Environmental Science and Pollution Research (2022) 29:36273–36280
https://doi.org/10.1007/s11356-021-18138-2

RESEARCH ARTICLE

International tourism, digital infrastructure, and CO_2 emissions: fresh evidence from panel quantile regression approach

Liu Wei[1] · **Sana Ullah**[2]

Received: 15 September 2021 / Accepted: 12 December 2021 / Published online: 21 January 2022

Abstract

The main motivation behind this study is the importance of tourism and ICT industry in the economic development of a country and their potential effects on the country's environmental quality in the digital era. For empirical analysis, the study applies FMOLS, DOLS, and quantile regression techniques for Asian economies. The findings of the study confirmed that tourism and digitalization improve environmental quality in FMOLS and DOLS models. In the basic quantile regression model, the estimates attached to tourism arrival are positive 5^{th} quantile to 40^{th} quantile and then turn negative from 60^{th} quantile and onwards. Likewise, the estimates attached to tourism receipts in the robust quantile regression model are positive from quantile 5^{th} to quantile 20^{th} and negative and increasing from quantile 30^{th} and onwards. Conversely, the estimates of digital infrastructure are insignificant in the basic quantile model at all quantiles except the 95^{th}. However, the estimated coefficients of digital infrastructure in the robust model are negative and rising from 40^{th} quantile to 70^{th} quantile and negative and declining from 80^{th} quantile to 95^{th} quantile. In general, we can say that as the tourism and digital sectors grow, the CO_2 emissions decline.

Keywords International tourism · Digital infrastructure · CO_2 emissions · Asia

Introduction

An incredible intensification of economic events has been detected in the previous few decades and, combined with this bang in universal economic actions, there has been a swift increase in worldwide greenhouse gasses emissions (Hussain et al. 2020; Aslam et al. 2021). It is observed that the colossal upsurge in CO_2 discharges, weather variation, and the unexpected temperature increase is because of intricate phenomena arising from a complicated collaboration amid energy, growth, and the environment. Though energy is called a chief contributor to economic growth, however, it is considered as the main source of carbon releases (Ullah et al. 2020). Carbon production is linked with the increased use of energy due to rising economic activities (Lei et al. 2021). The need to cut CO_2 emissions at a sustainable level is essential than ever; thus, it is considered the hottest topic among the international community. Consequently, it is indispensable to recognize the determinants of carbon emissions that would enable the whole world to reach a consensus regarding policies to mitigate the effects of global heating (Sohail et al. 2021).

The share of carbon emissions in greenhouse gasses is more than 80%, hence, it is the most common indicator used for environmental quality. All the actions that contribute to fostering economic activities also add CO_2 to the atmosphere. The substantial increase in tourism enlarges the world economy, produces jobs, and stimulates exports. Apart from wealth and job creation, its swift development has added to the worries of the international community about sustainability. The use of non-renewable and unclean energy in this sector has exerted negative impacts on environmental quality (Gokmenoglu and Eren 2020). According to Tugcu and Topcu (2018), tourism not only generates income but also increases the present stock of CO_2. In 2016, the share of

Responsible Editor: Ilhan Ozturk

✉ Liu Wei
1374489020@qq.com

✉ Sana Ullah
sana_ullah133@yahoo.com

[1] College of Geographical Sciences, Qinghai Normal University, Qinghai, China

[2] School of Economics, Quaid-I-Azam University, Islamabad, Pakistan

tourism in terms of carbon emissions was almost 5% of the world's total emissions and this is expected to increase 5.3% by the year 2030 (UNWTO 2019). Due to the rising share of tourism in carbon emissions, it has become imperative for economists, environmentalists, and policy-makers to test the nexus between the environment and tourism (Adedoyin and Bekun 2020). A plethora of studies have examined the tourism-led growth hypothesis and, to some extent, there is unanimity among them that tourism stimulates economic growth (Etokakpan et al. 2019; Tecel et al. 2020; Aslan et al. 2021). However, this growth is not free rather it comes at the expense of economic, social, and environmental decay (Azam et al. 2018). Positive shocks in tourism and transportation surely lead to increase energy demand that will eventually stir the environmental crisis like weather variation and heating of the globe (Katircioglu et al. 2014). The UNWTO (2019) observed that, in the year 2018, the total number of tourists jumped to 1.4 billion and this number is expected to reach 1.7 billion by the year 2030. Tourism-tempted economic activities have attracted almost US$ 1.7 trillion. Hence, it is quite obvious for nations to try to catch a fair share of this inside this economic cycle and the increasing tourism industry. However, the important question is how to separate the goods of tourism from its bad, i.e., how to promote tourism by not damaging the environment? From this viewpoint, we can say that tourism is significant in understanding the relationship between economic growth and the environment and achieving sustainable development.

Theoretically, the excellence of the environment with constant economic growth is called a medium to examine the "sustainability of a country" (Zhao et al. 2021a, b). The continuous growth in tourism, over the last few decades, and its contribution to both the pillars of sustainable development, i.e., economic growth and environmental quality have induced the researchers to include the variable of tourism in the production as well as environment functions. As far as tourism-environment nexus is concerned, two strands of studies with opposing views are available. The first study in this context is by Bach and Gößling (1996) who attempted to disclose the relationship between tourism and environmental quality and contended that tourism has significantly led to environmental decay due to an enormous increase in CO_2 discharges. This finding was also supported by Goudie and Viles (2013). Moreover, Chan et al. (2018) and Latif et al. (2018) pointed out that tourism contributes to the wastage of water and natural resources that may augment the process of soil erosion and increase the extent of air, water, and land pollution. Furthermore, as the number of tourists in the destination country increases, it will augment the energy consumption, due to a massive increase in transportation, hoteling, and other related services, that will eventually contribute to environmental pollution (Nepal et al. 2019). Conversely, some opine that tourism improves the environmental quality by providing crucial services, encouraging innovations in technology, and promoting the more efficient use of energy. Therefore, we can say that tourism can become a tool to protect the environment if used sensibly (Gössling and Hall 2006; Imran et al. 2014; Naradda Gamage et al. 2017; Dogan and Aslan 2017; Paramati et al. 2018; Adedoyin et al. 2021; Bamidele et al. 2021).

The role of ICT in increasing economic growth is well established; however, its role in spreading environmental pollution is underexplored (Salahuddin et al. 2016; Chen et al. 2019 and Chien et al. 2021). Given the importance of ICTs in every sector, their usage is growing at the pace of 7% per annum in the last few decades (Salahuddin et al. 2016). As a result, the energy consumed by the ICTs worldwide had soared to 4.7% in 2012 against 3.9% in the year 2007 (Van Heddeghem et al. 2014). Consequently, the share of ICTs in total CO_2 emissions has crossed 2% in 2012 (Greenpeace International 2014). This confirms the positive role of ICTs in degrading the environmental quality by emitting more CO_2 emissions in recent years (Zhao et al. 2021a, b). ICT can contaminate the environment via two channels: first, during the manufacturing of ICT goods, the factories emit CO_2 emissions (Park et al. 2018); second, the increased use of ICTs pushes the energy demand upward (Moyer and Hughes 2012), which is a primary determinant of environmental degradation (Salahuddin et al. 2016). Conversely, ICTs help reduce the reliance on the use of physical materials, or in other words, ICT leads to the dematerialization of the economy, which also lowers the burden on the environment (Usman et al. 2021a, b). Moreover, the energy consumption also decreases because society depends more on e-commercing, virtual meetings, and distance learning instead of physical shopping, business meetings, and classroom learning; hence, lowering the CO_2 emissions (Zhang and Liu 2015; Bastida et al. 2019; Ozcan and Apergis 2018).

Sustainable tourism and digital infrastructure are a question that requires serious attention. Tourism is desirable to attain economic development but attached to the enormous consumption of energy, due to transportation and other services, thus promoting CO_2 emissions. Hence, it is very pertinent to keep the balance between tourism growth, digital infrastructure, and its hazardous impact on the environment. Against this backdrop, in this study, we have tried to divulge the tourism, digital infrastructure, environment nexus for Asain economies, a first of its kind. For Asian economies, tourism and digital infrastructure are a blessing because of their contribution to economic development but the flip side of the story is that they can further speed up the process of environmental degradation in these economies. Hence, discovering the impacts of tourism and digital infrastructure on CO_2 emissions in the context of Asian economies is a very pertinent topic. This study attempts to explore CO_2 emissions determinants with a particular focus on international

tourism and digital infrastructure as the driver of environment for Asian economies over the period 1996–2019.

The composition of the rest of the study is as follows. In the "Model and methods" section, the data and estimation methods are elaborated. In the "Results and discussion" section, we shed light on the results and, finally, concluded the study in the "Conclusion and policy implications" section.

Model and methods

Following the previous studies (Zhang and Liu 2019; Koçak et al. 2020; and Usman et al. 2021a, b), we have developed a model to investigate the relationship between international tourism, digital infrastructure, and carbon emissions in Asian economies.

$$C0_{2,it} = \varphi_0 + \varphi_1 Tourism_{it} + \varphi_2 DI_{it} + \varphi_3 GDP_{it} + \varphi_4 EC_{it} + \varepsilon_{it} \quad (1)$$

where the carbon emission (CO_2) is a function of international tourism (Tourism), digital infrastructure (DI), GDP per capita (GDP), energy consumption (EC), and random-error term (ε_{it}). Our focused variables have reduced CO_2 emissions in the long run; thus, estimates of φ_1 and φ_2 are expected to be positive. This study analyzes the long-run relationship between the concerned variables through robust empirical strategies such as fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS). The problem of endogeneity is a very common issue while analyzing the panel data arrangements, and FMOLS and DOLS are reliable techniques to deal with the problem of endogeneity among regressors. Moreover, these techniques are also helpful in resolving the problem of serial correlation between the error terms. Although both approaches help solve the same issues. Still, FMOLS relies on the non-parametric technique to solve the problems of endogeneity and correlation. At the same time, DOLS uses the parametric approach by adding leads and lags to the independent variables to address the problems mentioned above (Kao and Chiang 2001). Another advantage of using DOLS is that it can provide efficient and better results in the case of small sample size (Ahmad et al. 2021). The cross-sectional dependence is a serious problem while estimating panel data and, if not taken into account, can give biased results; however, the DOLS method can deal with the problem of cross-sectional dependence by relying on attaining country explicit measurements and giving unbiased, efficient, and consistent estimates. Both FMOLS and DOLS can deal with heterogeneity in the long-run variance as well as panel cointegration with the help of their weighted criteria.

Various econometric techniques are prevalent to analyze the panel data arrangement. In this study, our technique is quantile regressions, which is a unique choice because it can measure the impact of independent variables on the dependent variable by taking into account the conditional distribution at the various points of the dependent variable. Quantile regression provides robust results even if some of the normality assumptions of the error term are not strictly followed (Koenker and Bassett 1978). This can also be used to project the specifications with censoring. Recently, this method has been used to get information with regards to the various points in the dispersal of the regressand by using a method other than the conditional mean. The data related to energy and the environment often contains discrete top or heavy tails. As already discussed, this method is superior to OLS because, as opposed to OLS in this technique, we don't have to rely on strict assumptions for the disturbance terms (Koenker and Bassett 1978). And if a violation occurs, OLS provides biased results, whereas the quantile regression provides efficient and robust estimates. The estimates attached to independent variables in different quantiles are different, meaning that the impact of independent variables on the dependent variables is different across different quantiles. The main problem in estimating the panel data is to deal with unobserved heterogeneity, and the quantile regression method can help resolve the issue by using a penalty term in the procedure of minimization that eradicates the undetected fixed effects (Koenker 2004).

Data

The focus of the study is to examine the impact of international tourism and digital infrastructure on CO_2 emissions through a panel quantile regression approach for the time period 1996–2019 for 37 Asian economies. CO_2 emissions are a dependent variable that is measured as carbon dioxide emissions in kilotons. International tourism and digital infrastructure are independent variables. Where international tourism is measured through two proxies, namely international tourism in a number of arrivals (TA) and international tourism in current US$ receipts (TR). This study has also adopted a variable-based method to check the robustness of findings. Therefore, we have used two variables for international tourism, while a similar approach is also adopted by Le and Nguyen (2021). Digital infrastructure is measured by individuals using internet as a percentage of population, which is one of the important sources of CO_2 emissions (Usman et al. 2021a, b). International tourism and digital infrastructure are vital to preserving the environmental quality; thus, we have a focus on it in analysis. The study also incorporated some control variables such as GDP measured as GDP per capita at constant 2010 US$ and energy use that is measured by kg of oil equivalent per capita. All the data for empirical investigation is extracted from the World Bank.

Results and discussion

Before executing regression analysis, some preliminary tests are commenced to confirm the time-series properties of data. For investigating the unit root properties of data, we employ the IPS and ADF panel unit root tests. Table 1 reports that all the variables are stationary at their first difference. However, none of the variables is stationary at the second difference. Afterward, the study confirmed whether the cross-sectional dependence exists within the panel or not. The existence of cross-sectional dependence among panels can mislead the values of coefficient estimates of the true parameters. Therefore, in order to produce robust coefficient estimates, it is imperative to take into account this issue. In this regard, the study employed Pesaran et al. (2001) test for investigating the cross-sectional dependence. The results in Table 2 show the existence of cross-sectional dependence in the variables.

Table 3 delivers the empirical findings of POLS, FMOLS, and DOLS for basic models and robust models. From Table 3, we can perceive that obtained coefficient estimates from all three regressions are quite different from each other in terms of coefficient size, although all possess almost similar significance levels. As the study measures international tourism through two proxies, i.e., international tourism in a number of arrivals (TA) and international tourism in current US$ receipts (TR) to confirm the robustness of findings. The empirical findings reveal that tourism arrivals have a significant and negative impact on CO_2 emissions according to FMOLS model and DOLS model; however, tourism arrival has a significant and negative impact on CO_2 in all three models. It conveys that a percentage increase in tourism arrivals negatively affects CO_2 emissions by 0.640% in case of FMOLS estimator and 1.360% in case of DOLS estimator. The coefficient estimates of robust models reveal that 1 percentage increase in tourism receipts negatively influences CO_2 emissions by 0.713% in case of POLS model, 0.040% in case of FMOLS model and 0.670% in case of DOLS model. In case of digital infrastructure, the findings of basic models reveal use of internet has a negative impact in case of FMOLS model i.e., 1% increase in internet use results in decreasing CO_2 emissions by 0.010% and use of internet has a positive impact on CO_2 emissions in case of

Table 1 Panel unit root tests

	IPS			ADF		
	I(0)	I(1)	Decision	I(0)	I(1)	Decision
CO_2	−1.235	−11.78***	I(1)	0.506	−6.987	I(1)
TA	−0.907	−13.51***	I(1)	−0.879	−21.26***	I(1)
TR	1.359	−3.117***	I(1)	−1.235	−22.20***	I(1)
DI	−0.558	−8.970***	I(1)	−0.908	−12.99***	I(1)
GDP	−0.298	−9.076***	I(1)	−0.679	−12.97***	I(1)
EC	−0.888	−12.56***	I(1)	−0.356	−3.199***	I(1)

***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$

Table 2 Pesaran's test of cross-sectional dependence

	CO_2	TA	TR	DI	GDP	EC
CD-stat	5.987***	3.025***	8.345***	19.18***	8.472***	4.879***
Off-diagonal elements	0.517	0.407	0.632	0.513	0.559	0.476
Prob	0.000	0.002	0.000	0.000	0.000	0.000

***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$

Table 3 Results of panel estimation for Asian countries

	Basic models			Robust models		
	POLS	FMOLS	DOLS	POLS	FMOLS	DOLS
TA	0.034	−0.640***	−1.360***			
TR				−0.713***	−0.040*	−0.670***
DI	−0.006	−0.010***	−0.060***	−0.011*	−0.010***	−0.150***
GDP	4.555***	3.490***	1.360***	4.753***	3.600***	−3.560***
EC	0.545***	0.750***	1.820***	0.437***	0.560***	−0.210***

***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$

DOLS model revealing that 1% increase in internet use tends to increase CO_2 emissions by 0.060%.

The findings of robust models conclude that digital infrastructure leads to increase CO_2 emissions in case of POLS and FMOLS models and decrease CO_2 emissions in case of DOLS model. The coefficient estimates reveal that due to 1% upsurge in use of internet, CO_2 emissions increase by 0.011% in case of POLS estimator and 0.010% in case of FMOLS estimator; however, CO_2 emissions reduces by 0.150% in case of DOLS estimator. The findings of control variables reveal that GDP and energy consumption has a significant and positive impact on CO_2 emissions in all three basic regression models; however, in case of robust models, GDP and energy consumption have a significant and positive impact on CO_2 emissions in case of POLS and FMOLS models but these variables negatively influence CO_2 emissions in case of DOLS regression.

The focus variables of the study, international tourism measured by tourism arrivals, have a significant negative impact on CO_2 emissions in most regressions. This reveals that tourism arrival results in improving environmental quality by minimizing carbon emissions. These findings are in line with many previous studies such as Leon et al. (2014); Dogan and Aslan (2017). Literature reveals that tourism arrival consumes green energy or less polluted energy as compared to industrial and agricultural sectors (Kocak et al. 2020). Furthermore, the robust measure of international tourism, tourism receipts also has a significant and negative impact on CO_2 emissions in all three regressions. The existing literature reveals that well-organized tourism can protect the environment by endorsing the usage of environmentally friendly transportation and technology. Literature also elaborates that tourism is included in the service sector and this sector is relatively cleaner than the agriculture and industrial sector (Grossman and Krueger 1995). There is a transitional shift from the agricultural and industrial sector to the services sector. Hence, tourism contributes more to enhancing quality of environment and produces lesser CO_2 emissions. Paramati et al. (2018) study reported that tourism policies result in raising awareness regarding the protection of the environment and can become an instrument to provide their efforts for ensuring reduction in environmental degradation.

The contribution of digitalization is increasing in CO_2 emissions because the increased usage of computers, mobiles, and internet has increased the energy demand that contributes more to reducing quality of environment (Usman et al. 2021a, b), and the production of digital sector-related material has contaminated the environment. The digital industry has encouraged green culture, hence, contributing to the expansion of a sustainable economy and society. The utilization of digital infrastructure in various sectors can ease energy efficiency by reducing footprints of CO_2 emissions by shrinking energy consumption while encouraging economic development. The study done by Moran et al. (2016) reveals that digital infrastructure contributes significantly to preserving the use of clean energy in economic activities. The modern and digital society determined by digital infrastructure has encouraged the considerable development of the industrial sector (Ullah et al. 2021). Furthermore, digital infrastructure produces green and clean manufacturing processes to conserve costs, attainment of better economic activities in all sectors, and improvement in the efficiency of production, which, in turn, enhances environmental quality. Hence, the application of digital infrastructure has influenced the decision-making of consumers and producers regarding energy-saving (Shabalov et al. 2021).

Table 4 delivers the findings of panel quantile regression for tourism arrivals and CO_2 model, where, the results show that the impact of tourism arrival on carbon emission is positive and statistically significant for lower quantiles (i.e., quantile 1 to quantile 5), statistically insignificant for quantile 6^{th} and 7^{th}, while positive and statistically significant for higher quantiles (i.e., quantile 8^{th} to quantile 11^{th}). These results conclude that due to the rise in tourism arrivals, the quality of the environment deteriorates at lower quantiles and quality of environment improves at higher quantiles. In the case of digital infrastructure, the findings show that use of internet has a statistically insignificant impact on CO emissions from 1^{st} quantile to 10^{th} quantiles, but it exerts a statistically significant and positive impact on CO_2 emissions at 11^{th} quantile. The findings of GDP and energy consumption reveal that these two variables exert a positive and statistically significant impact on CO_2 emissions from lower to higher quantiles considering their deteriorating effect on environmental quality. The robust model produces almost similar kinds of effects as shown by Table 5.

Conclusion and policy implications

Since the industrial revolution, humans' social and economic activities have increased manifold, which is the main reason behind rising carbon emissions into the atmosphere. However, over the past few decades, the infusion of carbon into the atmosphere has gathered the pace. As a result, the world temperature is rising, and natural calamities such as floods, droughts, sea storms, severe fluctuations in weather, etc., appear more often. Therefore, environmental policymakers and world leaders have shown serious concerns over deteriorating environmental quality. Consistent with this view, many empirics have tried to analyze the factors that can lower the burden on the environment without compromising on the process of economic growth.

The main motivation behind this study is the importance of the tourism sector and digitalization in the economic development of a country and their potential effects on the

Table 4 Results of panel quantile regression

	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95
TA	0.302***	0.360***	0.411***	0.282***	0.186**	0.104	−0.050	−0.438***	−0.964***	−1.664***	−1.994***
DI	0.002	−0.001	−0.003	0.001	−0.001	0.000	−0.004	0.004	0.015	−0.004	−0.038**
GDP	1.831***	1.881***	2.47***	2.528***	2.771***	2.991***	3.430***	4.059***	5.220***	6.973***	7.202***
EC	0.171***	0.190***	0.275***	0.409***	0.566***	0.631***	0.548***	0.557***	0.591***	0.709***	0.849***
C	−18.76***	−19.79***	−25.24***	−24.05***	−24.90***	−25.51***	−25.40***	−23.93***	−24.35***	−26.12***	−23.58***

***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$

Table 5 Results of panel quantile regression (robust)

	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95
TR	0.247***	0.227***	0.122*	−0.002	−0.133*	−0.368***	−0.670***	−0.978***	−1.310***	−1.096***	−1.148***
DI	0.002	0.004	0.000	0.002	−0.007*	−0.010*	−0.021***	−0.030***	−0.024*	−0.016*	−0.027*
GDP	1.913***	1.828***	2.467***	2.603***	2.837***	3.258***	3.702***	4.447***	5.378***	6.670***	6.766***
EC	0.158***	0.144***	0.336***	0.397***	0.510***	0.575***	0.557***	0.660***	0.652***	0.692***	0.800***
C	−20.36***	−18.94***	−22.07***	−20.36***	−19.74***	−18.15***	−14.69***	−14.07***	−13.04***	−24.95***	−24.79***

***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$

country's environmental quality. For empirical analysis, the study applies the POLS, FMOLS, DOLS, and quantile regression techniques. The findings of the study confirmed that the tourism arrival and receipts negatively impact the CO_2 emissions in the basic models with FMOLS and DOLS techniques. Similarly, the estimated coefficients of tourism arrival and receipts negatively impact the CO_2 emissions in the robust models with POLS, FMOLS, and DOLS techniques. The estimates of digital infrastructure also exert a negative impact on the CO_2 emissions in the basic and robust models with POLS, FMOLS, and DOLS estimation techniques. On the other side, in the basic quantile regression model, the estimates attached to tourism arrival are positive 5^{th} quantile to 40^{th} quantile and then turn negative from 60^{th} quantile and onwards. Likewise, the estimates attached to tourism receipts in the robust quantile regression model are positive from quantile 5^{th} to quantile 20^{th} and negative and increasing from quantile 30^{th} and onwards. Conversely, the estimates of digital infrastructure are insignificant in the basic quantile model at all quantiles except 95^{th}. However, the estimated coefficients of digital infrastructure in the robust model are negative and rising from 40^{th} quantile to 70^{th} quantile and negative and declining from 80^{th} quantile to 95^{th} quantile.

Based on the findings, some important policy implications are suggested for the concerned stakeholders. Our findings indicate that the rising tourism activities improve the environmental quality in selected Asian countries. This means that the selected countries have adopted well-balanced ecological conservation strategies to attain sustainable development. These effects can be further strengthened by adopting ecotourism policies and inducting green infrastructure in the tourism sector. On the other side, digitalization also improves the environmental quality of the selected nations, which supports the idea that to control CO_2 emissions, smart products need to be promoted in the whole economy such as smart transportation, smart appliances in homes and offices, and smart green energy projects. Digitalization shifts the economy from physical resources to information resources, promoting environmental quality. Therefore, easy credit facilities should be provided to the industries and sectors that promote the use of green ICT products that are less energy-intensive.

This study is ignoring other most-visited countries, advanced econometric methods, and green innovation in empirical analysis. There is a need to explore the nexus between international tourism, digital infrastructure, green innovation, and CO_2 emissions for least-visited and most-visited countries in the globe for comparison. Upcoming studies should also explore the effects of green investments in tourism and ICTs industry on CO_2 emissions. Alternatively, the impacts of green investments and ICTs industry on renewable energy consumption could also be explored in different regions, samples, and methods.

Author contribution This idea was given by Liu Wei. Liu Wei and Sana Ullah analyzed the data and wrote the complete paper. While Sana Ullah read and approved the final version.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate The corresponding author is free to contact any of the people involved in the research to seek further clarification and information.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Adedoyin FF, Bekun FV (2020) Modelling the interaction between tourism, energy consumption, pollutant emissions and urbanization: renewed evidence from panel VAR. Environ Sci Pollut Res 27(31):38881–38900

Adedoyin FF, Agboola PO, Ozturk I, Bekun FV, Agboola MO (2021) Environmental consequences of economic complexities in the EU amidst a booming tourism industry: accounting for the role of brexit and other crisis events. J Clean Prod 305:127117

Ahmad W, Ullah S, Ozturk I, Majeed MT (2021) Does inflation instability affect environmental pollution? Fresh evidence from Asian economies. Energy Environ 32(7):1275–1291

Aslam B, Hu J, Majeed MT, Andlib Z, Ullah S (2021) Asymmetric macroeconomic determinants of CO 2 emission in China and policy approaches. Environ Sci Pollut Res 1–14

Aslan A, Altinoz B, Özsolak B (2021) The nexus between economic growth, tourism development, energy consumption, and CO 2 emissions in Mediterranean countries. Environ Sci Pollut Res 28(3):3243–3252

Azam M, Alam MM, Hafeez MH (2018) Effect of tourism on environmental pollution: further evidence from Malaysia, Singapore and Thailand. J Clean Prod 190:330–338

Bamidele R, Ozturk I, Gyamfi BA, Bekun FV (2021) Tourism-induced pollution emission amidst energy mix: evidence from Nigeria. Environ Sci Pollut Res 1–10

Bastida L, Cohen JJ, Kollmann A, Moya A, Reichl J (2019) Exploring the role of ICT on household behavioural energy efficiency to mitigate global warming. Renew Sustain Energy Rev 103:455–462

Chan APC, Darko A, Olanipekun AO, Ameyaw EE (2018) Critical barriers to green building technologies adoption in developing countries: the case of Ghana. J Clean Prod 172:1067–1079

Chen X, Gong X, Li D, Zhang J (2019) Can information and communication technology reduce CO 2 emission? A quantile regression analysis. Environ Sci Pollut Res 26(32):32977–32992

Chien F, Anwar A, Hsu CC, Sharif A, Razzaq A, Sinha A (2021) The role of information and communication technology in encountering environmental degradation: proposing an SDG framework for the BRICS countries. Technol Soc 65:101587

Dogan E, Aslan A (2017) Exploring the relationship among CO2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: evidence from panel models robust to heterogeneity and cross-sectional dependence. Renew Sustain Energy Rev 77:239–245

Etokakpan MU, Bekun FV, Abubakar AM (2019) Examining the tourism-led growth hypothesis, agricultural-led growth hypothesis and economic growth in top agricultural producing economies. Eur J Tour Res 21:132–137

Gokmenoglu KK, Eren BM (2020) The role of international tourism on energy consumption: empirical evidence from Turkey. Curr Issue Tour 23(9):1059–1065

Gössling S, Hall CM (2006) An introduction to tourism and global environmental change. Tourism Glob Environ Change 1–34

Hussain J, Khan A, Zhou K (2020) The impact of natural resource depletion on energy use and CO2 emission in Belt & Road Initiative countries: a cross-country analysis. Energy 199:117409

Imran S, Alam K, Beaumont N (2014) Environmental orientations and environmental behaviour: perceptions of protected area tourism stakeholders. Tour Manage 40:290–299

Kao C, Chiang MH (2001) On the estimation and inference of a cointegrated regression in panel data. In: Nonstationary panels, panel cointegration, and dynamic panels. Emerald Group Publishing Limited

Katircioglu ST, Feridun M, Kilinc C (2014) Estimating tourism-induced energy consumption and CO2 emissions: the case of Cyprus. Renew Sustain Energy Rev 29:634–640

Koçak E, Ulucak R, Ulucak ZŞ (2020) The impact of tourism developments on CO2 emissions: an advanced panel data estimation. Tour Manag Perspect 33:100611

Koenker R (2004) Quantile regression for longitudinal data. J Multivar Anal 91(1):74–89

Koenker R, Bassett G Jr (1978) Regression quantiles. Econ: J Econ Soc 33–50

Latif MT, Othman M, Idris N, Juneng L, Abdullah AM, Hamzah WP, … Jaafar AB (2018) Impact of regional haze towards air quality in Malaysia: a review. Atmos Environ 177:28–44

Le TH, Nguyen CP (2021) The impact of tourism on carbon dioxide emissions: insights from 95<? A3B2 show $132#?> countries. Appl Econ 53(2):235–261

Lei W, Liu L, Hafeez M, Sohail S (2021) Do economic policy uncertainty and financial development influence the renewable energy consumption levels in China? Environ Sci Pollut Res 1–10

Leon CJ, Arana JE, & Hernández Alemán A (2014) CO2 emissions and tourism in developed and less developed countries. App Eco Lett 21(16):1169–1173.

Moyer JD, Hughes BB (2012) ICTs: do they contribute to increased carbon emissions? Technol Forecast Soc Chang 79(5):919–931

Naradda Gamage SK, Hewa Kuruppuge R, Haq IU (2017) Energy consumption, tourism development, and environmental degradation in Sri Lanka. Energy Sources Part B 12(10):910–916

Nepal R, Al Irsyad MI, Nepal SK (2019) Tourist arrivals, energy consumption and pollutant emissions in a developing economy—implications for sustainable tourism. Tour Manage 72:145–154

Ozcan B, Apergis N (2018) The impact of internet use on air pollution: evidence from emerging countries. Environ Sci Pollut Res 25(5):4174–4189

Paramati SR, Alam MS, Lau CKM (2018) The effect of tourism investment on tourism development and CO2 emissions: empirical evidence from the EU nations. J Sustain Tour 26(9):1587–1607

Park Y, Meng F, Baloch MA (2018) The effect of ICT, financial development, growth, and trade openness on CO 2 emissions: an empirical analysis. Environ Sci Pollut Res 25(30):30708–30719

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Economet 16(3):289–326

Salahuddin M, Alam K, Ozturk I (2016) The effects of Internet usage and economic growth on CO2 emissions in OECD countries: a panel investigation. Renew Sustain Energy Rev 62:1226–1235

Shabalov MY, Zhukovskiy YL, Buldysko AD, Gil B, Starshaia VV (2021) The influence of technological changes in energy efficiency on the infrastructure deterioration in the energy sector. Energy Rep 7:2664–2680

Sohail MT, Ullah S, Majeed MT, Usman A (2021) Pakistan management of green transportation and environmental pollution: a nonlinear ARDL analysis. Environ Sci Pollut Res 1–10

Tecel A, Katircioğlu S, Taheri E, Bekun FV (2020) Causal interactions among tourism, foreign direct investment, domestic credits, and economic growth: evidence from selected Mediterranean countries. Port Econ J 19(3):195–212

Ullah S, Ozturk I, Majeed MT, Ahmad W (2021) Do technological innovations have symmetric or asymmetric effects on environmental quality? Evidence from Pakistan. J Clean Prod 316:128239

Ullah S, Ozturk I, Usman A, Majeed MT, Akhtar P (2020) On the asymmetric effects of premature deindustrialization on CO2 emissions: evidence from Pakistan. Environ Sci Pollut Res 27(12):13692–13702

Usman A, Ozturk I, Hassan A, Zafar SM, Ullah S (2021) The effect of ICT on energy consumption and economic growth in South Asian economies: an empirical analysis. Telematics Inform 58:101537

Usman A, Ozturk I, Ullah S, Hassan A (2021) Does ICT have symmetric or asymmetric effects on CO2 emissions? Evidence from selected Asian economies. Technol Soc 67:101692

Van Heddeghem W, Lambert S, Lannoo B, Colle D, Pickavet M, Demeester P (2014) Trends in worldwide ICT electricity consumption from 2007 to 2012. Comput Commun 50:64–76

Zhang C, Liu C (2015) The impact of ICT industry on CO2 emissions: a regional analysis in China. Renew Sustain Energy Rev 44:12–19

Zhang S, Liu X (2019) The roles of international tourism and renewable energy in environment: new evidence from Asian countries. Renewable Energy 139:385–394

Zhao S, Hafeez M, Faisal CMN (2021) Does ICT diffusion lead to energy efficiency and environmental sustainability in emerging Asian economies? Environ Sci Pollut Res 1–10

Zhao W, Hafeez M, Maqbool A, Ullah S, Sohail S (2021) Analysis of income inequality and environmental pollution in BRICS using fresh asymmetric approach. Environ Sci Pollut Res 1–11