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Carbon Dioxide Emissions Reduction Efficiency and Growth Potential (A Case of Pakistan and China)

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Abstract

The current study undertakes an empirical investigation aiming to find out how ecological, economic and environmental factors, such as energy consumption, GDP growth rate, and ecological footprint per person, influence CO2 emission in the CPEC region. The study relies on the panel data series for Pakistan and China over the period of 1980-2030, because the year 2030 is the most probable time of the CPEC project completion. The forecasted values of the respective factors with possible influence of CPEC projects assisted the authors in gaining a clearer picture of their interrelationship. According to regression results, energy consumption and production have been significant positive determinants of CO2 emission, while energy intensity has had a considerable negative impact on this emission. Among economic factors, the dynamics of GDP, GPI, per capita income, HDI, unemployment rate, and GINI coefficient are found to have made a positive impact on CO2 emission; as to GDP growth, the regression unexpectedly showed its insignificant negative impact. Among ecological factors, the expenditures on environmental protection appear to be negative determinants of CO2 emission, while environmental footprint and costs of elimination of natural disasters positively impact the CO2 emission. The mediation analysis showed that the population growth would be the key factor of influence on CO2 emission. It is therefore recommended that, being a developing economy, Pakistan should reconsider its strategies towards CPEC projects, especially those involving coal energy production which may accelerate the CO_2 emission in the country and lead to additional costs in terms of natural hazards and climate change.

Keywords
CO2 Emission, Green Finance Policies, Economy, Population, Energy, Fossils fuel, Ecological footprint.

JEL: F3, G0, G3, Q40, M2.

1. Introduction

China's industrial sector is the priority area of endeavour for the country's announced carbon-reduction targets and global warming mitigation efforts. Since its joining the World Trade Organization in 2001, China's industrial sector has expanded at a breakneck pace, causing significant increases in carbon emissions. Climate change has become a global concern because of greenhouse gases (GHGs). CO_2, CH_4, N_2O, and F-gas emissions are produced by a variety of sources and are modeled in accordance with the sources. CO_2 emissions produced when fossil fuels are burned are taken into account by the Global Trade Analysis Project (GTAP) and entered in its database version 10 (Nong, D., Simshauser, P., & Nguyen, D. B. 2021); the fossil fuels include coal, crude oil, natural gas, and petroleum products. Changes in the land use, using livestock as a source of energy, the use of chemicals and various production processes are only a few examples of non-CO_2 emission sources. The energy industry and farm-livestock production are the major producers of greenhouse gas (GHG) emissions in Pakistan and China. Since the 1980s, China has experienced rapid financial expansion and become the world's largest manufacturer (Munir & Khayyam, 2020). Coal has contributed to reducing ozone-depleting pollutants, notably CO_2 outflows. China has shut down the world's largest coal-fired power plant (CFPP) and is transitioning to clean energy sources. According to Raza and Shah (2020), the CPEC (Pakistan) was one of the world's major framework projects in line with One belt one road initiatives, reducing CO_2 emissions by 50% to 80%, with a 13% to 15% development limit, which is greater than China, India, and the USA.

In 2017, industrial added value (IVA) accounted for 33.9% of China's GDP. Interestingly, CPEC energy projects are carbon-based petroleum derivative ventures (Volz, 2018). The use of coal forces plants to rely on coal ignition; this causes natural concerns about possible environmental harm (Baloch, 2018), changes in barometric production, increases in radioactivity, ozone depletion and, especially, CO_2 outflows (IPCC, 2007) which, in turn, may result in dangerous atmospheric deviation, ice-sheet dissolving, ocean levels ascent of around 7 m, air temperature ascents of 5.5°C, changes in the temperature of coal power plants (Haeberli & Hohmann, 2008), glacier downturn, chilly lakes upheavals, various lakes in the icy mass, farming corruption and water framework aggravations.

Today, environmental changes are much more numerous than in the past (Schimel et al. 2001), which was discussed during the COP-21 negotiations (Lin & Ahmad, 2017). The Carbon Capture and Storage (CCS) strategy that was expected to reduce CO2 emissions by half to 80% could not be implemented (Viebahn et al. 2015). Furthermore, environmental assurance gear (Khayyam & Nazar, 2021) and the plants' disinfection hardware for dewatering, desulphurization, denigration, and high-effectiveness electrostatic dewatering frameworks, which were ordered before plant execution, were not fully installed.

These facts and figures reveal that the industrial and transport sectors are not the only critical sources of CO2 emission in both countries; there are other ecological, economic, and environmental factors that significantly influence CO2 emission. Although there is a vast difference between China and Pakistan in terms of economic, ecological, and environmental factors, in both countries high CO2 emissions are now causing severe environmental hazards (Soomro et al., 2020). Both China and Pakistan have invested vast amounts in CPEC projects with specific objectives, and one of the project's key objectives is to promote sustainable environmental growth through the reduction of CO2 emission. Hence the obvious relevance of the present empirical research, which attempts to estimate the influence of ecological, economic and environmental factors, such as energy consumption, GDP growth rate, and ecological footprint per person, on the CO2 emission in the CPEC region.

The current study consists of five main sections. A brief overview of the topic and research background is followed by literature review. Sections three, and four present the research methodology, data analysis and critical findings. The last section of the current study contains a brief summary of the study along with theoretical and practical implications of its findings.

2. Literature Review

With a view to improving the living standards in China and Pakistan, in 2013 the two countries entered into an agreement on building China Pakistan Economic Corridor (CPEC) to promote bilateral connectivity and explore the possibilities for bilateral investment, construction, trade, people-to-people contact and economic logistics. The key objective of this agreement was to strengthen the mutual relationship that could benefit both countries. CPEC has emerged as one of the mega projects of the 21st century, and more than half of its investment is channeled to different energy projects in Pakistan (Khayyam & Nazar, 2021). The corridor has opened ways for higher economic growth; however, some of the recent studies on the project by the Asia Development Bank (ADB) have shown a rise in greenhouse gas emissions related to the new coal-based electricity production units built under the CPEC agreement.

The main reason for climate change is the combustion of principal energy sources in the economic manoeuvres of the economy. Due to primary energy ingesting, there is a far-reaching increase in GHG emanations in which CO2 emission is on top, leading to an unembellished threat of climate change in the Asian region. However, because of its demographic position, Pakistan is one of Asia's countries most affected by climate change. Pakistan's average temperature increased significantly because of its demographic situation compared to the temperature of the rest of the world.

Due to the changes in weather conditions, Pakistan faces severe threats of natural disasters: it is now ranked 16th in the Susceptibility Index among 170 countries, having dropped from 29 to 16 after 2010 (Maplecroft 2010a). Pakistan was ranked 8th among 180 countries in the global climate risk index of the German Watch. According to Commission Planning (2007), Pakistan faces a serious threat of shortages of safe drinking water, the available amount of which significantly decreased from 5600 to 1200 cubic meters between 1951 and 2003. In the Maplecroft Food Security Table (2010), Pakistan was ranked 30^{th} among 163 countries; this means that it had no stable food security situation. Agriculture is not only the country's dominant sector - it is the foundation of Pakistan's economy. Yet, its area of agricultural land is shrinking because of the country's explosive industrial boom.

Strong population growth leads to deforestation and Pakistan is the top-ranked Asian nation affected by deforestation. Ongoing industrialization and economic growth mean greater use of energy, which harms the environment. Along with ushering in a period of explosive economic growth, the industrial revolution also gave rise to the well-known phenomena of today, global warming and climate change. The transition of the world economy from the organic economics based on human and animal energy to the inorganic based on fossil fuels is one of the key components of this industrial revolution. Pakistan's energy needs are increasing and traditional energy sources can supply this need. However, using traditional energy resources results in carbon dioxide emissions that degrade the environment (Menyah and Wolde-Rufael,2010). Examples include using fossil fuels for daily needs (Shahbaz et al., 2013), factories' smoke, and using wood as a fuel. According to Ahmad et al. (2016)'s, environmental degradation in Pakistan caused by massive emissions of greenhouse gases such as carbon dioxide, nitrous oxide, and methane is already affecting people's health. Carbon emissions harm the whole economy, including forestry, trade, and agriculture.

Most research has focused on industrialized European nations and the United States (Kasman and Duman, 2015). The earlier studies typically concluded that CO2 emissions were caused by energy use and economic growth. For the best possible energy and environmental policies to be developed, it is crucial to understand the true nature of the relationship between energy use and economic growth. A major concern among economists worldwide is how to expand energy consumption while lowering carbon emissions. Since the two-thirds of all greenhouse gases (GHG) are linked to energy use, shifting away from fossil fuel energy and toward low-carbon emission solutions will be crucial (Pachauri and Reisinger, 2008). Therefore, a worldwide energy transition is expected to automatically invoke the goal of keeping the increase in the average global surface temperature below 2 degrees Celsius (Gielen et al., 2019). The work on SDG included the implementation of policies aiming to ensure energy security, eradicate poverty and reduce dependency on non-renewable energy sources thus creating a cleaner environment without impeding economic growth. Issues related to the energy-environment-economy nexus need to be addressed through increased energy efficiency and reliance on renewable energy sources (RES). Many organizations, nations and associations of nations such as the European Union have already prioritized these techniques in their energy policy. Asian countries are not an exception; they follow a similar pattern, even those whose natural resources include fossil fuel deposits. Renewable energy sources have recently begun to replace fossils thanks to their low financial and environmental costs.

According to the Global Climate Risk Index (GCRI2020th)'s annual report, Pakistan's per-unit GDP has dropped to 0.53%. The country suffered economic losses totaling around US$ 3792.52 million due to extreme weather occurrences. A bivariate framework of models that establishes a correlation between CO2 emission, advancement, and energy consumption is used to estimate possible long term negative effects of climate change. Unlike other parameters, energy consumption and economic growth were theoretically viewed as opposing. While Pakistan Vision 2025 acknowledges in its Energy Policy that adequate, dependable, and clean energy is necessary for sustainable economic progress and development, the government cannot implement the environmental protection measures stated in this document. The primary energy source in Pakistan's energy sector is fossil fuels, also known as the "engines of economic progress."

Environmental deterioration, energy use, and economic growth are all causally related, as demonstrated by a wealth of empirical data. The causal relationship between these variables is still largely unexplored; there are several studies on the issue regarding Pakistan but no clear conclusions have been formulated. The present Paper therefore fills a gap in recent research literature by examining the relationship between energy consumption, economic growth, and carbon emission in a bivariate model. It also discusses policy measures that Pakistan may need to introduce in order to prevent further environmental deterioration. Also, the study examines the short-term and long-term dynamics in a multivariate model using significant factors disregarded by earlier studies, such as trade openness, urbanization, agricultural land, declining forestry area, and research and development expenditure. This Paper attempts to examine the data sets on geographic areas and methodology that have remained disputed.

Li Qianqian and Liu Yijun in their research combined quantitative and qualitative evidence while studying the media coverage in Pakistan, which can provide insights regarding the communications used to boost confidence in the CPEC and can also improve understanding of greening the Belt and Road Initiative (Li Qianqian and Liu Yijun, 2020). Muhammad Yousaf Raza with the co-author showed that as a huge fossil fuel energy consumer and fossil fuel importer, Pakistan required crucial technology diversification and policies to control carbon dioxide emissions for different groups, including national and international (Lin, Zhu, and Raza, 2022). Yet, although the "green" approaches are obviously available, they are not applied and the use of petroleum products is visibly growing (Raza and Lin, 2021) (Raza and Lin, 2022).

In another research concerning Bangladesh, Muhammad Yousaf Raza with the co-author estimated CO2 emissions growth and found that it had been rising with lower environmental effects since 2019. They expect this trend to continue till 2040. This means that technological progress has a positive effect on the global economy helping to curb carbon emissions (Raza and Hasan, 2022). The authors emphasize that Pakistan is currently in the stage of urbanization and industrialization, with growing demand for and supply of energy and increasing carbon dioxide emissions due to the excessive use of fossil fuels. However, investments in petroleum reduction show that carbon emissions will cause supply to shrink accordingly, hence the need for energy-conserving policies, particularly under the China–Pakistan Economic Corridor (Raza and Tang, 2022).

China is one of the major CO2 emitters and the world's chief energy consumer countries, with a recently observed tendency towards continuous exponential growth. The CO2 emissions have grown from 671.1 Million Metric tons (MMT) in 1990 to 2247 (MMT) in 2010, at 7.66% annual growth rate. Energy consumption alone led to an increase in CO2 emissions from 1448 (MMT) to 8320 (MMT) between 1990 and 2010, at 6.7% annual average growth rate (Chang 2010). The country still uses a lot of coal, which, being more carbon-intensive than oil and gas, is the world's second-largest source of CO2 emissions; however, it remains a driver of China's economic growth (Jinke and Dianming 2008; Wolde 2010). A decrease in energy ingesting could help reduce CO2 emissions. Yet, China accounts for almost 69% of total energy consumption and any effort to reduce it could have an undesirable effect for the country's financial development. It is therefore vital to identify, as soon as possible, the complex connection between energy consumption, CO2 production, and economic growth in the PIC countries.

Dam (2007) and Scholtens (2007) showed that G.F. and Equator Principles could gain societal recognition and popularity if there was adequate monetary foundation and the work was aimed at economic outcomes. Cui & Huang (2018) examined various public finance schemes used by non-industrial countries, such as verifiable Emission Responsibility (H.R.), instalment limit (A.P), United Nations enrollment costs, ODA, and the Global Environmental Facility (GEF). During the 2010-2015 years, varieties in the green security market were found that were dependent on the day shutting costs of the S&P Green Bond Index. It is essential to investigate how the Green Climate Fund has possibly counterbalanced the worldwide environment structure for adaption and moderation practices. EPA protection can be essential for lessening natural danger issues (Yang, Y.; Lan Q, Liu, 2017). To improve the administration of G.F. it is absolutely necessary to evaluate G.F.

The main goal of CPEC was to foster regional economic development, so its connection with environmental risks cannot be ignored. In the context of the pledges made during the COP-21 negotiations (Lin & Ahmad, 2017), it is interesting to note that the CPEC energy projects are carbon-based petroleum derivative ventures. Besides, a Carbon Capture and Storage (CCS) strategy aiming to reduce CO2 emissions by half to 80% could not be implemented (Viebahn et al. 2015). Moreover, enterprises did not always install and use the environmental assurance gear stipulated by the project agreement (Khayyam and Nazar, 2021), which included the plants' disinfection hardware for dewatering, desulphurization, denitration, and high-effectiveness electrostatic dewatering frameworks.

There is genuine concern about environmental change, which at present is undermining human wellbeing and financial advancement. Emerging countries are the top global producers of fossil fuel byproducts. In their report at the Intergovernmental Panel on Climate Change, Pachauri & Reisinger (2014) called attention to the fact that the fundamental drivers of the Earth-wide temperature increases include the ignition of petroleum derivatives and recently produced ozone-depleting substances. Exorbitant amounts of fossil fuel byproducts lead to contamination and prompt other negative externalities (Zhang & Bian et al. 2017). The public authorities need to take measures against attempts to disguise their outer effects through tax assessment.

Local governments in China are the implementers of environmental policy and the beneficiaries of index ratings. Excessive carbon emissions harm the environment, resulting in negative consequences (Zhang & Wei, 2010; Song et al., 2020). Pigou (1951) believed that the government should intervene by taxing the resulting externalities when the spillover effect occurs due to economic activity. In contrast to Pigou's theory, Coase (1960) advocated for economic management to be carried out through property rights, saying that market and property rights determination technique should help to deal with external challenges. According to Wang et al. (2004), the sulfur dioxide emission trading mechanism had no control effect on sulfur dioxide emissions. According to Liu et al. (2016), China's sulfur dioxide emission trading policy model comprises several subsystems, indicating that the program's contribution to total sulfur dioxide emission management would increase steadily beginning in 2011. They examined the macroeconomic effects of limiting China's carbon dioxide emissions using a time-recursive dynamic computable general equilibrium model. It investigated the impact of the environment on the macroeconomic parameters, carbon emissions, income distribution, sectorial production, trade structure, and factor demand, using the general equilibrium analysis system for the environment (GREAT-E) and five-carbon tax collection schemes with varying tax rates.

The current study's contribution consists in the examination of how energy use, economic variables, and environmental factors affect CO2 emissions in Pakistan and China. The research will help find out how population, GDP per capita, GPI, HDI, and other economic and environmental factors determine increases or decreases in CO2 emissions. Many studies have been carried out on CO2 emissions in China, but there is very little information on these emissions in Pakistan. As we all know, the situation with environmental issues such as global warming and greenhouse gas emissions in Pakistan is really grave as most businesses there have taken no steps to limit CO2 emissions by filtering hazardous smoke. Numerous factors contribute to CO2 emissions, including population, ecological impact, and the use of oil and gas in energy-generating facilities and automobiles. Our work is the first attempt to assess CO2 emissions in both Pakistan and China.

3. Research Methodology

The present study is empirical *par excellence*; it uses quantitative approach and also offers interpretation of the obtained data. To test the hypothesis, partial least square structural equation modelling was employed using Stata _14 software for analysis. The PLS-SEM technique was used because, according to Hair et al. (2010) such technique is more appropriate for the explanatory part of an empirical research. The current study sought to investigate the impact of energy consumption, economic variables, and ecological factors on CO2 emissions. The quantitative data for this study came from World Development Indicators (WDI), a credible and authoritative World Bank source database.

The data was collected between 1980 and 2020 and anticipated for 2030. As a result, the study's time frame is 1980-2030. In the current research, the CO2 emission is the dependent variable, while energy consumption, economy, and ecological factors are independent variables. The energy consumption comprises the energy consumption of gas measured in (mm cft), the energy consumption of oil/petroleum (tons), the energy consumption of electricity (GWH), energy production (GWH), and energy intensity (triple index). Economic factors include Gross Domestic Product (GDP), GDP Growth, GDP per capita, GPI, Human Development Index (HDI), GINI coefficient, and unemployment rate. Ecological factors in the study are the total investment in the environment, environmental footprint per person, annual wastes, bio-capacity per person (GHA), elimination of natural disasters' costs, and ecological protection expenses.

$$CO2_{Emmission} = f\ (E.C, E.F, EE.F)$$

Where E.C is energy consumption, E.F is economic factors, and EE.F represents ecological factors. The above mathematical relationship can be explained in econometric terms.

$$CO2_{Emmissionit} = b_0 + b_1 EC_{it} + b_2 E.F_{it} + b_3 EE.F_{it} + e_{it}$$

Where β_0, β_1, β_2, and β_3 are the coefficient values of independent variables, e_{it} represents residuals, and "it" denotes the panel features.

Linear regression calculates the predicted weights, indicated with b_0, b_1, …, b_r, which defines the estimated regression function $f\ (x) = b_0 + b_1 x_1 + \cdots + b_r x_r$. For polynomial, the regression function takes the form $(x) = b_r + b_r x + b_r x^2 + ¼ + b_r x r_r^r$ A larger value of R-square indicates a better fit, suggesting that the model can better explain the amount of variation in the predictors (independent variables) with different dependent variables.

4. Data Analysis and Result Discussion

4.1. Descriptive Statistics

From Figure 1, one can see that during the Great Financial Crisis of 2007-08, Pakistan had negative growth of CO2 emissions; during the Covid-19 pandemic, both China and Pakistan had a negative growth rate of carbon dioxide emission. The trend line suggests that between 1980 and 2020, there is a downward linear trend in the CO2_ Emission in both countries, indicating that both countries have significantly reduced their CO2_Emission.

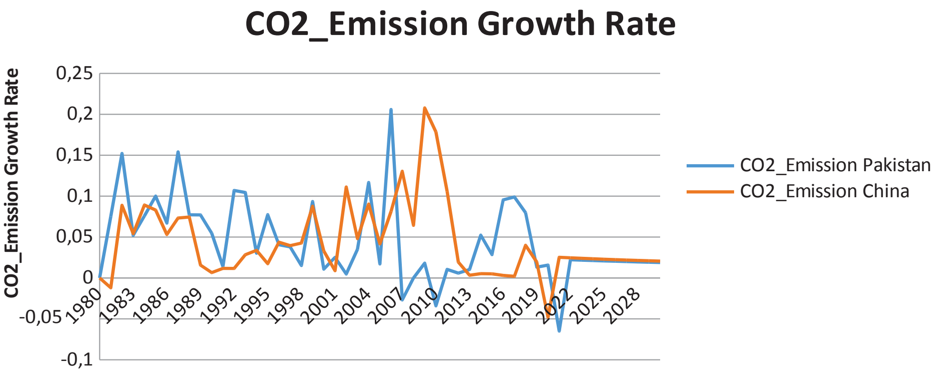

Figure 1. CO2_Emission Growth Rate in Pakistan and China during 1980-2030

The mean value of CO2_emission in Pakistan obtained for 1980-2030 is at 137.01 metric tons with an average standard deviation of 70.51 metric tons, i.e. the possible deviation from the mean value is less than the actual mean value. The kurtosis value for CO2 emission was 1.27, indicating that carbon dioxide emissions during the particular epoch were bell-shape showing the skewness value of CO2 emission in Pakistan. CPEC energy projects in Pakistan are carbon-based petroleum derivative enterprises; the adherence to coal and coal ignition certainly causes serious concerns about possible harm to the environment (Baloch, 2018) and the Pakistani government is taking steps to reduce CO2 emissions: CPEC (Pakistan) has been one of the world's most important framework projects, with a 13% to 15% greater development limit than that in China, India, and the United States, aiming to reduce CO2 emissions by half to 80.

In contrast, China's mean value of CO2 emission recorded was 6214.4 metric tons, more than 4000 times greater than that of Pakistan. The standard deviation of CO2_ emission for China recorded 3871 metric tons with a -1.69-kurtosis score representing a much steeper nature of the standard distribution curve. The skewness value of 0.25 means that the standard distribution curve is right–side-tailed.

Pakistan's average energy consumption was 178569 GWH, while China's average energy consumption was 307422 GWH. At the same time, Pakistan's average energy production was 34.25 million tonnes, whereas China's was roughly 1489.46 million. Pakistan's GDP skewness number reflects smooth growth with a normal distribution, whereas China's GDP skewness value indicates a positively skewed nature. This demonstrates that China's development has significantly improved over time, because local governments in China are the executors of environmental policy and the beneficiaries of index ratings, and they are taking serious steps to reduce carbon emissions that are harmful to the environment and have other negative consequences. Pakistan's average GDP growth rate was 4.26%, while China's was 7.548%. China's HDI index has significantly improved: China's current HDI score is 0761 leaving it in the 85th position out of 189 in terms of human development index score. In contrast, the HDI score of Pakistan is recorded at 0.557, making it 154th in this global ranking.

On the other hand, the ecological footprint per person in Pakistan during the study period is recorded at 0.75, while for China, it is 2.46. This means that in China, the ecological footprint per person is four times greater than in Pakistan, where the average overall environmental expenditure is one million USD while in China it is 7844 million USD. The table below offers a brief overview of descriptive statistics concerning the variables under consideration separately for Pakistan and China.

Table 1. Descriptive Statistics for Pakistan and China

	Descriptive Statistics For Pakistan				Descriptive Statistics for China			
Variables	**Mean**	**Std.Dev**	**Kurtosis**	**Skewness**	**Mean**	**Std.Dev**	**Kurtosis**	**Skewness**
CO2 em	137.01	70.51	-1.27	0.11	6214.40	3871.02	-1.69	0.25
En_C	178569	7053266	-0.93	-0.19	307422	184940	-1.46	0.11
EP	34.25	6.89	-1.35	0.40	1489.46	760.93	-1.65	0.29
EI	5.13	0.37	0.00	0.58	11.03	7.12	-0.87	0.44
GDP	154.66	112.39	-1.62	0.30	5311007	5192203.9	-1.61	0.44
GDP gr	4.26	2.17	-0.32	0.44	7.548	1.9691	43.27	6.35
GDPPC	865.01	464.29	-1.63	0.25	9.14	2.48	0.27	0.53
GPI	3.23	0.29	1.33	1.55	2.17	0.74	-0.07	0.90
HDI	0.48	0.07	-1.41	0.10	0.64	0.14	-1.25	0.00
UR	0.02	0.01	-1.05	0.82	3.30	0.52	-1.16	-0.34
GINI	31.38	1.14	-0.42	0.00	40.28	9.77	-0.99	-0.15
TOE	46969.71	14647.56	-1.21	0.03	9455	7844	-1.75	0.38
EF	0.75	0.08	-1.22	-0.14	2.61	1.09	-1.66	0.19
EPE	2.40	0.10	2.30	-1.53	3.33	0.41	2.58	0.63
ENDE	1.47	0.29	-1.71	-0.08	2.88	0.27	-0.66	-0.45

4.2. Regression Analysis between Energy Consumption Factors and CO2 Emission

The current study uses total energy consumption, total energy production, and energy intensity index to represent ecological factors. The table below summarizes the regression results between the predictors and outcome variables.

Table 2. Relationship between Energy Consumption Factor and CO2_Emission

Coefficient	Model 1	Model 2	Model 3
Log En_C	2482.694*	527.38*	416.151*
	(370.661)	(40.055)	(90.3)
E.P.	-	4.849*	4.779*
	-	(0.0407)	(0.0669)
E.I.	-	-	-15.073
	-	-	(11.144)
Constant	18685.890*	-3848.420*	-2973.319*
	(2343.530)	(272.810)	(693.407)
R-Square	0.310	0.995	0.995
F-Statistics	44.86	10271.96	6871.86
P-F Statistics	0.000	0.000	0.000

Note: Standard Errors are given in parenthesis: *, **, & *** represents the significance of variables at 1%, 5%, and 10% respectively.

As it is clear from the regression results table, the coefficient of Long total energy consumption shows a significant positive impact on CO2_emission in a simple regression model, in which with every 1% increase in total energy consumption, the CO2_Emission increases by 2482.694 units. The results indicate that the log value of total energy consumption is responsible for around 31% variations in CO2 emissions. The coefficient values for energy consumption and energy production are positive, suggesting that the considered variables positively impact CO2 emissions. For every one percent increase in total energy consumption, the CO2 emission on average increases by 527.38 units. Similarly, the CO2 emissions increased by 4.89 units for every one per cent of total energy production. The final model shows that total energy consumption and energy production have a significant positive impact on CO2 emissions, while the energy intensity index has an insignificant negative effect on CO2 emissions. It can thus be concluded that among energy consumption factors, total energy consumption and energy production are significant positive determinants of CO2 emissions.

The research uses Gross Domestic Products (GDP in log form, GDP Growth, GDP per capita income (log value), Genuine Progress Index, Human Development Index, Unemployment Rate, and GINI coefficient as economic indicators. The table below provides an overview of the impact of economic factors on CO2 emissions.

Table 3. Relationship between Economic Factors and CO2_Emission

	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Log_GDP	1349.29*	1692.7*	1462.7*	2091.9*	1057.6*	497.33**	484.33*
	(91.80)	(116.30)	(153.58)	(114.35)	(149.90)	(185.44)	(176.21)
GDP gr	-	-371.33*	-333.89*	-99.33	46.27	-0.45	-28.71
	-	(86.26)	(86.20)	(59.90)	(48.61)	(45.58)	(44.12)
Log_GDPPC	-	-	695.8**	-213.75	2182.55*	2667.76*	1758.69*
	-	-	(311.35)	(218.29)	(328.06)	(318.44)	(406.98)
GPI	-	-	-	2795.79*	1022.90*	1150.46*	471.15
	-	-	-	(243.92)	(279.57)	(256.76)	(317.61)
HDI	-	-	-	-	5193.63*	1771.88*	1438***
	-	-	-	-	(613.67)	(947.67)	(905.84)
U.R.	-	-	-	-	-	1010.46*	629.90*
	-	-	-	-	-	(225.74)	(242.85)
GINI	-	-	-	-	-	-	140.25*
	-	-	-	-	-	-	(42.00)
Constant	-2216.2*	-1096.5*	-2407.2*	-11663.6*	-13849*	-12847*	-12180*
	(433.99)	(477.14)	(750.14)	(944.57)	(762.05)	(730.65)	(722.33)
R-Square	0.6857	0.7357	0.7486	0.8939	0.9395	0.9501	0.9555
F-Statistics	216.010	136.400	96.300	202.150	295.000	298.460	285.000
P-F Statistics	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: Standard Errors are given in parenthesis: *, **, & *** represents the significance of variables at 1%, 5%, and 10% respectively.

The above table suggests that for every one percent increase in GDP, the CO2 emissions in Pakistan and China increase by 1349.29 units, which explains around 68.57% variations in CO2 emissions. The coefficient value is statistically significant at 1%. With the inclusion of GDP growth as an economic factor, the total variations in CO2 emissions due to GDP and GDP growth increased to 73.57%. The results are statistically significant, which means GDP and GDP growth have different impacts on CO2 emissions. The coefficient value of HDI indicates that it has a significant positive impact on CO2 emissions. The HDI index showed the highest coefficient value, which means that the improvement in HDI has a significant positive effect on CO2 emissions.

The unemployment rate shows a significant negative impact on CO2 emissions. The results suggest that the unemployment rate and GDP, GDP growth, GDP per capita, GPI, and HDI are responsible for around 93.95% variations in CO2 emissions. The GINI coefficient also shows a significant positive impact on CO2_emission, which means that with increases in income inequality, CO2_emission also increases significantly. All regression models have a probability value of less than 5%, indicating that all models employed to investigate the impact of economic factors on CO2 emissions are statistically significant. That is why, between 1972 and 2008, a preliminary study looked at per-capita carbon emissions, revenue, energy consumption, and foreign commerce in Pakistan.

Ecological factors selected by the authors of this research are: total expenditures on environmental protection, environmental footprint, environmental protection expenses, and costs of elimination of natural disaster consequences. The table below gives a summary of environmental factors' impact on CO2 emissions.

Table 4. Relationship between Ecological Factors and CO2_Emission

	Model 11	Model 12	Model 13	Model 14
Log_TOE	-1787.26*	-256.2*	-149.11*	-554.35*
	(739.65)	(86.42)	(148.9)	(207.43)
E.F.	-	3377.8*	3394.7*	3122.2*
	-	(38.26)	(42.820)	(108.42)
EPE	-	-	-139.3	-122.53
	-	-	(157.8)	(153.05)
ENDE	-	-	-	594.08*
	-	-	-	(218.42)
Constant	10694.88*	-3568.4*	-2744.6*	-5336.8*
	(3145.7)	(389.2)	(1010.9)	(1366.6)
R-Square	0.0552	0.9881	0.9882	0.9891
F-Statistics	5.84	4125.96	2744.79	2194.83
P-F Statistics	0.000	0.000	0.000	0.000

Note: Standard Errors are given in parenthesis: *, **, & *** represents the significance of variables at 1%, 5%, and 10% respectively.

The results of the regression model suggest that every one percent increase in total investment in the environment reduces the CO2_emission by around 1787 unit factors while ecological footprint showed a significant positive impact on CO2_emission. The 11^{th} and 12^{th} models suggest that total investment in the environment and environmental footprint is responsible for around 98.81% variations in CO2 emission. The probability value of F-statistics for all regression models indicate that all models are statistically significant at 5%. The regression analysis showed the relationship's direct effect among the considered variables. The mediating variable describes the relationship between independent and dependent variables more coherently. Section 4.3 first elaborates on the mediating role of the population in the relationship between energy consumption factors and CO2 emissions and, second, depicts the mediating part of the population in the relationship between economic factors and CO2 emissions.

4.3. Mediation Analysis

The table below shows the population's mediating role in the relationship between energy consumption factors and CO2 emissions. The first part of the table presents the indirect effects of the population; the second part demonstrates the total effects, which imply that the total energy consumption had a significant negative impact on CO2_emission, while the impact of total energy production was significantly positive. The population mediates the relationship between 1937.847 unit factors. In primary regression, i.e. direct relationship, we discovered that environmental protection costs were a minor component having a negative but minor impact on CO2 emissions, even though literature suggests that population growth and energy use are major contributors to CO2 emissions. On the other hand, the total investment in the environment showed a statistically significant negative impact on CO2 emissions in the presence of population as a mediating factor. The results are summarized below in table 5.

Table 5. Indirect Mediation Effects

	Factor	Coef	OIM Std. Err	Z	P>z	95% Conf.Interval	
Structural Log P <--	**log En_C**	1.345	0.060	22.56	0.000	1.228	1.462
	EP	0.000	0.000	-11.08	0.000	-0.001	0.000
	EI	0.006	0.007	0.79	0.431	-0.009	0.020
	Log GDPP	-0.390	0.030	-13.00	0.000	-0.673	-0.012
	GDP gr	-0.006	0.008	-0.76	0.487	-0.003	0.000
	Log GDPPC	0.318	0.069	4.59	0.000	0.215	0.499
	GPI	0.001	0.054	0.01	0.932	0.000	0.002
	HDI	2.135	0.154	13.84	0.000	1.786	3.125
	UR	-0.548	0.041	-13.25	0.000	-0.012	-0.785
	GINI	0.000	0.000	3.33	0.012	0.000	0.000
	Log_TOE	0.016	0.001	12.66	0.000	0.000	0.003
	EF	0.025	0.003	7.83	0.000	0.002	0.128
	EPE	0.238	0.015	16.37	0.000	0.012	0.433
	ENDE	-0.037	0.000	-170.66	0.000	-0.001	-0.168

Table 6. Total Mediation Effects

	Factor	Coef	OIM Std. Err	Z	P>z	95% Conf.Interval	
	Log_P	-1937.85	180.3717	-10.74	0	-2291.369	1.462086
	log En_C	-2606.796	268.452	-9.70	0.000	-3133.540	-2080.051
	EP	0.949	0.123	7.71	0.000	0.708	1.190
	EI	-11.223	14.301	-0.78	0.433	-39.252	16.805
	Log GDPP	755.691	91.358	8.27	0.000	576.633	934.750
	GDPgr	11.047	14.588	0.76	0.487	-17.545	39.640
	Log GDPPC	-615.602	145.987	-4.22	0.000	-901.730	-329.473
CO2_Emission <--	**GPI**	-1.326	104.747	-0.01	0.990	-206.627	203.976
	HDI	-4133.088	487.735	-8.47	0.000	-5089.031	-3177.146
	UR	1061.532	127.357	8.34	0.000	811.917	1311.148
	GINI	-0.462	13.851	-0.03	0.973	-27.609	26.686
	Log_TOE	0.036	0.012	2.87	0.021	0.000	0.003
	EF	0.055	0.033	1.70	0.075	0.002	0.128
	EPE	0.938	0.145	6.45	0.000	0.012	0.433
	ENDE	-0.037	0.021	-1.71	0.074	-0.001	-0.168

Among economic factors, the GDP growth, GPI, and GINI coefficient showed an insignificant relationship with CO2_emission in population presence as a mediating factor. On the other hand, the relationship with the unemployment rate is rather unexpected. The result suggests that population plays a positive mediating role in the relationship between the unemployment rate and CO2 emissions. In contrast, the theory of unemployment claims that higher unemployment means lower economic growth, which implies that CO2 emissions are reduced because of lower economic growth and activity.

Pollutant emissions in China, such as sulfur nitride emissions, are tending upwards due to waste discharge, waste gas, and waste slag. Therefore, China must prioritize economic growth, at the same time dealing with the rising CO2 emissions caused by economic expansion. Surprisingly, adverse shocks in CO2 emissions increase carbon pollution in all the examined economies. This means that Green Finance is a critical component of green growth; it allows businesses to raise funds, develop and use green technology to reduce CO2 emissions and thereby limit global warming and greenhouse gas effects. To gain finance for these environmental concerns, the financial sector needs to find new financial solutions that will allow the target industries to reduce their CO2 emissions with the help of green technology.

Pakistan's government is concerned about environmental damage because, among other things, the country is one of the most sensitive to the impact of climate change. It has been found that the populace and GDP per capita are the essential factors emphatically affecting the expansion in CO2 discharges, though carbon power is adversely impacting the increment in CO2 emanations. Mumtaz and Smith (2019) argue that the impacts of expanded energy force and replacement of petroleum products are blended. Over time, the positive advantages of GDP per capita and populace offset the adverse effects of carbon power and the combined impacts of energy force and primary/petroleum derivative replacement. The proficiency of dealing with carbon power in lessening discharges requires executing a carbon charge, an effective technique for diminishing future energy-related CO2 emanations in Pakistan. Rather than changes in energy structure, it is the energy protection that should be the essential method for bringing down the energy power.

5. Conclusion and Policy Recommendations

5.1. Conclusion

As one of the world's mega projects in the 21st century, the CPEC is raising certain hopes and expectations. Most economists expect this project to become a changer for both countries, especially for Pakistan (Zubaidi et al., 2018). Khayyam and Nazar (2021) are confident that Pakistan's extensive infrastructure and energy projects will improve the transportation system. Most importantly, the shortfalls in the energy sector will be covered: this is seen as the backbone of the industrial revolution. However, environmental economists (Khalid, Ahmad, and Ullah, 2021; & Durrani and Khan, 2018) point out that most energy projects in Pakistan under the CPEC program are coal-based projects that directly increase CO2 emission and influence the countries most vulnerable to climate change, so the Pakistan Government should be keen to mitigate the effects of climate change.

The current study empirically investigated the influence of certain economic, ecological and energy factors on CO2 emissions in China and Pakistan. The data for 1980-2030 were used because most of the CPEC projects are to be completed by 2030. Including the projected values of respective variables helps us get a clearer picture of the economies. The study relied on multiple regression and the PLS-SEM model for estimating the coefficient values.

The study's findings show that energy factors, i.e. energy consumption, energy production, and energy intensity are responsible for around 99.5% of CO2 variation. Energy consumption and production have a significant positive impact on CO2 emission, while energy intensity has a negative but insignificant effect on CO2 emission. Earlier, Khan et al. (2019) obtained similar results for energy intensity and concluded that it was not a problem for the environment in the short run but might increase CO2 emission in the long run; they believe that it depends on public interest how the countries choose to treat this factor.

Having analysed the regression results for economic factors, we found that GDP, GDP growth, per capita GDP, HDI, and GINI coefficients showed around 95.5% variations in CO2 emissions. Energy factors are responsible for less variation than economic factors, and it is a natural phenomenon that energy factors are directly related to CO2 emission. In contrast, economic factors influence CO2 emissions indirectly. Among the individual factors, GDP, per capita GDP, HDI, unemployment, and GINI coefficients are statistically significant, while GPI has been found to have an insignificant coefficient value. Economic uncertainties and stability directly influence the demand for energy components and the use of controls over CO2 emissions. Thus, we found that economic factors have a statistically significant and positive impact on CO2 emission.

Ecological factors, i.e. total expenditure on the environment, ecological expenses, investment in the environment and ecological footprint, are responsible for around 98.91% variation in CO2 emission. However, total expenditure on the environment has been found to have a significant negative impact on CO2 emissions. Durani and Khan (2018) saw it as inevitable truth that for initial environmental investment, there must be some ecological degradation, such as planting, making check-dams etc. that may worsen environmental pollution by increasing CO2 emission.

PLS-SEM results show that population is the key mediating factor influencing CO2 emission. We found that it positively mediated the relationships between different factors and CO2 emission. According to demographic research, higher population growth in the region increase housing, transport use and other factors related to CO2 emissions.

5.2. Policy Implications

Energy pricing reforms in most developing and developed economies remained a long-term strategy for mitigating energy-related CO2 emissions. For Pakistan and China, it will play a vital role in following energy pricing strategy because we found that energy factors, i.e. consumption and production, are significant positive determinants of CO2 emission. Therefore, other nations can reduce CO2 emissions by adopting an energy pricing strategy. There is also a need for fuel tariff rationalization and government support for renewable energy sources. Pakistan with its geographic features has the potential to produce hydro power electricity. Therefore, by focusing on renewable energy sources, Pakistan can play a vital role in reducing CO2 emissions. Another critical policy instrument, as the present study found, is related to the mediating part of population growth. The population growth in Pakistan is among the top in the continent, and this rapid growth boosts the demand for energy, ultimately increasing CO2 emissions. It is therefore recommended that the economies follow counteractive measures to reduce the population growth in the region.

5.3. Limitations of the Study

The current study outlines brief policy implications for sustainable economic growth by reducing CO2 emissions or degradation. Some constraints might influence the findings of the study. The study has not made a cross-comparison of two countries, i.e. China and Pakistan, mostly because China's economy is as much as 50 times bigger than that of Pakistan. The future research, therefore, may focus on comparing the countries using coefficients separately. Another critical limitation of the study is using projected values for 2022-2030. Since most of the projects under CPEC are to be completed by 2030, we still have a long time to get the relevant data for the respective years. The instability, uncertainty, and natural hazards such as COVID-19 and the most recent floods in Pakistan in 2022 may reduce the speed of CPEC growth, which makes it necessary for future researchers to keep an eye on the internal and external shocks before making any final assessment of the relationship.

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