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Public Investment, Technological Innovations, and Environmental Degradation: Asymmetric ARDL Approach

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ABSTRACT

Environmental degradation is the biggest problem for the entire world and especially for the developing countries which are already facing many problems and challenges and the environmental problem is one of them. That's why the present research scrutinizes the different factors which are affecting the environmental condition. However, examination of the unequal effects of public investment, technology, and other controlled variables on environmental destruction in Pakistan is the main goal of the current study. The study use the asymmetric (NARDL) technique with data from 1971 to 2021. Also, the study's findings indicate that the economy sampled produced varied outcomes. The study's findings, however, support the existence of an asymmetric (NARDL) relationship in Pakistan between public investment, ICT, economic expansion, sustainable sources, and environmental damage. Moreover, the existing study scrutinized nonlinearities that are missing in previous studies and showed some misleading inferences. Furthermore, this research examined at how technology, state investment, and other controlled variables affected Pakistan's environment in asymmetric ways. The study's findings also suggested that lawmakers adopt some laws that would urge the federal government to spend its money on carbon-free or low-carbon initiatives in order to maintain a sustainable environment.

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1. Introduction

The biggest issue facing the globe now is environmental degradation, which is also a key contributor to fatal diseases. Mining, exploration, and industrialization are accelerating environmental pollution. Developed and developing nations are working to protect the environment but developed countries are contributing more. Environmental pollution is damaging human beings. The main types of environmental pollution are air, land, and water Bruce, Perez-Padilla, and Albalak (2000), Etchie et al. (2018), Ali, ur Rahman, and Anser (2020). Moreover, due to the depletion of forests and natural resources, environmental pollution is increasing rapidly in the world (Appannagari, 2006). Likewise, a recent study by World Data Atlas Pakistan Environment (2020) examined that environmental pollution is increasing more speedily in Pakistan. For instance, CO_2 emission per capita was 0.3 tons in 1971, and in 2020, it increased by 1.04 tons. Thus, CO_2 emissions per capita are growing at an annual rate of 2.63%. Further, greenhouse gas emissions are also the major source of climate change, and BP statistic (2019) has reported a result about CO_2 emissions, according to its report on carbon secretions correlated toward remains fuel energy have increased by 33890.8 million tons in 2018, while in 1965 it was only 11,190 million tons. However, according to the BP statistic (2019), it is confirmed that carbon emissions grow fastest at 2.0% per annum in 2018. Moreover, Pakistan belongs to the developing countries where the people are utilizing the traditional methods of cooking and these methods are increasing the carbon emissions rapidly in the atmosphere. For instance, the level of carbon emissions lies between 260-290 parts per million in the 19th century but today's situation has totally changed because Co_2 emissions are speedily increasing and it reached 385 parts per million annually, and its average level is almost 2 parts per million (Dogan, Altinoz, Madaleno, & Taskin, 2020). Pakistan's susceptibility to environmental contamination further elevated its position in the world. The two major sources of pollution are the energy and transportation sectors, which together account for 50% of all pollution. In Pakistan, energy-related CO2 emissions increased from 68,242 (kt) in 1991 to 166,298 (kt) in 2014 (Majeed, Tauqir, Mazhar, & Samreen, 2021).

The previous literature on environmental degradation looked into factors that have a relationship with the environment such as economic growth, communication technology, telecommunication infrastructure, foreign direct investment, trade openness, oil prices, economic progress, the role of the fiscal instrument, deforestation, water scarcity, industrialization, urbanization, agricultural sectors, forestry sectors, human capitals, institutional quality, financial development, poverty, population size, energy consumptions, mechanism, globalization matter, shadow economy, environmental Kuznets curve, tourism, renewable energy, economic freedom, technology innovations, temperature, human health, international trade, corporate social responsibility, public investment, innovation technology(ICT) but the economic growth, foreign direct investment, energy consumptions, and industrialization are most cited in Pakistan region. Moreover, these four factors like foreign direct investment, trade openness, the agricultural sector, and technology are very important for the economic growth of Pakistan Rahman, Chaudhry, Meo, Sheikh, and Idrees (2022), Younas, Idrees, and ur Rahman (2021), (Li et al., 2022). The current study examines how public investments, technology, economic expansion, renewable energy, and environmental deterioration interact.

Public investment has a significant role in environmental pollution. Thus, fiscal policy can play a vital role in decreasing deforestation. The fiscal instruments like charges, fines, and taxes are not sufficient to manage the environmental issue but effective governance is also needed and showed an important and favorable effect on the environment (Bilal, Shah, Rahman, & Jehangir, 2022; Cadman et al., 2019; Qureshi et al., 2016; Zahra, Nasir, Rahman, & Idress, 2023). Further, another study by (Postula & Radecka-Moroz, 2020) examined the fiscal instruments used to control environmental pollution; however, taxes and public spending and especially important budgetary instrument to reduce environmental degradation. Likewise, (Du et al., 2020) explored another study in China and evaluate the diverse impacts of physical structure on the ecological quality, they determined that highways are the primary contributor to rising carbon emissions, whereas train infrastructure reduces carbon emissions, and they demonstrated the detrimental effects of investment on the environment. Also, it was demonstrated by (Shahbaz, Raghutla, Song, Zameer, & Jiao, 2020) that energy use and PPPG investment have a favorable effect on CO2 emissions in China. Additional research on the effects of energy, innovation, and public-private partnership investment in China was conducted in 2019 by Khan et al. Their findings indicated that both public-private partnership investment and technical innovation can enhance the environment. In order to reduce environmental pollution and securitize the beneficial effect of public investment on the environment, public-private partnerships must invest in technical innovation in energy production.

ICT is very important for a sustainable environment and many developed and developing countries are using different technologies to mitigate pollution into the environment. Further, (An Hign, Gholami, & Shirazi, 2017; Chaudhary, Nasir, ur Rahman, & Sheikh, 2023) examined the ICT reduces CO_2 emissions with digital transport structures, smart electrical grids, effective usage of energy, and manufacturing development and showed significant relationship with the environment. Additionally, the largest use of ICT goods increased the demand for electricity in developing countries. It can affect the environment by emitting a high amount of CO_2 emissions and various indicators of ICT like the internet, satellites, cell phones, and computers, play an important role to manage the issue of environmental pollution (Sair & Danish, 2018). Economic growth has a great influence on the progress of developed and developing countries and has a significant role in CO_2 emissions. Likewise, environmental pollution is one of the big challenges for the entire world. But emerging economies are more affected because of their priority of economic growth instead of environmental quality and showed a certain and substantial reduction in CO2 emissions (S. Ahmed, Quadeer, & Mckay, 2020; Hafiza et al., 2022; Li et al., 2022; Rahman et al., 2022; A. U. Shahid et al., 2022).

The primary cause of climate change is the use of fossil fuels by the manufacturing sector. Fuels like gas, oil, and coal release harmful gases when they are burnt, which has led to environmental damage. Furthermore, (Mahmood, Alkhateeb, & Furqan, 2020; ur Rahman, 2018; Zhu, Fang, Rahman, & Khan, 2023) employed the ARDL model to study the role of industry production regarding the environment and they showed that energy has a substantial impact on the environmental quality. Also, another study examined by Wu et al. (2021) demonstrated the beneficial effects of renewable solar energy in reducing environmental carbon emissions.

The present study scrutinized the literature review on public investment and technology (ICT) with CO_2 emissions nexus has revealed a linear relationship. While the majority of macroeconomic factors, particularly business cycles, had nonlinear characteristics, carbon emissions were actually only assessed using a linear framework (Neftci, 1984). However, the fundamental flaw in the linear time series model is that variables are represented as linear although, in reality, the majority of time series contain nonlinear characteristics (Anoruo, 2011). Moreover, Meo, Chowdhury, Shaikh, Ali, and Masood Sheikh (2018) investigated the linear time series framework and demonstrated a few false conclusions. Therefore, it is imperative to assess the asymmetric relationship between public investment, technology (ICT), economic growth, renewable energy, and carbon emissions due to the importance of nonlinear inference in the time series model. Yet, policymakers would benefit greatly from a detailed understanding of the current study since it will enable them to implement effective measures to boost economic growth without degrading the environment.

The current study solves the several extensive gaps in the prior literature about how public investment and technology effect carbon emissions. As a straight point, only a few studies have used this aggregate and disaggregate analysis to explore panel data, and the current study is the first to examine the aggregate analysis in the context of Pakistan among developing nations. Also, the NARDL technique was used in this study to examine the nonlinear framework linking macroeconomic determinants to carbon emissions. Furthermore, current research creates a distinct model using various environmental pollution proxies and obtains various outcomes in a different model. Moreover, carbon emissions exhibit nonlinear properties (Chang, Saydaliev, Meo, & Mohsin, 2022). In addition, the current study looks into the combined effects of economic growth, renewable energy, technology, public investment, and asymmetric (NARDL) effects on environmental degradation.

After this segment of introduction, the paper rest in the following structure: the second section recognizes data and methods. The third section evaluates as results and empirical explanation. The fourth section describes the policy and its implications.

2. Data and Methodology

The current study utilizes a total of five variables and including environmental degradation such as public investment, technology (ICT), economic growth, renewable energy, and environmental pollution. Further, this study evaluates the annual data for Pakistan and has been taken from the "World Bank Indicator and Economic Survey of Pakistan" from 1971 to 2021.

Table 1: Description of the Variables

Variables	Symbols	Proxies/ Measurement of variables	Data-Source
Environmental degradation	ED	"CO_2 emissions from transport (% of total fuel combustion)	World development indicator
Public investment	PI	Development expenditure (% of GDP)	Economic Survey of Pakistan
Technology (ICT)	ICT	"Mobile cellular subscriptions (per 100 people), Fixed telephone subscriptions (per 100 people)	World development indicator
Economic Growth	EG	Economic growth annual %)	World development indicator
Renewable energy	RE	Renewable energy consumption (Billions of kilowatts)	World development indicator

The econometric form of the model is as follows:
This study has taken the logarithmic from all the existing variables.

$$\Delta ED_t = \theta_0 + \sum_{i=1}^{Z} \psi_1 \Delta ED_{i-1} + \sum_{i=0}^{Z} \psi_2 \Delta PI \; + + \sum_{i=0}^{Z} \psi_3 \Delta ICT_{t-i} + \sum_{i=0}^{Z} \psi_4 \Delta EG_{t-i} \; + + \sum_{i=0}^{Z} \psi_5 \Delta RE + \gamma_1 lnED_{t-1} + \gamma_2 lnPI_{t-1} + \gamma_3 lnICT_{t-1} + \gamma_4 lnEG_{t-1} + \gamma_5 lnRE_{t-1} + \mu_t$$

The current research postulates the following linear equation based on the long-run linear relationship between variables like public investment, technology (ICT), economic growth, and renewable energy with environmental deterioration.

2.1 NARDL

As we already discussed in above section 1, in the traditional way the previous studies already scrutinized the association between public investment and technology (ICT) with carbon emissions by standard different period cycles approaches for instance, "Granger causality, cointegration, vector miscalculation amendment model, unrestricted VAR model, standard ARDL (Usman et al., 2020). Further, the above methods are just used for the time series linear relationship between the public investments and technology with CO2 emissions. The ARDL-based cointegration approach only produced long-run and short-run results; it was unable to identify the variables' nonlinear relationships (Anwar et al., 2021; Fatima, Karim, & Meo, 2021). Moreover, the behaviours of public investment and energy generally follows nonlinear cycles (Deaton & Miller, 1995). As a result, the study uses a nonlinear (NARDL) approach to identify the variables' asymmetrical associations (Shen, 2014). As stated by (Pesaran, Shin, & Smith, 2001), the nonlinear technique is the extension of the linear approach (ARDL). Further, the nonlinear (NARDL) bound testing cointegration approach breaks the public investment, technology, economic growth, and nevertheless, historically, the ARDL approach merely identifies the positive or negative shocks at the same time. Renewable energy into positive and negative shocks to find its effects on carbon emissions. For instance, the asymmetric approach provides both the short- and long-term associations between the variables of interest. Also, the current study examines the various models shown in table 2 and assesses the relationship between the variables over both the long and short runs as it applies the long-run equation shown below (Chowdhury, Meo, Uddin, & Haque, 2021).

Table 2: Functional forms of model:

Functional form
Aggregate analysis
EP= f(PI,ICT, EG, RE)

CO_2 refers to carbon emissions of transport, PI (public investment), ICT (Technology), EG (economic growth), and RE (renewable energy):

$$X_t = Y_0 + \alpha_1(Y_t) + \mu_t \quad (1)$$

In the above equation X is denoted as dependent variables such as EP, CO_2tra, at t time, and Y is denoted as independent variables such as public investment (PI), technology (ICT), economic growth (EG), and renewable energy (RE) at time t. Further, linear cointegration (ARDL) evaluated for independent and dependent variables can be scrutinized as:

$$\Delta X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 Y_{t-1} + \sum_{J=1}^{k-1} \alpha_3 \Delta X_{t-J} + \sum_{J=1}^{k-1} \alpha_4 \Delta Y_{t-J} + \mu_t \quad (2)$$

In the above equation, α_1 and α_2 are denoted as long-run coefficients and α_3 and α_4 the short-run coefficients, respectively. The optimal lags were used in the current study as the Schwarz information criterion (SIC), which is also known as K in the equation above. Equation 2's test for the absence of cointegration is indicated by _1= _2 =0, and Pesaran et al. also depict it as an ARDL model (2001). However, the standard linear framework time series model offered a number of benefits and was particularly well suited to tiny amounts of data (Romilly, 2001). While the linear (ARDL) cointegration approach and the traditional based correlation approach are not the same (Ibrahim & Mas'ud, 2016). After all the variables are stationary at level I (0) or first difference I (1) and produced mixing results at the first difference, we can move forward with the ARDL technique. Moreover, the ARDL technique is inappropriate for linear cointegration if the variables are stationary at the second difference. Furthermore, (Grossman & Razin, 1984) introduced the hidden cointegration that exists among the purposed variables and made the case that the ARDL cointegration approach does not specify positive and negative shocks in the long-run period. For example (Schorderet, 2003), suggested a NARDL regression model and described it very well defining the hidden cointegration. In a similar vein, (Shen, 2014) developed the asymmetric (NARDL) technique and divided the variables into positive and negative shocks for long- and short-run outcomes. However, the Shin et al. (2014) NARDL cointegration model is illustrated as follows:

$$X_t = \varphi + \varphi^{+} y_t^{+} + \varphi^{-} y_t^{-} + \mu_t \quad (3)$$

Where the φ^{+} and φ^{-} are identified as long-run coefficients, and the following equation decomposes Y into positive and negative shocks as exogenous variables (Chowdhury et al., 2021)

$$X_t = X_0 + X_t^{+} + X_t^{-} \quad (4)$$

The initial value at time t = 0 is given by X (0) in the equation above, and the partial sum of positive and negative shocks of independent variables is denoted by X t+ and X t- in equations no. (5) and no. (6), respectively (Chowdhury et al., 2021). Also, as exogenous factors like pubic investment (PI), information and communications technology (ICT), economic growth (EG), and renewable energy undergo positive and negative changes, the calculation will continue (RE).

$$X^{+} = \sum_{J=1}^{t} \Delta X_i^{+} = \sum_{J=1}^{t} \max(\Delta X_i, 0) \quad (5)$$

$$X^{-} = \sum_{J=1}^{t} \Delta X_i^{-} = \sum_{J=1}^{t} \min(\Delta X_i, 0) \quad (6)$$

Here, the current study put equation (5) and equation (6) into equation (2) and find the asymmetric NARDL framework formula as follows (Chowdhury et al., 2021).

$$\Delta X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 y_{t-1}^{+} + \alpha_3 y_{t-1}^{-} + \sum_{J=1}^{k-1} \alpha_4 \Delta X_{J-i} + \sum_{J=1}^{k-1} \alpha_5 \Delta y_{J-i}^{+} + \sum_{J=1}^{k-1} \alpha_6 \Delta y_{J-i}^{-} + \mu_t$$

Equation (7) denoted as Δ is difference operators and long-run parameters are α_1, α_2, and α_3 respectively and short-run parameters are denoted as α_4, α_5, and α_6. Further, for NARDL no cointegration testing as a null hypothesis denoted as $\alpha_1 = \alpha_2 = \alpha_3 = 0$

3. Empirical Analysis and Findings

In the initial segment the present study applies the NARDL approach and took some analysis about aggregate and disaggregate and after that will show the difference between the aggregate results and disaggregate results. Further, the current research evaluates the descriptive statistic tables and after that will apply the unit root test for stationary variables, and after these results will show some short-run and long-run results.

Table 3: Descriptive Statistics

	EP	PI	ICT	EG	RE
Mean	-1.252	1.295	0.401	7.067	6.088
Median	-1.08	1.231	0.459	7.069	6.097
Maximum	-0.914	3.839	0.497	7.103	6.144
Minimum	-1.754	-1.182	0.249	7.029	6.023
Std. Dev.	0.443	2.511	0.133	0.037	0.061
Skewness	-0.587	0.047	-0.641	-0.094	-0.257
Kurtosis	1.500	1.500	1.500	1.500	1.500
Jarque-Bera	0.453	0.282	0.487	0.285	0.314
Probability	0.796	0.868	0.783	0.866	0.854

Table 3 demonstrates the results of descriptive statistics and findings show that the mean of the EG is higher than the PI, ICT, EP, AND RE. Further, the data is normal When the magnitude of all proposed factors is deemed to be bigger, the Jarque-Bera test than a 1% level of significance (0.453, 0.282, 0.487, 0.285, and 0.314 < 0.01). Moreover, PI has a high value of standard deviation while EG has a lower value of standard deviation from table 1, these results show the mean values have different magnitude and their characteristics indicate the asymmetric relationship can proceed.

Table 4: Unit Root Test

Variables	ADF		PP		Conclusion
	I(0)	I(1)	I(0)	I(1)	
ED	0.004***	0.000***	0.006***	0.000***	I(0), I(1)
PI	0.149	0.01***	0.369	0.02***	I(1)
ICT	0.02***	0.000***	0.02***	0.000***	I(0), I(1)
EG	0.655	0.001***	0.228	0.000***	I(1)
RE	0.000***	0.000***	0.002***	0.000***	I(0), I(1)

Note: The augmented Dickey Fuller (ADF) and Philip Peron (PP) unit root tests have been performed with intercept and intercept and trend first at the level and then at first difference The lag length was selected using the SBIC which is shown in the parentheses * **, ** and * represent the significance at 1% ,5% and 10% respectively.

Table 4 The Augmented Dickey-Fuller test (1979) and the Phillip-Perron test (1988), two of the most well-known tests for determining whether a variable is stationary, were used to analyse the unit root test findings. It was established that none of the variables are stationary at I (2) difference. Additionally, results demonstrate that ED, ICT, and RE are stationary at level I(0) and at the first difference I(1), respectively, while PI and EG are stationary at first difference in both tests. However, the study now has mixed results, and all variables are incorporated at level I(0) and first difference I(1) (1). As a result, the current study can use an asymmetric NARDL technique for both short- and long-term findings (Shin, Yu, & Greenwood-Nimmo, 2014).

Table 5: Bound cointegration for linear and nonlinear tests

Test-Statistic	F-Statistic	Sig. level	Critical values bounds Lower bound at 5%	Upper bound at 5%	Decision
Linear ARDL	2.335	1%	2.62	3.77	Inconclusive
Asymmetric ARDL	6.620	5%	2.11	3.15	Cointegration exists
		10%	1.85	2.85	

Note: The critical bound value from (Pesaran et al., 2001) exists in the above table. And ***, **, and * denoted as significance level at 1%, 5%, and 10% respectively. Further, the value of F- Statistic is greater than the upper bound value so it is confirmed that there is strong cointegration is exist and the null hypothesis of nonlinear (NARDL) cointegration is $p = \theta^{+} = \theta^{-} = 0$.

Table 5 shows the results of the bound-based cointegration for the symmetric (ARDL) and asymmetric (NARDL) cases. Table 5 shows the outcomes of the linear and nonlinear F-statistic values for model A. Additionally, the linear (ARDL) F-statistic value is (2.335), which is less than the lower bound at a 1% level of significance, while the nonlinear (NARDL) boun cointegration value is (6.620), which is greater than the upper bound at a 1% level of significance, indicating that hidden cointegration is present in the current study as it moves forward with the short-run and long-run outcomes of asymmetric data (NARDL).

Table 6: Dynamic NARDL

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
EP(-1)	0.341	0.209	1.678	0.148
PI_POS	0.057	0.011	4.658	0.035
PI_POS(-1)	0.015	0.017	0.784	0.424
PI_POS(-2)	0.023	0.014	0.027	0.924
PI_POS(-3)	0.027	0.012	1.973	0.093
PI_POS(-4)	-0.054	0.009	-0.738	0.483
PI_NEG	-0.035	0.017	-2.053	0.084
PI_NEG(-1)	0.047	0.011	3.252	0.013
PI_NEG(-2)	-0.052	0.010	-0.123	0.903
PI_NEG(-3)	-0.019	0.011	-0.764	0.479
PI_NEG(-4)	0.043	0.017	3.305	0.012
ICT_POS	2.361	0.810	2.848	0.023

ICT_POS(-1)	-1.721	0.793	-2.185	0.075
ICT_POS(-2)	-0.231	0.772	-0.300	0.766
ICT_POS(-3)	-1.087	0.373	-2.903	0.022
ICT_POS(-4)	-1.224	0.573	-2.124	0.077
ICT_NEG	-1.052	0.512	-2.040	0.083
ICT_NEG(-1)	0.527	0.738	0.711	0.509
ICT_NEG(-2)	0.860	0.723	1.181	0.282
GDP_POS	0.015	0.002	2.416	0.053
GDP_POS(-1)	0.072	0.003	2.020	0.082
GDP_POS(-2)	-0.020	0.009	-3.870	0.082

Positive and negative cumulative sums are evaluated by "POS" and "NEG" respectively. And $\alpha^{+} = \frac{-\psi^{+}}{m}$ and $\alpha^{-} = \frac{-\psi^{-}}{m}$ are the symbol of long-run coefficients relationship of positive and negative in the above model.

Table 7: NARDL Short-Run

Variable	Coefficient	Std. Error	t-Statistic	Prob
D(PI_POS)	0.054***	0.011	4.654	0.003
D(PI_NEG)	-0.035*	0.014	-2.057	0.081
D(ICT_POS)	2.363**	0.830	2.846	0.023
D(ICT_NEG)	-1.052*	0.514	-2.041	0.089
D(EG_POS)	0.012**	0.005	2.414	0.055
D(EG_NEG)	-0.065	0.009	-0.548	0.603
D(RE_POS)	-0.018**	0.006	2.738	0.032
D(RE_NEG)	0.069**	0.018	-3.684	0.010
ECT	-0.654**	0.206	-3.178	0.019
R-Square	0.898			
F-statistic	80.978			
Serial Correlation	0.321			
Heteroscedasticity	0.371			

Note: ***, **, and * denotes as coefficients are significant at 1%, 5%, and 10% respectively and where the POS and NEG evaluates as positive and negative changes in short-run NARDL time series model and denoted as $\sum_{j=1}^{k-1} y_{j-i}^{+}$ and $\sum_{j=1}^{k-1} y_{j-i}^{-}$ respectively. While, "Breusch-Godfery" and "Breusch- Pagan-Godfery" were evaluated as serial correlation and heteroscedasticity tests respectively.

Table 7 demonstrates Because the value of cointegration is (-0.654) and significant at a 5% level of significance, which suggests that our dependent variable will return within a year, the asymmetric short-run outcomes and the findings support the existence of a short-run and long-run nonlinear relationship. Also, the R-square value is 89%, indicating that explanatory variables are affecting 89% of our dependent variable. Also, our data is free of serial and hetero issues because the value is greater than the 5% level of significance according to the Breusch-Godfery and Breusch-Pagan-Godfery tests. Further, table 7 also looked at the results of our explanatory factors throughout the near term. Where the coefficients of PI POS and PI NEG are (0.054, and -0.035) and significant at 1% and 10%, respectively, it follows that an increase of 1% in public investment that is a positive shock will result in an increase in the 0.054% environmental deterioration in Pakistan.

As the government begins new projects, they disregard environmental quality since the negative shock of public investment demonstrates that a 1% decrease in public expenditure will lessen the 0.035% environmental degradation in the short-term. Moreover, the coefficients of ICT_POS and ICT_NEG are (2.363, and -1.052) and also significant at 5% and 10% respectively, which means 1% increase and decrease in positive and negative change of ICT will increase and decrease (2.363, and -1.052) respectively but the positive shock is very effective than negative effect in the short run. The outcomes of studies are aligned with (Ali et al., 2020; Hassan, Sheikh, & Rahman, 2022; Rahman et al., 2022; Shahid, Muhammed, Abbasi, Gurmani, & ur Rahman, 2022; Zulfiqar et al., 2022). Further The positive shock of EG is significant at a level of significance of 5%, meaning that a 1% increase in EG will increase 0.012% of ED in the short run, whereas the negative shock is minor, meaning that in the short term, the negative shock of EG is irrelevant in Pakistan. A positive shock has an inverse relationship with ED in the short run, and both a positive and negative shock of RE are significant at a 5% level of significance, which means that a 1% increase in RE will decrease ED by 0.018% in the short run. A negative shock investigates whether a 1% decrease in RE will do the same.

Table:8 NARDL Long-Run Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PI_POS	0.135**	0.035	3.621	0.011
PI_NEG	0.064*	0.026	2.306	0.060
ICT_POS	-0.925**	1.837	-2.590	0.012
ICT_NEG	0.508**	0.677	3.748	0.044
EG_POS	0.086**	0.014	2.743	0.040
EG_NEG	0.088*	0.029	3.315	0.070
RE_POS	-0.047**	0.020	-2.776	0.016
RE_NEG	-0.063*	0.037	-2.185	0.072
C	-0.563**	1.576	-2.625	0.059

*Notes: Asterisk ***, ** and * denote significance levels at 1%, 5%, and 10%, respectively. The values in parentheses are the p-values.*

Table 8 reported the long-run NARDL results. The coefficients of PI_POS and PI_NEG are (0.135 and 0.064) and significant at 5% and 10%, respectively. This means that a 1% increase in public investments will, over time, result in an increase of 0.135% in environmental pollution because the governments of developing nations are responsible for the majority of it, like Pakistan's governments just want to increase their expenditure and do not care about the environment and introduced new projects which enhance the carbon emissions in the country. Further, a 1% decrease in public investments will decrease the 0.064% of environmental pollution in the atmosphere, which means when governments control their expenditure it will control the carbon emissions. Moreover, the coefficients of ICT_POS and ICT_NEG are (-0.925 and 0.508) and significant at a 5% level of significance which means a 1% increase in positive shock of ICT will decrease the 0.925% carbon emissions which means technology will mitigate the environmental pollution from the atmosphere and positive shock has inverse relationship while the negative shock also demonstrates if 1% decrease ICT will decrease 0.508% ED and has direct relationship but the positive shock is very effective rather than negative shock. These finding are aligned with (Khan, 2022; Rehman, Ali, Idrees, Ali, & Zulfiqar, 2022; Sarwar, Ali, Bhatti, & ur Rehman, 2021; Shahzadi, Sheikh, Sadiq, & Rahman, 2023; Zulfiqar et al., 2022). Further, EG_POS and EG_NEG have coefficients (0.086 and 0.088) almost the same and significant at 5% and 10% respectively which means a 1% increase in positive shock will increase 0.086% ED, while a 1% decrease in EG will decrease 0.088% ED from the environment so there is no any difference between the positive and negative shocks of EG. Moreover, the coefficients of RE_POS and RE_NEG are (-0.047 and -0.063) and significant at 5% and 10% respectively, which means a 1% increase in RE will decrease the 0.047% ED from the environment and has an inverse relationship while the 1% decrease in RE will decrease 0.063% environmental degradation from the atmosphere and has a direct relationship with the ED.

3.1. Model Stability Test

CUSUM and CUSUM-Square tests scrutinizes the data stability test in below diagrams blue line are and the lower and higher critical bound lines now we can says that our data is stable (Brown & Vincent, 1987).

Figure 1: CUSUM test

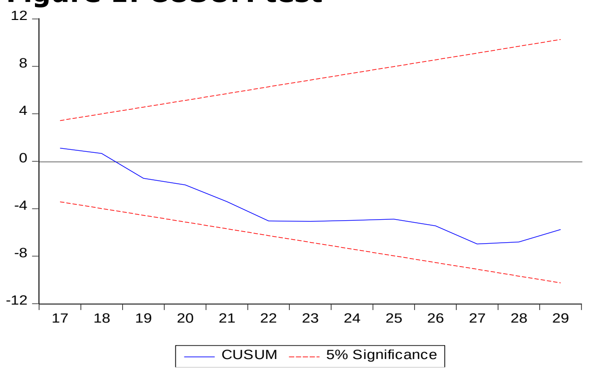
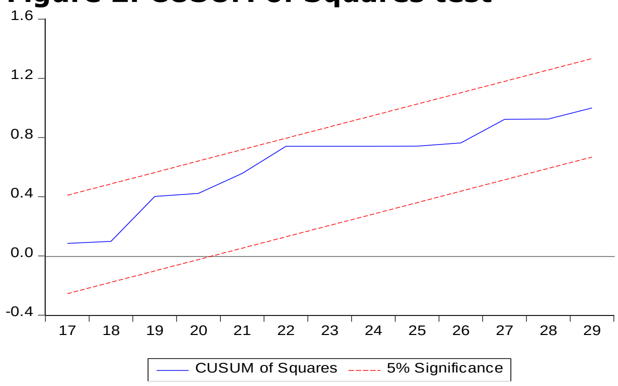


Figure 2: CUSUM of Squares test



4. Conclusion and Policy Implications

Environmental pollution has become an important problem for developing nations like Pakistan, and it became a substantial fragment of current national and international policy debates. Environmental degradation has become a public concern (K. Ahmed, Shahbaz, Qasim,

& Long, 2015). Likewise, a recent study by World Data Atlas Pakistan Environment (2020) examined that environmental pollution is increasing more speedily in Pakistan. For instance, CO_2 emission per capita was 0.3 tons in 1971, but in 2021, it increased by 1.04 tons. Further, the present research postulates conclusive information about the nonlinear (NARDL) relationship between the public investments, ICT-based technology the environmental degradation in Pakistan. Moreover, the positive change in public investment is very effective than the negative effect on the environment. When the government increases their expenditure, they do not care about the country's welfare because they just want to earn money. Further, negative change in public investment shows less change in the environment due to Long-term public investment is declining, but short-term public investment has a negative impact.

However, the positive change in ICT decreases environmental degradation but the negative change in ICT is also decreasing the environmental pollution in Pakistan in aggregate analysis. Likewise, the positive change in economic growth enhances the environmental degradation because when developing nations start any projects, they do not think about the environmental condition and they just want to enhance their production, according to the "Environmental Kuznets Curve" in the first stage developing countries just have dire need to increase their growth and they ignore the environmental sustainability. Further, the negative shock shows not a big change is occurring in the environment due to less economic growth. Moreover, a good impact of renewable energy lessens Pakistan's environmental damage because when a country produced electricity in some natural ways like solar-based energy and this energy mitigates the environmental pollution, but negative shock shows to increase the environmental degradation in aggregate analysis when a nation does not use the renewable energy to produce the electricity.

Further, in this study, the positive change shows that public investment increases transportation pollution in Pakistan because the transportation sector is tremendously consuming energy and polluting the air quality. Further, negative shock is very effective which means environmental degradation will decrease due to the decrease in public investment. Moreover, the positive change of renewable energy is very effective in Pakistan because in developing countries energy consumption is very high in form of fossil fuels, cued oil, and coal. Further, positive change is very effective rather than negative shocks because positive shocks indicate that carbon emissions mitigate due to the renewable energy in Pakistan (Rahman et al., 2022). Pakistan's exposure to environmental pollution placed it on the high ranks in the world. Further, Pakistan belongs among those countries which are facing environmental pollution problems and Pakistan also is the highest carbon emissions country among the top 10 countries that are releasing carbon emissions into the atmosphere. Moreover, the present study suggests some policies for government and policymakers which are very helpful for a sustainable environment.

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