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To cite this article: Junyi Niu (2023) Novel research methods on evaluating the nexus between environment and energy use: evaluating the role of tourism in the pre-COVID period, Economic Research-Ekonomika Istraživanja, 36:1, 1490-1509, DOI: [10.1080/1331677X.2022.2089709](https://doi.org/10.1080/1331677X.2022.2089709)

To link to this article: <https://doi.org/10.1080/1331677X.2022.2089709>



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Published online: 30 Jun 2022.



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Novel research methods on evaluating the nexus between environment and energy use: evaluating the role of tourism in the pre-COVID period

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ABSTRACT

Since the fossil fuels are the principal energy sources across the globe, it is considered as the major reason for environmental degradation. Although, the fossil fuel consumption contributes to maintain industrial production, which is a key factor of economic growth, yet tourism is also among the key sources of revenue for China in the pre-Covid-19 pandemic. However, after the emergence of this novel pandemic, both fossil fuel consumption and tourism are severely affected that slowdowns China's economic progress and could have influence on environmental quality. This study investigates the impact of traditional fossil fuel, economic growth, and tourism on carbon emissions level in China over the period 1995–2020. Using time series estimating approaches, all the variables are found stationary at first difference. Due to irregular distribution of data, this study employed the novel Quantile-on-Quantile regression. The estimated results reveal that consumption of fossil fuel significantly enhances the level of carbon emissions in China. Whereas the impact of economic growth and tourism on carbon emission is mixed. The influence of both the variables is found positive in the lower and medium quantiles, while negative in the upper quantiles. This study also employed the pairwise Granger causality test, that validates two-way causal nexus between fossil fuel consumption—carbon emission and economic growth—carbon emissions. While one way causality from tourism to carbon emissions is evident in the empirical results. This study suggests lowering of fossil fuel consumption by using the alternative energy sources and increase tourism stringent environmental regulations for environmentally destructive tourism activities.

Abbreviations: GDP: Gross Domestic Product; FFC: Fossil Fuel Consumption; TOUR: Tourism; CO₂: Carbon dioxide; QQ regression: Quantile-on-Quantile Regression; ARDL: Autoregressive Distributed Lag; EKC: Environmental Kuznets Curve; ADF: Augmented Dickey-Fuller; OLS: Ordinary Least Square

ARTICLE HISTORY

Received 1 April 2022
Accepted 3 June 2022

KEYWORDS

Fossil fuel; carbon emission; economic growth; tourism; quantile-on-quantile regression; causality

JEL CODES

P18; K32; Z32

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1. Introduction

Since the industrial revolution in the 1900s, the global temperature has been amplified by 2° Fahrenheit. However, in retrospect, the annual rise in temperature is approximately 0.32° Fahrenheit, per decade. The rising temperature is generally caused due to escalating global warming. Global warming arises when carbon dioxide is absorbed in the atmosphere while burning coal, oil and natural gas for generating energy (Shahzad et al., 2020). Carbon emissions are released into the atmosphere and pollute the environment. With increasing human activities and globalisation, climate change has become an area of modern study in the environmental sciences nowadays (Ben et al., 2022). The climatic problems are linked with an increased buildup of pollution influencing the economy of the world. Among these fossil fuels is one of the chief contributors to greenhouse gas and carbon emissions. According to the Global Business data report (2020), China is the largest fossil fuel emitter around the world accounting for approximately 30.6% of the world's emissions ranking (Shahzad et al., 2022).

The tourism industry has the ability to create employment, incomes, and hard monies. Promoting tourism can be vital to sustainable development and the environment if it operates on a low carbon economy that limits carbon emissions (Can & Hongbing, 2011). Tourism comprises of transportation and hosting of tourists through a widespread series of infrastructure, i.e., roads, ports, railroads, etc. creating incomes for the locales. Though it has several economic benefits for the country. However, increased tourism has a substantial adverse impact on environmental deterioration and some cultural and psychological impacts. Almost eight percent of the world's emissions come from tourism. Transportation is fuelled through petroleum came from fossil energy mostly. Increasing the use of fossil energy damages environment via increasing carbon and greenhouse gas emissions. Supplementary, tourism is an essential factor in food production (Global) that again becomes a source of greenhouse gas and carbon emissions (Paramati et al., 2022; Yan et al., 2021). The association of carbon emissions and tourism in the prevailing literature is constructive and is highly susceptible to climate change. The increasing tourism activities increase carbon dioxide emissions and contaminate the environment (Dogan et al., 2017; Khan & Ahmad, 2021).

Economic growth and energy consumption are thoroughly associated with carbon emissions. Since the existing literature provides evidence of the positive relationship between carbon dioxide emissions, GDP, and consumption of energy in the long run (Acaravci & Ozturk, 2010). Which on the one hand, enhances economic productivity and performance, while worsen the environmental quality led by the increased discharges of carbon emissions (Demissew-Beyene & Kotosz, 2020). Also, increasing dependence on energy consumption has a damaging impact on the environment (Ahmed et al., 2021). Besides the specific influence of under-discussion variables, the causal association between them is also explored, which is existing (Lee & Brahmasrene, 2013; Ali et al., 2021; Otim et al., 2022). In other words, economic activities pressurise the environment through transportation, productivity, distribution, and fossil energy utilisation which destroys environmental sustainability. Due to

such activities, the world is facing disastrous issues like global warming and climate change.

Nonetheless, countries across the globe are struggling to eliminate environmental issues, which is on the rise. However, China remained the top of the list in pollution emissions across the globe. Due to increasing urban sprawl and industrial development, China is dependent on fossil consumption. China's major portion of energy consumption comes from fossil fuel that deteriorates the environment (Luan et al., 2022). Additionally, the key culprit of carbon emissions directly or indirectly comes from the tourism industry in China (Luo et al., 2020).

The main purpose of the paper is to evaluate the role of tourism in pre-covid times in order to move forward with the low-carbon tourism economy in China which has been an area of interest for many. Due to rising global warming and tourism activities, at all times, upsurges the harmful greenhouse gas (pollution) emissions. Hence, to achieve this goal we utilised International tourism or number of arrivals (TOUR), Gross Domestic Product (GDP), and Fossil fuel energy consumption (FFC) to examine the environmental and energy nexus in the country. The tourism arrivals, GDP, and fossil fuel consumption impact on the carbon dioxide emissions are analysed in the current study employing the novel econometric techniques along with the Pairwise Granger Causality test from the year 1995 to the year 2020. China is considered as the highest emitter of carbon emissions around the world and its urban working-class spends one-third of its time on leisure lifestyle. Therefore, it is necessary to scrutinise the subject under consideration.

The study contributes to the literature in the construction of low-carbon tourism and travel policies for China. The importance of the research is based on several aspects. For instance, China is determining various stratagems to deal with climate change challenges and adopting clean & green energy practices for limiting carbon emissions. Moreover, the tourism sector plays a vital part in the economic growth and development of a country. It is considered the backbone of a flourishing economy. Hence, identifying the environment and energy linkage considering tourism is significant in China. It helps to evaluate the importance of the tourism sector in economic and environmental sustainability in post-Covid times. Although, the literature is comprehensive regarding the association between carbon emissions and various economic, energy, and tourism indicators. Still, the earlier studies opted traditional estimating measures to identify the association exist between them. In this sense, the current study contributes to the existing literature by empirically analysing the said nexus while utilising the novel quantile-on-quantile regression. The said approach is considered as more powerful in dealing the non-linear data and provides coefficient values at each specific quantile in a visualised form. This will not only help the policymakers to design appropriate policies for carbon neutrality target achievement, but also helpful for the scholars that scrutinises the relevant nexus in other parts of the world.

The organisation of the manuscript is as follows: Section 2 deals with a literature review related to carbon emissions, Gross Domestic Product, and fossil fuel energy consumption. Section 3 is about the data, model, and methodology elaboration. Section 4 explains the results and their on-point discussion while Section 5 elucidates conclusions and policy implications.

2. Literature review

2.1. Association of carbon dioxide emissions and tourism

Can and Hongbing (2011) reviewed the low-carbon tourism theory for limiting carbon emissions and enhancing the socio-economic benefits of the people. Low carbon theory was developed to initiate a low carbon economy through tourism without harming the natural resources of the country. It has been made known positively worldwide over the past years. Even in China, low-carbon tourism has attracted the world, especially in the year 2010 in Shanghai World Expo, China has implemented low-carbon resolutions for mitigating carbon emissions. Lee and Brahmasurene (2013) inspected the long-run association of tourism on carbon emissions and economic growth in European Union economies. The panel data is taken from 1988 to 2009 and the empirical findings show a statistically substantial association of variables. Dogan et al. (2017) scrutinised the panel time-series data in the case of OECD economies. The results suggested that increasing consumption of energy and tourism led to an increasing level of carbon emissions. Investing in essential environmental protection policies in the tourism sector helps to achieve a sustainable environment. Balli et al. (2019) explored the impact of tourism on carbon emissions and economic growth in Mediterranean economies. The outcomes depicted a positive association of tourism activities on carbon emissions and have a significant impact on the growth of the economy. The findings verified the 'tourism-led growth hypothesis' in the study countries. Sharif et al. (2020) examined the dynamic link among carbon emissions, tourism, renewable energy, and energy utilisation in China for the years 1974 to 2016. They employed Wavelet techniques and found that increasing usage of energy increases carbon emissions and energy utilisation that hampers sustainable tourism goals. However, renewable energy utilisation limits environmental impacts in the long run. Leitão and Balsalobre-Lorente (2021) confirmed that the tourism division highlights carbon dioxide emissions and climate change. In the United States, (Xiangyu et al., 2021) discovered that the arrival of tourists in the country decreases carbon dioxide emissions in the long run while in the short run it has a negative asymmetric association with the emissions of carbon. Ghosh (2022) investigated a set of hundred countries around the world to analyse the influence of international tourist arrival on carbon ejections from 1995 to the year 2014. The findings again confirmed that emissions are increased due to growing tourism activities in a country and recommended efficient policies for sustainability of development and environment mitigate carbon emissions in the long run. Khan and Ahmad (2021) indicated a positive impact of tourism on carbon emissions employing Generalised Methods of Moments, Fully modified OLS, and Dynamic OLS in developed European countries and developing Asia Pacific nations. The outcomes depicted tourism, renewable energy consumption, and international trade have a substantial role in emissions of carbon. Razzaq et al. (2021) applied Quantitative ARDL on quarterly data and the findings were consistent with the current literature. They emphasised tourism integrated policies for eliminating carbon emissions. Technological innovation and tourism development help in a significant reduction of carbon dioxide discharge. The environmental problems have gained attention in the world. Li and Lv (2021) re-

inspected the role of tourism on the emissions of carbon. The study confirmed that the development in the tourism sector enhances carbon emissions in 95 study countries from 2000 to 2014. This occurs due to spatial dependence across countries' carbon emissions. Wei and Lihua (2022) empirically analysed the environmental Kuznets hypothesis in ASEAN nations. The study discovered the long-run and short-run impacts of tourism and innovations on the emissions of carbon. They proposed that tourism and innovations not only initiate the growth of the economy but also threaten the sustainability of the environment (increases emissions). However, the improvement in the development of tourism can overcome carbon emissions by the promotion of green technologies to improve environmental quality and implementing environmental laws and regulations.

2.2. Why China has shown importance to develop a low-carbon tourism economy?

Annually almost one-third of vacations time, the Chinese urban working-class spends on leisure. It is a new sustainable strategy for Climate change impacts. Further, the international tourists along with domestic arrivals have been grown rapidly. It will encourage low-carbon consumption tourism and limit the carbon footprint of individual tourist activities. Due to this very purpose, China shows importance on a low-carbon tourism economy (Can & Hongbing, 2011).

2.3. Association of carbon dioxide emissions and GDP

Heil and Selden (1999) studied the association of Gross Domestic Product and carbon dioxide emissions on panel data analysis allowing structural break of 1973 and found a significant relationship. Odhiambo (2011) investigated the one-way causal association of economic growth and carbon dioxide emissions irrespective of the long or short run in South Africa applying ARDL bound tests and Granger causality tests. The study endorsed energy conservational policies to reduce carbon footprint in South Africa. Lee and Brahmasrene (2013) found a significant influence of economic growth on carbon emissions in European Union economies. Narayan et al. (2016) inspected the relationship between the growth of the economy (GDP) and carbon emissions in 181 countries. In which 49 countries showed a negative relationship of income growth and carbon emissions while 21 out of 181 nations supported Kuznets hypothesis. In a panel study of 58 countries of the world from 1990 to 2012, Kais and Sami (2016) analysed the statistically substantial impact of Growth (GDP) on greenhouse (carbon) emissions and indicated the existence of reversed U-shaped bend between both variables. Zhang and Zhang (2018) investigated the impact of GDP on carbon emissions in the Chinese economy. The ARDL bound test, cointegration, and Granger tests validated the EKC hypothesis and show the substantial impact of variables on carbon dioxide emissions. Cetin et al. (2018) investigated the impact in the case of Turkey from 1960 to 2013. The causality analysis shows one-way causality of economic growth and carbon emissions in the country. Ahmad et al. (2018) found uni-directional causality from GDP to the emissions of carbon from 1971 to

2013 in China. Khan et al. (2022) examined the causal relationship between Gross Domestic Product and carbon emissions in South Asian countries. The time series analysis from the year 1972 to 2017 demonstrated a causal association between the two variables. In the case of Uganda, from 1986 to 2018, the Granger causality tests revealed one-way causality between Gross Domestic Product and Greenhouse emissions indicating the positive influence on the emissions in the long run. Further, the outcomes support the Environmental Kuznets hypothesis in the country (Otim et al., 2022).

2.4. Association of carbon dioxide emissions and Fossil fuel energy consumption

Rehman et al. (2019) analysed the long-run and short-run causalities of energy consumption, renewable energy, economic growth, and carbon emissions in Pakistan from 1990 to 2017. The outcomes suggested increasing utilisation of fossil fuel consumption increases environmental degradation (global warming and carbon dioxide emissions). the granger causality shows a unidirectional association among variables. In the case of China, Rehman et al. (2021) determined the asymmetric impact of fuel energy consumption and carbon emissions along with economic growth. Ali et al. (2021) employed ARDL techniques for short and long-run relationships of the coefficients and found a positive influence of fossil fuel consumption on carbon dioxide emissions (1975–2014 in Pakistan). Weili, Khan, and Han (2022) also confirmed that increasing utilisation of energy consumption leads to increased emissions of carbon in Belt and Road countries. Wang and Yan (2022) analysed China's fossil fuel consumption increases that drive carbon emissions by almost 11.28%. Li et al. (2022) examined Sichuan Province (2005–2019) for fossil fuel energy adjustment. They emphasised the transition of conventional energy structure because fossil fuel generates carbon emissions and deteriorates the environment. It is well known that the traditional fossil fuel energy including coal, oil, natural gas, etc. are obtained from natural resources, which could have a substantial role in economic growth (Rahim et al., 2021). On the other hand, these fossil fuel sources significantly enhance environmental degradation via increasing carbon emissions and the ecological footprints, and harms human health (Farooq et al., 2019; Shahzad et al., 2021a; Jiang et al., 2022a). Yet there are number of studies that provides measures to reduce the effects fossil fuel consumption on environmental degradation. For instance, the recovery measures include renewable energy consumption (Usman & Balsalobre-Lorente, 2022; Balsalobre-Lorente et al., 2022), financial development and financial inclusion (Qin et al., 2021a, Qin et al., 2021b), investment in energy industry and pollution prevention of the industry (Luan et al., 2022), environmental taxes, environmental related policy, and technological innovation (Doğan et al., 2022; Shahzad et al., 2021b), environmental-related research and development (Jiang et al., 2022b). Where all these mentioned measures are the most advantageous to attain sustainable development (Cai et al., 2022).

3. Data and methodology

3.1. Data and variables

Based on the objectives and given literature, this study uses four variables in total. Concerning environmental quality, this study uses carbon dioxide (CO₂) emissions (measured in kt) as dependent variable. Since the CO₂ emission is the leading greenhouse gas that is responsible for environmental quality degradation. Therefore, it is suitable to assess the determinants of environmental quality while using the CO₂ emissions. As an indicator of the CO₂ emissions, this study uses three explanatory variables, including fossil fuel consumption (FFC), which is measured as a percent of total energy consumption, economic growth—captured via gross domestic product (GDP) and is measured in constant US\$2015, and the international tourism, which is the number of arrivals. Data for these variables is extracted from the World Development Indicators (World Bank, 2022),¹ covering the period from 1995 to 2020, in case of China.

3.2. Estimation technique

3.2.1. Descriptive statistics and distribution

This research provided descriptive statistics for all of the variables that are included in the econometric investigation. It is helpful to use descriptive statistics to summarise the data. Descriptive statistics include measures such as the mean, median, minimum and maximum (the latter two are known as a range of a time series variable), and standard deviation (which is a representation of how much an observation deviate from the mean). In addition, this study also evaluates the skewness and Kurtosis, where both are measures of data normality. The critical values for these two normality measures are 1 and 3, respectively. If the estimated values exceed or fall behind these critical values, the data could be labelled as nonnormally distributed.

3.2.2. Stationarity

Augmented Dickey-Fuller test (ADF) proposed by Dickey and Fuller (1979) is an econometric and statistical test that tests the assertion (null hypothesis) that a time series sample includes a unit root against the alternate explanation that it does not have any unit root. There is a negative value assigned to the ADF statistic, used in this study. Unit root hypothesis is severely rejected at certain confidence levels when it is more negative. As seen in the regression formulation below, the ADF test is similar to the simple Dickey-Fuller test.

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \dots + \delta_\rho \Delta y_{t-\rho-1} + \varepsilon_t, \quad (1)$$

From Eq. (1), α represents a constant, β signifies a coefficient on a time trend and denotes the lag order of the auto-regressive mechanism. By applying the constraints, i.e., $\alpha = 0$ and $\beta = 0$, a random walk is simulated, however, by implementing the restriction, i.e., $\beta = 0$, a random walk with drift is simulated. As a consequence, three significant versions of the under-discussion mechanism exist. By inserting lags of order ρ , the ADF formulation converts to higher auto-regressive procedures. This

indicates that the lag length of order ρ should be determined throughout the test. One technique is to conduct tests starting with the highest order and evaluating the t -values of coefficients. Alternatively, you may study the Hannan–Quinn, Bayesian, or Akaike information criterion. Following that, the unit root test is employed to examine the null hypothesis, i.e., $\gamma = 0$, relative to the alternate hypothesis, i.e., $\gamma < 0$, given as.

$$DF_{\tau} = \frac{\hat{\gamma}}{SE(\hat{\gamma})}, \quad (2)$$

Once the statistical values are obtained via the said test, these values could be contrasted to the critical values of ADF test, to reject or accept the null hypothesis.

3.2.3. Quantile-on-quantile regression

Sim and Zhou (2015) Quantile-on-Quantile (QQ) technique are used in this study. This technique—often referred to as the generalisation of standard quantile or conventional regression models, allows the quantiles of one variable to be contrasted to another variable’s quantiles. Also, it incorporates two main approaches: firstly, quantile regression, which evaluates the influence of indicators on the quantiles of an explanatory variable, and secondly, non-parametric regression, which evaluates the influence of indicators on the quantiles of a dependent variable. Koenker and Bassett (1978) presented the more sophisticated form of ordinary least square (OLS) regression analysis, wherein the average of one variable is compared to another variable’s average. In Contrast, quantile regression could allow for a greater share of the variance in quantiles, allowing scholars and analysts to make more precise predictions. Additionally, as Stone (1977) and Cleveland (1979) argue and report, traditional regression lowers the dimensionality of the data to match a linear model, causing a loss in accuracy of prediction. When the quantiles of predictor variables are contrasted to the quantiles of a dependent variable, as enabled by the QQ technique, forecasting performance increases since additional variation between the elements is explained (Shahzad et al., 2017). A non-parametric QQ regression model is represented in the following equation form:

$$CO_{2,t} = \beta^{\theta}(X_t) + \mu_t^{\theta}, \quad (3)$$

Where Eq. (3) defines a paradigm wherein the CO_2 is used to represent carbon dioxide emissions over the specified period of time t . Meanwhile, X_t is a matrix that contains the values of each of the regressors employed in this study, namely *TOUR*, *GDP*, and *FFC*, across the time period selected. Furthermore, θ is the θ th quantile, determined in accordance with the normal conditional distribution, and the symbol μ_t^{θ} signifies the quantile’s standard error when the conditional θ th is assigned a value of zero. Moreover, $\beta^{\theta}(\cdot)$ represents an ambiguous expression as a result of a lacking the understanding of the connection between the stated explanatory and dependent variables, namely CO_2 and X_t .

The QQ method is concerned with the collective behaviour of notions and the interactions between several factors. In other words, any change in X_t , whether

positive or negative, would have the same effects on CO₂. For example, the inconsistency in X_t may either be positive or negative, and the response of CO₂ could be asymmetric or symmetric.

To investigate the effect of CO₂ θth quantile on X's th quantile—indicated by X_t—Eq. (3) may be utilised in combination with X_t in a linear regression study. The unidentified function of β^θ(.) enables the computation of the first-order Taylor expansion function, which may be represented below:

$$\beta^\theta(X_t) \approx \beta^\theta(X^\tau) + \beta^\theta(X^\tau)(X_t - X^\tau), \tag{4}$$

Where Eq. (4) reveals that β^θ is a partial derivative of β^θ(X_t) for each independent variable—also known as response or marginal effect. However, this influence may be evaluated in a parallel method such as the traditional linear regression approach (OLS). Further, the parameters' indices is doubled—as seen in Eq. (4), that is, β^θ(X^τ) and β^θ(X^τ) in correspondence to θ and τ. Furthermore, the vector X^τ shows β^θ(X^τ) and β^θ(X^τ), while X^τ is also an operator of τ, that expand discussion on β^θ(X^τ) and β^θ(X^τ), and also are the functions of θ and τ. These functions can be altered as β₁(θ, τ) and β₂(θ, τ), accordingly. As a result, the transformed structure of Eq. (4) is given below:

$$\beta^\theta(X^\tau) = \beta_1(\theta, \tau) + \beta_2(\theta, \tau)(X_t - X^\tau), \tag{5}$$

Where Eq. (5) could adopt the following form after additional alteration, given as:

$$\text{CO}_{2,t} = \beta_1(\theta, \tau) + \beta_2(\theta, \tau)(X_t - X^\tau) + \mu_t^\theta \tag{6}$$

(*)

In above Eq. (6), the (*) designates the θth conditional quantile of the dependent variable (CO₂). The parameters of these conditioned quantiles are denoted by two indices, β₁ and β₂, in terms θ of and τ, respectively, and they correlate the θth quantile of the dependent variable with the τth quantile of independent variable. There is a likelihood that the specifications for the θth quantiles of the dependent variable and the θth quantile of the regressors are numerically inconsistent. Furthermore, there is no expectation of a linear association between the two variables at any point in time. As a result, Eq. (6) examines the model's overall interconnectedness in terms of the distribution-based dependence of the variables. Additionally, in Eq. (6), the anticipated analogs \widehat{X}_t and \widehat{X}^τ should be replaced for X_t and X^τ, respectively. Accordingly, the coefficients β₁ and β₂ assigned by b₁ and b₂ are projected by local regression analysis and may be obtained by executing the complex optimisation technique as follows:

$$\min_{b_1, b_2} \sum_{i=1}^n \rho_0 \left[\text{CO}_{2,t} - b_1 - b_2(\widehat{X}_t - \widehat{X}^\tau) \right] \times K \left(\frac{F_n(X_t) - \tau}{h} \right), \tag{7}$$

Where Eq. (7) reveals that $\rho_\theta(u)$ is the representation of quantile loss function, given as $\rho_\theta(u) = u(\theta - I(u > 0))$. Particularly, I indicate the unusual indicator's function, where K^* illustrates the kernel function, and h the kernel bandwidth's parameter.

This study uses the Gaussian kernel to evaluate the neighbourhood data's weightage of X^τ . This specific approach is a highly recognised and renowned kernel function in economic and finance's fields. This is due to the reason of flexibility in its utilisation. The Gaussian kernel function is also beneficial of being symmetric since it is moving towards zero while allocating lower weights to the subsequent data. The distance and weightage among the distributional function of \widehat{X}_t is adversely linked in this research study, expressed as follows:

$$F_n(\widehat{X}_t) = \frac{1}{n} \sum_{k=1}^n I(\widehat{X}_k > \widehat{X}_t) \quad (8)$$

The results of this distributional function could interact with the quantile \widehat{X}^τ indicated by τ .

3.2.5. Granger causality

We were able to identify the long-run linkage between each explanatory element and the CO₂ emissions at each particular quantile using the QQ regression approach. This approach, however, has shortcomings in establishing causal links between TOUR and CO₂, GDP and CO₂, as well as between FFC and CO₂ emissions. As a response, we used Granger's (1969) test of causality. Despite regression models often reflecting 'simple' connections, Granger (1969) proposed that in economics, causality might be quantified by evaluating a time series's potential to effectively forecast future values given the values of prior time series. This test may be done on either $I(0)$ or $I(1)$ data. To test the proposition of this test, that z does not Granger cause x , adequate lagged values of x should be chosen for insertion in a univariate auto-regression of x .

$$x_t = \theta_1 + \theta_2 x_{t-1} + \theta_3 x_{t-2} + \dots + \theta_m x_{t-m} + \varepsilon_t, \quad (9)$$

The enhanced auto-regression model is denoted in the following form:

$$x_t = \theta_1 + \theta_2 x_{t-1} + \theta_3 x_{t-2} + \dots + b_p z_{t-p} + \dots + b_q z_{t-q} + \theta_m x_{t-m} + \varepsilon_t, \quad (10)$$

All lagged values of z which remain separately significant according to their t -statistics are included in this analysis as they cumulatively improve the predictive ability of an F -test regression. Consequently, p is the smallest lag length and q is the maximum lag length where the lagged value of z is significant in the previously extended model. If the regression does not include lag values for z , the claim that z does not affect x will be approved.

Table 1. Descriptive statistics and normality statistics.

	CO ₂	FFC	GDP	TOUR
Mean	6818773	84.94133	6.86E + 12	1.09E + 08
Median	7091610	87.31595	5.97E + 12	1.26E + 08
Maximum	10313460	88.89836	1.46E + 13	1.63E + 08
Minimum	3064880	78.42786	1.83E + 12	30402000
Std. Dev.	2883991	3.907766	4.22E + 12	36997585
Skewness	-0.130014	-0.655297	0.470606	-0.590734
Kurtosis	1.347939	1.656212	1.859941	2.228623

Source: authors own estimations.

4. Results and discussion

4.1. Results interpretation

The empirical results obtained via above discussed methodology is presented and discussed in this section of paper. Prior to empirical test results such as unit root test, QQ regression, and Granger causality, this study provides descriptive statistics that provide summary of the data under consideration, as reported in Table 1. From the results, it is noted that the mean and median values of CO₂, FFC, GDP and TOUR are positive. This indicates that economic growth, fossil fuel consumption, CO₂ emissions, and tourist arrival to China is increasing every year. However, fluctuations are there in all the variables since these variables are inconsistent. Specifically, the minimum and maximum values reports that the gap between the lowest and highest value of these variables in the given time period. Where the gap between minimum and maximum values are positive. Yet this gap could be observed via standard deviation, which is a simple measure of volatility in a time series. The standard deviation reveals higher values for all the variables. This validates the inconsistency of observations in contrast to the mean values. Concerning data's normality distribution of all the variables, the estimated values of skewness and Kurtosis are found lower than their critical values, i.e., 1 and 3, respectively. This demonstrates the non-normal distribution of all variables, which requires an appropriate estimating approach.

After variable's data description and normality test, this study tested for the unit root in variables. In this regard, this study employed the Dickey and Fuller (1979) ADF unit root test and the estimated results are provided in Table 2. From the examined results, all the variables are observed as non-stationary at levelled data. This indicates the presence of unit root in all variables. The unit root in the data means a structural break due to any external shock. However, data having a unit root could lead to misleading results. Therefore, this study employed the ADF unit root test on first differenced data, where all the variables provide statistically significant results at 1%, and 10%. As a result, the null hypothesis of the unit root presence could be rejected and concludes that all the variables are stationary.

Since the skewness and Kurtosis reveals that the variables' data is irregularly distributed, therefore, this study employs a novel QQ regression proposed by Sim and Zhou (2015), which tackles the issue of data's abnormality. This approach tends to estimate the association of two time series. The estimated results of FFC and CO₂ are portrayed in Figure 1. From the examined results, it is noted there is a positive influence of fossil fuel consumption on the CO₂ emissions in China. Specifically, the

Table 2. Unit root test results.

Augmented Dickey-Fuller test statistic

Variables	I(0)	I(1)
CO ₂	-1.514	-4.543***
FFC	-1.160	-1.935*
GDP	-2.819	-4.514***
TOUR	-0.085	-3.142***

Note: Significance level is denoted by *** for 1%, ** for 5% and * for 10%. I(0) is for level, and I(1) is for the first difference.

Source: authors own estimations.

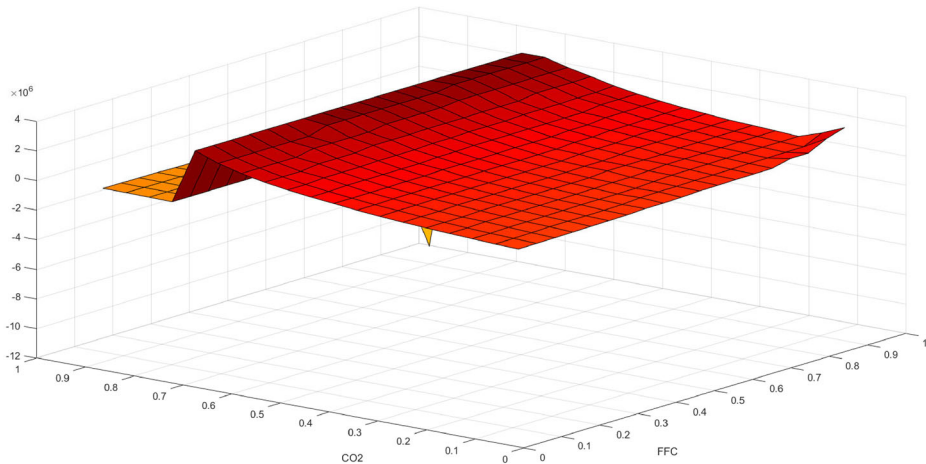


Figure 1. QQ Results for FFC and CO₂. Note: The z-axis indicates the coefficient values, the x-axis indicates FFC, and the y-axis represents CO₂

Source: authors own estimations.

coefficient value ranges 2–4, reveals that enhancement in the consumption of fossil fuel significantly enhance the level of CO₂ emissions in the region. These results are consistent to the study of Rehman et al. (2019) in case of Pakistan, and Weili, Khan, and Han (2022) in Belt and Road initiative economies. Besides, the positive association of fossil fuel on CO₂ emissions is also validated by Rehman et al. (2021) in case of China. Although there are many reasons for CO₂ emissions, where the most significant factor of emissions is fossil fuel consumption. The fossil fuels consist of natural gas, coal and oil, which indeed are the major sources of energy in China and across the globe. Yet these sources of energy carbon intensive, where consumption of these variables leads to emit environmentally destructive gases and particularly the CO₂, which are considered as the major reason of environmental quality degradation, global warming, and climate change,

With reference to Figure 2, the estimated results of QQ regression reveals that there is mixed association of GDP and CO₂ emissions across different quantiles. Specifically, in the lower (0–0.4) quantiles, the impact of GDP on CO₂ emissions is positive. However, the coefficient value dropped to negative from the middle to higher (0.4–1) quantiles. Nonetheless, in the initial stages of development, economy is more focussed towards the development of their industrial sector. In order to expand industrial sector, economies take various steps such as enhancing domestic

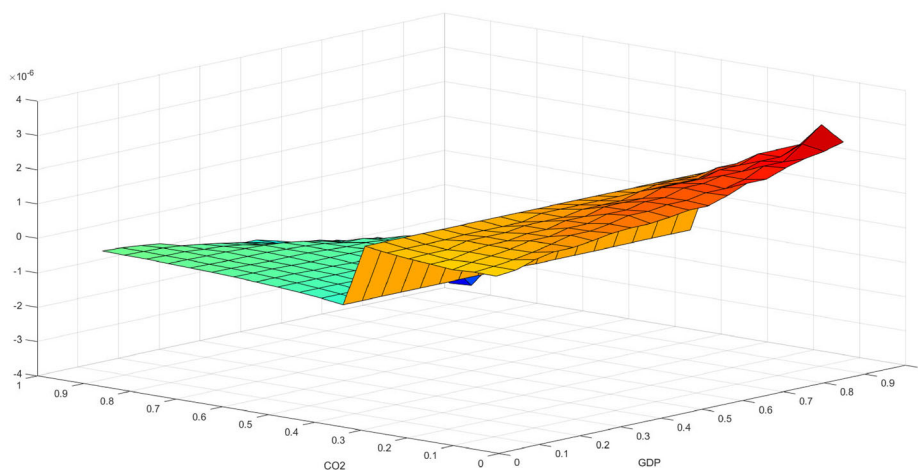


Figure 2. QQ Results for GDP and CO₂. Note: The z-axis indicates the coefficient values, the x-axis indicates GDP, and the y-axis represents CO₂
Source: authors own estimations.

investment level, foreign direct investment, subsidies to the industries, among others. Although, this action enhances the productivity of industrial sector, yet the energy demand also increases to accomplish energy demand and maintain the industrial sector. Yet the higher level of energy consumption, as mentioned earlier (see [Figure 1](#)) is destructive for environmental sustainability. The positive influence of economic growth on CO₂ emissions is also evident in the research work of [Lee and Brahmaresne \(2013\)](#) in the European Union countries, and [Narayan et al. \(2016\)](#) in case of 181 economies. Once the country reached to substantial income level, they started investment in environmentally friendly energy resources, and environmental protective measures, such as energy efficiency, renewable energy, energy productivity, among others. As a result, the use of traditional fossil fuel dropped down, which directly reduces the level of emissions ([Otim et al., 2022](#)), hence, the economy moves towards sustainable development.

With reference to [Figure 3](#), the results demonstrate the association between tourism and CO₂ emissions. The estimated results of these variables reveal that there is a positive and significant impact of tourism on CO₂ emissions. Specifically, from lower to medium (0–0.7) quantiles, enhancement in the number of tourist arrival surges the level of CO₂ emissions. Even prior to tourist arrival, resorts, airports and other tourism infrastructure open their doors to travellers, they may generate huge amounts of pollution, and carbon in particular. Construction of the new building is an energy-intensive operation—producing materials, its required transportation, and building the structure all create CO₂ emissions. Still, it is not only constructions that cause global warming; the expansion of roads and other tourist infrastructure also adds to the problem. Tourism development contributes to carbon emissions by damaging natural ecosystems. By collecting and storing carbon dioxide emissions, ecosystems such as forests operate as carbon sequestration. When this CO₂-rich flora is damaged, CO₂ is added to the atmosphere. The positive impact of tourism on CO₂ emissions is also evident in the research work of [Khan and Ahmad \(2021\)](#), and [Li and Lv \(2021\)](#), that

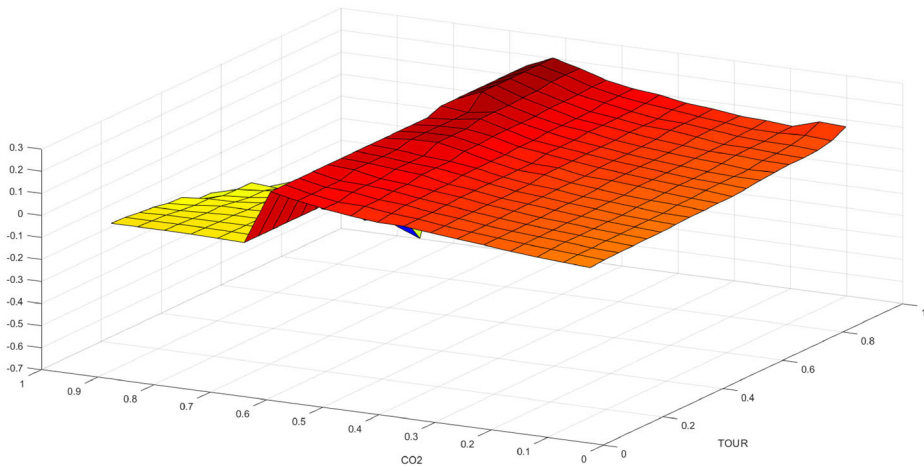


Figure 3. QQ Results for TOUR and CO₂. Note: The z-axis indicates the coefficient values, the x-axis indicates TOUR, and the y-axis represents CO₂
Source: authors own estimations.

Table 3. Pairwise Granger-Causality Test.

Null Hypothesis	F-Statistic	Prob.
FFC—CO ₂	39.4004***	3.E—06
CO ₂ —FFC	8.84012***	0.0070
GDP—CO ₂	5.61638**	0.0270
CO ₂ —GDP	33.4150***	8.E—06
TOUR—CO ₂	10.0396***	0.0044
CO ₂ —TOUR	0.17291	0.6816

Note: Significance level is denoted by *** for 1%, ** for 5% and * for 10%.

Source: authors own estimations.

reveals that the CO₂ emissions surges with an increase in the level of tourism. Recently, China has implemented low-carbon resolutions for mitigating carbon emissions, in which the low-carbon tourism has attracted tourist throughout the world. Therefore, in the upper (0.7–1) quantiles, the impact of tourism on CO₂ emissions is noted weaker and negative. The negative association of tourism and CO₂ emissions is in line with Xiangyu et al. (2021) and Razzaq et al. (2021), asserted that tourism integrated policies for eliminating carbon emissions. technological innovation and tourism development help in a significant reduction of CO₂ emissions.

Although QQ regression establishes a correlation between FFC and CO₂, GDP and CO₂, and TOUR and CO₂, it does not define the causal relationship. In this sense, the present work uses Granger's (1969) pairwise Granger causality test. Table 3 presents the projected outcomes. The findings indicate that there is a bidirectional causal link between FFC and CO₂ emissions, as well as between GDP and CO₂ emissions. This demonstrates that increasing economic development stimulates economic activity. As a consequence, demand for energy-intensive products and services grows, resulting in increased CO₂ emissions, which contribute significantly to environmental deterioration. This viewpoint is supported by the research work of Rehman et al. (2019) and Khan et al. (2022), which demonstrate empirically that economic expansion and the use of fossil fuel energy results in environmental damage. Moreover, there is a one-way causal

association running from TOUR to CO₂ emissions. This demonstrates that CO₂ emissions does not play any major role in the development or destruction of tourism in the country like China, whereas tourism is a substantial indicator of CO₂ emissions in China. Such results are in line to the study of Xiangyu et al. (2021). Thus, from a policy standpoint, both GDP, FFC and TOUR have the potential to play a significant role in lowering emissions and improving environmental quality.

4.2. Discussion

This study empirically investigates the association between economic, energy and tourism on environmental quality of the China during the last three decades. Since the time series data is found irregularly distributed. Therefore, it is important to utilise a powerful estimator that could tackle the non-linearity issue. The results of the QQ regression asserted that there is a positive and significant impact of fossil fuel consumption and tourism on carbon emissions in China. Specifically, enhancement in economic activities tends to increase the energy demand in the said sector. As a result, the higher level of fossil fuel consumption significantly enhances the pollution level via increased CO₂ emissions. For instance, the enhanced economic growth is basically the output of increased production and manufacturing of the products and services. Also, the increased investment in the industrial sector significantly helps in the expansion of the industrial sector, causing the need of more natural resources, raw materials, and energy. Hence, the tremendous increase in such non-renewable energy resources promote environmental quality degradation (Rehman et al., 2019; Weili et al., 2022). Furthermore, the enhancement in the tourism activities also boost the production and consumption of goods and services, that enhances environmental degradation as discussed earlier. In addition, the transport, which is heavily dependent on the fossil fuel energy consumption, also increases. As a result, the higher use of tradition non-renewable energy sources in the tourism industry significantly increases the issue of climate via emitting the CO₂ emissions in China (Khan & Ahmad, 2021; Li & Lv, 2021). Moreover, the empirical findings of the QQ regression regarding the GDP and CO₂ emissions asserted asymmetrical association. In other words, both the positive and negative associations have been validated by different quantiles, which reveals the existence of environmental Kuznets curve in China across the quantiles. This indicates that in the earlier stages of economic development, China utilises more fossil fuel that causes CO₂ emissions. However, after achieving a threshold income level, the economy starts transition towards environmentally friendly energy resources, that not only maintain economic growth, but also enhances environmental quality and sustainability. Therefore, China must focus on their sustainable economic growth by utilising renewables and other environmentally friendly energy resources, that not only enhance economic growth but also promote environmental quality. As a result, the economy will move towards the sustainable development.

5. Conclusion and policy implications

This study investigates the association between fossil fuel consumption, economic growth and CO₂ emissions in China over the period 1995–2020. Besides, this study

tested the role of tourism in environmental quality. In this regard, time series estimating approaches are utilised, where the ADF unit root test validate the stationarity of variables. Where the non-normal distribution of data allows current study to employ the novel QQ regression. The estimated results of the study reveals that there is a significant positive impact of fossil fuel consumption on the CO₂ emissions. Throughout all the quantiles, the association is found statistically significant that reveals that the leading sources of CO₂ emissions. On the other hand, GDP exhibit mixed impact on the CO₂ emissions. The GDP positively influences CO₂ emissions in the lower quantiles, while negatively affect emissions in the higher quantiles. Enhancement in the income level open the doors for investment and consumption. As a result, demand for products and services surges, which leads to expansion of the industrial sector, where the energy requirement increases. Nonetheless, the most prominent energy source in emerging economy like China is considered as fossil fuel, which adversely affects the environmental quality via CO₂ emissions. Yet the higher level of income promotes technological innovation and investment in environmentally friendly resources, due to which the level of CO₂ emissions dropped as evident in the higher quantiles. In addition, the tourism is also found as a contributing factor of environmental degradation. These results are found robust as validated by the pair-wise Granger causality test. This test confirms the there is a two-way causal nexus between, FFC-CO₂ and GDP-CO₂. Yet, only one-way causal nexus is found running from tourism to CO₂ emissions.

Based in the obtained results, this study suggests that fossil fuel consumption should be reduced in a way that the industrial sector shall not be affected. Specifically, alternative energy resources such as renewable energy should be promoted, which will not only maintain industrial production, but lowers carbon emissions in the country. Besides, energy saving mechanism should be encouraged such as energy efficiency and energy productivity. Since the primary reason for higher demand of fossil fuel is the income level. Therefore, policies are required that should divert the focus of increased income from fossil fuel to environmentally friendly energy resources. In other words, the higher economic growth shall be utilised in a way that could promote structural transformation of the industrial sector, which is energy intensive. As a result, the economy will attain sustainable development. Moreover, policies regarding tourism shall be more stringent regarding the use of environmentally destructive resources, and flexible for environmentally friendly resources in the tourism.

Nonetheless, this study empirically estimated various economic and non-economic indicators in relation to carbon emissions. Still, this study is limited in various dimensions. Specifically, this study neglected the role of renewable energy in evaluating the relationship. Therefore, this study suggests the future researchers to consider the role of renewable energy in environmental degradation. Besides, this study also limited in terms of the excluding natural resources' role in CO₂ emissions. Therefore, the scholars in future could consider the role of these resources to comprehensively analyse the environmental quality of China. Further, this study could also be extended to other individual economies for establishing appropriate policy implications. Moreover, the time period of this study could also be extended to comprehensively analyse the said nexus.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Funding

The author acknowledges the grant from the Henan planning office of education on “thirteen five”. (Grant number 2020YB0219).

Note

1. Visit <https://databank.worldbank.org/source/world-development-indicators>

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