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Decarbonizing Tourism: The Impact of Renewable Energy in the World's Most Tourism Intense Countries

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ABSTRACT

This study investigates the dynamic relationship between tourism, renewable energy consumption, and CO_2 emissions in the top 50 tourism-intensive countries, measured by the share of tourism receipts in total exports. Using panel data from 2000 to 2020, the analysis applies a two-step system GMM estimator to address endogeneity concerns, along with fixed effects and quantile regression techniques. The findings reveal that while tourism contributes to increased CO_2 emissions, renewable energy consumption plays a significant mitigating role. Specifically, a 1% increase in renewable energy use is associated with a 1.1% reduction in CO_2 emissions, with the strongest effects observed in high-emission countries. The study also finds empirical support for the Environmental Kuznets Curve (EKC) hypothesis, with a calculated turning point at approximately USD 5,420 GDP per capita. By focusing on tourism-driven economies, this research makes several novel contributions: It highlights the environmental risks posed by tourism, underscores the importance of renewable energy in achieving sustainable development, and offers policy-relevant insights for balancing economic growth with environmental preservation. The results suggest that integrating renewable energy strategies into tourism planning is essential for reducing the sector's carbon footprint without compromising growth.

Keywords: Renewable Energy, Tourism, CO_2 Emissions, GDP per Capita
JEL Classification: Q20

1. INTRODUCTION

In 2024, the Travel and Tourism sector contributed US$ 10.9 trillion to global GDP, encompassing its direct, indirect, and induced impacts. This accounted for 10% of the global economy. The sector also supported 357 million jobs worldwide, or roughly 1 in 10 jobs. According to the World Bank, tourist arrivals have grown significantly over the past two decades, rising from 1.33 billion in 2000 to 2.4 billion in 2019. During the same period, global tourism receipts more than tripled. Considering the growing importance of tourism sector, the research on its socio-economic impacts has proliferated. One strand of studies examines the contribution of tourism to economic development and finds that tourism has positive effect on GDP growth in Africa (Fayissa et al., 2008), Island economies (Durbarry, 2004), developed and developing countries (Paramati et al., 2017) and globally (Risso, 2018). At the same time, while promoting economic growth tourism can contribute to increased CO_2 emissions through various channels, primarily due to the increased energy consumption and transportation sector. Air travel, which is a major mode of transport for tourists, is particularly carbon-intensive, as flights emit large amounts of CO_2 per passenger. Thus, a second strand of research has emerged that examines the relationship between tourism and CO_2 emissions (Kocak et al., 2020; Shakouri et al., 2017). The empirical literature on the relationship between tourism and CO_2 emissions is mixed

at best (Mishra et al., 2022). Some studies indicate that tourism contributes to increased CO_2 emissions, primarily through transportation and infrastructure development. In contrast, other research suggests that tourism may help mitigate environmental degradation by fostering investment in sustainable practices and promoting environmental awareness. Additionally, some scholars argue that the tourism-emissions nexus should be examined in the context of broader socio-economic factors, such as GDP growth, globalization, and renewable energy consumption, to better understand the complex dynamics at play (Rahaman et al., 2022; Meșter et al., 2023). Indeed, it is essential to examine the role that renewable energy can play in reducing the effects of tourism on CO_2 emissions without harming economic growth processes.

Therefore, the aim of this study is to examine the relationship between tourism, renewable energy and CO_2 emissions in a sample of top 50 tourism intense countries by share of tourism receipts in total exports. We use data from 2000 to 2020 and several panel data methods such two-step system GMM estimator to account for simultaneity and endogeneity problems, panel fixed effects quantile method and fixed effects regression. This paper makes several key contributions to the literature on renewable energy and CO_2 emissions in tourism-intensive economies. First, it provides a novel empirical analysis of the relationship between renewable energy adoption and CO_2 emissions specifically within countries heavily dependent on tourism. While much of the existing literature has focused on general energy consumption and emissions, this study adds value by considering the unique economic structure of tourism-driven nations. Second, the paper investigates how the transition to renewable energy may influence the environmental footprint of the tourism sector, offering insights into whether renewable energy can offset the emissions generated by tourism-related activities. Third, it expands on the tourism-environmental sustainability debate by integrating renewable energy consumption as a critical factor in reducing CO_2 emissions, an area not sufficiently explored in tourism-heavy economies. Finally, the study highlights policy implications for tourism-dependent countries, suggesting pathways for achieving sustainable development goals through a combination of tourism management and energy policy.

Our results suggests that 1% increase in renewable energy consumption is associated with 1.1% decrease in CO_2 emissions. We document the presence of the EKC framework in tourism intense countries as both GDP per capita and GDP per capita squared are significant. The turning point in column 1 is 5420 USD. The effect of renewable energy consumption is strongest in countries with the highest levels of CO_2 emissions, where the transition to renewable energy appears to have the most pronounced impact on reducing emissions.

The rest of the study is structured as follows. Section 2 reviews recent related empirical literature. Section 3 presents data and Section 4 discusses the empirical results. Section 5 concludes the study and provides policy implications.

2. LITERATURE REVIEW

2.1. Renewable Energy and CO_2 Emissions

Previous empirical studies on the relationship between various variables and CO_2 emissions have produced mixed or inconclusive results. Increased CO_2 emissions are often correlated with economic growth because growth patterns typically correlate positively with energy consumption, which in turn leads to greater pollution.

The linkage between economic growth, carbon dioxide emissions, renewable energy and globalization for the period 1970-2010 in Portugal was analyzed by Leitão (2014). The author uses OLS, GMM, unit root test, VEC model, and Granger causality methods, and according to research, economic growth exhibits a positive correlation with both CO_2 emissions and renewable energy usage.

Bilgili et al. (2016) have investigated validity of the EKC hypothesis employing the dependent variable of CO_2 emissions, using FMOLS and panel DOLS estimations using a panel data set of 17 OECD countries from 1977 to 2010. The study revealed evidence of a positive association between GDPs per capita and CO_2 emissions, while GDP per capita squared has an impact on CO_2 emissions. Additionally, the research underlined that renewable energy consumption has a negative effect on CO_2 emissions.

In another study, Hasnisah et al. (2019) conducted research to examine the influence of environmental quality, economic development, renewable and non-renewable energy consumption on 13 developing countries in Asia for the period 1980-2014. Using a panel cointegration and FMOLS, they discovered the existence of the inverted U-shape EKC hypothesis in 13 Asia countries. Nevertheless, the results indicate that the consumption of renewable energy has an insignificant effect on lowering CO_2 pollution. These findings highlight the need for the Asian countries to design a strategic plan aimed at reducing the rate of global warming and climate change.

Al Araby et al. (2019) examined the dynamic effect of GDP, renewable and non-renewable energy and industrial sector share on carbon emissions over the period 2002-2016 in 25 Euro Mediterranean Countries. The results emphasized that renewable resources have a negative impact on CO_2 emissions. However, at the same time, positive relationships exist between economic growth and electricity generation from coal, leading to increased environmental pollution.

Recent studies by Wang et al. (2021) have investigated relationships between renewable energy consumption and carbon dioxide emissions across twenty-five countries involved in the Belt and Road Initiative from 2005 to 2019 using the generalized Divisia index method. Authors found that the growth of renewable energy is a principal factor increasing CO_2 emissions in many Belt and Road Initiative countries, while the carbon intensity of renewable energy is the main factor decreasing CO_2 emissions.

Additionally, the carbon mitigation effect of increasing renewable energy share is significantly greater than that of technological developments in renewable energy sources. This will contribute to the transformation of the relationship between renewable energy and environmental pollution into a stronger, decoupling relationship.

Namahoro et al. (2021) confirm that in in a panel of 50 African countries over the period 1980-2019, renewable energy consumption contributed to the mitigation environmental pollution. In contrast, energy use intensity promoted emissions across regions and income levels. Based on the results of analyses, it was shown that renewable energy significantly contributed to the reduction of CO_2 emissions over a 10-year period. This effect is explained by the roles of energy intensity and economic growth.

Chen et al. (2022) examined the relationship between renewable, non-renewable energy consumption, economic growth, and CO_2 emissions, using dynamic panel threshold models in 97 countries for the period 1995-2015. Their findings suggest that an increase in renewable energy consumption per capita exerts a negative impact on the growth of CO_2 emissions per capita if countries exceed a certain threshold level of renewable energy usage.

The dynamic interrelationship in the renewable energy consumption –environment nexus was investigated by Mirziyoyeva and Salahodjaev (2022). Using regression and two-step GMM, their analysis focused on countries with the highest carbon emissions between 2000 and 2015. Their study finds support that a percentage increase in renewable energy usage results in a 0.98% decrease in CO_2 emissions.

Khezri et al. (2022) explore the environmental consequences of economic complexity and its influence on how renewable energies impact CO_2 emissions across 29 Asia-Pacific countries using a series of panel data models and estimation methods from 2000 to 2018. The research highlighted the existence of scale effects of renewable energy resulting in increased CO_2 emissions which suggests that increasing the share of wind and solar energy in countries with lower economic complexity has led to reduced CO_2 emissions. In contrast, counties with greater economic complexity experience a scale effect that increasing renewable energy usage leads to a rise in CO_2 emissions.

Jamil et al. (2022) analyzed and contrasted the correlations between CO_2 emissions, renewable energy utilization, trade openness, gross domestic product, financial sector advancement, and remittance inflows within a selection of G-20 nations, using FMOLS and DOLS models for the period 1990-2019. A study found that there is a significant and negative relationship between renewable energy and CO_2 emissions. Two models demonstrated that the economic growth of selected G-20 countries is positively correlated with CO_2 emissions.

In another study, Szetela et al. (2022) conducted research to examine the influence of renewable energy and carbon dioxide (CO_2) emissions in the leading natural resource-dependent countries during 2000-2015. Using OLS and two-step GMM estimators, the authors discovered that renewable energy usage has a considerable mitigating impact on per capita CO_2 emissions. Specifically, one percentage point increase in renewable energy consumption leads to a 1.25% decrease in CO_2 emissions per capita.

Using MMQR with fixed effects, DOLS and the Driscoll and Kraay estimators, Wolde-Rufael and Mulat-Weldemeskel (2022) analyzed the impact of environmental tax and renewable energy in mitigating CO_2 emissions in 18 Latin America and Caribbean (LAC) countries for the period 1994-2018 including variables how financial development, non-renewable energy and economic growth. Their research provided that both environmental taxes and renewable energy sources can contribute to the reduction of carbon emissions. However, the emissions mitigation effect of renewable energy is significantly higher than that of environmental taxes. Also, they found that environmental taxes not only reduce CO_2 emissions but also encourage the consumption of renewable energy.

Using panel data, Balsalobre-Lorente et al. (2023) analyzed the dynamic causal relationship between CO_2 emissions per capita, the economic complexity index, renewable energy, and inward foreign direct investment for the BRICS countries from 1995 to 2020. Their study provided evidence supporting the environmental Kuznets curve hypothesis, demonstrating a positive but reduced influence of economic growth on environmental damage. Eventually, CO_2 emissions may stabilize to a neutral level.

In the recent study, Wahyudi (2024) explore the impact between renewable energy and CO_2 emissions over the period 1990-2021 in Indonesia. Using VECM, this study considers both short-term and long-term relationships among the variables. The results showed that carbon emissions have a positive and significant effect. Additionally, renewable energy usage in Indonesia is still limited, as non-renewable energy continues to show a negative and significant impact in both the short and long term. The authors highlight the importance of an incremental and phased approach to energy replacement.

2.2. Tourism and CO_2 Emissions

An expanding body of research has explored the impact of tourism development on environmental outcomes, particularly on carbon dioxide (CO_2) emissions (Pata et al., 2023; Irmatova et al., 2025). In a recent systematic review of tourism-emissions nexus, Sun et al. (2022) analyze 81 published studies over the period 2013-2021. The authors conclude that "contradictory results being reported across regions, income levels, and the sector's economic importance. highlighting the need to critically reconsider tourism-carbon interrelationships and the methods used in empirical studies" (p. 1). Indeed, the relationship is nuanced and often context-specific. Some studies report a positive association, while others suggest a mitigating or even neutral effect. For example, Shakouri et al. (2017) investigated the relationship between international tourist arrivals and CO_2 emissions in 12 Asia-Pacific countries over the period 1995-2015. Employing the generalized method of moments (GMM) model, their results indicate that both tourist arrivals and GDP are positively associated with CO_2 emissions.

Paramati et al. (2017) investigates the complex associations between tourism, economic growth, and CO_2 emissions, with a comparative focus on developed and developing countries. Utilizing advanced panel econometric methods, the analysis confirms that tourism significantly contributes to economic growth in both groups, aligning with the tourism-led growth hypothesis. Moreover, the findings indicate that tourism-induced CO_2 emissions are declining more rapidly in developed economies than in their developing counterparts, lending empirical support to the Environmental Kuznets Curve (EKC) hypothesis in the context of tourism. These results highlight the relevance of distinguishing countries by their level of economic development to better understand the nuanced relationships among tourism, growth, and environmental impact. The study concludes with a discussion of policy implications derived from the findings. Katircioglu et al. (2014) explores the long-term equilibrium relationships among international tourism, energy consumption, and carbon dioxide (CO_2) emissions in the context of Cyprus—a small island nation hosting over two million international tourists annually. The findings from tourism-driven models indicate a stable long-run relationship among the three variables, with international tourist arrivals exerting a positive, statistically significant, and inelastic effect on both energy consumption and CO_2 emissions, highlighting tourism's adverse impact on climate change. Results from error correction models show that CO_2 emissions adjust toward their long-run equilibrium path at a rapid rate of 95.4%, mediated by tourism and energy use, whereas energy consumption adjusts more slowly—at a rate of 13.5%—through the influence of tourism and emissions. Moreover, conditional Granger causality analysis reveals that international tourism serves as a driving force behind increased energy use and CO_2 emissions in Cyprus. In a different study, Kocak et al. (2020) investigate how carbon dioxide (CO_2) emissions—recognized as a primary driver of global warming—respond to tourism-related developments. Focusing on the world's most visited countries over the period 1995-2014, the analysis employs the continuously updated fully modified (CUP-FM) and Continuously Updated Bias-Corrected (CUP-BC) estimators. The empirical findings suggest that while increases in tourist arrivals are associated with higher CO_2 emissions, tourism receipts are linked to a reduction in emissions. Additionally, the results point to a potential long-run co-movement and causal relationship between tourism activity and environmental outcomes.

Eyuboglu and Uzar (2019) focused on Turkey, analyzing the relationship between tourism, GDP, energy consumption, and CO_2 emissions from 1960 to 2014. Using the vector error correction model (VECM) causality framework, they found a positive correlation among these variables. Leitão and Lorente (2020) tested several hypotheses across 28 European Union countries using the GMM-System estimator. These included: (H_1) a positive relationship between income per capita and CO_2 emissions; (H_2) reduced climate change in economies using renewable energy; (H_3) the role of sustainable tourism in promoting environmental awareness and reducing climate change; and (H_4) the positive influence of trade openness on environmental systems. Their results supported the hypothesis that tourism negatively affects CO_2 emissions, suggesting that sustainable tourism may contribute to environmental improvements. The authors recommended extending future research to BRICS and Central and Eastern European countries, possibly using the panel ARDL model.

Some studies have also explored reverse causality—namely, the effect of CO_2 emissions on economic and tourism indicators. Zhang and Zhang (2021), analyzing data from 30 Chinese provinces between 2000 and 2017, employed a VECM Granger causality approach. They found that CO_2 emissions positively influence both GDP and tourism. They recommended future studies expand the analysis to include prefecture-level data and differentiate between renewable and non-renewable energy, as well as domestic versus international tourism.

Rehman et al. (2021) explored two contrasting theoretical views: one positing that tourism increases CO_2 emissions, and the other suggesting tourism not only stimulates economic growth but also reduces emissions. Analyzing data from Pakistan (1991-2019) using the Nonlinear ARDL (NARDL) technique and Granger causality, their results confirmed both theoretical strands.

Interesting findings were presented by Handoyo et al. (2022), who analyzed data from high-, upper-middle-, and lower-middle-income Asian countries between 2010 and 2019 using the Poisson Pseudo-Maximum Likelihood (PPML) method. Grounded in the Environmental Kuznets Curve (EKC), Pollution Haven Hypothesis, Pollution Halo Hypothesis, and Heckscher-Ohlin Theory, their study revealed that in lower-middle-income countries, tourism increases CO_2 emissions, whereas in higher-income groups, tourism reduces emissions.

Salahodjaev et al. (2022) tested the EKC hypothesis using panel data from 45 European and Central Asian countries and applied a two-step GMM estimator. They found that renewable energy use reduces CO_2 emissions, while tourism increases them. The authors acknowledged the study's limitation in not exploring multiple dimensions of tourism or long-run interactions among tourism, renewable energy, and emissions. A similar topic was investigated by Qodirov et al. (2024), who focused on Uzbekistan using ARDL modeling over the period 2000-2023. Their results indicated a positive relationship between GDP growth, exchange rate, CO_2 emissions, and tourist arrivals.

3. DATA AND METHODOLOGY

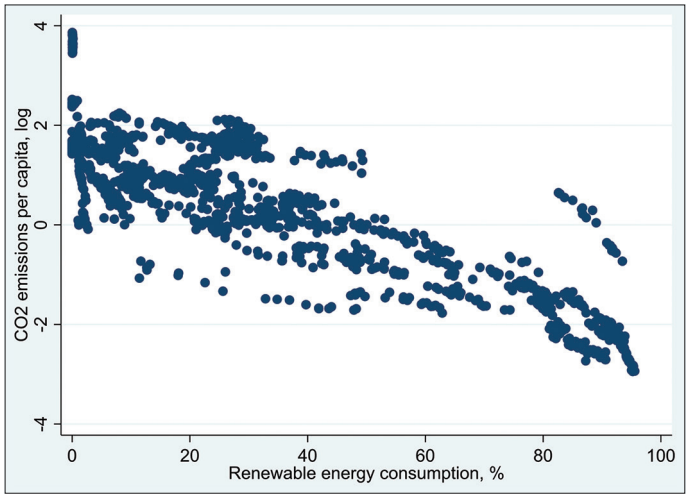
The aim of this research is to examine the effects of tourism and renewable energy on CO_2 emissions in a sample of the top 50 tourism intense countries for which data is available. The sample covers countries for the years 2000-2020 due to the lack of tourism data post 2020. The dependent variable in this study is CO_2 emissions (metric tons per capita). The data comes from the World Bank. In our sample CO_2 emissions range from 0.05 to 47.66 in Qatar. We take natural logarithm (log) to make the distribution of CO_2 emissions more symmetric and reduce the influence of extreme values, helping satisfy regression assumptions. Our main independent variable is renewable energy consumption as a % of total energy consumption. The data was obtained from the World Bank. Figure 1 reports the scatterplot between renewable energy consumption and carbon emissions in our sample for the period

2000-2020. As can be seen, there is a negative association between renewable energy use and environmental degradation.

Following related empirical studies, we include a set of control variables in our econometric model. First, we include GDP per capita and its squared term to account for non-linear (inverted U-shaped) link between economic growth and CO_2 emissions. The EKC hypothesis was tested for Small Island States (Akadiri et al., 2021), Caribbean countries (Al-Mulali et al., 2015), 208 countries (Wang et al., 2023) and OECD member states (Isik et al., 2021). The data comes from the World Bank. Next, we include urban population growth from the World Bank. Urbanization can increase CO_2 emissions by concentrating population and economic activity in cities, leading to greater energy consumption, transportation use, and industrial production. However, it can also reduce per capita emissions through more efficient infrastructure, public transportation, and compact urban planning. The urbanization-emission nexus has been examined by a number of studies recently (Ozturk et al., 2023; Yao et al., 2021; Gierałtowska et al., 2022; Umarov et al., 2025). Apart from economic growth and urbanization, internation trade is shown to be linked with CO_2 emissions (Dauda et al., 2021; Chen et al., 2021). Trade as % of GDP from the World Bank is also included in the model. Finally, we include tourism receipts to capture the effect of tourism income on environmental quality in tourism intense economies. The descriptive statistics are reported in Table 1.

To explore the relationship between the variables selected in our study we use two-step system GMM estimator. The two-step system GMM estimator is particularly essential for analyzing the relationship between renewable energy and CO_2 emissions in tourism-intense countries using panel data, as it addresses several econometric challenges inherent in this type of analysis. First, system GMM effectively controls for unobserved country-specific effects and endogeneity of explanatory variables, which is crucial when key variables such as renewable energy use and emissions may be jointly determined or influenced by omitted factors. Second, it accommodates the dynamic nature of environmental outcomes by allowing the inclusion of lagged dependent variables, capturing the persistence of CO_2 emissions over time. Third, the two-step version provides robust and efficient estimates, especially in panels with a larger number of countries (N) and a shorter time dimension (T). Thus, the empirical model in its linear form can be expressed as:

Figure 1: Scatterplot between renewable energy and CO_2 emissions



$$CO_{2,it} = a_0 + a_1 RE_{i,t} + a_2 GDP_{i,t} + a_3 GDP_{i,t}^{\ 2} + a_4 URB_{i,t} + a_5 TRADE_{i,t} + a_6 TOUR_{i,t} + \varepsilon \quad (1)$$

Where CO_2 stands for CO_2 emissions per capita, RE denotes renewable energy consumption, GDP is for GDP per capita, URB is urban population growth, TRADE is trade openness, TOUR is tourism receipts and ε is an error term satisfying normality assumptions: α_0, α_1, α_2, α_3, α_4, α_5 and α_6 are parameters to be estimated.

Eq. (1) under the assumptions of the two-step system GMM estimator can be specified as:

$$CO_{2,it} = \sigma_0 + \sigma_1 CO_{2,it-\tau} + \sigma_2 RE_{i,t} + \sum_{h=1}^{k} \delta_h X_{h,it-\tau} + v_{i,t} \quad (2)$$

$$CO_{2,it} - CO_{2,it-\tau} = \sigma_1 \left(CO_{2,it-\tau} - CO_{2,it-2\tau} \right) + \sigma_2 \left(RE_{i,t} - RE_{i,t-\tau} \right) + \sum_{h=1}^{k} \delta_h \left(X_{h,it-\tau} - X_{h,it-2\tau} \right) + \left(v_{it} - v_{it-\tau} \right)$$

Where i stands for country, t denotes year, X is the vector of control variables, τ is parameter of autoregression and v is the vector of error term.

4. RESULTS

The baseline results are reported in Table 2. Columns 1 and 2 present the results from the mean regression estimator. As can be seen, renewable energy has negative link with CO_2 emissions

Table 1: Descriptive statistics

Variable	Description	Mean	Standard deviation	Min	Max
CO_2	CO_2 emissions, per capita log	0.38	1.37	−2.94	3.86
GDP	GDP per capita, log	8.47	1.42	4.70	11.68
URBAN	Urban population growth, %	1.93	2.04	−4.01	19.61
RE	Renewable energy consumption as % of total energy	29.45	28.85	0.00	95.55
TRADE	Trade as % of GDP	85.87	36.89	2.70	235.82
RECEIPTS	Tourism receipts, log	20.42	1.96	14.22	24.89
ARRIVALS	Tourism arrivals, log	13.80	1.95	8.43	18.19

Table 2: Baseline results

Variable	I	II	III	IV
CO_2, lag	0.6799	0.6631	0.6799	0.6631
	(22.60)***	(22.06)***	(15.65)***	(15.22)***
GDP	0.3679	0.3546	0.3679	0.3546
	(5.30)***	(5.32)***	(3.37)***	(3.15)***
GDP^2	−0.0214	−0.0211	−0.0214	−0.0211
	(5.34)***	(5.51)***	(3.25)***	(3.19)***
URBAN	−0.0028	−0.0036	−0.0028	−0.0036
	(1.09)	(1.80)*	(0.75)	(1.35)
RE	−0.0111	−0.0109	−0.0111	−0.0109
	(9.17)***	(9.37)***	(7.68)***	(7.55)***
TRADE	0.0010	0.0008	0.0010	0.0008
	(3.92)***	(3.48)***	(3.43)***	(3.09)***
RECEIPTS	0.0167		0.0167	
	(1.63)		(1.25)	
ARRIVALS		0.0407		0.0407
		(4.54)***		(2.67)**
Constant	−1.4252	−1.5627	−1.4739	−1.5843
	(4.40)***	(5.11)***	(3.08)***	(3.44)***
R^2	1.00	1.00	0.88	0.88
N	877	900	877	900

*P<0.1; **P<0.05; ***P<0.01

Table 3: Two-step system GMM estimator

Variable	I	II
CO_2, lag	0.6961	0.8260
	(13.51)***	(23.74)***
GDP	0.2624	0.2267
	(2.27)**	(1.43)
GDP^2	−0.0058	−0.0094
	(1.01)	(1.26)
URBAN	−0.0011	−0.0036
	(0.33)	(0.88)
RE	−0.0055	−0.0041
	(4.57)***	(2.56)**
TRADE	0.0012	0.0019
	(2.41)**	(4.07)***
RECEIPTS	0.0093	
	(0.75)	
ARRIVALS		−0.0227
		(1.35)
Constant	−1.7640	−0.8142
	(2.93)***	(1.10)
AR (1)	0.000	0.000
AR (2)	0.635	0.697
Hansen P-value	0.142	0.162
N	877	900

*P<0.1; **P<0.05; ***P<0.01

in our sample. In particular, 1% increase in renewable energy consumption is associated with 1.1% decrease in CO_2 emissions. These results are similar to Kuldasheva and Salahodjaev (2023) reported for rapidly urbanizing countries. Turning to tourism measures only tourism arrivals are positively associated with environmental degradation: A 1% increase in the number of tourist arrivals is associated with 0.04% increase in CO_2 emissions. We document the presence of the EKC framework in tourism intense countries as both GDP per capita and GDP per capita squared are significant. The turning point in column 1 is 5420 USD. Trade openness is also positive and significant: a 1% increase in trade as % of GDP leads to 0.1% rise in carbon emissions. Urbanization is not significantly linked to CO_2 emissions in tourism intense countries. Columns 3 and 4 report the results from the fixed effects regression estimator. Fixed effects regression is superior to OLS when analyzing panel data because it controls for time-invariant unobserved heterogeneity across entities, which OLS cannot address. By accounting for these unobserved individual effects, fixed effects provide more consistent and unbiased estimates, especially when omitted variables are correlated with the regressors. The results are similar to the ones reported using OLS approach in columns 1 and 2. We again document renewable energy mitigates CO_2 emissions.

Table 3 reports the results from the two-step system GMM estimator. As discussed above, this approach enables us to account for the problems of endogeneity and simultaneity. These results suggest that while tourism is not significantly related to CO_2 emissions, renewable energy has a negative and significant effect on environmental degradation. In column 1, a 1% increase in renewable energy consumption leads to 0.55% decrease in CO_2 emissions over the period 2000-2020. Our results are similar to Salahodjaev et al. (2022) who examine the relationship between tourism, renewable energy and CO_2 emissions in a sample of Europe and Central Asian countries. They show that 1% increase in renewable energy use leads to 0.4% decline in CO_2 emissions. Turning to control variables, GDP per capita and trade openness are positive and significant in Column 1. The reliability of the two-step GMM estimator is validated through the Arellano-Bond second-order autocorrelation test (AR[2]) and the Hansen test for overidentifying restrictions. Thus, the results in Tables 2 and 3 show that renewable energy has significant effect in mitigating CO_2 emissions in tourism-intensive economies.

Next, we use a panel quantile regression model to investigate the impacts of renewable energy consumption on CO_2 emissions. By adopting a fixed effect panel quantile regression method, we are able to depict the effect of green energy on CO_2 emissions throughout the conditional distribution. Quantile panel regression for Stata which was proposed by Machado and Santos Silva (2019) is helpful in investigating asymmetric features of variable distributions. This method can obtain the estimated coefficients across the different quantiles. Moreover, this method is widely used in related empirical studies on the relationship between renewable energy and CO_2 emissions (Chen and Lei, 2018; Alharthi et al., 2021). Quantile regression offers a valuable alternative to traditional mean regression by providing a more comprehensive understanding of the relationship between variables, particularly when the data exhibits heterogeneity. Furthermore, quantile regression is particularly useful when the data contains outliers or extreme values, as it does not assume a symmetrical distribution of the error terms, unlike ordinary least squares regression.

The results of fixed effects quantile regression are reported in Table 4. First, we observe that the inverted U-shaped relationship between GDP and CO_2 emissions holds consistently across all quantiles, suggesting that while economic growth initially leads to an increase in emissions, beyond a certain threshold, further growth begins to reduce emissions. This pattern is evident across different segments of the emission distribution, indicating that the relationship is not confined to the mean but is also robust in the lower and upper tails of the data. Renewable energy continues

Table 4: Quantile regression with fixed effects

Variable	0.2	0.4	0.6	0.8
GDP	1.0930	1.0698	1.0416	1.0122
	(7.49)***	(9.70)***	(9.67)***	(6.63)***
GDP^2	−0.0557	−0.0542	−0.0523	−0.0504
	(6.54)***	(8.41)***	(8.31)***	(5.65)***
URBAN	0.0079	0.0047	0.0008	−0.0032
	(1.17)	(0.92)	(0.17)	(0.45)
RE	−0.0228	−0.0234	−0.0240	−0.0247
	(12.45)***	(16.86)***	(17.75)***	(12.90)***
TRADE	0.0008	0.0008	0.0009	0.0009
	(1.54)	(2.09)**	(2.20)**	(1.60)
RECEIPTS	0.0150	0.0093	0.0024	−0.0048
	(0.85)	(0.70)	(0.18)	(0.26)
N	916	916	916	916

*P<0.1; **P<0.05; ***P<0.01

to show a negative and statistically significant relationship with CO_2 emissions, with significance at the 1% level across all quantiles. The effect of renewable energy consumption is strongest in countries with the highest levels of CO_2 emissions, where the transition to renewable energy appears to have the most pronounced impact on reducing emissions. This implies that renewable energy adoption plays a critical role in decoupling economic growth from environmental degradation, especially in high-emission economies.

5. CONCLUSION

The tourism sector plays a significant role in driving GDP growth across the globe. In 2024, the global Travel and Tourism sector contributed a total of US$10.9 trillion to GDP, encompassing its direct, indirect, and induced economic effects. Given its importance as a source of tax revenue, income, and employment, scholars have increasingly investigated tourism's environmental implications. However, the existing literature has largely overlooked the interconnected relationship between tourism, renewable energy, and CO_2 emissions within the countries that significantly dependent on tourism sector stability. At the same time, policymakers across different nations have introduced a variety of initiatives aimed at promoting sustainable development through investments designed to minimize tourism's environmental footprint. Thus, the aim of this study is to examine the relationship between tourism, renewable energy and CO_2 emissions in a sample of top 50 tourism intense countries by share of tourism receipts in total exports. We use data from 2000 to 2020 and several panel data methods such two-step system GMM estimator to account for simultaneity and endogeneity problems, panel fixed effects quantile method and fixed effects regression. The results suggest that while tourism is positively related to CO_2 emissions, renewable energy has a negative and significant effect on environmental degradation: a 1% increase in renewable energy consumption leads to 0.55% decrease in CO_2 emissions over the period 2000-2020. We also find evidence of a nonlinear (inverted U-shaped) relationship between per capita GDP and environmental degradation, consistent with the Environmental Kuznets Curve hypothesis.

The findings of this study offer critical policy insights for promoting sustainable tourism and environmental protection. Given that tourism significantly contributes to CO_2 emissions in the sample, there is an urgent need to integrate environmental sustainability into tourism development strategies. Governments should prioritize the decarbonization of the tourism sector by incentivizing the transition toward renewable energy sources. This includes introducing green financing schemes such as low-interest loans and investment guarantees for hotels, tour operators, and transport companies that adopt solar, wind, or geothermal technologies. Additionally, public-private partnerships can be encouraged to modernize energy infrastructure in tourism hotspots—especially airports, hospitality clusters, and heritage sites—by installing energy-efficient lighting, electric vehicle charging stations, and solar-powered utilities. National tourism agencies should develop eco-certification programs to promote environmentally responsible business practices, rewarding enterprises that reduce emissions, minimize waste, and use local and low-carbon supply chains. Moreover, transport policies must aim to shift from high-emission modes (e.g., diesel buses, short-haul flights) toward rail and electric mobility, particularly for domestic and regional tourism. Tax incentives can be introduced for tourism companies investing in green infrastructure, while carbon pricing mechanisms can discourage environmentally harmful practices. Local governments and municipalities should also integrate sustainable tourism goals into urban and regional development plans by supporting low-impact tourism models such as eco-tourism, community-based tourism, and off-season travel to reduce pressure on fragile ecosystems. Finally, regional cooperation mechanisms among countries—such as joint sustainability targets, knowledge-sharing platforms, and coordinated investment in cross-border green infrastructure—can amplify the effectiveness of national efforts and ensure a cohesive, low-carbon tourism future.

Nonetheless, this study is not without limitations. Due to data constraints from international sources, we are unable to differentiate between various forms of tourism—such as mass tourism, community-based tourism, religious or cultural tourism, and event-driven tourism. As a result, our analysis focuses exclusively on the aggregate effects of international tourism on environmental outcomes. Furthermore, the temporal nature of the available data does not allow us to explore long-term dynamics between tourism, renewable energy, and CO_2 emissions.

Future studies should examine the relationship between tourism, renewable energy and CO_2 emissions across other sample of countries, and accounting for other socio-economic and cultural variables (Salahodjaev and Sadikov, 2025).

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