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# Quantile lens on carbon footprints: Renewable energy, tourism, financial development, and the pursuit of Sustainable Development Goals 2030

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**Abstract**

The pursuit of sustainable development goals (SDGs) by 2030 has become a global imperative, necessitating a comprehensive examination of factors influencing carbon footprints across various sectors. In light of varying levels of sensitivity among the top five tourist countries—France, Spain, the United States, Turkey, and Italy—to renewable energy, tourism, financial development, and sustainable development goals (SDGs), this study addresses the challenge of effectively harnessing these factors to achieve comprehensive carbon emissions reduction and sustainable development objectives. By taking data from 1997 to 2021, novel panel quantile regression analysis is performed to ascertain the long-run impacts in lower, middle, and upper quantiles. It finds that renewable energy investments and eco-friendly tourism practices, supported by financial development initiatives, can substantially reduce carbon dioxide emissions in top tourist destinations. These measures are essential for maintaining the concerns of the economy and environmental preservation. Renewable energy and financial development unequivocally lead to decreased carbon emissions in the middle and higher quantiles. Tourism development leads to an escalation in carbon emissions approximately in all the quantiles, i.e., from 0.10 to 0.90. The findings of this study underscore that it is crucial to implement specific measures to encourage the use of renewable energy, environmentally friendly practices in tourism, and sustainable financial initiatives. It will not only effectively reduce carbon emissions in top tourist destinations, but also make progress towards achieving sustainable development goals by 2030.

**Keywords:** Financial development index, Quantile wise regression, Renewable energy, Sustainable development goals, Top five tourist countries, Tourism development index.

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## 1. Introduction

The United Nation's 2030 Agenda for Sustainable Development highlights the importance of affordable and environmentally-friendly energy—Sustainable Development Goal (SDG 7)—and taking action to combat climate change (SDG 13) (United Nations, 2015). In recent decades, the global community has witnessed a growing awareness of the pressing need for sustainable development in the face of escalating environmental challenges (Adebayo *et al.*, 2023; Mehmood & Kaewsaeng-on, 2024b). The sustainability discourse has evolved to address the interplay between economic growth, environmental conservation, and social well-being. Nevertheless, the quest for sustainability is now deemed a multifaceted challenge that demands a thorough examination of the various factors and sectors influencing our environment (Kaewsaeng-on & Mehmood, 2024; Robaina-Alves *et al.*, 2016). The global community is currently at a pivotal moment in dealing with increasingly pressing environmental issues (Allegretti *et al.*, 2022). The need to balance economic and financial growth with environmental conservation is a difficult task that requires significant consideration (Ojekemi *et al.*, 2023; Ulucak & Khan, 2020). In this context, the present research endeavours to scrutinize the complex dynamics at the intersection of renewable energy (SUR), tourism (TUR), financial development (FUR), and carbon footprints (ERD). However, this seeks to illuminate sustainability's crucial crossroads.

Renewable energy technologies with their promise of reducing carbon emissions and lessening dependence on fossil fuels hold the potential to lead toward a more sustainable energy future (Musa *et al.*, 2021; Wang *et al.*, 2023). However, the rate and scope of their adoption varies greatly among countries, and their true environmental advantages must be considered in a broader context (Adams & Nsiah, 2019; Akram *et al.*, 2021). Tourism, an industry deeply rooted in cultural exchange and economic prosperity, often has the paradoxical effect of placing immense pressure on fragile ecosystems and local communities (Azam *et al.*, 2018; Dwyer, 2022; González-Rodríguez *et al.*, 2023). Nevertheless, the necessity for sustainable tourism practices is becoming significant as it gains popularity among the stakeholders (Balsalobre-Lorente *et al.*, 2020; Qureshi *et al.*, 2017). Financial development, encompassing banking, investment, and economic growth, can enable or hinder sustainability efforts. Access to financial resources can foster green innovation and perpetuate environmentally harmful practices if unchecked (Khezri *et al.*, 2021; Shoaib *et al.*, 2020). The urgency of carbon emissions reduction is underscored by the undeniable evidence of climate change, habitat loss, species extinction, and pollution. However, all of these threaten the delicate equilibrium of the planet's ecosystems (Allegretti *et al.*, 2022; Charfeddine & Kahia, 2019). Concurrently, the growing demand for energy, tourism, and financial services in an interconnected global economy presents a problem. Although these sectors are unquestionably vital for human advancement and welfare, improper management could potentially worsen environmental hazards.

This study focuses on the top five tourist countries globally, as identified by the United Nations World Tourism Organization (UNWTO, 2023). However, their rating is based on data from 2022. France holds the highest place with approximately 75 million international tourist arrivals. Spain, the United States, and Turkey rank second, third, and fourth, respectively, with 71.7, 50.9, and 50.5 million tourist arrivals. Italy ranks fifth, with a total of 49.8 million international tourist arrivals. In order to reduce carbon emissions, France has made significant advances in the adoption of renewable energy sources such as wind, solar, and hydroelectric power. France has set ambitious targets for carbon reduction and renewable energy. The country aims to reduce greenhouse gas emissions by 40% by 2030 compared to 1990 levels and achieve carbon neutrality by 2050. France's Energy Transition for Green Growth Act mandates that 40% of electricity consumption should come from renewable sources by 2030 (French Ministry for an Ecological and Solidary Transition, 2024). Spain promotes renewable energy and supports wind and solar electricity with feed-in tariffs. Spain places a high value on renewable energy and has taken action to support the growth of wind and solar power through regulations such as feed-in tariffs. Spain's National Energy and Climate Plan (NECP) includes a goal of 42% renewable energy in the overall energy mix by 2030, with a specific target of 74% renewable electricity. Spain aims to reduce greenhouse gas emissions by 23% by 2030 compared to 1990 levels (MITECO, 2024). Differences in political and regulatory frameworks contribute to variations in renewable energy adoption among different states in the United States. The United States has set a target to reach 100% carbon pollution-free electricity by 2035 and achieve net-zero greenhouse gas emissions economy-wide by 2050. Various states have implemented their renewable energy standards, with California aiming for 100% renewable electricity by 2045 (USEPA, 2024). Nevertheless, a multitude of states have enacted policies to promote the production of renewable energy, indicating a broader trend towards environmental sustainability. Turkey has been increasing its wind and solar energy capacity to diversify its energy mix and achieve the SDGs. Turkey's current policies aim to increase the share of renewables in its energy mix to 38.8% by 2023. The country has committed to reducing its greenhouse gas emissions by up to 21% from the business-as-usual level by 2030 as part of its Intended Nationally Determined Contribution (INDC) under the Paris Agreement. Italy's NECP targets a 30% share of renewables in final energy consumption by 2030, with 55% renewable electricity. Italy aims to reduce its greenhouse gas emissions by 33% by 2030 compared to 2005 levels (INDC, 2024). Italy has actively promoted renewable energy, utilizing incentives such as feed-in tariffs to enhance solar and biomass energy generation (MET, 2024; UNWTO, 2023). The financial sectors in these countries are progressively acknowledging the significance of sustainable financing, as indicated by the growing inclination to engage in renewable energy projects and support programs that are in line with the SDGs. Overall, despite variations in sensitivities, these countries collectively demonstrate a commitment to transitioning towards a more sustainable future through the adoption of renewable energy, fostering economic development, and actively pursuing the SDGs.

The dimensions for examination (carbon emissions, tourism, financial development, and SDGs) were chosen based on their interconnectedness and relevance to global sustainability challenges. Carbon emissions are a critical global concern linked to climate change, making it imperative to study their sources, including tourism. Whereas, tourism is a major economic sector with both positive and negative environmental impacts, making it crucial to explore its sustainability implications (Azam *et al.*, 2018; Mehmood & Kaewsaeng-on, 2024b). Nevertheless, financial institutions play a pivotal role in funding sustainable initiatives, including renewable energy projects, which are vital for mitigating carbon emissions (Adebayo *et al.*, 2023; Shahbaz *et al.*, 2019). The SDGs provide a comprehensive framework for assessing global sustainability efforts, making them a suitable benchmark for evaluating the study's outcomes. However, the rationale behind the selection of the concerned countries is due to their significant tourism activity, diverse economic structures, and a strong commitment to the SDGs 2030. These countries are leading tourist destinations, providing an ideal context to examine tourism's impact on carbon emissions across different quantiles. Additionally, their diverse economies and varying degrees of reliance on tourism, financial services, and renewable energy offer a comprehensive view of how these factors influence carbon emissions.

This investigation, nevertheless, made four scholarly contributions to the field: **First,** this study addresses carbon footprints concerning renewable energy, tourism, financial development, and the pursuit of SDGs 2030. This is different from the previous studies that were concerned with environmental efficiency (Iram *et al.*, 2020; Wang *et al.*, 2023), quality (Adebayo *et al.*, 2023; Danish & Wang, 2018), and risk (Kaewsaeng-on & Mehmood, 2024). **Second,** a substantial amount of literature thoroughly examines tourist development and its impact on the environment in diverse fields (Conefrey & Hanrahan, 2024; Khan & Hou, 2021; Mishra *et al.*, 2022). This study contributes to the literature by examining and creating a tourism development index. Nevertheless, this index is based on three ingredients: 1) the number of tourist arrivals; 2) tourism expenditures; and 3) tourism receipts. **Third,** previous studies have emphasized the significance of financial development in environmental contexts. Nevertheless, they have solely relied on a solitary element or substitute indicator (Abid *et al.*, 2022.; Bekhet *et al.*, 2017; Khezri *et al.*, 2021). This study advances the field by developing a comprehensive financial development index incorporating the World Bank's components: 1) financial depth, 2) access, 3) efficiency, and 4) stability. **Lastly,** the United Nations' 2030 Agenda for Sustainable Development places great importance on United Nations SDGs 7 and 13. SDG 7 emphasizes the necessity of accessible and environmentally friendly energy, while SDG 13 highlights the urgency of taking action to combat climate change. These objectives seek to address the urgent global issue of climate change and its far-reaching repercussions. However, this analysis provides insightful policy recommendations that align with the SDGs. Nevertheless, this study aims to guide policymakers, businesses, and the general public regarding the way forward through the identification of possible synergies, conflicts, and trade-offs concerning the ingredients of this study. The comprehension of these dynamics will direct us toward a future in which environmental sustainability and economic drivers can coexist in perfect harmony.

The remaining sections of the paper are organized in the following manner: Section 2 provides a review of the existing literature. Section 3 presents the data and methodology used in the study. Section 4 presents the empirical analysis and outcomes of the study. Finally, Section 5 concludes the study and provides policy recommendations.

## 2. Literature Review

Sustainability has emerged as a critical global concern, prompting scholars to investigate the complex interplay between renewable energy, tourism, financial development, and their impact on environmental concerns (Abid *et al*., (2022; Adebayo *et al*., 2023; Mehmood & Kaewsaeng-on, 2024a; Ojekemi *et al*., 2023). This literature review provides an overview of the existing research on these critical components and their relationships, offering a foundation for the present study on sustainability at the crossroads. However, the literature is subdivided into the following three sub-sections.

### *2.1. Renewable Energy and Carbon Footprints*

The 21st century presents humanity with a pivotal juncture where our actions today will determine the well-being of future generations. Climate change, habitat degradation, pollution, and resource depletion have reached alarming proportions, threatening ecosystems and livelihoods across the globe (Charfeddine & Kahia, 2019; Muhammad & Khan, 2021). Renewable energy sources play a crucial role in improving the environment by reducing the negative effects of traditional energy generation that relies on fossil fuels (Iram *et al*., 2020; Ojekemi *et al*., 2023). The expansion of renewable energy sources such as hydroelectricity, wind, and solar power is critical for reducing carbon emissions and combating climate change (Bekhet *et al*., 2017; Muhammad & Khan, 2021). These sources reduce greenhouse gas emissions, helping to combat climate change, and improve air quality by reducing pollutant discharge (Akram *et al*., 2021; Ulucak and Khan, 2020). This review of the literature provides a thorough examination of the scholarly discourse on renewable energy and its environmental implications, taking into account both the positive aspects and potential concerns. Transitioning to renewable energy sources diminishes our dependence on finite and environmentally detrimental fuels like coal and oil (Fang *et al*., 2024; Mehmood & Kaewsaeng-on, 2024b). Renewable energy provides conservation advantages compared to the resource-intensive processes of extracting and transporting fossil fuels. The disposal and recycling of components from renewable energy systems such as solar panels and wind turbine blades present substantial challenges. Nevertheless, poor waste management practices can lead to contamination and environmental damage (Adams & Nsiah, 2019). The transition to the global renewable energy sources to address climate change and environmental issues is gaining momentum (Selvanathan *et al*., 2021; Wang *et al*., 2023). Conversely, regions susceptible to rising sea levels and extreme weather phenomena are also imperiled by nonrenewable energy sources, which not only intensify climate change but also pose a threat to these areas (Danish & Wang, 2018; Qureshi *et al*., 2017).

Renewable energy technologies possess the capacity to reduce greenhouse gas emissions and mitigate environmental hazards. Nevertheless, recent research has also investigated the apprehensions and possible hazards associated with the adoption and operation of renewable energy systems (Allegretti *et al.*, 2022; Mehmood & Kaewsaeng-on, 2024c; Wang *et al.*, 2023). However, it also presents difficulties with land utilization and the exploitation of resources (Musa *et al.*, 2021). Renewable energy technologies generally necessitate fewer resources and have reduced environmental effects over life cycles. Renewable energy projects, although generally less harmful to biodiversity than fossil fuel operations, still pose potential threats to species, especially birds and bats, around wind turbines and hydropower dams (Allegretti *et al.*, 2022; Selvanathan *et al.*, 2021). The study of Mehmood and Kaewsaeng-on (2024b) concludes that renewable energy is a significant source of carbon emissions in top tourist countries. Based on the above literature, this study postulates the following hypothesis:

*H1: Higher levels of renewable energy adoption are associated with lower carbon footprints in the top five tourist countries.*

### *2.2. Tourism and Carbon Footprints*

Tourism, an integral component of the global economy, has witnessed exponential growth in recent decades, significantly contributing to economic development and employment opportunities (Azam *et al.*, 2018; Balsalobre-Lorente *et al.*, 2020). However, the rapid expansion of the tourism industry has raised environmental concerns, as it intersects with fragile ecosystems, cultural heritage, and resource consumption (Eyuboglu & Uzar, 2020; Raza *et al.*, 2017). Tourism, a major global industry, promises economic prosperity but can simultaneously strain ecosystems and local cultures (Robaina-Alves *et al.*, 2016). The transportation sector within tourism, particularly air travel, significantly contributes to greenhouse gas emissions. Overcrowding in ecologically sensitive areas can lead to habitat destruction, soil erosion, and disturbances to wildlife. Furthermore, activities such as snorkeling, hiking, and off-road tours can cause direct harm to ecosystems (Pope *et al.*, 2019; Whitelaw *et al.*, 2014).

The impact of the tourism sector on environmental concerns is far from straightforward (Huddart *et al.*, 2020; Wei & Ullah, 2022). Tourism serves as a significant source of revenue for various places, but it also brings about both positive and adverse effects on the environment. These effects range from the detrimental consequences of over-tourism to the positive outcome of safeguarding cultural assets (Dwyer, 2022; Mehmood & Kaewsaeng-on, 2024b; Mishra *et al.*, 2022). Robust environmental impact assessments (EIAs) are essential for responsible tourism development. Countries might require EIAs for infrastructure and resort construction projects to avoid irreparable environmental damage (Pope *et al.*, 2019). Zoning stipulations can be used to control tourism and safeguard vulnerable places. These strategies serve to reduce overcrowding and habitat destruction (Khan & Hou, 2021; González-Rodríguez *et al.*, 2023; Huddart *et al.*, 2020). Revenue generated from tourism can support conservation efforts. National parks, wildlife reserves, and heritage sites often rely on tourism income to fund habitat protection and wildlife conservation (Khan & Hou, 2021; Whitelaw *et al.*, 2014). Sustainable tourism initiatives aim to minimize environmental impacts through eco-certifications, responsible behavior codes, and the promotion of conservation projects (Danish & Wang, 2018; Selvanathan *et al.*, 2021). These practices can alleviate carbon footprints. Based on the literature review, this study considers the following hypothesis:

*H2: Tourism development positively correlates with carbon footprints in the top five tourist countries.*

### *2.3. Financial Development and Carbon Footprints*

The direction and magnitude of resource allocation and economic activity are significantly impacted by financial development, which comprises capital markets, banking, and investment (Khan & Hou, 2021; Selvanathan, 2021). Nevertheless, despite their inherent differences, these sectors are integral participants in the discourse surrounding sustainability. Financial development can encourage sustainable practices through investment in green technologies, but it can also incentivize resource exploitation and short-term profit-seeking at the expense of long-term environmental sustainability (Abid *et al*., 2022; Shoaib *et al*., 2020; Zhao & Yang, 2020). Financial institutions can require comprehensive environmental impact assessments for those projects that they were financing (Bekhet *et al*., 2017; Musa *et al*., 2021). Categorically, these assessments cater to tourism infrastructure and construction which ensure that projects have minimum impact on ecosystems, habitats, and local communities (Charfeddine & Kahia, 2019; Khezri *et al*., 2021). Financial institutions may provide loans and funds to popular tourist sites in order to boost sustainable tourism efforts. This support can facilitate the development of eco-friendly accommodation, transportation, and activities, hence reducing environmental concerns (Kaewsaeng-on & Mehmood, 2024; Musa *et al*., 2021). Nevertheless, financial development may encourage investors to deploy their capital to environmentally responsible projects and businesses by providing them with Socially Responsible Investment (SRI) options. This allocation of resources can support environmentally friendly practices in important sectors, such as energy and tourism (Whitelaw *et al*., 2014; Zhao & Yang, 2020). However, the financial incentives for sustainable development are crucial in effectively incorporating renewable energy into the tourism sector. This transformation mitigates environmental hazards and promotes the attractiveness of these nations as sustainable and conscientious tourist destinations, aligning with worldwide endeavors to combat climate change and foster eco-friendly tourism (Fang *et al*., 2024; Qureshi *et al*., 2017). Based on the earlier discussion, this study considers the following hypothesis to represent the relationship between financial development and carbon footprints nexus:

*H3: Financial development leads to reduced carbon emissions in the top five tourist countries.*

This study delves into the intricate relationships between the adoption of renewable energy, tourism, financial development, and carbon footprints in the top five tourist countries. Nevertheless, these dynamics offer a valuable understanding of the complex mechanisms that mold environmental sustainability in the most popular tourist destinations. The prominence of these countries in global tourism highlights the importance of understanding the intersection of renewable energy, tourism practices, and financial processes in influencing carbon footprints.

## 3. Data and Empirical Methodology

### *3.1. Data*

This study collected data for the top five tourism countries from 1997 to 2021 and normalized it using a z-score. Altman *et al*. (2017) underscore the importance of employing robust statistical methods, such as the z-score estimator, to improve the reliability and precision of data analysis and predictive modeling. The role of renewable energy is considered to determine whether it elevates or mitigates carbon footprints. Following Shahbaz *et al*. (2019) and Mehmood & Kaewsaeng-on (2024b), this study pooled three components of the tourism development index: tourist arrivals, tourism expenditures (USD), and receipts (USD). The number of tourist arrivals reflects the volume of tourists visiting a destination, indicating the attractiveness and popularity of the location. International tourism receipts focus on the money spent by foreign visitors within a particular country, while international tourism expenditures focus on the spending of residents of a country when they travel outside of their own country. They represent two sides of the tourism expenditure coin, providing insights into both inbound and outbound tourism dynamics (Mehmood & Kaewsaeng-on, 2024b; Shahbaz *et al*., 2019; UNWTO, 2023). To reduce problems caused by multicollinearity among the main tourism indicators, we employed the principal component analysis (PCA) to create a tourism development index. This index combines weighted contributions from the three standard tourism variables, creating a single composite measure of tourism development for the top tourist destinations. The World Bank claims that combining its four parts—depth, access, efficiency, and stability—creates a financial development index that improves comprehension and results. This study incorporates several factors to produce the financial development index, including domestic credit to the private sector, domestic credit to the private sector by banks, the number of commercial bank branches per 100,000 people, and the bank capital to assets ratio. By condensing the data from these indicators into a single index, this study can better capture the overall level of tourism and financial activity, as well as its impact on the environment. Nevertheless, this single index will help in minimizing redundancy and potential biases associated with using multiple correlated variables in an econometric model (Kaewsaeng-on & Mehmood, 2024; Shahbaz *et al*., 2019). Table 1 presents the variables and their descriptions.

**Table 1.** *Description of Variables*

| Variables | Abbreviation | Description | Reference |
|---|---|---|---|
| Carbon footprint | ERD | Carbon Dioxide ($CO_2$) emissions in kilotonnes (kt). | WDI |
| Renewable energy | SUR | It represents the proportion of total ultimate energy consumption attributable to renewable energy. | WDI |
| Tourism development | TUR | PCA is utilized to generate an index by aggregating tourism receipts, tourism expenditures, and tourism arrivals. | WDI |
| Financial development | FUR | An index is established by quantifying financial depth, access, efficiency, and stability and is expressed by PCA. | GFDD |

Sources: World Development Indicators (WDI) and Global Financial Development Database (GFDD).

### *3.2. Methods and Modeling*

Based on the objectives and materials of this study, the following model is designed.

$$ERD = f\,(SUR, TUR, FUR) \quad (1)$$

Equation 2 shows the estimation of the model.

$$ERD_{it} = \beta_0 + \beta_1 SUR_{it} + \beta_2 TUR_{it} + \beta_3 FUR_{it} + \epsilon_{it} \quad (2)$$

Meanwhile, the ingredients of Equation 2 are explained in Table 1. Whereas, $i$ and $t$ represent cross sections and time. $\epsilon_{it}$ refers to the error term. The flow chart of analysis is presented in Figure 1.

#### *3.2.1. Unit Root Testing*

Unit root tests check if a variable is a stochastic process that may cause regression. Unit-root variables may be non-stationary, making it challenging to create meaningful and consistent correlations. Chaudhry *et al*. (2013) suggest using transformations, differencing, or modeling to address non-stationary dynamics. LLC (Levin, Lin, and Chu), ADF (Augmented Dickey-Fuller), and PP (Phillips-Perron) are unit root tests referred to assess the stationarity of data (Kaewsaeng-on & Mehmood, 2024; Kwatia *et al*., 2024). LLC evaluates the null hypothesis that a series has a unit root, indicating non-stationarity, while ADF extends this test to account for autocorrelation in the data. PP, similar to ADF, tests for the presence of a unit root but is robust to heteroscedasticity and serial correlation. By determining whether a series is stationary or non-stationary, these tests ensure the validity of subsequent analyses and forecasts, which rely on the stationarity assumption (Mehmood & Kaewsaeng-on, 2024d). The present study used these robust unit root tests before conducting an econometric analysis.

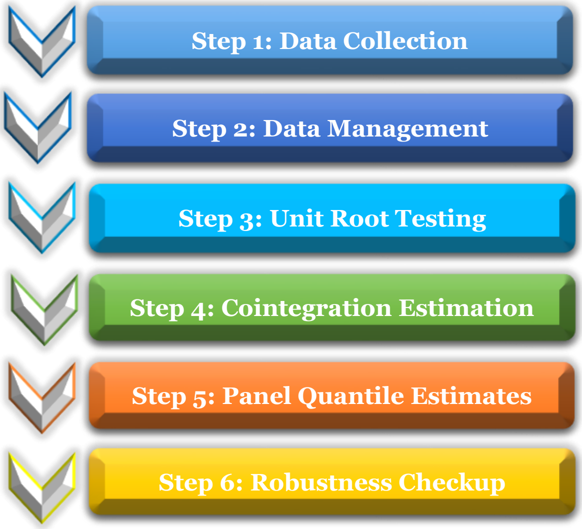


**Figure 1.** *Flow Chart of Analysis*

*3.2.2. Cointegration Testing*

After examining the unit root, assess variable cointegration. Johansen-Fisher Panel aims to explain and analyze underlying elements and dynamics that cause a phenomenon or problem. This method determines if these variables co-move throughout time, indicating a lasting and significant connection (Khan & Hou, 2021; Mehmood & Bilal, 2021; Ojekemi *et al.*, 2023). The Pedroni co-integration test, specifically, aims to determine if linear combinations of the stated variables are stationary, indicative of a lasting equilibrium relationship among them. However, Kao's (1999) cointegration test behaves similarly.

*3.2.3. Panel Quantile Regression Analysis*

Koenker and Bassett (1978) came up with quantile regression, which is equally applicable when the assumptions of normality in the error term are not exactly met. This method works especially well with energy and environmental datasets that have clear peaks or values that are very high or very low (Mehmood & Kaewsaeng-on, 2024b; Wei & Ullah, 2022). Quantile regression is more robust than Ordinary Least Squares (OLS) because it does not depend on strict assumptions about the disturbance terms, making it less affected by breaches of these assumptions. Furthermore, quantile regression offers accurate and resilient estimates, even when there are violations, while OLS may provide biased outcomes. Quantile regression has a significant benefit in that it can effectively capture the differences in how independent factors affect the dependent variable at different points in the data distribution. Unobserved heterogeneity presents a substantial obstacle in case of panel data. However, panel quantile regression (PQR) can efficiently address these challenges by incorporating a penalty term into the minimization procedure (Kaewsaeng-on & Mehmood, 2024; Kwatia *et al.*, 2024). Outliers could be handled by PQR by focusing on specific quantiles which could reduce the occurrence of extreme outcomes and enhance the accuracy of variable's calculations. PQR is a statistical technique that allows for the derivation of conclusions using reliable standard errors and hypothesis testing, which is especially useful when dealing with complicated data structures. Nevertheless, in case of utilization of PQR, the estimated effects of independent factors on the dependent variable become more accurate and reliable across different quantiles. This provides significant insights into the interconnections identified within the dataset (Kaewsaeng-on & Mehmood, 2024; Mehmood & Kaewsaeng-on, 2024c)

$$y_{i,t} = \alpha_i + \beta(q)x_{it} + \delta_{it} \quad (3)$$

Equation (3) estimates the link between the endogenous variable $y_{it}$ and the exogenous variable $x_{it}$ across distinct quantiles of its conditional distribution. The fixed effects $\alpha_i$ correspond to steady individual effects throughout time. Whereas, $\beta_q$ represents exogenous variables that fluctuate with quantiles.

Equation (4) shows a PQR model with fixed effects:

$$Q(y_{it} \mid x_{it}, \alpha) = \acute{x}_{it}\beta_q + \alpha_i \quad (4)$$

$Q(y_{it} \mid x_{it}, \alpha)$ is the $q^{th}$ conditional quantile of $y_{it}$, given the independent variable $x_{it}$. $\beta_q$ represents the quantile regression coefficients, and $\alpha_i$ is the individual-specific fixed effects.

Equation (5) has been formulated to estimate multiple quantiles simultaneously. The minimization problem associated with this equation is addressed by following the Koenker (2004) guidelines. This provides a framework for effectively minimizing the objective function and obtaining reliable estimates for each quantile.

$$min_{\alpha\beta} = \sum_{k=i}^{\vartheta}\sum_{j=i}^{\omega}\sum_{i=1}^{\delta} w_k\rho_k\left(y_{ij} - \alpha_i - \beta(q_k)x'_{ij}\right) \quad (5)$$

The utilization of a penalty mechanism represents a strategic avenue for the regularization or mitigation of discrepancies in individual impacts. However, this could be helpful in fostering convergence towards a standardized value. PQR entails the incorporation of a penalty term within the regression framework that strategically formulated to deter significant deviations and foster stability in estimations. Equation (6) encapsulates this procedural framework by elucidating the integration of the penalty term to engender a more robust and consistent estimation paradigm.

$$min_{\alpha\beta} = \sum_{k=i}^{\vartheta}\sum_{j=i}^{\omega}\sum_{i=1}^{\delta} w_k\rho_k\left(y_{ij} - \alpha_i - \beta(q_k)x'_{ij}\right) + \lambda\phi(\alpha) \quad (6)$$

Whereas $\phi(\alpha) = \sum_{i=1}^{\omega}|\alpha_i|$ is the penalty considered.

*3.2.4. Robustness Analysis*

The current investigation assessed the robustness of PQR by employing quantile slope equality (QSE) and symmetric quantile (SQ) tests. Wald tests for the equality of slopes are a statistical procedure used to determine whether the slopes of two or more regression lines are statistically different. These tests are commonly applied in multiple regression analysis, where you have multiple predictor variables and want to assess whether the relationships between these predictors and the response variable are significantly different across different groups or conditions. The symmetric quantile test determines if groups differ statistically in the quantile. Researchers use this test to check if the conditional distribution of the answer variable at the specified quantile is significantly different, which can reveal how different causes or situations affect that area of the distribution (Koenker, 2004; Mehmood & Kaewsaeng-on, 2024c).

## 4. Results and their Discussion

Table 2 represents the descriptive stats of this study. Descriptive statistics, such as kurtosis and skewness, are employed to understand the shape and symmetry of the data distribution. High values of kurtosis and skewness indicate non-normality in the data. The Jarque-Bera test is then used to formally test the normality assumption. When this test rejects the null hypothesis of normality, it signifies that the data significantly deviates from a normal distribution. As a result, the study opts for panel quantile regression, an advanced statistical method capable of capturing how the relationship between variables varies across different parts of the distribution. This method is chosen to accommodate the observed non-normality and variability in outcomes across the inquiry variables, allowing for a more nuanced analysis.

**Table 2.** *Descriptive Statistics*

| Consideration | ERD | SUR | TUR | FUR |
|---|---|---|---|---|
| Mean | 1327071.0 | -0.181989 | 0.369006 | 0.154976 |
| Median | 349219.9 | -0.227921 | 0.174460 | 0.464300 |
| Maximum | 5775807.0 | 1.239349 | 3.960140 | 2.813950 |
| Minimum | 192651.4 | -1.650892 | -1.232660 | -1.616560 |
| Std. Dev. | 2013012.0 | 0.635572 | 1.194984 | 1.080523 |
| Skewness | 1.523811 | -0.121774 | 1.129583 | 0.142947 |
| Kurtosis | 3.370630 | 2.582916 | 3.990708 | 3.013980 |
| Jarque-Bera | 47.12684 | 1.214976 | 31.69447 | 0.426720 |
| Probability | 0.000000 | 0.544718 | 0.000000 | 0.807865 |

Stationarity issues should be resolved with a unit root test before starting an econometric investigation. This study used many unit root tests to determine issue responsibility. Table 3 shows that all series variables show first-difference stationarity. Whereas, after establishing data stationarity, the analysis progresses to perform panel cointegration tests using three distinct methods: Pedroni, Johansen-Fisher, and Kao. Cointegration analysis is crucial for investigating whether the variables maintain a long-term relationship despite potential short-term fluctuations, particularly pertinent in time series data. The results of these tests, presented in Table 4, offer insights into the presence of long-term relationships among the variables, enriching the understanding of their interdependencies and dynamics within the dataset.

**Table 3.** *Unit Root Checkup*

| Varia-bles | Level | | | Δ | | | Decision |
|---|---|---|---|---|---|---|---|
| | LLC | ADF | PP | LLC | ADF | PP | |
| ERD | 2.64320 | 0.58510 | 0.49849 | -2.94743*** | 33.5291*** | 51.1357*** | Δ |
| SUR | 3.54308 | 4.96444 | 7.91342 | -4.60800*** | 30.6171*** | 39.9846*** | Δ |
| TUR | 0.00223 | 10.1175 | 5.21056 | -3.90748*** | 27.7414*** | 48.2126*** | Δ |
| FXD | -2.00416* | 13.5372 | 12.4039 | -3.47800*** | 26.9161*** | 57.7936*** | Δ |

Note: ****p* <0.01, ***p* <0.05 and **p* <0.1. This criterion is also applicable in Tables 4 to 7.

There are two primary classifications for the estimated outcomes of Pedroni's (2004). These estimations can be categorized into two groups: i) estimations within the dimensions and ii) estimations between the dimensions. In total, there are eleven estimations. According to a predetermined criterion, if at least six out of eleven statistics are significant, we can conclude that there is cointegration. Conversely, if less than six statistics are significant, cointegration cannot be proven. The results meet the cointegration test assumption of six out of eleven significant statistics. The Johansen cointegration approach empirically supports a connection's persistence. In conclusion, panel cointegration test results show a long-term relationship between variables. Kao's (1999) test results support rejecting the null hypothesis. Nevertheless, cointegration is endorsed through all three tests.

**Table 4.** *Cointegration Checkup*

| Pedroni Panel Cointegration Test | | | | |
|---|---|---|---|---|
| **Within-dimension (Common Coefficients)** | | | | |
| | | | **Weighted** | |
| | **Statistic** | **Prob.** | **Statistic** | **Prob.** |
| Panel v-Statistic | 3.761374*** | 0.0001 | 1.861750** | 0.0313 |
| Panel rho-Statistic | 0.989784 | 0.8389 | -0.121964 | 0.4515 |
| Panel PP-Statistic | -0.448330 | 0.3270 | -2.764125*** | 0.0029 |
| Panel ADF-Statistic | -0.393598 | 0.3469 | -2.592729*** | 0.0048 |
| **Between-dimension (Individual Coefficients)** | | | | |
| | **Statistic** | **Prob.** | | |
| Group rho-Statistic | 0.783735 | 0.7834 | | |
| Group PP-Statistic | -2.345485*** | 0.0095 | | |
| Group ADF-Statistic | -1.963073** | 0.0248 | | |
| **Kao Panel Cointegration Test** | | | | |
| | | | **t-Statistic** | **Prob.** |
| ADF | | | 4.348094*** | 0.0000 |
| Residual variance | | | 0.054692 | |
| HAC variance | | | 0.047085 | |
| **Johansen Fisher Panel Cointegration Test** | | | | |
| **Hypothesized No. of CE(s)** | **Fisher Stat.● (from trace test)** | **Prob.** | **Fisher Stat.● (from max-eigen test)** | **Prob.** |
| None | 57.10*** | 0.0000 | 30.10*** | 0.0008 |
| At most 1 | 36.19*** | 0.0001 | 17.36* | 0.0667 |
| At most 2 | 31.18*** | 0.0005 | 22.27** | 0.0138 |
| At most 3 | 25.74*** | 0.0041 | 25.74*** | 0.0041 |

Note: ● represents probabilities are computed using asymptotic Chi-square distribution.

PQR with fixed effects is a method utilized to account for distributional heterogeneity, as Koenker (2004) explains. As stated, bias may be introduced into conventional time series analysis results if time-period fixed effects are omitted. The outcome of PQR is presented in Table 5. The study's findings on the impact of renewable energy on carbon footprints indicate consistent results across a wide range of data points, from the 0.20 to the 0.90 quantile. The analysis reveals a strong positive correlation between SUR and carbon footprints in the countries examined. However, there is variation in the magnitude of the results because as the quantiles increase, the impact of SUR on carbon footprints also increases.

In the quantiles (specifically, the 0.10, 0.20, and 0.40 quantiles), the SUR insignificantly impacts EDR. Nevertheless, in the middle quantiles, 0.50 and 0.60 quantiles, a 1% rise in SUR will lead to an estimated decrease in ERD ranging from 0.272% to 0.236% in the top five tourist countries. Simultaneously, a 1% rise in SUR caused a reduction in ERD ranging from 0.292% to 1.484% in the higher quantile (0.70 to 0.90 quantile). These findings are aligned with the study of Allegretti *et al.* (2022), Muhammad & Khan (2021), and Ulucak & Khan (2020), which concluded that renewable energy is a vital element in mitigating environmental concerns and increasing its quality. However, the results differ from those of Adams & Nsiah (2019), who identified renewable energy as a source of long-term $CO_2$ emissions. One of the most significant environmental hazards is climate change, caused by greenhouse gas emissions. Wind, sun, and hydropower electricity emits little to no greenhouse gases. However, according to Adams &

Nsiah (2019) and Ojekemi *et al*. (2023), transitioning from fossil fuels to renewables can significantly cut carbon dioxide emissions and global warming, reducing climate-related tragedies.

**Table 5.** *Panel Quantile Regression*

| Consideration | Level(s) | Quantile(s) | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|---|---|
| SUR | | 0.100 | 0.009942 | 0.016297 | 0.610037 | 0.5430 |
| | LQs | 0.200 | -0.000763 | 0.025170 | -0.030310 | 0.9759 |
| | | 0.300 | -0.051240*** | 0.016281 | -3.147195 | 0.0021 |
| | | 0.400 | -0.126115 | 0.183482 | -0.687342 | 0.4932 |
| | MQs | 0.500 | -0.272487*** | 0.091812 | -2.967873 | 0.0036 |
| | | 0.600 | -0.236061*** | 0.088904 | -2.655215 | 0.0090 |
| | | 0.700 | -0.292645*** | 0.109169 | -2.680666 | 0.0084 |
| | HQs | 0.800 | -0.285889** | 0.121338 | -2.356134 | 0.0201 |
| | | 0.900 | -1.484839*** | 0.412222 | -3.602033 | 0.0005 |
| TUR | | 0.100 | 0.075446*** | 0.024574 | 3.070186 | 0.0026 |
| | LQs | 0.200 | 0.076335** | 0.032885 | 2.321282 | 0.0219 |
| | | 0.300 | 0.040005** | 0.018896 | 2.117128 | 0.0363 |
| | | 0.400 | 0.413282 | 0.557618 | 0.741156 | 0.4600 |
| | MQs | 0.500 | 0.752028*** | 0.053400 | 14.08291 | 0.0000 |
| | | 0.600 | 0.773653*** | 0.053978 | 14.33263 | 0.0000 |
| | | 0.700 | 0.900638*** | 0.116513 | 7.729931 | 0.0000 |
| | HQs | 0.800 | 1.123574*** | 0.176006 | 6.383718 | 0.0000 |
| | | 0.900 | 0.626362* | 0.331442 | 1.889809 | 0.0612 |
| FUR | | 0.100 | -0.051789** | 0.020972 | -2.469440 | 0.0149 |
| | LQs | 0.200 | -0.035868 | 0.022306 | -1.608027 | 0.1104 |
| | | 0.300 | -0.012956 | 0.008159 | -1.587982 | 0.1149 |
| | | 0.400 | -0.107771 | 0.132955 | -0.810583 | 0.4192 |
| | MQs | 0.500 | -0.219780*** | 0.042051 | -5.226475 | 0.0000 |
| | | 0.600 | -0.244393*** | 0.041803 | -5.846275 | 0.0000 |
| | | 0.700 | -0.303948*** | 0.061469 | -4.944769 | 0.0000 |
| | HQs | 0.800 | -0.390859*** | 0.086744 | -4.505895 | 0.0000 |
| | | 0.900 | -0.507869*** | 0.139561 | -3.639047 | 0.0004 |
| C | | 0.100 | -0.428264*** | 0.011474 | -37.32637 | 0.0000 |
| | LQs | 0.200 | -0.390946*** | 0.015120 | -25.85640 | 0.0000 |
| | | 0.300 | -0.363241*** | 0.007506 | -48.39189 | 0.0000 |
| | | 0.400 | -0.274848** | 0.133732 | -2.055218 | 0.0420 |
| | MQs | 0.500 | -0.151487*** | 0.057372 | -2.640456 | 0.0094 |
| | | 0.600 | -0.045866 | 0.055233 | -0.830424 | 0.4079 |
| | | 0.700 | 0.080181 | 0.079189 | 1.012532 | 0.3133 |
| | HQs | 0.800 | 0.390349*** | 0.125720 | 3.104906 | 0.0024 |
| | | 0.900 | 1.226060*** | 0.255278 | 4.802842 | 0.0000 |

The tourism development index poses ERD across all three quantiles (lower, middle, and upper), while the magnitudes of these impacts differ among the quantiles. Within the range of the 0.10 to 0.30 quantile, a one percent increase in TUR resulted in a respective rise of 0.075, 0.076, and 0.040 percent in ERD. The impact of TUR on rising ERD is heightened in the middle quantiles. Nevertheless, a one percent rise in TUR leads to a 0.752 to 0.773 percent surge in ERD in the 0.50 and 0.60 quantiles. The introduction of TUR resulted in a 0.900, 1.123, and 0.626 increase in ERD in the 0.70, 0.80, and 0.90 quantiles, respectively. These findings are aligned with the findings of Azam *et al*. (2018) and Balsalobre-

Lorente *et al.* (2020) and contradict Khan & Hou (2021), which states that tourism enhances environmental quality. Tourist hotspots can suffer from over-congestion, resulting in environmental deterioration, such as harm to pristine landscapes and ecosystems. Over-tourism worsens this problem and can lead to the degradation of habitats and disturbances to wildlife.

The financial development index has proven to significantly mitigate ERD in the top five tourist countries. This is evident from the coefficients connected with the index, which consistently indicate a substantial reduction in ERD across all quantiles. Financial development has a negligible effect on ERD in the lower quantiles, except for the 0.10 quantile. The anticipated consequences of FUR are also not substantial in the 0.40 quantile. Nevertheless, within the 0.50 to 0.90 quantile range, FUR significantly mitigates ERD in the top five tourism countries. Specifically, a one percent momentum in FUR leads to a 0.219 and 0.244 decrease in the 0.50 and 0.60 quantiles, respectively. At the upper quantiles, the findings revealed that a one percent rise in FUR can lead to a decrease in ERD ranging from 0.303 to 0.507 percent. The results supported the conclusions of Khezri *et al.* (2021), Musa *et al.* (2021), and Shoaib *et al.* (2020), which identified financial development as the primary factor in determining environmental concerns. Financial institutions specializing in development can distribute capital and offer incentives to support implementing renewable energy projects, such as solar and wind farms. These investments aid in the shift towards cleaner energy sources, thereby diminishing the carbon emissions associated with the energy sector, which frequently poses significant environmental hazards. Nevertheless, this assistance can promote environmentally sustainable projects and contribute to reducing carbon footprints. Figure 2 provides graphical representations that illustrate the impacts of the study's elements on ERD based on the estimates. The figure portrays the variations in results across different quantiles through the utilization of ten processes and 95% confidence intervals.

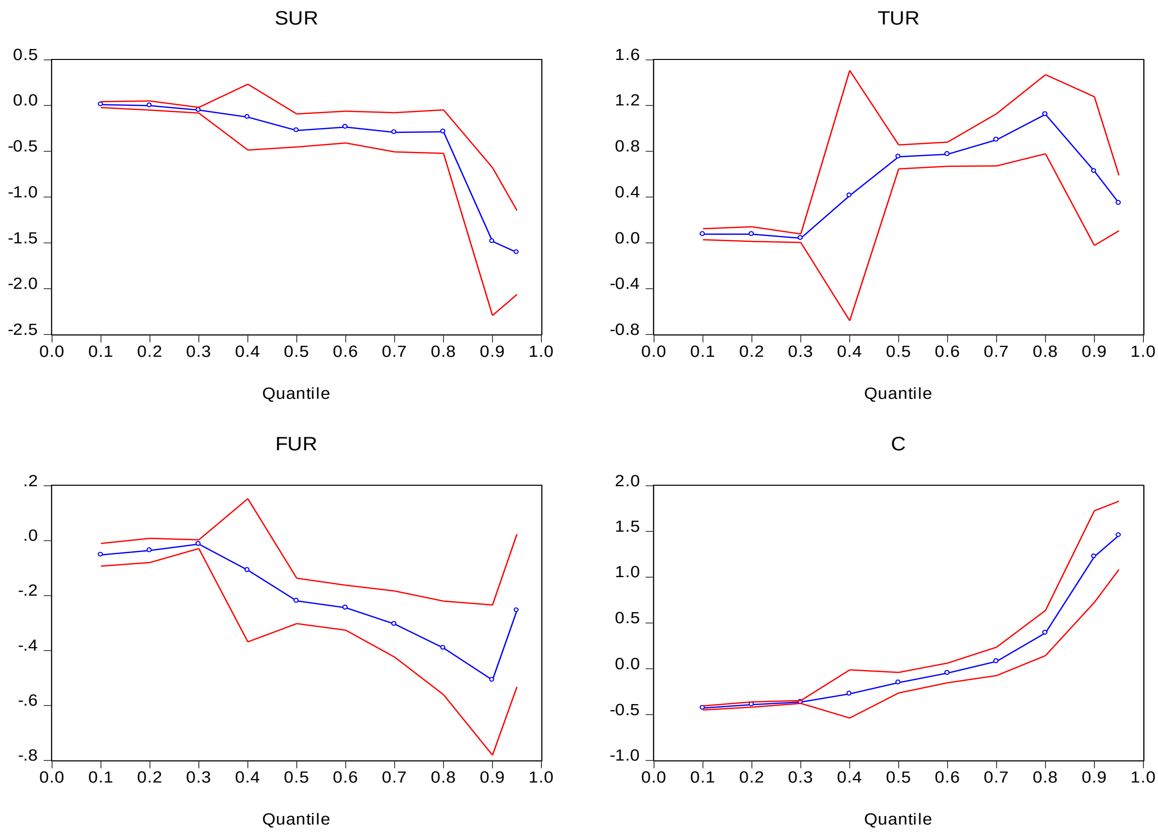


**Figure 2.** *Graphical Representation of PQR Estimates*

The present study employed the QSE and SQ tests to examine the diverse distribution of the generated quantile parameters. The results of these computations are presented in Tables 6 and 7. These tests are calculated for robustness using the ten quantile process estimates. The Wald test statistic contrasts the quantile coefficients obtained from the estimated equations for the slope equality quantile test and the symmetric test quantiles. Wald's test indicates the 953 statistically significant value at the 1% significance level. One can infer from this that the coefficients are not uniform and differ between quantile levels and the conditional quantile. Wald's test on the SQs in Table 7 provides an $x^2$ value of 182, which is statistically significant at the 1% significance level. There is evidence of asymmetry observed in the quantiles being analyzed. The results of these two trials support the choice to employ quantile modeling.

**Table 6.** *Quantile Slope Equality Test*

| **Test Summary** | | $x^2$ | $x^2$ **d.f.** | **Prob.** |
|---|---|---|---|---|
| **Wald Test** | | 953.6306*** | 27 | 0.0000 |
| **Quantiles** | **Variable** | **Restr. Value** | **Std. Error** | **Prob.** |
| 0.1, 0.2 | SUR | 0.010705 | 0.022284 | 0.6310 |
| | TUR | -0.000889 | 0.025734 | 0.9725 |
| | FUR | -0.015921 | 0.018690 | 0.3943 |
| 0.2, 0.3 | SUR | 0.050478*** | 0.016886 | 0.0028 |
| | TUR | 0.036331 | 0.022809 | 0.1112 |
| | FUR | -0.022912 | 0.017162 | 0.1819 |
| 0.3, 0.4 | SUR | 0.074874 | 0.178333 | 0.6746 |
| | TUR | -0.373278 | 0.543856 | 0.4925 |
| | FUR | 0.094815 | 0.127931 | 0.4586 |
| 0.4, 0.5 | SUR | 0.146373 | 0.160164 | 0.3608 |
| | TUR | -0.338746 | 0.515749 | 0.5113 |
| | FUR | 0.112009 | 0.124786 | 0.3694 |
| 0.5, 0.6 | SUR | -0.036427 | 0.056103 | 0.5162 |
| | TUR | -0.021625 | 0.032782 | 0.5095 |
| | FUR | 0.024612 | 0.025997 | 0.3438 |
| 0.6, 0.7 | SUR | 0.056585 | 0.066164 | 0.3924 |
| | TUR | -0.126985 | 0.080339 | 0.1140 |
| | FUR | 0.059555 | 0.039733 | 0.1339 |
| 0.7, 0.8 | SUR | -0.006757 | 0.084363 | 0.9362 |
| | TUR | -0.222936* | 0.115815 | 0.0542 |
| | FUR | 0.086911 | 0.056696 | 0.1253 |
| 0.8, 0.9 | SUR | 1.198950*** | 0.367744 | 0.0011 |
| | TUR | 0.497212 | 0.309593 | 0.1083 |
| | FUR | 0.117010 | 0.120153 | 0.3301 |
| 0.9, 0.95 | SUR | 0.119541 | 0.312259 | 0.7018 |
| | TUR | 0.277741 | 0.267396 | 0.2989 |
| | FUR | -0.253578** | 0.124127 | 0.0411 |

**Table 7.** *Symmetric Quantiles Test*

| **Test Summary** | | $x^2$ | $x^2$ **d.f.** | **Prob.** |
|---|---|---|---|---|
| **Wald Test** | | 182.4868*** | 20 | 0.0000 |
| **Quantiles** | **Variable** | **Restr. Value** | **Std. Error** | **Prob.** |
| 0.05, 0.95 | SUR | -1.047651*** | 0.272327 | 0.0001 |
| | TUR | -1.082307*** | 0.154417 | 0.0000 |
| | FUR | 0.130231 | 0.148067 | 0.3791 |
| | C | 1.321869*** | 0.203853 | 0.0000 |
| 0.1, 0.9 | SUR | -0.929922** | 0.418889 | 0.0264 |
| | TUR | -0.802247** | 0.327010 | 0.0142 |
| | FUR | -0.120097 | 0.140041 | 0.3911 |
| | C | 1.100770*** | 0.254983 | 0.0000 |
| 0.2, 0.8 | SUR | 0.258323 | 0.163276 | 0.1136 |
| | TUR | -0.304147* | 0.157103 | 0.0529 |
| | FUR | 0.012834 | 0.089596 | 0.8861 |
| | C | 0.302378** | 0.128125 | 0.0183 |
| 0.3, 0.7 | SUR | 0.201089 | 0.135439 | 0.1376 |
| | TUR | -0.563414*** | 0.092370 | 0.0000 |
| | FUR | 0.122657 | 0.065788 | 0.0623 |
| | C | 0.019915 | 0.089644 | 0.8242 |
| 0.4, 0.6 | SUR | 0.182799 | 0.167393 | 0.2748 |
| | TUR | -0.317121 | 0.509784 | 0.5339 |
| | FUR | 0.087397 | 0.129095 | 0.4984 |
| | C | -0.017739 | 0.130310 | 0.8917 |

The bottom line is that renewable energy and financial development reduce carbon emissions at middle and high quantiles, while tourism development increases carbon emissions across all quantiles from 0.10 to 0.90. Figure 3 provides a summary of the findings of this study.

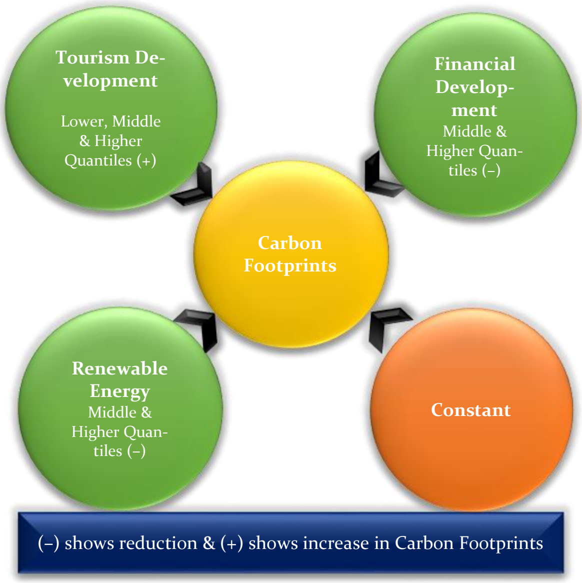


**Figure 3.** *Summary of the Findings*

## 5. Conclusion

The United Nations' 2030 Agenda for Sustainable Development prioritizes two specific SDGs: SDG 7 and 13. This study investigates the impact of the SUR, TUR, and FUR on the ERD of the top five tourist countries, as determined by the UNWTO (2023), between 1997 and 2021. The study used PQR modeling to yield long-term estimates across lower, middle, and upper quantiles. The data indicates that all variables exhibit a first-difference stationary characteristic. Additionally, panel cointegration tests—Pedroni, Kao, and Johansen Fisher—reveal the existence of a long-term link among the variables in the model. The findings suggest it is indisputable that advancements in renewable energy and financial development reduce ERD at the middle and upper quantiles. Particularly, among the middle quantiles (0.50 and 0.60), a 1% rise in SUR will result in a decrease in ERD by 0.272% to 0.236%. In the higher quantile (0.70 to 0.90 quantile) of the top five tourist countries, a 1% increase in SUR will lead to a reduction of ERD by 0.292% to 1.484%. FUR has a negligible effect on ERD at the lower quantiles, except the 0.10 quantile. Categorically, a 1% momentum in FUR leads to a 0.219 and 0.244 decrease in the 0.50 and 0.60 quantiles, respectively. At the upper quantiles, the findings revealed that a 1% rise in FUR can lead to a decrease in ERD ranging from 0.303 to 0.507 percent. The expansion of tourism results in an increase in ERD throughout a spectrum of quantiles, particularly between 0.10 to 0.90, which includes the lower, middle, and upper quantiles. However, FMOLS also confirms the robustness of the existence of a long-term association. The present study employed the QSE test and the SQ test to examine the uneven distribution of the generated quantile parameters. The robustness tests performed in this study corroborated the findings. The main conclusion of this study is the adoption of ecologically friendly tourism activities powered by renewable energy. Nevertheless, financial development is contributing to reducing ERD. Considering the continuous discourse regarding SDGs, the subsequent recommendations are put forth for policymakers, regulatory entities, and interested parties.

### *5.1. Theoretical Implications*

First, the findings of this study underscore the importance of renewable energy adoption, sustainable tourism, and financial development as key stakeholders while defining environmental concerns, i.e., carbon emissions, and attaining SDGs 7 and 13. Second, the empirical relationship between tourism development and the carbon emissions nexus underscores the need for a paradigm shift towards environmentally responsible tourism practices. The study's findings on the impact of unsustainable tourism practices on environmental sustainability can enrich theoretical frameworks in sustainable tourism. Third, the relationship between financial development and carbon footprints suggests a theoretical framework that explores how financial institutions can influence carbon emissions. For example, financial depth can be seen in the availability of green bonds and climate-focused investment funds that channel resources into renewable energy projects, thereby reducing reliance on fossil fuels. Access to finance is another critical aspect, where microfinance institutions provide loans for small-scale renewable energy installations in rural areas, promoting sustainable energy use at the grassroots level. The integration of environmental, social, and governance (ESG) criteria in lending and investment decisions illustrates the efficiency of financial systems by directing funds towards environmentally sustainable projects. Stability frameworks can include regulatory measures that mandate financial disclosures related to carbon emissions, encouraging transparency and accountability in carbon-intensive sectors. These theoretical aspects of the findings illustrate how financial institutions and frameworks can actively support low-carbon development pathways and contribute to the achievement of SDGs 2030. Fourth, applying quantile regression allows for the identification of variations in the impact of the ingredients of this study on carbon emissions across different quantiles. However, this provides insights into how sustainability interventions and policies can address disparities in environmental outcomes.

### *5.2. Policy Implications*

First, the findings suggest that renewable energy is a significant source of carbon emission reduction in middle and higher quantiles for top tourist countries. However, these countries should enact policies mandating a minimum percentage of energy generation to come from renewable sources, gradually phasing out the use of fossil fuels. This standard would incentivize investment in renewable energy infrastructure and accelerate the transition towards cleaner energy alternatives, reducing reliance on fossil fuels and lowering $CO_2$ emissions. France targets 40% renewable electricity by 2030 and carbon neutrality by 2050. Spain aims for 42% renewable energy and a 23% emissions reduction by 2030. The U.S. plans for 100% carbon-free electricity by 2035 and net-zero emissions by 2050. Turkey targets 38.8% renewable energy by 2023 and a 21% emissions cut by 2030. Italy aims for 30% renewable energy and a 33% emissions reduction by 2030 (INDC, 2024; IRA, 2022; USEPA, 2024). Second, the governments and international bodies can provide incentives and subsidies for green investments in renewable energy, encouraging financial institutions to support sustainability initiatives. For instance, the European Union's Green Deal Industrial Plan aims to boost the competitiveness of Europe's net-zero industry by supporting green technologies and innovations. This plan includes funding mechanisms, regulatory frameworks, and incentives to facilitate investment in renewable energy and reduce carbon emissions (EC, 2023). Similarly, the U.S. Inflation Reduction Act (IRA 2022) provides significant tax credits and subsidies for renewable energy projects and green technologies. These schemes illustrate how governments can actively promote sustainability by creating favorable conditions for green investments, thus encouraging financial institutions to support low-carbon initiatives.

### *5.3. Practical Implications*

First, financial institutions should prioritize investments in renewable energy projects and technologies, such as solar, wind, and hydroelectric power, to reduce reliance on fossil fuels and mitigate carbon footprints. This requires developing financial products and mechanisms that support renewable energy development, such as green bonds, venture capital funds, and project finance. Second, practical implementation of environmentally responsible tourism practices, including energy-efficient infrastructure, waste reduction measures, and eco-friendly transportation options. Tourism businesses and operators are encouraged to adopt sustainable technologies and practices to mitigate environmental degradation.

### *5.4. Limitations and Future Research Avenues*

Notwithstanding its contribution to the current body of literature, this research also has certain limitations that could open up the doors for areas of future research. First, due to data availability constraints, this research can only analyze data spanning 25 years, specifically from 1997 to 2021. For more robust results, future research should contemplate utilizing larger data sets. Second, this study used CO2 emissions as a metric for environmental contamination. Nevertheless, additional types of gases, including methane ($CH_4$), Nitrous Oxide ($N_2O$), etc., also contribute to environmental pollution. Future investigations ought to incorporate these components in their carbon footprint calculations. Third, our model incorporated the total renewable energy consumption for this investigation. However, renewable energy can manifest in a variety of ways, including wind and solar. Further investigation could be warranted into the impact of alternative forms of renewable energy on the interplay between tourism development, financial development, and carbon footprint. Finally, while the current study focuses on the top tourist countries, future research could potentially examine tourism-dependent economies, as identified by the contribution that tourism makes to gross domestic product (GDP). Nevertheless, factors like manufacturing, agriculture, and geopolitical events (e.g., the Ukraine conflict and sanctions on Russia) are indeed influential, have had a much stronger influence on energy policy changes, and could be considered in future studies.

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