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RESEARCH ARTICLE

Assessing the impact of human capital, renewable energy, population growth, economic growth, and climate change policies on achieving the sustainable development goals

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Abstract

The global emphasis on achieving sustainable development goals necessitates the involvement of researchers and regulators worldwide. In light of this, recent research has examined the effect of human capital, renewable energy, population growth, economic growth, and environmental protection on the sustainable development goals (SDGs) in a developed economy like Pakistan, which is the most important country in the South Asian Association for Regional Cooperation (SAARC) region. This study analyzed secondary data from 1990 to 2019, using the World Development Indicators as the secondary data source. Using the augmented Dickey-Fuller test to investigate stationarity and the autoregressive distributed lag model to evaluate the nexus between variables, the researchers analyzed the relationship between the variables. The findings indicate that all predictors, such as the human capital index (HCI), renewable energy consumption, and renewable energy, exhibit a negative correlation with carbon emissions and a positive correlation with the SDGs. In this study, sustainability and the HCI are positively correlated. Reducing carbon emissions requires competent and dependable employees. As Pakistan transitions to renewable energy and strives for 30% green electricity by 2030, the report highlights the ecological benefits of controlled population growth. According to the Climate Change Performance Index (CCPI), effective climate policies advance the environmental objectives of a nation. Economic and population growth have a positive correlation with carbon emissions as well. These results facilitate Pakistani policymakers' creation of effective SDG-related initiatives for sustainable development.

Keywords Human capital · Renewable energy · Sustainable development goals · Economic growth · Climate change

Introduction

The environment has such a substantial impact on the health and well-being of all living organisms that it is of vital significance to the economy and culture of Pakistan (I. Khan et al. 2022). A nation that maintains healthy levels of air, land, and water not only benefits from an abundance of rich natural resources but also does a better job of protecting the health and contentment of its citizens (Z. Khan et al. 2023). Increased production levels and general well-being are the outcomes of robust populations that can interact in mutually beneficial and amicable ways. Because numerous economic activities in Pakistan depend on the availability of natural resources and a healthy labor force, the country's economic development needs a clean and sustainable environment (De Faria et al. 2020). Despite this, various factors are responsible for the increasing levels of atmospheric carbon dioxide (CO_2) emissions in Pakistan, which poses

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several significant challenges to environmental quality and long-term sustainability.

According to Fang (2023) Pakistan's CO_2 emissions originate from natural and anthropogenic sources. Natural sources of CO_2 emissions comprise everything from breathing to the decay of organisms and plants and fluctuations in the nutrient levels of the ocean (Usman and Rozar 2021). On the other hand, human activities like pruning trees, cement manufacture, and other business operations all contribute to the emission of carbon monoxide, which in effect contributes to global warming contributes to the warming of the planet's atmosphere and the devastation of its ecosystem (Pandey and Asif 2022). Even though the natural sources of atmospheric CO_2 emissions have been there for tens of thousands of years, human beings continue to be the primary contributor that have thrown the atmosphere out of balance (Lin et al. 2023). Even though human activities have affected CO_2 levels, this is the case.

As a result of Pakistan's rapid economic growth, the country's natural resources and environment are under great pressure. Sadly, participation in social action to address these problems and promote environmental sustainability is still relatively low Das et al. (2022) as shown in Fig. 1.

Numerous academicians and researchers have emphasized the significance of human capital and sustainable energy solutions in Pakistan for preserving the environment and conserving natural resources. Due to a growing emphasis on social responsibility and environmental performance, Pakistan's businesses are establishing objectives beyond monetary profit (Liu et al. 2022). These objectives involve environmental and social outcomes. Recognized for its contribution to Human Capital development, the relationship between human capital and the impact on the environment, particularly emissions, is complex. If not handled sustainably, the rise in industrialization, urbanization, and consumption patterns accompanying the growth and development of economies based on human capital can increase emissions (Ozturk 2010). In 2014, the UN Assembly of Nations endorsed the 2030 Agenda for Change for Sustainability Development's seventeen SDGs, associated with 169 goals and objectives.

According to Xue et al. (2022), these goals aim to resolve various aspects of social, economic, and environmental sustainability and close the achievement gap (Niziołek 2021). The SDGs are a set of objectives that seek to develop economies centered on people, creativity, and sustainability and provide employment opportunities for youth in particular (Mir et al. 2022). These goals are founded on the principles of planet, people, peace, prosperity, and cooperation (Xiuhui and Raza 2022). In addition to selecting sustainable energy sources Zhou et al. (2022), this is necessary. According to Akram et al. (2021), the pursuit of SDGs is a worldwide essential, but the challenges and possibilities related to achieving these goals can differ considerably between regions. Human capital, the adoption of renewable energy, population growth, economic development, and climate change policies play significant roles in SAARC countries. The complicated relationship of variables needs an in-depth understanding to establish efficient approaches to ensure the region's sustainable development.

The SDGs are an international imperative requiring the attention of academics and policymakers at all levels of government (Rehman et al. 2021). Human assets, conservation of the environment via the consumption and manufacture of

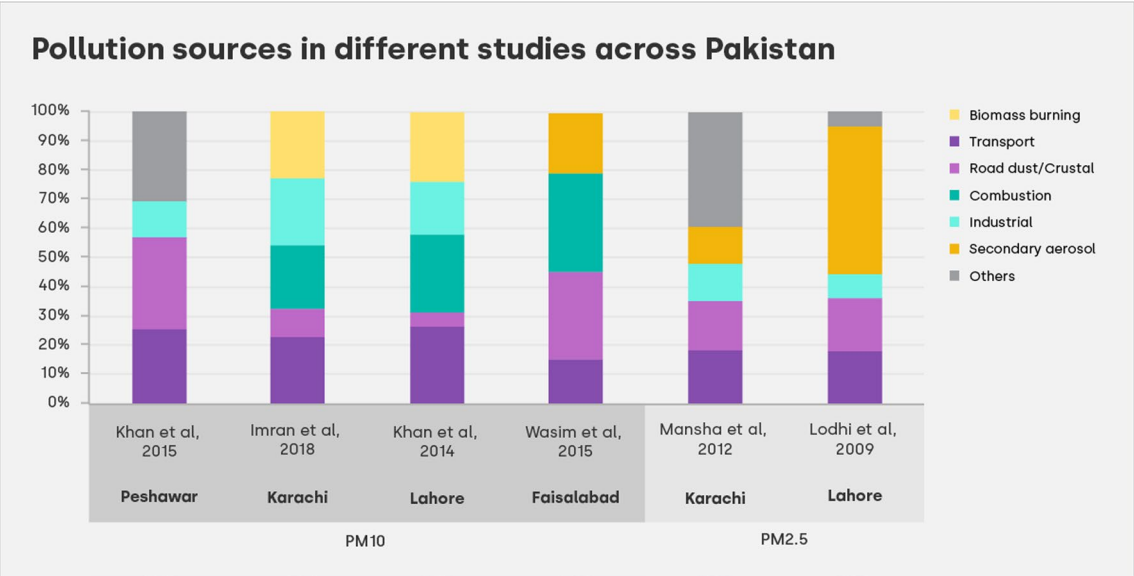

Fig. 1 Environmental challenges in Pakistan: balancing growth and sustainability

clean energy, revenue growth, and a growing population all play a role in Pakistan's hopes for equitable growth, which are the focus of this study (Byrka-Kita et al. 2020). Pakistan is a vast nation containing a sizeable population. It is a country that is still developing and has a young economy. Pakistan, in relation to real gross domestic product (GDP) plus the equivalent of purchasing power, has a chance of becoming one of the largest economies worldwide (PPP), according to (Li and Umair 2023). Pakistan's three most significant economic sectors agriculture, industry, and services contribute to the country's GDP. Figure 2 shows that the industrial and service sectors, characterized by high energy consumption and diverse processes, contribute significantly to CO_2 and other greenhouse gas emissions (Zhang et al. 2022).

In contrast, the agricultural sector is vital to the sustained viability of the environment (Wahhab and Al-Shammari 2021). Pakistan is confronted with difficulties associated with pollution and rising CO_2 emissions due to its growing population and expanded economic operations (J. Chen et al. 2022).

This research aims to discover solutions to Pakistan's social and economic issues by analyzing their compatibility with the 2030 Agenda's SDGs. This study analyses how human capital, the preservation of the environment through the use and production of renewable energy, the expansion of the economy, and the growth of Pakistan's population all contribute to the country's ability to achieve its SDGs (De Guimarães et al. 2020). Even though previous research has examined the individual effects of each of these components in Pakistan, it is crucial to analyze their combined effects (Akram et al. 2021). By bridging this knowledge divide, our work significantly contributes to the current body of knowledge. The research investigates the use and production of renewable energy sources as crucial factors in preserving the natural environment (He and Collins 2021). It sheds significant light on the connections between Pakistan's human capital, environmental protection, and economic growth.

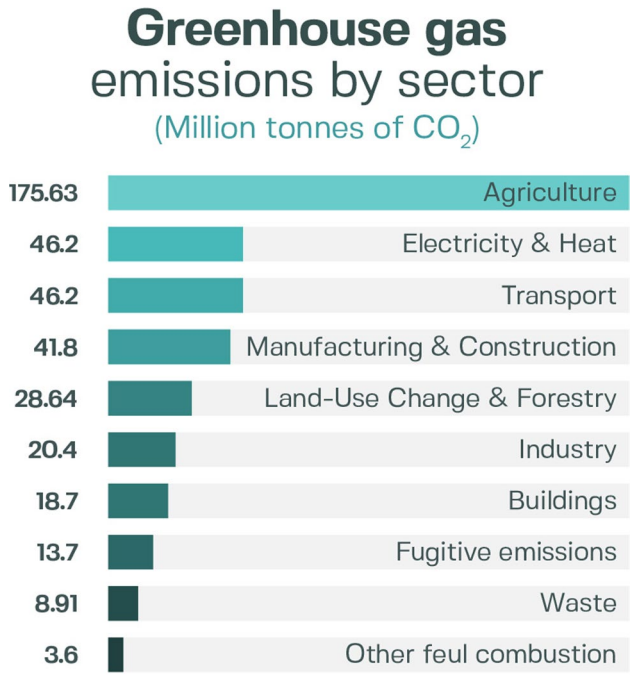

Fig. 2 Emission hotspots in Pakistan's carbon footprint

The structure of the paper is comprised of various components. In the section that follows the introduction, we will examine the impact of human capital, the effects of population expansion, business growth, and energy generated from renewable sources consumption on the surroundings in Pakistan's ability to achieve its sustainable development objectives. The third section dissects and discusses the data collection and analysis methods used to generate the research's findings. The fourth section presents supporting evidence from prior studies pertinent to this study's findings. The study concludes with specific conclusions and recommendations. Due to industrial and economic growth, Pakistan's carbon emissions have skyrocketed since 1990 as shown in Fig. 3. This growth increased energy usage, CO_2 emissions, and other greenhouse gases. Pakistan's carbon footprint is mostly due to the industrial and service sectors' diversified operations and high energy needs.

Production, power, and transportation are major greenhouse gas emitters. Carbon emissions greatly affect climate change and environmental sustainability. Carbon dioxide, a greenhouse gas, causes global warming and climate change as well as rising temperatures, changed weather patterns, sea level rise, and ecological impacts. Governments, businesses, and people must address carbon emissions. Sustainability and switching to better energy sources are crucial. Energy conservation, renewable technology, and eco-friendly solutions reduce carbon footprints. Pakistan can help fight climate change and secure a sustainable future by reducing carbon emissions.

Literature review

The rise in human domestic activity and the exponential growth of the commercial sector has both hurt the world's natural resources and environment. This is because both industries have contributed to natural resource depletion. Concurrently, societal initiatives intended to mitigate these effects have proven ineffective, and environmental degradation may deplete or destroy the natural resources of future generations (Elgaddafi et al. 2021). This issue necessitates immediate attention. Let us begin with this matter requires close attention (Opoku 2019). In light of the imminent hazard, a large number of individuals, in addition

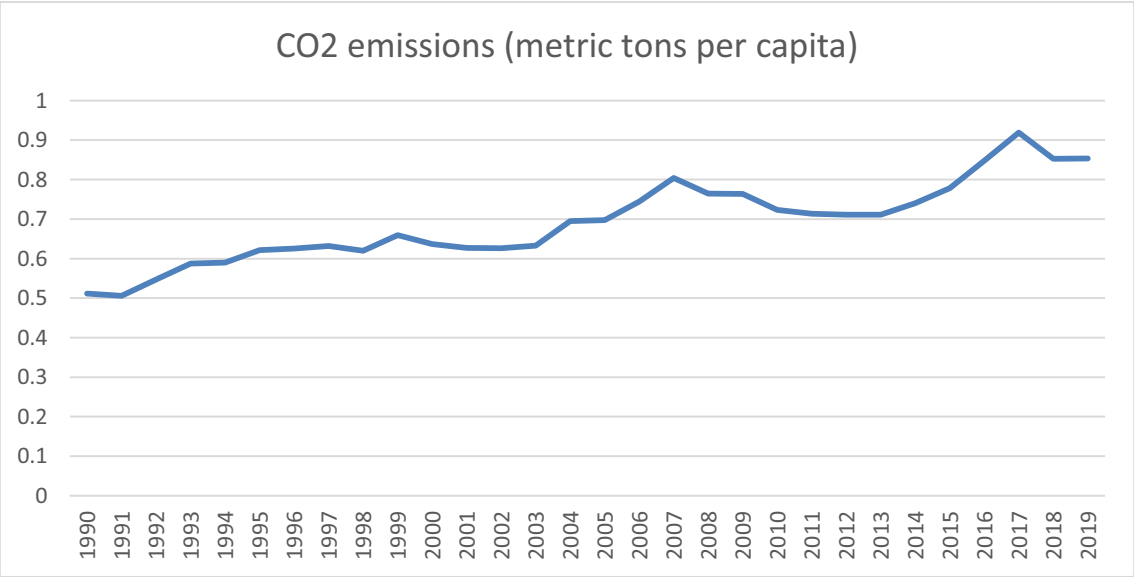

Fig. 3 CO2 emissions metrics (metric tons per capita) from 1990 to 2019. Source:https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?contextual=default&end=2019&locations=PK&start=1990&view=chart

to organizations and governments, have devised measures to safeguard economic growth and social welfare (Zhao et al. 2022). These objectives were considered while formulating The U.N. General Assembly's eight Sustainable Development Targets (Silva et al. 2020). Nevertheless, the preservation of ecological diversity, improvement of human resources, and enlargement of economic prospects and the growth of the population substantially affect the achievement of these objectives (Mehmood and Mansoor 2021).

Human capital refers to the value created by a worker's past experiences and inherent skills. This value considers the individual's knowledge, education, training, prudence, creativity, and other characteristics employers value, such as loyalty and consistency (Wang et al. 2020). These essential human resources must be able to reduce CO_2 emissions to a decreased level. According to Jabeen and Khan (2022), nations with a high HCI, which indicates the presence of healthy, well-educated, and capable employees, are more likely to emit less carbon and have a higher probability of attaining sustainable development. Mohsin et al. (2020) companions discovered this. Furthermore, environmental preservation is essential for sustainable development because it encourages creating a pleasant working environment, maintaining a healthy workforce, and protecting of natural resources for both the present and the future (Liu et al. 2022). This can be achieved by utilizing renewable energy sources such as biomass, biofuel, solar, wind, hydro, and tidal power, which emit no greenhouse gases (Ngo et al. 2022). Biomass is an organic substance that can be transformed into biofuel. There is also the possibility of utilizing tide power (Jena et al. 2022).

The volume of literature on climate change significantly influences both environmentally friendly development and conservation efforts. In their academic study, Valencia (2020) and his colleagues investigate the relationship between sustainable development, the preservation of natural environments, and the use of alternative forms of energy (Radmehr et al. 2022). Recent studies have demonstrated that the implementation of business practices that utilize renewable energy contributes to the reduction of environmental contamination, the promotion of a healthier atmosphere, and the preservation of natural resources (Popkova and Sergi 2020). Therefore, climate change mitigation strategies, such as producing renewable energy, contribute substantially to achieving sustainability objectives (Ayyildiz 2022; Madaleno and Nogueira 2023).

Despite the significance of human capital and environmental preservation in resolving environmental issues, economic and population growth are also required to reduce CO_2 emissions and achieve sustainable development (Mosala and Chinomona 2020; Talha et al. 2021). This is the case even though human capital and ecological preservation are essential components of an effective response to environmental challenges. In their study, Dankyi et al. (2022) illustrate the impact of economic growth on sustainable development by showing how an increase in economic activity can initially increase CO_2 emissions. This demonstrates the connection between financial success and sustainable development (Tsalis et al. 2020). This is one manner in which economic development may hinder the process of sustainable development (Lim et al. 2018). Despite this, the ability of a nation to sustain economic growth is the

essential factor in determining whether or not it will successfully bring its CO_2 emissions under control and attain its sustainable development objectives (Pécora et al. 2021).

In addition, population growth impacts both the quantity of CO_2 emissions emitted and sustainable development objectives. To improve its profundity and coherence, we plan on broadening our literary nature to include knowledge of government initiatives, global partnerships, and societal behaviors, thereby creating a broader overview of the influences on sustainable development (Al-Mulali et al. 2015). We anticipate an effortless transition among sections in which the discussion on the critical role of human capital in reducing CO_2 emissions flows gracefully into the need for environmental preservation, highlighting the synergy between an educated population and sustainable habitats (Ozturk and Acaravci 2010). In addition, we recognize a significant research deficit in understanding the complex interplay between economic growth, rising population numbers, and the march toward sustainability, especially in Pakistan's complex regional context.

Existing literature tends to compartmentalize these components; our research aims to fill this gap with a comprehensive review of the interconnected processes and practical recommendations for regions facing these obstacles. Using the findings of (Ozturk and Acaravci 2010; J. Wang et al. 2022), for instance, we will draw attention to the vital role of renewable energy sources, integrating them into a larger narrative that examines the complex relationship between economic prosperity and preservation of the environment, as highlighted by (I. Khan et al. 2021; Y. Li et al. 2021). According to research conducted by Boukhelkhal (2022), an influx of educated employees can contribute to the economy by reducing pollution and raising living standards. Despite the prospect that a population increase could lead to a rise in CO_2 emissions, this is the case.

Research methodology

In this research, scientists aim to scrutinize the influence exerted on the basis of the SDGs, human assets, and conservation policies within a mature economy like Pakistan. In the earliest phases of our research, we adopted an exploratory strategy to fathom the complex relationship between many variables affecting Pakistan's SDGs, especially SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). Consequently, we designed the study to be more descriptive, emphasizing capturing and describing patterns and relationships rather than confirming certain assumptions. This study was carried out after thoroughly reviewing the research objectives, the nature of the issue being investigated, and the available data. Given human capital widely recognized dual role in driving economic growth and potentially influencing emissions, our methodology endeavors to apprehend this dynamic (Akram et al. 2021). To identify trends and correlations, we compared variables such as educational attainment, health indicators, and skills development to emissions data.

We acknowledge the significance of explaining our reasoning to ensure the approach corresponds to the study's purposes. Our investigation examined the intricate dynamics underlying Pakistan's sustainable development problems. Due to the exploratory character of our research and the numerous difficulties of sustainable development in Pakistan, we adapted our approach to capture these subtleties and produce profound insights after examining prior research in this field (Dagar et al. 2022).

Previous investigations discussing similar topics and employing similar methodologies were particularly effective at clarifying the complex nature of sustainable development issues. The available data set for our research necessitated a method capable of effectively combining disparate data points to draw meaningful conclusions. Our methodology allowed for a thorough analysis of these data, guaranteeing the accuracy and applicability of the resultant insights (Alam et al. 2016). This methodology was essential for fostering a comprehensive understanding of Pakistan's sustainable development landscape, and we are sure that it will significantly contribute to the existing body of knowledge on this topic. The secondary data spanning from 1990 to 2019, employing the World Development Indicators for this purpose.

Their model of study can be expressed by Equation 1:

$$\begin{aligned}\text{Emission}_t = {} & \alpha_0 + \gamma_1 \text{HCI}_t + \gamma_2 \text{REGen}_t + \gamma_3 \text{RECon}_t \\ & + \gamma_4 \text{EconGrowth}_t + \gamma_5 \text{PopGrowth}_t \\ & + \gamma_6 \text{ClimatePolicy}_t + \varepsilon_t\end{aligned} \tag{1}$$

Here:
Emission_t = CO_2 emission at time t
HCI_t = human capital index at time t
REGen_t = renewable energy generation at time t
RECon_t = renewable energy consumption at time t
EconGrowth_t = economic expansion at time t
PopGrowth_t = population growth rate at time t
ClimatePolicy_t = climate change policy index at time t
ε_t = statistical error

The given equation symbolizes a multivariate linear regression model where CO_2 emissions are gauged against human capital, energy from renewable sources production, consumer spending, and rise in population and the climate change policy index.

The coefficients are understood as follows:

γ_1: Highlights the influence of human capital on CO_2 emissions. A positive coefficient indicates that human capital growth may lead to increased carbon emissions, while a negative coefficient signifies the contrary.
γ_2: Demonstrates the relationship between renewable energy generation and CO_2 emissions. A negative coefficient suggests a decrease in carbon emissions with an increase in renewable energy generation.
γ_3: Sheds light on the effect of renewable energy consumption on CO_2 emissions. A negative coefficient implies lower carbon emissions with higher renewable energy consumption.
γ_4: Represents the correlation between economic expansion and carbon emissions. A positive coefficient means that CO_2 emissions increase with economic growth.
γ_5: Reveals the effect of population growth on CO_2 emissions. A positive coefficient implies that population growth is directly proportional to carbon emissions.
γ_6: Denotes the impact of climate change policies on CO_2 emissions. A negative coefficient indicates lower carbon emissions with an effective climate change policy index.

It should be underscored that the direction and significance of the coefficients may vary based on the data and regional context. Thus, implementing statistical analyses, like hypothesis testing and evaluation of *p*-values, is crucial to affirm the significance and direction of these relationships.

By probing the coefficients, the researchers can deduce the relative impact of each variable in terms of CO_2 emissions. This information would enable an evaluation of the efficacy of human capital, environmental conservation, economic expansion, population growth, and climate change policy in achieving the carbon emissions reduction aspect of the SDGs.

The change in CO_2 emissions (ΔCO_2_t) is determined by the combination of lagged variables and coefficients capturing short-term and long-term effects, including the climate change variable. Equation 2 is expressed as the following:

$$\begin{aligned}\Delta\Delta \boldsymbol{CO2}_t = {} & \alpha_0 + \sum \delta_1 \Delta CO2_{t-1} + \sum \delta_2 \Delta HCI_{t-1} \\ & + \sum \delta_3 \Delta REP_{t-1} + \sum \delta_4 \Delta \mathrm{REC}_{t-1} + \sum \delta_5 \Delta EG_{t-1} \\ & + \sum \delta_6 \Delta PG_{t-1} + \sum \delta_7 \Delta CC_{t-1} + \varphi_1 CO2_{t-1} \\ & + \varphi_2 HCI_{t-1} + \varphi_3 REP_{t-1} + \varphi_4 REC_{t-1} \\ & + \varphi_5 EG_{t-1} + \varphi_6 PG_{t-1} + \varphi_7 CC_{t-1} + \varepsilon_1\end{aligned} \quad (2)$$

In this equation, the additional term ΔCC_ (t-1) represents the change in the climate change variable in the previous period. The coefficient δ_7 captures the short-term effect of changes in the climate change variable on the change in CO_2 emissions, while the coefficient φ_7 represents the long-term effect.

The inclusion of the climate change variable allows researchers to examine the direct impact of climate change-related factors on CO_2 emissions. This variable could represent metrics such as climate change policy effectiveness, greenhouse gas emissions from other sources, or natural climate variability.

The error correction model (ECM) is as follows:

To account for short-run dynamics and the adjustment process towards the long-run equilibrium, the error correction model is updated with the climate change variable. Equation 3 is expressed as the following:

$$\begin{aligned}\Delta CO2_t = {} & \alpha_0 + \sum \delta_1 \Delta CO2_{t-1} + \sum \varphi_2 \Delta HCI_{t-1} \\ & + \sum \rightarrow_3 \Delta REP_{t-1} + \sum \theta_4 \Delta REC_{t-1} \\ & + \sum \omega_5 \Delta EG_{t-1} + \sum \omega_6 \Delta PG_{t-1} \\ & + \sum \omega_7 \Delta CC_{t-1} + \delta ECM_t + \vartheta_t\end{aligned} \quad (3)$$

Similar to the estimation equation, the error correction model now includes the term ΔCC_ (t-1) to represent the change in the climate change variable. The coefficient ω_7 captures the short-term effect of the climate change variable on CO_2 emissions in the error correction model. By incorporating the climate change variable, the research model allows for a comprehensive analysis of the interplay between human capital, renewable energy, economic growth, population growth, climate change policies, and climate change itself on CO_2 emissions. As a result, the stationary aspect of each of the constructions has been investigated separately, and the formulae for each unique ADF are provided in the following section.

The indicators for sustainable development, human capital, environmental protection, economic growth, population growth, and climate change include the climate change policy index, the HCI, renewable electricity, energy consumption, GDP growth, population growth, and CO_2 emissions damages as a percentage of GDP, and these metrics emphasize development and sustainability as shown in Table 1.

Results and analysis

CO_2 level across the 34 observations is 3.04, with a median of 2.89 and a standard deviation of 2.21. The lowest observed CO_2 level was 0.90, while the highest was 7.99. Similar interpretations can be made for the remaining variables based on their mean, median, standard deviation, and observed range as shown in Table 2.

The correlation between different pairs of variables as shown in Table 3. There is a negative correlation between CO_2 and HCI (−0.463), indicating that as HCI increases, CO_2 tends to decrease, and vice versa. Conversely, there is a strong positive correlation between EG and PG (0.811), suggesting that when EG increases, PG also tends to increase.

Table 1 Variables and measurements

Variables	Measurement
Sustainable Development Goals	Carbon dioxide damages (% of GNI)
Human Capital	Human capital index (% of HCI)
Environmental protection	Renewable electricity output (% of total electricity output) Renewable energy consumption (% of total energy consumption)
Economic Growth	Gross domestic product growth (annual %)
Population Growth	Population growth (annual %)
Climate Change	Climate Change Policy Index (% of CCPI)

Source: World Bank Database

Table 2 Descriptive statistics

Variable	Mean	Median	Std. Dev.	Min	Max	Observations
CO_2	3.04	2.89	2.21	0.90	7.99	34
REC	0.34	0.35	0.05	0.25	0.42	34
REP	0.46	0.50	0.61	0.22	0.93	34
HCI	95.39	95.55	3.69	90.07	112.69	34
EG	1.53	1.28	0.88	0.49	3.40	34
PG	0.86	0.79	0.45	0.28	1.82	34
CCPI	60.00	59.50	5.00	52.00	70.00	34

Source: Authors' calculation

Table 3 Correlation matrix

Variables	CO_2	HCI	REP	REC	EG	PG	CCPI
CO_2	1.000	-0.463	-0.347	-0.098	0.298	0.415	0.521
HCI	-0.463	1.000	-0.213	-0.197	0.459	0.514	0.345
REP	-0.347	-0.213	1.000	0.654	0.029	-0.386	-0.278
REC	-0.098	-0.197	0.654	1.000	-0.644	-0.389	-0.436
EG	0.298	0.459	0.029	-0.644	1.000	0.811	0.612
PG	0.415	0.514	-0.386	-0.389	0.811	1.000	0.486
CCPI	0.521	0.345	-0.278	-0.436	0.612	0.486	1.000

Source: Authors' calculation

ADF test checks if a given time series is stationary. Here, CO_2 and HCI are stationary at level ($I(0)$), while others are stationary after first differencing ($I(1)$). *P*-values indicate the significance of these results as shown in Table 4.

The ARDL bound test checks the existence of a long-run relationship among variables. Table 5 shows the calculated *F*-statistic (3.58) lies between the $I(0)$ and $I(1)$ critical values at all levels of significance, suggesting evidence for a long-run relationship between CO_2 and the other variables in the model.

Based on the given values, Table 6 shows the short-run dynamics of the model. For example, a unit increase in HCI leads to a 0.45 unit decrease in CO_2 in the short run. Similar interpretations can be made for the other variables. The model explains 66% of the variability in CO_2 (R-squared = 0.66).

Table 4 Unit root test (augmented Dickey-Fuller test)

Variable	Level	t-statistics	p-values
CO_2	I(0)	-3.28	0.02
PG	I(1)	-4.79	0.00
HCI	I(0)	-3.90	0.01
REP	I(1)	-4.46	0.00
EG	I(1)	-6.21	0.00
REC	I(1)	-3.66	0.01
CCPI	I(0)	-2.12	0.03

Source: Authors' calculation

In the extended term, an increment of one unit in HCI corresponds to a decrease of 0.27 units in CO2 emissions. The constants "C" and "CCPI" have positive long-term impacts

Table 5 ARDL bound test: critical values and interpretations

Model: CO_2/(HCI, REP, REC, EG, PG, CCPI)			
F-statistics	3.58		
Lag	5		
Level of Significance	1%	5%	10%
I(0) Critical Value	3.05	2.38	2.07
I(1) Critical Value	4.14	3.39	3.01

Source: Authors' calculation

Table 6 Short-run coefficients

Variable	Coefficient	Std. error	t-statistic	Prob.
D (HCI)	-0.45	0.15	-2.99	0.03
D (REP)	-0.67	0.13	-5.09	0.00
D (REC)	-8.27	3.04	-2.72	0.04
D (EG)	0.17	0.03	5.96	0.00
D (PG)	0.25	0.11	2.27	0.05
CointEq(-1)	-1.27	0.22	-5.71	0.00
CCPI	0.92	0.19	4.94	0.00
R-squared	0.66			
Adjusted R-squared	0.65			
Mean dependent var	-0.06			
S.D. dependent var	2.13			

Source: Authors' calculation

Table 7 Long-term coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HCI	-0.27	0.13	-2.10	0.04
REP	-0.67	0.23	-2.91	0.00
REC	-0.20	0.02	-9.02	0.00
EG	1.29	0.82	1.57	0.15
PG	2.10	0.92	2.29	0.03
C	0.85	0.33	2.58	0.00
CCPI	0.76	0.17	4.39	0.00

Source: Authors' calculation

on CO_2. Probabilities indicate the significance of these effects. Table 7 shows the long-run effects of variables on CO_2.

Discussion and policy implications

Taking climate change into account, the research gives important insight into the link between a variety of elements and reaching sustainable growth goals. According to the conclusions of the study, there is a favorable relationship between environmentally conscious development and objectives and the HCI, which measures a population's education, expertise, and health level. This is consistent with the findings of Han et al. (2022), who concluded that nations with a higher HCI are likely to have reduced carbon emissions and a greater capacity to achieve sustainable development objectives. This conclusion is supported by the fact that it is consistent with Saqib et al. (2023) findings. Various factors can explain the relationship between HCI and sustainable development objectives. A competent workforce, in good health and possessing various cognitive and physical skills, is better equipped to address sustainability issues like carbon emissions (Muller 2020). These employees have an increased likelihood of acquiring employment.

They can identify the factors contributing to CO_2 emissions and devise effective countermeasures due to their extensive knowledge. Samour et al. (2022) research places a heavy emphasis on human capital's role in achieving sustainable development objectives. This lends credence to the notion that access to individuals with outstanding health, education, training, and relevant skills is crucial for addressing environmental challenges and advancing sustainable development. Regarding their contribution to sustainable development, the research also emphasizes the importance of activities that protect the environment, notably the use and generation of renewable energy. Given the country's expanding energy demands, Pakistan must immediately transition to more sustainable and renewable energy sources. Renewable energy, such as that generated by the sun and wind, results in almost no greenhouse gas emissions and decreases reliance on fossil fuels (Tutal and Yalcin 2021). Increasing the proportion of renewable energy in Pakistan's total energy balance is one method for the country to reduce its carbon emissions and make substantial progress toward its sustainable development objectives. These results are consistent with the findings of the Hasan and Du (2023) study, which highlights the advantages of utilizing renewable energy for attaining high-quality workplaces, a healthy workforce, and societal well-being.

The research also acknowledges Pakistan's population growth and economic expansion's tremendous impact on the country's efforts to achieve its sustainable development objectives. With the proper education and training, the growing population could become a benefit rather than a burden, according to the findings. Even though population growth can cause a rise in carbon emissions, the results indicate this can be achieved (Sekerci and Yilmaz 2021). It is possible to leverage the capacity of the population to contribute to sustainable development by investing in human capital development, assuring access to exceptional education and healthcare, and promoting sustainable population growth (Liu and Faye 2021). Similarly, managing economic development to minimize its negative environmental effects effectively is essential (Šimberova et al. 2020). Utilizing sustainable practices, encouraging the development of

environmentally benign technology, and enacting pro-environment laws are all methods for Pakistan to achieve its sustainable development objectives. This research concurs with the findings of Esquivias et al. (2022) and emphasizes the importance of education and training in attaining sustainable development through population growth.

In the final stage of the research, the climate change variable (CCPI), which evaluates the efficacy of climate change policies in addressing environmental concerns, is incorporated into the analysis. According to the findings, increasing the value of the CCPI positively affects an organization's ability to achieve its sustainable development objectives (Petit and Marnewick 2021). This demonstrates the importance of implementing comprehensive climate change policies to reduce carbon emissions, promote sustainable practices, and protect the environment. The findings are consistent with global efforts to halt or stop the effects of climate change, and they demonstrate how crucial it is for Pakistan's sustainable development initiatives to account for climate change. Our findings corroborate the complex relationship between human capital and emissions (Tugcu et al. 2012). Countries with significant expenditures in health, education, and skills encounter a surge in revenue generation, which, if not coupled with sustainable practices, can lead to an increase in greenhouse gas emissions. It exemplifies the dual nature of human capital-driven development.

This research provides valuable new insights into the factors that influence the attainment of Pakistan's SDGs. This includes the interaction between human capital, environmental protection mechanisms, population growth, economic growth, and climate change policies. Pakistan has the potential to move towards a more sustainable and environmentally conscious future if it prioritizes investments in the development of human capital, increases the use and production of renewable energy, controls population growth sustainably, and adopts policies that effectively address climate change methods (Tugcu et al. 2012).

As with all other studies, our analysis is necessarily restricted by several limitations. First, our study significantly relied on secondary data sources, which may result in potential biases due to data collection methods and the level of accuracy of these sources (Ozturk 2010). Moreover, the scope of our analysis was restricted to specific periods, which might not have reflected long-term consequences or evolving trends. Given that we concentrated primarily on Pakistan, the generality of the findings may be restricted; results might vary depending on socioeconomic and cultural environments. In addition, despite all of our attempts to control for confounding variables, there may be unknown factors that affected the results that were not accounted for in our model (Bhattacharya et al. 2016). This study's findings have theoretical and empirical ramifications, contribute to the existing corpus of knowledge, and aid Pakistani policymakers and regulators in developing policies consistent with sustainable development aims.

Conclusion and limitations

Environmental issues, socioeconomic disparities, and the effects of climate change prevent Pakistan from achieving its SDGs, as it is a developing nation. With a population of over 220 million and limited resources, Pakistan's efforts towards sustainability for the sake of its people, growth, and reducing the effects of warming temperatures are important, including the preservation of its natural environment. According to the CCPI, Pakistan happens to be one of the countries most impacted by the effects of climate change. It is dealing with an upsurge in the occurrence and severity of severe weather conditions including landslides, droughts, and extreme temperatures. Prosperity and environmental management are critical for its residents' well-being. These events have catastrophic consequences for the nation's agriculture, water resources, infrastructure, and overall socioeconomic stability.

Pakistan has taken significant steps to combat climate change and promote sustainable development in recent years. The country has committed to the objectives of the Paris Agreement, aiming to lessen the output of greenhouse gases and adapt to the impact of climate change. Pakistan's environmentally friendly policy calls for the country to produce 30% of its power from sources that are green by 2030. On Pakistan's agenda for sustainable development, investments in renewable energy have acquired a central position. Deploying renewable energy technologies, particularly solar and wind power, has made significant strides. For instance, the Quaid-e-Azam Solar Park in Punjab is one of the largest solar power initiatives in the world, contributing to the reduction of CO_2 emissions and the transition to renewable energy. In addition to renewable energy, Pakistan is implementing several climate change adaptation measures.

This includes initiatives to enhance water resource management, agricultural practices, afforestation and reforestation, and early warning systems for natural disasters. These measures aim to strengthen communities' resistance to climate change and reduce their susceptibility to its effects. Additionally, Pakistan's climate change policies emphasize sustainable land use practices, biodiversity conservation, and sustainable urban development. To reduce carbon emissions and improve overall environmental sustainability, efforts are being made to promote energy-efficient buildings, improve waste management systems, and promote sustainable transportation options. Despite these efforts, Pakistan continues to face numerous obstacles in the pursuit of its sustainable development and climate change goals. Limited financial resources, institutional capacity, and technological constraints present formidable obstacles. Aiding Pakistan in

addressing these challenges and implementing effective mitigation and adaptation strategies for climate change requires international support and cooperation.

The SDGs are at the forefront of Pakistan's climate change and sustainable development initiatives. Pakistan's journey toward a more sustainable and resilient future is intertwined with these global goals. SDG 7 exemplifies Pakistan's commitment to generate 30% of its electricity from renewable sources by 2030, emphasizing solar and wind power. In addition, as Pakistan confronts the effects of climate change, SDG 13 takes center stage, focusing on reducing greenhouse gas emissions and implementing climate adaptation. In addition, as Pakistan focuses on urban development and sustainable infrastructure, SDG 9 and SDG 11 enter into play. In conjunction with the interconnectedness of other SDGs, these objectives represent Pakistan's comprehensive strategy for addressing environmental, socioeconomic, and climate challenges along the path to sustainable development.

Pakistan can make substantial progress towards achieving its SDGs and mitigating the effects of climate change by emphasizing human capital development, promoting renewable energy, instituting climate change adaptation measures, and employing sustainable land use practices. Despite its indisputable advantages for economic growth, human capital poses obstacles to environmental sustainability. As governments advance, legislators must ensure that human capital-fueled development does not come to the detriment of the environment. Our research emphasizes the significance of this equilibrium. To assure a more sustainable and resilient future for Pakistan and its future generations, collaboration, policy coherence, and a long-term commitment are required from all stakeholders. The present investigation found some drawbacks that should be taken into account by future researchers who want to replicate and improve on the findings. It is suggested that future research focus on overcoming these constraints to give a more thorough knowledge of the predictors of sustainable development objectives in to give a more thorough knowledge of the forecasters of successful development objectives in the surroundings of Pakistan.

Moreover, to strengthen the research findings, it is essential to gather supportive data from Pakistan specifically. Pakistan, as a developing country, possesses unique characteristics, including a significant population, distinct atmospheric conditions, and specific economic challenges. These factors necessitate a focused examination of how changes in human resources and safeguarding the environment procedures including energy from renewable sources demand and production, renewable energy-based growth in the economy, and population expansion all affect Pakistan's ability to reach its SDGs. Future research should aim to conduct a thorough analysis of these factors, considering the specific economic and environmental conditions prevailing in Pakistan. By doing so, the study would contribute to a more comprehensive and nuanced understanding of the predictors of SDGs, tailoring the findings to the specific challenges and opportunities faced by Pakistan.

The clear relationship between human capital and sustainable development demonstrates to policymakers the importance of investing in education and health to achieve broader sustainability objectives. Sustainability's focus on renewable energy suggests transitioning from fossil-based energy sources to sustainable, renewable alternatives. Furthermore, a nuanced comprehension of how growing populations can be an obstacle or an asset provides insight into how demographic trends can be leveraged effectively. Our research enables researchers to examine more nuanced facets of sustainable development, such as the role of developments in technology and changes in culture in driving sustainable practices. By contextualizing the research within Pakistan, future researchers can generate insights that are relevant and applicable to the country's unique circumstances. This knowledge would enable policymakers, stakeholders, and development practitioners to develop targeted strategies and policies that effectively contribute to the attainment of SDGs in Pakistan.

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Data availability The supporting statistics for the findings of this study are available upon reasonable request to the first author.

Declarations

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Consent to participate Not applicable.

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