International Journal of Human and Society (IJHS)

P-ISSN: 2710-4966	E-ISSN: 2710-4958
Vol. 3. No. 04 (Oct-Dec) 2023	Page 413-426

Impact of Renewable and Non-Renewable Energy Consumption on Economic Growth of Pakistan

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Abstract: *The study empirically investigates the influence of renewable and non-renewable energy consumption on economic growth of Pakistan by employs ARDL technique for the data period 1980 to 2021. The analysis emphasizes energy consumption's crucial part in economic growth and advocates for transformation to renewable energy sources. The findings indicate co-integration among independent variables and GDP growth. The long-term investigation illustrates positive influence of renewable energy and negative effects of specific non-renewable sources on economic growth. Capital stock, labor force, and natural gas exert significant influences on GDP growth. In essence, RE utilization plays a vital role in GDP growth, warranting cautious interpretation of non-RE sources. The study recommends increased investment in renewable energy to drive sustainable economic development. To alleviate potential interruptions to GDP growth, it also suggests falling reliance on non-RE sources and promoting renewable energy sources.*

Keywords: Renewable Energy (RE), Non- Renewable Energy (Non-RE), Auto Regressive Distributive Lag Model (ARDL), Carbon Dioxide (CO_2) emissions, Gross Domestic Product (GDP)

1. Introduction

Energy consumption plays a vital role in economic growth and development. All countries around the world rely on energy to boost their industries, transport, and households' output (Bilgen et al., 2014). Though, the form of energy consumed have a major effect on economic growth and environmental sustainability. Renewable energy sources like, hydropower, solar and wind have grown popularity in recent years as a cleaner and more sustainable alternative to non-renewable sources like oil, gas, and coal. Admittedly, the use of non-RE has resulted in significant environmental and health problems. The extraction, transportation, and burning of fossil fuels have contributed to water and air pollution, climate change, and a lot of health issues. Furthermore, the utilization of non-RE sources are limited, depleting and it will eventually finish. In contrast, RE sources, are sustainable and do not emit harmful pollution into the environment. These sources have gained popularity in recent years as countries aim to halt their CO_2 emissions and endorse sustainable development (Shahzad, 2022).

Renewable and non-renewable energy are essential indicator for power industries,

transportation, households, and their availability and affordability can significantly impact on economic growth. A report by the IEA, 2020 depicted that the energy sector accounts for around 7% of global GDP and is critical for driving economic growth. Countries that have access to reasonable and reliable energy sources have an aggressive advantage in attracting investment, developing industries, and improving living standards. RE sources, such as wind, solar and hydropower, have become increasingly important for meeting global energy demand while shrinking CO_2 emission and thus lessening the influences of climate change. In contrast, the utilization of finite sources of non-RE can result in noteworthy environmental consequences. (Lee et al., 2023).

The economic progress of a country is significantly impact by the energy sector. Over the past few years, energy demand has been rising significantly due to several factors, including economic growth, population expansion, and technological advancements. The surge in commodity prices during 2021 and early 2022 was mainly driven by the global economic recovery, better growth prospects, and the battle between Russia and Ukraine (Raza at al., 2023). The IEA attributes the sudden increase in electricity demand of over 6 percent in 2021 to the COVID-19 pandemic's economic rebound and unusual weather conditions. However, the rise in fuel and electricity costs have resulted in an increase in overall production costs, leading to a substantial rise in the cost of living and a decrease in households' purchasing power worldwide. Presently, the global economy is facing higher energy prices that may remain unchanged due to the Russian-Ukraine conflict, which has caused significant disruptions to production and trade. The World Bank has projected that this conflict will cause the largest commodity shock, resulting in a significant surge in energy-related stuff, including natural gas and oil. As per the World Bank's estimation, energy prices are anticipated to surge by over 50 percent, which could place a burden on households and businesses. This development has prompted worries, especially in developing nations where extending energy subsidies has become difficult due to their precarious financial condition (Dong at al., 2022).

Energy sector is the main contributors to greenhouse gases emissions in Pakistan, with fossil fuels accounting for over eighty percent of the country's energy mix (Longden et al., 2020). Secondly, Pakistan is a developing country, and its economy heavily relies on energy-intensive sectors such as agriculture, manufacturing, and services. These sectors are highly dependent on the availability of energy, and any disruptions in the energy supply chain can have severe implications for the overall economic growth of Pakistan. Hence, it is noteworthy to know how the utilization of RE and non-RE can impact the GDP of the country (Saeed et al., 2023).

Figure 1 Non-RE consumption

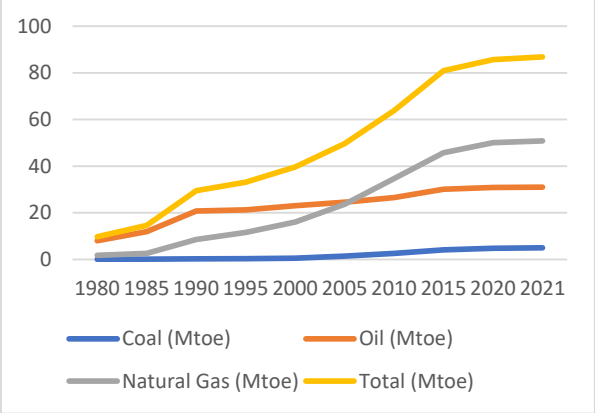


Figure 2 RE consumption

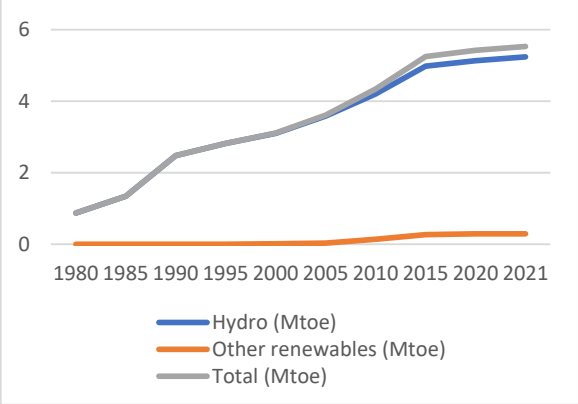
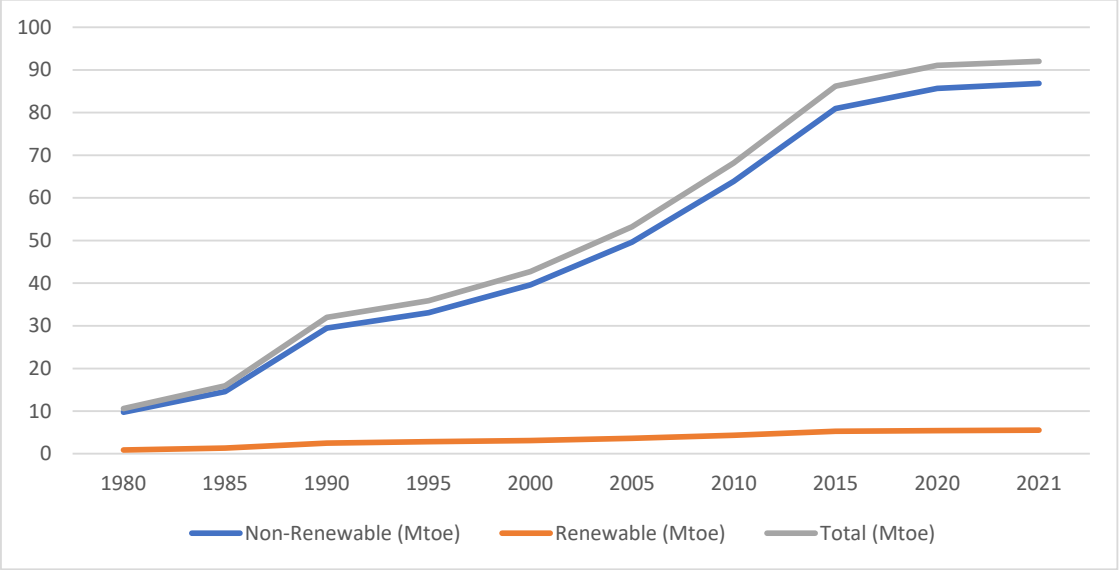


Figure 3
Total Energy Consumption



The above figures, shows that Pakistan has been heavily dependent on NRE to meet its energy requirements. However, the past few decades, Pakistan's RE consumption has gradually increased since inception. In 1980, it stood at 0.87 Mtoe, and by 2020, it had risen to 5.42 Mtoe. It reveals that Pakistan is committed a strong focus on increasing its utilization of renewable energy sources, in pursuit of a more environment friendly and sustainable energy. In 1980, NRE accounted for 10.59 Mtoe, while RE contributed only 0.87 Mtoe. By 2020, NRE consumption increased to 85.66 Mtoe, and RE consumption rose to 5.42 Mtoe.

The primary purpose of this analysis is to measure the influence of RE and non-RE utilization on economic growth. The study is unique in that it focuses on the outcome of both RE and non-RE utilization on economic growth Pakistan. Most of the aforementioned studies have focused either on renewable or non-RE consumption and gives inconclusive empirical indication. Therefore, this study uses the latest data and analytical techniques to provide new insights to the linking between economic growth and energy utilization. Moreover, this study is exceptional in a logic that it analyzes the influence of each individual components of non-RE (natural gas, oil and coal) on GDP growth of Pakistan. Furthermore, keeping in view the depreciation of capital stock over time, this study attempts to generate a capital stock variable.

The analysis gives insights into the economic benefits and costs of using RE and non-RE sources, which inform energy policy decisions in Pakistan. It can also highlight the potential environmental impacts of energy consumption and identify strategies to mitigate these impacts. Overall, the study can help to promote sustainable economic development in Pakistan and contribute to transition towards a sustainable energy future.

Furthermore, after preliminary introduction chapter, structured of this study is given under: Chapter 2 discusses trend of RE and NRE in the context of Pakistan. Chapter 3 review past studies relevant with this analysis Chapter 4 presents the data sources of variables comprised in the empirical model. Moreover, this chapter also discusses relevant estimation method used to empirically evaluate the econometric model. Chapter 5 of the study presents results and a discussion. Finally, chapter six concludes empirical results of the analysis. In this chapter, the analysis also suggests policy recommendations based on empirical results obtained in this analysis.

2. Literature Review

As Pakistan attempts for sustainable economic development, the role of energy consumption has emerged as a critical factor. This literature review explores the connection between utilization of RE and non-RE sources and the economic growth.

Precisely, many analyses have been highlighted the link among RE and non-RE utilization and economic growth of Pakistan. A significant segment of the research focuses on a variety of variables, including pollutant emissions and international trade. Different methodologies, such as symmetric and asymmetric approaches, are employed to analyze their effects (Jafri et al). Specifically (Wada et al., 2021 inspect the association among energy utilization, population, imports and exports, GDP, and environmental quality in case study of Brazil. The study finds that environmental quality is negatively impacted by economic growth and exports. Environmental deprivation is further exacerbated by heightened energy utilization, GDP per capita, imports, exports per capita, and population growth, affecting the environment both in the short term and over an extended period. It suggests that policymakers have to be cautious while making conservation policies. (Abbasi et al., 2021), Inspect the effects of energy usage, industrial expansion, CO_2 emissions, and their effects on economic development by applying the ARDL technique with diverse variables such as industrial output, electricity and CO_2 emission. The long run findings indicate that Pakistan's economic growth benefits from energy utilization, industrial output, and CO_2 emissions. Effective management, efficient electricity generation, and strategic policies are deemed essential. The recommendation is for increased government investment in RE to guard the environment.

In contrast (Yikun et al., 2021), observe the connection between RE and sustainable economic progress for the panel of the SAARC counties and revealed that RE exert positive and substantial impacts on economic progress in the SAARC countries. likewise (Pegkas., 2019), finds the same results in the Greece. Notably, (Kirikkaleli et al., 2020), using Toda Yamamoto estimation technique for UK to evaluates the influence of RE on GDP growth and uncovers the correlation among nuclear energy consumption and economic growth and find positive corelated. These findings underscore the need for the UK government to prioritize RE utilization, aligning with Sustainable Development Goals for clean energy and environmental sustainability. Similarly (Mohsin et al., 2021) explore the association among energy utilization, economic progress, and CO_2 emissions in Pakistan. The ARDL approach reveals that both energy utilization and economic growth drive increased CO_2 emissions, both immediately and over the long term. Based on these findings, policymakers are recommended to encourage RE sources to fulfill rising energy demands.

Recently, (wang et al., 2023) evaluate the correlation among economic growth, RE, non-RE utilization and CO_2 emissions in Northeast Asian countries. Rigorous cross-sectional dependence tests confirm the absence of such dependence, and Cointegration tests establish enduring relationships among the variables. Notably, the study by Le and Sarkodie (2020) enhances the body of existing literature by exploring the relationship among RE, conventional energy, environmental conditions, and economic progress across a panel of 45 EMDEs. The findings underscore that the economic prosperity of the selected EMDEs is significantly influenced by both RE and non-RE utilization. The results suggest a trade-off between economic progress and environmental well-being. An inspection by (Shahbaz et al., 2012), assess the connection among economic growth and natural gas utilization in Pakistan. The findings of ARDL methodology reveals that positive impact of natural gas, along with labor, capital, and exports, on economic growth. Interestingly, the study suggested that increased natural gas consumption contributes to economic growth, implying that policies aimed at preserving natural gas might inadvertently hinder economic expansion. In contrast, lessening in gas utilization has a positive influence on environmental well-being, whereas an increase in gas utilization is associated with

adverse effects on environmental conditions (Majeed et al., 2021).

Furthermore, a comprehensive study conducted in five south Asian nation (Rahman and Velayutham., 2019), examine the connection between RE and non-RE utilization. The results revealed positive effects of both RE and non-RE utilization. Additionally, the study highlighted a one-way causal link, indicating that the implementation of RE contributes to the stimulation of economic growth. Similarly, the empirical analysis of (Kakar and Khilji., 2011; Abbasi et al.., 2017)), finds the same result with irregular variables. In contrary bi directional causal connections find among energy utilization, economic growth, and CO_2 emissions (Mirza & Kanwal 2017).

After conducting an extensive review of the existing literature, it becomes obvious that the nexus RE, non-RE, and economic progress is a serious issue, and innumerable studies observed the issue with various aspect. No preceding analyses have found examining the association between RE and dis-aggregate effect of non-RE utilization on economic growth. Numerous researchers used the aggregate energy usage of non-RE.

Dis-aggregating energy utilization for non-RE sources can reveal the impression of each source on economic growth more obvious. Moreover, the analysis also used new variables of net capital stock. All of these indications consent to conduct an analysis to distinguish the consequence RE energy consumption, non-RE, on economic growth.

3. Model, Data, and Methodology

3.1. Theoretical framework

The correlation among economic growth, RE and non-RE consumption has gain substantial trend among researchers. Consequently, numerous prior studies have sought to explore this connection from various perspectives. In our analysis, we aim to examine this nexus from a different angle, specifically focusing on the disaggregated effect of non-RE utilization on the economic growth. Additionally, we introduce a novel variable that excludes the depreciation of capital stock. However, it is essential to construct fundamental models capable of capturing the influence of energy utilization on economic progress and vice versa. This article focuses on assessing the impression of both RE and non-RE utilization on economic progress. The hypothetical framework considers two contrasting viewpoints regarding the energy-growth connection. The neoclassical growth theory postulates that energy has no direct influence on production, while an alternative perspective highlights the importance of energy utilization (Ozturk et al., 2010).

$$Y_t = AK_t^{\alpha} L_t^{\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Initially, the Cobb-Douglas production equation is presented, where A represents the technological parameter, Yt signifies aggregate output at time t, Kt signifies capital output at time t, Lt reveals labor output at time t, and α and β denote the elasticity coefficients reflecting the responsiveness of output to changes in capital and labor.

Along with the traditional inputs (capital and labor) energy utilization also play a crucial role in economic growth (Yuan et al., 2008). In this study the, Cobb-Douglas production function, which includes energy as an input along with other conventional inputs such as labor and capital is given as under:

$$Y_t = A\ K_t^{\alpha} L_t^{\beta} E_t^{\lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

where 'Et expressed energy and 'r' output elasticity with respect to energy. By Arbex and Perobelli., 2010) energy is categorized into two class; renewable and non-renewable.

$$Y_t = A\ K_t^{\alpha} L_t^{\beta} R_t^{\lambda 1} N_t^{\lambda 2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

In this equation, Rt represents RE (RE) and Nt signifies non-RE (NRE). Within this context, λ_1 and λ_2 denote the elasticity of output concerning RE and NRE, respectively.

To convert this theoretical form into functional form is under;

GDP = f (RE, Capital Stock, Labor Force,

Natural Gas, Coal, and oil) ……. (4.4)

To translate these practical expressions into econometric models, we have included intercept terms and slope parameters for each variable, accompanied by an error term with a normal distribution on the right side of the eq 4.4. Furthermore, we have transformed these econometric models into semi-natural logarithmic forms, as depicted in Equation 4.5.

$$LnGDP_t = \alpha + \beta_0 RE_t + \beta_1 LnCS_t + \beta_2 LnLF_t + \beta_3 NG_t + \beta_4 COAL_t + \beta_5 OIL_t + \varepsilon_t$$

……. (4.5)

In the above equation 4.4 GDP_t represents GDP total in US dollar at fixed prices 2015, RE_t indicates renewable energy CS_t represent net capital stock, LF_t represents total labor force, NG_t, $COAL_t$ and OIL_t represents the proportion of natural gas, coal, and oil ε_t is the residual.

3.2. Data

The study selected Pakistan for the area and together data over the period 1980–2021 on relevant variables. GDP total is used to measure the economic growth of a country. Fossil fuels are composite variables, consisting of oil, gas, and coal. RE comprises hydropower, nuclear power, biomass, wind, and solar energy. The data on three macroeconomic indicators, including GDP, RE consumption, and labor force, have taken from WDI. Meanwhile the data on coal, natural gas, and oil consumption is taken from EIA. In addition, the study has obtained data about capital stock from the Federal Reserve Bank of the USA.

3.3. Methodology

Given that none of our variables exhibit a unit root at order I(2), we can employ the ARDL methodology established by (Pesaran et al., 2001).To do this, we must transform Equation 4.5 into an ARDL as demonstrated below:

$$\Delta \ln GDP_t = \beta_0 + \sum_{i=1}^{n1} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=0}^{n2} \beta_2 \Delta \ln RE_{t-i} + \sum_{i=0}^{n3} \beta_3 \Delta \ln CS_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta \ln LF_{t-i}$$
$$+ \sum_{i=0}^{n5} \beta_5 \Delta \ln NG_{t-1} + \sum_{i=0}^{n6} \beta_6 \Delta \ln COAL_{t-1} + \sum_{i=0}^{n7} \beta_7 \Delta \ln OIL_{t-1} + \alpha_1 \ln GDP_{t-1} + \alpha_2 \ln RE_{t-1}$$
$$+ \alpha_3 \ln CS_{t-1} + \alpha_4 \ln LF_{t-1} + \alpha_5 \ln NG_{t-1} + \alpha_6 \ln COAL_{t-1} + \alpha_7 \ln OIL_{t-1} + \varepsilon_t$$

… (4.6)

The above equation 4.5, referred to as ARDL models, offers several advantages compared to other methodologies. Firstly, it allows us to obtain short-term and long-term estimates using a single equation. Secondly, it has the capacity to incorporate the integration properties of variables, enabling the utilization of variables that are either stationary at order I(0), integrated of order I(1), or a combination of both. Thirdly, it performs effectively even when dealing with limited sample sizes. Furthermore, the study follows Schwarz Information Criterion (SIC), is used to facilitate model selection by evaluating difference between model fit and complexity, giving preference to models that offer a suitable fit without an unnecessary number of parameters (Meo et al., 2018). Furthermore, to examine how GDP adjusts quickly into the long-run equilibrium connection with the independent variables (as captured by the ECT). The ECM model provides insights into examining the dynamics and long-term associations among GDP and the explanatory variables. To validate the model's results (Gul & Khan, 2020; Gul et al., 2023). it is essential to perform ECT value. The ECM model includes the first differences of the variables

$$\ln GDP_{t-1} = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta \ln RE_{t-1} + \sum_{t=1}^{n} \beta_i \Delta \ln CS_{t-1} + \sum_{i=1}^{n} \beta_i \mathrm{B} \ln LF_{t-1} + \sum_{i=1}^{n} \beta_i \Delta \ln NG_{t-1}$$
$$+ \sum_{i=1}^{n} \beta_i \Delta \ln COAL_{t-1} + \sum_{i=1}^{n} \beta_i \Delta \ln OIL_{t-1} + \gamma ECM_{t-1} + \varepsilon_t \qquad (4.7)$$

Where:

ECM_{t-1} is the lag value of ECT, which captures the convergent to the long-term equilibrium and γ is the coefficient of the ECT, indicating how quickly the variables correct. Besides, conducted diagnostic tests in research are essential to objectively assess and validate hypotheses, ensuring the reliability and credibility of research findings. Several commonly employed Diagnostic examinations, including the BPG test to assess heteroscedasticity, the Jarque-Bera test for normality/ familiarity, the BG test for autocorrelation, and the CUSUM test for stability, are utilized. These are the essential tools to assess model specification and estimate quality, ensuring the reliability of econometric findings.

4. Results and Discussion

In this section, the analysis assesses the effect of energy utilization by using the ARDL model on data from 1980–2021. The first step involves conducting descriptive statistics to summarize and describe the main features of a dataset and offer a concise and informative sketch. Later the study used unit root test to diagnose the stationarity of all variables in the model. The F-bound test is used to assess the presence of cointegration in the model. Furthermore, an evaluation of the ECM is conducted to establish the rate at which the model adjusts to long-term equilibrium. At the end, diagnostic tests are utilized to evaluate the consistency of the data.

In table 1, shows result of descriptive statistics, it reveals to precise and describe the main features of a dataset, offering a concise and informative summary. The mean value representing the average level of variable across the data, standard deviation measures the dispersion of a variable across the data. Moreover, P value indicates the probability of obtaining the observed value of a variable if null hypothesis is true.

In accordance with (Jafri et al., 2021), Table 2 outlines the prerequisite for applying the Autoregressive Distributed Lag (ARDL) model, emphasizing that none of the variables should be stationary at order I(2). The validity of ARDL results hinges on the absence of any I(2) variables in the model. Consequently, it is imperative that all variables exhibit stationarity.

Table 1: Descriptive statistics

	LNGDP	RE	LNCS	LNLF	NG	COAL	OIL
Mean	10.95506	0.242405	6.099808	7.628812	0.810857	0.156571	0.697452
Std. Dev.	0.375882	0.088288	0.684568	0.151130	0.373740	0.141895	0.273226
Probability	0.181348	0.465512	0.209248	0.194989	0.125307	0.000000	0.523581

The ADF, was employed for this endeavor, and the results are presented in Table 2. Importantly, none of the series were found to be integrated at order 2 or higher, affirming the appropriateness of proceeding with the ARDL test.

Table 2: ADF Unit Root Test

	With Intercept				With both Intercept and Trend			
	At level		At 1st diff		At level		At 1st diff	
	Stat	Pro	Stat	Pro	Stat	Pro	Stat	Pro

GDP	-0.2404	0.9249	-5.8839	0.0000	-2.2265	0.4629	-5.8555	0.0001
RE	-0.7464	0.8233	-8.1374	0.0000	-3.7408	0.0306	-8.0322	0.0000
CS	-1.3209	0.6105	-8.9359	0.0000	-3.0582	0.1297	-9.0479	0.0000
LF	-0.1813	0.9328	-6.0010	0.0000	-1.3195	0.8689	-5.9208	0.0001
COAL	2.8448	1.0000	-3.8087	0.0059	0.8919	0.9997	-4.4037	0.0060
NG	-0.7005	0.8354	-5.7489	0.0000	-1.9222	0.6249	-5.6811	0.0002
OIL	-1.6169	0.4650	-5.1536	0.0001	-3.0302	0.1373	-5.2699	0.0006

Table 3 The ARDL model encompasses both short-term and long-term predictions, examining the impacts of both RE and non-RE usage on GDP growth. In the short run the ARDL estimates suggest that RE has a positive impact on GDP growth, although this effect is not statistically significant. However, in the long run, this impact becomes significant, exerting a noteworthy influence on GDP growth. The findings align with previous empirical research. (Khan Baz.,2021) and (Luqman., 2019). This evidence suggests that RE serves as a fundamental driver of economic activities, exerting a substantial positive influence on GDP growth over the long term. It underscores that the utilization of RE contributes to output enhancement, consequently bolstering GDP in the extended time frame. This outcome is parallel to that of (Abbasi et al., 2021). However, the utilization of non-RE sources, such as oil, demonstrates a non-significant negative influence on GDP in the short term; however, in the long run, the impression becomes both negative and significant. This outcome is consistent with the findings (Yusuf et al., 2020 and Adekoya, 2021). Similarly, the coefficients of CS and LF demonstrate a positive and significant influence on GDP growth in both the short and long run. These results underscore the consistent and meaningful impact of the LF and CS on the dependent variable, in line with (Mahmoudinia et al., 2020; and Nguyen, 2021) for OIC countries and Nigeria, respectively. Examining other non-RE sources, such as coal and natural gas, their relations are positive and insignificant in the short run. In the long timeframe, coal demonstrates a detrimental effect on GDP growth, whereas natural gas shows a positive and noteworthy impact. These findings align with the investigations conducted by (Utomo et al., 2021; Yang et al., 2021). To sum up, the outcomes indicate that the utilization of RE has a substantial and positive influence on long-term GDP growth emphasizing its fundamental role in driving economic activity and enhancing GDP over time. On the contrary, the consumption of non-RE sources, particularly oil and coal, shows an adverse and significant influence on GDP in the long timeframe. Additionally, the constructive and significant influence of CS, labor force, and natural gas on GDP growth is consistently observed in both the short and long timeframe, highlighting their crucial contributions. Furthermore, the significance of the ECM indicates the existence of cointegration in the models, indicating that the adjustment of variables from short-run to long time equilibrium is offset by a factor of 0.486360.

Table 3: Long-run and Short-run ARDL Results

Long Run ARDL				
Variable	**Coefficient**	**Std. Error**	**t-Stat**	**Pro**
RE	1.136129	0.568716	1.997708	0.0572*
LNLF	1.338152	0.068598	19.507185	0.0000
LNCS	0.084284	0.015717	5.362601	0.0001
COAL	-0.087444	0.038560	-2.267738	0.0300
OIL	-0.156465	0.076377	-2.048587	0.0485
NG	0.264414	0.096720	2.733804	0.0116
Short Run Result				
Variables	**Coefficients**	**Std. Errors**	**t-Stat**	**P-value**
D(RE)	0.196425	0.179345	1.095234	0.2843
D(LNLF)	0.650823	0.156053	4.170539	0.0003
D(LNCS)	0.197062	0.042609	4.624922	0.0001
D(COAL)	0.138317	0.126974	1.089329	0.2868
D(OIL)	-0.119128	0.081186	-1.467338	0.1553
D(NG)	0.128600	0.048599	2.646139	0.0141
Coint Eq (-1)	-0.486360	0.117860	-4.126588	0.0004

The below table 5 shows ARDL bound test, is a statistical technique used to discover whether there exists a long-term connection among variables in econometric models. It specifically investigates the link between RE, NRE utilization, and economic growth. This test calculates the F-statistic, which is then compared to critical values at different level of significance (1%, 5%, and 10%). If the F-statistic surpasses both upper and lower critical bounds, it indicates substantial evidence of long run co-integration among the variables. In this instance, the F-statistic value of 8.771869 significantly surpasses the critical values across all significance levels. This robustly supports the existence of a sustained construction between the variables under scrutiny, implying their prolonged interdependency and meaningful influence on each other's patterns over time.

Table 5: ARDL Bound Testing

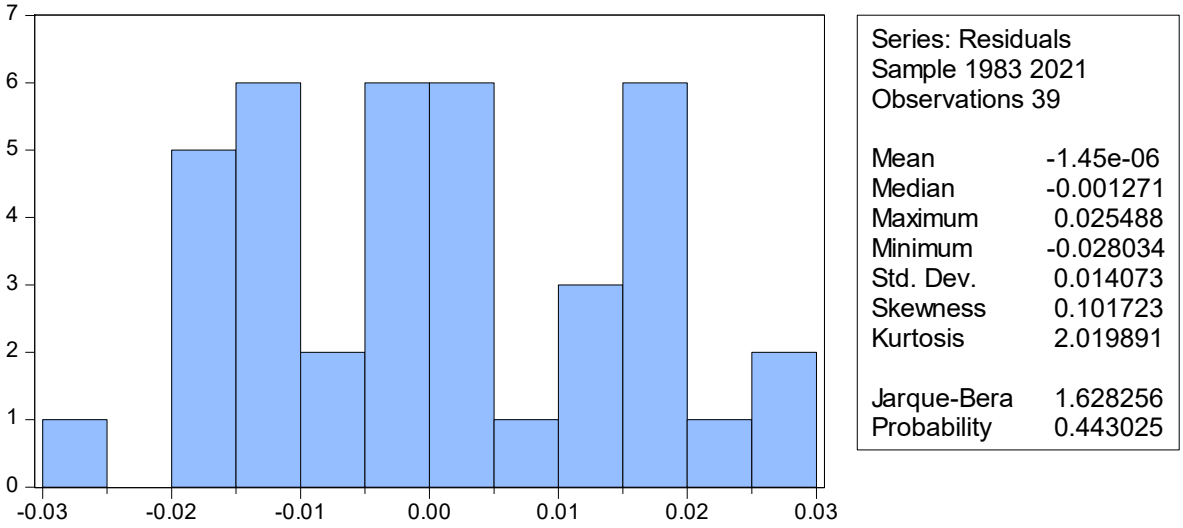
F- Test		***Ho: No co-integration***		
Test Stat	***Value***	***Significance***	***I (0)***	***I (1)***
F-stat	**8.771869**	*10%*	1.75	2.87
		5%	2.04	3.24
		1%	2.66	4.05

In addition, the study evaluates the validity and reliability of statistical models such as, BPG test, LM test, Jarque-Bera test and CUSUM test. The empirical analysis reveals in Table 4; the investigated that the model does not suffer from any of the above issue. The LM test for serial correlation yields a p-value of 0.4181, suggesting no strong evidence of serial correlation in the data. The BPG test for heteroscedasticity results in a p-value of 0.7267,

indicating no significant heteroscedasticity. The Jarque–Bera test for normality provides a p-value of 0.4430, inferring that the residuals may follow a normal distribution. Overall, these p-values suggest no serial correlation, no heteroscedasticity, and normality of residuals may reasonably hold in the analysis.

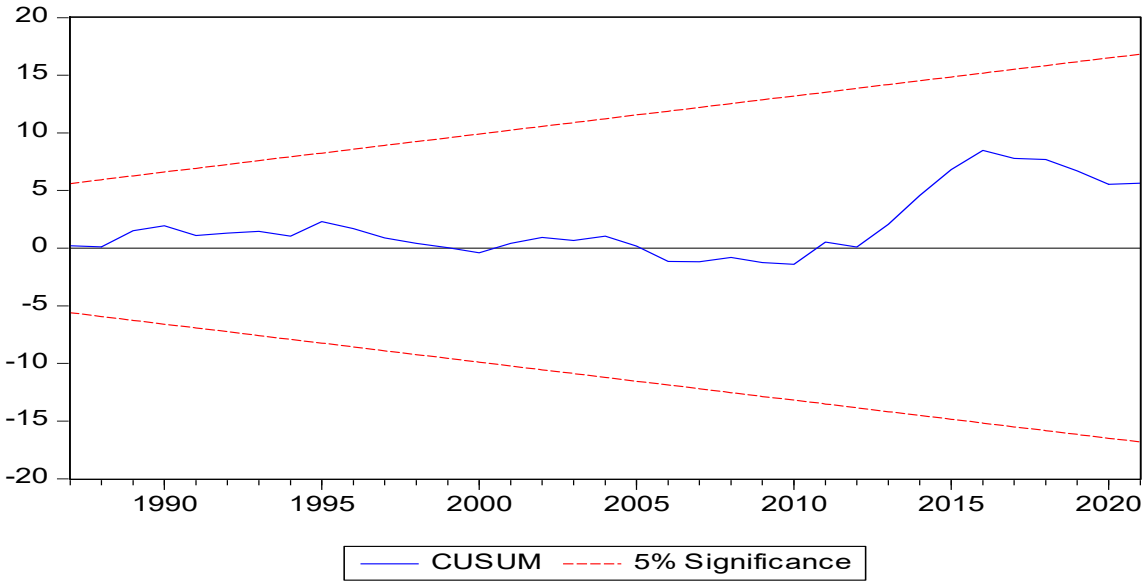
Table 4: Diagnostic Analysis

Diagnostic test	Serial Correlation χ^2 (P-value)	Heteroscedasticity χ^2 (P-value)	Normality (P-value)
LM test	**0.4181**		
Breusch-Pagan-Godfrey		**0.7267**	
Jarque–Bera			**0.4430**



The figure 1 indicate the analysis of CUSUM test, which specifies that the model's coefficients remain reliable over time, as the CUSUM line remains within the predetermined significance boundaries. This suggests that the regression model maintains stability and reliability in its parameters.

Table 4: Diagnostic Analysis



The establishment of a long-run relationship, as supported by (Bahmani-Oskooee and Bohl, 2000), relies on optimal lags and stock considerations. Using an excessive number of

lags or too few, as cautioned by (Stock and Watson, 2012), may lead to the loss of crucial information or result in unacceptable estimations. Recognizing the significance of optimal lags, we adopt three lags as the optimum choice based on the Akaike criteria. The results of the bounds test, presented in Table 5, interpret an F-statistic value of 8.771869, surpassing the critical value at a 5% significance level. This confirms the occurrence of asymmetric cointegration, necessitating the progression to asymmetric ARDL specifications.

5. Conclusion & Policy Recommendations

The purpose of this empirical analysis is to inspect the effect of RE and non-RE consumption on the economic growth of Pakistan from 1980 to 2021 by utilizing the ARDL approach. In conclusion, this analysis emphasizes the key role of energy utilization in determining economic growth and development. The analysis highlights the significance of RE sources in diversifying Pakistan's energy mix and falling dependence on fossil fuels. The ARDL bound test provides robust indication of a long-term connection between RE and NRE energy utilization and economic growth, underlining the likely for sustainable development through energy sector transformation. The findings of the long-term analysis indicate a substantial positive influence of RE sources on the country's economic growth., the analysis finds that few NRE (oil & coal) negatively influence GDP growth. Further, the study finds other independent variables like CS, LF and natural gas significantly influence GDP growth. Additionally, the adverse coefficient of the ECT value implies that the dependent variable adapts to its long-term equilibrium association with the independent variables at a rate of 48% per period, assuming the constancy of all other variables, and this outcome holds statistical significance. Overall, the outcomes revealed that RE consumption and the labor force are significant drivers of the GDP growth in the long run, and care should be followed when utilizing non-RE sources like natural gas, coal consumption and oil.

The potential directions for future research are recommended to employs advanced time-series techniques could highlight on short-term dynamics and potential fluctuations in energy utilization and economic growth. Incorporating panel data analysis, which reflects both cross-sectional and time-series variations, may provide a more comprehensive perspective.

Drawing upon the study's estimation, the following policy recommendations are proposed. The analysis reveals a noteworthy and positive long-term effect of RE utilization on GDP. Therefore, the government of Pakistan should increase investment in RE sources like solar, wind, hydel power to promote sustainable economic growth. Furthermore, the study found that non-RE sources meaningful influence on economic growth of the country. Though, negative association of oil and coal with GDP growth, indicates that heavy reliance on non-RE will be an alarming situation for the growth of the country. Therefore, the analysis advocates that government should reduce its dependence on non-RE sources and instead focus on promoting renewable energy sources to ensure sustainable economic growth.

References:

Lee, C. C., Zhang, J., & Hou, S. (2023). The impact of regional RE development on environmental sustainability in China. *Resources Policy*, *80*, 103245.

Raza, M. A., Aman, M. M., Rajpar, A. H., Bashir, M. B. A., & Jumani, T. A. (2022). Towards achieving 100% RE supply for sustainable climate change in Pakistan. *Sustainability*, *14*(24), 16547.

Dong, F., Li, Y., Gao, Y., Zhu, J., Qin, C., & Zhang, X. (2022). Energy transition and carbon neutrality: Exploring the non-linear impact of RE development on carbon emission efficiency in developed countries. *Resources, Conservation and Recycling*, *177*, 106002.

Syed, Q. R., Apergis, N., & Goh, S. K. (2023). The dynamic relationship between climate policy uncertainty and RE in the US: Applying the novel Fourier augmented autoregressive distributed lags approach. *Energy*, *275*, 127383.

Longden, T., Jotzo, F., Prasad, M., & Andrews, R. (2020). Green hydrogen production costs in Australia: implications of RE and electrolyser costs. *Centre for Climate & Energy Policy: Canberra, Australia*.

Malik, M. Y., Latif, K., Khan, Z., Butt, H. D., Hussain, M., & Nadeem, M. A. (2020). Symmetric and asymmetric impact of oil price, FDI and economic growth on carbon emission in Pakistan: Evidence from ARDL and non-linear ARDL approach. *Science of the Total Environment*, *726*, 138421.

Jafri, M. A. H., Liu, H., Usman, A., & Khan, Q. R. (2021). Re-evaluating the asymmetric conventional energy and RE consumption-economic growth nexus for Pakistan. *Environmental Science and Pollution Research*, *28*, 37435-37447..

Khan, Y., ShuKai, C., Hassan, T., Kootwal, J., & Khan, M. N. (2021). The links between RE, fossil energy, terrorism, economic growth and trade openness: the case of Pakistan. *SN Business & Economics*, *1*(9), 115..

Wada, I., Faizulayev, A., & Bekun, F. V. (2021). Exploring the role of conventional energy consumption on environmental quality in Brazil: Evidence from cointegration and conditional causality. *Gondwana Research*, *98*, 244-256.

Abbasi, K. R., Shahbaz, M., Jiao, Z., & Tufail, M. (2021). How energy consumption, industrial growth, urbanization, and CO2 emissions affect economic growth in Pakistan? A novel dynamic ARDL simulations approach. *Energy*, *221*, 119793.

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*, 32945-32961.

Yikun, Z., Gul, A., Saleem, S., Shabbir, M. S., Bilal, K., & Abbasi, H. M. (2021). The relationship between RE sources and sustainable economic growth: evidence from SAARC countries. *Environmental Science and Pollution Research*, *28*, 33390-33399.

Shahbaz, M., Raghutla, C., Chittedi, K. R., Jiao, Z., & Vo, X. V. (2020). The effect of RE consumption on economic growth: Evidence from the RE country attractive index. *Energy*, *207*, 118162.

Oryani, B., Koo, Y., Rezania, S., & Shafiee, A. (2021). Investigating the asymmetric impact of energy consumption on reshaping future energy policy and economic growth in Iran using extended Cobb-Douglas production function. *Energy*, *216*, 119187.

Mohsin, M., Kamran, H. W., Nawaz, M. A., Hussain, M. S., & Dahri, A. S. (2021). Assessing the impact of transition from nonrenewable to RE consumption on economic growth-environmental nexus from developing Asian economies. *Journal of environmental management*, *284*, 111999.

Le, H. P., & Sarkodie, S. A. (2020). Dynamic linkage between renewable and conventional energy use, environmental quality and economic growth: Evidence from Emerging Market and Developing Economies. *Energy Reports*, *6*, 965-973.

Kirikkaleli, D., Adedoyin, F. F., & Bekun, F. V. (2021). Nuclear energy consumption and economic growth in the UK: evidence from wavelet coherence approach. *Journal of Public Affairs*, *21*(1), e2130.

Abbasi, K., Jiao, Z., Shahbaz, M., & Khan, A. (2020). Asymmetric impact of renewable and non-RE on economic growth in Pakistan: New evidence from a nonlinear analysis. *Energy Exploration & Exploitation*, *38*(5), 1946-1967.

Pegkas, P. (2018). The link between energy consumption and environmental pollution. How effective is RE in reducing CO2 emissions? The case of

Greece. *International Journal of Energy, Environment and Economics*, *26*(2), 143-157.

Rahman, M. M., & Velayutham, E. (2020). Renewable and non-RE consumption-economic growth nexus: new evidence from South Asia. *RE*, *147*, 399-408.

Charfeddine, L., & Kahia, M. (2019). Impact of RE consumption and financial development on CO2 emissions and economic growth in the MENA region: a panel vector autoregressive (PVAR) analysis. *RE*, *139*, 198-213.

Zafar, M. W., Shahbaz, M., Hou, F., & Sinha, A. (2019). From nonrenewable to RE and its impact on economic growth: the role of research & development expenditures in Asia-Pacific Economic Cooperation countries. *Journal of cleaner production*, *212*, 1166-1178.

Mirza, F. M., & Kanwal, A. (2017). Energy consumption, carbon emissions and economic growth in Pakistan: Dynamic causality analysis. *Renewable and Sustainable Energy Reviews*, *72*, 1233-1240.

Abbasi, K. R., Shahbaz, M., Jiao, Z., & Tufail, M. (2021). How energy consumption, industrial growth, urbanization, and CO2 emissions affect economic growth in Pakistan? A novel dynamic ARDL simulations approach. *Energy*, *221*, 119793.

Waleed, A., Akhtar, A., & Pasha, A. T. (2018). Oil consumption and economic growth: Evidence from Pakistan. *Energy Sources, Part B: Economics, Planning, and Policy*, *13*(2), 103-108.

Danish, Zhang, B., Wang, Z., & Wang, B. (2018). Energy production, economic growth and CO 2 emission: evidence from Pakistan. *Natural Hazards*, *90*, 27-50.

Menegaki, A. N., & Tugcu, C. T. (2017). Energy consumption and Sustainable Economic Welfare in G7 countries; A comparison with the conventional nexus. *Renewable and Sustainable Energy Reviews*, *69*, 892-901.

Ahmad, A., Zhao, Y., Shahbaz, M., Bano, S., Zhang, Z., Wang, S., & Liu, Y. (2016). Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy. *Energy Policy*, *96*, 131-143.

Khan, D. I. (2015). Impact of energy crisis on economic growth of Pakistan. *International Journal of African and Asian Studies*, 33-42.

Adedoyin, F. F., & Zakari, A. (2020). Energy consumption, economic expansion, and CO2 emission in the UK: the role of economic policy uncertainty. *Science of the Total Environment*, *738*, 140014.

Nayyar, Z. A., Zaigham, N. A., & Qadeer, A. (2014). Assessment of present conventional and non-conventional energy scenario of Pakistan. *Renewable and Sustainable Energy Reviews*, *31*, 543-553.

Shahbaz, M., Zeshan, M., & Afza, T. (2012). Is energy consumption effective to spur economic growth in Pakistan? New evidence from bounds test to level relationships and Granger causality tests. *Economic Modelling*, *29*(6), 2310-2319.

Kakar, Z. K., & Khilji, B. A. (2011). Energy consumption and economic growth in Pakistan. *Journal of International Academic Research*, *11*(1), 33-36.

Mehrara, M. (2007). Energy consumption and economic growth: the case of oil exporting countries. *Energy policy*, *35*(5), 2939-2945.

Ozturk, I., Aslan, A., & Kalyoncu, H. (2010). Energy consumption and economic growth relationship: Evidence from panel data for low- and middle-income countries. *Energy policy*, *38*(8), 4422-4428.

Yusuf, A. M., Abubakar, A. B., & Mamman, S. O. (2020). Relationship between greenhouse gas emission, energy consumption, and economic growth: evidence from some selected oil-producing African countries. *Environmental Science and Pollution Research*, *27*, 15815-15823.

Adekoya, O. B. (2021). Revisiting oil consumption-economic growth nexus: Resource-curse and scarcity tales. *Resources Policy*, *70*, 101911.