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ANALYSIS OF PRODUCTION EMISSION (INDUSTRIAL EKC) AND CONSUMPTION EMISSION: AN EMPIRICAL INVESTIGATION OF STIRPAT MODEL IN CASE OF PAKISTAN.

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Abstract: *This study investigates a long-term and short-term association among climatic change due to industrialization in Pakistan by using ARDL technique for the time span of 1990 to 2019. The Present study uses Industrial value added in its place of economic growth for EKC in case of Pakistan as the industrial sector is considered the key cause of carbon dioxide (CO2) emission. Besides that, study used Population density, Nuclear energy, Households Final consumption expenditure and trade openness as independent variables. Empirical findings come out with U shaped EKC instead of Inverted U shape EKC in incident of Pakistan in short and in long run. This is because of consumption of modern technology and Nuclear energy consumption in Industrialization, i.e evident with negative association of Nuclear energy with carbon emission in short and in long run in Pakistan. Household's Final consumption expenditure also shows significant and negative association, as income increases people use more advanced home appliances so carbon emission decreased. Being the most densely populated country of the world Population density is the significant contributor of carbon emission in case of Pakistan. Policy Implication for Pakistan is to control Population Pressure and to use of Nuclear power in Industrialization may reduce carbon emission.*

Keywords: *CO2 Emission, The Value Added of Industrial Sectors, Environmental Kuznets Curve, Households Final Consumption Expenditure*

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Introduction

Due to population and economic growth, the world energy demand is increasing. Pakistan is one of the victims of climatic change resulted in global warming due to increase in the GHGs. It is a big threat for Pakistan's food, water and energy security. It is observed noticeable increase in Pakistan's average temperature by 0.6C over past century and expected to increase further by 1.1 to 6.4C by the end of the current century. According to the climate change Vulnerability Index (CCVI) Pakistan is one of the "High Risk" countries in the global ranking. This climatic change will cause extreme weather conditions like floods and droughts. Precipitation in Pakistan is also increased to 25%. According to the current statistics 2019 Pakistan's Energy consumption segregates energies percentages and gave industrialization to 14.7% and Electricity & heat (24.9).

On the other hand if we want to check the amount of diverse gases in environment of Pakistan's total CO2 emission is 309 million tones (mt) and it constitutes carbon dioxide 54%, methane 36%, nitrous 9% and other gases 1%. It indicates that carbon dioxide is the major cause of air pollution. If we see the share of different sectors in GHGs emission energy sector having the largest share as it contributes to 50% of the total. During the time period of 2013 to 2018 though there is an increase in nominal GDP of Pakistan at the rate of 8.5 but country faced circular debt in power sector (85% of crude oil and POL demand) and degeneration in native gas production. To set up China-Pakistan Economic Corridor (CPEC), there is greater than before commercial and industrial development for the betterment in power sector, in the transport sector.

Government of Pakistan also realized the seriousness of this problem and has been trying to design environment protecting and friendly policies since 1992. National Conservation Strategy (NCS) implemented in 1992 was the first step to secure environment. Pakistan Environment Protection Act in 1997 was first environment legislation. From then till now different environment protection programs were launched by government and NGO's in collaboration with different international institutions aim at improvement of environment quality and for creating awareness. For instance, National Environment Action Plan (NEAP) in 2001, United Nation development Program, National Environmental Information Management System (NEIMS) were launched.

Figure 1

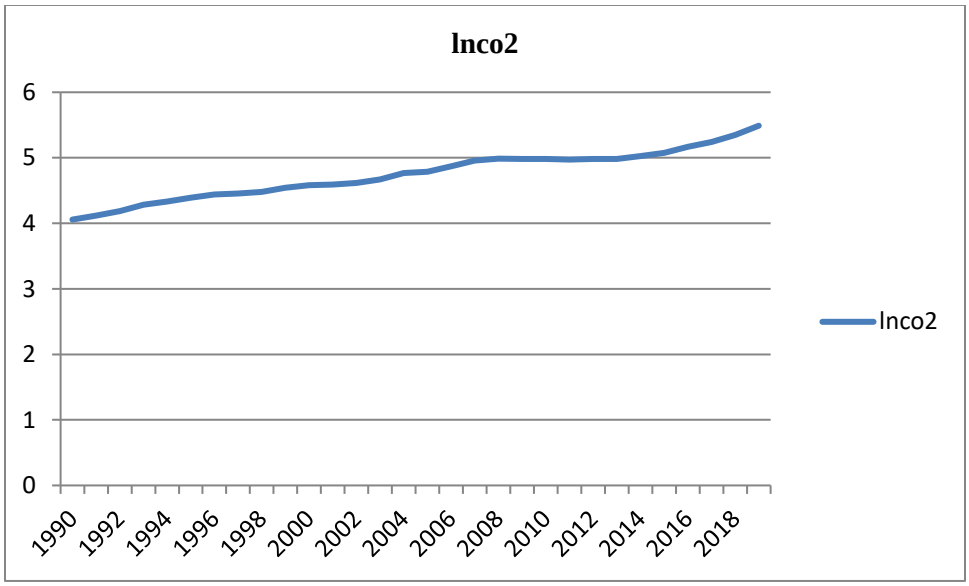


Figure 1 shows Pakistan's CO2 emissions (Mt) have increased as of 4.05 to 5.49 metric tons of CO2 per capita between 1990 and 2019, but comparatively very low with world's average of around 36.6 billion metric tons of carbon dioxide universally emitted in 2018. Year 1997 considered the birth of the Kyoto Protocol due to universally emission of CO2 erected at about 24.4 billion metric tons. In 2020, it touched 416.3 ppm. (Mauna Loa Observatory, Hawaii (NOAA) Preliminary data released July 6, 2020).

Government of Pakistan has also declared 2009 as National Year of Environment is to create awareness about environment. For that purpose different workshops were held on climatic change at regional and provincial level. The demand for energy is increasing with economic growth. Energy can be produced through different sources like oil, coal, natural gas, hydro and nuclear power. Hydro and nuclear sources of energy production discharge a very little amount of CO2 as compared to other resources. This gives a rise to the need to study the role of nuclear energy in controlling the emission of carbon dioxide to save our country from extreme weather events. Two possibilities for nuclear power development have been considered. In one case the nuclear capacity is allowed to increase gradually with the addition of successive 600 MW nuclear power plants. It has been estimated that the maximum technically feasible additions of nuclear power capacity up to the year 2022 would be about 13500 MW. In order to analyze the economic, fuel import and environmental advantages of a nuclear power programmed, a "Nuclear moratorium scenario" has also been considered. This scenario includes only the 325 MW nuclear power plant under construction with no further addition of nuclear power plants.

According to the Father of Economics "consumption is the sole end and purpose of all production" (Smith 1904). Therefore consumption should place firmly in the field of industrial environmentalism. Households are

also accountable for universal carbon emissions so we have to understand the drivers of these emissions if we want to remove carbon emission completely in future. This paper is an effort to lay emphasis on the importance of by elucidating the significance of consuming a suitable consumption perception accounting framework for evaluating the carbon footmark of households. This distinct from the more generally used production's point of view, imported goods and services are considered mainly responsible, carbon emission in consumption is greater than production emissions around 72% globally. (Hertwich and Peters 2009; Wilson et al. 2013).

This study will attempt to discover the role of industrialization in carbon dioxide emission in case of Pakistan. Industrial value added is utilized as the proxy for economic growth. This relationship is termed as Environmental Kuznets curve. Environmental Kuznets Curve demonstrates an association amongst income and environmental degradation. In the initial phase of development with an increase in income pollution also increases but when country achieves a certain level of development the situation moves towards betterment. As with an increase in economic activity, a rise in per capita income, expenditure on improvement of environmental quality increases. People start using environment friendly technology and new methods of production which are less harmful for environment.

Research Gap

The debate on energy consumption and economic growth has been discussed comprehensively in energy economic literature generally and in Pakistan particularly. The role of industrial growth with nuclear energy consumption and its impact on environment is not researched yet. This study tries to find out that relation of consumption by using household's final consumption expenditure with CO2 emission. Pakistan as an atomic power is having the potential of generating nuclear energy. This type of energy is environmentally friendly as compared to coal consumption and natural gas consumption. The present study is an attempt to fill gap by finding new dimension of environment Kuznets curve (EKC) through investigating the role of nuclear energy consumption in production.

Objective of the study

The study aims to take into account the association among POPD, IND, NUC, FCONS, and TRD on CO2 of Pakistan economy covering the time duration of 1990-2019.It has following specific **objectives**

- To estimate Industrial Kuznet Curve with the help of Industrial value added and square of industrial value added.
- To analyse the carbon emission from production and consumption sectors across countries.
- To assess the environmental effects of nuclear energy for Pakistan economy.

Hypothesis:

Present study formulates and examines the following hypothesis.

- H0: There exists no long-run relation among popd, industrial value added, nuclear energy, final consumption expenditure and carbon emission.
- H1: There exists a long-run association among popd, industrial value added, nuclear energy, final consumption expenditure and carbon emission.

Literature Review

To study different empirical studies before going to find the actual research gap and setting

one's own objective is fundamental. The study of environmental degradation is get due importance in early 1990's. This relationship is usually designated as environmental Kuznets curve (EKC). It is inverted U-shaped association originated from Kuznets' work that developed the comparable affiliation among income inequality and economic development. But in reality, different studies have been discovered various shapes like the Inverted U shaped, U shaped and N shaped environmental curve e.g. Mehmood et al (2019), Song et al (2008)

Khan (2020) investigated the affiliation amongst energy consumption, economic growth and CO2 emission for 1965 to 2015 with ARDL bound testing method for Pakistan economy. The assessed outcomes of ARDL specify that CO2 emission increased from energy consumption and from economic growth both in short run and long run. Study suggested that renewable energy sources will assist to happen the enlarged demand for energy for sustainable growth in Pakistan.

Shaheen et al. (2020) focuses on GDP, energy consumption and urbanization distress on Carbon dioxide (CO2) emissions for the time period of 1972-2014 in Pakistan by using ARDL bound testing approach. The observed estimates confirmed that GDP and energy consumption are the chief contributor of the polluted environment of Pakistan as long run results determine that energy consumption and GDP increase CO2 emissions as these two showed significant impact though industrialization and urbanization proved to be unimportant. Empirical results suggested that narrowing the economic gap enactment among urban and rural areas, certain modifications are required in energy creation and automatic originality will increase opportunities to decrease carbon emission in Pakistan.

Kim (2020) analyzed the impacts of foreign direct investment, economic growth, industrial structure, renewable and nuclear energy, and urbanization on greenhouse gas emissions in Korean economy from 1981 to 2014 by using ARDL bound testing approach. The results of short-run and long-run coefficients shows that economic growth and urbanization are the central determinant of GHG emissions, whereas manufacturing industry, renewable energy and nuclear energy lead to the decrease of GHG emissions.

Nawaz et al. (2020) estimated the growth, energy and environmental degradation nexus in Pakistan by using data that have been taken from the World Bank for the year 1971 to 2011 with the help of ARDL approach to confirm the effective long-term positive relationship among carbon dioxide emissions, per capita income growth and the per capita income gap to monitor the trend of the Environmental Kuznets Curve in Pakistan. Energy usage and per capita real income has a encouraging relationship with CO2 emissions. The study has concluded that there is an indication of an inverse U shaped EKC in Pakistan and this association varies with different types of pollutants and geographical regions. Initially, income has a positive relationship with CO2 emission but after the turning point, both have a negative relationship.

Abokyi et al. (2019) engaged the ARDL technique with structural breaks and the Bayer–Hanck joint cointegration method to study the rationality of the EKC hypothesis in the vibrant connection among industrial growth and carbon emissions for Ghana for analyzing the part of fossil fuel consumption and financial

development. Cointegration among the variables exist and study found U shaped EKC instaed of inverted shaped EKC in short and in the long amongst industrial growth and carbon emissions it was established by the Lind and Mehlum U-test in further. A unidirectional causality is in succession from fossil fuel consumption to carbon emission.

Mehmood et al. (2019) found associations among different energy variables and the industrial production for a developing country and try to formulate different hypothesis to find different shapes of EKC with the help of time series data. The research discovers robust long-run connections among energy, environment, and industrial production of Pakistan economy. Study also proved that the capital and labor elasticities of income indicate rise in the existence of energy and carbon emission. EKC is found to be present in quadratic model and it could not confirm in cubic model. Policy prescription is suggested that environment friendly resources must be used in energy sector.

Nugraha (2018) investigated the fundamental affiliation among CO2 emissions, energy consumption, the value added of industry, agriculture and manufacturing with household final consumption expenditure for the time period of 1971 to 2014 for Indonesia by using ARDL approach and Granger causality. It is evident from the study that rise in energy consumption and an rise in value added of industry sector and services sector increase carbon emission, though there is reduction in carbon emission by rise in the value added of agriculture sector and rises energy consumption but all these three sectors have causal relation between the household final consumption expenditure and a unique correlation to energy consumption with carbon emission for Indonesian economy.

Hassan et al. (2017) explored the bond amongst energy consumption and economic growth for Pakistan economy using Johansson maximum likelihood approach from 1977 to 2013 to find the way of causal relation Granger Causality test also applied. Dependent variable used is per capita gross domestic product and independent variables are total labour force, gross capital formation and electricity production. Results indicate that these variables have progressive and substantial effect on economic development. Co-integration relationship approved in long run between dependent and independent variables. Granger causality shows unidirectional relationship towards energy to economic growth.

Attari et al. (2016) examined a long-term association among climatic modification and economic progress for the time span of 1971-2009 to find out the environmental Kuznets curve in Pakistan. Per capital carbon dioxide (CO2) emission is used as dependent variable as an environmental indicator and per capita industrial income as independent economic sign. ADF test and Granger causality is applied to determine association among variables. It is suggested for Pakistan economy to develop new principles and observing system for reducing CO2 emission

Baig & Baig (2014) highlighted the relationship between CO2 per capita as dependent variable and independent variable GDP per capita, Energy Consumption and population growth of Pakistan with ARDL econometric technique for the time period of 1970-2010. The observed consequences found long run relationship amid all independent variables energy consumption, GDP per capita, and

population with carbon emission as 1% increase in all will l raise the CO2 emission per capita and it this study proved unidirectional relationship among variables in Pakistan.

Shahbaz et al. (2013) considered the relationship amid economic growth, energy intensity and CO2 emission by combining financial development in CO2 emission for Portuguese during the time of 1971-2011 by utilising ARDL bound testing approach. Granger causation is applied to observe the direction of causality and is tested by innovative accounting approach (IAA) to check robustness of causality analysis. Results indicate that economic growth and energy intensity rise in CO2 emissions whereas financial developments reduce it. The study proposes that environmental deprivation can be reduced with the help of efficient technologies in energy sector.

Nanji (2013) observed the collaboration amongst local energy consumption and exports for the economy of Nigeria from 1970 to 2009 through Johansson Cointegration technique, Granger causality and impulse response function. The observed results of Co integration depict progressive and significant association amongst domestic energy consumption and exports in the long run and IRF demonstrate Positive shocks to energy. Unique causality runs from energy to exports according to Granger causality. Study suggested that increased energy contribute towards exports that will enhance economic growth of Nigeria.

Ahmed & Long (2012) analyzed economic progression, energy consumption, and trade liberalization and population density on carbon emission of Pakistan economy for the time period of 1971 to 2008 by using ARDL bound testing approach to find long run association. Empirical findings proved Inverted U shaped EKC amongst CO2 emission and economic growth in short and in long run. Trade and Population both support an environmental deprivation in case of Pakistan. The other two variables energy consumption and growth also contributed to environmental pollution in Pakistan.

Fodha and Zaghdoud (2010) tried to find out bond among economic growth and energy contaminants for Tunisia from 1961-2004 using cointegration analysis. They determined that cointegrating found is long run among per capita income and CO2 and SO2 emissions. Their experiential implementation confirmed the presence of environmental Kuznets curve (EKC) in Tunisian economy.

Iwata et.al (2009) examined the environmental Kuznets curve of France by captivating the role of nuclear energy for the production of electricity for the time period of 1960 to 2003 by utilizing ARDL approach and investigate the Granger causality relationships between the variables in the system. The results estimated that EKC hypothesis is stable. The unidirectional relationship from other variables and Nuclear energy to CO2 emissions are definite from the casualty tests and prove the significant part of nuclear energy in decreasing CO2 emissions.

Song et al. (2008) test the observed evidence of Kuznets curve in China by taking provincial data from 1985 to 2005 by using Panel cointegration technique for 29 provinces and proved the existence of EKC. The discussions demonstrated for three EKCs, three pollutants related to per capita GDP comprising per capita waste gas, per capita wastewater, and per capita solid wastes. The test results specify that cointegrating associations exist among per

capita emission and GDP per capita, so all pollutants approved to inverse U-shaped, though inverse N-shaped relationship is found for wastewater.

Rickmond and Kaufman (2006) is one of the earlier studies which tested the presence of EKC for CO2 by utilizing panel data of OEDC and Non-OEDC countries. They did not find the presence of EKC in Non-OEDC countries and limited support in case of OEDC countries. Time series investigation of EKC for CO2 for an distinct country was taken into account by Wata et al. (2010) which explained the effects which were ignored in Panel data.

Grossman and Krueger (1991,1993,1995) tested the association among environment and GDP growth termed as environmental Kuznets curve after them Nawaz et al. (2020), Mahmood et al. (2019), Ahmed and Long (2014) reported an inverse U-shaped association amongst economic activity and environmental quality. Grossman and Krueger also tested the effects of North American Free Trade Agreement on environment to report the affiliation among international trade and environment deprivation.

Almost all the recant literature with few exceptions supports the existence of EKC for both time series data and panel data. Nuclear energy consumption will be helpful in controlling the environmental degradation with an increase in GDP. As Nuclear energy causes very little amount of CO2 emission. Final Consumption expenditure may expose positive and negative both type of results, this area has not got much importance in environment literature Hiroki at al. (2009) first time tested the role of nuclear energy in EKC for CO2.

3. Data and Methodology

Pakistan's Annual data covering 1990-2019 are used in this research for empirical analysis. CO2 emissions (CO2, measured in metric tons), represent dependent variable and other independent variables are Population (Population Density) , Industrial value added production proxy for economic growth, Nuclear energy Alternative and nuclear energy (% of total energy use), Final Consumption expenditure and Trade openness (measured as Imports + Exports as percentage of GDP). The data on CO2 emissions, population, Industrial value added, Nuclear energy, Final consumption expenditure and Trade openness are attained from the 'World Development Indicators' data bank for Pakistan. For missing values an interpolation technique forward and backward is used, if require completing the data of nominated variables.

The current literary trails the approach of Ang, (2007, 2008), Soytas et al. (2007), Halicioglu, (2009), Jalil and Mahmud, (2009) and Shahbaz et al. (2012) Ali et al. (2014) to inspect the connection amid economic growth and environmental deprivation. Halicioglu, (2009) examined the environmental Kuznets curve together with foreign trade to observe its effect on environmental degradation to escape the difficulty of misspecification as in Jalil and Mahmud, (2009) for China. The model of this paper is an extension of Jalil and Mahmud, (2009) and Shahbaz et al. (2012). Shaheen et al. (2020).

The present study try to find the effect of production and consumption on carbon emissions by retaining a flexible environmental structure recognized as the STIRPAT model. IPAT, Impact and STIRPAT model is introduced by York et al. (2003) in their paper to examine vibrant forces of environmental

effects. For the specification of the STIRPAT model Lin et al. (2009) illustrate that industrialization and urbanization have a impending influence on GHG emissions in China during 1978–2006. Shahbaz (2017) also reverify this relationship amongst urbanization and energy consumption for Pakistan economy during (1972Q1-2011Q4) with the help of STIRPAT Model. Sadorsky (2014) utilised IPAT Identity to measure the effect of Population (P), growth (A), and technologic (T) issues on the environment. STIRPAT model supports to observe the influence of human activities on the environment. Anser (2019), Afawubo & Ntouko (2016), Liu et al. (2015). STIRPAT model's flexibility approves variations in technology variable into numerous additional socio-economic variables excluding the variables used in the STIRPAT equation. The description of STIRPAT can mathematically explain as.

$$I_{it} = \alpha P_{it}^{\beta} A_{it}^{\gamma} T_{it}^{\theta} \mu_{it} - - - 1$$

Eq (1) can be explain as,

I Impact on environment

P Population mass

T Technology or influence per unit socioeconomic activity

Here, α is a constant term, and β, γ, θ are the exponents of population, affluence, and technology and u signifies the error term. Many studies used diverse proxies of technology to demonstrate the effect of Socio economic human activities on environmental degradation. For example, Shahbaz et al (2017) employed the share of transportation as a Technology along with natural log of technology per capita. Anser (2019) used a share of the Renewable energy consumption, Fossil fuel consumption, and hydro electrical consumption with Urbanization. Li & Lin (2014) also took urbanization as a variable of technology. The STIRPAT model additionally allows adding the quadratic term in the equation for testing environmental Kuznets curve. The comprehensive STRIPAT Model cab be written as follows.

$$CO2 = f(POPD, IND, IND^2, NUC, FCON, TRO, \mu) - - - -2$$

$$CO2_{it} = \beta_0 + \beta_1 IND_{it} + \beta_2 IND^2_{it} + \beta_3 \emptyset_{it} + \mu_{it} \ - - - -3$$

Here, CO2 shows the carbon emissions in metric tons similar with Sana Ullah 2020 and POPD shows population density, alike measures have been used by Ali et al. (2014) and Ahmad and Long (2012). In eq. 2, IND shows Industrial value added as percentage of GDP similar with Sana Ullah (2020), Afawubo (and Nuclear energy (NUC), and the same measures used by Long (2015). Furthermore, to observe the effect of Consumption on carbon emissions, here (FCONS) Final Consumption expenditure is used and a comparable measure is used by Druchmen & Tim Sackson. (2015). Moreover, to examine the impact of Trade on carbon emissions, Trade as percentage of GDP (TRO) is used and similar indicator has been used in the study of Shahbaz et al. (2014, 2012, 2010), Iwata (2012) and Tiwari (2012). Study use log-linear specification after Cameron,

(1994); Ehrlich, (1996) and Ehrlich, (1975, 1977).

This study employs autoregressive distributive lag model or ARDL bounds testing approach advanced by Pesaran et al. (2000, 2001) to judge long run cointegration relationship among dependent and Independent variables. This approach is used to test cointegration has various benefits over different cointegration techniques as Engle-Granger and Johansen co-integration approaches. Most of the cointegration techniques entail that variables should be stationary only at level or at one. But ARDL bounds testing approach have a quality to handle mix order of integration at I(0) or I(1) or having mixed order of integration. To check the cointegration among small data size this approach is more suitable as parallel to some traditional approaches.

By taking log on both sides the STIRPAT model can be explained as:

$$lnCO2_{it} = \beta_0 + \beta_1 \ln\mathrm{POPD}_{it} + \beta_2 \ln\mathrm{IND}_{it} + \beta_3 \mathrm{IND}^2{}_{it} + \beta_4 NUC_{it} + \beta_5 lnFCON_{it} + \beta_6 lnTRO_{it} + \mu_{it} \quad ----4$$

In above equation 4 to study the long-run affiliation of independent with dependent variable, Autoregressive Distributive Lag (ARDL) approach is applied to test co integration, a bound test is implemented. Weather long run relationship exists or not can be expressed in the null hypothesis and alternative hypothesis respectively.

$$H_{\circ} = \gamma_{CO2} = \gamma_{popd} = \gamma_{IND} = \gamma_{IND^2} = \gamma_{NUC} = \gamma_{FCON} = \gamma_{TRO} = 0$$

(no cointegration) against null hypothesis such as

$$H_{\circ} \neq \gamma_{CO2} \neq \gamma_{popd} \neq \gamma_{IND} \neq \gamma_{IND^2} \neq \gamma_{NUC} \neq \gamma_{FCON} \neq \gamma_{TRO} \neq 0$$

The null hypothesis is confirmed by comparing the F-statistics of bound test with the critical values offered by Pesaran et al. (2001). The value of F stat must be greater than the upper critical bound than tabulated critical value to accept the results of cointegration, by Pesaran et al. (2001). After founding long run affiliations, to check the stability of the model an error correction mechanism is introduced.

Short Run Equation

$$\Delta lnCO2_{it} = \phi_0 + \sum_{j=1}^{k} \phi_{1j}\, \Delta lnCO2_{t-j} + \sum_{j=0}^{k} \phi_{2j}\, \Delta lnPOPD_{t-j} + \sum_{j=0}^{k} \phi_{3j}\, \Delta lnIND_{t-j} + \sum_{j=0}^{k} \phi_{4j}\, \Delta lnIND^2{}_{t-j} + \sum_{j=0}^{k} \phi_{5j}\, \Delta lnNUC_{t-j} + \sum_{j=0}^{k} \phi_{6j}\, \Delta lnFCON_{t-j} + \sum_{j=0}^{k} \phi_{7j}\, \Delta lnTRO_{t-j} + \beta 1 lnCO2_{it-1} + \beta_2 lnPOPD_{it-1} + \beta_3 lnIND_{it-1} + \beta_4 lnIND^2_{it-1} + \beta_5 lnNUC_{it-1} + \beta_6 lnFCON_{it-1} + \beta_7 lnTRO_{it-1} + \varepsilon_{it} \quad --5$$

For the convergence check of the model from the short run to long run to achieve the steadiness with the help of the following equation, the ARDL bounds testing approach to cointegration involves estimating the following unobstructed error correction model (UECM) as follows:

$$\Delta lnCO2_{it} = \beta_0 + \sum_{i=1}^{n} \delta_{1i}\, \Delta lnCO2_{it-i} + \sum_{i=1}^{n} \alpha_{2i}\, \Delta lnPOPD_{it-i} + \sum_{i=1}^{n} \Upsilon_{3i}\, \Delta lnIND_{it-i} + \sum_{i=1}^{n} \omega_{4i}\, \Delta lnIND^2{}_{it-i} + \sum_{i=1}^{n} \theta_{5i}\, \Delta lnNUC_{it-i} + \sum_{i=1}^{n} \mathrm{T}_{6i}\, \Delta lnFCON_{it-i} + \sum_{i=1}^{n} r_{7i}\, \Delta lnTRO_{it-i} + \beta + \beta 1\, lnCO2_{it} + \beta_2 lnPOPD_{it} + \beta_3 lnIND_{it} + \beta_4 lnIND_{it}^2 + \beta_5 lnNUC_{it} + \beta_6 lnFCON_{it} + \beta_7 lnTRO_{it} + \sigma EC_{it-1} + \mu_{it} \quad ---5$$

Here, σ symbolizes the coefficient of error correction term (ECt − 1). This p value must be significant, and its coefficient should be inverse for cross certification of cointegration or long-run connection among dependent and a set of independent variables to check the convergence of the model from short-run to long-run equilibrium.

Finally, the goodness of fit of the **ARDL** model and sensitivity examination has also been estimated. The diagnostic tests or sensitivity analysis study the serial correlation, autoregressive conditional heteroscedisticity, and normality and heteroscedisticity related with the model.

Description of the Variables

Carbon dioxide CO2

Carbon dioxide (CO2) is naturally produced gas as a result of photosynthesis into organic substance. It is a consequence of burning of fossil fuel and biomass combustion, it can also produce from variations in usage of land and other industrial progressions, that can also distress the Earth's radiative equilibrium. Global warming can be measured with CO2 and other greenhouse gases. Its emission concentration is the usual emission rate comparative to the intensity of a activity of a given pollutant from a given source. Many researcher used CO2 Mt in their research like Sana Ullah at al. (2020), Abokyi (2019),Mohaudin (2016), Saidi et al. (2015).

Population Density

Population density can be defined as ratio of midyear population to land area in square kilometers. From total world population Pakistan's population is correspondent to 2.83%. Total population density in Pakistan is 287 per Km2 (742 people per mi2). Pakistan is the world's fifth-most-populous country. The population growth rate in Pakistan has been around 2.50 % per annum for the last 10 years. The government is conscious about the rapidly growing population and has been pursuing an intensive population welfare program aimed at curtailing population growth because growing population increase carbon emission as per theory. Many studies used these in EKC Hypothesis as Jeremy (2009), Ascar (2014), Ali et al (2014), Ahmad and Long (2011).

Industrial Value added as

Since from the industrial revolution burning of carbon-based fuels has risen speedily, so concentrations of atmospheric carbon dioxide, is rising the global warming rate and resultantly anthropogenic climate changes are appearing. Sana Ullah (2020), Shaheen et al. (2020) Zhang & Jialan (2011), Abokyi (2019), Anees (2011), Xu (2015), Shahbaz (2014), Gokmenglu (2015), Lin (2014) used it in their research.

Nuclear Power Development

Nuclear power plants during their operation do not produce greenhouse gas emissions, and by comparing it with solar energy its emission is equivalent with per unit of electricity as wind, and one-third of the emissions per unit of electricity emissions during the course of its life. Theory suggested its negative impact on CO2Ahmad &Long (2005) also used Nuclear energy variable. In Pakistan Nuclear power technology was introduced in 1971 when a 137 MW CANDU type reactor was constructed with Canadian support. Then a second nuclear plant was constructed with the capacity of 325 MW PWR, it is in process with the help of China and its completion is expected to be final. To build up further of indigenous technological and industrial capability is required coupled with favorable political circumstances.

Trade openness

Trade openness intensifies the balance of economy and also becomes a reason to increase pollution. Trade is also beneficial for the economy because it can improve the production technique which helps to reduce pollution that is known as technique effect. Trade is explained as ratio of sum of imports and exports to GDP and has dual effect from the point of view of its effect. Iqra (2020), Shahbaz (2014), (2012), (2010), Tiwari (2012), Anees (2011), Iwatta (2009), Ang (2009), Jalil and Mahmud 2009 used trade openness to see the impact of Carbon emission.

Estimation of Results

This section consists of empirical results and the interpretation of the results. Explanation of variables is given in Table 1.

Table 1. Description of the Variables

Variable (Symbol)	Definition	Source
CO2 emissions (LCO2)	CO2 emissions (metric tons)	WDI
Population (LPOPD)	Population density (people per sq. km of land area)	WDI
Industrial production (LIND)	Industry (including construction), value added (% of GDP)	WDI
Industrial production square (LIND2)	Industry (including construction), value added (% of GDP) square	WDI
Nuclear energy (LNUC)	Alternative and nuclear energy (% of total energy use)	WDI
Final Consumption expenditure (LFCON)	Final consumption expenditure (% of GDP)	WDI
Trade openness (LTRO)	Sum of Import and Export as ((% of GDP)	WDI

Table 2. Descriptive Statistics

	LCO2	LPOPD	LINDC	LINDC2	LNUC	LFCON	LTRO
Mean	4.715934	5.300502	3.050611	9.313414	1.136674	4.469070	3.487691
Median	4.769785	5.314330	3.078033	9.474289	1.141811	4.463251	3.494685
Maximum	5.238936	5.617823	3.239788	10.49623	1.394297	4.534615	3.661238
Minimum	4.057218	4.939088	2.887160	8.335691	0.697631	4.411444	3.231051
Std. Dev.	0.341824	0.205897	0.086262	0.525798	0.188504	0.043079	0.121688
Skewness	-0.272480	-0.160944	-0.082331	-0.000912	-0.319338	0.139339	-0.617731
Kurtosis	1.973021	1.832919	2.942379	3.000602	2.332592	1.491939	2.613866
Jarque-Bera	1.633263	1.771044	0.036774	4.46E-06	1.031120	2.841890	2.024524
Probability	0.441918	0.412499	0.981781	0.999998	0.597166	0.241486	0.363396

Source: author's own calculation.

Descriptive statistics estimations are given in Table 2 for each variable which discloses that natural log of carbon dioxide, population density, Industrial value added, Square of Industrial value added, Nuclear energy, Final consumption expenditure and trade openness. Table shows its Mean, Maximum, Minimum and standard deviation of dependent and Independent variables. The probability value of all dependent and Independent variables is statistically insignificant showing the normal distributed series.

Table 3. Variance of Inflation Factor

	LNCO2	POPD	LNIND	LIND2	LNNUC	LNFCON	LNTRB
LNCO2	-						
LPOPD	49.72193	-					
LNIND	1.731824	1.72063	-				
LIND2	1.701783	1.692205	2674.047	-			
LNNUC	1.785757	1.976761	1.442448	1.426398	-		
LNFCON	2.309292	2.427523	2.244432	2.227291	1.676666	-	
LNTRO	1.998125	2.135652	1.4575	1.435813	1.21334	1.187067	-

Source: author's own calculation.

Along with descriptive statistics we also calculated Variance Inflation Factor in Table 3 showing the magnitude of VIF amongst all the independent variables [e.g., VIF (lnCO2, lnIND) = 1.731824), VIF (lnCO2, lnIND2) = 1.1701783 , VIF (lnREER, lnNUC) = 1.785757 and VIF (lnCO2, lnFCON) = 2.309292] and VIF (lnCO2, (ln TRO) have been found to be less than 10. We can clearly see from the VIF matrices that there is no problem of multicollinearity because almost all the values are less than 10.

After testing the multicollinearity of independent variables of the study, now the

next phase is to observe the stationarity of the factors subsequently we may ascertain as we have to continue with estimations of ordinary least square or co-integration method or to evade any fake results. The outcomes of unit root test through ADF unit root tests are confirmed equally at level and at first difference on Hypotheses that.

H_0 = Series is non-stationary, Trended, have unit root.

H_1 = Series is stationary, not trended.

The consequences anticipate that the null hypotheses is recognized contrary to the alternate hypotheses; at level however at first difference, alternate hypotheses is accepted and therefore it is concluded that lnCO2, lnPOPD, lnIND, lnIND2, and lnTRO are stationary at first difference I(1) and lnFCON is stationary at level I(0). So the order of integration is mix for all dependent and independent variable. The most comprehensive technique for mix order of Integration is Auto Regressive Distributed lag Model would be functional to find long run association among the variables.

Table 3. Unit Root Test

ADF Unit Root Test

	Level	Lags	First difference	Lags	Decision
LCO2	-1.5479 (0.4952)	1	-3.0056 (0.0470)	1	I(1)
LPOPD	-1.1215 (0.6922)	1	-6.8334 (0.0000)	1	I(1)
LIND	-2.8272 (0.1999)	1	-6.5971 (0.0000)	1	I(1)
LIND2	-1.5489 (0.4947)	1	-6.6249 (0.0000)	1	I(1)
LNUC	-1.0323 (0.7274)	1	-4.26215 (0.0026)	1	I(1)
LFCON	-4.1590 (0.0141)	1	-8.10396 (0.0000)	1	I(0)
LTRO	-0.71591 (0.8268)	1	-3.86641 (0.0067)	1	I(1)

Source: author's own calculation

Bound Testing

Results are depicting that the explained and explanatory variables are in mix order so at first co-integration is verified by using bound test approach. The outcomes of the bound test for Carbon emissions, Population density, Industrial Value added, Nuclear energy, Final consumption expenditure and trade openness. are shown in Table 4 indicating that the Value of both F stat and W stat is higher than the value of upper critical bound at 5% and 1% respectively, so rejecting the null hypothesis of no level effect and accept the alternative suggesting presence of co-integration affiliation between variables.

Table 4. Results of bound test

LogCO2, Log POPD, Log IND, LogIND2, Log NUC, Log FCON, Log TRO	Bound Test Value 95% Upper bound	90% Upper bound	Conclusion
F Statistics	4.6406 > 4.5846	4.6406 > 3.8412	Cointegration exists

W statistics	32.4845> 32.0925	32.4845 > 26.8881	Cointegration exists

Source: author's own calculation.

Results and Discussion

Co-integration Analysis to Determine the Long-run Relationship*:* The present study is employed to test Autoregressive Distributive Lag (ARDL) model and will give homogeneous long run estimations and specific short run estimations. Moreover it has good properties and quality to produce robust results for short samples. It also provides vigorous error correction model by using simple linear transformation. Shaheen et al (2020), Abokyi.(2019), Hanif (2019), Mirza (2017), Riti.(2016), Baig (2014), Tiwari (2012), Shahbaz (2010) also employed this technique to find their own estimations. So, after confirming cointegration through bound test, which observe the association of CO2 emission, Population density, Industrial Value added, Nuclear energy, Final consumption expenditure and trade openness, long run association is developed in Table 5.

Table 5. ARDL long run estimates.

Variable	Coefficient	t-Statistics	Prob
LPOPD	1.0922***	3.4185	.004
LINDC	-32.5739***	-3.8103	.002
LINDC2	5.1355***	3.7342	.023
LNUC	-.27103**	-2.5060	.052
LFCON	-1.6510***	-2.0950	.010
LTRO	.51926***	2.9350	.001
Turning point	**3.17$**		

Source: author's own calculation

Note: ***, ** and * represents the significance level at 1%, 5% and 10% respectively.

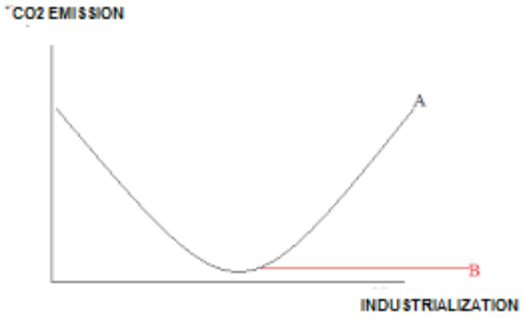
The log run estimation shows that Population density is significantly positively associated with high carbon emissions of Pakistan. As 1% increase in Population brings 1.0922% increase in carbon emission. CO2 emissions per capita Mt in Pakistan are equivalent to 0.89 tons per person (based on a population of 207,896,686 in 2019), an increase by 0.25 over the 0.64 CO2 tons per person registered in 1990, this represents a change of 39% in CO2 emissions per capita. The findings of this study are similar with the outcomes of Rasool et al. (2019), Abdul Mansoor (2018), Ali et al. (2017) Mahmood (2012). Theory also supports these findings as currently total population of Pakistan is above 200 million people.

Industrial value added is significant but negatively related to CO2 emission revealed by results. As 1% increase in Industrial value-added decrease carbon emissions by 32.5739%. Opposite to the Theory there exist the long-term Inverse relationship amongst industrial structure and the CO2 emissions due to many reasons. Firstly, many Industries have been closed due to Inflation and due to Terrorism in past Pakistan. Low percentage of GDP is given to Industrial sector, Industrial production fell 41.9 % YoY in Apr 2020. So, less no of Industries produce low carbon emission in Pakistan. Kim (2020) pointed out that Industrial

share reduce GHG. Secondly, the industrialization may a cause of carbon emission, but the latter is not an objective for the earlier, the influence rate is destructive, which specifies that fluctuations in industrial structure limit the emissions. Technical proficiency is also the central factor to decrease emissions.

The positive relationship between Square of Industrial value added and carbon emissions of Pakistan has been shown in table above. The results show 1% rise in Industrial value added indicates to rise in carbon emissions of around 5.1355% by keeping all other factors constant. So our Industrial EKC found to be U shaped. Industrial value added as percentage of GDP has inverse and significant bond with CO2 emission. Results are opposite to earlier anticipation but in accordance with the study of Aye and Adoja they found U shaped EKC in case of low-income countries. So, Pakistan is also considered a low income country. Abokyi (2019), Zhang & Jianlan (2011), Iqra.(20), Roca (2001), Hettige. (2000), Iqbal (2019). The inverse affiliation among industrial value added and CO2 emissions may explain in several means. First explained Naude (2011), lives tock farming to Industrialization. This may lead to considerable decrease in greenhouse gas emissions linked with non-energy agricultural foundations. Secondly the socio economic and political conditions of Pakistan supported low Manufacturing that's why This curve is U shaped.

Figure 2



The results show that Nuclear energy has a significant and adverse influence on carbon emissions in case of Pakistan. As 1% raise in Nuclear energy decreases carbon emissions approximately .27103% that is according to theory and long (2015) also supports. Nuclear power plants avoid producing gases like CO2, SO2 and NO, mainly responsible for acid rain and global warming. Though, some radiative substances also released by usage of Nuclear energy, but the released amount is very small. Results are similar with Kim (2020) and Iwatta et.al (2018).

In actual Nuclear energy creates practically no air contamination, produced from burning fossil fuels like oil, coal and natural gas. Advanced societies always demand on energy to power infrastructures, transportation, computer networks, industry products, farming and habitations always. If we do not have Nuclear energy or power, conveniences must burn fossil fuels to save the energy grid consistent, though with access to solar and wind energy, because of being an irregular source. Nuclear power is the only feasible way for a country to realize energy impartiality for this Nationally Determined Contributions (NDCs) is established to decrease carbon emissions in agreement with the Paris Agreement signed by 195 countries.

The results also show the significant and negative impact of Households Final Consumption expenditure on carbon emissions in Pakistan. As 1% rise in Final consumption expenditures decreased the carbon emissions by nearly 1.6510% by keeping other factors constant. Caron & Fally, (2018) discovers that part of expenditure spent on energy and related to energy intensive goods inclines to reduce with income across a large set of countries simply income expenditure reduces carbon emission. It is concluded that income is one of the main instruments of carbon emissions but with the use of income on best technology may reduce carbon emission. These findings are similar with Lee et al. (2017).

Table shows the turning point for CO2 emission. The turning point approximation for the long run model by IND value added and IND value added squared is about USD 3.17$. The turning points are the levels of IND value added at which CO2 emission levels starts to increase because of U shaped EKC hypothesis. The turning point is very much low suggesting that the Pakistan economy will not take time to turn the corner of EKC. In actual Pakistan is in phase of high carbon emission. The realistic consequences are familiar with the conclusion of Sinha (2017).

Table 6. ARDL Short Run estimates

Variable	Coefficient	t-Statistics	Prob
dLPOPD	-18.8912*	-2.6769	0.014
dLNIND	-13.9219*	-3.7993	0.001
dLIND2	2.2277*	3.7538	0.001
dLNNUC	-.11757**	-2.0711	0.052
dLNFCON	.24872	.84871	0.406
dLNTRB	-.07198	-.70507	0.489
Ecm(-1)	-.43379*	-4.0912	0.001

Source: author's own calculation

Note: *, ** and *** represents the significance level at 1%, 5% and 10%, respectively.

Table 7. ARDL ECM estimates.

Test Statistics	LM Version	F Version
Serial Correlation	CHSQ(1) = .10147[.750]	F(1,15) = .054556[.818]
Functional Form	CHSQ(1) = .26851[.604]	F(1,15) = .14524 [.708]
Normality	CHSQ(2) = 1.4919[.474]	-
Heteroscedasticity	CHSQ(1) = 2.1654[.141]	F(1,26) = 2.1792[.152]

Source: author's own calculation

Note: *, ** and *** represents the significance level at 1%, 5% and 10%, respectively. D is the Ist difference operator.

The short run results show that Population density is significant but negatively associated with carbon emission of Pakistan by keeping all other things constant. As 1% increase in population will decrease CO2 emission by 18.8912% in Pakistan. Industrial value added is also significant and negative like in long run. As 1% increase in Industrial value added will decrease carbon emission by 13.9219%. Results of Industrial value-added square are

surely associated with CO2 emission. 1% rise in square of Industrial value added increases the CO2 emission by 2.2277% resultantly U shaped EKC is also confirmed in short run. Nuclear energy is significant at 5% level of significance and negatively associated with carbon emission. As 1% increase in Nuclear energy reduced CO2 emission by .11757%, this is exactly according to economic theory and long run results of this study also has negative association with carbon emission. Final consumption expenditure is statistically insignificant but positive with carbon emission. Trade openness is also insignificant but inversely related with carbon emission of Pakistan in short run.

Table 6 shows the outcomes of error correction model. This error correction term ECt-1 is statistically significant at a 1% level of significance and has a negative sign. Significance of this error correction term is a signal of long-term association among Population, Industrial Value added, Nuclear energy, Final consumption and Trade openness with carbon emissions of Pakistan. The inverse sign demonstrates the convergence towards equilibrium of the assessed model. The result of the error correction model of this particular study describes that to achieve the equilibrium from short-run to long-run 43% error will be amended each year. The convergence coefficient (ECt-1) demonstrates the movement back to equilibrium if it deviates from the equilibrium and how much time it will take. For the above given models, the convergence coefficient is significant and negative, indicating 2.33 years' time is required to converge back to an equilibrium state.

Lower part of the table 7 shows results of diagnostic tests Results demonstrates that there is no problem of serial correlation among the error term and carbon emissions. No issue of non-normality of residual term is found in short run model and proved normally of the error term that is disseminated with zero mean and covariance. There is no autoregressive conditional hetroscedasticity is found in the results. Hence, it is proved that our short run model confirms all diagnostics test (i.e the LM test for serial correlation, normality test of residual term and the white hetroscedasticity test). Functional form is also correct.

5.1. Stability Test

Figure 3

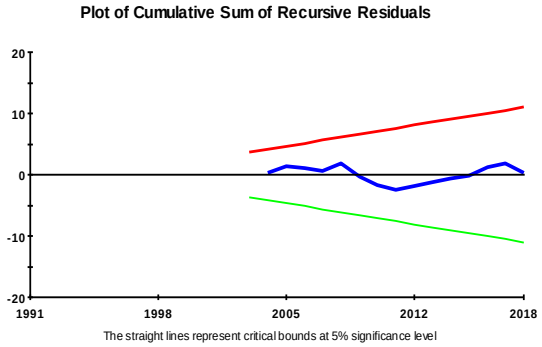
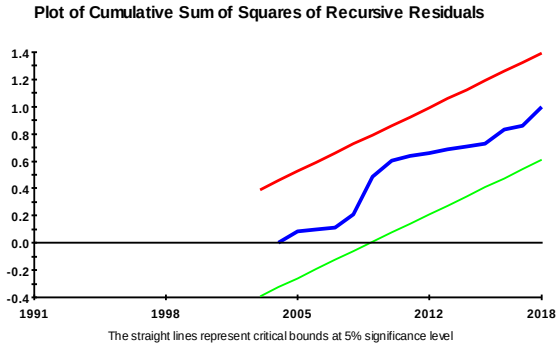


Figure 4



Figures 3 and 4 shows Ramsey reset test for Stability that at 5% level of significance the cumulative sum of recursive residual (CUSUM) and the CUSUM of the squares are between the upper and lower critical bounds. Therefore, these graphs approve the stability of the probable model and approve that the residual is normally distributed.

6. Conclusion and Policy Implication

The current study observes the fundamental association among CO2 emissions, Industrial value added (as percentage of GDP), Nuclear energy, household final consumption expenditure and Trade openness in Pakistan using annual data from 1990 - 2019. First, we examined stationary of data series using Augmented Dickey-Fuller (ADF) unit root tests. After ensuring that variables are stationary in the form I(0) and I(1), we then checked existence of relationship between the variables using bound test procedure and found that the variables are co integrated. Then significance of the short-run and long-run coefficients is checked as well as error correction term so as to explore the relationship between the variables in the short-run and long-run.

Our results indicate that contribution of Population towards CO2 emission is larger only in long run in case of Pakistan being a more populace country of the world. Industrial value added and square of Industrial value added depicts U shaped EKC in Pakistan both in the short and in long run. This might be possible due to low production in industrial sector in early 90's of Pakistan. Pakistan faced challenge of decreasing worker remittances in the 1990s, and external deficits increased. Then second worst thing faced by Pakistan was Inflation Unemployment rate abruptly augmented to 5.9% in 1991 and 7.2% in 2000. Probability of external debt evasion arose in 1996, and 1998, due to the Western economic endorsements executed in response to Pakistan's nuclear tests on 28 May 1998. Rate of poverty severely raised to 30.6% in 1990.This all badly affects the sector manufacturing of Pakistan. Pakistan also faced some political issues in that era therefore; the industrial policy was never the top priority of those two governments. This is result in lesser CO2 emission so U shaped EKC found in short and in long run.

It is also concluded that Nuclear energy is significant and inversely related with CO2 emission both in short and in long run. Nuclear energy is usually without pollutants and sustainable energy basis that can provide uninterrupted energy without deteriorating environmental degradation that cause global warming. It is a best technology that reduces emission and our results also supports. Its benefits are plentiful, good jobs opportunity, energy security, decrease dependency on imported fuels and disclosure to price risks related with Middle East politics. Pakistan is now planning to make large scale use of nuclear power in future. It is planned to develop systematically local competence, principally & progressively to increasing native design, and manufacture of nuclear power plants along with their components and fuel.

Household final consumption expenditure has a significant but negative contribution towards the carbon emission of Pakistan in long run only. Having low income most of the spending's of the people is related to basic needs. Trade openness has significant and direct relation with CO2 emission in long run. Imports of luxury energy consumption goods and fuel (petrol gas and oil) may increase

carbon emission. So it can easily exerts from these findings that Pakistan must use Nuclear energy even in Industrialization to avoid environmental degradation and Trade of Imported items that produce carbon emission must reduce.

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