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Research article

Catalyzing sustainable development: Exploring the interplay between access to clean water, sanitation, renewable energy and electricity services in shaping China's energy, economic growth, and environmental landscape

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ABSTRACT

The Sustainable Development Goals (SDGs) reflect the shift in global economic conversation toward inclusive growth. The growth can promote inclusivity and widespread sharing of its advancements by concentrating on four key dimensions. (a) Equality of opportunity, (b) sharing prosperity, (3) environmental sustainability/climate adaptation, and (4) macroeconomic stability. We used the Kao cointegration test to study how certain variables are connected over a long period. The relationship between CO2 and GDP per capita, renewable energy and tourism, improved water and sanitation, and access to power all have a positive feedback effect on each other. Based on FMOLS's findings, a 1 % increase in Inclusive growth leads to a 0.342 % (Model 1) and 0.258 % (Model 3) increase in CO2 emissions. An increase of 1 percent in energy consumption per person resulted in a rise of 1.343 % in CO2 emissions in Case 1, 0.524 % in Case 2, and 0.618 % in Case 3. Increasing the tourism sector's proportion of total exports by just one percent will reduce CO2 emissions by 0.221 % (case 1) and 0.234 % (case 3). Based on CCR findings, a 1 % improvement in inclusive growth leads to a 0.403 %

1. Introduction

A person's living conditions and ability to absorb climate stress are particularly shaped by access to basic public services like electricity, water, sanitation, transport, and good institutions [1]. It shows variations across countries [2]. In Asian developing countries, about 800 million and 600 million people face difficulty accessing electricity and safe drinking water, respectively [3]. Deepening inequality and climate vulnerability have become important challenges for policymakers. Thus, the concept of "Inclusive Growth" has been introduced by the Asian Development Bank (ADB) to cope with this situation [4] Inclusive economic growth can eliminate poverty by providing the means for better living standards, increasing productivity, generating quality jobs, and ensuring equitable access to opportunities for the entire society [5]. The Sustainable Development agenda also recognizes that expanding infrastructure (SDGs 6, 7, and 9) and adapting to climate change (SDGs 13 and 15) are essential for sustained and inclusive economic growth (SDGs 8) to reduce poverty (SDGs 1). Therefore, sustainable development is possible through inclusive growth [6].

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Nomenclature

Abbreviations

ARDL	Autoregressive Distributed Lag
CD	Cross-sectional Dependence
CIPS	Cross-sectionally Augmented IPS
DOLS	Dynamic Ordinary Least Square
CE	C02 Emission
EN	Energy Use
TOU	Tourism
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Square
GHG	Greenhouse gases
GSTC	Global Sustainable Tourism Council
HDI	Human Development Index
ICT	Information and Communications Technology
IMF	International Monetary Fund
IRP	International Resource Panel
LM	Lagrange Multiplier
$\widehat{\beta}_i$	Pooled OLS estimator
b_j^*	Standardized slope
$\widehat{\rho}_{ij}$	pair-wise correlation of the residuals
FOR	Forest Area
LMICs	Lower-Middle-Income Countries
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Square
PCA	Principal Component Analysis
SDG	Sustainable development Goals
IG	Inclusive Growth
EL	Access to Electricity
SD	Standard Deviation
SDG	Sustainable Development Goal
Wat	Water
T&T	Travel and Tourism
GDP	Gross domestic Product
UN	United Nations
UNWTO	United Nations World Tourism Organization
VAR	Vector Autoregression
VECM	Vector Error Correction Model
VIF	Variance Inflation Factor
WDI	World Development Indicators
WTTC	World Travel and Tourism Council
GI	Globalization Index
GTI	Global Tourism Index
N	Cross-sections
REN	Renewable Energy Consumption

The growth can spur inclusion that is broadly sharing these improvements by focusing on four main dimensions: (a) equality of opportunity, (b) sharing prosperity, (3) environmental sustainability/climate adaptation, and (4) macroeconomic stability [7]. Over the last decades, a frequent claim has been that traditional growth patterns must be transformed to address environmental concerns and climate change. However, the emphasis has been placed on rapid growth that ignores the socio-economic benefits of the growth [8]. On this point, the current attempt explores the nature of linkages between inclusive growth and development. Thus, the motivation behind the present research is to study the dimensions of inclusive growth. This paradigm promotes broad-based economic growth, which is sustained across different income groups and provides equal and equitable opportunities to the people via productive employment generation (increase in income), access to better infrastructural services, shared prosperity, climate adaptation, price stability, and the like [9,10]. This goes beyond the primary objective of eradicating poverty and inequality [10].

1.1. Equality of opportunity

Equality of opportunity to access basic public services is central to inclusion. Infrastructure development is an integral part of a county or region's progress in terms of productivity and growth. It expresses fundamental and universal aspirations driving inclusive growth [11]. By providing services to households and industries, the role of infrastructure is important in the economy and society [12]. The availability of transportation, energy, clean water supplies, sewage management facilities, and other essential amenities significantly impacts the quality of life, particularly for poor ones. Investment in physical infrastructure (water, electricity, clean fuels, and sanitation) is needed for development, employment, equity, and security [12]. Infrastructure services aid businesses with production, transportation, and transactions that promote growth, increasing income distribution between the poor and rich and reducing unemployment [13–16]. In addition, infrastructure facilitates the physical mobility of people and products and eliminates productivity constraints. Access to infrastructure lead to better living quality by promoting trade and sustainable growth [17–19]. Conversely, a lack of basic infrastructural services indicates constraints on growth which cause inequalities; therefore, the main task is to develop effective and high-quality infrastructure that may encourage inclusive growth through increased job opportunities and ease of doing business [20–22].

1.2. Shared prosperity

One of the objectives of inclusive growth is 'shared prosperity.' International trade can significantly increase prosperity and lower poverty in emerging nations [23–25]. Trade openness facilitates better resource allocation by enabling countries to benefit from comparative advantages, positively impacting growth. Specialization enhanced productivity in several industries by increasing output, resulting in learning by doing [26,27]. Proponents of free trade claim that it is required for long-term economic growth and shared prosperity for all [28]. Trade openness coupled with FDI shows a beneficial role in knowledge spillovers in human capital [29,30]. Moreover, both trade openness and FDI help developing nations by transferring technology (via the import of high-tech items) [31], and increasing firm productivity [32]. In reality, the influx of FDI and trade openness have been viewed as opportunities for job creation that can result in inclusive growth and the development of economies worldwide [33,34].

1.3. Environmental sustainability

Inclusive growth is the main target of development policy, but it is also crucial to consider climate resilience in the development agenda [35]. Prepared against climate change is a key adaptation strategy [36]. Adaptation should focus on increasing resilience across different countries and all sectors [37]. Fostering climate resilience is a central goal of the 2015 Paris Agreement approved at the Climate Change Framework Convention of the United Nations [38]. Frequent extreme weather events occurred due to climate change, negatively impacting food and livelihood security and threatening socio-economic development [39,40].

The global system for producing food and the management of ecosystem-related benefits have an influence on several of the Goals for Sustainable Development (SDGs), including eradicating hunger (SDG 2), ensuring universal water and adequate sanitation facilities (SDG 6), taking action on climate change (SDGs 13), and preserving life underwater and on land (SDGs 14 & 15). Therefore, the key challenges of feeding a growing population while minimizing environmental damage and safeguarding natural resources for the next generations must be addressed together to achieve these objectives [41]. However, climate change has become a pervasive threat to biodiversity, affecting individual species' interaction with the physical environment and each other, altering the ecosystem structure [42]. At the same time, agriculture contributes significantly to environmental issues, such as the climate crisis, ecosystem services degradation, and pollution of soil, air, and water [43]. Ecological systems, crop cultivation, and climate changes are all interconnected global processes, and their link to one another has become more important as the disparity between environmental challenges increases [44,45]. In light of this background, this study aims to identify, quantify and assess the interactive link between changing climate, ecosystem services, and agriculture production. Balancing the increasing consumer demand for nutritious meals with environmental threats has become a complex sustainability issue [46].

Fuel prices are rising as a result of a limited supply and rising demand for fossil fuels. Fossil fuels are important for economic activities but they may lead to Greenhouse Gases (GHGs) and climate change. Additionally, fossil fuels require a sizable quantity of foreign reserves [47]. Oil price volatility is responsible for financial and macroeconomic risks, which adversely affected the world markets [48]. Risks associated with climate change pose a threat to humankind and require substantial foreign reserves. It is required to mitigate loss through renewable energy [49]. It is beneficial to develop cheap and environment-friendly renewable energy sources, such as biomass, hydropower, solar, and wind [50]. It could address a number of issues, including the reliance on fossil fuels, the lack of energy, and the rise in import costs [50].

A fast-growing economy in transition and Increasing population requires more energy. Over the past few years, China's economic growth and greenhouse gas emissions have increased together. Examining the dynamic link between environment, growth, and energy has numerous policy consequences connected with these variables [50].

The dominant discourse is headlined by the necessity to shift from traditional growth models, including climate change; however, rapid growth is currently taking precedence over considerations of being socio-economic inclusive. It is against this background that this study embarks on a journey to probe the delicate interrelations existing between inclusive growth and development, focusing on the dimensions of inclusive growth in the way to observe paths that go beyond mere economic expansion and reach out for all-round socio-economic development [51].

1.4. Research gap and contribution

Most of the research has employed GDP per capita as a means of empirical analysis to examine the relationship between environment and growth. Nonetheless, the idea of inclusive growth must be discussed in relation to the growing environment. First, in the context of growth-energy-environment, it considered the variable of inclusive growth for the first time rather than standard growth measurements.

1.4.1. Research questions

The research questions that guide this paper are as follows:

1. What is the impact of Inclusive growth on Co2 Emission?
2. What is the impact of Renewable Energy on the Co2 Emission?
3. What is the impact of tourism on Co2 Emission?
4. What is the impact of Access to water and Sanitation on C02 Emission?

Hypothesis:

H1. Increase in the renewable energy consumption leads to decrease in the CO2 Emission.

Table 1
Details of previous research.

Author (s)	Variables	Methodology	Findings
[58]	CO2 emission, renewable energy	Quantitative	An interesting finding concerning India's environmental achievements was revealed by this research: the first step on an inverted U-shapped EKC for CO2 emission of USD 2937.77 as a watershed or a move for the national level to juncture into the international efforts. It is suggested that the nation was on its way towards establishing long-term prosperity. In Contemporary
[59]	energy consumption, real GDP, tourism and trade, CO2	Panel Cointegration Analysis	Within the OECD countries, this study revealed a nuanced environmental landscape: energy consumption and tourism were identified as contributors to greenhouse gas emissions, while increased trade held the potential for environmental improvements. Nonetheless, the Environmental Kuznets Curve (EKC) hypothesis faltered, with GDP and GDP2 coefficients showing conflicting signs, prompting a call for multifaceted policy approaches centered around bolstering energy efficiency, implementing robust environmental measures for tourism, and incentivizing trade for achieving a harmonious equilibrium between economic expansion and ecological preservation.
[60]	Clean technologies, energy, finance, and food	Quantitative	This research showed that Sub-Saharan Africa has a complicated natural landscape, which has implications for sustainable development. It found that the concept of an inverted U-shaped Environmental Kuznets Curve (EKC) with a tipping point at US$5540 GDP per capita was not supported for CO2 emissions but was supported for PM2.5 emissions. And it supported the "the contamination haven hypothesis" for CO2 emissions but not PM2.5 emissions. Carbon pollution in SSA nations was analyzed from the perspectives of technological advancements, FDI, and food insecurity. The number of people was found to be the primary driver for CO2 emissions in the decade that followed, while high incomes per capita, trade openness, and technology adoption were found to be the most significant variables for PM2.5 emissions, even though the IPAT hypothesis did not hold true for either type of emission. To realize a green growth agenda consistent with the UN's sustainable development objectives, it is crucial that SSA member states cooperate to solve these issues.
[61]	Greenhouse Gas, Sustainable Sanitation	Panel Data Models	Important information regarding the weather in rural Sichuan, China, was uncovered in this research. The average GWC for homes with anaerobic digesters was 54 % lower than that of those without biogas. GWC decreased by 48 % in biogas dwellings, and that was after accounting for methane loss. Value of a biogas plant was calculated at US$28.30 per ton of CO2-equivalent based only on reduced GHG emissions over a decade; this might offset part of the initial construction expenses. These findings demonstrate the potential importance of biogas facilities in the fight against GHG emissions. They also demonstrate the potential for synergy between policies that promote improved stoves, sustainable biomass collection, and energy initiatives that have positive effects on public health.
[62]	CO2 emissions, electricity	Quantitative analysis	This research provided crucial evidence for the validity of the Environmental Kuznets Curve (EKC) hypothesis in the context of Italy's economy and environment by demonstrating that rising prosperity was associated with declining pollution levels over time. In addition, the generation of renewable energy per person proved to be an effective factor in lowering CO2 emissions per person in both the short and long run, while international commerce was beneficial in the long term. The research also showed a Granger relationship between the two types of power generation, non-renewable and green, as well as between the two types of electricity generation. These findings highlight the importance of renewable energy generation in the long-term effort to lessen environmental damage. Legislators should give this a lot of thought.

H2. Increase in the tourist arrival leads to decrease in the C02 Emission.

H3. Improvement in access to water and sanitation leads to decrease in the C02 Emission.

H4. Increase in the inclusive growth leads to improvement in the environment.

2. Literature review

Scholars have done a lot of study on the link between energy, the environment, and the business [52]. Some of these studies have expanded their focus to include more factors, such as the use of green energy and tourists, to look at how their effects on this connection are linked [53]. For example, scholars have looked at the part of using green energy sources and the effects of tourists at the same time. In this Table-1 we see how the CO2 emission, economic expansion, energy usage, integration of green energy mixing, trade, tourism, social infrastructure, financial development, and a few other factors are connected together [54]. This table delineates the environmental impact of tourism, good and bad, be it waste or green energy, and cleanliness as well as trade [55]. On the positive side, tourism promotes recycling, reforestation, gentle touring, and promotes the idea to get involved in environmental activities. Literature has indicated that in different instances such as an increase in pollution at Malaysia versus a decrease in pollution at Tunisia and Turkey, tourists. Moreover, green energy will not only diminish the environmental impact of tourists but that of economic development as well such as governments, businesses, and manufacturing firms. Research authors have brought into light the fact that the enhanced and easy accessibility to clean water as well as sanitary amenities can further bring about a healthier life for people as well as improve the surrounding [56]. Researchers have observed that in the most sustainable countries there is a proper equilibrium, with growth and energy consumption in the long term being kept at the same level. Hence, the author ponders on the fact that green energy, clean water and sewage access, and sustainable tourism should be regarded as the key components of such ventures in a quest for environmental sustainability and economic development together [57].

Energy-growth-environment nexus is, in essence, a complicated and mutually reinforcing trilateral relationship that links the energy production/consumption, industrial productivity, and environmental fitness [63]. The unraveling of this connection is a central part of the process of modern development, especially in the case of China, but this progress cannot occur without it. This section aids in the understanding of the general framework that I am using and what the major relational aspects between energy, growth, and environment are. It has such features as more production, income, and job opportunities([64]. Energy assumes the vital role of production of commodities, making of infrastructures and creation of good living standards. The sustainability of environment relates to the wise utilization of the nature-given resources, minimization of pollution, and slash of the environmental effects. Energy generation and consumption process that nature can be harmed by it; pollution of air and water, release of greenhouse gasses and habitat loss are the examples of disadvantages of energy production and consumption. Supply of clean water, facility of sanitation and electricity, being essential for both personal health and economic productivity, should be given a priority. [65], There are various methods that can be employed to attract and retain the attention of target customers for a SaaS product in the software industry. The interrelation between regulations set by the government, energy offering, and economic activities varies, together with the goal to protect the environment. The efficient legislations can be aimed at promoting green energy at the same time striking balance between the sustainable economic growth and the environment [66]. Government policies and regulations shape the energy landscape, economic activities, and environmental protection measures. Effective policies can promote sustainable energy use, economic growth, and environmental conservation. Recognizing the dynamic nature of the nexus, feedback loops represent the consequences of actions taken within the system. For example, increased energy consumption may lead to environmental degradation, which, in turn, necessitates environmental policies that influence energy production [67].

Within the energy-growth-environment nexus, several key interactions and linkages shape the outcomes: A robust supply of affordable and reliable energy is essential for economic growth. Industrial processes, transportation, and modern conveniences all rely on energy. With economic expansion, demand for power is usually higher which results in higher generation, consumption and consequently, higher negative impact on the environment. Using fossil fuels as a source for energy is a Chief factor of environmental degradation. GHGs, particularly, air pollutants and the depletion of the finite natural resources known are the important environmental obstacles. On the other hand, moving to make power derived from the sun and wind contributes the reduction of these impacts. The increase of access to clean water, plumbing, and electricity upgrades living conditions and incorporates the foundation of economic success [68]. Basic Services have a huge role in the process of the making human lives easier by decreasing risks and sustain productive life while also making people able to join the formal economy. Element of economic empowerment, electricity provision support many aspects of essential services supply. It is the good water source for water pumping and sanitation issues, and it helps to healthcare services and supports educational institutions. On the one hand, the insufficiency of energy can offset the supply and The delivery of the most basic services such as lighting, heating, health, and communications. The formulation of government policies is one of the crucial elements that determines energy sector trends and influences the environmental results. Through the adopting of rules that sustain renewable energy adoption, that partly regulate emissions and that into the creation of a green economy, the environmental sustainability and the economic growth get a positive impact [69]. Clarifying the contribution of such links and associations to the overall formulation of strategies and policies on economic development and environmentally sound methodologies for equitable provision of social amenities is also of paramount importance [70].

Water shortage is one of the most destructive elements for agricultural production and is a big factor for food security issues. Industries that use water, and for instance, manufacturing and textile production industries, may face production collisions sometimes, affecting the economy of a country. The water-energy connection is two-way as the use one affects the other. A large amount of water is drawn for cooling in power plants, carbonation, desperately of water among other energy production activities. Whereas, on one hand the supply and treatment of water are essential factors, on the other hand it is water availability that makes it a paramount issue [71] on energy availability. It must be mentioned here that the nexus shows the need for having comprehensive planning for the sake of mutual security not only of water, but also energy sector. Water scarcity can become a great challenge especially in places where the resources being used are already limited. In China this is the inseparable aspect that emphasizes the sustainable management of resources onward. Water is a pivotal ingredient for quite a number of economic activities ranging from agriculture, to manufacturing to services industry. Sufficient water serves economic growth mechanisms namely, by raising agricultural production, conservation of industries, and creation of urban settlements. China which entirely depends on the irrigation of its agriculture activities, is the main player in the water issue [72].in the nation's economy. Overall, provision of water for irrigation is mainly the source for growth of crops and food security. The water estate due to grow cities requires increasing the storage, transportation, treatment and distribution of water. A situation when people do not enjoy access to clean water and sanitation in the urban areas can be detrimental to overall economic growth and good living standards. Human activities are found to be responsible for the unsustainability of water ecosystems and the environment. Pollution, overfishing and the destruction of marine ecosystems can endanger biodiversity and even the viability of various particular water species [73]. In addition, water-related hazards, for instance, flooding and drought, can have both high and low status environment impacts. The ecosystems with healthy water are the ones that lead to biodiversity and many ecosystem services e.g. clean water supply or flooding regulation. Impacts of climate change represented by altered precipitation patterns and the ever more regular heat wave even can turn water-related environmental challenges to the worse. Learning about a water-energy-growth-environment link are key pillars for China's sustainable development. Availability of good quality water, using the water with care or water efficient methods, and guarding of water sources are among the priorities [74]. water as a major concern for dealing with water scarcity, economic advancement, and environmental security issues. Rule makers of China must take these complicated interdependencies into account as they work on their strategies for natural resource management, energy production, economic growth, and to preserve environment [75].

This study extended the literature (Table 1) the first study on evaluating the possible long-run dynamics of socio—economic development on environmental degradation in China. The Goal 6 of SDGs "Ensuring availability of water and sanitation for all" has been much improved up-till 2015 (over 90 & 66 percent) of world population has access to improved drinking water sources and sanitation facilities respectively. At the same time, under the Goal.7 of SDGs Ensure access to affordable, reliable, sustainable and modern energy for all" from 2000 to 2016, the access to electricity has increased to 87 percent from 78 percent globally but still 43 percent of the world's population is using polluting sources for cooking purpose being highest in Asian and African countries.

2.1. *The data*

From 1990 to 2021, this study used data from the World Development Indicators about China that was collected every year [76]. The variables chosen for the analytical framework were per capita CO2 emissions, per capita energy consumption, per capita GDP, the share of renewable energy use [77], the share of tourism exports, the level of improved access to water, the level of improved access to sanitation, and the level of access to electricity [78].

2.2. *Descriptive analysis*

Table 2 gives a full picture of the summary data for the factors being looked at in this study, with a special focus on China [79]. The table shows the mean, median, minimum, maximum, kurtosis, skewness, and the Jarque-Bera normality test, all of which are important statistics measures. The average amount of CO2 emitted per person was 0.91 metric tons, with a low of 0.68 metric tons [80] and a high of 0.72 metric tons. In terms of GDP per person, the mean was 722.12 with the minimum value was 741.80 and maximum value was 1041.31. On average, each person used 475.35 kg of oil equivalent worth of energy. Also, the study of the data showed that green energy made up an average of 48.72 % of all the energy used The study also looked at how easy it was for people to get better water, better toilets, and power. On average, 78.95 % of people had access to better water sources, 78.16 % had access to power, and 42.38 % had access to better sewage [81]. Notably, the number of people with access to better cleaning stayed below 50 % throughout

Table 2
Descriptive analysis of variables (1990–2021).

Descriptive Indicators	Variables					Control Variables		
	CE	IG	EN	REN	TOU	SAN	WAT	EL
Unit	metric tons per capita	GDP per person employed	kg of oil equivalent per capita	% of total	% of total exports	% of population		
Mean	0.91	722.12	475.35	48.72	4.68	42.38	78.85	78.16
Median	0.90	845.86	365.12	39.23	4.61	31.22	79.01	68.21
Maximum	0.72	1041.31	422.65	48.16	5.28	53.41	81.20	88.12
Minimum	0.68	741.80	397.27	43.95	3.12	23.70	66.21	38.44
Std. Dev.	0.18	114.15	24.86	2.86	1.02	12.22	1.48	11.21
Skewness	−0.33	0.31	−0.31	0.50	−0.13	0.17	−0.18	−0.17
Kurtosis	1.59	1.46	2.12	2.23	1.51	1.60	1.71	1.68
Jarque-Bera	1.88	2.44	1.32	2.04	2.13	1.82	1.47	1.68
Probability	0.29	0.35	0.39	0.42	0.43	0.28	0.38	0.35

the whole study. Also, the factors in Table 2 were tested for normality with tools like kurtosis, skewness, and the Jarque-Bera test. The data showed that all factors had a normal distribution, which makes them easy to study in the future [82,83].

3. Materials and methods

3.1. Model

The following models [84] were used to describe the relationship between the variables in the form of Eqs. (1)–(3):

$$\mathrm{CE_t = A_0 IG_t^{\alpha_1} EN_t^{\alpha_2} REN_t^{\alpha_3} TOU_t^{\alpha_4} WAT_t^{\alpha_5}} \epsilon^{\varepsilon_t} \tag{1}$$

$$\mathrm{CE_t = B_0 IG_t^{\beta_1} EN_t^{\beta_2} REN_t^{\beta_3} TOU_t^{\beta_4} SAN_t^{\beta_5}} \epsilon^{\varepsilon_t} \tag{2}$$

$$\mathrm{CE_t = C_0 IG_t^{\gamma_1} EN_t^{\gamma_2} REN_t^{\gamma_3} TOU_t^{\gamma_4} EL_t^{\gamma_5}} \epsilon^{\varepsilon_t} \tag{3}$$

The natural logarithm minimized the heteroskedasticity and Eqs. (1)–(3) turn into Eq. (4):

$$\ln(\mathrm{CE_t}) = \alpha_0 + \alpha_1 \ln(\mathrm{IG_t}) + \alpha_2 \ln(\mathrm{EN_t}) + \alpha_3 \ln(\mathrm{REN_t}) + \alpha_4 \ln(\mathrm{TOU_t}) + \alpha_4 \ln(\mathrm{WAT_t}) + \varepsilon_t \tag{4}$$

where, $\alpha_0 = \ln(A_0)$, the subscript t denote the time period, and α_1, α_2, α_3, α_4 and α_5 show the elasticity of CE with respect to GDP, EN, REN, TOU, and WAT, respectivelyin the form of Eqs. (4)–(6).

$$\ln(\mathrm{CE_t}) = \beta_0 + \beta_1 \ln(\mathrm{IG_t}) + \beta_2 \ln(\mathrm{EN_t}) + \beta_3 \ln(\mathrm{REN_t}) + \beta_4 \ln(\mathrm{TOU_t}) + \beta_4 \ln(\mathrm{SAN_t}) + \varepsilon_t \tag{5}$$

where, $\beta_0 = \ln(B_0)$, the subscript t denote the time period, and β_1, β_2, β_3, β_4 and β_5 show the elasticity of CE with respect to GDP, EN, REN, TOU, and SAN, respectively.

$$\ln(\mathrm{CE_t}) = \gamma_0 + \gamma_1 \ln(\mathrm{IG_t}) + \gamma_2 \ln(\mathrm{EN_t}) + \gamma_3 \ln(\mathrm{REN_t}) + \gamma_4 \ln(\mathrm{TOU_t}) + \gamma_4 \ln(\mathrm{EL_t}) + \varepsilon_t \tag{6}$$

where, $\gamma_0 = \ln(C_0)$, the subscript t denote the time period, and γ_1, γ_2, γ_3, γ_4 and γ_5 show the elasticity of CE with respect to IG, EN, REN, TOU, and EL, respectively.

3.1.1. Econometric methodology

First, it was important to make sure how things are going together and if there is a good match between them. So, first we checked if our data was stationary by using tests for unit roots.

3.2. Stationarity analysis

Four ways were used to check if stationarity exists. This was done to get better guesses and because of some math mistakes related with every single test. This study used a test by Ref. [85]. It also included tests such as the ADF or PP method.

3.2.1. Cointegration analysis

We used the Kao cointegration test to study how certain variables are connected over a long period of time. Two variables have a connection of (1, 1) when their mix in straight line stays stable but they do not stay the same by themselves. Scientists said that when one thing causes another, it always goes in just one way between the factors and there is something called cointegration happening [86]To check if the cointegration worked for the error correction model [87],test was suggested by Aïssa and others in 2014. This is based on something called ADF-statistics [88] also used the same basic ideas in their test. But, Kao (1999) shows same coefficients and unique starting points in the first-step regressor [89]. It uses DF and ADF methods by using the null hypothesis (meaning there's no connection). If we look at two-variable model, Kao is shown by the diagram below [89]. in term of Eqs. (7)-9)

$$y_{it} = \alpha_i + \beta x_{it} + e_{it}, i = 1, \ldots\ldots., N; T = 1, \ldots\ldots., T \tag{7}$$

$$y_{it} = y_{it-1} + u_{it} \tag{8}$$

$$x_{it} = x_{it-1} + \varepsilon_{it} \tag{9}$$

in here, alpha can change but stays constant at different lines and b shows the level of slope. The random events in each case represent yit for i's total, with xits being independent incidents only when all are equal or higher than a fixed value. In this same situation we compute residual effects from ADF test in terms are described in equations (10) and (11) respectively,

$$\widehat{e}_{it} = \rho \widehat{e}_{it-1} + \sum_{j=1}^{p} \varphi_j \Delta \widehat{e}_{it-j} + v_{itp} \tag{10}$$

If null hypothesis that there is no cointegration is considered, estimated ADF test is shown as:

$$\mathrm{ADF} = \frac{t_{\overline{p}} + \sqrt{6N\widehat{\sigma}_r/(2\widehat{\sigma}_{0r})}}{\sqrt{\widehat{\sigma}_{0r}^2/(2\widehat{\sigma}_r^2) + 3\widehat{\sigma}r_r^2/(10(6\widehat{\sigma}_{0r}^2)}} \tag{11}$$

The estimated variance is $\sigma_r^2 = \sigma_r^2 - \sigma_r^{-2}$ with estimated long run variance $\sigma_{0r}^2 = \sigma_{0u}^2 - \sigma_{0u\in}^2\sigma_{0\in}^{-2}$. The covariance of $\omega_{it} = \begin{bmatrix} u_{it} \\ \in_{it} \end{bmatrix}$ is estimated in the form of Eq. (12)

$$\sum \begin{bmatrix} \widehat{\sigma}_u^2 \widehat{\sigma}_{0u\in} \\ \widehat{\sigma}_{0u\in} \widehat{\sigma}_{\in}^2 \end{bmatrix} = \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \omega_{it}\omega_{it}^{'} \tag{12}$$

Estimation of long-run covariance is done through the kernel estimator in the form of Eq. (13):

$$\widehat{\Omega} = \begin{bmatrix} \widehat{\sigma}_{0u}^2 \widehat{\sigma}_{0u\in} \\ \widehat{\sigma}_{0u\in} \widehat{\sigma}_{0\in}^2 \end{bmatrix} = \frac{1}{N} \sum_{i=1}^{N} \left[\frac{1}{T} \sum_{i=1}^{T} \omega_{it}\omega_{it}^{'} + \frac{1}{T} \sum_{\tau=1}^{\infty} k(\tau / b)x \sum_{t=\tau+1}^{T} \omega_{it}\omega_{it-1}^{'} + \omega_{it-\tau}\omega_{it}^{'} \right] \tag{13}$$

where k shows the supported kernel function while b denotes the bandwidth.

3.3. Regression analysis

Kao and Chiang (2001) along with [90]suggest panel Dynamic Ordinary Least Square as a potential method because it seems that there are issues like poor efficiency or inconsistency when using the normal least square approach to estimate regression lines over time for co-integrated data. Suggested we use Fully Modified Ordinary Least Square, which is a term-free method for working out long-run flexibility. This plays an important part in how certain things react to changes over time. FMLOS says we need to have stable variables and can face issues with connections in a series or problems with repeated causes of estimation using OLS. DOLS, a team version of one-time series regressions created by Ref. [91] The regression model is represented in terms of Eq. (14):

$$y_{it} = \phi_i + \delta_t + \beta^{'} Z_{it}, \sum\nolimits_J^P = -Pd_{ij\Delta Zi,t+j+\mu it} \tag{14}$$

in which:

$i = 1, 2, 3, \ldots\ldots.N.$
$t = 1, 2, 3, \ldots\ldots.$
ϕ_i = fixed effect individual intercepts
δ_t = time pattern
Zit = Vector of explanatory variables
β i = potential effects in the long term

The error term, which must follow the I(0) process, is represented by μit. Equation (15) becomes when the DOLS coefficient is estimated.

$$\hat{\beta}_{DOLS} = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} X_{it}X_{it}^{'} \right) \left(\sum_{t=1}^{T} X_{it}\widehat{X}_{it} \right) \tag{15}$$

where

Table 3
Unit root tests result.

Variables	Case 1:at level [intercept & trend]			Case 2:at First difference [intercept only]			Case 3: atFirst difference [intercept &trend]			Order of Integration
	ADF	DF GLS	PP	ADF	DF GLS	PP	ADF	DF GLS	PP	
lnCE	−4.231	−1.214	−0.858	−4.112[a]	−5.462[a]	−4.221[a]	−4.816[a]	−6.578[a]	−4.723[a]	I(1)
lnIG	−2.282[c]	−3.484	−0.991	−4.211[b]	−2.381[a]	−2.154[b]	−4.523[c]	−4.413[b]	−4.121	I(1)
lnEN	−1.784	−2.182	−0.895	−4.651[a]	−4.645[a]	−4.651[a]	−5.588[a]	−5.522[a]	−5.587[a]	I(1)
lnREN	−0.273	−2.278	−1.030	−5.748[a]	−5.773[a]	−5.748[a]	−4.561[a]	−6.579[a]	−4.25[a]	I(1)
lnTOU	−2.278	−4184[c]	−3.099	−6.452[a]	−6.574[a]	−6.524[a]	−6.378[a]	−8.712[a]	−6.227[a]	I(1)
lnSAN	−1.575	−3.323	−1.139	−3.634[c]	−2.778[b]	−3.655[c]	−4.734[b]	−4.218[c]	−4.457[a]	I(1)
lnWAT	−1.345	−1.851	1.292	−4.412[b]	−4.414[a]	−4.612[b]	−4.179[a]	−4.316[a]	−6.469[a]	I(1)
lnEL	−2.743	−2.654	−2.269	−8.217[a]	−7.857[a]	−7.481[a]	−11.457[a]	−9.326[a]	−12.558[a]	I(1)

[a] significance at 1 % level.
[b] significance at 5 % level.
[c] significance at 10 % level.

$$\boldsymbol{X_{it}} = \left[\boldsymbol{Z_{it}} - \overline{\boldsymbol{Z}}_{\boldsymbol{i}}, \boldsymbol{\Delta Z_{i,}t} - \boldsymbol{p}, ...\boldsymbol{\Delta Z_{i,}t} + \boldsymbol{p}\right]$$

Xit can be reached by using 2(K+1) multiplied by 1 and X raised to the power of it can found from. DOLS is a method that uses lag spots of changed regressors. It helps fix endogeneity and serial connections problems. It can deal with biases caused by having a small number of samples.

4. Results and discussion

4.1. Unit root test result

Using three alternative scenarios form (level) (intercept and trend), form (first difference) (intercept only), and form (level) (intercept and trend). The empirical results of three experiments are displayed in Table 3. In scenario 1, both the 1 % and the 5 % significance level tests conclude that a unit root exists in all of the chosen variables, rejecting the stationarity hypothesis. However, the stationarity in all variables was confirmed by all three tests only when expressed in first difference form, indicating that the correct integration order was 1, or I(1). In these evaluations, The specified lag length automatically based on the Schwarz criterion.

4.2. Cointegration test result

Johansen cointegration test results are presented empirically in Table 4. Long-term elasticity and Granger causality both rely on the presence of cointegration. Two indicators, including trace statistics and maximum eigenvalue statistics, are provided by this test. For the existence of cointegration between the chosen variables, the null hypothesis must be rejected because it implies the absence of cointegration. In the current study, China has 2 cointegration(s) associations, according to both the maximum eigenvalue test and the trace test. Because of the cointegration, Granger causality could be investigated. If cointegration is absent, then the VAR causality model is the most suitable.

4.3. Granger causality analysis

Table 5 explores the VECM result for the causality between carbon dioxide emissions, Energy utilization, GDP, and green energy, the percentage of exports attributable to tourism, and the improved access to electricity, sanitary facilities, and water. The Granger causality analysis explored that whether a variable x causes a variable y. A variable x is considered as Granger-cause variable y if the present value of y is predicted by using past values of x. A negative and significant ECM coefficient is required to establish the long run causality of a specific variable with all other variables.

In Table 5, the VECM result is used to analyze carbon dioxide emissions, Energy utilization, GDP, and green energy, the percentage of exports attributable to tourism, and the improved access to electricity, sanitary facilities, and water. The Granger causality test

Table 4
Results of the Johansen co-integration test.

H_0	Model with access to improved water access				
	Eigenvalue	Trace		Max-Eigenvalue	
		Statistics	p-values	Statistics	p-values
None[a]	0.825	142.333	84.645	0.001	0.825
At most 1[a]	0.914	81.825	95.728	0.002	0.912
At most 2[a]	0.817	62.852	54.765	0.016	0.817
At most 3	0.568	32.524	38.865	0.335	0.536
At most 4	0.322	7.669	21.584	0.275	0.222
At most 5	0.212	4.284	4.732	0.087	0.223
H_0	**Model with access to improved sanitation**				
None[a]	0.866	281.474	84.835	0.001	0.866
At most 1[a]	0.664	81.574	78.26	0.002	0.664
At most 2[a]	0.745	45.753	56.745	0.021	0.573
At most 3	0.412	16846	36.684	0.071	0.413
At most 4	0.364	10.114	24.584	0.236	0.462
At most 5	0.001	0.005	2.734	0.841	0.001
H_0	**Model with access to electricity**				
None[a]	0.812	144.201	85.644	0.001	0.130
At most 1[a]	0.724	86.148	68.720	0.002	0.744
At most 2[a]	0.628	51.866	44.746	0.016	0.548
At most 3	0.344	23.436	29.666	0.232	0.456
At most 4	0.244	6.313	16.395	0.434	0.412
At most 5	0.082	1.666	3.742	0.173	0.121

[a] denotes rejection of the hypothesis at the 0.05 level.

Table 5
VECM Granger F-test results.

Variables	Case 1: Model with access to improved water access						
	Δ lnCE	Δ lnIG	Δ lnEN	Δ lnREN	Δ lnTOU	Δ lnWAT	ECM
Δ lnCE		5.03^{b} (0.058)	13.28^{a} (0.002)	4.85^{c} (0.042)	3.53^{c} (0.088)	0.77 (0.532)	-0.225^{a} (0.020)
Δ lnIG	5.42^{c} (0.088)		0.23 (0.742)	0.53 (0.684)	6.04^{b} (0.041)	24.31^{a} (0.002)	−0.031 (0.625)
Δ lnEN	0.77 (0.453)	5.72^{c} (0.082)		3.53 (0.231)	11.42^{a} (0.004)	15.08^{a} (0.003)	−0.381 (0.561)
Δ lnREN	0.35 (0.765)	2.56 (0.571)	3.12 (0.222)		7.63^{b} (0.013)	17.62^{a} (0.002)	−0.505 (0.231)
Δ lnTOU	1.52 (0.41)	0.44 (0.843)	0.46 (0.732)	5.862^{b} (0.042)		13764^{a} (0.003)	−0.057 (0.564)
Δ lnWAT	0.65 (0.581)	3.58(0.352)	0.512 (0.723)	17.23 (0.003)	16.12^{a} (0.003)		0.005 (0.426)
Variables	**Case 2: Model with access to improved sanitation**						
	Δ lnCE	**Δ lnIG**	**Δ lnEN**	**Δ lnREN**	**Δ lnTOU**	**Δ lnSAN**	**ECM**
Δ lnCE		7.42^{b} (0.025)	11.29^{a} (0.007)	1.225 (0.424)	2.72 (0.222)	3.29 (0.176)	-0.365^{b} (0.014)
Δ lnIG	3.26 (0.174)		0.06(0.755)	0.04 (0.777)	6.06^{b} (0.038)	7.42^{b} (0.013)	−0.003 (0.826)
Δ lnEN	0.44 (0.666)	1.68 (0.320)		0.38 (0.768)	5.47^{b} (0.049)	8.38^{a} (0.001)	−0.434 (0.344)
Δ lnREN	0.14 (0.836)	2.00 (0.504)	0.04 (0.884)		4.38^{b} (0.049)	10.62^{a} (0.004)	−0.235 (0.665)
Δ lnTOU	1.46(0.368)	0.47 (0.945)	0.52 (0.842)	8.01^{b} (0.041)		8.15^{a} (0.021)	−0.243 (0.584)
Δ lnSAN	12.07^{a} (0.001)	21.66^{a} (0.002)	1.33 (0.587)	22.03^{b} (0.002)	12.71^{a} (0.004)		−0.037 (0.135)
Variables	**Case 3: Model with access to electricity**						
	Δ lnCE	**Δ lnIG**	**Δ lnEN**	**Δ lnREN**	**Δ lnTOU**	**Δ lnEL**	**ECM**
Δ lnCE		22.42^{a} (0.003)	16.88^{a} (0.002)	2.85 (0.255)	4.52 (0.253)	6.44^{c} (0.053)	-0.381^{b} (0.023)
Δ lnIG	4.245^{c} (0.075)		0.86 (0.651)	3.26(0.224)	21.29^{a} (0.005)	14.24^{a} (0.003)	−0.024 (0.542)
Δ lnEN	0.85 (0.534)	2.52 (0.221)		3.26(0.214)	6.14^{b} (0.026)	21.32^{a} (0.001)	−0.045 (0.861)
Δ lnREN	3.35 (0.222)	1.24 (0.734)	4.21^{c} (0.067)		12.42^{a} (0.004)	19.58^{a} (0.003)	-2.235^{c} (0.080)
Δ lnTOU	2.45 (0.262)	1.82(0.522)	2.33 (0.582)	6.27^{b} (0.028)		14.53^{a} (0.004)	−0.034(0.645)
Δ lnEL	17.22 (0.002)	1.03 (0.500)	2.65 (0.325)	3.46^{a} (0.001)	13.81^{a} (0.003)		−0.005 (0.548)

The values in parentheses are the p-values.

[a] significance at 1 % level.

[b] significance at 5 % level.

[c] significance at 10 % level.

Table 6
Long run elasticity of CE_t.

Variables	Cointegration Regression Tests							
	FMOLS				CCR			
	Coefficient	Std. Error		Prob.	Coefficient	Std. Error	t-Statistic	Prob.
Model [access to improved water]								
lnIG	0.342^{b}	0.240		0.052	−0.166	0.221		0.249
lnEN	1.343^{a}	0.282		0.001	1.556^{a}	0.253		0.001
lnREN	−0.362	0.213		0.234	0.203	0.228		0.642
lnTOU	-0.221^{b}	0.051		0.024	-0.201^{a}	0.053		0.01
lnWAT	-1.553^{b}	0.522		0.023	-2.262^{a}	0.641		0.001
Diagnostic tests	**test Stat.**	**Prob.**	**Decision**		**test Stat.**	**Prob.**	**Decision**	
JB test for normality of error	0.631	0.662	Normality exist		0.225	0.833	Normality exist	
Model [access to improved sanitation]								
lnIG	0.123	0.124		0.388	-0.403^{a}	0.230		0.001
lnEN	0.524^{a}	0.234		0.001	1.252^{a}	0.282		0.001
lnREN	-1.227^{a}	0.081		0.001	-0.810^{a}	0.0281		0.002
lnTOU	−0.213	0.052		0.213	-0.222^{a}	0.072		0.002
lnSAN	−0.082	0.053		0.233	-0.234^{c}	0.084		0.07
Diagnostic tests	**test Stat.**	**Prob.**	**Decision**		**test Stat.**	**Prob.**	**Decision**	
JB test for normality of error	2.758	0.338	Normality exist		0.589	0.278	Normality exist	
Model [access to electricity]								
lnIG	0.258^{c}	0.212		0.072	-0.123^{b}	0.222		0.034
lnEN	0.618^{a}	0.234		0.001	1.321^{a}	0.281		0.003
lnREN	-1.084^{a}	0.048		0.002	-0.734^{a}	0.045		0.002
lnTOU	-0.234^{a}	0.034		0.024	-0.271^{a}	0.092		0.001
lnEL	-0.233^{b}	0.324		0.024	-0.254^{a}	0.321		0.009
Diagnostic tests	**test Stat.**	**Prob.**	**Decision**		**test Stat.**	**Prob.**	**Decision**	
JB test for normality of error	2.024	0.245	Normality exist		0.065	0.845	Normality exist	

[a] significant at 1 %.

[b] significant at 5 %.

[c] significant 10 %.

investigated links between x and y to see if there was any evidence of causation. It is claimed that x is a Granger-cause of y in the event that its current value can be predicted using just past information about x. An ECM that is statistically significant and negative coefficient indicates a long-term causal connection between the variables and the one that is provided. The Granger causality study saw the availability of improved water, sanitation, and power as separate factors.

Long-term carbon dioxide emissions in China were found to be causally related to the availability of better water, sanitation, and electricity, as indicated by a negative and statistically significant ECM coefficient. The selected variables were discovered to possess a causal effect on long-term CO2 emissions. The final case study examined the ultimate causes of switching to renewable energy sources.

The feedback hypothesis linking CO2 emissions to GDP per capita (cases 1 and 3) was supported by short-run causality results, as were the hypotheses linking tourism to consumption of renewable energy (all cases) and to increased availability of potable water (case 1), sanitary facilities (case 2), and electricity (case 3). The theory of feedback suggests that these elements influence one another through a feedback loop. In the short-run, using more energy leads to higher CO2 levels (in all cases); tourism boosts GDP per person (all situations too). Meanwhile, there's a connection between renewable energy and less CO2 emissions in one case. More travel results in increased carbon dioxide production as well. Lacking electricity access means greater emissions from human activities 3 times respectively.

Granger causal relationship analysis supports the inclusion of these factors in the analysis. Access to clean water, modern sewage systems, and reliable electricity were all shown to be critically important by the energy-growth-environment framework. Improved water accessibility boosted economic productivity, tourism, renewable energy, and energy consumption. It highlighted the urgency of upgrading the country's water infrastructure. An increase in sanitary facilities has a similar multiplicative impact on tourism, renewable energy, energy use, and GDP. Access to electricity was a contributing portion of the increase in CO2 emissions, GDP, energy use, renewable energy, and tourism. In the context of the environment-growth nexus, the findings of the causality analysis highlighted the significance of renewable energy, tourism, and improved access to power, water, and sanitation.

4.4. The long-run elasticity of CE_t

Estimating Elasticity in the long run coefficients of CO2 emissions regarding inclusive growth, usage of energy, renewable energy, and the role of tourism of exports, and access to better sanitation and water resources, and power is explored in Table 6. Two cointegration regression methods, FMOLS and CCR, were used to estimate the regression coefficients for more accurate estimates. Three separate experiments were conducted to estimate long-run elasticity, with better water, sanitation, and electricity availability serving as independent variables.

Based on FMOLS's findings, a 1 % increase in Inclusive growth leads to a 0.342 % (Model1) and 0.258 % (Model 3) increase in CO2 emissions per person. Economic development pushes carbon dioxide emissions and in turn the more you spend, the more emissions arise. The bigger the economy the better, it the higher the consumption of energy [92].

An increase of 1 percent in energy consumption per person resulted in a rise of 1.343 % in CO2 emissions in Case 1, 0.524 % in Case 2, and 0.618 % in Case 3. The emission of CO2 which is mainly attributed to the development of urban areas have a positive long run relationship with urbanization. 1 % additional renewable energy resources incorporation into the energy mix.CO2. Release is the main driver of 0.865833 % rise of the urbanization. 0.681991 % respectively. Moreover, over an urbanization of a one more percent as well as an increase in CO2 emission there will be a readiness in energy consumption, that is how we see it [93].

0.571683 % and 0.883922 % respectively Increasing the tourism sector's proportion of total exports by just one percent will reduce CO2 emissions by 0.221 % (case 1) and 0.234 % (case 3). Certainly, tourism and travelling are among the reasons of emission of greenhouse gases from such sources as CO2 and CH4. However, nox, HFCs, PFCs, and SF6 are also large contributors of greenhouse gases [94]. For every A 1 % rise in the utilization of green energy, CO2 emissions were reduced by 1.117 % (case 2) and 1.093 % (case 3). If only one percent more people had access to clean water and reliable energy, global CO2 emissions could be reduced by 1.553 % and 0.0.233 %, respectively.

Based on CCR findings, a 1 % improvement in inclusive growth leads to a 0.403 % decrease in per capita CO2 emissions (case 2) and a 0.123 % decrease (case 3). In scenario 1, the rise in CO2 emissions per person was 1.556 %; in case 2, 1.252 %; and in case 3, 1.321 %. Case 1 had a 0.201 % drop, Case 2 saw a 0.222 % drop, and Case 3 saw a 0.271 % drop in CO2 emissions per person because of a 1 % rise in the tourism sector's proportion of exports. In cases 2 and 3, a 1 % increase in the use of renewable energy led to a 0.810 % and 0.734 % reduction in CO2 emissions per person. A 1 % rise in the populace's access to better sanitation and water, and power resulted in a 2.262 %, 0.234 %, and 0.254 % drop in CO2 per capita, respectively.

The regression results make it abundantly evident that the rise in CO2 emissions per capita owing to rising energy use and GDP can be readily counteracted by the growth in renewable energy consumption, tourism, and population access to improved water, sanitation, and power. Thus, the government of China should boost the percentage of renewable energy in the country's overall energy mix. The government should also take action to boost the tourism industry's contribution to total exports. An uptick in visitors means more money from out of country and more work for those already employed in the sector. The government's responsibility in attracting international tourists is twofold: maintaining popular destinations and finding.

5. Conclusion and policy implications'

Extreme weather, such as floods and pollution, are among the natural calamities that China has experienced because of environmental deterioration. China is a developing nation that recognized the importance of energy to its development goals of raising GDP per capita. It is also crucial to boost the tourism industry's contribution to total exports. Citizens have a right to expect that their fundamental needs, such as access to clean water, adequate sanitation, and reliable energy, will be met. Thus, the current study synthesizes these topics and describes the interplay between carbon dioxide emissions, inclusive growth, per capita energy use, renewable energy sources, tourism, and the availability of better water, sanitation, and power infrastructure in China between 1990 and 2021. Three-unit root tests were used to specify the proper sequence of integration before any empirical analysis was performed. Long-term cointegration was demonstrated by the Johansen cointegration test. Long-term the relationship between CO2 emissions and the country was demonstrated by the vector error correction model. The feedback hypothesis between carbon dioxide emissions and GDP per capita, tourism and renewable energy, tourism and improved water and sanitation, and tourism and access to electricity, was developed by using short-run causality data. According to the feedback hypothesis, there is a causal relationship between the aforementioned factors. Economic output, energy consumption, renewable energy, and tourism all benefited from easier access to better water. It drove home the need for better water infrastructure throughout the country. In a similar vein, GDP, energy consumption, renewable energy, and tourism were all influenced by the availability of better sanitation. Electricity availability also had a significant causal effect on carbon dioxide emissions, GDP, energy consumption, renewable energy consumption, and travel and tourism. Renewable energy, tourism, and access to improved water, sanitation, and electricity were all highlighted as having a significant impact on the environment-growth nexus by the results of the causality analysis. Increasing the tourism sector's proportion of total exports by just one percent will reduce CO2 emissions by 0.221 % (case 1) and 0.234 % (case 3). For every 1 % increase in the utilization of renewable energy, CO2 emissions were reduced by 1.117 % (case 2) and 1.093 % (case 3). If only one percent more people had access to clean water and reliable energy, global CO2 emissions could be reduced by 1.553 % and 0.0.233 %, respectively. According to the long-run elasticity coefficients, the rise in CO2 emissions per person owing to rising energy use and GDP is readily offset by rising use of renewable energy, tourism, and access to improved water, sanitation, and electricity. The government of China must take action to boost tourism and the use of renewable energy sources. The government's responsibility in attracting international tourists is twofold: maintaining popular destinations and finding new ones. The government should take the necessary steps to give every citizen in the country access to modern utilities like running water, flush toilets, and power. Sites and uncover the new destinations that will entice the world's travelers. To boost tourism in the north, the government should work to strengthen the region's security. Improving people's standard of living is a top priority for governments everywhere. The key factors in determining a person's level of life are their availability to basic infrastructure like running water, proper sanitation, and power. Water, sanitation, and energy availability are all indicators of economic health. Therefore, the government should take the required steps to provide modern water, sanitation, and energy to the entire population.

6. Caveats and limitations

Due to time and financial constraints, this study has some limitations.

Data Limitations: The paper uses the data starting from 1990 which is the time when the cold war was over to 2021, when there may have been agreeable changes in policies, technology, and the world economy that could have not been fully captured in the data. Using current data can help to take a clearer picture of what is happening right now and shed light on possible future of the issue. Second: this study used Co2 emission as dependent variable, future study could use Ecological footprint as indicator of environment. Third: Future studies could check the cross-country analysis and panel data analysis for the variable under consideration.

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Availability of data and material

Data will be available on request.

CRediT authorship contribution statement

Shiqi Wang: Formal analysis, Data curation, Conceptualization. **Manman Zhang:** Writing – original draft, Software, Project administration, Methodology, Conceptualization. **Nana Tang:** Writing – review & editing, Supervision, Methodology, Data curation. **Qamar Ali:** Visualization, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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