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Asymmetric Impact of Renewable Energy Consumption on Environment in Pakistan

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ABSTRACT

Although the current literature has widely explored the paraphernalia of renewable energy on environment, the literature overlooks the asymmetric association of renewable energy with the environment. To contribute this gap in the existing body of related literature, this study carry out the nonlinear impact of renewable energy consumption along with control variables like non-renewable energy, urbanization, and gross domestic product on CO2 emission in Pakistan. The study employs the nonlinear autoregressive distributed lag model (NARDL) from 1980 to 2018. The results reveal that renewable energy consumption mitigates the environmental degradation asymmetrically. While other variables non-renewable energy consumption, gross domestic product and urbanization positively associated with Co2 emissions. The study gives some guidance for policymakers of Pakistan that should formulate policies and regulations to promote renewable energy usage which mitigates environmental degradation.

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1. Introduction

Due to the impact of shifting weather patterns and rising sea levels over practically all regions of the world, climate change has become an issue that transcends national borders (Adebayo et al., 2022). Today's sustainable environment and economic growth have become the hottest issues for the emerging world. It is currently a problem for practically all economies (Ali et al., 2022). The tremendous increase in CO_2 emission causes environmental degradation (Tanveer et al., 2021). Greenhouse gases that are added to the environment with this percentage as carbon dioxide CO_2 (90%), Methane (9%) and Nitrogen gases (N2) are only (1%). Most of the energy sources also perform a basic role in this scenario. The fossil energy sources are a very facilitating source for the manufacturing sector but also a big source of carbon emission. In 1997 Kyoto Protocol take a step for a reduction of emission of these greenhouse gases. Pakistan is the most affected country by these energy sources and climatic changes also have a more adverse effect on the environment (Farooq et al., 2020). When the economic growth of Pakistan is shifted from agriculture to the industrial sector it consumes more energy sources for the manufacturing sector. So, when the production increased then the energy usage is also increased (Solomon et al.2021). Pakistan is also dependent on more renewable sources of energy like natural gas, coal, and oil, for the manufacturing sector. So, the industrial sector releases more carbon emissions in the respect of production which destroyed the whole environment's sustainability (Meng et al., 2021). In the year 2014, a report shows Japan, India and Russia are considered highly producing CO_2 emissions. In this regard, Pakistan is the fifth-ranked country for the last 20 years.

While the growing threat of global warming and climate change has engrossed emphasis on the link between economic growth and pollution, study into the influence of renewable energy as a potential panacea for emission reductions has been noticeable by its absence (Apergis et al., 2010). Renewable energy, according to the literature, aids in enhancing energy efficiency and tackling global warming issues. Depending on the scenario, sources of renewable energy could provide 50% of the world's energy needs by 2050, averting ecological disaster (Kirikkaleli and Adebayo, 2021). The energy sectors of nations must be reorganised in order to curb climate change and reduce emissions. Global economic activity, which is primarily what drives usage, will shed light on how usage underwrites to the creation of global emanations. Energy use and emissions are significantly influenced by consumer behaviours and lifestyles. A significant amount of the global greenhouse (GHG) productions can be linked to consumer behaviour and trends. Economic activity geared toward development and growth, such as prouctions and manufacturing, which involves the production and usage of goods, is one of the factors contributing to climate modification. The shift from an agrarian to an industrial society paved the door for an overindulgent use of fossil fuels, which has contaminated the earth's bodies. Two viewpoints on the economic activities that result in emissions are usage and production. Production-based emissions are made up of all carbon dioxide footprints from domestic and foreign fabrication of services and goods, whereas usage-based emissions are triggered by the nation's final demand for services and goods that are produced primarily overseas. A general increase in wealth typically results in increased usage, which is one of the key factors contributing to global resource use and environmental degradation (Adebayo et al., 2021).

Urbanization will continue, but there are clear worldwide efforts to cut carbon emissions. Researchers have also suggested that cities change their approach to economic expansion and focus on both the rate and character of growth. Future CO2 emissions from the construction industry will also rise due to the rising demand for infrastructure and buildings. The total CO2 emissions linked to urbanisation could be decreased with the help of decreased CO2 productions from the construction and buildings sector. However, it is quiet unclear if urbanisation and CO2 releases from the building sector are related. Significant struggles have lately been designed in current studies to examine the affiliation between urbanisation and CO2 emanations (Shahbaz et al., 2016).

Many of the reasons that work behind the story of the environmental degradation when natural sources are destroyed, deforestation, pollution in the air, erosion of soil pollution in water sources and also the rapid growth of population. Many countries are focused on the production process and neglect the destruction of the environment (Cheng et al., 2021). Most of the evidence shows that greenhouse gases especially CO_2 emissions are creating many challenges on Earth. Because of these facts, greenhouse production especially CO_2 emissions take the attention of researchers, where evidence shows, the energy usage (Tanveer et al., 2021), population (Faheem et al, 2021), foreign direct investments (Chaudhry et al, 2021).

Aside from introduction, the remaining portion of the paper is as given: Section 2 presents the literature review of previous studies, and section 3 outlines the methodology. Section 4 and 5 portray the discussion of results and policy recommendations.

2. Literature Review

Adebayo et al. (2021) researched Chile about the nonlinear association of renewable energy usage with CO_2 emission by employing nonlinear ARDL estimation methodology from dataset 1990-2018. The authors inveterate the presence of the nonlinear influence of renewable sources of energy on CO_2 emission. Similarly, Adebayo et al. (2022) guaged the connectedness of trade openness, GDP, and renewable energy usage with CO2 emission by utilizing a novel method quantile on quantile dataset spanning from 1965 to 2019 in Sweden. The upshots from the study bare the asymmetric impact of trade openness, renewable energy usage and economic growth on CO_2 emission. Liu et al. (2020) probe the linkage of green energy and CO_2 emission in BRICS and findings support that green energy helps to lessen CO_2 emission. Similarly, the study of Waheed et al. (2017) explored the association of renewable energy usage and CO_2 emission amid Pakistan and found negative association between concerned variables. Besides, some studies portrayed the reverse findings in their empirical works about renewable energy usage and the environment. They found a positive significant but some found insignificant association between renewable energy usage with CO_2 emission. For instance, Apergis et al. (2010) conducted the research to reveal the linkage of renewable energy usage with CO_2 emission in 19 developed and developing countries and notice pragmatic significant connection of renewable energy and CO_2 emission. Nathaniel and Iheonu (2019) estimated the connectedness of renewable energy and CO_2 emission in Africa and found an insignificant association between the concerned variables. The study of Mehmood (2022) tries to look into the factors of financial inclusion, GDP, globalisation, and renewable energy on CO_2 productions. Second-generation approaches are used to evaluate annual data from 1990 to 2017. Financial inclusion, according to the studies, increases carbon dioxide emissions.

Kasman et al. (2015) discovered a link between CO_2 emission, energy usage, trade openness, urbanisation, real income, and in EU member and economic development candidate nations. The results revealed that trade openness, GDP, energy usage, and urbanization are significantly affected by CO_2 emissions. In order to analyse the dynamic relationship between economic development, financial development, and energy usage on CO2 emissions during the years 1980 to 2010, Nasreen and Anwar (2015) used the Granger causality and cointegration methodology. According to the data, financial development reduces environmental deterioration in high-income nations while increasing CO2 emissions in middle- and low-income panels. Park et al. (2018) estimated the link between ICT, financial development, economic growth, trade openness and CO2 productions using panel data for selected European Union countries for the period 2001-2014 by employing pooled mean group methodology. Results highlighted that electricity usage is associated positively while financial development and economic development are negatively affected. Arif et al. (2020) pointed out the fact that there is a dynamic link between financial development, trade openness, globalization and environmental degradation and economic growth by conducting study on South Asian countries. Empirical results revealed a positive and significant association with financial development.

Bayar et al. (2021) described the association of municipal wastage, recycling energy, renewable sources of energy, energy usage with CO_2 in European Union nations. The employed cointegration and casualty analysis were employed during 2004-2017. The findings revealed the significant effect between renewable energy, recycling rate and CO_2 emissions. Adewuyi and Awodumi. (2017) evaluated the connection between biomass energy usage, economic growth and CO2 emissions in West African countries. The study used panel data with causality analysis over the period 1980 to 2010. The findings showed that feedback relationship between concerned variables. More GDP and carbon releases in five countries while the remaining countries have unidirectional causality. In 13 Asian emerging nations, Gao and Zhang (2021) explained the connection between CO2 emissions, biomass energy usage, economic expansion, and urbanisation. The study applied the FMOLS method for the period 1980 to 2010. They found urbanization with CO2 is positive and significant, while biomass did not reduce carbon dioxide productions.

According to Shahbaz et al. (2016), urbanisation seems initially reduces CO2 emissions but subsequently increases them once a specific threshold is achieved. This link between urbanisation and CO2 is U-shaped. The causation analysis reveals that Granger's urbanisation results in CO2 emissions. This research of Ahmed et al. (2019) looked at the non-linear relation between urbanisation and CO2 releases from 1971 to 2014 amid Indonesia. The data showed that urbanisation and CO2 emissions have an inverted U-shaped connection. Urbanization boosts CO2 emissions initially, but after a certain point, it has a negative impact on emissions. Shahbaz et al. (2017) determined the linkage of biomass energy usage, urbanization with CO_2 emissions in the US. The results revealed biomass energy usage reduces carbon dioxide emissions, while urbanization and energy usage on carbon dioxide emission had mixed results.

Salahuddin et al. (2018) estimated ARDL, cointegration VECM, and Granger causality methodologies for a time series of Kuwait from 1980-to 2013. With the help of this information, we looked at the empirical relationships between CO2 discharges, electricity usage, and financial development, economic growth, and foreign direct investment. Findings showed that FDI and power usage had a positive link among CO2 emissions in both the long and short directions of economic expansion. Shahbaz et al. (2017) determined the association of various variables like energy usage, economic growth, income, globalization, climate change with environmental degradation for the period of 1970-to 2014 in one country, Japan. They used the NARDL threshold methodology. This estimation revealed the results that globalization with CO_2 emissions association is linear, unwanted climate change, and in Japan verse changing for globalization and economic usage. Sun et al. (2020) determined the linkage between CO_2 productions, environmental hazardeous pollution regulation and foreign direct investment in China from specific manufacturing sectors. They employed techniques for the data from 2001 to 2007. Findings indicate environmental regulations and foreign direct investment caused production of manufacturing pollution. EKC validates pollution in China. Tanveer et al. (2021) conducted the relationship between financial development, foreign direct investments, ENR, and globalization on CO2 emissions in Pakistan. ARDL, NARDL methodologies employed for the period 1985-2018. The empirical findings showed a positive relationship between globalisation and foreign direct investment as well as a negative relation between ENR and CO2 emissions.

The analyzed symmetric and asymmetric link for energy usage (EC) and CO2 gases in Pakistan has been studied by Tanveer et al. (2022). From 1976 to 2019, ARDL and NARDL techniques are used for empirical testing. According to the findings of NARDL, same negative with positive shocks to the EC significantly boosted CO2 emissions in the short term. That's why, over time, Pakistan's CO2 emissions are greatly reduced by negative shocks and little affected by positive shocks. To encourage the usage of renewable energy, it is advised that the government stressed on clean energy production programmes. In a similar vein, it is expected that ecologically responsible planning at the capital investment level of manufacturing activities and the proper use of environmental degradation levies will be advantageous in reducing carbon footprints.

3. Econometric Methodology

Our study uses unit root tests (ADF & PP) to check the sequence of integration. The existence of cointegration the employs F-bound test. The study uses an autoregressive distributed lag model because it's better to standard mixed-order of integration with no variables are stationary at I. (2).

3.1 Data Sources

The study covers data from 1980-to 2018 for Pakistan. Table 1 shows the detail of variables.

Table 1

Variable	Symbol	Description	Data Source
Carbon Emissions	CO_2	CO_2 emissions (kt)	World Bank
Renewable Energy	RENR	Renewable Energy consumtion	World Bank
Non-renewable Energy	ENR	Energy Use (Kg of Oil Equivalent per capita)	World Bank
Gross Domestic Product	GDP	GDP growth (annual %)	World Bank
Urbanization	URBN	Urban Population	World Bank

3.2 Models Specification

The study is based on the following model in which renewable energy usage is the main independent variable and nonrenewable energy, gross domestic product and urbanization is taken as control variables against the CO_2 emission dependent variable. All variables are used in logarithmic form to tackle the normality issues.

$$LCO_2 = f(LRENR, LENR, LGDP, LURBN) \qquad (1)$$

Where LCO_2 is the carbon dioxide, LRENR is the renewable energy, LGDP is the gross domestic product of the country, LENR is the energy , and LURBN stands for urbanization.

$$LCO_{2t} = \gamma_0 + \gamma_2 LRENR_t + \gamma_3 LENR_t + \gamma_4 LGDP_t + \gamma_5 LURBN_t + \mu_t \qquad (2)$$

Concerning the LCO_2 emissions γ_2, γ_3, γ_4, γ_5, γ_6, are elasticities coefficient of the regressors i.e. LRENR, LGDP, LENR, and LURBN. Our study applies the nonlinear ARDL model which is an extension of the ARDL model for the nonlinear association of the variable. The methodology is based on the ARDL model with some extensions.

$$\Delta LCO_{2t} = \gamma_0 + \sum_{i=1}^{l}\gamma_{1i}\Delta LCO_{2t-1} + \sum_{i=0}^{p}\gamma_{2i}\Delta LRENR_{t-i} + \sum_{i=0}^{q}\gamma_{3i}\Delta LENR_{t-i} + \sum_{i=0}^{r}\gamma_{4i}LGDP_{t-i} + \sum_{i=0}^{s}\gamma_{5i}\Delta LURBN_{t-i}$$
$$+ \delta_1 LCO_{2t-1} + \delta_2 LRENR_{t-1} + \delta_3 LENR_{t-1} + \delta_4 LGDP_{t-1} + \delta_5 LURBN_{t-1} + \mu_t \quad (3)$$

The unrestricted standard error correction model (ECM) is manipulated as given below:

$$\Delta LCO_{2t} = \gamma_0 + \sum_{i=1}^{l}\gamma_1\Delta LCO_{2t-i} + \sum_{i=0}^{p}\gamma_2\Delta LRENR_{t-i} + \sum_{i=0}^{q}\gamma_3\Delta LENR_{t-i} + \sum_{i=0}^{r}\gamma_4\Delta LGDP_{t-i} + \sum_{i=0}^{s}\gamma_5\Delta LURBN_{t-i} +$$
$$+ \lambda ECT - 1 + vt_t \quad (4)$$

The following formulation of Shin, Yu, and Greenwood-(2014) Nimmo's ARDL model can be represented as NARDL: The NARDL mathematical model provides both positive and negative numbers to describe the use of renewable energy. It makes an estimate of the variable that measures the consequences of changing the LRENR's value. The NARDL approach, which is the ARDL method's expanded version, accurately forecasts the positive and negative blows of the particular variables. The NARDL approach explains the growing and decreasing impacts of LRENR.

$$\Delta LCO2_t = \alpha_0 + \sum_{i=1}^{l}a_{1i}\Delta LCO2_{t-1} + \sum_{i=0}^{p1}\alpha^{+}{}_{2i}\Delta LRENR^{+}{}_{t-i} + \sum_{i=0}^{p2}\alpha^{-}{}_{2i}\Delta LRENR^{-}{}_{t-i} + \sum_{i=0}^{q}\alpha_{3i}\Delta LENR_{t-i} + \sum_{i=0}^{r}\alpha_{4i}\Delta LGDP_{t-i} + \sum_{i=0}^{s}\alpha_{5i}\Delta LURBN_{t-i} +$$
$$+ \beta_1 LC2_{\ t-1} + \beta_2^{+} LRENR_{t-1}^{\ +} + \beta^{-}{}_2 LRENR^{-}{}_{t-1} + \beta_3 LENR_{t-1} + \beta_4 LGDP_{t-1} + \beta_5 LURBN_{t-1} + \mu_t \quad (5)$$

4. Empirical Outcomes

4.1 Unit Root Test

The unit root test of the econometric model needs to be in a mixed order of integration and no variable is stationary at I(2) is a prerequisite condition for the application of linear and nonlinear autoregressive distributed lag models. It provides you with reliable results while using a small sample also. The stationarity is checked in our study through two different unit root tests Phillips-Peron test (PP) and the Augmented Dickey-Fuller test (ADF) and the results are reported in the following table.

Table 2 : Stationarity Results

	Level		1^{st} difference	
Variables	**ADF**	**PP**	**ADF**	**PP**
CO_2	-3.547**	-3.473**	-2.258	-2.896
RENR	-2.253	-2.228	-5.407***	-5.433***
ENR	-2.367	-2.199	-4.937***	-5.033***
GDP	-4.647***	-4.647***	-6.263***	-7.486***
URBN	-0.534	-0.043	-3.484**	-3.248**

Note: ***, **, and * for 1 %, 5% and 10%, respectively.

4.2 Bounds Test Estimations

The study conducts the F-bound test to test the cointegration. The criteria for this test is to check the calculated F stat if is above the upper bound that is the sign of cointegration, and if only the value is less than the given lower bound that is verification of no cointegration; the third case is if the value lies in between upper and lower bound that means inconclusive result. In our case, the value of the F-bound test shows cointegration in the nonlinear ARDL model but no cointegration in the linear ARDL model.

Table 3: ARDL Bound Test Estimation						
Model (LCO2)	**F-Stat**	**k**	**Range**	**Critical Values**		**Decision**
				I (0) bound	**I (1) bound**	
	2.798	4	10%	3.03	4.06	
			5%	3.47	4.57	
			2.5%	3.89	5.07	
			1%	4.4	5.72	
						No Cointegration

NARDL Bounds Test Estimation						
	F-Stat	**k**	**Range**	**Critical Values**		**Decision**
				I (0) bound	**I (1) bound**	
Model (LCO2)	7.322	4	10%	2.26	3.35	
			5%	2.62	3.79	
			2.5%	2.96	4.18	
			1%	3.41	4.68	
						Cointegration

4.3 Long Run Estimations

Long-run results demonstrate that LRENR-POS and LRENR_NEG are associated negatively with CO_2 emission. More specifically 1 unit surge in LRENR-POS initiative decrease CO2 emission by 0.867224, and a 1 unit decrease in LRNER- NEG will increase CO2 emission by 0.269484. While other factors like LENR, LGDP, and LURBN have a long-term positive correlation with CO2 emissions.

Short-run results illustrate that the LRENR_POS and LRENR_NEG are associated negatively with CO2 emission. Specifically, a 1 unit increase in LRENR-POS will decrease CO2 emission by 0.675689, and a 1 unit decrease in LRNER- NEG will increase CO2 emission by 0.501157. On the other hand, other variables like LENR, LGDP, and LURBN are positively associated with CO_2 gas emissions in the short term.

Table 4: Long-Run NARDL Estimation	
Variables	**Coefficient [Prob]**
LRENR-POS	-0.867224*** [0.0092]
LRENR-NEG	-0.26948*(0.0922)
LENR	0.679171***[0.0004]
LGDP	0.124834** [0.0473]
LURBN	0.011046 [0.3808]
C	-4.636615*** [0.0007]

The significance levels indicated by the symbols *, **, and *** are 10%, 5%, and 1%, respectively. The values of probability are listed in [].

The results showsthe error correction terms (ECT) for the above model is significant with negative sign.

Table 5: Short run NARDL Estimation	
Variables	**Coefficient [Prob]**
D(LCO2(-1))	-0.02531[0.7759]
D(LCO2(-2))	0.15343**[0.0144]
D(LRENR-POS)	-0.67568***[0.0065]
D(LREN-NEG)	-0.50115***[0.0018]
D(LENR)	0.52916***[0.0001]
D(LGDP)	0.09726*[0.0819]
D(LURBN)	0.02215**[0.0272]
CointEq(-1)	-0.779*** [0.0000]

The significance levels indicated by the symbols *, **, and *** are 10%, 5%, and 1%, respectively. The values of probability are listed in [].

4.4 Diagnostic Test

To check whether the model is statistically adequate the study conduct the diagnostic tests on errors for normality, misspecification, heteroskedasticity and statistical serial correlation. The results reported in the table show the model is stable and shows the absence of no normality, misspecification, heteroskedasticity and serial correlation. As a result, the study provides no dubious findings through the nonlinear ARDL. The strength of the parameter of the error correction model is assessed by CUSUM and the CUSUM of squares and the results showed in the following plots.

Table 6: Diagnostic Tests Results	
R^2	0.9993
Adj R^2	0.9990
LM Test	2.682 [0.5215]
J.B Test	2024850 [0.363337]
Hetero Test	0.3905 [0.9324]
Ramsey reset test	0.0169 [0.898]
W_{LR}	4.6752 [0.018]
W_{SR}	5.3790 [0.029]

P-value is shown by parenthesis [].

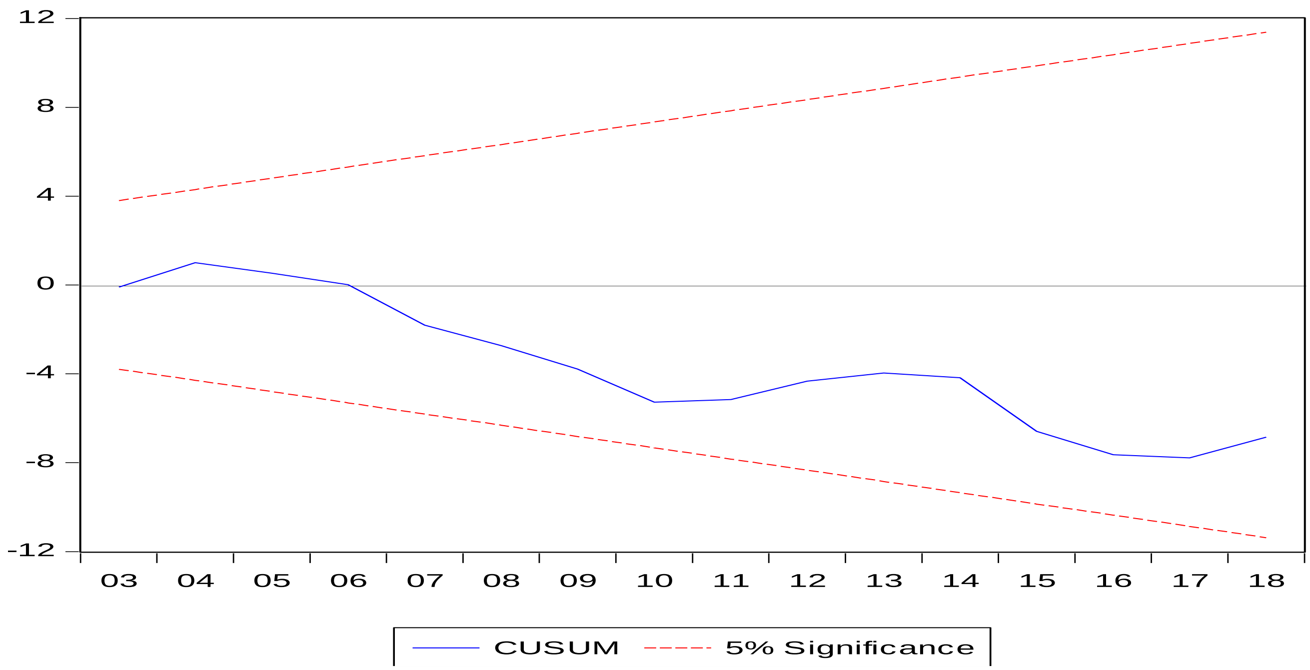

Figure 1: Cusum

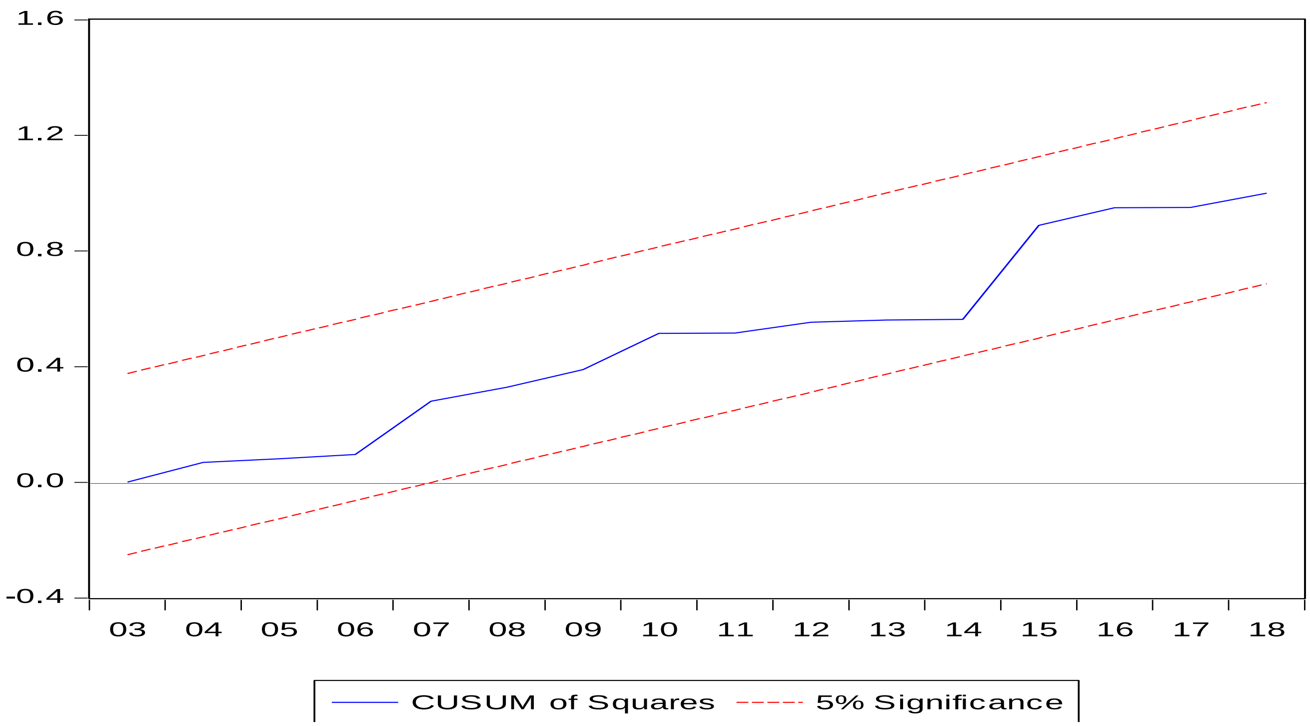

Figure 2: CusumQ

The study uses a cumulative multiplier graph to illustrate how renewable energy affects CO2 emissions in an asymmetries manner. The graph shows asymmetric behaviour exists in the model in the long run. It is calculated by the Wald test clearly shows long-run asymmetric of renewable energy. It is also demonstrated through Wald Test results in the above table.

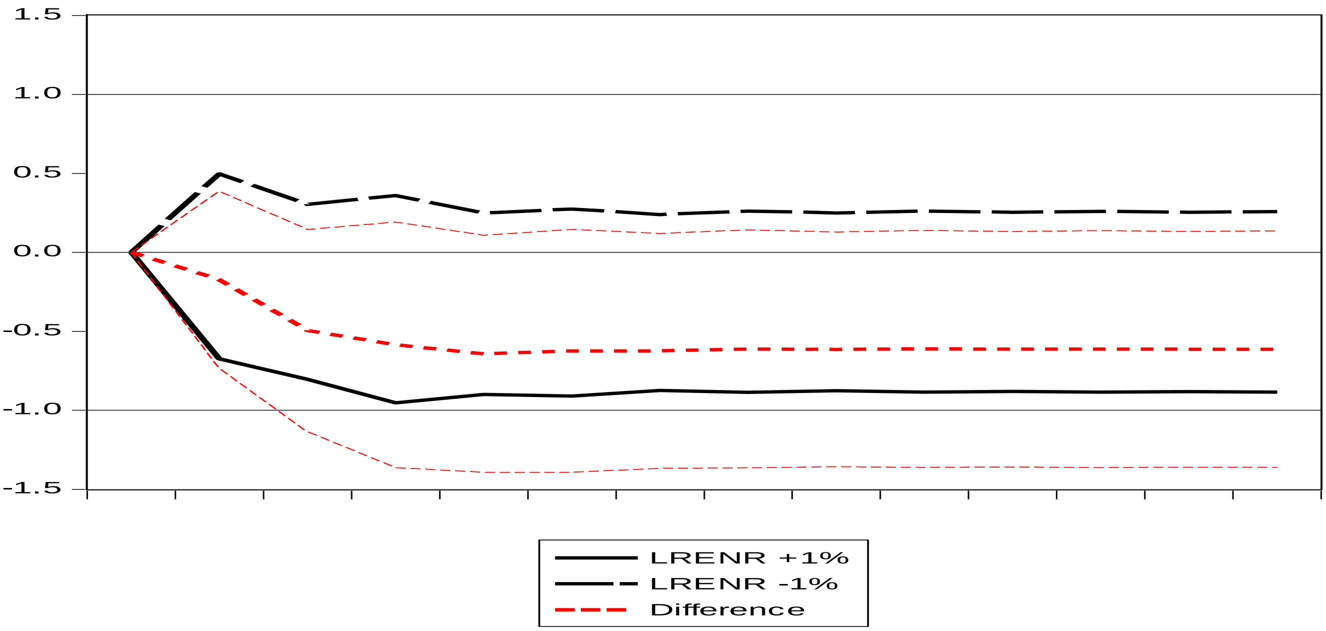

Figure 3: Multiplier graph

5. Conclusion with Policy Implications

Our research probes the empirical influence of disaggregate energy , urbanization, and gross domestic product on carbon emissions in Pakistan using time series data for the period 1980-to 2018. To achieve this goal, we applied the non-linear autoregressive distributive lag (NARDL) approach and found that cointegration exists among the series and confirms the nonlinear impact of renewable energy with the environment. Findings indicate that in both the long run and short run LRENR-POS and LRENR_NEG are associated negatively with CO2 emission. While other variables like LENR, LGDP, and LURBN are positively associated with CO_2 emissions. The policymakers prerequisite the alternative energies apart from conventional energies with adopting strategies to minimize environmental degradation.

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