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Does Environment Really Matter for Economic Sustainability: Exploring the Role of Green Energy in Pakistan's Economy

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ABSTRACT

The key objective of the study is to investigate empirically the long-run Environment and Growth Sustainability nexus in Pakistan economy. To empirically achieve the objectives of the study, the Auto-Regressive Distributed Lag (ARDL) Bound testing method was employed from 1990 to 2022. Green energy is used to signify environmental performance indicators and GDP growth rate along with other conventional growth factors; physical capital and human capital are used as potential economic sustainability indicators. To rationalize the findings of ARDL, restricted and unrestricted models are also estimated. The findings of the study disclose that the series under consideration are co-integrated which directs the existence of the long-run relationship. It is found that green energy enhances economic sustainability in the long run however it adversely impacts economic sustainability in the short run in the case of Pakistan's economy. The empirical outcomes of the study validate the widespread concern of the literature on the existence of the "growth hypothesis" which supports, that there is a systematic positive causation running from green energy to economic sustainability. The study findings suggest that regulations in the energy sector can encourage the applications of green energy resources, particularly in the real sector of the economy, leading to reduced emissions. It is important to adopt international standards for firms and industries and an international collaboration framework is required to ensure economic sustainability to prevent environmental degradation.

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1. Introduction

It is generally believed that environmentally friendly energy sources potentially contribute to sustainable economic growth and development through a variety of socioeconomic channels. It create domestic and regional economic opportunities, enhance the scope of domestic production, and augment exports of local products. Environmentally friendly energies are those renewable resources that do not adversely affect the quality of the environment, are infinite, are relatively cheaper over protracted periods, and are sustainable in the future (Huan & Hong, 2020). Green energy is the sole factor of production and is the solution to future environmental challenges. It is one of the key contributing factors of growth sustainability (Dincer & Rosen, 1998; Rosen, 1996). With the course of development, the consumption of energy has tremendously increased globally which has brought severe changes in the environmental state (Munir & Riaz, 2019). Authorities have long been concerned about addressing the environmental challenges but the environmental objectives along with economic growth could not be achieved due to policy incoherence. The majority of the countries across the globe face serious environmental challenges. The reason is that on one side the demands for energy are mounting multifold while on the other side, the global challenges to the environment are escalating which need serious attention. It is hypothesized that green energy, the environment, and, the economy go hand in hand and there are multiple indicators of all of this phenomenon. Generally, energy consumption, CO_2 emission as well as some composite indicators are taken as the environmental performance indicators (Dechezleprêtre, Koźluk, Kruse, Nachtigall, & De Serres, 2019) while GDP growth, physical and human capital accumulation, profitability indicators of firms and returns on assets or liquidity, etc. are taken as a key economic performance indicators. Among other important indicators of environmental performance, green energy is of prime importance. Generally, the consumption of energy can be classified into two major categories i.e., consumption of green energy commonly called renewable energy, and consumption of nonrenewable energy.

The majority of the globe is using environmentally unfriendly energy sources such as firewood, fossil fuels, natural gas, and petroleum products to meet the energy requirements at the domestic and commercial levels. Production of such fuel is damaging to our environment, and it has serious repercussions for global warming. On the other hand, renewable or green energy has the ability to renew itself and have environmentally friendly consequences. Studies show that renewable energy is a good source of economic development reduces local pollutants and mitigates environmental challenges (Masud, 2009). Among other developing countries, Pakistan has been facing severe energy problems for a few decades however there is huge potential for green energy technologies that can reduce the energy deficit by bridging the gap between the supply and demand of energy. Ever-increasing energy prices, a massive gap between supply and demand, and high reliance on imported energy are the key problems that hinder the growth of the manufacturing industry of the country. Neighboring countries like China and India have a substantial amount of green energy in their energy mix. Hence, encouragement of green energy technologies is unavoidable to maintain growth sustainability for any country. By following the pattern of other emerging nations, the demand for energy use has elevated up to 80 percent in Pakistan. During the 90s, it was 34 million TOE which almost doubled during the era of 2000 and reached up to 61 million TOE. Pakistan has a plentiful latent for green energy sources. For example, one of the cheaper sources of energy is Solar energy. The coastline precincts of Pakistan are very likely for wind energy production (Sheikh, 2010). It is projected that 50000MW of energy can be produced from wind energy. The landscapes of northern areas are much friendly and suitable for wind energy production. It is predictable that approximately 5000 villages can be electrified if wind energy is outfitted in the country.

The significant contributions of the current study are divided into the following distinctive ways. First, the novelty of this research highlights the significance of green energy technologies, on the sustainable economic growth and sustainable environment for Pakistan from 1980 to 2020. Consecutively, the original relation of green energy, economic performance through GDP growth, and energy reliance are examined by an empirical method. The present study is distinct from the preliminary studies to some degree, particularly the innovation of this study that appears from re-investigating the consequences of green sources from conventional energy sources. Second, the study establishes the short and long-run association between environment and economic sustainability, by exploring the role of physical capital formation, consumption of green energy, and human capital in Pakistan's economy. Third, the present study contributes to the existing body of literature on this matter by analyzing the relationship between the consumption of green energy in the form of renewables and its impact on economic sustainability and environmental sustainability in the case of Pakistan. For that purpose, the ARDL model is estimated for short and long-run analysis as suggested by the existing literature. Surprisingly, hardly any empirical studies explore the real impact and significance of green environmentally friendly energies on the economic and environmental variables together.

Largely, the analysis has been focused on the regional developed world and a focus on the national level, especially the developing countries like Pakistan has been given relatively less weightage. The current research has attempted to cover this gap, by empirically examining the impact of green energies on economic and environmental sustainability. It is however based on the previously constructed conceptual and methodological framework by different authors. Environment, green energy, and growth sustainability have largely been studied in the economic literature however, the majority of the studies focus on the energy production and consumption in manufacturing firms which tends to be the key source of toxic waste and pollution across the globe. The country has ample resources to achieve the goal of sustainable environment along with a sustainable economy. The current debate about the role of green energy is directed towards two key questions; does green energy consumption contribute to growth sustainability and does it lead to a sustainable environment? The objective of this study is to address these two key concerns as well as to empirically validate the relationship between green energy, environment, and growth sustainability and to re-investigate how environmental and economic performance go hand in hand in Pakistan. The empirical evidence of the study is in line with the previous studies that green energy impacts positively growth sustainability and there prevails a long-run positive association between green energy and economic sustainability.

2. Literature Review

Many studies in the past have been carried out to examine the linkages among energy, economic growth, and the environment. Payne (2011) argued that investing in environmentally friendly energy not only improves the environment but also satisfies the growth needs of the country. Thus investing in environmentally friendly energies makes growth sustainable. Similarly, Tiwari (2011) inspected that an enhancement in the share of renewable energy to the mix of total consumption of energy leaves a significant positive influence on economic performance. Comparatively, Magnani and Vaona (2013) have reached a different conclusion in the case of Italy. Trumpp & Guenther (2018) studied a global dataset of 696 firms and found that more carbon emissions due to non-renewable energy damage the environment and hence the firm's profitability through a U-shaped relationship. They further argued that there exists an environmental performance threshold above which only the environment is sustainable. Later, Palmer and Truong (2017) investigated the role of green technologies and firm's profitability. They argued that the introduction of green technological products can prove to be profitable for the firms. The reason is that new technological green products are built on technological advancements which minimize the environmental footprints, through better-quality energy and better techniques of waste management. M. A. Khan, Khan, Zaman, and Arif (2014); Sari, Ewing, and Soytas (2008) argue that growth accelerates the consumption of energy. Hence, to explain the environmental performance of the countries, energy consumption should be reduced. For example, in the USA, reducing energy consumption does not harm economic growth. Sadorsky (2009) has also found results that support this hypothesis which is also called the "conservation hypothesis". Studies validating the conservation hypothesis provide good news for the environment. As an implication, countries can reduce their energy consumption without halting their economic growth. Apergis and Payne (2010) studied the interrelationship between energy and growth in the OECD countries and found evidence of a two-way causal relationship between the economy and the environment. Similarly, Apergis and Payne (2012) argue that once some country invests in green energy, it would increase its economic growth which further increases investment in green energy through the multiplier effect and hence, a worthy cycle would begin. Contradicting, Ewing, Sari, and Soytas (2007) stated that the consumption of environmentally friendly energy does not contribute significantly to the economic growth of the USA. This is also called the neutrality hypothesis which was found to be true for European countries by Menegaki (2011).

In this context, there are some other key empirical studies that are important to discuss in the current scenario. Kisswani (2017) determined that there is a nonlinear asymmetric association between energy and economic performance in ASEAN countries. The relationship between the economy, environment, and consumption of environmentally friendly energy in the BRICS countries was examined by Liu, Zhang, and Bae (2017). Results showed that non-renewable energy impacts inversely on environmental health through CO_2 emissions, while other hand, renewable energy positively impacts on environment. In a similar manner, Appiah (2018) investigated the empirical relationship between Ghana's energy consumption, GDP, and CO_2 emissions and discovered that the consumption of energy caused economic growth with a substantial effect on CO_2 emissions. Further, Munir and Ameer (2018) explored both the short-run and long-run effects of trade, urbanization, technology, and economic growth on environmental degradation in developing Asian economies. The environmental Kuznets hypothesis between economic expansion and CO_2 emissions was supported by the findings. In a subsequent study, Munir and Riaz (2019) followed the same methodology and used a panel nonlinear ARDL model to examine the short- and long-term relationships between energy consumption and CO_2 emissions in South Asian economies. The study discovered that over time, the level of CO_2 emissions rises due to the rising use of non-renewable sources of energy, and vice versa. Through a nonlinear ARDL approach, Toumi and Toumi (2019) looked into the asymmetry of CO_2, renewable energy, and economic growth in the KSA. The long-term asymmetry between these variables was confirmed by the findings.

There is a large amount of studies that focused on the consumption of green and non-green energy sources, collectively support that the consumption of energy in any form has a significant positive association with CO_2 emission and consequently on economic performance (Ali, Anwar, & Nasreen, 2017; Liu, Zhang, & Bae, 2017; Shafiei & Salim, 2014). There is a mutual relationship among all of them, and the causal relation runs mostly from the use of energy to economic performance. Yet there is a need to reinvestigate the empirical relationship among green energies, environmental performance, and growth sustainability by using the most recent data. Yet there is hardly any consensus made in the literature about the way of causality and magnitude between economic growth and energy. Literature has found support for all possibilities of the linkages between economic growth and energy. The results of the studies are mostly dependent upon the choice of methodology, sample selection, and variables chosen.

3. Theoretical Underpinnings

To comprehend the empirical exercise, the study makes use of the most updated time series from 1990 to 2022. The key data sources are WDI and Penn World data. Neoclassical growth theory provides a sound theoretical foundation to analyze the Green Energy, Environment, and Economic Sustainability nexus. To start with the Cobb Douglas production function,

$$Y_t = A(GE)^{\alpha} (K)^{\beta} (L)^{\gamma} \tag{1}$$

Where, Y_t is represents GDP growth; GE shows the consumption of green energy, K and L are the conventional growth variables which are measured in terms of physical capital and human capital respectively. A is technological growth. In the Neoclassical formulation, returns to scale are associated with Green Energy (GE), Physical Capital (K), and Human Capital (L) expressed by α, β and γ, respectively. By following Layson (1983) the study took log-linear econometric modeling to attain reliable, improved, and unbiased empirical outcomes. Further empirical modeling of the Cobb-Douglus production function's log-linear functional form looks like the following.

$$Y_t = lnGE_t + lnGFCF_t + lnLF_t + U_t \tag{2}$$

Where Y_t, $lnGE_t$, $lnGFCF_t$ and $lnLF_t$ are real GDP growth, the logarithm of consumption of Green Energy (% of total energy), Gross Fixed Capital Formation (% of GDP) and Labor Force participation (% of total population 15+), respectively. Keeping the technology constant, this specification will investigate empirically the long and short-run nexus between environment, and economic sustainability. To empirically investigate the long-run relationship among the series, the study employs the ARDL bounds testing, which has its own advantages over other co-integration techniques. As in the above econometric specification, integration order is found at difference so we are free to use any suitable co-integration method to justify the study findings. However, due to the short time series, Johanson co-integration is not very suitable in this analysis. However, ARDL is found to be more suitable (Haug, 2002). The unrestricted ARDL model captures the data-generating process by choosing the proper lag length and it also helps to carry out the short-run as well as the long-run analysis (Shahbaz, Lean, & Shabbir, 2012). The following equations present the ARDL unrestricted and restricted econometric specifications.

$$\Delta Y_t = \alpha_1 + \alpha_t T + \alpha_y Y_{t-1} + \alpha_R lnGE_{t-1} + \alpha_k lnK_{t-1} + \alpha_l lnL_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta lnY_{t-i} + \sum_{j=1}^{p} \alpha_j \Delta lnR_{t-j} + \sum_{l=1}^{p} \alpha_l \Delta lnK_{t-l} + \sum_{m=1}^{p} \alpha_m \Delta lnL_{t-m} + u_t \tag{3}$$

$$\Delta lnR_t = \beta_1 + \beta_t T + \beta_y Y_{t-1} + \beta_R lnGE_{t-1} + \beta_k lnK_{t-1} + \beta_l lnL_{t-1} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=1}^{p} \beta_j \Delta lnR_{t-j} + \sum_{l=1}^{p} \beta_l \Delta lnK_{t-l} + \sum_{m=1}^{p} \beta_m \Delta lnL_{t-m} + u_t \tag{4}$$

$$\Delta lnK_t = \rho_1 + \rho_t T + \rho_y Y_{t-1} + \rho_R lnGE_{t-1} + \rho_k lnK_{t-1} + \rho_l lnL_{t-1} + \sum_{i=1}^{p} \rho_i \Delta lnY_{t-i} + \sum_{j=1}^{p} \rho_j \Delta lnR_{t-j} + \sum_{l=1}^{p} \rho_l \Delta lnK_{t-l} + \sum_{m=1}^{p} \rho_m \Delta lnL_{t-m} + u_t \tag{5}$$

$$\Delta lnL_t = \lambda_1 + \lambda \rho_t T + \lambda_y Y_{t-1} + \lambda_R lnGE_{t-1} + \lambda_k lnK_{t-1} + \lambda_l lnL_{t-1}$$

$$+\sum_{i=1}^{p}\lambda_i\Delta Y_{t-i} + \sum_{j=1}^{p}\lambda_j\Delta lnGE_{t-j} + \sum_{l=1}^{p}\lambda_l\Delta lnK_{t-l} + \sum_{m=1}^{p}\lambda_m\Delta lnL_{t-m} + u_t \quad (6)$$

Where, Δ indicate the differenced term and u_t is the residual term. To choose the suitable lag structure, the study uses the "Schwarz information criterion" (SIC) at first differenced time series. To determine whether the coefficients of the lagged series are significant, the F-test is used (Pesaran et al., (2001). According to the null hypothesis: $H_0 = \alpha_y = \alpha_R = \alpha_k = \alpha_l = 0$, there is no long-run relationship among the time series shown in Eq. (2) against the alternate hypothesis $H_1 \neq \alpha_y \neq \alpha_R \neq \alpha_k \neq \alpha_l \neq 0$, there exists a long-run relationship between the chosen series. By following Pesaran, Shin, and Smith (2001), the asymptotic higher and lower bounds help to decide whether the time series are co-integrated in the long run or otherwise. By following the rule, if all of the series are stationary at level then lower critical bounds are taken to test co-integration but if the series are co-integrated at first difference, then upper critical bounds are used to grasp the long-run association. The decision-making process in co-integration is based on F-statistics; if the F-statistic is larger than the upper critical constraint, co-integration is present however there is no co-integration when F-statistics does not exceed the lower critical bound. Moreover, given that it resides between these two bounds (upper and lower), it is termed as the impulsive value of F-Statistics with regard to co-integration.

4. Results and Discussions

Before jumping into the empirical findings, it is appropriate to comprehend a short summary of the study series. For that purpose, Table 1 shows the summary statistics of the variables under study. The variance, means, minimum, and maximum of each series are given against each variable. Y_t and lnL_t are skewed negatively, whereas all other series are positively skewed. The probability value of Jarque-Bera is insignificant for all variables which shows that all of the included series are normally distributed. Observations are the same because the study has used the annual time series for a single country, Pakistan from 1990 to 2022.

Table 1: Summary Statistics of Series Under Consideration

	Y_t	$lnGE_t$	lnK_t	lnL_t
Mean	4.158	3.896	23.614	17.689
Median	4.427	3.860	23.590	17.703
Maximum	7.705	4.062	24.625	18.118
Minimum	0.988	3.790	22.657	17.253
Standard Deviation	1.796	0.077	0.603	0.275
Skewness	-0.025	0.594	0.064	-0.033
Kurtosis	2.351	2.194	1.545	1.721
Jarque Bera	0.528	2.577	2.666	2.048
Probability	0.767	0.275	0.263	0.359
Sum Sq. Dev.	93.580	0.174	10.576	2.200
Observations	30	30	30	30

To carry out the time series analysis, the study employed suitable diagnostics. Firstly, the problem of non-stationary is detected by using the standard tests; 1) Augmented Dicky Fuller (ADF) and 2) Phillip Perron (PP). Findings suggest that all of the included time series are unit roots at the level however they are stationary at the first difference (Table 2). Phillip Perron (PP) test is considered better as compared to other traditional unit root tests due to its less sensitive behavior in the presence of autocorrelation. This is the reason that it is the more reliable test when the data is more likely to have an issue of serial correlation. Even when the fundamental normally distributed errors are violated, the PP test can still function successfully. Secondly, the problem of serial correlation is detected by using the LM serial correlation test and ARCH test. Thirdly, the functional form of the econometric specification is verified by using the Ramsey reset test. Fourthly, stability tests such as Cumulative Sum (CUSUM) is also used to check the authenticity of ARDL-bound test outcome. Lastly, to resolve the likely problems of endogeneity and residual serial correlation, the study employed the ARDL estimation approach (Pesaran, Shin, & Smith, 2001).

Table 2: Stationarity Analysis of the Series

ADF test				PP test		
Series	**I(0)**	**I(1)**	**Remarks**	**I(0)**	**I(1)**	**Remarks**
Y_t	-0.682* (0.015)	-1.266* (0.000)	I (1)	-0.682* (0.017)	-1.266* (0.000)	I (1)

$lnGE_t$	-0.082	-1.099*		-0.082	-1.165*	
	(0.393)	(0.000)	I (1)	(0.343)	(0.000)	I (1)
lnK_t	-0.039	-1.023*		-0.039	-1.019*	
	(0.747)	(0.000)	I (1)	(0.747)	(0.000)	I (1)
lnL_t	-0.001	-1.000*		-0.001	-0.936*	
	(0.196)	(0.000)	I (1)	(0.196)	(0.000)	I (1)

* show the significance @1%

Before applying the suitable integration technique, it is essential to check the integrating orders of the time series (Baum 2004). ARDL bounds testing can only be done on I(0) or I(1) integrated series. Conversely, the F-statistic becomes irrelevant when the variables are integrated at I(2). In the unit root analysis (table 2), it is clear that the variables are stationary at I(1) while the unit root at I(0), and hence all of the series on the right-hand side are integrated of order one I(1). As ARDL bound test identify the occurrence of long-run relationship among different time series it is important to fix the number of suitable lags. The current study has applied all necessary criteria for lag selection and uses the "Schwarz Information Criterion (SIC)" to choose the appropriate lag length (Table 3).

Table 3: Criteria of Lag Selection of the Series

Lags	logL	LR	FPE	AIC	SIC	HIQ
0	23.457	NA	2.63e-06	-1.496	-1.303	-1.441
1	148.576	202.115*	6.07e-10	-9.890	-8.922*	-9.611
2	158.340	12.768	1.08e-09	-9.410	-7.668	-8.909
3	183.219	24.878	7.21e-10	-10.093	-7.577	-9.369
4	210.002	18.542	5.91e10*	-10.923*	-7.632	-9.975*

Note that the * designates the order of lag which is chosen through some criterion

Table 4 reports the empirical results (the short-run and long-run) of the model. The short-run results demonstrate that the impact of green energy and its lagged impact is significant but appears with the opposite sign. This clearly leads to the conclusion that; In the short run, green energy inversely impacts economic sustainability. These findings contradict (Arif, Sadiq, Shabbir, Yahya, Zamir, & Bares Lopez, 2022; Gasparatos, Doll, Esteban, Ahmed, & Olang, 2017; Pahle, Pachauri, & Steinbacher, 2016). However, these findings support (Bouyghrissi, Berjaoui, & Khanniba, 2021; Khribich, Kacem, & Dakhlaoui, 2021). The possible economic justification could be that improving environmental performance may induce costs in a shorter period of time but benefits in the longer run. Social development is not enough to affect green energy in the short term. In developing economies like Pakistan, at the initial stage, the cost of green technologies is comparatively higher, and it is challenging to magnify its applications across different sectors. As long as the development takes place in the longer run, the benefits of green renewable technologies in the energy sector steadily becoming significant, serving as a key tool for economic development. This is the reason that the short-run impacts of green energy in Pakistan are negative.

Similarly, the lagged impact of physical and human capital contributes significantly to economic sustainability. Most importantly, ECM is statistically significant with an inverse sign ECM(t-1) which supports the previous arguments of the well-known long-run relationship among green energy, environment, and economic sustainability in Pakistan's economy. The findings contradict the outcomes of Namahoro, Wu, Xiao, and Zhou (2021), however, these findings support the argument of Azam, Rafiq, Shafique, Zhang, and Yuan (2021); M. M. Khan et al. (2016); Maji and Adamu (2021); Usman, Akadiri, and Adeshola (2020) and show that the consumption of green energy positively impacts economic performance, hence environmental sustainability impact economic sustainability in the longer run. The empirical findings of restricted and unrestricted models (Appendix) also support the view that in the short-run, green energy do not positively impact economic sustainability however, it does impact positively in the longer run. Keeping all else constant, the coefficient of our variable of interest; green energy is 14.672 which shows that in the long run, a 1% rise in green energy may stimulate economic sustainability by 14.672 %. In addition, green energy impacts positively to economic sustainability at a 1% level of significance.

Table 5. presents the bound test's findings. It is evident that there exists a long-term relationship between the variables. It is important to estimate the error correction term (ECT)

which reiterates and suggests a long-run co-integrating relationship between the series of empirical models. The analysis specifies that the estimate of $\mathrm{ECT}(-1)$ is -0.032, significant at a 1% significance. The value of ECT designates that if any deviation from the steady-state equilibrium occurs, it will adjust back to equilibrium at a 3% rate of adjustment. The negative sign implies the speed of convergence of the economic growth (Y_t). Notably, the coefficient value shows that equilibrium is corrected in the long run at the speed of 3 percent annually.

Table 4: ARDL (Short and Long Run Results)

Variable	Co-efficient	S.E	t-statistics	P-value
Long Run results				
lnY_t	-3.325*	0.477	-6.966	0.000
$lnGE_t$	48.800*	8.954	5.449	0.001
lnK_t	4.954***	2.537	1.952	0.091
lnL_t	6.216	4.935	1.259	0.248
Short Run results				
$lnGE_t$	-61.647*	10.975	-5.616	0.000
$lnGE_{t-1}$	8.533	13.042	0.654	0.533
$lnGE_{t-2}$	29.320***	12.872	2.277	0.056
$lnGE_{t-3}$	27.756***	12.312	2.254	0.058
lnK_t	7.113**	1.656	4.295	0.003
lnK_{t-1}	7.225**	2.797	2.582	0.036
lnK_{t-2}	0.691	2.083	0.331	0.749
lnK_{t-3}	0.981	2.268	0.432	0.678
lnL_t	16.221	21.725	0.746	0.479
lnL_{t-1}	58.766***	26.627	2.207	0.063
lnL_{t-2}	-14.213	23.891	-0.594	0.570
lnL_{t-3}	-14.095	23.885	-0.590	0.573
lnL_{t-4}	-40.463***	21.257	-1.903	0.098
$ECT(-1)$	-0.032*	0.047	-6.966	0.000

Explained variable $\boldsymbol{lnY_t}$ * shows the 1% level of significance ** shows the 5% level of significance *** shows the 10% level of significance

Next, we examine the stability of the confidence in the short run and long run. For that purpose, we have performed the ARDL bound test of stability for the ECM model, discussed in the preceding section. The soundness of the ARDL bound test is initially based on its F-Statistics. The current empirical estimations confirm that F-statistics is 17.892 which is significant at all levels of significance (1%, 5%, and 10%). Further, F-statistics is greater than all critical values of the upper bound (Pesaran, Shin, & Smith, 2001). This directs towards the rejection of the Null hypothesis which states that "there is no long-run relationships exist between the series". The study safely argues that there exists a long-run relationship between Environment and economic sustainability and in this context, green energy plays a significant role. These statistics confirm the existence of co-integration among the included series in Pakistan over the studied period (1990–2022).

Table 5: ARDL Bound Test Analysis

Critical value	Higher Bound I(1)	Lower Bound I(0)	F-Statistics	Durbin Watson
10%	3.77	2.72		
5%	4.35	3.23	17.892*	2.031
2.5%	4.89	3.69		
1%	5.61	4.29		

Note: * indicate the level of significance @ 1%. H_0: Series are not integrated in the long run

After the findings if the ARDL bound test, it is vital to recognize the stability of parameters. For that purpose, the Cumulative Sum (CUSUM) test is employed. This helps to show whether the coefficient regression is changing systematically or not. Plot 1 is presented here by a blue line that falls in between the given array of upper and lower bounds shown by two red lines. The red lines are actually reflecting the upper and lower bounds at a 5% significance. As in plot 1, the analysis of stability checks, the blue line falls in between the red lines, suggesting that the residual variance follows stability. Hence we accept the hypothesis that parameters are stable (desirable). The bottom line is, the ARDL findings are stable and robust. Therefore, the findings designate that there is no instability in the error correction model. This also entails that the empirical findings of ARDL co-integration are consistent, reliable, and robust for this analysis at a 1% level of significance.

Figure 1: Parameters Stability Diagnostics (CUSUM)

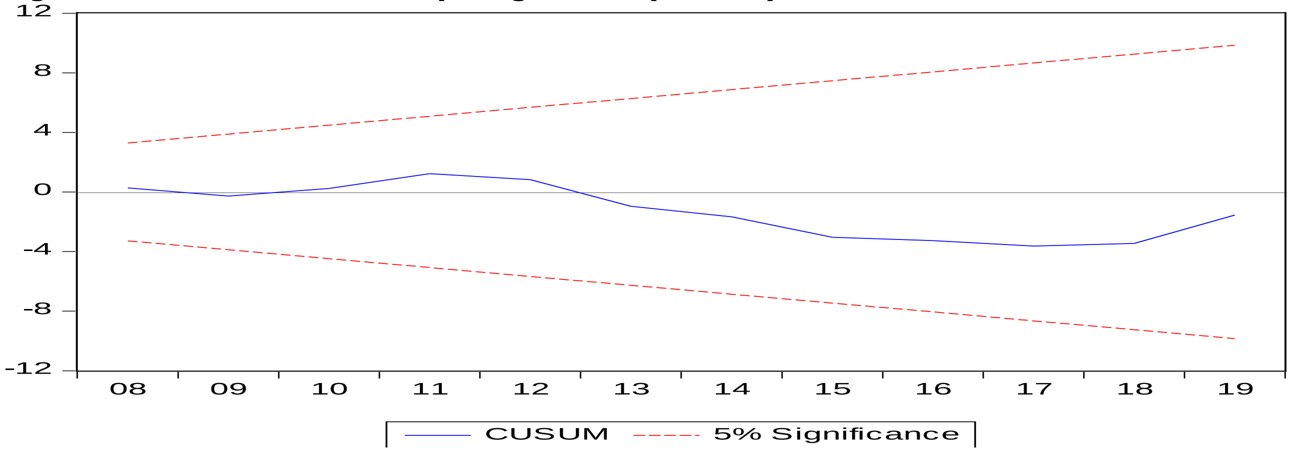

Table 6 present the key diagnostics: goodness of fit, serial correlation, heteroscedasticity, and stability of the empirical outcomes. The presence of serial correlation is detected by using the LM serial correlation test. On the basis of these diagnostic tests reported in Table 6, it is evident that the model is not suffering from the problem of serial correlation. Similarly, to check whether errors are heteroscedastic or not, the ARCH test is employed which exhibits that the series of residuals is homoscedasticity. To check the accurate functional form of the model, the Ramsey reset test is employed which appears with an insignificant p-value and shows that the model's functional form is acceptable and well-specified. Furthermore, adjusted R^2 shows that 97% of the variations in economic sustainability are explained by regressors of the empirical model, confirming the goodness fit of the specification. Lastly, to analyze the robustness of the empirical outcomes and model stability, the CUSUM stability test is used which is discussed above. By recursively estimating the coefficients and residuals of the regression equation, this test produces a graph (figure 1). It is evident from Plot 1 that the stability line represented by the blue line lies between the critical red lines, signifying the stability of the residual variance.

Table 6: Diagnostic checks

Description	Test statistics	Conclusion
R^2 and adjusted R^2	0.971 (0.676)	The model is fitted good
χ^2SERIAL	0.024 (0.976)	The problem of serial correlation is not present
χ^2ARCH	0.457 (0.505)	Errors are Homoscedastic
χ^2REMSAY	3.405 (0.114)	The model's specification is satisfactory
CUSUM	---	The model is stable

Theoretically, when there exists co-integration, there must exist an error correction mechanism. In this regard, restricted and unrestricted models are estimated (Appendix A1 & A2). The findings of the restricted model are the same as the findings of the ARDL bound test. The unrestricted model shows the long-run form and all the long-run relationships are well specified in this model. When this long-run relationship is replaced by its residuals, the model turns into ECM because the Error Correction term automatically corrects the disequilibria that occurred in the short-run, by bringing the situation to a steady state. According to Pesaran, Shin, and Smith (2001), we distinguish the long-run relationship (co-integrating equation) (and thus the bounds-test and the restricted ECMs) in different cases. All cases do differ in terms of whether the intercept and the trend are restricted to contribute in the long-run relationship or they are unrestricted and so they contribute in the short-run relationship only. For the robustness and sensitivity analysis, the study also makes use of the Johansen multivariate co-integration analysis. The empirics of the Johanson co-integration test are stated in Table 6. Here we refer to trace statistics and maximum Eigen statistics. Each value of both of these statistics is greater than its critical range which explicitly confirms the existence of long-run relationship between series. Further, the significant p-values also support the long-run hypothesis.

Table 6: Johansen Cointegration Analysis

Hypothesis	Trace Statistic	Critical Range	P-Value	Maximum Eigen Value	Critical Range	P-Value
None *	148.205	47.9*	0.000	74.226*	27.6*	0.000
At most 1 *	73.979	29.8*	0.000	39.406*	21.2*	0.000
At most 2 *	34.572	15.5*	0.000	29.621*	14.3*	0.000
At most 3 *	4.951	3.9*	0.026	4.951*	3.9*	0.026

5. Conclusion and Policy Suggestions

The key purpose of the current research is to investigate and validate the existing empirical evidence that does environment, and economic Sustainability nexus go hand in hand in Pakistan. The study used green energy as an environmental performance indicator and physical and human capital as key economic sustainability indicators in the case of Pakistan spanning from 1990-2022. The study hypothesis is tested empirically with the help of the ARDL model which confirms the long-run relationship among the economic and environmental variables. For the sensitivity analysis and robustness checks, the bound, Johanson co-integration, and CUSUM stability tests are also applied. The empirical outcomes of ARDL and Johanson co-integration support the findings of the bound test. Largely the findings of the study confirm that the variables are co-integrated in the long run over the period of 1990 – 2022. Based on these empirical findings, it is safely concluded that green energy raises long-run economic sustainability while in the short-run, green energy does not play a significant role in economic sustainability. Conventional growth factors such as physical capital and human capital are also very important for economic sustainability contributing positively to the output of the country. So, the study lastly argues that it really pays to be green. On the basis of the study findings, it is suggested that it is very important to invest in the green energy sector of the economy to achieve economic and environmental sustainability. Green technologies are significant, so there is a need to invest in environmentally friendly technologies. It is important to adopt international standards in the production process by the firms and industries and an international collaboration charter is required to guarantee the sustainable growth path of the economy and environment. As the current study is conducted under certain assumptions and limitations there is a great need to further explore the present study from a broader perspective. The same hypothesis can be tested by future researchers at the regional level by using the panel data. Similarly, other environmental aspects must be taken for the sensitivity analysis.

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