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ECONOMIC UNCERTAINTY, (GEO)POLITICAL RISK, AND SUSTAINABLE DEVELOPMENT GOALS

Environmental impacts of international tourism: examining the role of policy uncertainty, renewable energy, and service sector output

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Abstract

The contributions of the tourism sector and its development to economic growth are widely recognized across the economies. However, development in this sector also has its impacts on environmental quality and sustainability. In addition, elevated economic policy uncertainty also has repercussions on the environment. The objective of this study is to examine the impact of international tourism on environmental sustainability while considering EPU, renewable energy consumption (REC), and service sector output (SSO) in the model estimated based on panel data from 17 economies. Having the heteroskedasticity and autocorrelation issues in the panel data, the author used multiple econometric methods (pooled OLS with Drisk/Kraay standard errors (DKSEs), GLS, PCSE, and quantile regressions) to examine the relationship between international tourism and environmental sustainability. DKSEs address the common issue of heteroskedasticity and GLS also accounts for both heteroskedasticity and autocorrelation. PCSE method corrects these errors. Finally, quantile regression estimates the relationships between variables at different points of the distribution. The results show that international tourism and EPU adversely impact environmental quality and sustainability by increasing GHG emissions. The findings show that increased GHG emissions from international tourism and EPU harm environmental sustainability. Furthermore, SSO and REC significantly reduce GHG emissions and enhance sustainability. Nevertheless, the tourism sector should adopt sustainable practices like using eco-friendly lodging, conserving energy and water, and utilizing renewable energy (RE) to reduce negative environmental impacts. Conserving biodiversity and regional cultures while minimizing waste and resource use is also essential. Tourists should embrace eco-friendly practices such as choosing green hotels, conserving energy and water, and supporting environmental causes while adhering to regulations to reduce emissions. The study recommends establishing uniform trade laws that support green technology and RE to reduce EPU. The findings stress the need for international collaboration to promote eco-friendly tourist practices and minimize the sector's environmental impact.

Keywords International tourism · Economic policy uncertainty · Renewable energy · Environmental sustainability · GHG emissions

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Introduction

International tourism has played a significant role in economic growth and development, particularly in developed and emerging nations (Raza et al. 2017). However, tourism may also harm the environment, especially regarding resource use, waste production, and carbon emissions (Sharif et al. 2017; Leal Filho et al. 2022; Baloch et al. 2023). Striking a balance between the need to preserve the environment for future generations and the economic advantages of tourism takes time (IPCC 2018). With the current economic policy uncertainties in many prominent and emerging nations, this is especially crucial. International tourist arrivals surpassed 1.5 billion in 2019, with earnings of US$1.5 trillion (UNWTO 2021). However, the uncertainty caused by the COVID-19 pandemic has adversely affected the global tourism economy. In 2022, more than 900 million tourists traveled, but the number was much less than in 2019 (UNWTO 2023). In general, over the years, the tourism industry has contributed to the economic activity and welfare of the economies, with the tourist economy as one of the major sectors. This expansion, however, has come at a cost to the environment, with tourism accounting for around 5% of global GHG emissions (IPCC 2018).

The relationship between international tourism and environmental sustainability is complicated since several aspects exist, such as transportation, lodging, food, and activities (Pan et al. 2018). The objective is to reduce the negative environmental consequences of tourism while increasing the economic advantages to local communities (IPCC 2018). Climate actions are indispensable to lower GHG emissions and combat climate change. Sustainable and green tourism is one of the critical economic activities that to be considered to enable this sector to contribute to climate change mitigation and adaptation. It is essential to integrate measures to address climate change into tourism strategies, rather than relying solely on the traditional approach of prioritizing economic benefits and tourist arrivals (Becken et al. 2020; Apergis et al. 2022a). Furthermore, EPU might impact global tourism sustainability (Wu et al. 2022). A decline in demand and investment in tourism and an increase in expenses for and an increase in tour costs follow the increased levels of EPU. It needs modifications in trade policies, taxes, and regulations. The supportive and innovative sustainable tourism policies may have a positive impact on the ability of tourist locations to adopt sustainable practices and the sustainability of tourism-related activities (Haibo et al. 2020; Shahzad et al. 2022).

Hence, it is crucial to create policies that balance economic development and environmental sustainability, especially considering economic policy uncertainties (Pirgaip and Dinçergök 2020). This might involve supporting eco-friendly tourist practices, funding green infrastructure, and providing financial incentives to eco-friendly tourism companies (Ahmad et al. 2018). The relationship between global tourism, environmental sustainability, and economic policy uncertainty is a complicated one that calls for a diverse strategy. A comprehensive analysis of economic policy uncertainty, tourism, and environmental sustainability is imperative to make sure that international tourism continues to contribute to economic development while safeguarding the natural environment and its quality for future generations by supporting sustainable tourist practices and putting in place laws that strike a balance between economic growth and environmental conservation (Katircioglu 2014; Balsalobre-Lorente et al. 2020; Baloch et al. 2023). However, the effects of uncertain economic policy on environmental sustainability have not been adequately investigated. By studying the effects of both tourist and economic policy uncertainty on environmental sustainability, this study will add to the body of existing work.

The study aims to investigate the effects of tourism and economic policy uncertainty on environmental sustainability. Because of its resource-intensive nature, the tourist sector has long been seen as a significant contributor to environmental deterioration. The study does, however, consider the influence of economic policy uncertainty on environmental sustainability in the context of tourism. The authors estimated the tourism-policy uncertainty-environmental sustainability model using panel data from 17 industrialized and emerging nations from 2001 to 2019. They used quantile regression techniques. The study examines the influence of tourism and economic policy uncertainty using various estimating methodologies and variable quantile distributions. The study would assist policymakers and stakeholders in identifying the elements that contribute to environmental deterioration in the tourist industry and developing appropriate policies to prevent its negative impact. The findings provide policymakers and stakeholders with valuable information on the impact of tourism and economic policy uncertainty on environmental sustainability and insights into potentially beneficial policy solutions.

Literature review

The tourism sector has been recognized as one of the contributing sectors to the economic growth and development of the economies. There is a wide range of empirical studies focusing on the role of the tourism sector in economic growth and development. These studies find a robust long-run association between tourism and economic growth (Raza et al. 2017). There is another stream of literature that focuses on the association between tourism development and environmental degradation. Studies have shown tourism has a significant impact on environmental quality by affecting carbon emissions in the economy (Sharif et al. 2017). An analysis of the long-term connections between tourism, energy use, and CO_2 emissions in Turkey (now Türkiye) was carried out by (Katircioglu 2014). Notably, Türkiye is the sixth most visited nation in the world with over 30 million tourists yearly. The findings of (Katircioglu 2014) show that changes in tourist development have increased energy consumption and CO_2 emissions, significantly accelerating climate change. The study emphasized the significance of environmentally friendly tourist activities in Türkiye. (Balsalobre-Lorente et al. 2020) examine the relationship between economic expansion, foreign travel, globalization, energy use, and CO_2 emissions in OECD economies.

The study demonstrates that elements that aggravate climate change include energy usage, tourism, and economic expansion. Globalization appears to lessen the influence of international tourism on climate change in the latter phases of development, and there is also an inverted U-shaped link between CO_2 emissions and international tourism. To change the present energy mix in OECD nations, legislative frameworks that emphasize energy efficiency and the deployment of RE sources are supported by this research.

Current research indicates that environmental degradation is significantly impacted by tourism development (TD) in nations with both high and low visitor arrivals. (Raza et al. 2017) focused on the empirical impact of TD on environmental deterioration in the United States, an economy with a significant level of international travel. The wavelet transform framework, which allows for the breakdown of time series at various temporal frequencies, is used in this study. The study examines the relationship between TD and CO_2 emissions using monthly data from 1996 to 2015. The findings of (Raza et al. 2017) indicate that TD has a short-, medium-, and long-term impact on CO_2 emissions that are primarily beneficial. The study also discovers that TD has a short-, medium-, and long-term unidirectional effect on CO_2 emissions in the USA.

Significant environmental deterioration has been brought on by China's rapid economic growth and the industrial shift from its eastern to western regions. Yet, if not properly managed, tourism can also potentially destroy the environment (Ahmad et al. 2018). In recent years, it has emerged as a viable answer for both economic and environmental growth. The western region of China, which comprises the provinces along the One Belt One Road (OBOR) route, is a desirable location for the development of travel and tourism (T&T) due to its extraordinary variety of natural beauty sites and distinctive ancient civilizations. This area still needs to be developed and explored despite its significance. In five provinces along the OBOR route between 1991 and 2016, this study seeks to examine the connection between tourism and environmental damage. The findings of (Ahmad et al. 2018) suggest that while tourism has a beneficial impact in Xinjiang, it has a negative impact in Ningxia, Qinghai, Gansu, and Shanxi. Nonetheless, the detrimental effects of GDP development and energy consumption are greater than those of tourism. The findings imply that, depending on specific provincial characteristics and governmental regulations, the link between tourism and environmental pollution differs between provinces in the same region. The expansion of tourism might also enhance the economic and environmental sustainability of these provinces.

The panel study (Khan et al. 2019) aims to investigate the link between green logistics indices and economic, environmental, and social aspects in Asian emerging economies. According to the findings, logistics operations, namely the effectiveness of customs clearance processes, the quality of logistics services, and trade and transportation-related infrastructure, are positively and strongly connected with per capita income, manufacturing value-added, and trade openness. On the other hand, more extraordinary logistical operations are related to social and environmental issues such as climate change, global warming, carbon emissions, and pollution, all of which negatively influence human health. Political insecurity, natural catastrophes, and terrorism all have a detrimental influence on economic development and environmental sustainability, according to the report. The findings emphasize the significance of embracing RE and green ideology to address macro-level social and environmental challenges. Nonrenewable energy increases environmental deterioration, whereas RE and financial development contribute to reducing environmental degradation (Sharif et al. 2019). Overall and globalization and economic globalization enhance environmental degradation in the long run (Suki et al. 2020). The quantile autoregressive lagged (QARDL) estimates of (Sharif et al. 2020) reveal that, in Turkey, there is a substantial long-term equilibrium relationship between factors and ecological footprint Turkey. Renewable energy, in particular, reduces the ecological footprint in the long run, but economic expansion and non-renewable energy increase it in the short and long term. The analysis verifies the EKC hypothesis and discovers a bidirectional causal link between RE utilization, energy consumption, economic growth, and ecological footprint in the Turkish economy.

Tourism is a significant contributor to economic growth, but it can also harm the environment if not properly managed. (Ahmad et al. 2019) investigate the association between tourism and environmental pollution in 3 lower-middle-income Southeast Asian countries. The study uses carbon emissions as an indicator of environmental pollution and employs the FMOLS approach to analyze tourist arrivals and control variables. The results show that tourism has a negative impact on the environment in Indonesia and the Philippines but a positive impact in Vietnam. The findings highlight the importance of country-specific characteristics and policies in shaping the relationship between tourism and the environment. Governments can use the dominant factors identified to develop persuasive policies to reduce carbon emissions from tourism and enhance sustainable development in the region.

Gulistan et al. (2020) investigate how CO_2 emissions, economic development, energy consumption, trade openness, and tourism affect environmental deterioration measured by CO_2 emissions. A study of the association between the variables is conducted within four income and five geographical categories using data from 112 countries between 1995 and 2017. The findings support the existence of an environmental Kuznets curve (EKC), which has a tipping point at which a person's money can elevate the standard of the environment. The study concludes that environmental damage is caused by economic expansion, energy use, and tourism, but the effect of trade openness is not statistically significant. Mixed results are obtained from subsamples. The results point to the necessity for national and international environmental organizations to take action to save the environment through eco-friendly travel and effective energy utilization. Some studies focused on how tourism and institutional quality relate to environmental sustainability. Using the principal component analysis to create three environmental sustainability indexes for 134 nations, Nguyen and Dinh (2021) showed that the reduced environmental sustainability indicators have improved in low- and middle-income nations while declining in several high-income ones. It was also demonstrated that institutional quality, notably regulatory quality, government efficacy, corruption control, and the rule of law, are critical elements in ensuring environmental sustainability. Domestic and international tourist expenditures, on the other hand, have negative consequences on environmental sustainability. Surprisingly, the study ascertained that strong institutional quality worsens the negative environmental outcomes of international tourism. These findings underline the importance of rigorous policymaking in the tourist sector to achieve long-term tourism growth.

The SDGs of the United Nations are to end poverty, protect the environment, and promote prosperity. These objectives may be attained through travel and tourism. The UN SDGs are aligned with Saudi Arabia's 2030 agenda for sustainable development, innovation, and tourist growth. Anser et al. (2021) assesses Saudi Arabia's e-tourism activities and green development goals. Findings reveal that while ICT's contribution to energy consumption, inbound tourism, and trade openness preserved natural resources, oil rents, ore and metal exports, and transportation of railroad goods drained them. The study suggests encouraging green ICTs, cleaner industrial technologies, sustainable consumption and production, stringent environmental legislation, and green travel and tourist infrastructure to realize the objectives of Saudi Arabia's Agenda 2030.

Recently, the relationship and susceptibility between tourism and climate change have drawn attention on a worldwide scale. Liu et al. (2022) intends to evaluate the geographical spillover impact of tourist development on environmental pollution and how changes in tourism development affect carbon dioxide emissions. This study adopts a spatial econometric technique to evaluate tourism's direct, indirect, and total impact on environmental pollution. Panel data from 2000 to 2017 for 70 countries are used in the study. The results of Liu et al. (2022) indicate that tourism has both a positive direct effect and a negative indirect effect, with the indirect effect being more detrimental than the direct effect and having a considerably negative total impact. The study also discovers a link between financial development and carbon emissions that is inverted U-shaped and U-shaped, in the direct and indirect consequences. Additionally, through spatial spillover, population density, trade openness, and economic growth have a significant impact on environmental pollution, while infrastructure investment and education spending have a significant moderating effect on the association between tourism growth and environmental pollution. These findings have substantial policy ramifications because they demonstrate an inverse U-shaped relationship between tourism and environmental pollution and that a nation's emissions initially increase with the expansion of the tourism sector but then begin to decline once they reach a certain threshold.

The tourism industry drives economic growth and employment but has negative environmental impacts due to higher energy consumption. Using ARDL bound testing and Gradual shift causality methods, Irfan et al. (2023) analyzed the role of globalization, energy consumption, and economic growth in normalizing the environmental effects of tourism sub-sectors. The authors found that tourism-related food and beverage services contribute to higher greenhouse gas emissions, while the tourism-traveling sector primarily contributes CO_2. Shopping and entertainment are the most significant sectors contributing to N_2O, CH_4, and other air pollutants. Furthermore, all tourism industry subsectors have a favorable impact on energy consumption and economic growth, but tourism-linked traveling consumes more energy. Using panel data from 2000 to 2019, Ahmad et al. (2022) examine how innovation and tourism affect sustainable development in G7 nations. The findings imply that innovation, as measured by scientific publications and patents, is related to more economic prosperity and less environmental degradation. Tourist arrivals favorably affect economic growth and pollution reduction, whereas refugees have no positive influence on economic success or environmental improvement plans. The education level promotes economic expansion and thwarts environmental damage. The research recommends boosting innovation, tourist growth, and higher technical education for the G7 nations' sustainable development, making significant contributions to businesses, decision-makers, and SDGs.

In another study, Wan et al. (2022) examine the influence of natural resources, green funding, and environmental policies on lowering carbon emissions in China. The results of the bootstrap ARDL technique reveal that natural resource management, green investment, and environmental taxes reduce carbon emissions in the long term, but economic expansion increases carbon emissions. According to short-run estimates, natural resources, green investment, and environmental levies all favorably influence environmental sustainability.

The role of finance in contributing to man-made environmental challenges has long been a source of concern, but recent advancements have seen environmental concerns integrated into long-term funding. Furthermore, technological advancements are viewed as a tool to reach carbon neutrality. (Jian and Afshan 2022) investigated the efficiency of green finance (GFIN) and green technology in reaching carbon neutrality in the G10 economies. To accomplish this, the authors use sophisticated panel estimating methods, including cross-sectional ARDL, cross-sectional dependency, unit root test with and without structural discontinuities, slope homogeneity, and panel cointegration. Long-term and short-term projections show that GFIN and green technology successfully promote carbon neutrality. Furthermore, the long-term results support the EKC's validity. Except for the EKC, similar outcomes are obtained in the short term. However, their contribution to attaining carbon neutrality is more substantial in the long run. Furthermore, the negative sign of the error correction component implies that the system is approaching steady-state equilibrium.

Despite the importance of economic welfare, population, international tourism, and energy transition in mitigating environmental degradation, there was a lack of comprehensive research examining their combined effects. (Satrovic and Adedoyin 2023) examined the combined impact of economic welfare, population, international tourism, and energy transition on environmental degradation in ten southeastern Europe (SEE) countries using the EKC perspective. The study found that the relationship between environmental degradation and economic welfare follows an inverted U-shaped curve, supporting the validity of the EKC hypothesis. However, energy transition and international tourism have adverse effects and contribute to environmental degradation. The population has a positive but insignificant impact. The study recommends prioritizing energy transition and international tourism in efforts to mitigate environmental degradation in the examined sample of countries. (Baloch et al. 2023) evaluated the link between tourist development and environmental appropriateness and offered a sustainable ecotourism paradigm that balances commercial and ecological objectives through government policy interventions. The data from 650 questionnaires were collected from various tourist stakeholders, and the reliability and validity of the data were confirmed using hierarchical regression analysis. The authors discovered that tourist expansion provided socioeconomic benefits but also resulted in environmental deterioration and social vulnerability. A sustainable ecotourism framework involving government policy interventions to safeguard natural and environmental resources while ensuring economic feasibility and social welfare was advocated. The factors and structures studied in this study can be utilized as a model for sustainable destination management in other areas.

The model and methodology

The model

To assess the impact of tourism on environmental degradation, (Ahmad et al. 2018), (Ahmad et al. 2019), (Gulistan et al. 2020) and (Balsalobre-Lorente et al. 2020) used CO_2 emissions as an indicator of environmental degradation. (Balsalobre-Lorente et al. 2020) used international tourism expenditure (US $) as an indicator of international tourism. Moreover, (Ahmad et al. 2019), (Sharif et al. 2019), (Sharif et al. 2020), (Balsalobre-Lorente et al. 2020), and (Huang et al. 2023) also included energy use in the explanatory variables in the model. Whereas, (Gulistan et al. 2020) used the number of international tourist arrivals as an indicator of international tourism. (Ahmad et al. 2018) used tourist arrivals in the Chinese provinces. In a natural resource protection-fintech model, (Tan et al. 2023) used the natural resource protection indicator as a dependent variable while considering the FDI as an independent variable along with the fintech variable. Some of the studies also included energy variables in the model, as energy consumption or use, has a very pivotal impact on environmental sustainability. (Ahmad et al. 2018), (Ahmad et al. 2019) and (Balsalobre-Lorente et al. 2020) used energy use as an energy indicator in tourism-CO_2 models. (Gulistan et al. 2020) included energy consumption as an independent variable in the tourism-environmental degradation model. (Tan et al. 2023) used REC as an independent variable in the natural resource protection-fintech model.

$$\begin{aligned}\ln(GHG)_{it} = \beta_0 + \beta_1 \ln(ITA)_{it} + \beta_2 \ln(EPU)_{it} + \beta_3 \ln(FDI)_{it} \\ + \beta_4 \ln(REC)_{it} + \beta_5 \ln(SPW)_{it} + \mu_{it}\end{aligned} \tag{1}$$

In model (1), GHG is total greenhouse gas emissions (kt of CO_2 equivalent), ITA is the number of international tourism arrivals, EPU is the economic policy uncertainty index, FDI is foreign direct investment, net inflows (BoP, current US$), REC is renewable energy consumption as a percentage of total final energy consumption, and SPW is service sector output per worker. The symbols of variables and expected signs are summarized in Table 1. The study used data from 17 developed and emerging economies from 2001 to 2019, including Brazil, Canada, China, France, Germany, Greece, India, Ireland, Italy, Japan, Netherlands, Russia, Spain, the UK, the USA, Sweden, and Mexico.

The GHG, ITA, FDI, and REC data is taken from World Bank (2022), and EPU is collected from EPU (2023).

Table 1 Expected signs of the variables

Variable	Expected sign	Reference(s)
ITA	$\beta_1 < 0$	(Greentumble 2022; Li and Sohail 2022; Wei and Ullah 2022)
	$\beta_1 > 0$	(Katircioglu et al. 2014; Malik et al. 2016; Qureshi et al. 2017; Giulietti et al. 2018; UNWTO 2018; Lenzen et al. 2018; Erdoğan et al. 2022; Leal Filho et al. 2022; Gössling et al. 2023)
EPU	$\beta_2 > 0$	(Sun et al. 2022; Apergis et al. 2022b; Huang et al. 2023)
FDI	$\beta_3 < 0$	Pollution halo hypothesis (Huang et al. 2022; Wang and Huang 2022)
	$\beta_3 > 0$	Pollution haven hypothesis (Huang et al. 2022, 2023; Wang and Huang 2022)
REC	$\beta_4 < 0$	(Ali et al. 2019; Gielen et al. 2019; Li et al. 2021; Szetela et al. 2022; Iqbal et al. 2023; Tan et al. 2023)
SPW	$\beta_5 < 0$	(Suh 2006; Okamoto 2013)
	$\beta_5 > 0$	(Lamb et al. 2021; EPA 2023)

Econometric methodology

Depending upon the characteristics of the panel data, the multiple econometric methods, including pooled OLS with Driscoll and Kraay standard errors (Driscoll and Kraay 1998), generalized least squares (GLS) (Parks 1967), panel-corrected standard errors (PCSEs) (Beck and Katz 1995) for estimation of the models. The econometric methodologies are summarized in the following.

Pooled regression with Driscoll/Kraay standard errors

A technique for estimating panel models considering cross-sectional dependency and heteroskedasticity in the residuals is pooled regression with Driscoll/Kraay standard errors (Driscoll and Kraay 1998; Hoechle 2007). It uses a nonparametric covariance estimator resistant to common spatial and temporal correlation types. With cross-sectional dependency, Driscoll/Kraay standard errors are well-calibrated compared to other standard error estimates like OLS, White, Rogers, or Newey-West. However, they also lower the degrees of freedom by the number of periods minus one (Driscoll and Kraay 1998; Hoechle 2007).

Generalized least squares

When the residuals of the panel data model exhibit heteroskedasticity and/or autocorrelation, panel GLS (Kmenta 1997) can be used. It can also be employed when the individual impacts are random and unrelated to the explanatory factors. When the error structure is appropriately set, panel GLS produces more accurate and reliable estimates than OLS or fixed effects (Kmenta 1997). Notably, GLS is suitable to apply for the panel estimations when the panels are heteroscedastic, have cross-sectional dependence, and are characterized by AR(1) autocorrelations. It is applied on the panels when $N < T$ (Hoechle 2007).

Panel-corrected standard errors

For panel data models, panel-corrected standard errors (PCSEs) are robust standard errors considering heteroskedasticity and contemporaneous correlation across panels (Beck and Katz 1995; Hoechle 2007). They are calculated using a sandwich-type estimator of the inferred parameters' covariance matrix. They make it possible for linear models estimated using OLS or Prais-Winsten regression to yield superior inferences. PCSE is applied better when $N > T$ (Hoechle 2007).

Two techniques for estimating panel data models that consider non-spherical errors are GLS and PCSE. Although PCSE employs ordinary least squares and a sandwich-type estimator to generate the standard errors, GLS uses generalized least squares to estimate the errors' parameters and covariance matrix (Beck and Katz 1995; Hoechle 2007). Although PCSE can manage heteroskedasticity and contemporaneous correlation across panels, GLS can handle both heteroskedasticity and autocorrelation within panels. While PCSE is more flexible and resilient but may be less efficient than GLS, GLS makes significant assumptions about the error structure and may need to be more robust to misspecification (Beck and Katz 1995; Hoechle 2007; Megbowon et al. 2019).

Quantile regression

Regression technique that estimates the conditional median or other quantiles of the response variable across values of the predictor variables is known as quantile regression (Koenker 2005). It is more resistant to outliers and can capture the heterogeneity of the response variable at various quantiles, which are its two key benefits over standard least squares regression. There are several ways to execute quantile regression, including reducing the median absolute deviation, employing a check function, or utilizing Bayesian or machine learning approaches (Koenker 2005). The benefit of quantile regression is that it is less susceptible to outliers and non-normal errors than conventional least squares regression (Wooldridge 2010). Furthermore, can capture response variable heterogeneity at different quantiles and give a more detailed examination of the connection between variables. Moreover, in circumstances when there is no or a weak association between the means of such variables, it can identify more relevant predictive correlations between them. Lastly, It may be used for growth charts, risk assessments, and other applications using quantiles (Koenker 2005; Wooldridge 2010).

Results and discussion

Cross-sectional dependence, panel autocorrelation, heteroskedasticity, and heterogeneity tests

The study used Pesaran cross-sectional dependence (CSD) (Pesaran 2004) to test the presence of cross-sectional dependence in the panel data. The results of the CSD test in Table 2 reveal that all the variables in the model show cross-sectional dependence as CSD-test for all variables has $p-$ value < 0.01. Moreover, the $\ln(FDI)_{it}$, $\ln(REC)_{it}$, and $\ln(SPW)_{it}$ have heterogeneity issue as the values of delta and adj. delta (Pesaran and Yamagata 2008) are significant. However, the heterogeneity test values of $\ln(GHG)_{it}$, $\ln(ITA)_{it}$, and $\ln(EPU)_{it}$ are not significant. Moreover, the Q(p) test, LM(k) test (Born and Breitung 2016), and HR test (Born and Breitung 2016) values are also significant confirming the autocorrelation and heteroskedasticity. Moreover, for the modified Wald test for group-wise heteroskedasticity test, the χ^2 test has the value of 1328.34 with $p-$ value < 0.01 confirming the presence of heteroskedasticity. In addition, the Wooldridge test (Wooldridge 2010) for panel autocorrelation also confirm the presence of autocorrelation in the panel with F-value of 58.026 ($p-$ value < 0.01). The properties of the current data provided the authors to use pooled OLS with Drisk/Kraay Standard errors, GLS, PCSE, and quantilile regressions (Hoechle 2007).

Results

The results of the pooled OLS, GLS, and PCSE analyses summarized in Table 3 unveil that international tourism increases GHG emissions. The coefficient of $\ln(ITA)_{it}$ estimated by the three different econometric methods is positive and sign cant at 0.01 level. Notably, the quantile coefficients of $\ln(ITA)_{it}$ are also positive across the quantiles estimations (Table 4). The coefficients increase from the 10^{th} quantile to the 60^{th} quantile then decline but then show a slight increase at the 95^{th} quantile. (Erdoğan et al. 2022) also confirm that international tourism increases carbon emissions and this positive impact is stronger at higher quantiles of carbon emissions. In another study, (Lenzen et al. 2018) show the global carbon footprint of tourism has increased. Transport, shopping, and food have contributed to global GHG emissions in this regard.

Table 3 Tourism-policy uncertainty-GHG model results

Dependent variable: $\ln(GHG)_{it}$			
Variable	Pooled OLS[€]	GLS[¥]	PCSE[¥]
$\ln(ITA)_{it}$	0.3342*** (0.0328)	0.3535*** (0.0359)	0.4393*** (0.0500)
$\ln(EPU)_{it}$	0.3978*** (0.0747)	0.0884*** (0.0297)	0.1268** (0.0503)
$\ln(FDI)_{it}$	0.2895*** (0.0193)	0.0195*** (0.0077)	0.0428*** (0.0108)
$\ln(REC)_{it}$	−0.2883*** (0.0465)	−0.1910*** (0.0297)	−0.2827*** (0.0464)
$\ln(SPW)_{it}$	−0.9773*** (0.0454)	−1.0279*** (0.0376)	−0.9853*** (0.0607)
Intercept	14.0069*** (0.7082)	18.1192*** (0.5896)	16.0225*** (1.0302)
R^2	0.6114		0.9606
F(5, 18)	1011.33***	796.77[Ψ]***	359.72[Ψ]***
Root MSE	0.8768		

[€]with Drisk/Kraay standard errors. [¥]GLS and PCSE estimates with options of heteroskedasticity and common AR(1). [Ψ]Wald's $\chi^2(5)$. ***, **, and *indicate significance at 0.01, 0.05, and 0.10, respectively

Table 2 Pre-estimation diagnostics

Tests	$Q(p)$ test	LM(k) test	HR test	CSD test	Slope heterogeneity test	
					Delta	Adj. delta
$\ln(GHG)_{it}$	8.29***	2.87***	−2.28**	3.053***	1.55	1.69*
$\ln(ITA)_{it}$	8.84***	2.98***	−1.73*	27.26***	0.59	0.65
$\ln(EPU)_{it}$	26.62***	5.18***	0.62	24.15***	−0.65	−0.71
$\ln(FDI)_{it}$	15.50***	3.95***	1.78*	10.25***	3.19***	3.49***
$\ln(REC)_{it}$	7.87***	2.81***	−2.50**	11.14***	2.39**	2.63***
$\ln(SPW)_{it}$	3.40*	1.84*	−1.70*	13.27***	2.01**	2.20**

***, **, and *indicate significance at 0.01, 0.05, and 0.10, respectively

Table 4 Quantile regression analysis results

Quantile	$\ln(ITA)_{it}$	$\ln(EPU)_{it}$	$\ln(FDI)_{it}$	$\ln(REC)_{it}$	$\ln(SPW)_{it}$	Intercept
10th	0.2601*** (0.0510)	0.5439*** (0.1083)	0.2375*** (0.0274)	−0.2447*** (0.0383)	−1.2325*** (0.1053)	16.8320*** (1.6385)
20th	0.2741*** (0.0318)	0.5942*** (0.0690)	0.2009*** (0.0313)	−0.2755*** (0.0303)	−1.2619*** (0.0453)	17.2950*** (0.5440)
25th	0.2858*** (0.0431)	0.5306*** (0.0816)	0.1906*** (0.0416)	−0.2579*** (0.0335)	−1.2760*** (0.0537)	17.6548*** (0.6397)
30th	0.2858*** (0.0542)	0.5306*** (0.0961)	0.1906*** (0.0484)	−0.2579*** (0.0403)	−1.2760*** (0.0615)	17.6548*** (0.8761)
40th	0.3340*** (0.0727)	0.5429*** (0.1455)	0.2382*** (0.0519)	−0.2099*** (0.0505)	−1.2262*** (0.0795)	15.9582*** (1.1739)
50th	0.3482*** (0.0804)	0.3898** (0.1630)	0.2858*** (0.0444)	−0.2060*** (0.0523)	− 1.1448*** (0.0842)	15.3010*** (1.3113)
60th	0.4060*** (0.08478)	0.3900** (0.1600)	0.2936*** (0.0567)	−0.1552** (0.0696)	−1.0586*** (0.0776)	13.4210*** (1.3273)
70th	0.3729*** (0.1095)	0.1891 (0.1492)	0.3151*** (0.0716)	−0.2469** (0.1231)	−0.9506*** (0.0701)	14.0587*** (1.6538)
75th	0.3655*** (0.1246)	0.2325 (0.1450)	0.3159*** (0.0810)	−0.3234** (0.1596)	−0.9295*** (0.0767)	14.0477*** (2.0402)
80th	0.2957** (0.1309)	0.1309 (0.1565)	0.3612*** (0.0938)	−0.4875** (0.1969)	−0.8476*** (0.1016)	15.0371*** (2.4967)
90th	0.3245*** (0.0765)	0.0916 (0.1402)	0.3132*** (0.0628)	−0.6257*** (0.1330)	−0.6856*** (0.1107)	14.3199*** (1.6119)
95th	0.4084*** (0.0870)	0.0173 (0.1575)	0.2458*** (0.0515)	−0.7152*** (0.1612)	−0.7681*** (0.1132)	15.2316*** (1.5430)

***p-value<0.01, **p-value<0.05, *p-value<0.10

Notably, this GHG emission increase has occurred mostly in developed economies. It shows that international tourism, in developed and emerging economies, has consequences on environmental quality and sustainability. These results are supported by the previous studies (Giulietti et al. 2018; UNWTO 2018; IEA 2019; Erdoğan et al. 2022; Li et al. 2023). However, Wei and Ullah (2022) assert that tourism increases environmental quality.

When it comes to the EPU-GHG emission relationship, the $\ln(EPU)_{it}$ the elasticity of GHG is positive across the estimated methodologies (Table 3) and the quantiles (Table 4). When it comes to quantile regression results, there is little variation in the quantile coefficients of $\ln(EPU)_{it}$ from the 10th to 40th quantile and these coefficients are significant with $p-$ values < 0.01. However, the economic policy uncertainty coefficients reduce at the 50th and 60th quantiles and are significant at 0.05 level. Whereas, the quantile coefficients reduce further from 70 to 95th quantile. Moreover, these coefficients of economic policy uncertainty become insignificant. This shows that increased economic policy uncertainty exacerbates environmental conditions by increasing GHG emissions. The findings of the current study regarding positive association between EPU-GHG emissions have also been supported by the results of Baker et al. (2016); Adams et al. (2020); Zhang et al. (2021); Sun et al. (2022); Leal Filho et al. (2022); and Wang et al. (2022).

Though FDI has implications for economic growth and environmental quality, especially in the perspectives of the pollution halo/haven hypothesis. The results show that the $\ln(FDI)_{it}$ elasticities are positive and significant across the different estimation techniques with $p-$ values < 0.01 (Table 3). Moreover, the $\ln(FDI)_{it}$ are also positive across the quantiles and have $p-$ values < 0.01 confirming the pollution haven hypothesis for the panel of developed and emerging economies. The findings in previous studies such as (Hemberg and Hedenbergh 2018; Huang et al. 2022, 2023; Wang and Huang 2022; Apergis et al. 2022b). The signs of REC are negative and significant across the estimation methods used for estimation (Tables 3 and 4). However, the values of REC elasticities in quantile regression estimates (Table 4) increase at higher quantiles of the distributions. This GHG reduction impact of REC is following the prior expectations. This negative impact of REC on GHG emissions is also supported by the findings of (Ali et al. 2019; Gielen et al. 2019; Li et al. 2021, 2023; Szetela et al. 2022; Iqbal et al. 2023; Tan et al. 2023; Huang et al. 2023). REC negatively affects environmental degradation (Sharif et al. 2019). The economy's structure indicated by the service sector output also has its role in reducing GHG emissions and contributing to climate change mitigation efforts. It is evident from the results in Tables 3 and 4 that growth in the service sector in the panel of selected developed and emerging economies adds to the efforts to combat climate change by reducing GHG emissions. Notably, the quantile elasticities of $\ln(SPW)_{it}$ are higher than other explanatory variables of the model(s).

Discussion

Tourism can impact environmental sustainability in multiple ways. Tourism adds to GHG emissions through transportation (such as flights and driving), lodging (such as heating and cooling), and activities (such as motorized water sports). These emissions can contribute to climate change and have adverse environmental consequences. International tourism contributes significantly to carbon emissions from transportation, notably air travel (Leal Filho et al. 2022). Tourism contributes to around 8% of worldwide carbon emissions (UNWTO 2018). Furthermore, tourism-related transportation accounts for 5% of global CO_2 emissions (IEA 2019). Overconsumption of water, food, and energy resources can result from tourism. This can put a burden on local resources and ecosystems, especially in resource-constrained locations. Overuse of resources, particularly in countries with few resources, is a risk associated with international tourism. Tourism is one of the significant causes of water and energy use in Europe and can result in resource overuse and depletion (Giulietti et al. 2018). Encouraging the adoption of eco-friendly solutions, particularly in the tourism transportation industry, can be an efficient approach to reducing the carbon footprint of tourism travel (Lenzen et al. 2018; Erdoğan et al. 2022). By expanding infrastructure, off-road driving, and hiking, among other activities, tourism may lead to habitat damage. This may result in ecological fragmentation and a loss of biodiversity. Moreover, tourism may contribute to pollution by generating trash such as litter, sewage, and plastic garbage. This has the potential to harm wildlife, ecosystems, and human health. International tourists may contribute to pollution by generating litter, sewage, and plastic garbage. Tourism is a significant contributor to marine debris, with beach litter containing up to 90% plastic products (Conservancy 2022). Changing social structures and attitudes and the loss of traditional knowledge and practices are only a few of the cultural effects that tourism may have (Zhang et al. 2017).

There is no clear link between EPU and climate change. However, EPU can contribute to climate change through the channels of delayed actions (Baker et al. 2016), reduced investment (Zhang et al. 2021), (in)consistent policies (Leal Filho et al. 2022), and trade policy (Sun et al. 2022). In a recent study, Li et al. (2023) also support the finding of our research that economic policy EPU increases climate change by increasing ecological footprints. Moreover, climate policy uncertainty causes delays and postponements in RE-related investment and hampers climate action (Baker et al. 2016; Zhang et al. 2021). Inconsistent economic policies can cause uncertainty for firms and investors, making long-term planning and investment difficult. This can lead to a need for more investment in clean energy technology and practices, as well as an encouragement for firms to continue using fossil fuels and other ecologically harmful activities. Elevated levels of EPU may result in delays or postponement of the implementation of the strategies and actions devised for climate change mitigation. Furthermore, increased uncertainty may divert the attention of the government from the formulation of rules and regulations to ensure eco-friendly consumption and production practices. Moreover, it may slow down the pace of the energy transition from non-renewable to renewable sources of energy. Delaying action can make climate change worse by enabling emissions to remain high (Huang et al. 2023). EPU can also decrease investment in RE and other climate mitigation technology (Zhang et al. 2021). This can reduce the availability of resources needed to combat climate change, limiting the development and uptake of sustainable solutions. Uncertainty in trade policy can also have an impact on the environment. If trade laws impose impediments to the import or export of RE technology, their development and acceptance may be slowed, resulting in increasing emissions (Sun et al. 2022).

While generating electricity, RE sources such as solar, wind, hydropower, geothermal, and biomass create little to no greenhouse gases (GHGs) (Yasmeen et al. 2021). Non-renewable energy increases the ecological footprint (Li et al. 2023). However, the best alternative to non-renewable energy is RE. Which has an enormous potential to significantly cut GHG emissions and help prevent climate change by using these sources instead of fossil fuels (Ali et al. 2019; Li et al. 2021, 2023; Szetela et al. 2022). Technologies utilizing RE sources can also aid in lowering energy costs and improving energy effectiveness (Lins and Murdock 2015). For instance, energy-efficient structures that rely on RE sources can decrease the energy required to run appliances, lights, and heating and cooling systems (Satrovic and Adedoyin 2023). By reducing dependence on fossil fuels, RE sources can improve energy security and lower the likelihood of supply interruptions. This is especially crucial for nations that rely significantly on imported oil and gas. New employment in the energy industry and allied fields like manufacturing, installation, and maintenance may be generated by the switch to RE sources. This may support sustainable development and economic prosperity (IRENA-ILO 2022). RE technologies' costs are falling as they improve and become more efficient. RE sources are becoming cost-competitive, if not cheaper, than fossil fuels in many circumstances (IRNEA 2022). This could result in substantial cost reductions for both consumers and corporations. A significant contributor to GHG emissions is the design of the energy system, including the kind of fuel utilized and the energy mix. GHG emissions are higher in nations that rely significantly on coal-fired power plants than in those primarily using RE sources like solar, wind, or hydropower. As a result, implementing a low-carbon energy system is essential for reducing climate change. These studies show that FDI can stymie developed-country climate change mitigation efforts through various pathways, including carbon leakage (Hemberg and Hedenbergh 2018), inadequate control over environmental rules, resource rivalry, and restricted transfer of green technology. The research showed that FDI caused carbon leakage in Sweden, where emissions reductions were offset by increases in nations where Swedish multinational businesses had invested (Hemberg and Hedenbergh 2018). However, many studies show that FDI increases host economies' carbon emissions. However, the FDI can play a pivotal role in climate change mitigation in economies with higher economic growth levels and improved regulatory quality (Huang et al. 2022).

The economic structure substantially impacts the amount of GHG emissions and the possibilities for climate change mitigation (Li et al. 2021). For instance, the quantity of GHG emissions may vary depending on industries' makeup and relative size. Moreover, due to its energy-intensive operations, the manufacturing industry contributes significantly to GHG emissions (Prastiyo et al. 2020). Compared to an economy predominantly based on services, one mainly dependent on manufacturing is likely to have higher GHG emissions. Thus, moving towards a service-based economy could reduce GHG emissions (Okamoto 2013). Growth in the service sector shifts the economy away from more energy- and pollution-intensive sectors like manufacturing and agriculture, which decreases greenhouse gas emissions. Compared to manufacturing, mining, or farming, service sector activities, including education, healthcare, finance, and entertainment, often have fewer direct emissions. However, expanding the service sector is only sometimes beneficial to the environment. Activities in the service sector may also cause indirect emissions through their use of transportation, power, and other products and services made by other industries. As a result, more than an increase in the service sector is needed to slow down climate change. Using RE, increasing energy efficiency, implementing low-carbon technology, altering consumption patterns, and boosting natural carbon sinks can help cut emissions across all sectors (Suh 2006; Ritchie 2020; UCAR 2023). The service sector may lower its energy usage by implementing energy-efficient techniques in buildings, lighting, and equipment. For instance, innovative building technology, energy-efficient appliances, and LED lighting installations can all assist lower energy use and the resulting greenhouse gas emissions. The service industry may also encourage using RE sources, including wind, solar, and geothermal energy. Businesses may minimize their carbon footprint and aid in the shift to a low-carbon economy by investing in RE or installing RE systems on their premises (Gielen et al. 2019). The service industry may encourage the adoption of green building design, which incorporates elements like solar panels, green roofs, and natural ventilation. Buildings' energy use and carbon footprint, which contribute considerably to greenhouse gas emissions, may be significantly reduced via the adoption of green building design (Azhgaliyeva and Rahut 2022). Moreover, the service industry may also encourage the use of RE sources such as wind, solar, and geothermal energy. Businesses may minimize their carbon footprint and aid in the shift to a low-carbon economy by investing in RE or installing RE systems on their premises.

By supporting sustainable mobility, the service sector may also aid in mitigating climate change. For instance, businesses might reward staff who commute by bicycle, carpooling, or public transit. Also, companies can operate with electric cars or low-carbon fuels like biofuels or hydrogen fuel cells. Transportation contributes significantly to greenhouse gas emissions (Lorenzi and Baptista 2018). Compared to economies with well-developed public transportation systems or those that promote walking and cycling, economies that rely heavily on private automobiles for mobility are likely to have greater GHG emissions. Thus, measures that encourage environmentally friendly mobility, such as infrastructure for public transit or bike-sharing programs, can aid in reducing climate change. The service industry may help in reducing the effects of climate change by adopting energy-saving techniques, promoting green building design, encouraging sustainable mobility, utilizing RE, and encouraging sustainable practices in their daily operations. These initiatives can facilitate the transition to a low-carbon economy and help cut GHGs.

Conclusion

The study explored the impact of international tourist arrivals on environmental sustainability measured by GHG emissions in the developed and emerging economies panel. Moreover, the study also considered the impact of EPU, FDI, RE, and the economy's structure measured by service sector output. Since the data have the issues of cross-sectional dependence, heterogeneity, heteroskedasticity, and autocorrelations, the authors have used pooled OLS, GLS, PCSE, and quantile regression methods to estimate the proposed model. The results of the study show that international tourism has a negative impact on environmental sustainability as it increases GHG emissions. Moreover, EPU also increases GHG emissions, which confirms that EPU hampers the climate change mitigation process. RE plays a positive role in maintaining environmental sustainability by reducing GHG emissions. The study also confirms the presence of the pollution haven hypothesis in the panel. Moreover, the service sector output also plays a productive role in reducing GHG emissions and achieving the objective of environmental sustainably.

The findings emphasize the significance of developing sustainable tourism practices to reduce the environmental effects of the tourism sector. It involves lowering GHG emissions, decreasing waste and resource use, conserving biodiversity, and honoring local cultures and communities. Travelers may help the environment by making deliberate decisions like choosing eco-friendly hotels, saving water and electricity, and supporting conservation programs in the regions they visit. The tourism industry can also be essential in reducing its environmental impact by encouraging RE sources, implementing policies and regulations to reduce greenhouse gas emissions, and encouraging environmentally friendly travel behaviors such as responsible waste management and habitat protection. It may be accomplished by investing in clean energy technology and persuading businesses to switch to RE sources through monetary incentives and tax breaks. Raising public awareness, educating individuals on the environmental effects of tourism, and supporting eco-friendly tourist practices may assist in developing a culture of sustainable and green tourism. Encouragement of eco-friendly transportation, recycling, and support for local conservation programs may help reduce tourism's environmental effects. Furthermore, the report recommends implementing consistent trade norms and policies that encourage using RE sources and climate-resilient technology. It involves fostering the spread of green technology in developing countries and ensuring that multinational firms finance environmentally sustainable business practices. Collaboration with international organizations to promote ecologically friendly tourist practices can also aid in reducing the industry's negative environmental impacts.

This study investigates how international tourism affects environmental sustainability in different economies. It uses various regression methods to account for data issues and other variables. The findings indicate that international tourism and EPU worsens environmental sustainability by increasing greenhouse gas emissions. RE and service sector output help reduce emissions and improve sustainability. The study suggests promoting sustainable tourism practices and RE sources in the tourism industry. This study indicates that sustainable tourism practices should be promoted to reduce tourism's negative impact on environmental sustainability. This includes lowering emissions, waste, and resource use, and preserving biodiversity and local cultures. Tourists and the tourism industry should adopt eco-friendly behaviors, such as choosing green hotels, saving energy and water, supporting conservation efforts, using RE sources, and following laws and guidelines to reduce emissions. The study also recommends reducing EPU by creating consistent trade policies that favor RE and green technologies. The study urges collaborating with global organizations to foster environmentally friendly tourism practices and mitigate the industry's environmental harm.

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Declarations

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