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INVESTIGATING THE SIGNIFICANT IMPACT OF COAL CONSUMPTION, COAL PRODUCTION, AND COAL IMPORTS ON CO_2 EMISSIONS IN PAKISTAN

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Abstract
Reliance on coal based energy sources has substantially increased in last decade due to severe energy shortages in Pakistan. This study evaluates the impact of coal consumption, coal production and coal imports on the carbon emissions by using time series data. The data were obtained from EDGAR and economic survey of Pakistan published by ministry of finance in annual frequency. The data for a period spanning over twenty years from 2001 to 2022 were analyzed employing ARDL bounds testing approach. The findings reveal a significant impact of the explanatory variables on carbon emissions scaled by GDP. Further, granger causality test proved a unidirectional impact of coal consumption and coal import on carbon emissions. Policy recommendations and suggestions are made based on the reported results to tackle the impact of carbon emissions on ecological footprints in an emerging economy.

1. Introduction

The intricate relationship between coal consumption, production, and imports and their impact on carbon dioxide (CO2) emissions is a pressing concern in Pakistan. As energy demands surge, coal remains a pivotal source for electricity generation. However, this reliance comes at cost elevated CO2 emissions. Our research aims to comprehensively analyze this interplay, drawing insights from historical data, policy frameworks, and economic factors. Pakistan, ranked as the seventh most vulnerable country in the global climate change discourse, faces significant environmental challenges. The alterations in the country's natural climate are closely tied to elevated levels of carbon dioxide (CO2) emissions. These emissions primarily stem from extensive coal combustion in newly established coal-fired power plants across the nation (Korneta, 2018; Khaskheli et al., 2023). Our primary objective is to assess the substantial impact of coal consumption, production, and imports on carbon dioxide (CO2) emissions in Pakistan. Leveraging two decades of annual time-series data, we delve into the intricate relationship between coal-related activities and their environmental consequence. Pakistan's economy heavily relies on agricultural production and output. Our study emphasizes comprehensive policies aimed at mitigating coal-induced CO2 emissions. We employ autoregressive distributed lag (ARDL) technology, which offers robust evidence even with limited data samples. Through this research, we aspire to contribute valuable insights to the existing literature, fostering informed decision-making for sustainable energy practices in Pakistan (Khan et al., 2021; Xuezhou et al., 2022). Carbon dioxide (CO2) emissions play a significant role in the composition of greenhouse gases, contributing to climate change and global warming. These emissions primarily arise from the combustion of fossil fuels and cement production. Notably, they exclude emissions related to land use changes, such as deforestation. Oil Releases approximately 50% more CO2 than natural gas. Coal Emissions from coal combustion are roughly twice as high as those from natural gas. These findings underscore the importance of addressing CO2 emissions to mitigate their environmental impact.

Between 1986 and 2020, Pakistan experienced a continuous increase in carbon dioxide equivalent emissions (CO2es), with an average annual growth rate of 4.76%. During this period, several key factors played pivotal roles. As Pakistan's economy expanded so did its carbon emissions. Economic growth correlated with increased energy consumption and industrial activities. A growing population contributed to rising energy demands and subsequent emissions. Changes in land use patterns influenced CO2es. Deforestation, urbanization, and agricultural practices impacted carbon storage and release. Mitigating Forces Efforts to improve energy efficiency (energy intensity) and reduce emission factors (e.g., cleaner technologies) acted as mitigating forces (Raza & Lin, 2023). Notably, the carbon source (68.75 Mt) and carbon damage (208.56 Mt) dimensions collectively drove the overall rise in CO2e. These findings underscore the need for comprehensive policy measures to balance development with environmental stewardship. As Pakistan works on adaptation and mitigation, its increased energy consumption to improve living conditions for citizens necessitates an energy transition. Shifting from polluting fossil fuels to clean energy sources is crucial for reducing greenhouse gas emissions globally and protecting public health within the country. While Pakistan's energy sector has already replaced oil with coal for power generation, a comprehensive assessment and streamlined transition are essential to address environmental, ecological, climate change and economic challenges for current and future generations. Pakistan is the 10th largest economy of the region. Energy consumption of the country remained 3.5 oxy joules in 2019 (PB Stat 2020). Primary energy demand can be divided into demand of petroleum, natural gas, and coal. Electricity is the secondary source of energy. In Pakistan, consumption of natural gas, coal, and electricity has increased by 41%, 52%, and 11%, respectively, but consumption of oil has decreased by 9% from July 2019 to March 2020 (Naeem et al., 2021). Pakistan has been confronting economic challenges for two decades due to many factors such as the electricity crisis, among others. It is therefore essential to identify such factors that may play a constructive role in economic growth. In doing so, this study investigates the determinants of economic growth in Pakistan from 1972 to 2018 (Abbasi et al., 2021). While Pakistan contributes only a small fraction to global greenhouse gas emissions, it remains highly susceptible to the adverse effects of climate change. The National Climate Change Policy of 2012 outlines strategies for mitigating greenhouse gas emissions in the energy sector. However, given the country's diminishing indigenous natural gas reserves and reliance on oil imports, coal remains a viable option for electricity generation (Ishaque, 2017)

In Pakistan, energy sector emissions are categorized into two primary groups: fuel combustion emissions and fugitive emissions. Among the total CO2 emissions from fuel combustion, 52% originate from burning liquid fossil fuels, 36% from natural gas combustion, and the remainder from solid fossil fuels. From 1990 to 2016, the country's total CO2 emissions increased from 55.97 to 155.27 MtCO2. These emissions are growing at an annual rate of 6% and are projected to reach 400 MtCO2 by 2030. Despite Pakistan's vision to reduce greenhouse gas emissions by 30% by 2025, the current emissions level (130.52 MtCO2) indicates a 16% increase compared to 2008. Addressing this challenge requires solutions that consider political, economic, and sociocultural factors (Akram et al., 2019). The present study makes several contributions to the existing literature. Firstly, it utilizes the ARDL bounds testing approach for co-integration, which remains valid regardless of whether a series is integrated of order 0 (I(0)) or 1 (I(1)). Secondly, the paper provides plausible estimates of the impact of coal consumption, Coal Production and Coal Imports on CO2 Emissions in both the long and short run. Thirdly, VECM Granger causality tests are employed to examine the direction of causality in both time frames. Finally, an innovative accounting technique involving forecast error variance decomposition and impulse response functions is used to measure feedback effects.

2. Literature review

This study quantifies the potential impact of Pakistan's greenhouse gas (GHG) mitigation policies pertaining to coal-fired power plants on power sector emissions. The results show that the impact of coal plant efficiency scenario in emission reduction is limited despite significant fuel cost savings that result in negative abatement costs (Ishaque, 2017). This study aims to probe the robust nexus between carbon emission, energy, and economic progress both in bivariate and multivariate models for 1971–2019 in Pakistan. Variables' robustness and interaction are investigated using the Johansen co-integration, and Auto-regressive Distributed Lag bound testing method for estimating the long-run relationship at the significance level of 5%, respectively. The examined results of Auto-regressive Distributed Lag shows that energy consumption, economic growth, urbanization, research and development, and forest area have a positive and significant impact on carbon emissions of Pakistan in the long run while in the short run urbanization and forest area have found a negative effect on carbon emissions (Aftab et al., 2021). (Naeem et al., 2021) analyzed economic growth of Pakistan and obtain some alternate sources of production for sustainable environment. Time series data of Pakistan from 1985 to 2018 is used. In order to estimate direct and substitution effect among energy and non-energy factors on economic growth, Trans log functional form is used. And have to find Empirical analysis of CO2 emissions and sustainable use of energy sources in Pakistan. The primary goal of this study was to examine the relationship between fossil fuel energy, electricity production from nuclear sources, renewable energy, CO2 emissions, and economic growth in Pakistan. Data ranging from 1975 to 2019 were utilized, and the stationarity of this data was verified through the unit root testing. This study is used to find feasible progressive policies that are required to pay more attention for tackling the energy and power sectors' issues in terms of fulfilling the country's energy requirements (Rehman et al., 2022). This examined the asymmetric impact of renewable energy consumption on CO2 emissions by using the advanced econometric approach. While the asymmetric role of renewable energy production in the CO2 equation is largely unknown, our present study quantifies the asymmetric relationship between renewable energy production, natural resources, economic progress, and CO2 emission for Pakistan by using the NARDL approach. The results reveal that a positive change in economic progress significantly increases CO2 emissions in the long run. Based on findings, Pakistan's government should encourage local and international investors to increase their investment in the production of renewable energy by reducing environmental degradation (Iqbal et al., 2022). Raza & Lin (2023) and Hussain et al., (2020) analyze coal imports and indigenous reserves in relation to CO2 emissions. In particular, the study constructed the Logarithmic Mean Division index (LMDI) method to see the impact of the factors, decoupling index for the economic relationship, and pollution from coal-fired power plants from 1986 to 2019.

The results recognized that implementing clean coal technologies significantly saves fuel and, consequently, reduces emissions. This scenario attempts to estimate the impactful emission reduction percentage, which the country needs to adopt along with other necessary changes in the existing policies of the country. The results clearly indicate that the emissions are bound to increase under business as usual and CPEC scenarios and the country would fail to meet the Nationally Determined Contributions pledged at COP21 (Malik et al., 2020). (Abbasi et al., 2021) investigated the determinants of economic growth in Pakistan from 1972 to 2018. The dynamic autoregressive distributed lag (ARDL) approach applied to analyze positive and negative changes in energy consumption, industrial growth, urbanization, and carbon emissions on economic growth in Pakistan. The study suggested a requirement to integrate better electricity generation and management with the planning of economic policies.

The present study explored the relationship between coal consumption, industrial production and CO2 emissions in case of China and India for the period of 1971-2011. The structural break unit root test and co-integrating approach have been applied. These results validate the presence of co-integration among the series in both countries. This also finds the existence of inverted U-shaped curve between industrial production and CO2 emissions for India but for China it is U-shaped relationship. (Shahbaz, 2014). This study empirically examines the co-integrating relationship between carbon emissions, energy consumption, trade openness and financial development in Pakistan using ARDL bounds test for co-integration procedure. Annual time series data is used for the period 1971–2011. The results reveal an inverted U-shaped relationship between carbon emission and energy consumption with a maximum threshold value of energy consumption per capita 640 kg of oil equivalent (Shahzad et al., 2017). This theory examined the liaison between coal consumption and economic growth for Pakistan over the period 1971-2009 using ARDL bound testing. Application of the autoregressive distributed lag (ARDL) bounds test reveals a co-integrating relationship between real income, real capital stock, labor and coal consumption (Kumar & Shahbaz, 2012). This study aims to examine the impact of coal energy consumption on the economic progress in Pakistan by using annual time series data during 1972–2019. The findings of co-integration regression analysis uncover that via FMOLS (Fully Modified Least Squares) and DOLS (Dynamic Least Squares) that variables coal energy consumption in powe sector and brick kilns have an adverse connection with the economic progress, while total coal energy consumption uncover a productive linkage to the economic progress in Pakistan (Rehman et al., 2021; Hussain et al., 2023).

This study examine the relationship between coal consumption and economic growth by including other supporting variables such as capital use and labor participation rate in Pakistan over the 1972-2009 period. The results suggest that coal consumption, capital use and the labor participation rate have positive impact on economic growth. Causality analysis indicates bidirectional causal relation between coal consumption and economic growth and results are robust through innovative accounting approach. This implies that energy (coal) conservation policies may retard economic growth that in turn lowers the demand of coal (Kumar & Shahbaz, 2012; Akhtar et al., 2024). This paper explores the effects of financial development, economic growth, coal consumption and trade openness on environmental performance using time series data over the period 1965–2008 in case of South Africa. The Results showed that a rise in economic growth increases energy emissions, while financial development reduces it. Coal consumption has significant contribution to deteriorate environment in South African economy (Shahbaz et al., 2013; Zhang et al., 2022). This study applied the logarithmic mean Divisia index (LMDI) model to identify and discuss the main drivers of Pakistan's CO2 emissions over the period 1990–2016. The study examined the effects of five factors based on Pakistan's three main economic sectors while considering the 11 types of fuels consumed in that country. The results showed that the energy structure effect is the greatest driving force of CO2 emissions in this country, followed by scale effect and economic structure effect (Akram et al., 2019).

3. Methods and data collection

3.1 Data

The sample selected in this study is annual time series data for the period from 2001 to 2022 of Pakistan, duration was selected based on availability of the data for all proposed variables. The data was collected through secondary sources from EDGAR (Emissions Database for Global Atmospheric Research) and Pakistan Economic Survey 2021-22 published by Government of Pakistan Finance Division. The annual time series data used in the model and the data source information is provided in Table1.

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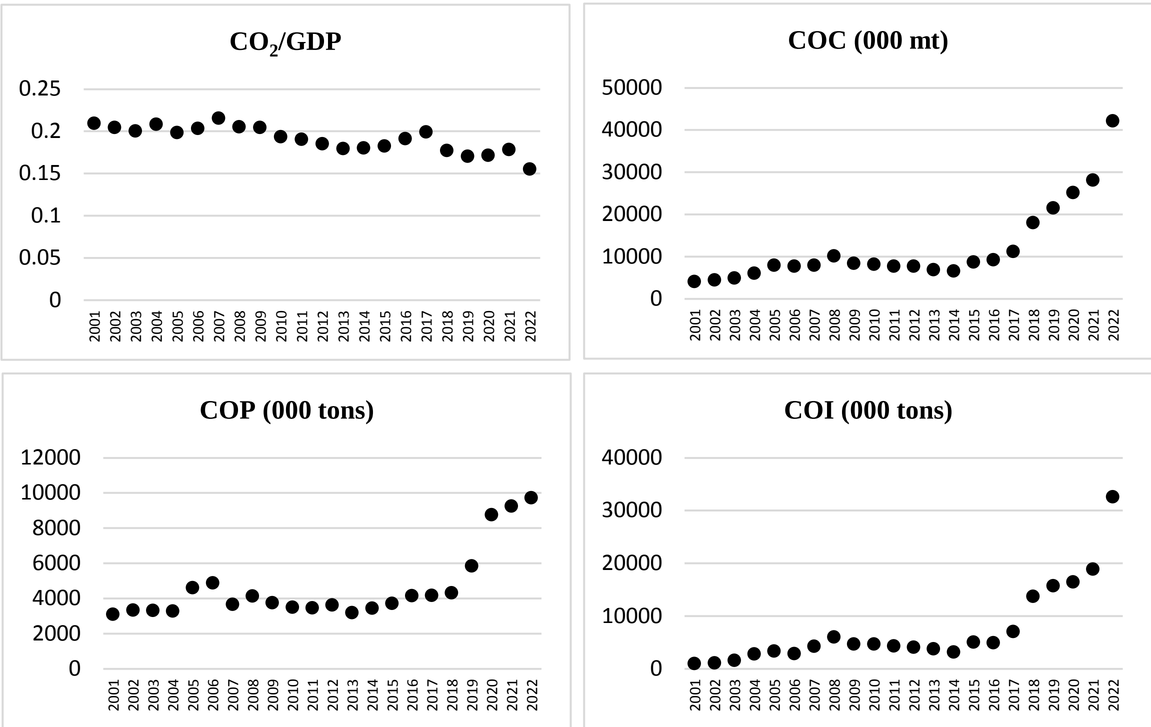
Table 1: Description and sources of variable used

Variable	Abbreviation	Measure/ Unit	Data Source
Dependent Variables:			
Carbon Dioxide/ GDP	CO_2/GDP	$\frac{\text{Carbon Dioxide Emissions}}{\text{GDP in USD}}$	EDGAR (Emissions Database for Global Atmospheric Research)
Independent Variables:			
Coal Consumption	COC	000 mt	Pakistan Economic Survey 2021-22
Coal Production	COP	000 tons	
Coal Imports	COI	000 tons	

The trends of all the study variables are shown in Figure 1. The trend of CO_2/GDP was up and down from but it decline in recent years from 2017 to 2022. The trend of COC, COP and COI increasing over time but in recent years from 2017 to 2022 they were increasing with rapid pace.

Figure 1: Time trend of study variables



The schematic diagram of the study variables is presented in Figure 2.

Figure 2: Schematic diagram of the study:

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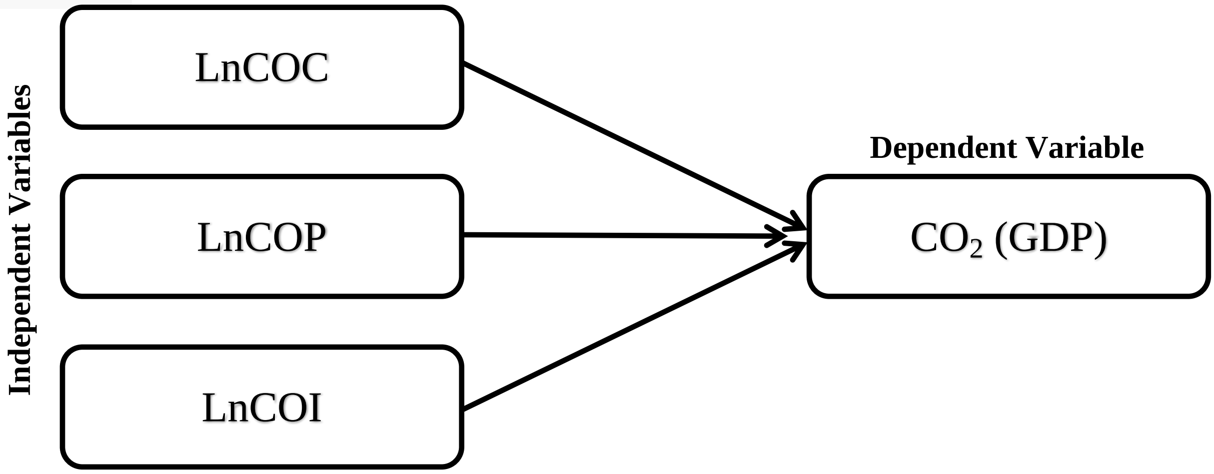

3.2 Model description

To examine the relationship between dependent variable CO_2/GDP and independent variables including LnCOC, LnCOP and LnCOI, the framework is established based on the autoregressive distributive lag (ARDL) model used by (Khan et al., 2021)(Rehman et al., 2020) (Eq. 1). The autoregressive distributed lag bounding test method was introduced by (Pesaran et al., 2001) to determine the co-integration existence. It is also used to check the short and long-run relationship between the selected time series data. The ARDL approach has edge over simple co-integration approach because of its flexible stationary properties of the selected variables and can be calculated at both level, even mutually co-integrated and at first difference (Pesaran et al., 2001). The ARDL method can deliver efficient and consistent results by a small sample (Haug, 2002). At the same time it can measure and estimate the coefficient of one variable on another in the short and long run.

$$CO_2/GDP = f(LnCOC_t, LnCOP_t, LnCOI_t) \quad (1)$$

Where CO_2/GDP stands for carbon dioxide emissions over GDP in dollars, LnCOC represents coal consumptions, LnCOP represents coal production and LnCOI represents carbon imports.

After assuming the linear relationship between the selected variables the model is specified as Eq. 2.

$$CO_2/GDP = \varepsilon_0 + \varepsilon_1\, LnCOC_t + \varepsilon_2\, LnCOP_t + \varepsilon_3 LnCOI_t + \varepsilon_t \quad (2)$$

By applying the logarithm to Eq. 2, the model follows a log-linear form and can be expressed as follows in Eq. 3:

$$CO_2/GDP = \alpha_0 + \alpha_1\, LnCOC_t + \alpha_2\, LnCOP_t + \alpha_3\, LnCOI_t + \varepsilon_t \quad (3)$$

Where Ln denotes the logarithmic form, t denotes the time period, and ε is the error term. The coefficient α_i(where i = 0,1,2,3) represents long elasticity.

3.3 Methodology

3.3.1 Stationary test

The variable used in this study were checked for stationary properties by testing Augmented Dickey-Fuller (ADF) tests (Dickey & Fuller, 1979) and Phillip-Perron (PP) tests (Peter C.B. Phillips & Pierre Perron, 1986) the time series data of the selected study variable

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are stationarity at level/first difference or both. The examination of stationarity between two variables was introduced by (Company & Diego, 1981). The null hypothesis is there is a unit root of non-stationary at the level for ADF and PP unit-root. The ADP unit root test is expressed in Eq. 4:

$$\Delta U_t = \delta_0 + \delta_1 U_{t-1} + \sum_{j=k}^{1} d_j \Delta U_{t-1} + Q_i \qquad (4)$$

Where U_t denotes time series, Δ is the first difference operator, $_0$ denotes constant, dependent variable optimum numbers of lags are represented by 1, and Q_i is the pure white noise error term. While the PP unit root test is expressed in Eq. 5:

$$\Delta U_t = \delta + 1 * U_{t-1} + Q_i \qquad (5)$$

Both unit root tests are grounded on t-statistics.

3.3.2 ARDL bounds testing method, short and long-run estimates

The ARDL model was introduced by (Peter C.B. Phillips & Pierre Perron, 1986) (Pesaran et al., 2001), and it was used to analyze the relationships among the time-series data variables used in this study, i.e., CO_2/GDP, LnCOC, LnCOP and LnCOI in the long run. The ARDL model is expressed as follows in Eq. 6:

$$\Delta CO_2/GDP = \alpha_0 + \alpha_1 \sum_{i-1}^{k} \Delta\, CO_2/GDP_{t-1} + \alpha_2 \sum_{i-1}^{k} \Delta Ln\, COC_{t-1} + \alpha_3 \sum_{i-1}^{k} \Delta Ln\, COP_{t-1} + \alpha_4 \sum_{i-1}^{k} \Delta Ln\, COI_{t-1} + \alpha_5\, \Delta CO_2/GDP_{t-1} + \alpha_6\, \Delta COC_{t-1} + \alpha_7\, \Delta COP_{t-1} + \alpha_8\, \Delta COI_{t-1} + \varepsilon_t \qquad (6)$$

The estimated short-run model is as follows in Eq. 7:

$$\Delta CO_2/GDP_t = \alpha_0 + \alpha_1 \sum_{i=1}^{k} \Delta\, CO_2/GDP_{t-1} + \alpha_2 \sum_{i=1}^{k} \Delta Ln\, COC_{t-1} + \alpha_3 \sum_{i=1}^{k} \Delta Ln\, COP_{t-1} + \alpha_4 \sum_{i-1}^{k} \Delta Ln\, COI_{t=1} + \varepsilon_t \qquad (7)$$

4. Results and Discussion

4.1 Descriptive Statistics

To get deeper understanding of the nature of our data, we conducted descriptive statistical analysis, the results are outlined in Table 2. This analysis offers valuable information about the selected variables. The mean of dependent variable CO_2 (GDP) stands at 0.190, the standard deviation is calculated at 0.015, the dataset values range from low 0.155 to high 0.215. In first independent variable LnCOC the mean value is 9.177, standard deviation stands at 0.612 and the data ranges between low 8.305 to high 10.648. Second independent variable LnCOP shows mean of 8.364, with standard deviation of 0.346 and ranges from low 8.037 to high 9.179. Final independent variable LnCOI have mean of 8.502, noted standard deviation of 0.895 and the data range between low 6.856 to high 10.390.

Table 2: Descriptive statistics

Variable	No of Obs	Mean	Std. Dev	Min	Max
CO_2/GDP	22	0.1907273	0.0153505	0.155	0.215
LnCOC	22	9.177577	0.6129852	8.305162	10.64845
LnCOP	22	8.36488	0.3460611	8.037543	9.179984
LnCOI	22	8.502917	0.8951878	6.856462	10.39001

4.2 Unit Root Test

There are multiple tests used for unit root testing in time series data. But we used the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) unit root tests are presented in table 3. These tests were recognized and presented by (Dickey & Fuller, 1979) and (Peter C.B. Phillips & Pierre Perron, 1986) for the very first time to inspect the stationary properties of the variables. According to ADP and PP test, our results presented in Table 3. The results indicates that some of the study variables are stationary at *I(0)* and some of them are

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stationary at the first difference *I(1)*. This condition confirms that we have to use ARDL model.

Table 3: Results of the unit root test

Variable	Level		1st Difference		Outcome
	Intercept	Trend and intercept	Intercept	Trend and intercept	
Augmented Dickey fuller					
CO_2 /GDP	-1.268	-2.590	-3.491*	-3.917*	I(1)
LnCOC	2.012**	-0.415	-1.280	-2.275	I(0)
LnCOP	1.222	-0.900	-2.792*	-3.607**	I(1)
LnCOI	2.005**	-1.601	-2.166**	-2.928	I(0) I(1)
Phillip-Perron					
CO_2 /GDP	-1.385	-2.706	-4.289*	-4.445*	I(1)
LnCOC	2.857*	-0.334	-2.049**	-3.250***	I(0) I(1)
LnCOP	1.531	-0.824	-3.529*	-4.030**	I(1)
LnCOI	2.638**	-1.470	-2.662*	-3.463***	I(0) I(1)

4.3 ARDL co-integration test and parameters estimates

To select the optimal lag various criteria are used, this study used the Schwarz Information Criteria (SIC) criteria to decide the optimal lag for the ARDL model. It is commonly used as it express better information (Pesaran & Shin, 2001)

The ARDL bound testing is used to investigate the co-integration association between the dependent variable CO_2 (GDP) and the independent variables LnCOC, LnCOP and LnCOI. The critical bounds value for the small and large sample sizes are accumulated by (Pesaran & Shin, 2001) According to Pearson, accept the null hypothesis if the f-statistics value is below the lower bound and the alternate hypothesis will be rejected. Reject the null hypothesis if the f-statistics value surpasses the upper bound and then the alternate hypothesis is accepted. The results are given in Table 4 and indicated that the value of f-statistics (3.472) is more than the upper bounds critical value (5.61), and it is significant at 1% level, which provides evidence that there is co-integration between CO_2/GDP, LnCOC, LnCOP and LnCOI in Pakistan. In developing countries the increasing in coal energy consumptions, production and imports causes to increase in carbon dioxide (Khan et al., 2021). These results clarify that the null hypotheses of no co-integration between study variables is rejected and the alternate hypothesis of existence of co-integration between study variables is accepted. This estimate confirms the association between dependent variable CO_2 (GDP) and independent variables LnCOC, LnCOP and LnCOI in Pakistan.

Table 4: Results of the ARDL bounds testing for co-integration

Test Statistics	**Value**	**K**
F-statistics	3.472	3
Critical value bounds		
Significance	I(0) bound	I(1) bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

4.4 Long-run and short-run analysis based on ARDL

The findings of the ARDL long-run and short-run between dependent variable CO_2 /GDP and independent variable LnCOC, LnCOP and LnCOI are presented in Table 5. The outcomes indicates evidence of the existence of short-run correlation among the study time-series variables so we adopted short-run relationship using ARDL. In case of short-run estimations the LnCOC proved a negative and significant at 1% level (coefficient -0.143127) which reveals that 1% change in LnCOC may decrease CO_2/GDP by 30%. As reported by international organization (World Bank) that Pakistan carbon emissions are far below then the average of World. Some experts also suggest that Pakistan can rely on Coal Energy in more carbon efficient plants to generate electricity by Coal it can help Pakistan economy to decrease petroleum imports and use their own Thar Coal Mines to produce domestic raw material. Also the green initiatives taken by Government of Pakistan in 2019 to start Billion Tree Project also reduces the carbon emissions in Pakistan. The LnCOP (0.0674764) and LnCOI (0.0707989) are positive and significant at 2% and 1% respectively. Means that 2% change in LnCOP can increase CO_2 (GDP) by 6% and 1% change in LnCOI can increase CO_2 (GDP) by 7%. This result shows that the coal production and import can cause increase in carbon emission.

Table 5: Short run estimates by ARDL

Variables	Coefficient	Std. Error	T-test	P-value
Long-run Association				
CO_2 /GDP	-0.3069928	0.15621	-1.97	0.070
LnCOC	-0.2922946	0.1961117	-1.49	0.158
LnCOP	0.2009565	0.1330885	1.51	0.153
LnCOI	0.1197871	0.0903559	1.33	0.206
Short-run Association				
CO_2 /GDP(-1)	0.7115251	0.1657862	4.29	0.001
LnCOC	-0.143127	0.0443493	-3.23	0.007
LnCOC(-1)	0.0589741	0.0425939	1.38	0.189
LnCOP	0.0674764	0.02594	2.60	0.022
LnCOP(-1)	-0.0103629	0.0225654	-0.46	0.654
LnCOI	0.0707989	0.0707989	2.77	0.016
LnCOI(-1)	-0.0358239	0.0213976	-1.67	0.118
R2	0.8613			
Adjusted R2	0.7867		Prob	0.0001

4.5 Granger causality test

To check the estimated of directional casual connections between the study variables we use Granger Causality test. The results of the Granger Causality test are presented in Table 6. We used lag value (2) in our test. The result shows that the CO_2/GDP, LnCOP and LnCOI can affect LnCOC. Similarly LnCOC and LnCOI can causes LnCOP. Finally CO_2 (GDP), LnCOC and LnCOP have impact on the LnCOI. These results prove a unidirectional impact of coal consumption on carbon emissions, no impact of coal production on carbon emissions and a unidirectional impact of coal import on carbon emissions.

Table 6: Granger Causality Test

Dependent Variables	**Independent Variables**			
	CO_2 (GDP)	LnCOC	LnCOP	LnCOI
CO_2 /GDP	-	0.84074	2.4982	0.34631
LnCOC	21.854*	-	6.0466**	7.6798*
LnCOP	2.8559	7.7055**	-	11.418*
LnCOI	11.418*	12.245*	9.3044*	-

*Acquired null hypothesis rejected at 1% level and **reject the null hypothesis as 5% significant level.

5. Conclusion and policy implications

In this study, we analyzed the relation between dependent and independent variables. The dependent variable include CO_2/GDP and independent variable include COC, COP and COI. The time period data of Pakistan collected from 2001 to 2022. Annual time-series data was gathered from EDGAR and Pakistan Statistical Supplement 2021-22. ADF and PP unit root tests confirmed that the variables are stationary at the level and first difference. In addition, the results of the ARDL bounding test shows that there are cointegration linkages among the study variables at a 1% significance level, which shows existence of cointegration between CO_2/GDP, LnCOC, LnCOP and LnCOI in Pakistan. These results clarify that the null hypotheses of no co-integration between study variables is rejected and the alternate hypothesis of existence of co-integration between study variables is accepted. This estimate confirms the association between dependent variable CO_2 (GDP) and independent variables LnCOC, LnCOP and LnCOI in Pakistan. Furthermore, the Granger causality test estimation provide the evidence of unidirectional causality running from between CO_2/GDP, COC, COP and COI.

Policy implications were measured based on the above empirical results. The government of Pakistan should manage the energy reforms and build the high efficient coal power plants to decrease the carbon impact although Pakistan's net carbon ratio is far below then others means Pakistan's carbon emissions are far below then average of world. Also, the Pakistani government should subsidize those industries which are making energy from coal because it is cheaper and Pakistan has own one of biggest mines of coal in the world, also need to urge them to use carbon efficient coal energy for low carbon emission to the environment. The potential reasons of carbon emission reduction in Pakistan can the measures taken by Government to promote solar energy, investment in hydropower plants and Billion Tree Project. It can cause a significant increase in forest area of Pakistan. By using own coal Pakistan can decrease import bill and overall energy import bills and will help to reach surplus. For decrease in imports at the international level, the government of Pakistan should organize exhibitions and introduce the new regulations for carbon energy Pakistan can take help from International partners like China and US to get the latest technology about carbon energy.

Data availability: The data used in the study for analysis can be found on the web links from Electronic Data Gathering, Analysis, and Retrieval EDGAR (https://edgar.jrc.ec.europa.eu/country_profile/PAK) and Pakistan Economic Survey 2021-2022 (https://www.finance.gov.pk/supplement_2021_22.pdf).

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