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How Strong Are Fdi, Population Growth, And Renewable Energy Consumption In Causing Co_2 Emission: Ardl And Nardl Based Evidence For Pakistan

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Abstract

The present study explores the impact of fossil fuel energy consumption, population growth, and renewable energy consumption on the climate change conditions in Pakistan. The study has utilized the symmetric and asymmetric ARDL techniques for estimation of coefficients. The length of data is from 1975-2020. The findings have shown diverse conclusion on account of the regressors in short and long run. As a policy recommendation, it is suggested that the renewable energy sources be used in order to have a better control over CO_2 emission.

Keywords: FDI, Population Growth, Renewable Energy Consumption, CO_2 Emission, ARDL

1. Introduction

Climate change is an established and a visible reality of 21st century that affects water, health, agriculture, biodiversity, forest, and socio-economic systems in an adverse manner. Intergovernmental panel on climate change ((IPCC) 2007), reported that less developed countries are suffering more due to the climate change as compared to the advanced economies and this fact can be scaled down to the community level where any anomaly caused by the bad climatic condition facing by the human beings is attributed to the consequences that are the direct results of greenhouse gases (GHGs) emissions and the vehicular fossil fuel burning. Therefore, anthropogenic activities are considered to be major factors responsible for surging trends of disasters due to the climate change around the globe.

Pakistan is also vulnerable to the climate change due to its warm climate and geographical location where its temperature are increasing more than the global average. Pakistan is agrarian and sensitive to the climate change because of its land that is arid and semi-arid. Moreover, its rivers are fed by the Hindu Kush-Karakoram Himalayan glaciers that are melting gradually but rapidly due to the global warming. Consequently, Pakistan is experiencing higher risks of variations in the monsoon rains and floods.

The climate is specified into five categories: tropical, dry, mild, continental, and polar. (Belda et al., 2014). In light of broader perspective, temperature and energy shape the climate by two forcing mechanism. Thermohaline is an internal while anthropogenic activities in form of greenhouse gases emissions are external mechanisms. The total sets of greenhouse gases emissions due to an organization, event, product, or person are called the carbon footprint. Environmental pollution is an undesirable physical, chemical, and biological alteration in water, soil, or food which pollutes the environment and also threatens health, survival, and different activities of human beings and living organisms (Weitekamp & Hofmann, 2021). Moreover, anthropogenic activities pollute the environment (Osipov et al., 2022).

According to the World Bank (2021), carbon dioxide emissions contributes three quarters of the total greenhouse gases emissions. The accumulation of the greenhouse gases is the major contributor towards climate change (IPCC, 2007). Consequently, CO_2 is the primary driver of the climate change. It is forecasted that the global temperature would rise to 3 to 4 degrees Celsius, if effective measures to reduce the CO_2 emissions are not taken (Li, et al., 2022; Marcotullio, et al., 2012; Zhang et al., 2021; Zhou et al., 2013; Ronaghi et al., 2019). Environmental sustainability is very important for the economic progress and social welfare. But such progress cannot be afford at the cost of high emissions of CO_2 emissions that deteriorate the environment (Sadorsky, 2014). Reduced carbon dioxide levels are associated with the stagnant economic growth in the developing countries (Liddle, 2013; Sun & huang, 2020; Zhang et al., 2021).

Fossil fuel energy consumption, increasing level of urbanization and population growth rate are the primary factors of the abrupt changes in the climatic conditions in Pakistan. Pakistan is considered most vulnerable to climate change (Mahmood et al., 2020; GOP, 2021; Xin et al., 2023). Urbanization is defined as a process that shifts labor force from agro-based economy to the urban-based or industrial-based economy. This transformation is called economic and social development. Industrialization, urbanization, and modernization pollute the environment which has become a thoughtful concern for all the developing countries including Pakistan (Grossman & Krueger, 1995).

Industrial activities cause more global warming as compared to the service sector. Energy is considered the most important factor of production that is used in industrial units as well as by the inhabitants who resides in the urban areas, so unregulated and unsustainable usage of energy leads to the environmental pollution (Neumayer, 2003). Exploitation of the natural resources is the major cause of environmental quality dilapidation. The natural resource-intensive growth that brings with it the rapid growth of urbanization and environmental degradation cast a negative impact on the development prospects of the economy. Anthropogenic activities because of the rapid economic growth degrade the environmental. Environmental degradation influence the human nourishment and the economic health. Population's behavior also rise the levels of contaminated emissions mainly due to their movements from rural to urban areas (Li & Ma, 2014).

Different social and economic activities deteriorate the environment that is the direct result of the depletion of the natural resources. Some natural resources such as lands, forests, grassland, and fishing areas can compensate the damage due to the anthropogenic activities. On the other hand, coal, oil, and gas increases the levels of contaminated emissions and degrade the environment (Ahmadov & Borg, 2019).

Renewable energy is a widely used determinant of the environmental quality and has an inverse relationship with CO_2 emissions (Ozcan & Ozturk, 2019; Hafeez et al., 2019; Ahmad et al., 2021). This relationship is also found valid in case of 17 OECD countries taking the data from 1977 to 2010 by utilizing the FMOLS and DOLS. Similar results are also found for the BRICS economies where the favorable effects of renewable energy consumption on the environment were observed (Liu et al., 2020).

In China, the policy of using coal energy has reduced the share of CO_2 emission in the atmosphere considerably (Qi et al., 2014). In China and Italy, it is observed that the non-renewable energy consumption has positive while renewable energy consumption has negative association with CO_2 emission (Chen et al. 2018; Moutinho et al., 2015).

Sustainable development demands the economic growth without harming the climate. Industrialized nations use fossil fuel energy due to their obsolete infrastructure to meet the energy demand. As a result, the economic development in the emerging economies generate the harmful gases and the usage of fossil fuel aggravate the air and land pollution (Fang et al., 2018). Considering the energy needs, the growth model of the sustainable development has substituted the traditional means of fossil fuel energy such as gasoline, biomass, and natural gas with wind, solar, and geothermal sources (Akadiri et al., 2019).

Climate change became a global issue when all the nations of the world signed the Paris Agreement in France. The purpose was to reduce the carbon emissions under the umbrella of United Nations Framework Convention for Climate Change ((UNFCCC), 2016). However, this process requires a handsome amount of money which developing countries often lack (Levinson & Taylor, 2008). Asian Development Bank report reported that the climate change brings disaster such as high evaporation, floods, and drought. According to the Global Climate Risk Index 2018, Pakistan stands in the top five countries where average temperatures are significantly high (Chaudhry, 2017; Salam, 2018).

FDI is beneficial in many ways as it generates employment, increases the production capacity, enhances the managerial skills, brings innovation and is a great source of technology spillover (Oxelheim & Ghauri, 2008; Ito et al., 2012; Lin et al., 2009). However, it is found that FDI increases CO_2 emissions and degrade the environment (Haug & Ucal, 2019; Shahbaz et al., 2018; Levinson & Taylor, 2008). FDI increases CO_2 emission by three channels such as increased demand for the inputs by operating firms which is known as the scale effect, demand for the latest technology by the firms to improve their production processes which is known as the technique effect, and finally migration from the rural areas to urban areas for the sake of employment in industry and in service sector which is known as a composition effect (Bakhsh et al., 2017; Zhang & Zhou, 2016; Shahbaz et al., 2015).

After taking a look at these arguments, the present study aims to analyze the following relationships.

First, the present study demonstrate the association between FFEC and CO_2 emissions in Pakistan. Second, it analyzes the influence of urbanization on CO_2 emission. Third, the paper allows us to gain an empirical insights to see the effects of FDI and CO_2 emission. And finally, with this information in mind, it provides the empirical results of how renewable energy affects CO_2 emission. Moreover, a detailed econometric analysis has been conducted to obtain the desired empirical results.

The remaining sections of the paper have been organized in following way: In Section 2, a detailed explanation of the previous literature is given; To prove the arguments presented in the proposed study, Section 3 provides the theoretical background of the empirical results; Section 4 demonstrates the data, their sources, empirical framework, and methodology of the paper. Results, and conclusion and policy implications are presented in Section 5 and 6, respectively.

2. Literature Review

Previous studies provide enough information about those factors that affect environmental quality in Pakistan. As this section is organized in four sections, one can get insight in these four sections separately.

2.1. Fossil Fuels Combustion-CO_2 Nexus

Rapidly increasing oil and gas energy production demand is the major cause of carbon emissions and global warming (Liang & Yang, 2019; Lin & Ahmad, 2017; Sun et al., 2009; Rehman, et al., 2021. Renewable energy is a sustainable, and a low-carbon energy resource. Wind, solar, biomass, water, geothermal, and marine sources are different kinds of renewable energy sources (Bayar et al., 2020; Manisalidis et al., 2020; Banday& Aneja, 2019).

Carbon dioxide emissions have got special attention of the researchers due to the international trade (Khan et al., 2020; Khan et al., 2019). Fossil fuels burning exacerbate the air pollution (Yang et al., 2015). Foreign investment and international trade deteriorate the environment by expanding the industries around the globe. It is observed that the greater investment and trade openness increase the CO_2 emission; however, this impact may also be negative if renewable energy sources are used (Wang et al., 2018).

The significance of climate change issue have also been realized in the face of catastrophic global warming. Energy consumption is compulsory for economic growth as well as for manufacturing sector. Constant supply of energy is needed for the upgradation of this sector which in turn causes the environmental pollution (Adebayo et al., 2021; Kihombo, et al., 2021).

2.2. Renewable Enrgy-CO_2 Nexus

Today, world is having the biggest warning like rising levels of greenhouse gases emissions that ultimately causes natural calamities through deteriorating the environment (Iqbal et al., 2021; Zafar et al., 2019). Developing countries extract the natural resources to encourage their economic growth (Balsalobre-Lorente et al., 2018). However, it is estimated that renewable energy sources emit less amount of CO_2 emissions and in some cases holds a negative association with CO_2 (Ozcan & Ozturk, 2019; Hafeez, et al., 2019a; Hafeez, et al., 2019b; Ahmed, et al., 2021a; Ahmad et al., 2021b; Ahmad et al., 2021c; Salim et al., 2019; Shafiei & Salim, 2014).

It is estimated that only 20% to 30% usage of clean coal sources can help Pakistan to lower their CO_2 emission. In Pakistan, five nuclear plants are working and two are under construction. Nuclear power plants help to reduce the CO_2 emissions from the environment (Mengal, et al., 2019).

Rehman et al., 2022 estimated that fossil fuel energy, GDP, renewable energy, CO_2 emissions and increase the economic growth in Pakistan. Short and long term dynamics have also been predicted between non-renewable energy, renewable energy, and economic growth and findings have confirmed a positive relationship between renewable based energy consumption and economic growth, while having a negative and significant association between non-renewable energy, economic growth and terrorism (Mahmood et al., 2019).

(Luqman et al., 2019) analyzed role of renewable energy and nuclear energy has always been minimal due to the electricity shortage in Pakistan. It has been documented that the share of fossil fuel energy related CO_2 will be more than doubled till 2050 (International Energy Agency, World Energy Outlook 2017, 2017). Bilgili et al. (2016) worked with Environmental Kuznets Curve (EKC) hypothesis and validated that there exists an inverted U-shaped relationship between CO_2 emission and per capita income, and found a negative association and causality from renewable sources to CO2 in case of 17 OECD countries.

Abbas et al. (2021) investigated that, on the average temperature, the impacts of urbanization and transportation have a positive association with CO_2 emission in long run in Pakistan. However, traditional energy sources and ecological footprints have an insignificant and significant relationships with CO_2 in the short and long run respectively, while renewable energy has an inverse relationship with it in long run. Biomass, biofuels, hydropower, geothermal, solar, nuclear, wind and sea are the clean energy sources that may help to improve the environment. They also help to slacken the CO_2 emission by giving solutions to the major problems like climate change, and global warming (Georgescu et al., 2011; Apergis & payne, 2012; Danish et al., 2017; Shahbaz et al., 2017; Zoundi, 2017; Ullah et al., 2020; Danish & Wang 2019).

2.3. FDI-CO_2 Nexus

FDI is considered a blessing for developing countries as they suffer from many financial constraints. FDI offers technological know-how, access to international technology and helps to trigger the economic growth by increasing the foreign capital investment (Nunnenkemp, 2001). The developing countries enjoy benefits by getting exposure to the new and innovative production techniques and inputs because of foreign investment (Mulali &Tang, 2013; Udemba, 2020; Alfaro et al., 2010; Nataniel et al., 2020; Zafar, et al., 2019).

(Omri et al., 2014) tested an empirical relationship between CO_2, FDI, capital stock, GDP, urban population, financial development, trade openness and exchange rate by utilizing GMM method for 54 countries taking data from the period 1990 to 2011 and confirmed the pollution haven hypothesis in these countries. According to the scale effect of Grossman and Krueger's (1991), in the first stage of economic growth, less developed countries are in need of more natural resources and thereby cause the environmental pollution. Furthermore, FDI triggers the economic growth and, resultantly, the economic activities degrade the environment (Zhang & Zhou, 2016).

China emerged as a second rapidly developed economy in the 2010 due to the FDI inflows, technology transfers, and employment generation. However, CO_2 emissions also increased as in 2007 these carbon emissions exceeded the US and China was first in the world's ranking of CO_2 emitter's countries. This scenario led to the environmental issues such as global warming and climate change (Dutta & Dutta 2016). Economic growth and technology are the two main streams through which FDI endanger the environment by increasing CO_2 emission in the atmosphere (Jaffe et al., 2002). First, it is believed that capital and technology stimulated the economic growth in China in multiple sectors. Just as economic growth is often linked with the urbanization and industrialization, increased demand for the energy consumption due to the scale effect leads to increase the CO_2 emission. (Wei & Liu, 2001; Whalley & Xin, 2010; Yao & Wei, 2007; Dean, 1999).

Acemoglu et al., 2012, investigated the two possibilities. First, possibility is that a country adopts clean technology that is environmental friendly and will decease CO_2 emissions. Secondly, a country may adopt the dirty technology first that is environmental unfriendly and will lead to increase the CO_2 emission. Clean technology and dirty technology refers to the renewable and non-renewable technologies respectively.

3. Theoretical Framework

3.1. Proposition No 1: Shadow price should impose on the depletion of non-renewable resources by the firms.

(Hotelling, 1931) proposed a model that how non-renewable resources are extracted. The main purpose is to detect the optimal depletion point of a firm. The firms seek to maximize its profits through channel of these resources to be extracted. The model depends upon the three basic propositions: (a) The entire resource stock is identifiable, (b) The entire reserve is subject to exhaustion during its entire life, (c) the interest rate will remain fixed.

In next step, the following terms are defined:

Q_t shows the extraction of the resource and its quality in the period t;

R_t shows the quantity of resource when period t begins;

C = C (Q_t , R_t) = total cost of extraction

P(Q_t) resource inverse demand function;

R shows discount rate;

T shows the time horizon.

Firm's objective function is to maximize its benefit.

$$Max(Q_t) \sum_{t=0}^{T}[\frac{1}{1+c^t}(P_t Q_t - k(Q_t , R_t))]$$ Eq. 1

S. T.

$$R_0 = \bar{R}_0 \; ; \; R_t = \bar{R}_t$$ Eq. 2

and

$$\frac{dR_t}{d_t} = -Q_t \qquad or \qquad R_{t=1} - R_t = -Q_t$$ Eq. 3

The Lagrange function is given by:

$$L = \sum_{t=0}^{T}[\frac{1}{1+c^t}(P_t Q_t - k(Q_t , R_t))] + \sum_{t=0}^{T-1} \mu_t(R_t - R_{t+1} - Q_t) + \alpha(\bar{R}_0 - R_0) + \beta(\bar{R}_T R_T)$$ Eq. 4

First order condition as a result of differentiation w.r.t. to Q_t is:

$$P_t - \frac{(\partial k / \partial Q_t)}{1+c^t} - \mu_t = 0 \; ;$$ Eq. 5

Which can be rewritten as:

$$P_t - \frac{\partial k}{\partial Q_t} = \mu_t(1+c)^t = \lambda_t$$ Eq. 6

User Cost is shown in Eq. 6 that shows the opportunity cost of the non-renewable resource. It suggests to include the opportunity cost of such resources that show the effect of their depletion.

4. Model and Methodology

4.1 Data

After analyzing the previous papers and literature reviews, this study attempts to analyze the impacts of foreign direct investment, fossil fuel energy consumption, coal rent, urban population, renewable energy consumption, and renewable electricity output on the CO_2 emission in of Pakistan. The annual time series data has been collected for last 50 years from 1972 to 2021. The data has been taken from the World Development Indicators. Environmental quality has been measured by carbon dioxide emissions from gaseous fuel consumption. All the variables along with their units of measurements and sources are described in the table 1.

Table. 1 Variables and their Description

Variables	Notation	Details	Source

Climate Change	CO_2	CO_2 emissions from gaseous fuel consumption (kt)	WDI
Foreign Direct Investment	FDI	Foreign direct investment, net inflows (% of GDP)	WDI
Fossil Fuel Energy Consumption	FFEC	Fossil fuel energy consumption (% of total)	WDI
Coal Rent	CR	Coal rents (% of GDP)	WDI
Population	UP	Urban population growth (annual %)	WDI
Renewable Energy Consumption	REC	Renewable energy consumption (% of total final energy consumption)	WDI
Renewable Energy Output	REO	Renewable electricity output (% of total electricity output)	WDI

4.2. Methodology

4.2.1. Stationary Test

This study has incorporated the Augmented Dickey-Fuller (ADF) tests (Dickey & Fuller, 1979) and Phillips-Parron (PP) tests (Phillip & Parron, 1988), in order to check the stationary properties of the variables. The ADF and PP unit-roots are traced in the following manner in Eq. (4.1).

$$\Delta T_t = \lambda_0 + \lambda_1 T_{t-1} + \sum_{N=k}^{M} d_N \, \Delta T_{t-N} + W_i$$
Eq. 7

Where T_t represents the time-series, Δ shows the first difference operator, and λ_0 denotes constant. M represents the optimum number of lags of the dependent variable and W_i is a pure white noise error term, Whilst the Phillip-Parron unit root test is expressed in the following Eq. (4.2).

$$\Delta T_t = \lambda + M^* T_{t-1} + W_i \quad \text{Eq. 8}$$

Both unit root tests have been constructed on the ground of t-statistics.

4.2.2. ARDL Bounds Testing Approach, Short run and Long run Estimates

The ARDL model was introduced by (Pesaran & Pesaran, 1997; Pesaran & Shin 1998; Pesaran et al., 2001), and the present study has employed this technique to examine the relationships among the time series data such as CO_2, FDI, FFEC, CR, UP, REC, and REO in the long run. The ARDL model is expressed as follows in Eq. 9.

$$\Delta lnCO_{2j} = \alpha_0 + \alpha_1 \sum_{q-1}^{k} \Delta lnCO_{2j-1} + \alpha_2 \sum_{q-1}^{k} \Delta lnFDI_{j-1} + \alpha_3 \sum_{q-1}^{k} \Delta lnFFEC_{j-1} + \alpha_4 \sum_{q-1}^{k} \Delta lnCR_{j-1} + \alpha_5 \sum_{q-1}^{k} \Delta lnUP_{j-1} + \alpha_6 \sum_{q-1}^{k} \Delta lnREC_{j-1} + \alpha_7 \sum_{q-1}^{k} \Delta lnREO_{j-1} + \alpha_8 lnCO_{2j-1} + \alpha_9 lnFDI_{j-1} + \alpha_{10} lnFFEC_{j-1} + \alpha_{11} lnCR_{j-1} + \alpha_{12} lnUP_{j-1} + \alpha_{13} lnREC_{j-1} + \alpha_{14} lnREO_{j-1} + \mu_j \quad \text{Eq. 9}$$

Where μ_j is the white noise error term and Δ shows the difference operator. The summation sign symbolizes error correction dynamics and α_0 entails constant. The second part of the equation is written to express the long run association. The ARDL bounds test approach is employed to examine the long run association in the study variables. In order to examine the long run associations among the couple of variables, it is observed that if the F-statistic test surpasses the upper critical bound value, the null hypothesis is rejected which states that there exists no co-integration among the variables. An alternative hypothesis is accepted, if the computed value of the F-statistic is less than the lower critical bound value. While if the calculated value of F-statistic lies between the lower and upper critical bounds value, the result will be inconclusive. Additionally, if the long run association exists among the variables of the study, the long run coefficients are estimated. The long run estimated model can be written in the following manner in Eq. 10.

$$\Delta lnCO_{2j} = \lambda_0 + \lambda_1 \sum_{q=1}^{k} \Delta lnCO_{2j-1} + \lambda_2 \sum_{q=1}^{k} \Delta lnFDI_{j-1} + \lambda_3 \sum_{q=1}^{k} \Delta lnFFEC_{j-1} + \lambda_4 \sum_{q=1}^{k} \Delta lnCR_{j-1} + \lambda_5 \sum_{q=1}^{k} \Delta lnUP_{j-1} + \lambda_6 \sum_{q=1}^{k} \Delta lnREC_{j-1} + \lambda_7 \sum_{q=1}^{k} \Delta lnREO_{j-1} + \varepsilon_j \quad \text{Eq. 10}$$

The short run estimated model is projected as follows:

$$\Delta lnCO_{2j} = \varphi_0 + \varphi_1 \sum_{q=1}^{k} \Delta lnCO_{2j-1} + \varphi_2 \sum_{q=1}^{k} \Delta lnFDI_{j-1} + \varphi_3 \sum_{q=1}^{k} \Delta lnFFEC_{j-1} + \varphi_4 \sum_{q=1}^{k} \Delta lnCR_{j-1} + \varphi_5 \sum_{q=1}^{k} \Delta lnUP_{j-1} + \varphi_6 \sum_{q=1}^{k} \Delta lnREC_{j-1} + \varphi_7 \sum_{q=1}^{k} \Delta lnREO_{j-1} + \varsigma ECT_{j-1} + \varepsilon_j \quad \text{Eq. 11}$$

Where, ς is coefficient of error correction term.

However, asymmetric impacts of these variables on the environmental quality have been ignored. Therefore, to fill this gap, we follow (Shin et al., 2014) econometric approach in order to check the asymmetric effects of independent variables on the dependent variable. The non-linear ARDL model also does not require that all the variables should be integrated of same order rather it accepts the variables to the integrated of different order.

$$\Delta lnCO_{2j} = \delta_0 + \sum_{q=1}^{p} \delta_q \Delta lnCO_{2j-q} + \sum_{q=0}^{p} \delta_i^{+} \Delta lnFDI_{j-q}^{+} + \sum_{q=0}^{p} \delta_q^{-} \Delta lnFDI_{j-q}^{-} + \sum_{q=0}^{p} \delta_q^{+} \Delta lnFFEC_{j-q}^{+} + \sum_{q=0}^{p} \delta_q^{-} \Delta lnFFEC_{j-q}^{-} + \sum_{q=0}^{p} \delta_q^{+} \Delta lnCR_{j-q}^{+} + \sum_{q=0}^{p} \delta_q^{-} \Delta lnCR_{j-q}^{-} + \sum_{q=0}^{p} \delta_q^{+} \Delta lnU_{j-q}^{+} + \sum_{q=0}^{p} \delta_q^{-} \Delta lnUP_{j-q}^{-} + \sum_{q=0}^{p} \delta_q^{+} \Delta lnREC_{j-q}^{+} + \sum_{q=0}^{p} \delta_q^{-} \Delta lnREC_{j-q}^{-} + \sum_{q=0}^{p} \delta_q^{+} \Delta lnREO_{j-q}^{+} + \sum_{q=0}^{p} \delta_q^{-} \Delta lnREO_{j-q}^{-} + \gamma_1 lnCO_{2j-1} + \gamma_2^{+} lnFDI_{j-1}^{+} + \gamma_3^{-} lnFDI_{j-1}^{-} + \gamma_4^{+} lnFFEC_{j-1}^{+} + \gamma_5^{-} lnFFEC_{j-1}^{-} + \gamma_6^{+} lnCR_{j-1}^{+} + \gamma_7^{-} lnCR_{j-1}^{-} + \gamma_8^{+} lnUP_{j-1}^{+} + \gamma_9^{-} lnUP_{j-1}^{-} + \gamma_{10}^{+} lnREC_{j-1}^{+} + \gamma_{11}^{-} lnREC_{j-1}^{-} + \gamma_{12}^{+} lnREO_{j-1}^{+} + \gamma_{13}^{-} lnREO_{j-1}^{-} + \varepsilon_j \quad \text{Eq. 12}$$

Where, $\Sigma_j^p \ \delta_j^{+}$ and $\Sigma_j^p \ \delta_q^{-}$ capture the short run positive and negative effects of lnFDI, lnFFEC, lnCR, lnUP, lnREC, and lnREO on the environmental quality, while γ_i^{+} and γ_i^{-} capture the effects of long run between the explanatory variables and explained variable.

From Eq. 13, short run model is represented where, θ shows the long run equilibrium speed of adjustment after shock in the short run. Similarly, from the non-linear ARDL model Eq. 4.14, we can obtain the error correction model. This asymmetric equation version of non-linear ARDL approach is represented as follows:

$$\Delta lnCO_{2j} = \sum_{q=1}^{p} \delta_q \Delta lnCO_{2j-1} + \sum_{q=1}^{p} (\delta_q^{+} \Delta lnFDI_{j-1}^{+} + \delta_q^{-} \Delta lnFDI_{j-1}^{-}) + \sum_{q=1}^{p} (\delta_q^{+} \Delta lnFFEC_{j-1}^{+} + \delta_q^{-} \Delta lnFFEC_{j-1}^{-}) + \sum_{q=1}^{p} (\delta_q^{+} \Delta lnCR_{j-1}^{+} + \delta_q^{-} \Delta lnCR_{j-1}^{-}) + \sum_{q=1}^{p} (\delta_q^{+} \Delta lnUP_{j-1}^{+} + \delta_q^{-} \Delta lnU_{j-1}^{-}) + \sum_{q=1}^{p} (\delta_q^{+} \Delta \mathrm{lnREC}_{j-1}^{+} + \delta_q^{-} \Delta \mathrm{lnREC}_{j-1}^{-}) + \sum_{q=1}^{p} (\delta_q^{+} \Delta \mathrm{lnREO}_{j-1}^{+} + \delta_q^{-} \Delta \mathrm{lnREO}_{j-1}^{-}) + \theta \mathrm{ECT}_{j-1} + \varepsilon_j \quad \text{Eq. 13}$$

In the Eq. 3.13, θ is representing the error correction term. It shows that after a shock in the short run, the long run equilibrium speed of adjustment is possible. It also shows that δ_q shows the short run coefficient estimates and δ_q^+ and δ_q^- are representing the short run adjustment asymmetries.

5. Results and Discussion

5.1. Descriptive Statistics

Table 2: Descriptive Statistic

	CO_2	FDI	FFEC	CR	UP	REC	REO
Mean	10.286	-0.671	3.951	-2.762	1.223	3.898	3.521
Median	10.352	-0.515	4.042	-2.774	1.272	3.907	3.503
Maximum	11.281	1.299	4.142	-1.855	1.505	4.062	3.813
Minimum	8.596	-3.102	3.563	-3.559	0.974	3.653	3.228
Std. Dev.	0.839	0.958	0.184	0.407	0.185	0.091	0.131
Skewness	-0.368	-0.458	-0.873	0.139	-0.048	-0.276	0.465
Kurtosis	1.852	3.369	2.299	2.531	1.440	2.753	2.981
Jarque-Bera	3.874	2.036	7.386	0.62	5.085	0.763	1.803
Probability	0.144	0.361	0.0248	0.733	0.078	0.682	0.405

Descriptive statistics of all the variables are shown in the Table 2. The mean value of the CO_2 is 10.286 and its median is 10.352 in the third row and second column, the maximum value and minimum value of the CO_2 are 11.281 and 8.596. The remaining rows are showing standard deviation, skewness, kurtosis, Jarque-Bera and probability of the CO_2 and their statistics values are 0.839, -0.368, 1.852, 3.874, and 0.144. The second column shows statistics of FDI. The average value and median of FDI are -.0671 and -0.515. Maximum and minimum values are 1.299 and -3.102. And standard deviation, skewness and kurtosis are 0.958, -0.458, and 3.369. The average mean value and median of fossil fuel energy consumption (FFEC) and coal rent (CR) are 3.951, 4.042, -.2.762, and -2.774, respectively. Moreover, standard deviation values, skewness, kurtosis, and Jarque-bera of FFEC are 0.184, -0.873, 2.299, 7.386 and of CR are 0.407, 1.139, 2.531, and 0.62. The fifth column id of population (UP). The average value, median, maximum and minimum values of UP are 1.223, 1.272, 1.505, and 0.974. The standard deviation, skewness, kurtosis, and Jarque-bera of population are 0.185, -0.048, 1.440, and 5.085. The last two columns are of REC and REO. Their average mean values, median values, maximum and minimum values are 3.898, 3.521, 3.907, 3.503, 4.062, 3.813, and 3.653, 3.228 respectively.

5.2. Correlation Analysis

Table 3: Correlation Test

	CO_2	FDI	FFEC	CR	UP	REC	REO
CO_2	1.00						
FDI	0.76	1.00					
FFEC	0.96	0.82	1.00				

CR	-0.20	-0.09	-0.30	1.00			
UP	-0.93	-0.62	-0.85	0.27	1.00		
REC	-0.40	-0.05	-0.24	-0.02	0.49	1.00	
REO	-0.39	-0.11	-0.26	0.17	0.53	0.53	1.00

The purpose of correlation analysis is to describe that there exists not any multicollinearity among the variables. It can be observed that all the correlation coefficients are found less than 80% except four values. The correlation coefficient value between CO_2 and FDI is 0.76 and it shows the positive association. The correlation coefficient value between CO_2 and CR, REC, and REO are showing the negative associations representing negative signs such as -0.20, -0.40, and -0.39 respectively. Furthermore, the relationships between FDI and CR, UP, REC, REO and the relationships between FFEC and CR, UP, REC, REO are -0.09, -0.62, -0.05, -0.11 and -0.30, -0.85, -0.24,and -0.26 respectively. Population shows the positive associations with the renewable energy consumption and output by the coefficient values of 0.49 and 0.53.

5.3. Unit Root Test Results

Table 4: Unit Root Test

Variables	ADF		PP		Conclusion
	Level	1st Difference	Level	1st Difference	
CO_2	-2.199	-3.930	-3.292	-3.930	I(1)
	0.209	0.003	0.020	0.003	
FDI	-2.119	-8.201	-1.970	-8.201	I(1)
	0.238	0.00	0.298	0.00	
FFEC	-3.023	-6.234	-3.023	-6.303	I(0,1)
	0.039	0.00	0.039	0.00	
CR	-3.601	-7.409	-3.787	-8.132	I(0)
	0.009	0.00	0.005	0.00	
UP	-0.895	-4.004	-0.042	-4.015	I(1)
	0.781	0.003	0.949	0.002	
REC	-2.435	-7.817	-2.431	-8.777	I(1)
	0.137	0.00	0.138	0.00	
REO	-1.902	-7.337	-1.896	-7.337	I(1)
	0.328	0.00	0.331	0.00	

The study has utilized the augmented Dickey-Fuller (ADF) and Phillips-Perron (P-P) (Dickey & Fuller, 1979; Phillips & Perron, 1988). The attribution of the linear-ARDL and non-linear ARDL is that, these methods help to get results successfully even when all the simulated variables are of integrated of zero and one. The first column of the Table 4 is of ADF- Fisher Chi –Square and shows these variables to be non-stationary at level except coal rent and FFEC. The variables such as CO_2, FDI, UP, REC, and REO are stationary at the first difference as their probability values are zero. The third column is showing the values of PP- Fisher Chi-Square. It also shows that fossil fuel energy consumption and coal rent do not hold stationarity at level; however, the remaining variables become stationary at first difference.

5.4. Symmetric Bounds Test to Co-integration

Table 5: Bound Test Estimation (ARDL)

F-statistic	k	Range	Critical values	
			I (0) bound	I (1) bound
6.45	6	10%	2.12	3.23
		5%	2.45	3.61
		2.5%	2.75	3.99
		1%	3.15	4.43

A symmetric method is used to analyze the linkages of long run association of variables through bounds tests approach. The Table 5 is showing that 6.45 is the value of F-statistics and critical values of upper and lower bounds at the 10%, 5%, 2.5%, and 1% which are 3.23, 3.61, 3.99, and 4.43. The study found a long run association among all the variables of the study as the coefficient F-statistics is higher than the upper bound value at 1%.

5.5. Linear Autoregressive Distributed Lag model Results (Linear-ARDL)

Table 6: Long Run Results of ARDL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FDI	0.046639	0.075202	0.620186	0.5395
FFEC	3.407531	0.983981	3.463005	0.0015
CR	0.08631	0.098887	0.872808	0.3893
UP	-0.12461	1.056513	-0.11794	0.9068
REC	0.343277	0.56264	0.610118	0.5461
REO	-1.302	0.680446	-1.91346	0.0647

Table 7: Short Run Results of ARDL

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.163692	0.017761	9.216568	0.0000
D(FDI)	-0.009317	0.011196	-0.832172	0.4115
D(FFEC)	0.457055	0.298839	1.529435	0.136
D(FFEC(-1))	-0.649162	0.27425	-2.367045	0.0241

D(FFEC(-2))	-0.446557	0.262982	-1.698054	0.0992
D(REO)	0.208614	0.074586	2.796942	0.0087
D(REO(-1))	0.385248	0.080856	4.764601	0.0000
D(REO(-2))	0.281097	0.082967	3.388065	0.0019
CointEq(-1)*	-0.210202	0.028694	-7.325565	0.0000

After checking the stationary properties, the joint t-significance is tested against critical values which show a long run association in Table 5 (Pesaran et al., 2001). The calculation of the F-statistic shows that there exists a long run relationship shown in the table 5. It is computed that F-statistic is greater than upper bound I(1) value and it is also highly significant even at one percent level (Narayan, 2005). Therefore, the results confirms the existence of long run relationships between CO_2 emission and FDI, FFEC, CR, UP, REC, and REO. Another way of checking the existence of co-integration is to examine ECT_{t-1} which is co-integration value. It suggests that if the ECT_{t-1} is statistically significant carrying a negative sign, it confirms long run association (Pesaran et al., 2001). In Table 6 and 7, ARDL short run and long run results are reported.

FDI is statistically insignificant in short and long run as the findings are consistent with (Haq et al., 2022; Demena & Afesorgbor, 2020). In the long run, fossil fuel energy consumption has a positive and a highly significant relationship with CO_2 emission in Pakistan. In the short run, fossil fuel energy consumption has a negative association with CO_2 emission and its value is also statistically significant. The values of CR, UP, and REC are highly insignificant in the long run. The findings are in line with the recently developed literatures for China and Pakistan (Abbasi et al., 2022; Uzair et al., 2022; Raza et al., 2021). In the short run, renewable energy output is positive and statistically significant. However, in the long run, it is showing the negative sign and is statistically significant. The results are consistent with the previous studies results (Abbas et al., 2021; Yuping et al., 2021). The ECT_{t-1} term coefficient is statistically significant with the negative sign. It shows that any disequilibrium, in the past years is connected in the period of one year at the speed of 21% and it is a reasonable convergence to the long run equilibrium.

5.6. Diagnostic Test Results

Table 8: Diagnostic Test Results

Breusch-Pagan-Godfrey Heteroscedasticity test	1.599 0.133
Ramsey test	0.153 0.697
Breusch-Godfrey Serial Correlation LM Test	1.081 0.352
Jarque-Bera TEST	1.197 0.549

CUSUM ARDL	Unstable
CUSUMQ ARDL	Stable

Table.8 shows the different diagnostic tests results. Breusch-Pagan-Godfrey heteroscedasticity test has found the insignificant chi-square values rejecting the alternative hypothesis of heteroscedasticity rather accepting the null hypothesis of homoscedasticity. In order to check the serial correlation, the study has incorporated the Breusch-Godfrey Serial Correlation LM test and Jarque-Bera test for the normality. Again it is found that the chi-square values are statistically insignificant. Moreover, the result of Ramsey test also shows that its value is statistically insignificant.

5.7. Asymmetric Bounds test to Co-integration

Table 9: NARDL Bound Test

F-statistic	**k**	**Range**	**Critical values**	
			I (0) bound	**I (1) bound**
7.62	12	10%	1.83	2.94
		5%	2.06	3.24
		2.5%	2.28	3.5
		1%	2.54	3.86

The degree of co-integration is checked by utilizing the asymmetric bounds tests approach. The F-statistic value is reported which is 7.62. The lower bounds critical values at 10%, 5%, 2.5%, and 1% are 1.83, 2.06, 2.28, and 2.54 respectively. The critical values for the upper bounds values are 2.94, 3.24, 3.50 and 3.86 respectively. It is observed that the F-statistic value is greater than upper bound critical value at 1% level.

5.8. Results of Non-Linear Autoregressive Lag Model (Non-Linear ARDL)

Table 10: Long Run Estimates (NARDL)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FDI_POS	-0.151839	0.044404	-3.419483	0.0041
FDI_NEG	0.112779	0.068208	1.653468	0.1205
FFEC_POS	0.719447	0.626206	1.148898	0.2698
FFEC_NEG	4.288592	1.408479	3.04484	0.0087
CR_POS	0.087669	0.029602	2.961566	0.0103
CR_NEG	0.125367	0.065402	1.916868	0.0759
UP_POS	6.290521	0.938646	6.701694	0.0000
UP_NEG	2.793258	0.384956	7.256045	0.0000
REC_POS	-0.729252	0.230942	-3.157728	0.007
REC_NEG	0.495633	0.224346	2.209236	0.0443

REO_POS	-1.211736	0.140691	-8.612722	0.0000
REO_NEG	0.401511	0.159704	2.514095	0.0248

Table 11: Short Run Estimates (NARDL)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	9.497923	0.69981	13.57219	0.0000
D(FDI_Positive)	-0.23066	0.0169	-13.6524	0.0000
D(FDI_Positive(-1))	-0.08004	0.01016	-7.87521	0.0000
D(FDI_Negative)	.027891	.01212	2.302026	0.0372
D(FDI_Negative(-1))	0.168729	0.0164	10.2869	0.0000
D(FFEC_Positive)	0.933054	0.14838	6.28833	0.0000
D(FFEC_Positive(-1))	-0.42029	0.15569	-2.69962	0.0173
D(FFEC_Negative)	-0.06853	0.37719	-0.18169	0.8584
D(FFEC_Negative(-1))	-2.60114	0.40336	-6.44871	0.0000
D(CR_Negative)	0.003569	0.01181	0.302181	0.767
D(CR_Negative(-1))	-0.11297	0.01662	-6.79627	0.0000
D(UP_Positive)	-3.09862	0.78199	-3.96249	0.0014
D(UP_Positive(-1))	3.812498	0.72076	5.289569	0.0001
D(UP_Negative)	-0.24339	0.24269	-1.00287	0.3329
D(UP_Negative(-1))	1.64833	0.389	4.237308	0.0008
D(REC_Negative)	0.288466	0.07072	4.078778	0.0011
D(REC_Negative(-1))	0.94957	0.09011	10.53814	0.0000
D(REO_Positive)	-1.170357	0.06962	-16.81063	0.0000
D(REO_Negative)	0.34175	0.05769	5.92411	0.0000
D(REO_Negative(-1))	0.19539	0.06183	3.16019	0.0069
CointEq(-1)*	-1.12908	0.08325	-13.5631	0.0000

Table 10 illustrates the findings of non-linear ARDL technique. Demonstrating the short run estimations of the non-linear ARDL, it is seen that the positive shock on FDI decreases the CO_2 emission in Pakistan. Its coefficient value shows that 1% change in the FDI due to the positive shock reduces the CO_2 emission by -0.1518 percent. The value is also statistically significant as its probability is less than 5% level of significance. On the other hand, a negative shock on the FDI does not increase or decrease the CO_2 emissions in the long run and the reason is that its value is not statistically significant. However, in the short run, the results are opposite. The findings confirm the arguments which were put forwarded by (Haq et al., 2022; Demena & Afesorgbor, 2020). The positive shock on the fossil fuel energy consumption does not decrease or increase the CO_2 emissions as its coefficient value is not statistically significant. However, the negative shock on the fossil fuel energy consumption has a positive relationship with the CO_2 emission in the long run and its coefficient value shows that 1% change in the FFEC reduces the CO_2 emission by 4.2885. The present study results have shown their reliability with the results presented in the previous studies (Abbasi et al., 2022; Uzair Ali et al., 2022; Abbas et al., 2021). A positive shock on the coal rent shows a positive and a significant result. Its coefficient value shows that 1% change in CR increases the CO_2 emission by 0.0876%. The findings are consistent with the results of (Uzair Ali et al., 2022). Similarly, the next coefficient value is of population which shows that a positive shock on the population increases the CO_2, while a negative shock decreases it in the long run. An increasing trend in the population shows that 1% change in population will increase the CO_2 emission by 6.2905 percent as its probability value is less than 5% level of significance and is highly statistically significant. A negative shock on the population shows that 1% decreasing trend of population will reduce the CO_2 emission by 2.7932 percent. In case of renewable energy consumption, positive shock cause reduction of CO_2 emissions to some extent. It can be seen by their coefficient values that the 1% increasing trend in the REC reduces CO_2 by -0.7292% and 1% decreasing trend also reduces it by 0.4956 percent. The last variable is renewable energy output. A positive shock on the REO deceases the CO_2 as its coefficient value shows that 1% increasing trend in the REO reduces the CO_2 emission by -1.2117%. A negative shock on REO reduces CO_2 in the long run because its coefficient value is positive which shows that 1% decreasing trend of REO decreases the CO_2 by 0.4015%.

The results of the short run estimates show that there comes a large rise in the carbon dioxide emissions due to the positive shock on the foreign direct investment. It coefficient value is -0.08004 which shows that a positive shock on the foreign direct investment deceases the CO_2 emission in the short run similarly a negative shock on the FDI or decreasing trend of FDI also decreases it. The harmful effects of carbon dioxide have increased by 0.93305 percent due to increased usage of fossil fuel energy consumption. On the other hand, a negative shock on fossil fuel energy consumption increases the CO_2 by -2.60114%.

Furthermore, a negative shock on the coal rent causes the CO_2 emission to increase by -0.1129 percent. An increasing trend in population tends to show a mixed effects on CO_2. Conversely, a decreasing trend in population tends to not impede the CO_2 emissions such as the coefficient value falls by 1.6483% as population squeezes by 1%. Additionally, a negative shock on the renewable energy consumption shows a positive association with CO_2 emission in the short run. It indicates that CO_2 emissions decreases by 0.2884% due to 1% decrease in REC. Further, a positive or increasing trend in renewable energy output shows that the CO_2 emissions will reduce by the amount of -1.1703%. Also, a negative shock on REC decreases CO_2 emissions by 0.3417% and 0.1953% at while first differenced and on 1 year lag. The results are in line with the previous findings (Abbas et al., 2021; Yuping et al., 2021).

5.9. Diagnostic Tests

Table 12: Diagnostic test Results (NARDL)

Breusch-Pagan-Godfrey Heteroscedasticity test	0.993627 0.5293
Ramsey test	1.361061 0.2933

Breusch-Godfrey serial Correlation LM Test	9.123499 0.4598
Jarque-Bera TEST	9.257 0.2497
CUSUM	Stable
CUSUMQ	Stable

In the Table. 12, diagnostic tests have been included for the current study. First, the Breusch-Pagan-Godfrey heteroscedasticity test has been conducted. It is found that its probability chi-square value is insignificant. It means that it rejects the null hypothesis of homoscedasticity. Next, in this study, Breusch-Godfrey serial Correlation LM test and Jarque-Bera tests are conducted in order to check the normality. The results of the both tests confirm that the probability chi-square is statistically insignificant and there exists normality and no serial correlation in the model. The study has further check the robustness of the results having applied cumulative sum of residuals (CUSUM) and cumulative sum of recursive residuals square (CUSUMQ). (Brown et al., 1975)

Figure. 3

5.10. CUSUM and CUSUM of Square ARDL and NARDL

The stability of the residuals is checked by CUSUM and RS-CUSUM graphs. The outcomes are obtained from the mean (CUSUM) and variance (CUSUM for square) for stability of the residuals for the specification purpose in the following graphs, 3, 4, 5, 6. These figures describe that the CUSUM and CUSUM square residuals do not deviate from their critical bounds values and remain at their conventional positions of five percent level of significance. So, the specifications of the model are plausible to confirm that the independent variables cast a significant influence on CO_2 emission in case of Pakistan.

5.11. CUSUM FOR MODEL (ARDL)

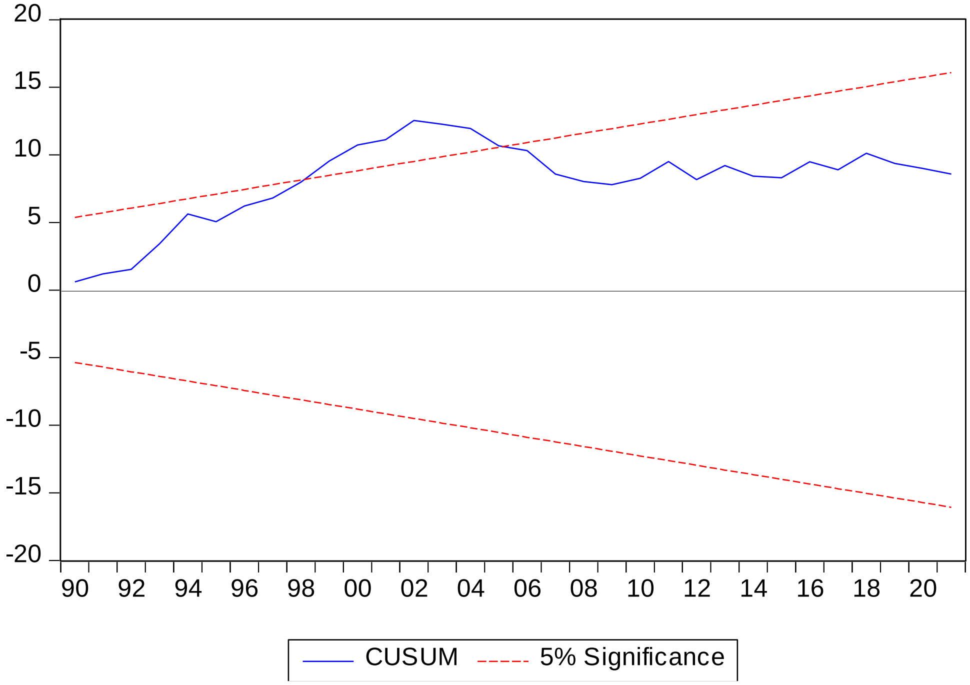

Fig. 3. ARDL CUSUM Graph

CUSUM OF SQUARE (ARDL)

Figure. 4

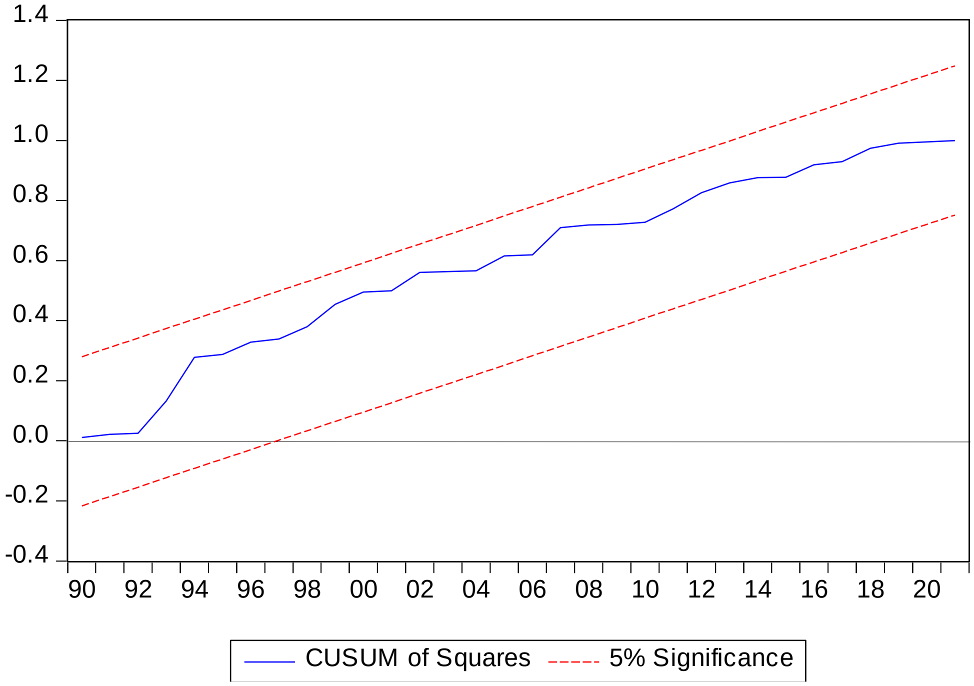

Fig. 4 ARDL CUSUM of Squares Graph

CUSUM FOR MODEL (NARDL)

Figure. 5

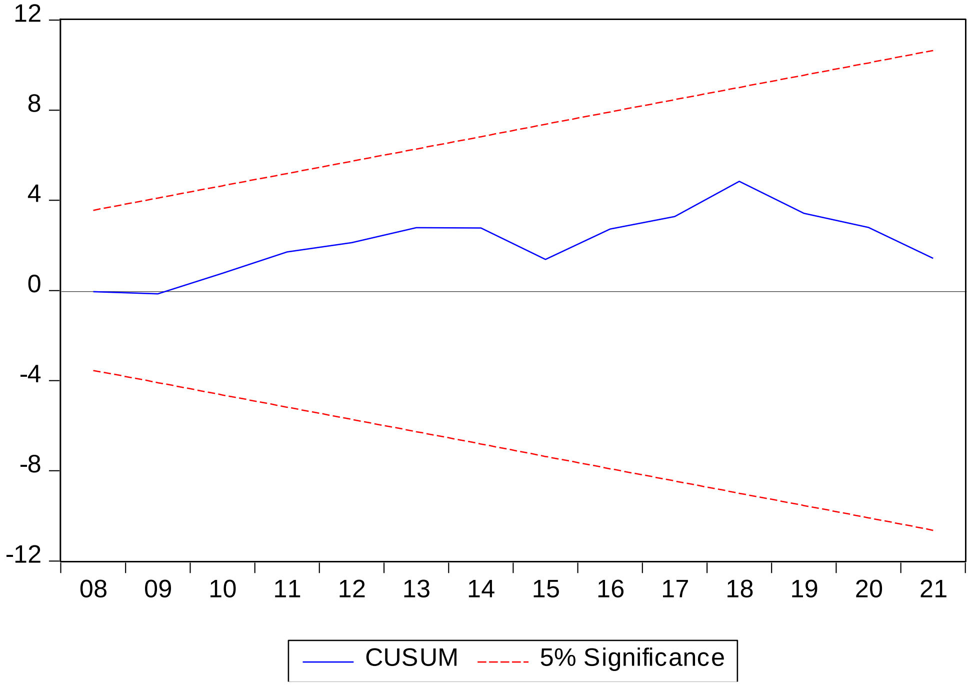

Fig. 5. NARDL CUSUM Graph

CUSUM of Square (NARDL)

Figure. 6

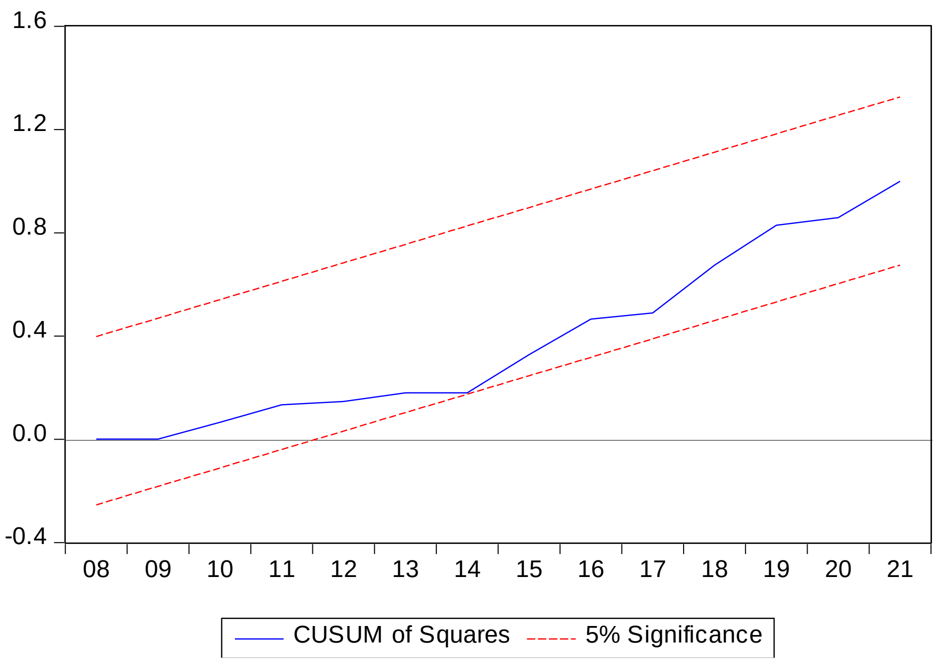

Fig. 6. NARDL CUSUM of Squares Graph

6. Conclusion

The present study explores the impact of fossil fuel energy consumption, population growth, and renewable energy consumption on the climate change conditions in Pakistan. The study has utilized the symmetric and asymmetric ARDL techniques to analyze the empirical relationships among the variables with the short run and the long run coefficients estimates. The unit root analysis is conducted to test the stationarity of the variables by taking the annual time series data for the year from 1975 to 2020. In addition, symmetric and asymmetric bounds tests to co-integration are employed in order to check the long run associations among the independent and dependent variables. The empirical findings have shown that FDI is favoring in reducing CO_2 emission in case of positive and negative shock. Moreover, positive shock on fossil fuel energy consumption bring mixed results on CO_2 emission in the short run and a negative shock increases it whereas fall in CO_2 emission is recorded in long run. Similarly, a positive shock on population degrades the environment by increasing CO_2 and a negative shock improves it. It has been observed that a positive shock on the renewable energy output and renewable energy consumption reduce CO_2 emission and negative shocks on both reduces it likewise in short run as well. The empirical findings have justified with the contemporary literature as well as with the theoretical background of the study.

Policy Recommendation

1. Pakistan government should realize the role of clean energy technologies. As they do not pollute the environment and help to stabilize the climate through reducing CO_2 emissions.
2. It is suggested that Pakistan government should reduce the usage of non-renewable energy resources as they possess the depletion characteristic. The usage of environmental friendly and cost efficient energy technologies should be promoted in residential and the commercial arenas of Pakistan
3. As renewable energy sources are less carbon intensive and do not contaminate the atmosphere, the renewable energy sources are needed in the coming years of Pakistan.
4. Urbanization has been identified as a main source of environmental degradation and the climate change conditions in Pakistan. It is suggested that the carbon emissions can be reduced from the environment by slowing down the process of urbanization. It is suggested that the taxes should be imposed on these firms that import or use the more energy-intensive products as this measure is crucial in mitigating the climate change effects in Pakistan.
5. It is suggested that the government should convince the industrial sector to become more efficient in energy usage by giving them incentives in the form of tax cut on the use of green technologies utilizing the foreign direct investment. Furthermore, Pakistan should make the strategies in order to attract the FDI as it would lead to the economic growth in Pakistan. Government should encourage FDI through private sectors so as to produce the efficient energy through the renewable energy sources.

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