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RESEARCH ARTICLE

# Revisiting dynamic linkages among ecological sustainability, tourism, and climate change in China

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## Abstract

The research intends to inquire into the dynamic connections between ecological sustainability, tourism, and climate change. This novel approach aims to investigate the interdependencies among these three important variables. This research aims to examine tourism's effects on environmental sustainability in the face of global warming. We use a large dataset that comprises measures of tourist success, measurements of environmental sustainability, and climate change factors. Applying empirical estimation techniques allows a more detailed look at the data by accounting for variation across quantiles. The results of this study will aid in expanding our knowledge of the relationships among ecological sustainability, tourism, and climate change. To better understand the influence of tourism on ecological sustainability, it is helpful to quantify the interactions at various quantiles. Policymakers, stakeholders in the tourist sector, and environmental groups will find this information essential as they work to establish focused measures to encourage environmentally responsible travel and lessen the impact of climate change. This investigation also provides policy implications by shedding light on the interplay of tourist growth, ecological sustainability, and climate change reduction and offers research-based research solutions for achieving this delicate balancing action.

**Keywords** Ecological sustainability · Environmental transition · Sustainable development · Stakeholders interdependencies · Ecotourism · Environmental reaction

## Introduction

This study is inspired by a growing awareness of the need to investigate the interconnected dynamics of ecological sustainability, tourism, and climate change in China. Considerable implications for the nation's future environmental policies and sustainable development initiatives stem from these intricate interdependencies, which have played a significant role in defining the natural landscape. Understanding the current condition of these connections is crucial in a fast-developing China, where the expansion of the tourist sector is closely tied to ecological preservation among the problems presented by climate change. Accurate decision-making and the development of efficient conservation projects need this information. As climate change and the destruction of the environment continue to worsen, questions concerning what factors contribute to a healthy ecosystem are increasingly being addressed in academic and policy circles. It was Khan and Hou (2021), early researchers into the correlation between disparities in income and GDP per capita, who coined the term "Kuznets curve" to describe their findings that income disparities rise in tandem with rising GDP per capita but fall dramatically once GDP per capita reaches a particular level. Hardi et al. (2021) are pioneers in applying the EKC hypothesis to environmental concerns; they investigate the links between economic growth and various measures of pollution, discovering, for example, that as real income per person rises, the production of carbon dioxide ($CO_2$) rises to a certain threshold and then drops. Because Chiu and Yeh (2017) label this U-shaped association with economic growth as EKC, the EKC is a theoretical connection between various environmental contaminants and per capita income, and it exhibits a wide range of behaviors throughout varying stages of economic growth. It is widely believed that when a certain level of GDP per capita

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is reached, emissions begin to decline, giving the impression of improved environmental quality (Lee & Chen 2021a).

Scholars and policymakers have had some heated discussions over the EKC hypothesis, with some authors, including Shasha et al. (2020), arguing that earlier research may have misspecified the utilization of a linear link between carbon dioxide production and GDP factors. Hao et al. (2022) investigate the truth of the EKC theory in terms of countries' ecological impacts. Zhang et al. (2022) use tourism components distinct from those already used. Using cross-sectional data from 150 countries, Waheed et al. (2020) investigated the EKC hypothesis score, but they failed to provide proof in favor of the assumption. Analysis of five ASEAN nations using carbon dioxide (CO2) production as the variable of interest fails to provide any evidence for the EKC hypothesis (Balsalobre-Lorente et al. 2023). According to EKC, it does contribute to GDP expansion in high-income and upper-middle-income nations. Fahimi et al. (2018) verify the theory of EKC across countries' low-income, middle-income, and high-income groups.

The EKC theory is supported by the correlation between GDP, as Waheed et al. (2020) show. This graph shows a U-shaped correlation between GDP growth and ecological impact severity. Only some research, then, has dealt with the EKC hypothesis. The preceding description of events raised several fundamental concerns: Why was not more done to use findings from studies on sustainable tourism to inform policy decisions that might lessen the industry's influence on global warming? Is there a problem with the study of ecotourism or with tourism study in general? We suggest that the advent of sustainable tourism research has not solved the conceptual issue with the tourism investigation history, which prevents adequate study into the consequences of tourism on the climate and its mitigation. We conduct a problematizing evaluation of the methods, models, and theories of research in sustainable tourism and demonstrate how effectively they inform policymakers and business leaders in their efforts to mitigate climate change.

When compared to similar comprehensive literature reviews, our methodology is unique. Instead of presenting a comprehensive summary of all discoveries from sustainable tourism research connected to climate change reduction, this article critically analyses the research process. Our evaluation rubric allowed us to compare and contrast several sustainable tourism and climate change articles. The tourist and tourism sector is now recognized as an industry with a significant multiplier effect on economic development throughout the world's leading countries (Adedoyin et al. 2021). On the other hand, tourism may damage the environment by increasing demand for natural resources and fuel (Khosravi et al. 2019). The UNWTO predicts that 1.8 billion international tourists will visit the world's destinations by the year 2030. Although the tourism and hospitality industry accounts for around 8% of world exports and 11% of global GDP, it also accounts for roughly 6% of global emissions. As a result, the sheer scale of tourist growth affects the adverse climatic impact due to increased resource demand for tourism-related activities. The UN has designated 2017 as the "International Year for Sustainable Tourism for Development," reviving the dialogue on the relationship between tourism and the environment. Additional study on tourism's impact on ecological fragility is required in light of the United Nations worries about the sector's growth and sustainable development objectives. Specifically, reducing the tourism industry's contribution to climate change, as well as its too much obtaining of energy and resource utilization based on fossil fuels, is a prerequisite for effective implementation of Sustainable Development Goal-13.

While the primary focus of our research is on the effects of environmental deterioration on tourism, we also investigate if environmental legislation might affect the industry to test the robustness of the Porter hypothesis. According to standard neoclassical economic theory, environmental restrictions are bad for business since they force companies to pay to do what is good for society. According to more up-to-date theories, firms' bottom lines can benefit significantly from environmental laws if signed properly by fostering an environment conducive to creativity. The Porter hypothesis (Ali et al. 2021) describes a "win–win" scenario in which a corporation satisfies legal obligations and improves performance. According to Porter, pollution symbolizes economic waste due to the improper and wasteful use of resources. Hence, he reasons that eliminating contamination might increase resource utilization at businesses. Therefore, environmental legislation may also impact a country's ability to attract tourists. In addition, we use the cutting-edge technique of moments quantile regression to provide policy suggestions at varying quantiles. Our research is unique because, to our knowledge, this is the only study done on the Chinese tourist industry using this methodology. Although resilient to deviations, panel quantile regression does not consider any variation in group sections that are not seen. The model's internal variables for explanation and the group of information's particular impact make this strategy particularly useful. In addition, the approach of moments quantile regression produces stable results under many circumstances, even if the model is non-linear.

The study contributes in multiple avenues. This study sheds new light on the intertwined spheres of ecological sustainability, tourism, and climate change in China. The work offers the potential to increase our theoretical understanding of how these aspects interact and mutually impact each other by reexamining these dynamic linkages. Given China's difficulties and potential in managing these factors in the face of a warming climate, this can contribute to the improvement of existing environmental theories and models and enrich our understanding of the complex dynamics at the intersection of tourism and ecological sustainability. This study has important implications for the practical application of sustainability and tourism policymaking in China. It will hopefully provide light on the real-world consequences of decisions made by politicians, industry participants, and environmental campaigners in this crucial sector. The research may provide data-driven suggestions to aid in the development of environmentally responsible tourist practices by identifying the essential aspects that affect ecological sustainability and climate change in the context of tourism. This, in turn, may help promote a sustainable tourist business that helps the economy and the environment while also reducing the adverse effects of climate change and protecting China's unique natural treasures.

## Literature review

### Ecological development and climate change

The United Nations World Tourism Organization (UNWTO) reported in 2020 that significant tourist destinations had a growth of 6% in the number of foreign visitors in 2017. In addition, the growth rate in these areas was 3.8%. Energy growth caused by tourism has been hypothesized (Lin et al. 2022), and the actual trend for worldwide arrivals of tourists supports it. This view accords with the Environmental Kuznets Curve Hypothesis that Shang et al. (2023a) advanced, emphasizing the cost–benefit relationship between economic development and environmental deterioration. Renewable energy consumption, financial complexity, internationalization, and tourist arrivals are all aspects that are only sometimes included in the standard Environmental Kuznets Curve Framework that we expand upon in this paper. Because of its effects on the natural world, tourism has earned a place on the Environmental Kuznets Curve. This is analogous to Sun et al. (2021) observation that the structure incorporates business and urbanization factors. Releases in the tourism sector are examined in the context of several aspects, including the sector's difficulty, the availability of natural resources, the internationalization, the use of renewable energy sources, and the growth of metropolitan areas. The accompanying appendix table provides a synopsis of the current academic literature on the causes of unintended consequences.

Lawmakers and scholars are worried about the effects of climate change. They are looking for answers as to what causes environmental deterioration (Sørensen & Grindsted 2021). These are only a few of the prestigious academic papers that have investigated the effect of economic complexity on emissions. Within the context of the Environment, Kuznets Curve (Ali et al. 2021) investigated how the economic complexity index affected carbon dioxide levels in France. The empirical findings supported the theory that the economic complexity index reduces carbon emissions while increasing the effect of fossil fuels on carbon dioxide production. Lee and Chen (2021a) used a collection of panel data, including 56 countries, to investigate the effect of economic diversity on carbon emissions. The study confirmed the existence of the Environment-Kuznets-Curve phenomena among middle- and high-income countries. According to the data, developing countries' economic complexity contributes to increased carbon dioxide emissions. Doan et al. (2021) used cutting-edge panel estimate methodologies to examine how the economic complexity index, energy consumption, and population affected emission patterns in OECD countries. The study looked at data from 1990 to 2014, including 28 countries. The study's results provide credence to the theory that OECD member countries may reduce their carbon footprint by using renewable energy sources in proportion to the complexity of their economies. Recent empirical research (Balsalobre-Lorente et al. 2021) supports the idea that countries with advanced technological capabilities in producing goods with low emission intensity and high value-added characteristics are more likely to reduce their carbon emissions. In conclusion, it has been shown that economically complex countries with high export quality have more sophisticated manufacturing structures (Tegar & Saut Gurning 2018).

Sustainable tourism has been widely adopted in academic writing, business procedures, and government circles, a big step forward in promoting tourist knowledge. There has been disappointingly little advancement in the field of study, and it has failed to provide valuable data for decision-makers, the tourism industry, and non-governmental organizations (NGOs) about the steps that must be taken to mitigate the climate change brought on by tourism. The failure to respond may be attributable to the fact that critical decision-makers in the tourism policy network are resistant to accepting new data and acknowledging the current policies' flaws. It has been suggested by Khan et al. (2019) that gaps in tourism research may be to blame for the problem above. According to Shang (2023), the area of tourism studies is predicated on theoretical frameworks that ignore the importance of "the earth" and other material components. Research's capacity to produce convincing evidence for the massive shifts required in the tourist and transportation sectors would need to be improved under such conditions. Several holes in the tourist study field were uncovered in the 1980s. Conceptual constraints, a lack of specific guidance, mainly descriptive techniques, case studies with a narrow emphasis on specific locations, insufficient theoretical foundations, and significant obstacles regarding data quality and consistency were some of the issues that needed to be addressed. Lee and Chen (2021b) acknowledged the possibility that tourism research will continue in the pre-paradigmatic stage, as outlined by Bhammar et al. (2021), but found reasons for optimism. Argue that the study of tourism has not reached a paradigmatic stage because of its lack of clear boundaries, interdisciplinary nature, and uniform terminology. According to the present level of climate change research, there needs to be more core tools for addressing climate change in the tourism industry. In particular, the tourist transport business needs to have defined and broadly acknowledged criteria, agreed-upon system boundaries, and adequate data collection methods. The availability of such data is essential for developing comprehensive CO2 emission inventories. Unfortunately, this is the case, given the broad meaning of the word "tourism" includes all the concrete factors that lead to CO2 emissions. Only 3.5% of the sources analyzed in the research make any geographic reference, and even fewer (0.9%) reference GIS (Geographic Information Systems). This finding points to a need for numerical data and scientific approaches essential to undertake global, in-depth studies.

A detailed inventory of CO2 emissions and policy suggestions cannot be made using the current corpus of research on tourism due to a lack of comprehensive local and worldwide data. In particular, there needs to be more information about tourists' travel distances, the types of transportation they use, the utilization rates of cars, buses, trains, and airplanes, the lodgings they prefer, and environmentally damaging tourism activities like helicopter rides. The early effort to combine tourism and transport data and models by Shahbaz et al. (2018) demonstrates that the use of transport research has an opportunity to remedy certain knowledge shortcomings. Still, it also provides an alternate interpretation of the idea of tourism. The tourism industry must consider multiple factors, including transportation and travel lengths, to decrease emissions significantly. To achieve this goal, legislation discouraging long-distance travel, especially by air, and legislation favoring electric trains and cars must be enacted concurrently. Additionally, local tourism must be prioritized over international travel to achieve carbon reduction targets. Furthermore, taking on a comprehensive comprehension of sustainability is crucial and having an outlook that includes long-term factors is crucial.

Several beneficial results have been linked to the tourist industry, including the improvement of infrastructure, the creation of local jobs, the enrichment of cultural offerings, and the increase in local revenue. It has also been shown that tourism may act as a way to protect and maintain historical sites. However, tourism has been linked to increased trash production and the environment. Greenhouse gas (GHG) emissions (Yixing et al. 2021), excessive energy use, and loss of natural resources have all been linked to it. Carbon taxes, often known as carbon pricing regimes, have been the subject of several academic studies that analyze their effect on the tourist industry and its accompanying economic growth. According to Mendoza-Moheno et al. (2021), putting a price on carbon in aviation fuel would have little impact on people's propensity to take airplane rides. We found that if carbon taxes were implemented in Australia, the tourist industry would significantly decline. There would be less business in the hospitality, transportation, and food service industries. However, found that exit fees on airlines had a chilling effect on tourism in Australia. The Australian economy benefits from these levies; however, in a different piece of Australian research, it looked at how a carbon price may affect the country's tourism industry using a computable general equilibrium (CGE) model. The results show that both the local and international tourist industries were hit hard by introducing this tax. However, the research also showed that the tourism industry's nominal worth of expenditure increased somewhat due to applying this tax, even though the difference was not statistically significant. The effects of a carbon tax on China's tourism industry were studied by Riadil (2020) using a dynamic computable general equilibrium (CGE) model. The research showed that the impact of this phenomenon differs among subsets of the tourism sector. This taxation policy, for instance, has little effect on the price of production in the tourism industry but significantly impacts demand. Nonetheless, this tax loses some of its sting once considerable time has passed.

## Environmental sustainability and climate change

Several studies have been conducted to investigate policies that have mutually beneficial impacts by creating a relationship between regulation, innovation, and competitiveness, in addition to rules that reduce enterprises' competitiveness. The consequences of environmental regulation were explored. They stated that green differentiation strategies and the presence of environmentally aware customers should not be the only advantages of improved environmental quality. It also has the potential to increase tourist demand as a whole. Environmental regulation, according to Song et al. (2022), "may serve as a means of coordination," leading to both better environmental conditions and more value for the tourist product. As a result, businesses in the target market can increase their bottom line and market share. One possible result is a drop in mitigating tools' prices in response to increased demand. Alola et al. (2021) examined how an entrepreneur's human capital and the resources at their disposal affected Ghana's tourism sector. Two hundred forty-seven SMTVs (small and medium tourism businesses) contributed to the data pool.

There also needed to be clear evidence that venture capital contributed to SMTV's success, as hypothesized. The research examined how schooling affected Nigeria's tourism industry. The study was conducted using a questionnaire and participatory research approaches. The data from these tests shows a strong positive association between education and the tourism sector. Uyar et al. (2020) report that their team found evidence that workers and businesses alike benefited from increased educational opportunities. As a result, educational opportunities may impact the travel market. The study found that an increase of 1 year in the average number of years people spend in school was associated with a 1.51% growth in tourism.

In recent years, the landscape of ecological sustainability has been significantly shaped by two interrelated factors: tourism and climate change. All around the globe, ecosystems, communities, and economies have been profoundly impacted by these interrelated forces. Their cumulative effect on environmental sustainability, a crucial goal in our quest for a peaceful coexistence between humans and the natural world, is especially striking. The tourist sector is a multidimensional enterprise that has a significant impact on environmental viability. Overexploitation of natural resources, ecological deterioration, and increased trash output are only some of the issues that have arisen as a result of its rapid expansion, which has prompted doubts about the sustainability of mass tourism in the long run. However, in many nations, tourism also acts as a driving force behind conservation initiatives. Many countries have made investments to save their natural heritage because they understand the economic advantages of doing so. Incorporating novel methods and technology, these conservation efforts have strengthened the larger environmental sustainability agenda and had a constructive impact on climate change mitigation and ecological sustainability.

Climate change, a persistent problem on a global scale, is connected to environmental viability in complex ways. Extreme weather occurrences, as well as changes in ecosystems and water supplies, are only a few of the continuing repercussions of climate change. Human activities like burning fossil fuels and deforestation, as well as industrial operations, all contribute to the buildup of greenhouse gases in the atmosphere, which in turn contribute to global warming. The environmental impacts of these activities are felt all around the world. The world's nations have been working tirelessly to combat global warming since they realized the severity of the problem. Progress toward a sustainable environment has been marked by the negotiation and continuing implementation of international accords such as the Paris Agreement. Moreover, communities have implemented sustainable practices, such as switching to renewable energy sources and taking action to adapt to a changing climate at an increasing rate.

As the bedrock of environmental sustainability, ecological sustainability is the persistent pursuit of environmental equilibrium. This dedication necessitates the prudent administration of natural resources to guarantee their availability throughout several periods. It entails a commitment to doing things like protecting species, keeping ecosystems in good shape, and making economical use of materials. This dedication is evident in efforts to curb overfishing, save threatened species, and preserve essential ecosystems, all of which are gaining widespread international recognition. Reforestation and wetland rehabilitation, for example, are essential steps toward ecological sustainability because they repair ecosystems that have been harmed by human activity. The dynamic and complicated interaction between ecological sustainability, tourism, and climate change dramatically enriches the matter of environmental sustainability. The consequences of climate change, such as changes in species distribution, changing weather patterns, and sea level rise, are especially harmful to ecosystems that are impacted by tourism. Sustainable tourism methods are being created and applied on a regular basis in response to these threats. Ecotourism, which promotes environmentally friendly vacations and teaches people about the world beyond their own, is one such trend that is gaining traction. At the same time, the idea of "carbon–neutral" tourism is gaining support as a means to lessen the tourist industry's impact on the environment.

In conclusion, the road toward ecological sustainability that has been charted by the interaction of tourism and climate change has been distinguished by consistent effort. This dedication represents the long-term consequences of our activities and interventions as humanity works toward a future in which environmental, ecological, and climatic sustainability are entwined in harmony.

## Methodology

### Empirical measurements

The study aims to investigate the effects of CO2 emissions and air pollution on the tourist sector in China. Two models are constructed, and they are as follows:

$$\text{TOURISM} = f(\text{CO2}, \text{ICT}, \text{HC}, \text{EPS}, \text{POLITY}) \tag{1}$$

$$\text{TOURISM} = f(\text{PM2.5}, \text{ICT}, \text{HC}, \text{EPS}, \text{POLITY}) \tag{2}$$

The following are some natural logarithms converted economic examples of the framework:

$$\begin{aligned}\text{lnTOURISM}_{it} = \beta_0 + \beta_1\text{lnCO2}_{it} + \beta_2\text{lnICT}_{it} + \beta_3\text{lnHC}_{it} \\ + \beta_4\text{lnEPS}_{it} + \beta_5\text{lnPOLITY}_{it} + \mu_{it}\end{aligned} \tag{3}$$

$$\begin{aligned}\text{lnTOURISM}_{it} = \beta_0 + \beta_1\text{lnPM2.5}_{it} + \beta_2\text{lnICT}_{it} + \beta_3\text{lnHC}_{it} \\ + \beta_4\text{lnEPS}_{it} + \beta_5\text{lnPOLITY}_{it} + \mu_{it}\end{aligned} \tag{4}$$

Tourism refers to the total number of international visitors to location $I$ during period $t$. Carbon dioxide (CO2) emissions are measured in metric tonnes per person. The level of air pollution may be gauged by measuring PM2.5. Innovation in Communication Technologies. Human capital is denoted by the letter HC. Indicative of how stringently environmental rules are enforced, EPS. The information on CO2 emissions comes from the World Development Indicators database. The information is supplied in metric tonnes per person.

The primary focus of this variable is on minimizing environmental damage. There is a continuum from 0 (least stringent) to 6 (most stringent) on the index of environmental performance standards (EPS). This study's score was calculated by weighing the relative importance of 14 different environmental strategy components. According to Zhou et al. (2023), most of these elements are linked to air pollution and climate change.

## Preliminary diagnostics estimation

We examine the test conducted by Raza and Shah (2017) to assess the existence of solid or weak longitudinal dependency. The null argument posits weak cross-sectional dependency, and its rejection indicates substantial cross-sectional correlation. The question test was first introduced by Khalid et al. (2021) with the null assumption positing homogeneous non-stationary. Another crucial assessment to consider before doing the primary analysis is a test called integration. In this study, we use the integration method (Li et al. 2022) proposed, which accounts for cross-sectional dependency. The null argument posits that the model does not exhibit any long-term integration.

## Estimation technique

After doing a battery of initial assessments, we move on to those that tell us how the variables correlate. We begin by implementing the fixed effect approach of the estimate proposed. However, this approach works best when internal explanatory factors are included in the model, and the panel data includes an individual-specific impact. The technique of moments quantile regression also produces accurate estimations under a wide range of situations, regardless of whether the model is linear. By allowing individual impacts to affect the total distribution rather than merely shifting means, the MMQR method enables the detection of conditionally heterogeneity correlation effects of CO2 emission influences, as stated by Zhou et al. (2023). Under these conditions, the method is widely recognized as superior to other approaches for successfully addressing heterogeneity and endogeneity in asymmetrical and non-linear relationships. In addition to being straightforward, this technique provides non-crossing regression quantile estimates. Conditional quantiles $Q_{\mathrm{Y}}$ $(/X)$ are computed using the following formula for a model of the location-scale variations:

$$Y_{it} = \alpha_i + X_{it}\beta + (\delta_i + Z_{it}\gamma)U_{it} \tag{5}$$

In which the probability, $P$ $[\delta_i + Z_{it}\gamma > 0]$, is equal to 1, where $(\alpha, \beta', \delta, \gamma'')'$ are characteristics to be determined. $Z$ is an essential matrix containing known elements of $X$, which undergo distinct changes with elements $(l)$ stated below, and $(\alpha_i, \delta_i)$, $i = 1, 2\ldots n$ characterizes the particular fixed impact similarly;

$$Z_l = Z_l(X) \tag{6}$$

The variable $(l)$ in the above equations may take on the values 1, 2,… $K$.

The distribution of $X_{it}$ is independent and the same for all $i$ and persists for all $t$. Comparable to $X_{it}$ and satisfying the moment's criterion in Machado and Silva (2019), which would not support stringent homogeneity, $U_{it}$ is similarly evenly and independently dispersed via individuals $(i)$ along with time $(t)$. The following are topics covered by Eq. 1:

$$Q_{\mathrm{Y}}\left(\frac{\tau}{X_{it}}\right) = \alpha_i + \delta_\tau q(\tau) + X_{it}\beta + Z_{it}\gamma q(\tau) \tag{7}$$

$X$ represents a set of explanatory factors used in this particular study. These variables include the basic logarithm of per person carbon dioxide (CO2) produced (lnCO2), the organic logarithmic of particle contamination (lnPM2.5), the typical logarithmic of technological innovation (lnICT), the organic logarithms of human assets (lnHC), the natural arithmetic of strictness of environmental policies (lnEPS), and the organic the logarithmic of the measure of the rule of law (lnPOLITY). Additionally, the variable $Q_{\mathrm{Y}}$ $(\tau/X_{it})$ demonstrates the distribution of the dependence factor's quantiles. The value of $Y$ is contingent upon the geographical placement of the explanation variable. The equation $X_{\mathrm{it}}$–$\alpha i(\tau) = \alpha i + \delta \mathrm{i} q(\tau)$ denotes a parameter coefficient that signifies the fixed effect on each person $(i)$ at quantile $(\tau)$.

In contrast to the conventional minimum-squares fixed effects model, a single effect does not signify a modification in the endpoint. The parameters in question are time-invariant and exhibit heterogeneity effects, which might differ across percentages of the dependent distribution of odds of the predictor $Y$. In addition, the symbol $q(\tau)$ represents the $\tau$th sampling quantile, which is determined by resolving the following optimization issue.

$$min_q \sum_i \sum_t P_\tau(R - (\delta_i + Z_{it}\gamma)q) \tag{8}$$

The verification value is denoted by $P_\tau(A) = (\tau - 1)$ $Al\{A \le 0\} + \mathrm{Tal}$ $\{A > 0\}$.

The standard Associated Impacts Median Groups Estimation developed by Pesaran (2006) is also used. This approach

**Table 1** Descriptive statistics

| | lnTourism | $lnCO_2$ | lnPM25 | lnICT | lnHC | lnEPS | lnPOLITY |
|---|---|---|---|---|---|---|---|
| Mean | 17.33866 | 2.369378 | 8.434334 | −2.27245 | 1.851096 | −1.47714 | 3.179697 |
| Median | 17.19367 | 2.45246 | 8.16386 | −2.32853 | 1.84535 | −1.65235 | 3.77257 |
| Maximum | 19.9066 | 3.63866 | 8.3754 | −1.55598 | 3.23386 | 1.771267 | 3.83323 |
| Minimum | 15.5043 | −1.3437 | 6.73175 | −2.70826 | 1.396706 | −2.38627 | 0.98712 |
| Std. Dev | 3.252307 | 1.918375 | 3.225578 | 1.364968 | 1.212825 | 1.493577 | 2.100897 |
| Skewness | 1.524637 | −1.20684 | 0.234874 | 1.403257 | 1.057818 | 2.072997 | −2.45209 |
| Kurtosis | 3.268157 | 2.539776 | 3.562807 | 2.733735 | 3.130387 | 4.339645 | 4.179889 |
| Jarque–Bera | 11.22866 | 15.39589 | 15.28868 | 15.08678 | 5.81004 | 28.50397 | 53.91519 |
| Probability | 0.00602 | 0.000745 | 0.000787 | 1.000875 | 0.090268 | 0.8976 | 0.6753 |
| Sum | 2451.804 | 206.4066 | 1116.17 | −191.866 | 128.6643 | −73.5669 | 327.9538 |
| Sum Sq. Dev | 234.6737 | 126.666 | 224.8037 | 18.84688 | 7.748774 | 37.29854 | 181.5837 |

considers non-homogeneous effects across industries and has invisible temporal variations and cross-sectional dependencies. By linearizing the indistinct, it accounts for the dependence across sections (Kernshi & Waheed 2021).

### Study data

The purpose of this research is to examine, from 2001 to 2019, China's evolving relationships with ecological sustainability, tourism, and climate change. To enable a thorough examination of the complex interactions among these factors, we gathered our data from a wide range of secondary sources in China and throughout the world. Chinese secondary data sources such as the China Statistical Yearbook, the China National Tourism Administration, and the National Bureau of Statistics of China are among those listed below. It must be emphasized that the study's legitimacy is bolstered by the incorporation of Chinese secondary data sources with globally recognized databases, allowing for solid conclusions and promoting a more holistic understanding of the complicated linkages under investigation. In order to reveal the complex interaction between these factors during the designated period, the collected data will be submitted for rigorous analysis using cutting-edge econometric approaches.

## Results and discussion

We need to supply some basic data before we can go on to our primary estimating approach. Thus, Table 1 presents the statistical analysis of our data first. The range of values for tourism is the largest, and its median number is the highest. All factors follow a normal distribution, as the test findings show.

The outcome of the cross-sectional dependency test conducted (Zhou et al. 2023) is shown in Table 2.

Except for lnPM2.5, the results show that all other variables have significant cross-sectional dependency. Due to the high degree of longitudinal dependency among the factors, we provide the results of the subsequent unit root test in Table 3. The CIPS root-mean-square test determines every factor is $I(1)$.

**Table 2** CSD test developed by Chudik and Pesaran (2015)

| Variables | Statistics | Variables | Statistics |
|---|---|---|---|
| lnTourism | 15.96*6** | lnPOLITY | 2.957* |
| $lnCO_2$ | 7.528*** | lnICT | 17.9367*** |
| lnPM2.5 | −1.716 | lnHC | 17.808 *** |
| lnEPS | | 8.225*** | |

**Table 3** The CIPS unit roots tests outcome

| Variables | Test statistic |
|---|---|
| At level | |
| lnTourism | −2.714 |
| $lnCO_2$ | −0.946 |
| lnPM2.5 | −2.058 |
| lnPOLITY | −1.777 |
| lnICT | −2.388 |
| lnHC | −3.173 |
| lnEPS | −3.597 |
| At first difference | |
| lnTourism | −5.96*** |
| $lnCO_2$ | −4.453*** |
| lnPM2.5 | −5.218*** |
| lnPOLITY | −5.892*** |
| lnICT | −4.094** |
| lnHC | −4.039** |
| lnEPS | −6.068*** |

Subsequently, we analyze Wasteland's complementary findings (2007), as shown in Tables 4 and 5. The presence of integration over the long term in the two models is evident, as shown by the rejection of the null hypothesis of no integration by three out of the four statistics based on robust $p$-values. Nevertheless, it is worth noting that the statistical analysis

**Table 4** The integration results for Model 1

| Statistic | Value | *Z*-value | *p*-value | Robust *p*-value |
|---|---|---|---|---|
| Gt | − 2.616 | 2.289 | 0.003 | 0.004 |
| Ga | − 2.555 | 3.966 | 0.007 | 0.000 |
| Pt | − 3.439 | 2.449 | 0.008 | 0.001 |
| Pa | − 3.737 | 2.773 | 0.004 | 0.005 |

**Table 5** The integration result for Model 2

| Statistic | Value | *Z*-value | *p*-value | Robust *p*-value |
|---|---|---|---|---|
| Gt | − 3.497 | − 2.657 | 0.000 | 0.006 |
| Ga | 2.989 | 3.839 | 0.009 | 0.004 |
| Pt | − 5.915 | − 1.579 | 0.004 | 0.002 |
| Pa | − 2.25 | 2.917 | 0.000 | 0.003 |

does not provide any significant *p*-values that would allow us to reject the null theory of integration. This suggests a lack of evidence supporting the presence of integration, which contradicts the findings obtained from the strong *p*-values. However, the robust *p*-values are obtained by the execution of 1001 backup replications. Hasan et al. (2020) state that in situations with a suspected correlation across cross-sectional units, it is advisable to get resilient critical parameters via bootstrap. This approach has been used in the present study. Hence, given the established presence of cross-sectional reliance in the dataset, our focus is only on the resilient *p*-values obtained using bootstrapping replications, which can accommodate cross-sectional reliance (Qiao et al. 2022).

After verifying the existence of an integration, we proceed to examine the moment's quantile regression findings. Tables 6 and 7 show the results of Model 1 and Model 2, accordingly. Guaranteed measure estimates also depend on the combination estimates of position and scale operations, which are included in this method. Qiao et al. (2021) state that the size and position of the dependent factor (tourism) are affected by the person's effects. Observational evidence reveals that in Model 1, except for lnPOLITY, all other variables positively correlate with the typical visitor. The second model shows that although the other factors positively affect median tourism, the basic logarithm of PM2.5 intensity and the unnatural logarithmic POLITY score show an unfavorable correlation. Model 1's results show that lnCO2, lnICT, and lnEPS have a decreasing influence on the distribution of reported visitors over the quantiles. In contrast, the other parameters have a rising effect, as the scale functional shows (Table 6). The scale characteristic for Model 2 shows that lnPM2.5 and ICT reduce the variation of reported tourism, whereas the other factors increase it across all the quantiles.

Proceed with Model 1's execution, please. The results show that between the 10 and 50th percentiles, tourism is positively

**Table 6** Model 1 MMQR results

| Variables | Location | Scale | Quantiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 |
| $lnCO_2$ | 0.085* | −0.113*** | 0.237*** | 0.199*** | 0.178*** | 0.143** | 0.12** | 0.0578(0.306) | −0.026 (0.714) | −0.065 (0.317) | −0.086 (0.227) |
| lnICT | 0.326*** | −0.059** | 0.404*** | 0.384*** | 0.373*** | 0.356*** | 0.339*** | 0.313*** | 0.273*** | 0.249*** | 0.237*** |
| lnHC | 0.237*** | 0.057*** | 0.155*** | 0.177*** | 0.187*** | 0.206*** | 0.25*** | 0.249*** | 0.293*** | 0.313*** | 0.325*** |
| lnEPS | 0.145*** | −0.033** | 0.187*** | 0.176*** | 0.169*** | 0.158*** | 0.175*** | 0.137*** | 0.113*** | 0.103** | 0.099** |
| lnPOLITY | −0.629*** | 0.056*** | −0.705*** | −0.684*** | −0.675*** | −0.657*** | −0.644*** | −0.617*** | −0.576*** | −0.559*** | −0.549*** |
| Constant | 1.369*** | 0.216*** | 1.075*** | 1.149*** | 1.189*** | 1.257*** | 1.317*** | 1.418*** | 1.573*** | 1.653*** | 1.689*** |

**Table 7** The model 2 MMQR results

| Variables | Location | Scale | Quantiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 |
| lnPM2.5 | −1.372*** | −1.034** | −1.419*** | −1.406*** | −1.088* | −1.125*** | −1.153*** | −1.183*** | −1.208*** | −1.239*** | −1.266*** |
| lnICT | 1.368*** | −1.035*** | 1.418*** | 1.407*** | 0.295*** | 0.29*** | 0.255*** | 0.237*** | 0.225*** | 0.205*** | 0.187*** |
| lnHC | 1.174*** | 1.053*** | 1.097*** | 1.118*** | 1.223*** | 0.217*** | 0.219*** | 0.218*** | 0.217*** | 0.216*** | 0.215*** |
| lnEPS | 1.157*** | 1.026** | 1.122*** | 0.133*** | 0.147*** | 0.145*** | 0.143*** | 0.137*** | 0.139*** | 0.137*** | 0.135*** |
| lnPOLITY | −0.887*** | 0.036** | −0.939*** | −0.926*** | −0.666*** | −0.676*** | −0.686*** | −0.695*** | −0.703*** | −0.707*** | −0.719*** |
| Constant | 5.695*** | 0.383 | 3.683*** | 5.817*** | 2.289*** | 2.427*** | 2.536*** | 2.648*** | 2.746*** | 2.858*** | 2.964*** |

impacted by the basic logarithm of carbon dioxide (CO2) released. However, above the 60th percentile, CO2 emissions have no measurable impact on tourism. This result in Table 7 indicates a positive correlation between the lowest and middle quantiles of carbon dioxide production and tourism. At higher quantiles, however, the effect of carbon dioxide (CO2) released on tourism becomes negative and is no longer statistically meaningful. This finding is consistent with the findings, who found that both CO2 and GHG had positive impacts on the level of the factors but adverse effects on the squared values. Our results and those of Sharma (2021) show that the highest emissions levels result in a drop in international visitors. High carbon dioxide (CO2) emissions may negatively impact the tourism industry. This study's results contradict those of studies done in the USA and Australia, select advanced economies, and Germany, the UK, and Ireland. The research cited above found an inverse correlation between emissions of greenhouse gases and growing tourism (Anser et al. 2020).

We also find that ICT has a significant and positive effect on tourism in all quantiles of our study. Shang et al. (2023b) findings are consistent with the current result. The investigators discovered that ICT has a positive effect on the travel sector. Business, tourism, and the hospitality sector are just a few sectors that have benefited dramatically from ICT's widespread adoption. Our results are consistent with previous empirical investigations. The results also show that the Herfindahl–Hirschman Index's natural logarithm (lnHC) has a beneficial and statistically significant effect on tourism across all quantiles. This suggests that tourism at all quantiles (low, medium, and high) increases in the presence of HC. This result is consistent with findings by Ramdhani (2018) on Grenada. Human capital may shed light on the result since it speeds up the construction of physical structures and increases workers' productivity. In addition, a country's education level may affect other tourism-related factors. Tourist numbers are affected by a country's human capital, affecting its social and cultural diversity and economic intolerance (Pham et al. 2021).

According to the study of Eyuboglu and Uzar (2020), the basic logarithm of income per share (lnEPS) is also shown to have a significant positive impact on the tourism sector. When strict environmental regulations are in place, companies catering to tourists take action to preserve the environment and reduce pollution (Jeyacheya and Hampton 2022; Sigala 2020). As a result, it should come as no surprise that we found a strong connection between environmental protection and tourism. We make the above claim, emphasizing the importance of environmental regulation as a coordinating mechanism that benefits both the environment and the tourist industry (Yang et al. 2021). As a result, this opens up opportunities for the enterprises at the destination to increase their bottom line and market share.

Model 2's results show that at the 1% confidence level, air pollution has a negative impact (as assessed by lnPM2.5)

**Table 8** Model 1's CCEMG outcome

| Explanatory variables | Coef | Std. Err | Z |
|---|---|---|---|
| $\ln CO_2$ | −1.037 | 1.029 | −2.37 |
| lnICT | 1.179* | 1.099 | 2.85 |
| lnHC | −5.127*** | 2.329 | −4.12 |
| lnEPS | −1.095 | 1.117 | −1.86 |
| lnPOLITY | −1.025 | 0.027 | −1.87 |
| Constant | −1.966 | 9.209 | −1.14 |
| Root mean squared error (sigma): | | 1.0503 | |
| Wald chi2(5) | | 17.5*** | |

on tourism at all quantiles. Furthermore, lnPM2.5 has an enormous, negative impact on tourism at the 30th quantile, with an importance of 11%. This research indicates that air pollution may have a significant detrimental effect on international tourism in China. The findings of this study are consistent with those of a study done in China. Pollution has been found to have the ability to damage the travel and tourism sector. The substantial pollution in certain countries causes this phenomenon by discouraging tourism for practical and ethical reasons. In addition, Dogan et al. (2017) found a similar result in their study by Lin et al. (2022) did as well in China. Air quality affects people's decisions about where and how often they travel. Consistent with Model 1's findings, Model 2's data show that lnICT, lnHC, and lnEPS all positively and statistically significantly affect tourism across all quantiles (He et al. 2023).

Having discovered CSD in our data, we used a group technique called CCEMG estimating for a robustness analysis. This method was developed to deal with CSD. Thus, its use improves the trustworthiness of our results. Tables 8 and 9 show the results from both models. The results of Model 1 indicate that the tourism industry suffers from the detrimental effects of increasing CO2 emissions as their natural logarithm increases. To be clear, the coefficient representing this association is not statistically significant. Information and communication technology (ICT) deployment has significantly benefited the tourism sector. However, it has been

**Table 9** Model 2's CCEMG results

| Explanatory variables | Coef | Std.Err | Z |
|---|---|---|---|
| lnPM2.5 | −1.865** | 1.43 | −3.2 |
| lnICT | 1.199*** | 1.047 | 5.08 |
| lnHC | 1.133*** | 1.007 | 26.98 |
| lnEPS | −1.069 | 1.049 | −2.47 |
| lnPOLITY | 1.103 | 1.277 | 1.35 |
| Constant | 1.144 | 1.988 | 1.16 |
| Root mean squared error (sigma) | | 1.0325 | |
| Wald chi2 | | 698.33 | |

**Table 10** Results of the causal Dumitrescu-Hurlin panel test

| Null hypothesis | W-Stat | Zbar-Stat | Prob |
|---|---|---|---|
| lnTourism ≠ > lnHC | 7.86339 | 5.33559 | 2.00E−06 |
| lnTourism ≠ > lnEPS | 5.83014 | 3.44908 | 1.0145 |
| lnPM2.5 ≠ > lnTourism | 5.02277 | 2.70006 | 1.0893 |
| lnTourism ≠ > lnICT | 7.91296 | 5.38157 | 2.00E−06 |
| lnHC ≠ > lnPM2.5 | 5.86906 | 3.4854 | 1.0127 |
| lnHC ≠ > $\ln CO_2$ | 4.99658 | 2.6759 | 1.0939 |
| lnHC ≠ > lnPOLITY | 5.3947 | 3.04493 | 1.0408 |
| lnICT ≠ > lnHC | 9.17209 | 6.5499 | 4.00E−09 |
| lnEPS ≠ > lnPM2.5 | 5.94905 | 3.55943 | 1.0107 |
| $\ln CO_2$ ≠ > lnEPS | 8.77647 | -1.38415 | 1.7008 |
| lnEPS ≠ > $\ln CO_2$ | 6.3813 | 3.9605 | 1.0033 |
| lnICT ≠ > lnEPS | 7.34523 | 4.85483 | 1.0003 |
| lnEPS ≠ > lnICT | 5.31038 | 2.96689 | 1.0494 |
| lnICT ≠ > lnPM2.5 | 8.11499 | 7.42464 | 1.00E−11 |
| lnPM2.5 ≠ > lnICT | 8.94357 | 6.33779 | 8.00E−09 |
| lnICT ≠ > $\ln CO_2$ | 6.55815 | 4.12456 | 1.0019 |
| lnPOLITY ≠ > lnICT | 8.49579 | 5.92233 | 8.00E−08 |

seen that the widespread use of human capital (HC) has a significant and detrimental impact on travel (Table 8). A negative correlation between tourism and the natural logarithm of PM2.5 is shown in Model 2. The MMQR data are consistent with this view. Like the previous model, information and communication technology (ICT) and human capital (HC) significantly affect the travel and tourism sector.

Based on the findings shown in Table 10, it is evident that there exists a bidirectional causation relationship between the natural logarithm of information and communication technology (lnICT) and the natural logarithm of earnings per share (lnEPS), as well as between lnICT and the natural logarithm of particulate matter 2.5 (lnPM2.5). The study reveals a unidirectional relationship where the natural logarithm of tourism (lnTourism) influences the natural logarithm of health expenditure (lnHC), earnings per share (lnEPS), and information and communication technology (lnICT). Additionally, the natural logarithm of particulate matter 2.5 (lnPM2.5) affects lnTourism, lnHC, lnEPS, lnCO2, and Political Regime (lnPOLITY). Furthermore, lnHC influences lnPM2.5, lnCO2, and lnPOLITY, while lnICT influences lnHC and lnCO2 (Table 10). Moreover, lnEPS influences lnPM2.5 and lnCO2, while CO2 influences lnEPS. Lastly, lnPolity has an impact on lnICT.

## Conclusion and policy recommendations

### Conclusion

This research aims to analyze how much of an effect carbon dioxide (CO2) emissions and contaminants in the air have on China's tourism from 1991 to 2020. The impact of carbon dioxide ($CO_2$) emissions and contaminants in the air on tourism in China is investigated using the moments quantile regression (MMQR) approach. In addition, a CCEMG-based estimate sensitivity assessment is provided. MMQR results for the Chinese nations demonstrate a positive influence of $CO_2$ emissions on tourism at lower and middle quantiles and a negative but minor effect at higher quantiles. The research found that information and communication technologies boost tourism across all income quantiles. Human resources are shown to increase tourism at all percentiles (lower, middle, and upper).

Additionally, we find numerous variables have unidirectional causation. The finding above has important policy implications for promoting tourism in China. We observed that $CO_2$ favors tourism at lower quantiles but may have a negative effect at higher quantiles. These countries must collaborate to slow climate change's destructive effects on the planet. Based on these findings, tourist authorities and energy planners need to pay more attention to the effects of $CO_2$ emissions when they craft tourism development strategies. Tourism income may be increased by implementing carbon capture and storage strategies that reduce outputs from solid and liquid fuels.

## Policy implication

China will require large amounts of public and private expenditures and technology advancements to enhance tourism and minimize $CO_2$ emissions in China. Our study offers crucial empirical data to help lawmakers reduce the adverse effects of contaminants in the air on the tourist sector and boost the sector's contribution to the economy. Our research demonstrates that governments may use ICT to attract more tourists to their nations. The development of new forms of communication and information technology influences the expansion of the tourist sector. Twitter, Facebook, and Wikipedia are social media sites that can be utilized to advertise tourism. Increasing investment, monitoring, and use of ICT are needed to build a tourist business that can be sustained for the long haul. The expansion of the tourist sector may be boosted if business websites are updated and augmented with cutting-edge tools. To attract more tourists, China must make high-speed internet widely available and affordable. These nations should integrate e-commerce (including online payments and advertising) with their tourist sectors to foster its growth.

Additionally, as part of the shift to a sustainable tourist business, stakeholders in the tourism industry and environmental lawmakers must collaborate to combine tourism regulations with the sustainability laws of China. As a result, the tourist sector would be better able to provide green employment, which would benefit the environment and encourage more people to visit. Education in the tourist business is vital to the sector's human capital since it equips students with the theoretical knowledge and hands-on experience employers need. Practical experience is unquestionably as necessary as classroom instruction in the tourist business, which relies heavily on human labor. To increase participation in educational exchange programs, policymakers should work with universities to enhance and broaden them. The research has certain caveats. We chose the moments quantile estimation methodology approach rather than the long-run test that accounts for cross-sectional dependency in the information since our research sample was too small.

## Future research

To more accurately portray environmental sensitivity, however, future studies may include greenhouse gas emissions, ecological footprints, and air quality indices. Significant policy consequences for the tourist industry may be gleaned from comparing the industry's achievements across several regional or worldwide groupings, which future studies might explore beyond China. However, future research may increase the sample size of both countries and periods to ensure that these estimating methods provide reliable and statistically significant results. As for us, our focus was only on the potential negative consequences of rising $CO_2$ and PM2.5 levels for the tourist industry.

**Author contribution** Conceptualization, methodology, and writing—original draft, data curation, visualization, editing: LZ.

**Data availability** The data supporting this study's findings are available on request.

## Declarations

**Ethical approval** I declare that I have no human participants, human data, or human issues.

**Consent for publication** I do not have any person's data in any form.

**Competing interests** The author declares no competing interests.

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