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Finding the Relationship between Agriculture and Carbon Emissions in Pakistan: An Empirical Investigation

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Abstract

Pakistan's economy depends on the agriculture sector which contributes approximately 25 percent to GDP and 45 percent to total employment. This research work inspects the link between agriculture value-added and carbon emit in Pakistan and other potential indicators for instance gross domestic per capita, Foreign direct investment, total population and resources energy. We retrieved data from the world indicators CD room spanning1988 to 2020 for this study and adopted auto regressive distributive log (ARDL) technique and Stata 18 version were used. The long run results of the study revealed that agricultural value-added, foreign direct investment, non-renewable energy utilization, population and Gross domestic per capita increased environmental deterioration. While consumption of renewable energy upsurge environment sustainability in the region. The outcomes also signpost the presence of bi-directional causality between the given indictors. The outcomes also signpost the presence of bi-directional causality between the given indictors. This study is only limited to only the Pakistan with specific indicators. Based on the empirical evidence, the study support to the agriculture sector through sustainable practices and green technological advancements to the economic growth and renewable resources to promote environmental sustainability in Pakistan.

Keywords: Carbon emissions, agriculture, foreign direct investment, energy resources, Pakistan, ARDL.

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1. Introduction

It takes a fool to ignore the hazardous health and environmental consequences stemming from human activities. The damages caused to the environment have become a sword of Damocles hanging over each individual's head. Among all the environmental problems, climate change has been pointed out to be the world's most critical challenge because of the continuous excessive amount of greenhouse gas emissions (S. Ali et al., 2022; P. A. Owusu & Asumadu-Sarkodie, 2016). Amongst the other contaminants triggering environment change, carbon emit (CO_2) alone represents nearly 58.8 percent of all the greenhouse gas emissions (Nihayah et al., 2022).

In place of the world's population continues to grow, there is also surge in demand for agricultural products and use of energy which requires substantial economic growth (Aye & Edoja, 2017). Consequently, the agricultural sector has become one of the lead industries that pose serious environmental problems due to technological advancement that has helped double-crop outputs but at the same time increase CO_2, leading to foodstuff safety concerns and weather change (Necpalova et al. 2018) (Rehman et al. 2019). As the agricultural sector counts approximately 20 percent of CO_2 (Bank), the damages inflicted on the environment continue to amplify with the growing demand for agricultural products. With many regards, the agricultural sector is a key contributing industry to the gross domestic per capita and economic development of any nation state. To keep up with the global demand for agricultural-related products, the agricultural sector needs more investment and more energy use.

On this basis, many studies have connected emit CO_2 to a combination of different factors, such as agricultural growth, economic growth, population growth, consumption of renewable and non-renewable energy and FDI (Begum et al. 2015;Behera & Dash, 2017a, 2017a; Bélaïd & Youssef, 2017a, 2017a; Cerdeira Bento & Moutinho, 2016, 2016; Dong et al., 2018a, 2018a; Hassan et al., 2023, 2023; Mirza & Kanwal, 2017, 2017; Rehman et al., 2019b)). Thereby, it

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remains important to tap into these factors when addressing the strategy to curb CO_2 emissions. Based on the above corpus of the works, this study at hand investigates the relation among value-added agriculture and carbon emit in Pakistan controlling for economic growth, FDI, usage of renewable energy, rural population, and consumption of non-renewable energy.

To the best of our information, this is the first manuscript that investigates the link between agriculture sector and carbon emission in Pakistan. There are main motives behind the choice of Pakistan. First, the agriculture sector occupies a major role in Pakistan's economy as it absorbs nearly 39.5 percent of the manual labor force and contributes approximately 18.5 percent of the GDP Siddiqui, 2019. Second, the Pakistan is also one of the world's most susceptible country of the growing consequences of climate change. The remainder of this paper presents the relevant literature, research context, method description, and econometric methodology, data base, empirical outcomes, discussion, conclusion and recommendations respectively.

1.1. Pakistan Context

Pakistan is one of the countries in South Asia that is facing serious environmental issues along with social and economic problems. Ecological problems in Pakistan ranging from air and water pollution, deforestation, environment change, soil destruction, and natural catastrophes. As Pakistan's economy is expanding alongside population growth, environmental issues are becoming more worrisome. Air pollution in Pakistan's urban areas significantly damages living conditions and the environment (Ijaz & Arif, 2021). Moreover, the increase in energy consumption has significantly damage the quality of life and the environmental wellbeing in most cities in Pakistan (Ijaz & Arif, 2021; Rasool et al., 2019). Also, air pollution in Pakistan exceeds most of the high-profile cases of public health issues, resulting in premature deaths and illnesses (Sánchez Triana, 2014), placing Pakistan among the world's top four polluting countries according to a recent report (Asia, 2018).

As the world's sixth-largest population and constant growth of its population, Pakistan faces challenges to complete the demands for foodstuff and energy and ensures substantial economic growth and sustainable growth. In Pakistan, approximately 60 to 75% of the papules lives in rural areas where cultivation remains the principal economic activity. The agricultural sectors of Pakistan contribute approximately 23.4 percent of the economy and count approximately 45 percent of the workforce (M, 2016). Besides being an important contributor to the economy, the agricultural-related activities in Pakistan are major contributors to greenhouse gas emissions and hazardous health issues; (Shahid et al., 2016; Ullah et al., 2018a).

During the past 14 years, Pakistan has registered a 5 % yearly GDP growth which disproportionately matches its fast population growth, requiring more energy to meet both its DGP and population growth. Energy consumption in Pakistan is derived from imported fossil fuels. To curb the carbon, emit from the use of nonrenewable energy, the government projects to supply between 5-6 percent of its energy from renewable sources as of 2030[†]. In recent years, Pakistan has expanded its renewable energy stance under the China-Pakistan-Economic-Corridor (CPEC) initiative aiming at funding infrastructure projects in Pakistan.

2. Theoretical Literature Review

2.1. Agriculture, population and carbon (CO_2) emissions

During the last two decades, CO2 emissions have been inspected the major source of the greenhouse influence and thereby have drawn intense attention from multiple groups of stakeholders. Because of the extreme usage of fossil fuel energy, the agriculture sector becomes a significant contributor to the world's greenhouse gas emit (S. Ali et al., 2022), accounting for 14-30% of emissions (Brief, 2018). The greenhouse gas emissions produced by the agricultures sector are stemming from the nature of agricultural products which necessitate fuel-driven agricultural equipment, a large amount of land use for crops and livestock, forest degradation and deforestation, and the use of nitrogen-rich fertilizers (Rehman et al., 2019b; Tubiello, 2019a).

Studies have investigated unlike greenhouse gases (e.g., carbon emit, methane, nitrous oxide, nitric oxide, ammonia) associated with agriculture production. Among these greenhouse gases, CO2 emissions have drawn attention for being

[†] For more insights, visit: http://global-climatescope.org/results/pk#clean-energy-policy

the major source of the greenhouse influence (Brief, 2018; Saidi & Hammami, 2015). According to a recent estimate, livestock and crop are two main agricultural activities contributing to approximately 5 billion metric tons of CO2 released into the atmosphere on a yearly basis (Tubiello, 2019b).

It has been predicted that the coming decades would result in pressure on the global agricultural system stemming from the demand to feed the world's growing population (Rees et al., 2014). With this regard, many authors have examined the joint results of agriculture and populace growth on CO2 emit ; ; (Lin & Xu, 2018; Mondal, 2019; Some et al., 2019; Zafeiriou & Azam, 2017)) and conclude that population growth increases the demand for agricultural products which thus increase CO2 emission (Dong et al., 2018b).

(Ullah et al. 2018) examine the causative association between agricultures related activities and CO2 emit in Pakistan from 1972 to 2014. To test this causal relationship, the authors use the Johansen cointegration, ARDL model, and VECM approach. The outcomes of their study shows a significance long-run connection between the agricultures-related activities and the CO2 emit. As CO2 is consider to be the main source in greenhouse gas emissions (Rehman et al., 2019b), the significant contribution of the agricultures department in emissions of greenhouse has, therefore, prompted the call for concrete action to mitigate its negative effect.

As reported by (FAO, 2022), organization of Food and Agriculture (FAO) estimates that the agriculture department has the power to curb nearly 88% of its CO2 emissions. Within this vein, soil organic substance is an important element that can be used to remove a big amount of CO2 emit from the soil and also harvest managing through means of different techniques (Rehman et al., 2019b), such as decreasing tilth and non-tilth, shifting land use from cultivated land to lifelong harvests and restoration of despoiled land (Paustian et al., 2016).

For example, (Hussain et al. 2015) investigate the influence of the harvest managing techniques on greenhouse gas emit using a meta-analysis. The authors found that varying tilth permutations, selecting crop regimes, managing organic and fertilizer as techniques that can mitigate greenhouse gas emissions. Consistently, this has patriated the usage of climate-smart soil management for agriculture purposes to curb CO2 emissions. Thereby, "Climate-smart soil management encompasses all sustainable management options and associated environmental, cultural, social, and economic activities within the framework of a changing climate" (Garcia-Franco et al., 2018).

Given the bad result of CO2 emits and the significant contribution of the agriculture area to this issue, businesses in this sector, as well as governments, need to take concrete actions by adopting or supporting the use of low-carbon agriculture and climate-smart soil management techniques in order to curb agricultural-related CO2 emission. This is very compelling for South Asian countries which constitute nearly 25% of the world population to act accordingly in order to mitigate different negative impacts associated with agricultural-related actives, with CO2 being an example while taking into account other negative impacts like degradation of land, deforestation, and biodiversity.

2.1.1. Gross domestic product and emissions

Gross domestic product is generally conceived as increase in the manufacture of things and services execution, discounted for inflation, over a particular passé. When referring to economic growth, we see different casual effects. For example, economic growth reflects the increase of profit for businesses which implies the possibility for additional investment leading to an increase in employment. Thus, more employment is translated into more purchasing power and consumption, driving to higher economic growth. Ultimately, higher economic growth determines the economic health or wealth of a nation.

Thereby, these implications make economic growth the most observed economic indicator because it results in higher CO2 emission. It becomes therefore crucial to understand the connotation between carbon emit and Gross domestic product. More importantly, understanding the link between carbon emit and gross domestic per capita can provide a well understanding regarding the interfaces between natural ecology and human activities in order to mitigate greenhouse gases (Han et al., 2018). The linkage between Gross domestic product and CO2 emission can be well-presented by the Environmental Kuznets Curve (EKC) named after Simon Kuznets for his seminal work.

According to the EKC assumption, environmental contamination (CO2) increases with growth economic. Since growth economic implies more energy utilization leading to more CO2 emission, the nexus among CO2, gross national product (DGP) as an expression of energy use , papules growth and economic growth has become a communal trend in the literature. By means of, a non-parametric frontier approach, (Lozano and Gutiérrez 2008) modeled the associations among the US population (input), GDP (output), energy use and CO2 emission.

The authors sort out evidence of a stable efficacy upsurge in the average of the modeled variables for the projected time. Using maximum entropy bootstrap approach, (Gul et al. 2015) sought out the association ship between CO2 emit and energy use for Malaysia from 1975 to 2013. These authors found one side causality exacting from usage of energy to CO2 emit. Within the same vein, (Qureshi et al., 2016) based on Johansen's cointegration method of variance decomposition to examine the nexus among energy disaster, greenhouse gas emit, and GDP for the world's largest regions, including Latin America & the Caribbean and East Asia & Pacific, South Asia, Europe and Central Asia, and Sub Saharan Africa using panel data spall from 1975 to 2012. The authors sought outed an undesirable and significant association between electrical energy access and energy lack in states like Europe and Asia.

In a similar fashion, (Begum et al., 2015) investigate the influence of fiscal development, energy use & populace evolution on CO2 emit for Malaysia from 1970 to 1980. Contrary to the EKC positing connotation between economic development and CO2, these authors found this hypothesis invalid for Malaysia during the period of their study. They also found a long-term positive influence of fiscal growth and usage of energy on CO2 emission. However, they sort out no significant influence of population growth on CO2 emission.

(Ozturk and Acaravci 2011) calculated the association amongst use of electricity and development economic in North Africa and Middle East realms as of 1971 to 2006 using ARDL bounds testing cointegration technique. Their study reveals no relation between electricity consume and the development economic in realms Syria, Iran, and Morocco. While the results of this study calculated evidence of co-integration and causal relationship in countries like Saudi Arabia, Israel, Oman, and Egypt, no relation between the electricity use and the economic development was found in the North Africa and Middle East nation state. Employing panel data analysis for new members of the European Union, (Kasman & Selman, 2015) examine the causal relationships amongst energy use, growth economic, CO2 emission, openness and urbanization, from 1992–2010. To test these relationships, the authors used panel causality, panel co-integration method, and panel unit root tests.

Consistent with the EKC theory, they found a positive correlation between environmental pollution and economic development. Similar to previous studies, (Asumadu-Sarkodie & Owusu, 2016) study the MCA-Kaya Analysis in Ghana by integrating energy utilization, economic development (GDP), CO2 emission, and population growth. The authors use data set spanning from 1980 to 2012 and thereby use the VECM to assess the relationships amongst the variables. Their findings indicate a long-term relationship involving population, Gross Domestic Product (GDP), and energy utilization leading to carbon emissions. Additionally, there is a bidirectional causality observed from CO2 emissions to energy utilization.

2.2. Top of Form

2.2.1. Renewable energy, FDI and non-renewable energy, carbon emission

FDI, resources of renewable and non-renewable energy (e.g., fossil fuel) and economic growth are often combined to estimate their joint impact on carbon emission. In their current research, (Hanif et al., 2019) investigate both the long-run and short-run influences of fossil fuel consumption, FDI and economic development on CO2 emission using panel data from 1990 to 2013 in fifteen Asian realms. The authors estimated the association between the variables by using an (ARDL) technique.

(Hanif et al. 2019) found that the efforts of fostering development economic adding to CO2 emission, and that utilization of nonrenewable energy (fossil fuels) adds to carbon emit and thus deteriorates the quality of the atmosphere. The authors also found that FDI as a foundation of the increase in CO2 emission, which confirms both the environment Kuznets curves and Pollution Haven assumptions in the developing Asian realms. Similarly, investigate the association among five variables namely, renewable energy, CO2 emissions, nonrenewable energy, economic development, and international openness in Italy from 1960 to 2011. In line with the EKC, the authors found that development economic overcome greenhouse gasses over time in the Italian context. They also found that renewable electricity creation diminishes the amount of CO2 emit both in the short and long way while openness influences positively CO2 emits only in the long way.

Furthermore, the result of the study by Cerdeira Bento & Moutinho indicates that trade openness short run causes CO2 emit and non-renewable electricity manufacture. The outcomes of their study also show the presence of the cointegration single direction Granger causality relationship running from nonrenewable energy production to renewable energy making and from output per capita to renewable energy production, and from non-renewable electricity making per capita to renewable electricity production.

(Ojewumi and Akinlo 2017) explore the dynamic relationships among three key variables, namely FDI, economic development, and environment sustainability by using Panel VECM approach in 33 nations in Sub-Saharan Africa countries. The authors found dynamic relationships amongst FDI, economic development, and environment sustainability and thus suggest a stability between investment-friendly policies and environment protection policies. Similarly, (Sung et al., 2018) explore the causal interrelationship between FDI and CO2 applying panel data spanning from 2002–2015 in the manufacturing industry in China. Different from the previous study, Sung and colleagues revealed that FDI has a nor good relationship with environment sustainability, which supports the assumption that FDI decreases CO2 emissions.

The influence of income, FDI, energy use, on CO2 in Vietnam was examined in research by (Tang & Tan, 2015). To meet the purpose of their, the amply the co-integration and Granger causality approaches over a single country data covering from 1976 - 2009. The results of their research work help the presence of long-way balance amongst the study variables. They also found the existence of bi-directional causalities between CO2 and income, and between CO2 emission and FDI. As they found evidence that consumption energy, FDI, and gross domestic as major elements of CO2 emit in Vietnam.

(Salahuddin et al., 2018) investigated the impact of fdi, electricity utilization and on CO2 emissions in Kuwait using time-series analysis from 1980 - 2013. The study used the ARDL bounds testing method and found evidence of co-integration among the variables. The study's findings reveal a positive association between electricity utilization, FDI, and economic growth with CO2 emissions, both in the long and short periods. The writers suggest that the adaptation of green technologies in the process of FDI might be an effective way to reduced CO2 emits and promote viable economic development.

(Behera and Dash 2017) study indicate that in both South East Asia and South, there is a significant interrelation among the FDI, primary energy, fossil fuel energy utilization, and CO2 emissions. This suggests that strategies destined at reducing CO2 emits in these regions may need to consider strategies to address these factors, such as promoting renewable energy and reducing reliance on conventional resources. On the other side, (Adams et al. 2018) study suggests that both renewable and nonrenewable energy have a pose impact on growth economic in Sub-Saharan Africa. However, they found that nonrenewable energy has a greater influence than renewable energy. This highlights the trade-offs that policymakers may need to consider when making decisions about energy policies in this region.

Employing the ARDL technique, (Bélaïd and Youssef 2017) explore the association ship among CO2, renewable electricity consumption, non-renewable electricity utilization and economic development in Algeria. The presence of a co-integration long-run relation among the variables was confirmed in their study. Furthermore, the authors found that both non-renewable electricity consumption and economic development have a harmful ecological upshot in the long-run while, whereas the renewable consumption has a beneficial effect on the atmosphere. (Danish et al. 2017) find out the causal effect of renewable and non-renewable energy consumption in Pakistan from 1970–2012. The results of their study show robust evidence for the Environment Kuznets curve assumption. Also, the results of their study support that the use of renewable energy significantly reduces Carbon emission, while the use of non-renewable energy outcome in an upsurge in carbon emits. (Ito 2017) investigate the relationship among carbon emits, non-renewable and renewable energy utilization, and development economic, using multiple under-developing realms data from 2002–2011. The author found that non-renewable energy consumption negatively impacts economic growth, whereas renewable energy consumption positively contributes to economic growth in the long run.

3. Research Design

3.1. Data

We retrieved data from the world indicators CD room spanning1988 to 2020 for this study. Carbon dioxide emission, Gross domestic product, renewable energy calculated by biomass, wind, and solar, non-renewable energy calculated by natural gas, coal, oil, (website, BP Statistic), Population and agriculture value added (% of GDP). For details see Table.1.

Authors estimations. Data retrieved the World Development Bank over 1988 to 2020.

4. Model Specification

A large corpus of the literature posits that agriculture contributes significantly to CO2 emissions. This significant contribution is thereby moderated by the population, Gross domestic, renewable energy, nonrenewable energy, and foreign direct. The impact of agriculture on carbon emits is depicted as:

$$CO_2 = f(GDP, FDI, NRE, RE, AGRI, POPU) \quad (1)$$

Log-linear data is more efficient and consistent than linear data (Jianguo et al., 2022; Luo et al., 2021). Below is a log-linear representation of the function;

$$LnCO2it = \sigma i + \sigma t + \beta 1 LnGDPit, \beta 2 LnFDIit, \beta 3 LnNREit, \beta 4 LnREit, \quad (2)$$
$$\beta 5 LnAGRIit, \beta 6 LnPOPUit + \varepsilon it)$$

Where in Eqs (1) and (2), CO2 is corban emission, GDP is the gross domestic product, FDI is foreign direct investment, NRE and RNE are energy resources undivators, AGRI is agriculture and POPU is the population. i, Pakistan, t, 1988-2020 and β_1…. β_6 are parameters, ε is error term.

Table 1. Definition of variables and descriptive statistic

Variables	Unit of measure	Definition
Carbon	Metric ton	It is excluded from combustion of oil, gas, coal and other solid liquid fossil fuels.
Gross domestic product	GDP (2015 US)	Gross domestic product divided total population
Renewable Energy	Metric ton	It is calculated by solar, wind, biomass.
Non-renewable Energy	Metric ton	It is measured by gas, coal, and oil.
Agriculture	% of GDP	It measured by forestry, hunting, fishing, in addition to cultivation of crops, and livestock production.
Population		Total population calculated by total register resident areas.
Foreign Direct Investment	% of GDP	FDI net inflow means that the non- resident investor made investment in the other country economy.

5. Econometric Strategy

Several econometric approaches are available for the time series data analysis. For example, Phillips and Hansen (1990), Engle and Granger (1987) and Johansen (1988). These techniques have been developed to observe the long-run co-integration analysis, but Engle and granger method has been developed only to find the one vector co-integration and is only used for the one dependent and independent variable. Moreover, the Johansen method is only relevant for the big sample size data and required all the variable ought to significant at the level (2). Because of these limitations, we have decided to apply the ARDL approach for the cointegration analysis. For details of econometric strategies see in Figure.1.

ARDL has many advantages. Such as, the ADRL approach best works with a small data set. Also, it can deal with data to generate a process from a general to a specific form and thus provide a sufficient number of legs. Since the sample size used in this study is small, and its econometric technique contains numerous variables that might cause an endogeneity problem; consequently, the ARDL remains the most proper method for this study.

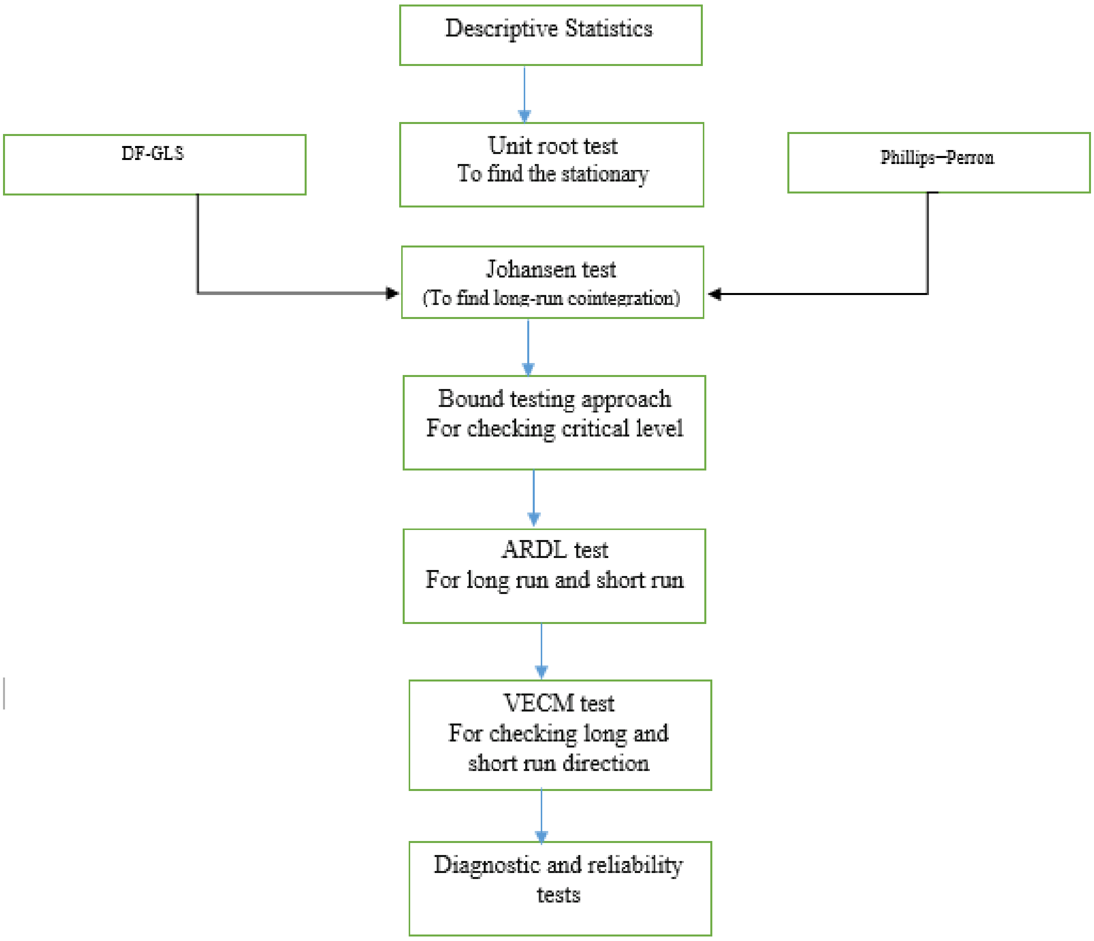

Figure 1. Analytical Model

$$
\begin{aligned}
\Delta \log CO2it &= \varphi 0 + \psi 1 \log GDPit - 1 + \psi 2 \log FDIit - 1 + \psi 3 \log NREit - 1 + \psi 4 \log REit - 1 \\
&+ \psi 5 \log AGRIit - 1 + \psi 6 \log POPUit - 1 \sum_{i=1}^{q} \psi 1 \Delta (\log CO2)it - 1 + \sum_{j=0}^{q} \psi 2 \Delta (\log GDP)it - 1 \\
&+ \sum_{j=0}^{q} \psi 3 \Delta (\log FDI)it - 1 + \sum_{j=0}^{q} \psi 4 \Delta (\log NRE)it - 1 + \sum_{j=0}^{q} \psi 5 \Delta (\log RNE)it - 1 \\
&+ \sum_{j=0}^{q} \psi 6 \Delta (\log AGRI)it - 1 + \sum_{j=}^{p} \psi 7 \Delta (\log Popu)it - 1 + \varepsilon 2it
\end{aligned} \qquad (3)
$$

Where q denoted lag length and Δ is express lag difference. Before estimating the long-run outcomes, it is integral to find the co-integration amongst the underlying variables. The null hypothesis of H0: $\psi_1 \neq \psi_2 \neq \psi_3 \neq \psi_4 \neq \psi_5 \neq \psi_6 \neq 0$ is tested against the alternative hypothesis of H0: $\psi_1 = \psi_2 = \psi_3 = \psi_4 = \psi_5 = \psi_6 = 0$. An F statistic value interprets the co-integration among variables. The F statistic value should cross the upper bound value. If it is not, then we can accept the null hypothesis and reject the alternative. And if the F statistic value crosses the upper bound limit, then the null hypothesis with no co-integration is rejected. Following the (Narayan, 2005), this research relies on the bound testing value for upper and lower bound limit. The sign of Σ express the short way and $\psi_1, \psi_2, \psi_3, \psi_4, \psi_5, \psi_6$ representing long-run parameters of the equation. The Diagnostic tests used for checking the stability and validity of the data. For example, Durban Watson (DW), and LM tests used to find auto-correlation while ARCH tests employed for checking heteroskedasticity.

6. Empirical Results and Discussion

Table 2. Descriptive Statistic

	LCO_2	LAgri	LGDP	LPopu	LRE	LNRE	LFDI
Mean	-0.168	10.622	3.033	8.181	-0.609	1.207	-0.153
Median	-0.165	10.649	3.016	8.201	-0.606	1.260	-0.164
Max	-0.001	10.856	3.176	8.356	-0.332	1.478	0.564
Min	-0.373	10.323	2.872	7.943	0.159	0.789	-0.988
Std. Dev.	0.097	0.163	0.084	0.125	0.125	0.181	0.315

Table 2 shows the descriptive statistic values after converting the variables into logarithmic from 1988 to 2020. The summary of descriptive statistics comprises info about the mean, median, maxi, mini and standard deviation. The carbon emission per capita ranges are, mean -0.168, median -0.165 and maximum -0.0004. The agriculture ranges are, mean 10.623, median 10.649 and maximum (10.8565).

6.1. Unit Root

To amply the ARDL method to co-integration for a one way long and short-run connotation among the variables; it is therefore mandatory to determent that variables are not integrated at l (2). In doing so, the Dicky Fuller (DF-GLS) technique and Phillips Perron technique (PP) are used to inspect the integration of the variables. The outcomes of the unit root tests, (Phillips and Perron1988 and Elliott et al. 1996) mentioned in Table 3, confirm that all variables are not-integrated at their level. Hence, the null hypothesis is accepted. The integration of all variables in order l (1) allows the ARDL technique to be used for further analysis.

Table 3. DF-GLS and PPS unit root test

	DF-GLS		PP	
Regressors	Level	First difference	Level	First difference
LCO_2	-0.232	-5.061*	-1.743 (0.401)	-5.434(0.000)
LGDP	-0.575	-3.004*	-1.408 (0.567)	-3.238(0.025)
LRE	-1.226	-9.220*	-2.433 (0.139)	-14.490(0.000)
LNRE	-0.908	-3.377*	-2.998 (0.044)	-3.522(0.012)
LAGRI	0.356	-3.273*	-4.152 (0.002)	-8.079(0.000)
LPOPU	0.264	-3.995*	-9.298 (0.000)	-1.932(0.052)
LFDI	-1.999	-5.084*	-2.338 (0.165)	-5.995(0.000)

*Authors estimations *indicate 1% ** indicate 5% and *** indicate 10% significant*

Table 4. ARDL Bound and diagnostic test

Bound testing approach				**Diagnostic test**		
Equation	**F-value**	**Lag order**	**Conclusion**	**Ramsey**	**LM**	**ARCH**
CO_2=f(Agri,GDP,Popu, RE,NRE,FDI)	7.121 [(a)]	(1, 0, 3, 2, 2, 0, 3)		0.638(0.527)	1.211 (0.372)	0.172(0.828)
Critical Bound Values						
Significance	**I0 Bound**	**I1 Bound**				
10%	1.75	2.87				
5%	2.04	3.24				
2.5%	2.32	3.59				
1%	2.66	4.05				

Author's estimation, a represent the value of significant. Ours estimated F value is upper the critical bound values it means that we can run ARDL approach.

6.2. Bound Test

We implied the ARDL bound technique for co-integration, and select the appropriate leg length, using the Akaike method (AIC). (Xu et al. 2018) highlighted that the Akaike criteria provide effective outcomes in capturing dynamic connections. Afterward selecting the appropriate leg length, the F value is calculated as shown in Table 4. The outcome of the bound method is presented in Table 4. The F statistic value is above the greater require value; therefore, the alternative hypothesis is accepted. Meanwhile, GDP, renewable energy, population, nonrenewable energy, agriculture, and carbon emissions are co-integrated for the long run and short run connection in Pakistan.

6.3. Johansen Cointegration Approach

We also used the Johansen co-integration technique to confirm the outcome of the bound testing approach. The Johansen co-integration method is dependent on the two statistics, namely trace and eigenvalue statistics. As a result of indicated in Table 5, there are at least 6 co-integration equation in the trace and 6 cointegration equation in the eigenvalue statistics, which confirm the steadiness of the data.

Table 5. Results Johansen cointegration

Unrestricted cointegration rank test (trace)				
Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None *	0.999	442.417	125.615	0.0001
At most 1 *	0.937	233.362	95.753	0.0000
At most 2 *	0.847	150.282	69.818	0.0000
At most 3 *	0.757	93.890	47.856	0.0000
At most 4 *	0.637	51.390	29.797	0.0001
At most 5 *	0.468	20.920	15.494	0.0069
At most 6	0.062	1.941	3.841	0.1635
Unrestricted cointegration rank test (maximum eigenvalue)				
Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 critical value	Prob.**
None *	0.999	209.054	46.231	0.0000
At most 1 *	0.937	83.079	40.077	0.0000
At most 2 *	0.847	56.392	33.876	0.0000
At most 3 *	0.757	42.499	27.584	0.0003
At most 4 *	0.637	30.470	21.131	0.0018
At most 5 *	0.468	18.978	14.264	0.0083
At most 6	0.062	1.941	3.841	0.1635

Max-eigenvalue test indicates 6 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values.

7. The Long and Short Run Analysis

After confirmation of ADRL Bound test, we employed the ADRL for cointegration analyze. We selected FDI, GDP, agriculture (value-added), (RE) renewable energy, (NRE) non-renewable, population, and emit as dependent variable for the historical analysis. The study also discusses the graphical interpretation of the summary findings in Figure. 2.

In table 6 we revealed the results of agriculture value added and emit CO2. The outcome shows that the one per cent agricultural value added enhance 1.4 per cent emit in the atmosphere. Approximately a quarter of Pakistan's overall greenhouse gas emissions can be attributed to the agricultural industry, making it a significant contributor to the country's carbon footprint. The mainstream of these emissions come from combustion conventional energy for agricultural activities for instance plowing, irrigation, and spraying of pesticides and fertilizers. Additionally, soil management practices for example tillage, burning of crops residues, and improper grazing practices contribute to emit of carbon and other gases. Livestock farming is a notable source of greenhouse gas emissions, as it is accountable for the exclude of methane and nitrous oxide, which are both potential greenhouse gases. Finally, deforestation and land-use change related to agricultural activities also result in increased emissions. Ours outcome is same with these researcher (N. Ali et al., 2021; Khurshid et al., 2022; Lynch et al., 2021).

Table 6. ARDL Results

Variables	Coefficient	Std. Error	t-Statistic	Prob.*
Long Run Analysis				
LogGDP	1.375[a]	0.100	13.748	0.0000
LogAGRI	1.439[a]	0.184	7.795	0.0001
LogPopu	1.198[a]	0.232	5.155	0.0013
LogRE	- 0.179[a]	0.037	- 4.848	0.0019
LogNRE	0.776[a]	0.046	16.769	0.0000
LogFDI	0.015[c]	0.007	1.964	0.0902
C	-10.232	1.084	9.436	0.0672
Short Run Analysis				
LogGDP	1.672[a]	0.151	11.024	0.0000
LogAGRI	0.250[b]	0.087	2.856	0.0245
LogPopu	11.389[a]	1.106	10.291	0.0000
LogRE	-0.020[c]	0.009	-2.048	0.0797
LogNRE	0.470[a]	0.035	13.306	0.0000
LogFDI	0.023[a]	0.006	3.618	0.0085
CointEq(-1)	-0.869[a]	0.047	-18.207	0.0000
R-squared	0.998			
Adjusted R-squared	0.994			
Durbin-Watson stat	2.731			
Jarque-Bera (Normality)	2.361	0.307		

Author's estimations, *a, b* and *c* indicates the significance level of 1%, 5%and 10%, respectively.

The outcome of carbon emit metric ton and (GDP) gross domestic product are shown in Table 6. Results observed that (GDP) economic growth has a positive correlation with carbon emissions in Pakistan. As (GDP) economic growth increases, the carbon emissions in the state have also increased. As the per capita GDP increases, there is typically a corresponding rise in the demand for energy required for the production and consumption of goods and services. The increased conventional energy demand is usually met by burning fossil fuels, resulting in more carbon emissions. Additionally, higher GDP per capita also increases the demand for other commodities, such as transportation and housing, which further increases the total carbon emissions in the realm. Ours results are same line with (Achour & Belloumi, 2016; Onofrei et al., 2022; E. L. Owusu, 2020; Rasool et al., 2019; Ul Hassan, 2024).

In table 6 we have expressed the results of FDI and carbon emissions, which shows positive and significant associationship. This study has found that FDI has a positive connection with emits as it brings in new technologies that courage to enhance the use of conventional energy consumption and emissions. For example, FDI in the manufacturing sector has been linked to an upsurge in the use of conventional fuels, leading to an upsurge in emissions. Additionally, FDI in the electricity sector has led to greater demand for electricity, resulting in enhance in emissions from the usage of coal and natural gas, oil etc. The increased emissions associated with FDI have been shown to have a bad effect on air quality and public health. Thus, it is important for Pakistan to take measures to ensure that FDI is managed in a way that minimizes its environmental impact. To reduce the negative impact of FDI on emits carbon in Pakistan, it is crucial for the government to implement policies and regulations to encourage the usage of renewable energy sources and energy-efficient technologies. Ours results are same pipeline with these authors (Abbasi & Riaz, 2016; Gokmenoglu & Taspinar, 2018; Imran et al., 2021; Linh & Lin, 2014; Seker et al., 2015; Shao, 2018).

Non-renewable energy and carbon emits has positive and significant correlation. The 1percent usage of non-renewable energy excluded 0.7764 percent emit (CO2). The outcomes shows that, Pakistan's reliance on non-renewable energy sources, such as coal and another fossil fuel, has led to an increase in carbon emissions. Coal, natural gas and oil are the primary sources of energy for Pakistan's electricity, transportation and industrial sectors, and the burning of these fuels releases carbon emits, a main contributor to world warming up. In addition, increased economic activity and population growth has created a demand for energy, which has resulted in enhance in the burning of fossil fuels and consequently, higher levels of carbon emits. Pakistan government ought to take steps to minimize emissions, for instance encouraging the use of renewable energy sources, introducing energy efficient measures, and improving the efficiency of existing power plants. Ours finding are same with scholar (Anees et al., 2018; Ben & Ben, 2015; Zafar et al., 2019).

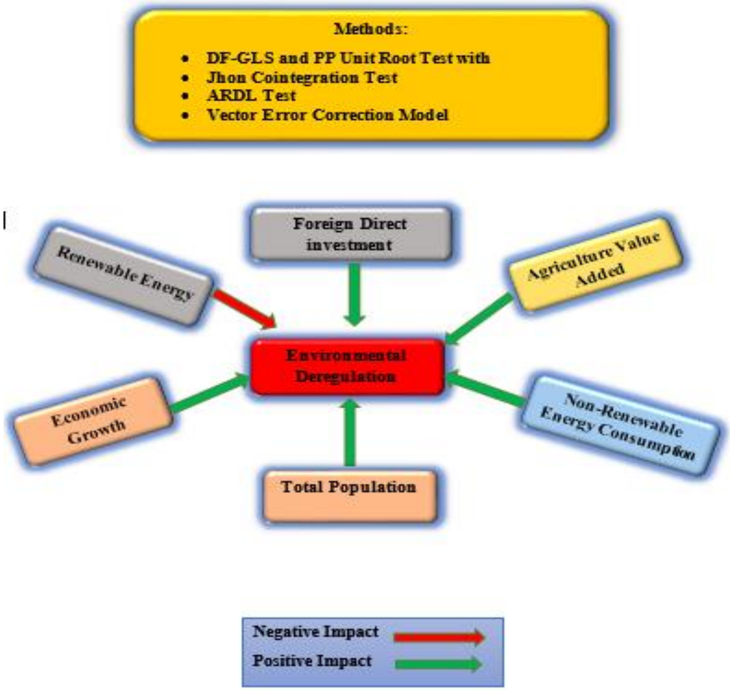

Figure 2. Summary of Empirical Findings with Methods

We have expressed the result of renewable energy and carbon emits in the table 6. The outcomes indicates that the renewable energy enhance the value of the environment quality and control emit. The negative sign provides evidence that renewable energy (RE) utilization upsurge the environmental health in the long-way analysis. Thereby, a 1 percent increase the trend of renewable energy consumption (RE) reduces CO2 emissions 0.1798 percent. Renewable energy is a vital factor in diminish emissions carbon in Pakistan. The source of renewable energy for instance wind, solar, and hydropower may offset the need for burning of coal, oil and gas, which exclude greenhouse gases and carbon emissions into the atmosphere. As Pakistan seeks to reduce its emissions and meet its commitments under the Paris Agreement, source of renewable energy would play a gradually important role. which is supported by several studies (Anees et al., 2018; Ben & Ben, 2015; Khan et al., 2022; Zafar et al., 2019). Here, we suggest to the government of Pakistan to encourage to rise the budget for renewable energy projects and also develop incentives to attract both international and domestic investment in this sector. To reduce air pollution, Pakistan needs to encourage and assist the use of renewable resources in the industry sector, transport sector, and agriculture, which generally consume a large amount of conventional energy.

The empirical outcome indicates a positive and significant affiliation between the population and CO2 emission. The result of the study revealed that an increase of 1 percent populaces will increase the amount 1.1984 percent emit of CO2. The population of Pakistan is up warding speedily and this is having a direct impact on the country's carbon emissions. By the population upsurges, the uses of energy and resources enhance, leading to more burning of fossil fuels and the emissions of more carbon dioxide into the environment. This is causing the country's greenhouse gas emissions to rise, which is exacerbating the effects of global warming and climate change.

The outcome of table 6 also revealed the short run analysis. The empirical analysis expressed that the FDI also destroyed the environment in the short time period. The government of Pakistan ought to design policies that make FDI sustainable and environment-friendly by deterring the use of non-renewable energy and by providing incentives to foreign investors to consider the use of renewable sources of energy in order to strengthen the country’s effort regarding environmental sustainability. They also need to ensure that both domestic and foreign investors comply with established policies on the use of renewable energy.

The ultimate result of this study shows a significant and positive relationship gross domestic product and CO2 emits. The short-way outcome indicates that a 1 percent enhance the GDP will trigger an increase in CO2 emissions by 1.6725 percent. This finding is same pipeline with the finding of several other studies (Ahmed et al., 2019). We found evidence for the short-run relationship between non-renewable energy (NRE) and the environment. As shown in Table 6, there is a significant and positive association between CO2 emits and non-renewable energy (NRE). This result concludes that a 1 percent increase in non-renewable energy (NRE) will outcomes in a 0.4701 percent increase CO2 emits.

The outcome of renewable energy (RE) indicates a significant and negative association with CO2. The 10 percent usage of renewable energy devaluate 0.0200 percent emission carbon dioxide in the environment. Meaning that the green energy play a vital role to build the good and healthy environment. So the government of Pakistan ought to consider on renewable energy (RE) and skip the conventional energy for their new generation future.

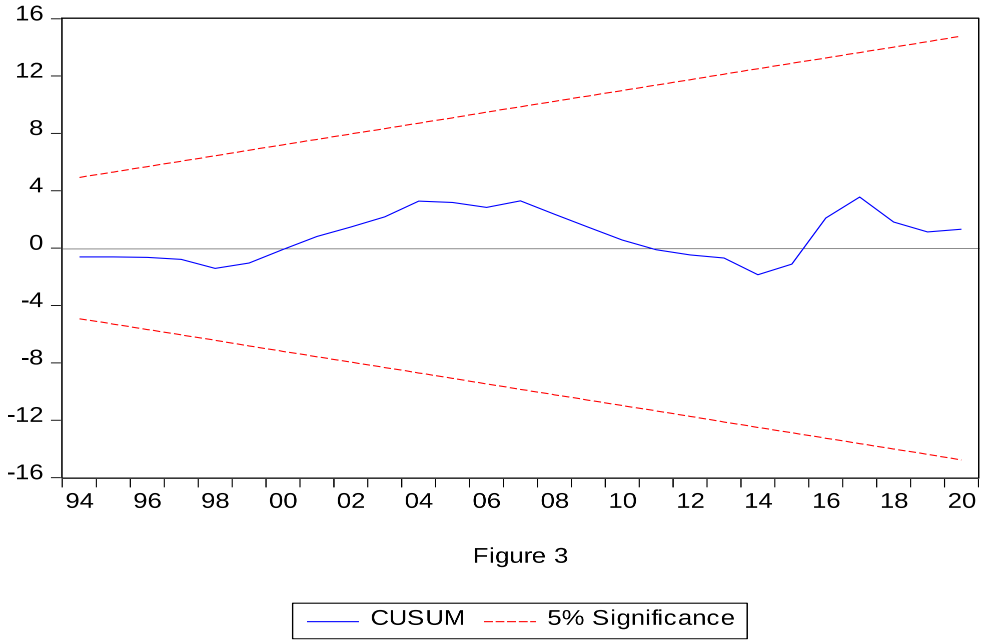

Figure 3. CUSUM

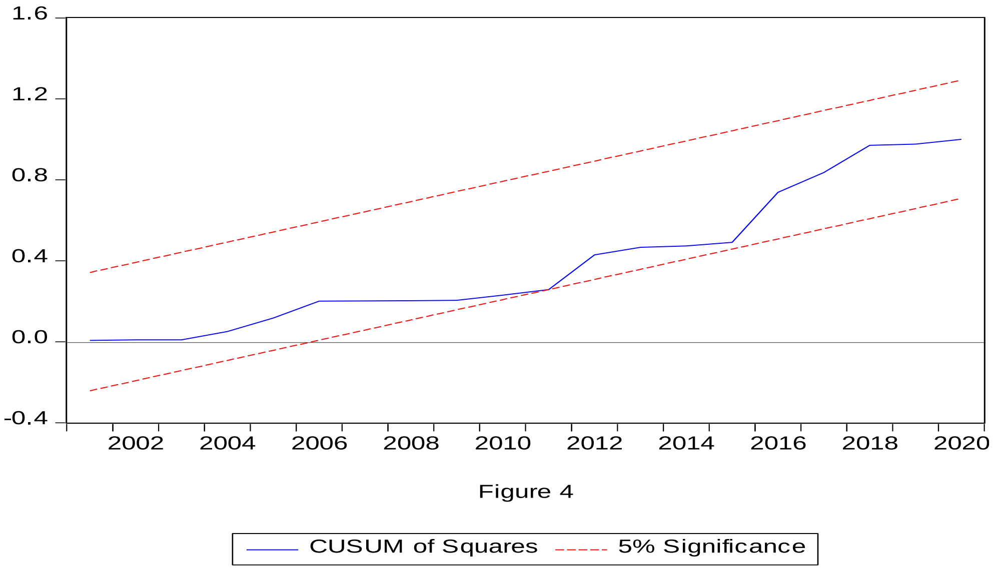

Figure 4. CUSUM of Squares

The result of the population and carbon emit has a significant and positive association. The positive sign shows that a 1 per cent population enhance11.38 per cent CO2 emissions within the context of Pakistan. The short-way analysis indicates a negative and in-significant interrelationship among agriculture and the atmosphere which infers that the agriculture sector has no impact on the environment in the short-period.

The sought-out outcomes revealed that imply of the renewable energy in Pakistan overcome the environmental degradation and strengthen the environment sustainability. But another side, in the same time, the population, agriculture value added, GDP, FDI and nonrenewable energy destroying the environment sustainability.

For the confirmation of model stability, we used recursive residuals techniques (CUSUM). Figures 3 and 4 disclose that the model is stable, as supported by the position of the blue line. The values of CUSUM and CUSUM of square both show that the model is valid and steady.

8. VECM Model

Table 7. Vector Error Correction Model

Variables	LCO_2	LGDP	LRE	LNRE	LAGRI	LPOPU	LFDI	ECM (-1)
LCO_2	------	1.276	7.156[a]	0.671	0.943	1.074	1.377	-0.585[a]
		(0.279)	(0.001)	(0.511)	(0.389)	(0.341)	(0.252)	(0.000)
LGDP	2.463[c]	-------	0.376	1.126	1.425	1.286	0.441	-0.036
	(0.071)		(0.686)	(0.324)	(0.240)	(0.276)	(0.643)	(0.556)
LRE	0.549	0.331	-------	0.290	0.204	0.146	0.126	-1.414[c]
	(0.577)	(0.718)		(0.748)	(0815)	(0.863)	(0.881)	(0.062)
LNRE	1.685	0.535	3.283[b]	-------	0.275	0.039	1.447	-0.038[b]
	(0.185)	(0.586)	(0.038)		(0.758)	(0.961)	(0.235)	(0.037)
LAGRI	4.305[b]	1.369	1.486	1.271	--------	2.479[c]	2.638[c]	-0.052
	(0.014)	(0.255)	(0.226)	(0.280)		(0.083)	(0.071)	(0.594)
LPOPU	0.551	0.085	0.051	0.106	0.136	-------	0.315	0.000
	(0.576)	(0.912)	(0.949)	(0.899)	(0.872)		(0.729)	(0.967)
LFDI	0.105	4.830[b]	1.992	0.695	1.249	1.554	------	-2.363
	(0.899)	(0.008)	(0.136)	(0.498)	(0.286)	(0.211)		(0.143)

Author's estimations, Note: ECT (-1) indicating long run causality

We employed the ADRL method for confirmation of the one-way association among the variables. For examine the multivariate direction among the variables, we applied the vector error correction (VECM) technique that lunch Engle and Granger (1987). As Toda and Phillips (1993) pointed out, when the long-run outcome is confirmed, it is a good option for finding the causality among variables. For the long-run causality, we used VECM technique (ECT_{t-1}) and for the short-run (f-statistic) we employed the Wald technique.

The below regression equation explains the VECM causality:

$$\begin{bmatrix} \log CO_2 \\ \log GDP \\ \log FDI \\ \log NRE \\ \log RE \\ \log AGRI \\ \log POPU \end{bmatrix} = \begin{bmatrix} \beta 1 \\ \beta 2 \\ \beta 3 \\ \beta 4 \\ \beta 5 \\ \beta 6 \\ \beta 7 \end{bmatrix} + \begin{bmatrix} \beta_{11\vartheta} & \beta_{12\vartheta} & \beta_{13\vartheta} & \beta_{14\vartheta} & \beta_{15\vartheta} & \beta 1_{6\vartheta} & \beta_{17\vartheta} \\ \beta_{21\vartheta} & \beta_{22\vartheta} & \beta_{23\vartheta} & \beta_{24\vartheta} & \beta_{25\vartheta} & \beta_{26\vartheta} & \beta_{27\vartheta} \\ \beta_{31\vartheta} & \beta_{32\vartheta} & \beta_{33\vartheta} & \beta_{34\vartheta} & \beta_{35\vartheta} & \beta_{36\vartheta} & \beta_{37\vartheta} \\ \beta_{41\vartheta} & \beta_{42\vartheta} & \beta_{43\vartheta} & \beta_{44\vartheta} & \beta_{45\vartheta} & \beta_{46\vartheta} & \beta_{47\vartheta} \\ \beta_{51\vartheta} & \beta_{52\vartheta} & \beta_{53\vartheta} & \beta_{54\vartheta} & \beta_{55\vartheta} & \beta_{56\vartheta} & \beta_{57\vartheta} \\ \beta_{61\vartheta} & \beta_{62\vartheta} & \beta_{63\vartheta} & \beta_{64\vartheta} & \beta_{65\vartheta} & \beta_{66\vartheta} & \beta_{67\vartheta} \\ \beta_{71\vartheta} & \beta_{72\vartheta} & \beta_{73\vartheta} & \beta_{74\vartheta} & \beta_{75\vartheta} & \beta_{76\vartheta} & \beta_{77\vartheta} \end{bmatrix} + \begin{bmatrix} \Delta \log CO_{2it} \\ \Delta \log GDP_{it} \\ \Delta \log FDI_{it} \\ \Delta \log NRE_{it} \\ \Delta \log RE_{it} \\ \Delta \log AGRI_{it} \\ \Delta \log POPU_{it} \end{bmatrix} + \begin{Bmatrix} \varsigma_1 \\ \varsigma_2 \\ \varsigma_3 \\ \varsigma_4 \\ \varsigma_5 \\ \varsigma_6 \\ \varsigma_7 \end{Bmatrix} + ecmit - 1 + \begin{Bmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \\ \psi_6 \\ \psi_7 \end{Bmatrix} \quad (4)$$

Where t interpreting the time period (1988 to 2020), I interoperating i= 1, 2, 3...32…, ECMit-1 reveals the error correction, and ε1t denotes the error term.

The long-way and short-way causality results mentioned VECM table. We used two techniques for finding the long and short run causality likewise VECM and Wald. The result of VECM sort out that the GDP and carbon emissions has unidirectional connection but renewable energy and emit has two side relationship in the long way. However, non-renewable energy, population, agricultures and FDI have one-side relationship with environment. Moreover, the Carbon emission and GDP per capita has unidirectional associationship. Meanwhile, the non-renewable energy and renewable energy cause each other. Although agricultures value added and carbon emissions has uni-directional correlation while population and others study variables has no feedback. At the end FDI doesn't cause to emit. But in the shot time period the GDP per capita granger cause to foreign direct investment. Additionally, the population, carbon emissions and FDI granger cause to Agricultures. The renewable energy granger cause to non-renewable energy. Carbon emissions granger cause to GDP per capita in the short time period.

9. Conclusion and Policy Recommendations

The existing research examine the connection between agriculture value added and carbon emissions in the context of Pakistan economy with controlling variables for instance gross domestic product, renewable energy resources, non-renewable energy and renewable energy consumption), foreign direct investment, and population into the model in the context of Pakistan. The ADRL cointegration approach is implied to find long way and short way association. We applied the VECM technique to compute the long way and short way causality among the study variables. We also applied some diagnostic methods to verify the stability and reliability of the model.

The outcomes suggest that agricultures plays a vital role in the environmental sustainability of Pakistan. The findings also show that FDI significantly contributes to CO2 emits. Moreover, we found that non-renewable energy and GDP are responsible for increasing emissions. At the end, renewable energy resources enhance the environment quality in the long term, whereas population growth increases carbon emission.

The empirical finding also suggests that FDI enhances carbon emit in Pakistan. Thus, the result shows that FDI boosts GDP and that high gross domestic product, in turn, is conducive to opening the economy leading to high energy utilization and thus high carbon emission. Hence, the responsible authority of Pakistan should make a strict rule regarding environmental policies as well as renewable energy policies and ensure compliance with these policies. Moreover, the government of Pakistan should encourage foreign investors to bring energy-saving plants and save anthropogenic life. Finally, the Pakistan government should sign an international agreement regarding emission and environmental change.

The economic growth of Pakistan largely depends on the usage of conventional energy, for instant gas, oil and coal. Moreover, the growth economic of Pakistan also triggers an increase in the amount of energy needed for household, transport, and industrial sectors. Given the current state of non-renewable energy consumption, Pakistan is facing a serious challenging of carbon emission. To meet the desired economic growth without hurting the environment quality, the government of Pakistan needs to analyze the possibility of extending the usage of renewable energy or mixed energy at disaggregate levels. To this end, the government of Pakistan is encouraged to shift from non-renewable energy to renewable energy by developing renewable energy policies and provide market incentives to the deployment and adoption of renewable energy.

The results of this research work provide insights for stakeholders to build the most favorable mixture of resources of renewable and non-renewable energy in order to complete the national demand for energy consumption. We set forth a proposal for instance there is a need to plan a strategic mix of all available energy assets in Pakistan to meet the growing demand for energy while also mitigate CO2 emissions. More importantly, responsible authority of Pakistan ought to encourage the industrialized sector and agriculture sector to use advanced and energy-saving technologies. Furthermore, the government of Pakistan is encouraged to promote and encourage its citizens to use energy-saving appliances.

In Pakistan 67% population living in rural areas. And in rural areas lack of facilities such as education institute, hospital, sewerage system. The rural population do not have knowledge the healthy environment. Hence, the government of Pakistan should open the public institute and educate rural population and aware about the value of healthy environment. Government should restructure the sewerage system and clean sewer. And also open the small dispensaries in the village.

Finally, as economic development has detrimental effects on the environment quality, the Pakistan government should make sure that clean energy sources continue to boost the economy. The growth of energy conservation and carbon reduction measure should be considered a priority for policymaker if the goal is to decrease energy consumption.

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