Power of Satisfaction. Pakistan. *Journal of Humanities and Social Sciences*, 13(1), 283–294. https://doi.org/10.52131/pjhss.2025.v13i1.2712

Alam , S.M.W., Zaman , S.U., Alam, S.H., & Ali, S.M.O. (2024) .Customer Experience and Satisfaction in Anti-Dandruff Shampoo Consumption: Standpoint of Customer Behavioral Outcomes. *The Asian Bulletin of Big Data Management* , 4(4), 114-131. https://doi.org/10.62019/p70m9850

Ali, W., Nathaniel, S. P., Adekunle, I. A., & Kumar, B. (2022). Energy consumption and economic growth linkage: Global evi-dence from symmetric and asymmetric simulations. *Quaestiones Geographicae*, *41*(2), 67-82. https://doi.org/10.2478/quageo-2022-0012

Alqaralleh, H., & Hatemi-J, A. (2024). Revisiting the effects of renewable and non-renewable energy consumption on economic growth for eight countries: asymmetric panel quantile approach. *International Journal of Energy Sector Management*, *18*(2), 334-349. https://doi.org/10.1108/IJESM-10-2022-0022

Andriamahery, A., & Qamruzzaman, M. (2022). A symmetry and asymmetry investigation of the nexus between environmental sustainability, renewable energy, energy innovation, and trade: Evidence from environmental kuznets curve hypothesis in selected MENA countries. *Frontiers in energy research*, *9*, 778202. https://doi.org/10.3389/fenrg.2021.778202

Baltagi, B. H. (2008). E*conometric analysis of panel data.* Rohn Wiley.

Bayramoglu, A. T., & Yildirim, E. (2017). The relationship between energy consumption and economic growth in the USA: A non-linear ARDL bounds test approach. *Energy and Power Engineering*, *9*(3), 170-186. https://doi.org/10.1016/j.procs.2017.11.294

Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica: Journal of the econometric society*, 1287-1294. https://doi.org/10.2307/1911963

Gershon, O., Asafo, J. K., Nyarko-Asomani, A., & Koranteng, E. F. (2024). Investigating the nexus of energy consumption, economic growth and carbon emissions in selected african countries. *Energy Strategy Reviews*, *51*, 101269. https://doi.org/10.1016/j.esr.2023.101269

Ilyas, M., Mu, Z., Akhtar, S., Hassan, H., Shahzad, K., Aslam, B., & Maqsood, S. (2024). Renewable energy, economic development, energy consumption and its impact on environmental quality: New evidence from South East Asian countries. *Renewable Energy*, *223*, 119961. https://doi.org/10.1016/j.renene.2024.119961

Jafri, M. A. H., Liu, H., Usman, A., & Khan, Q. R. (2021). Re-evaluating the asymmetric conventional energy and renewable energy consumption-economic growth nexus for Pakistan. *Environmental Science and Pollution Research*, *28*(28), 37435-37447. https://doi.org/10.1007/s11356-021-13131-1

Khawaja, W. S., Ali, A., Bhatti, S. R., & Khan, M. M. (2025). Trade Openness, Renewable Energy, and Environmental Outcomes: Evidence from Pakistan. *The Regional Tribune*, *4*(3), 284-300. https://doi.org/10.55737/trt/SR25.144

Khan, A. K., Zaman, S. U., & Alam, S. H. (2024). Impact of Big Data Analytics on Organizational Performance: The Role of Business Analytics, Decision-Making Quality and Sustainability. *The Regional Tribune*, 3(1), 389-406. https://doi.org/10.63062/trt/V24.069

Mahapatra, B., & Irfan, M. (2023). Investigating asymmetric impacts of total factor energy efficiency on carbon emissions in India. *Environmental Science and Pollution Research*, *30*(19), 55340-55353. https://doi.org/10.1007/s11356-023-26206-y

Majeed, M. T., Tauqir, A., Mazhar, M., & Samreen, I. (2021). Asymmetric effects of energy consumption and economic growth on ecological footprint: new evidence from Pakistan. *Environmental Science and Pollution Research*, *28*(25), 32945-32961. https://doi.org/10.1007/s11356-021-13130-2

Markard, J., & Rosenbloom, D. (2022). Phases of the net-zero energy transition and strategies to achieve it. In *Routledge handbook of energy transitions (pp. 102-123)*. Routledge.

Mmbaga, N. F., Kulindwa, Y., & Kazungu, I. (2024). Macroeconomic determinants of energy consumption in Eastern Africa: an empirical analysis using panel-ARDL models. *African Journal of Economic Review*, *12*(3), 1-25. https://www.ajol.info/index.php/ajer/article/view/276024

Mujtaba, A., Jena, P. K., Bekun, F. V., & Sahu, P. K. (2022). Symmetric and asymmetric impact of economic growth, capital formation, renewable and non-renewable energy consumption on environment in OECD countries. *Renewable and Sustainable Energy Reviews*, *160*, 112300. https://doi.org/10.1016/j.rser.2022.112300

Petrović, P., & Lobanov, M. M. (2022). Energy intensity and foreign direct investment nexus: Advanced panel data analysis. *Applied Energy*, *311*, 118669. https://doi.org/10.1016/j.apenergy.2022.118669

Rahaman, S. H., Chen, F., & Jiang, G. (2023). The asymmetric impact of renewable energy consumption on the economic growth of emerging South and East Asian countries: A NARDL approach. *Heliyon*, *9*(8). https://www.cell.com/heliyon/fulltext/S2405-8440(23)05864-4

Ritchie, H., Roser, M., & Rosado, P. (2025). *Energy*. Published online at OurWorldInData. org. In.

Şanlı, D., Muratoğlu, Y., Songur, M., & Uğurlu, E. (2023). The asymmetric effect of renewable and non-renewable energy on carbon emissions in OECD: new evidence from non-linear panel ARDL model. *Frontiers in Environmental Science*, *11*, 1228296. https://doi.org/10.3389/fenvs.2023.1228296

Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In *Festschrift in honor of Peter Schmidt: Econometric methods and applications (pp. 281-314).* Springer.

Tang, S., Raza, M. Y., & Lin, B. (2024). Analysis of coal-related energy consumption, economic growth and intensity effects in Pakistan. *Energy*, *292*, 130581. https://doi.org/10.1016/j.energy.2024.130581

Ullah, A., Kui, Z., Pinglu, C., & Sheraz, M. (2022). Effect of financial development, foreign direct investment, globalization, and urbanization on energy consumption: Empirical evidence from Belt and Road initiative partner countries. *Frontiers in Environmental Science*, *10*, 937834. https://doi.org/10.3389/fenvs.2022.937834

Urom, C., Abid, I., Guesmi, K., & Ndubuisi, G. (2022). Renewable energy consumption, globalization, and economic growth shocks: evidence from G7 countries. *The Journal of International Trade & Economic Development*, *31*(2), 204-232. https://doi.org/10.1080/09638199.2021.1961845

Warsame, A. A., Alasow, A. A., & Salad, M. A. (2024). Energy consumption and economic growth nexus in Somalia: an empirical evidence from nonlinear ARDL technique. *International Journal of Sustainable Energy*, *43*(1), 2287780. https://doi.org/10.1080/14786451.2023.2287780

WDI. (2023). *World development indicators*. World Bank.

Zaman, S.U., Ahmed, J., & Alam, S.H. (2025). Exploring Factors Influencing Behavioral Intention to Use E-Wallets Through Short-Form Video Shopping Platforms Among Generation Z. *Journal of Social Sciences Review*, 5(1), 290–304. https://doi.org/10.62843/jssr.v5i1.491

Zaman, S. U., Zubairi, S. A., Zubairi, N. A., & Alam, S.H. (2024). Consumer Adoption of Livestream Shopping: A Technology and Service Quality Perspective. *Qlantic Journal of Social Sciences and Humanities*, 5(4), 358-371. https://doi.org/10.55737/qjssh.v-iv.24322

Zaman, S.U., Sami, A., & Alam, S.H. (2025). Bridging Leadership and Performance: The Mediating Role of Corporate Social Responsibility in Ethical and Organizational Contexts. *Research Journal of Psychology*, 3(2), 107–128. https://doi.org/10.59075/rjs.v3i2.113

Zeraibi, A., Radulescu, M., Khan, M. K., Hafeez, M., & Jahanger, A. (2024). Analyzing the linkage between public debt, renewable electricity output, and CO2 emissions in emerging economies: does the N-shaped environmental Kuznets curve exist? *Energy & Environment*, *35*(5), 2407-2430. https://doi.org/10.1177/0958305X231151678