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# Tourism, Urban Growth and the Ecological Footprint: Empirical Insights from the European Union\*

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## Abstract

*Tourism, urban growth, and ecological sustainability are becoming increasingly intertwined in the European Union, where rapid urban expansion and economic activity intensify ecological pressures. Understanding how tourism interacts with these dynamics has become central to the sustainable tourism debate, as policymakers and stakeholders seek to balance economic development with environmental protection. This study examines the short- and long-run effects of tourism activity, urbanization, economic growth, and renewable energy consumption on the ecological footprint across 14 EU countries from 1995 to 2024. Employing the cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model, which accounts for cross-sectional dependence and slope heterogeneity, the analysis confirms a long-run cointegrating relationship among the variables. Findings indicate that economic growth and urbanization*

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*significantly increase ecological footprint, whereas international tourism exerts a mitigating effect on environmental pressures. Renewable energy contributes to ecological improvement in the long run, though its short-run impact is limited. These results underscore the need for integrated policy frameworks that combine sustainable tourism development, urban planning, and renewable energy strategies within the European Union. The study underscores the importance of coordinated action among urban planners, energy policymakers, and tourism stakeholders to foster economic growth while ensuring environmental sustainability for future generations.*

**Keywords:** *sustainable tourism development, urbanization, ecological footprint assessment, environmental sustainability, renewable energy adoption, economic growth dynamics, European Union*

**JEL classification:** *L83, Q56, R11*

## 1. Introduction

Sustainable tourism research has increasingly emphasized that *sustainability* is not a single environmental indicator but an integrated, contested, and governance-laden project spanning environmental limits, socio-economic distribution, and institutional choices—an orientation long embedded in debates (Bramwell et al., 2017). At the core of this debate lies a fundamental tension: how to reconcile mobility-driven economic growth—of which tourism is a central component—with biophysical limits and climate-neutrality ambitions. In parallel, the spatial locus of sustainability has become unmistakably urban: more than half of the world’s population now lives in cities, and urban systems are simultaneously engines of economic output and major sources of greenhouse gas emissions (United Nations Statistics Division, 2022; Ritchie et al., 2024). Previous research has documented an increase in the global tourism carbon footprint from approximately 3.9 GtCO<sub>2e</sub> in 2009 to 4.5 GtCO<sub>2e</sub> in 2013, representing around 8% of total anthropogenic greenhouse gas emissions (Lenzen et al., 2018). Updated estimates based on extended multiregional input–output modelling indicate that the global tourism carbon footprint reached approximately 5.2 GtCO<sub>2e</sub> in 2019, accounting for around 8.8% of total global emissions, with the sector’s average annual growth rate exceeding that of global emissions over the same period (Sun et al., 2024). These findings highlight a pronounced scale effect, whereby growth in mobility and tourism consumption outpaces technological improvements and relative gains in energy efficiency.

Following the pandemic-related contraction, more recent evidence indicates a partial reduction in tourism’s relative emission share, with the sector contributing between 6.5% and 7.3% of global greenhouse gas emissions in 2023–2024 (World Travel and Tourism Council, 2024, 2025). However, a lower relative share does not necessarily imply absolute decoupling between tourism growth and environmental pressure. Rather, it may reflect temporary disruptions in mobility patterns alongside

composition and technology effects. This raises a critical question: do tourism dynamics in highly developed and regulation-intensive regions demonstrate structural alignment with climate neutrality objectives, or does the sector remain constrained by inherent biophysical limits? For the European Union (EU), these dynamics are especially policy-salient. The region has positioned itself as a climate-policy frontrunner while simultaneously promoting tourism competitiveness and resilience through initiatives such as the European Green Deal and the Tourism Transition Pathway (European Commission, 2022). Consequently, the EU represents not merely a geographic sample, but a multi-level governance laboratory for climate–tourism integration, in which climate neutrality, urban development, and tourism policy are institutionally intertwined.

Despite a fast-growing literature on tourism–environment linkages, two limitations remain consequential for sustainable tourism policy in advanced, interconnected regions. First, evidence is often built on single-emission indicators or territorial inventories, which may understate consumption-driven pressures and global supply-chain effects. By contrast, the ecological footprint operationalizes environmental pressure as demand on biologically productive area required to provide consumed resources and absorb wastes (including carbon demand), thus aligning well with sustainability questions framed around lifestyles, mobility, and urban consumption systems (Global Footprint Network, n.d.). Although the ecological footprint is not without methodological critique, its consumption-based logic offers a normatively consistent metric for evaluating tourism within broader urban metabolism and lifestyle-oriented sustainability debates. Second, even within Europe—where tourism is economically significant and climate and carbon risks are widely recognized—important gaps persist in coherent national and sub-sector emissions evidence and in research systematically connecting climate-policy transitions to tourism dynamics. These gaps matter because the sign of tourism’s environmental association remains theoretically ambiguous. From a political-economy perspective, tourism may generate scale effects that amplify ecological pressure through mobility and consumption expansion; yet in high-income, regulation-intensive settings it may also produce composition and technology effects linked to cleaner energy systems, environmental innovation, and sustainability governance. The core empirical problem, therefore, is not whether tourism *matters*, but under what structural and policy conditions tourism intensity coincides with higher or lower consumption-based environmental pressure once urbanization and economic growth dynamics are jointly considered. Against this backdrop, examining tourism–environment dynamics within advanced European economies provides an opportunity to assess whether high-income, regulation-intensive contexts facilitate relative or absolute decoupling, or whether tourism growth continues to generate net ecological pressure. By integrating ecological footprint indicators with tourism and macroeconomic variables, this study seeks to provide new empirical evidence on sustainable tourism transitions in regulation-intensive European contexts.

To address this problem, the study investigates the following research questions:

*RQ1: What are the long-run and short-run effects of tourism activity and urbanization on ecological footprint in the EU context?*

*RQ2: To what extent can renewable energy transitions compensate for tourism- and urbanization-driven consumption pressures?*

*RQ3: After accounting for cross-country interdependence, do tourism dynamics appear footprint-amplifying or footprint-mitigating in the long run?*

Conceptually, the empirical specification is consistent with an extended consumption-pressure framework in which environmental impact reflects the combined influence of affluence (economic output), structural-demographic change (urbanization), technology and energy system characteristics (renewables), and sectoral demand shocks (tourism). This framework allows for the possibility that tourism operates simultaneously as a driver of environmental scale effects and as a vector of structural transformation within advanced urban economies. Methodologically, the paper employs a cross-sectionally augmented ARDL approach suited to macro-panels with cross-sectional dependence and dynamic adjustment, enabling simultaneous estimation of long-run relationships and short-run error-correction dynamics (Chudik & Pesaran, 2015). This strategy is complemented by second-generation panel procedures that explicitly recognize cross-sectional dependence in non-stationary settings, strengthening inference in integrated regions where common shocks and spillovers are plausible (Pesaran, 2007; Westerlund, 2007).

The paper makes four original contributions to sustainable tourism scholarship and EU-relevant policy debates. First, it reframes tourism–environment relations around ecological footprint, a consumption-oriented pressure metric that captures broader ecological demand than CO<sub>2</sub>-only indicators and is therefore more closely aligned with sustainability’s integrated remit (Global Footprint Network, n.d.). Second, it provides updated longitudinal evidence for an EU country panel (1995–2024), a period spanning deepening urbanization, acceleration of energy transition policies, and intensified sustainability governance under EU climate-neutrality commitments (European Commission, 2022). In doing so, it offers rare empirical insight into whether tourism intensity in advanced, highly urbanized economies is structurally compatible with ecological sustainability objectives. Third, by using cross-sectionally augmented dynamic panel techniques, it offers an empirically robust test of whether tourism is footprint-amplifying or footprint-mitigating once urban growth, income dynamics, and renewable energy are jointly modelled under cross-country interdependence (Chudik & Pesaran, 2015). Fourth, the findings speak directly to a central sustainable tourism governance dilemma emphasized in climate-transition scholarship: aligning tourism development trajectories with climate-neutrality ambitions requires evidence on where economic and urban

benefits coincide with measurable reductions (or increases) in environmental pressure, and which policy levers—especially renewable energy—are empirically associated with footprint mitigation (Scott, 2024; Peeters & Papp, 2024). By situating tourism within broader debates on green growth, urban transition, and multi-level climate governance, the study contributes to ongoing discussions about the structural conditions under which tourism can coexist with ecological stabilization in advanced economies.

After the introductory section, the paper provides a review of the relevant empirical literature examining the relationship between tourism, economic growth, urbanization, and emissions. It then outlines the research methodology and presents the empirical results, followed by a detailed discussion of the findings. The concluding section offers policy recommendations and suggests directions for future research.

## **2. Literature review**

Recent scholarship in sustainable tourism has increasingly adopted the ecological footprint as a comprehensive indicator capturing the cumulative environmental pressures associated with tourism development. While tourism expansion supports economic growth, empirical evidence links tourism growth with increased ecological pressures—including resource use, land transformation, and greenhouse gas emissions—in multi-country panel studies (Paramati et al., 2017b; Khan & Hou, 2021). At the EU level, recent panel analyses show that tourism development is significantly associated with higher carbon emissions, indicating that urbanized tourism destinations experience amplified environmental pressures as tourism and related economic activity expand (Nwaeze et al., 2023; Marić Stanković et al., 2024). In urban contexts, these pressures are often intensified through dense infrastructure, higher transport demand, and spatial concentration of tourism activities, making cities critical nodes in the sustainability debate.

A growing body of literature conceptualizes tourism as an integral component of urban systems rather than an isolated sector. Casals Miralles et al. (2023) emphasize that single-indicator approaches underestimate tourism's environmental impact and advocate for integrated assessments combining carbon, water, and ecological footprints. Empirical evidence from Mediterranean and coastal destinations indicates that tourism intensity and spatial concentration substantially increase ecological and carbon footprints, particularly in highly urbanized regions (Gössling et al., 2015). At the EU level, empirical research indicates that tourism growth is associated with higher environmental pressures, as tourism expansion exerts a negative effect on environmental sustainability—including ecological footprints—when analysed across groups of European Union countries, suggesting that tourism

and related urban development can intensify environmental degradation under certain conditions (Torres-Díaz et al., 2025, Veljković et al., 2025). Complementing this perspective, empirical research shows that hidden carbon emissions embedded in tourism-related supply chains—such as indirect emissions from accommodation and related sectors—often exceed direct emissions, demonstrating the need for policy reforms targeting *urban tourism systems* to reduce environmental pressures (Zhang & Xia, 2024).

Methodologically, the literature is dominated by panel econometric approaches designed to capture long-run relationships and cross-sectional dependence across countries. Techniques such as FMOLS, DOLS, and CS-ARDL are widely employed to address heterogeneity and unobserved common factors in tourism–environment nexus studies (Paramati et al., 2017b; Shaari et al., 2024; Shi & Smith, 2025). Within this framework, several studies test the Environmental Kuznets Curve (EKC) hypothesis, proposing that environmental pressures initially increase with tourism and urban expansion before stabilizing at higher income levels. Empirically, research on the tourism–environment nexus increasingly relies on panel econometric approaches to capture long-run relationships and cross-sectional dependence across countries. Estimators such as FMOLS and DOLS are widely applied to account for heterogeneity and unobserved common factors in empirical studies, while recent applications of CS-ARDL provide additional robustness in capturing both short- and long-run dynamics. Empirical evidence demonstrates the relevance of these methods in analysing the dual impact of tourism on economic growth and environmental pressures (Paramati et al., 2017a; Shahzad et al., 2017; Khan et al., 2019; Marković et al., 2023). Complementary findings suggest the presence of non-linear relationships consistent with the Environmental Kuznets Curve hypothesis, although tourism-driven urban regions may struggle to reach such turning points without substantial structural and policy interventions. In parallel, studies published in the *Journal of Sustainable Tourism* highlight inter-market variability in tourism-related emissions, showing that CO<sub>2</sub> intensities differ across destinations and emphasizing the need for location-specific, climate-sensitive tourism policies, particularly in highly urbanized and coastal regions (Gössling et al., 2015).

The energy transition has emerged as a key moderating factor in the tourism–environment literature. Empirical studies indicate that greater adoption of renewable energy and environmental technologies is associated with reductions in ecological footprints, even in tourism-dependent economies (Khan et al., 2019; Ali et al., 2021). Sectoral approaches, including input–output analyses, further highlight urban hotspots where tourism-related emissions are concentrated. These findings are consistent with global evidence that tourism-related emissions increased at an average annual rate of approximately 3.5% between 2009 and 2019—nearly twice the growth rate of the overall economy—underscoring the sector’s growing environmental significance (Sun et al., 2024).

Beyond environmental and energy dimensions, recent research increasingly incorporates governance, social equity, and institutional frameworks in sustainable tourism studies. Systematic reviews highlight the growing importance of Environmental, Social, and Governance (ESG) frameworks in shaping destination resilience and guiding tourism development, emphasizing that strong institutional quality and governance mechanisms can align tourism growth with sustainability objectives (Abd Rahman et al., 2025; Camilleri, 2025). Empirical studies provide evidence that ESG practices enhance operational efficiency and long-term resilience in tourism and hospitality firms, mitigating the environmental pressures associated with tourism expansion (Lu et al., 2025). Complementing this, bibliometric analyses reveal a growing scholarly focus on ESG dimensions—environmental, social, and governance—within the hospitality and tourism literature, indicating emerging research trends that link governance structures to sustainable tourism outcomes (Legendre et al., 2024). Collectively, these findings underscore the necessity of integrating governance, social equity, and institutional quality into policy-making and strategic planning to achieve more resilient and sustainable urban tourism systems.

The COVID-19 pandemic represents a structural turning point in the tourism–environment discourse. Lockdowns in 2020 led to sharp reductions in tourism-related emissions, yet subsequent recovery in many EU destinations approached or even exceeded pre-pandemic levels (Sigala, 2020; Sun et al., 2024). Sigala (2020) emphasizes that COVID-19 exposed deep vulnerabilities in tourism systems, highlighting the need for resilience and sustainability-oriented strategies. Quantitative analyses show that global tourism carbon emissions grew at an average annual rate of about 3.5% from 2009 to 2019, reaching approximately 5.2 Gt CO<sub>2</sub>-equivalent in 2019, underlining the sector’s environmental significance and the challenge of aligning recovery with international sustainability targets (Sun et al., 2024). These dynamics demonstrate that integrating destination-specific policies, renewable energy adoption, and resilience planning is critical to ensure sustainable post-pandemic tourism growth.

Despite notable advances, critical gaps remain. Much of the existing literature relies on aggregated national or regional data, which obscures micro-level urban dynamics where environmental pressures manifest through localized pollution, congestion, and biodiversity loss. Recent spatial studies highlight how GIS-based approaches and fine-scale data analytics can reveal tourism pressure at a local level, informing more targeted planning interventions (Salas-Olmedo et al., 2017; Šoltésová et al., 2025; Balletto et al., 2025). Furthermore, the pronounced heterogeneity of EU regions—from densely populated Mediterranean urban zones to more dispersed Alpine settlements—is seldom examined in detail, resulting in overly generalized conclusions. The limited incorporation of emerging tools such as AI-based forecasting and big data from digital tourism platforms further restricts the ability to anticipate future trajectories in line with the EU Green Deal objectives.

Collectively, the literature demonstrates a conceptual and empirical evolution toward a more integrated understanding of sustainable tourism. By linking tourism growth, urbanization, energy transition, and governance frameworks, existing studies establish a solid foundation for advanced empirical analysis (Paramati et al., 2017a; Shaari et al., 2024; Shi & Smith, 2025). Nevertheless, the interaction between tourism-driven urban growth and ecological footprints in the EU—particularly when accounting for cross-sectional dependence and long-run dynamics—remains insufficiently examined. To address these gaps, this study applies the CS-ARDL framework to EU urban tourism contexts, providing robust empirical evidence on both short- and long-run effects of tourism, urbanization, economic activity, and energy consumption on ecological sustainability.

### 3. Data and methodology

This section presents the methods used, along with the underlying equations and assumptions that form the basis for the subsequent analysis of the results. The sample for this study comprises EU-14 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain and Sweden). The research applies the operational framework described below, while holding all other factors constant.

$$EF = f(GDP, URB, TOUR, RE) \quad (1)$$

Equation 1 shows that ecological footprint (EF), represented by ecological footprint of consumption, measured in global hectares per person, is influenced by gross domestic product per capita (GDP), urbanisation (URB), international tourist arrivals (TOUR), and renewable energy consumption per capita (RE). The dataset used in this study covers the period from 1995 to 2024 for the EU-14 countries.

$$LEF_{it} = \alpha_0 + \alpha_1 LGDP_{it} + \alpha_2 LURB_{it} + \alpha_3 LTOUR_{it} + \alpha_4 LRE_{it} + \varepsilon_{it} \quad (2)$$

The log-linear model is applied to capture the continuous relationships among the variables in the framework, where  $\alpha_0$ ,  $\alpha_1$ ,  $\alpha_2$ ,  $\alpha_3$ , and  $\alpha_4$  represent the respective coefficients. In Equation 2, the error term is denoted by  $\varepsilon_{it}$ , where  $i$  refers to the cross-sectional unit and  $t$  refers to the time dimension. A detailed description of all variables is provided in Table 1. Data for all variables are available throughout the entire study period. However, for the tourism variable, missing observations for 2024 in several countries were estimated using interpolation to ensure a balanced panel.

The cross-sectional dependence (CSD) test is applied to identify the appropriate empirical techniques for analysis. The results of this test guide researchers in choosing between first- and second-generation panel data methods. Skipping

this diagnostic step may result in biased or unreliable estimates. Cross-sectional dependence typically arises from common shocks and unobserved factors (Hao et al., 2021). Increasing globalization and international economic integration have further intensified interlinkages among countries, making it essential to formally test for CSD to ensure the accuracy and reliability of empirical results. When the time dimension (T) is larger than the cross-sectional dimension (N), the Breusch–Pagan LM test is the preferred approach.

Table 1: Variables description

| Abbreviation | Variable                       | Detail  | Sources  |
|--------------|--------------------------------|---|--|
| LEF          | Ecological footprint           | Ecological footprint of consumption, measured in global hectares per person | Global Footprint Network (n.d.)                              |
| LGDP         | Gross domestic product         | GDP per capita (constant 2015US\$)  | World Development Indicators (2025)                          |
| LURB         | Urbanization                   | Urban population, % of total population                                     | World Development Indicators (2025)                          |
| LTOUR        | International tourist arrivals | International tourism, number of arrivals                                   | World Development Indicators (2025) & UN Tourism Data (2025) |
| LRE          | Renewable energy               | Renewable energy consumption per capita (kWh)                               | Our World in Data (2025)                                     |

Source: Authors’ compilation

Differences in slope parameters across units can also distort panel regression outcomes. Slope heterogeneity refers to variations in coefficients among cross-sectional units (Zeraibi et al., 2021). Considering the structural differences across the countries included in the study, it is necessary to examine whether the slope coefficients vary. Accordingly, the slope heterogeneity test proposed by Pesaran and Yamagata (2008) and refined by Blomquist and Westerlund (2013) was implemented.

The next stage involved assessing the stationarity characteristics of the panel data—specifically, determining whether the variables are stationary in levels or after differencing. For this purpose, the study employed the second-generation cross-sectional augmented Dickey- Fuller (CADF) test developed by Pesaran (2007). This test is commonly used because of its ability to account for cross-sectional dependence and heterogeneity among countries. The CADF is the individual (or single) augmented Dickey–Fuller test described by:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + \beta_i \bar{y}_{t-1} + \sum_{j=0}^k \gamma_{i,j} \Delta \bar{y}_{t-1} + \sum_{j=0}^k \gamma_{i,j} \Delta y_{t-1} + \varepsilon_{it} \tag{3}$$

where  $\alpha_i$ ,  $k$  and  $y_t$  are the constant, the lag specification, and the temporarily defined cross-sectional averages, respectively. Under the null hypothesis, the variables are non-stationary. If the panel unit root test shows that the variables are integrated of the same order, cointegration tests are applied to determine whether one or more long-term equilibrium relationships exist among the examined variables. In this study, both first- and second-generation tests are used. First, Pedroni's (1999, 2004) approach is applied, which proposes a residual-based cointegration test assuming cross-sectionally independent units. Furthermore, the Kao (1999) test was conducted as part of the analysis. Then, Westerlund's (2007) specification is employed, which assumes cross-sectional dependence. Both tests share the null hypothesis of no cointegration. Pedroni's tests rely on a within-dimension approach, which includes four statistics: panel  $\rho$ -statistic, panel  $v$ -statistic, panel PP-statistic, and panel ADF-statistic. These statistics account for common time factors and heterogeneity among units. A second set of statistics is based on a between-dimension approach and includes three statistics: group  $\rho$ , group PP, and group ADF.

Through CS-ARDL, short and long-run coefficients are being measured. Because of its powerful assumptions about CSD, endogeneity, and slope heterogeneity, this method outperforms other cointegration methods. Some issues were perceived when the cross-section correlations in the errors were ignored and to avoid this issue, this study employed panel CS-ARDL. The panel ARDL model is the most widespread heterogeneous panel data estimator, but it fails to address the potential cross-sectional dependence error. Hence, in this study, the Cross-Sectionally Augmented ARDL (CS-ARDL) is applied. Prior studies, Wencong et al. (2023) and Cai and Wei (2023) employed the CS-ARDL robust approach to determine the model's long and short-run coefficients. The panel function of the research, instead of the cross-sectional aspect, instigated the use of the CS-ARDL approach, which is a particularly suitable estimation method in such cases. The CS-ARDL method outperforms traditional empirical models by accounting for slope variability across countries and cross-country dependence, regardless of whether the associated data are nonstationary at the level,  $I(0)$ ,  $I(1)$ , or mixed order integrated. The equation for the CS-ARDL model can be presented as:

$$\begin{aligned}
 y_{i,t} &= \alpha_i + \sum_{j=1}^p \lambda_{ij} y_{i,t-j} + \sum_{j=0}^q \delta'_{ij} x_{i,t-j} + \sum_{j=0}^K \varphi'_{ij} \bar{z}_{i,t-j} + \varepsilon_{it} \\
 \Delta y_{i,t} &= \alpha_i + \zeta_i (y_{i,t-1} - \omega'_i x_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*'} \Delta x_{i,t-j} + \\
 &+ \sum_{j=0}^K \varphi'_{ij} \overline{\Delta z_{i,t-j}} + \sum_{j=1}^{p-1} \psi_j \overline{\Delta y_{i,t-j}} + \sum_{j=0}^{q-1} \zeta_j \overline{\Delta x_{i,t-j}} + \varepsilon_{it}
 \end{aligned} \tag{4}$$

#### 4. Results and analysis

The assessment of cross-sectional dependence (CSD) was conducted at the beginning of the study, and Table 2 presents the results of the cross-sectional dependence test. The null hypothesis, which states that there is no cross-sectional dependence among the units, is rejected based on the test findings. This indicates that there is no cross-sectional or inter-country independence among our indicators.

Table 2: The results of the cross- sectional dependence

| Cross- sectional dependence | Breusch- Pagan LM |
|-----------------------------|-------------------|
| LEF                         | 1225.24           |
| LGDP                        | 1890.22           |
| LURB                        | 2335.82           |
| LTOUR                       | 1364.54           |
| LRE                         | 1867.88           |

Note: All *t* values are statistically significant at 1% level

Source: Authors' calculations

Table 3: Results of the panel unit root test

| Variables | CADF     |                            |
|-----------|----------|----------------------------|
|           | Level    | 1 <sup>st</sup> Difference |
| LEF       | -1.994   | -4.198*                    |
| LGDP      | -1.192   | -2.792*                    |
| LURB      | -2.26**  | -2.752                     |
| LTOUR     | -1.874   | -2.962*                    |
| LRE       | -2.24*** | -4.37*                     |

Note: \*, \*\* and \*\*\* represent 1%, 5% and 10% level of significance, respectively

Source: Authors' calculations

Determining the integration properties of the variables involves applying a stationarity analysis (Ding et al., 2021). Conventional stationarity tests may yield biased results, as the residual terms encompass dependencies (Murshed & Dao, 2022). Therefore, the second-generation unit root test results presented in Table 3 are based on the assumption that all variables are integrated of order I(1), in order to confirm that the requirement of the proposed econometric technique regarding integration among variables is satisfied. Consequently, a homogeneity test, shown in Table 4 and proposed by Pesaran and Yamagata (2008), was also conducted. The

results confirm the existence of slope parameter variations, supporting the findings of Li et al. (2021) and Acheampong (2019), since all variables showed statistically significant results.

Table 4: Heterogeneity analysis

| Model  | Pesaran and Yamagata (2008) |            | Blomquist and Westerlund (2013) |            |
|--|-----------------------------|------------|---------------------------------|------------|
|  | Delta                       | Adj. Delta | Delta                           | Adj. Delta |
| $LEF_{it} = f(LGDP_{it}, LURB_{it}, LTOUR_{it}, LRE_{it})$ | 16.61                       | 18.57      | 11.80                           | 13.20      |

Note: All computed values are significant at 1% level of significance

Source: Authors' calculations

To further verify whether the variables in the empirical analysis are cointegrated, cointegration tests were applied. Table 5 presents the results of Pedroni, Kao and Westerlund's cointegration test, which provide evidence of the existence of cointegration among the variables.

Table 5: Panel cointegration test

| Panel EU-14 $LEF_{it} = f(LGDP_{it}, LURB_{it}, LTOUR_{it}, LRE_{it})$ |                             |         |             |                |
|--|-----------------------------|---------|-------------|----------------|
| Test   | Statistic                   | Value   | Probability | Co-integration |
| Westerlund panel cointegration   | Variance ratio              | -2.3563 | 0.009       | Yes            |
| Pedroni panel cointegration  | Modified Phillips- Perron t | -0.16   | 0.44        | No             |
|  | Phillips- Perron t          | -7.39   | 0.00        | Yes            |
|  | Augmented Dickey- Fuller t  | -7.54   | 0.00        | Yes            |
| Kao panel cointegration  | Modified Dickey- Fuller t   | -1.96   | 0.02        | Yes            |
|  | Dickey- Fuller t            | -1.86   | 0.03        | Yes            |
|  | Augmented Dickey- Fuller t  | -1.14   | 0.13        | No             |

Source: Authors' calculations

Table 6 summarizes the results obtained using this procedure. The next step is to determine the coefficient values for both long-term and short-term scenarios. In this study, the CS-ARDL method is used to achieve this goal. The CS-ARDL approach accounts for cross-sectional dependence in panel data series, ensuring robust results. The findings from the CS-ARDL approach are presented in Table 6.

Table 6: CS-ARDL model result

|       | Short- run results |         | Long- run results |         |
|-------|--------------------|---------|-------------------|---------|
|       | Coefficient        | P value | Coefficient       | P value |
| LGDP  | 0.86               | 0.00    | 0.77              | 0.00    |
| LURB  | 0.94               | 0.04    | 1.39              | 0.03    |
| LTOUR | -0.04              | 0.04    | -0.04             | 0.03    |
| LRE   | 0.01               | 0.94    | -0.09             | 0.05    |

Source: Authors' calculations

The study's results indicate that EU countries emit more emissions as a consequence of higher economic growth and urbanization rates. A 1% increase in economic growth leads to a 0.86% rise in emissions in the short term, while a 1% change in economic growth in the long term increases emissions by 0.77%. A 1% increase in the urbanization rate results in a 0.94% rise in emissions in the short term, and a 1% change in the urbanization rate in the long term increases emissions by 1.39%. Similar results were obtained by Raihan (2023). A 1% development in the tourism sector leads to a 0.04% decrease in emissions in both the short and long term. Additionally, the results of Satrovic and Muslija (2019) indicate a positive but decreasing impact of urbanization on emissions.

The findings of this study also point to a high level of environmental awareness among citizens in the top ten most visited tourist destinations. Purwono et al. (2024) reveal the existence of an inverted N-shaped relationship between tourism and emissions, indicating an initial decrease in CO<sub>2</sub>, followed by an increase as the sector matures, and a final decline. The study emphasizes the importance of controlling urbanization to mitigate CO<sub>2</sub> emissions. In analysing OECD countries, Alola et al. (2021) showed that the impact of international tourist arrivals and urbanization is statistically significant and harmful to environmental quality across the quantile spectrum, though slightly diminished in the upper quantile. Raihan and Tuspekova (2022) demonstrated that urbanization and tourism cause environmental degradation by increasing emissions in Brazil. Similar results were obtained by Raihan et al. (2022) for Argentina. Moreover, Bin Amin and Aftabi Atique (2021) identified a unidirectional causal relationship from urbanization to CO<sub>2</sub> emissions.

Policymakers should prioritize the adoption of renewable energy sources to meet the growing energy demands associated with rapid tourism development in the early stages. As tourism sectors mature, the focus should shift toward maintaining CO<sub>2</sub> reductions through active promotion and investment in renewable energy integration. Urbanization policies should be designed with a focus on sustainable practices to mitigate negative externalities. Furthermore, laws should promote green urban innovation and the development of smart buildings. EU governments

can enhance economic growth without harming the environment by prioritizing green and sustainable urbanization. Urban development initiatives must emphasize energy efficiency, technological innovation, and sustainable lifestyles, as rapid urbanization harms ecosystems. Authorities can encourage sustainable and green urbanization, which would increase the use of renewable energy sources, such as electric vehicles, energy-efficient lighting, ethanol for vehicles, and similar technologies, to reduce environmental damage. Renewable energy, along with energy-efficient devices and machinery in the workplace, can minimize urban energy consumption and carbon dioxide emissions.

## 5. Discussion

The empirical findings obtained in this study provide a clearer understanding of how tourism development, urbanization, economic growth, and renewable energy jointly shape environmental sustainability in the European Union. Although the estimated coefficients have already been presented in the previous section, their broader economic interpretation reveals several important implications.

First, the positive impact of economic growth on ecological footprint confirms that higher levels of production and consumption in EU countries continue to generate considerable pressure on natural resources. The estimated elasticities indicate that economic expansion still relies on intensive energy use, transport activity, and material consumption, despite the European Union's long-standing commitment to green transition. This result suggests that the process of decoupling growth from environmental degradation remains incomplete.

Second, urbanization appears as the long-run determinant of ecological footprint, which gives particular weight to the argument that spatial concentration of population and economic activities produces cumulative environmental costs. While urban development generally stimulates productivity, innovation, and service sector expansion, the obtained results indicate that these economic benefits are accompanied by rising demand for housing, transport infrastructure, municipal services, and energy-intensive urban lifestyles. Consequently, urbanization becomes a structural driver of ecological pressure when not managed through sustainable planning instruments.

A particularly interesting outcome of the analysis is the negative and statistically significant coefficient of tourism activity. Unlike the conventional assumption that tourism growth necessarily intensifies environmental degradation through higher mobility, accommodation demand, and resource use, the present study indicates that tourism in the European Union contributes to a modest reduction in ecological footprint. This suggests that the tourism sector in mature European destinations may increasingly operate under stronger environmental standards, including

green certification, sustainable destination management, and greater ecological awareness among tourists and service providers. The current findings imply that tourism should not automatically be treated as an environmental burden, but rather as a sector whose ecological effect depends on the quality of governance and sustainability orientation.

The long-run role of renewable energy additionally strengthens this interpretation. Although its short-run effect is statistically weak, renewable energy consumption shows a negative long-run impact on ecological footprint, indicating that environmental gains from clean energy adoption materialize gradually. This confirms that renewable transition is a structural process rather than an immediate corrective mechanism. As renewable infrastructure expands and dependence on fossil fuels decreases, the ecological pressure generated by growth and urbanization can be partially mitigated. In this regard, the findings support the policy logic emphasized in previous environmental studies that long-term investment in clean energy remains essential for achieving sustainable growth outcomes.

Taken together, the results reveal an important duality in the EU development model. On the one hand, economic growth and urbanization continue to intensify ecological footprint, confirming the persistence of traditional environmentally costly development patterns. On the other hand, tourism and renewable energy emerge as potential mitigating channels capable of reducing part of that pressure. This integrated perspective represents the main contribution of the study, as it shows that environmental sustainability in the European Union depends less on limiting economic activity itself and more on transforming the way in which growth, tourism expansion, and urban development are managed.

From the standpoint of public policy, the discussion suggests several practical directions. EU governments should place stronger emphasis on green urban planning, energy-efficient buildings, sustainable public transport, and circular municipal infrastructure in order to reduce the long-term environmental burden of urban concentration. At the same time, tourism policy should continue to support eco-certified accommodation, low-carbon destination branding, and environmentally responsible tourism services, since the sector has the capacity to contribute positively under adequate regulation. Finally, continued investment in renewable energy sources remains indispensable if the environmental costs of growth are to be neutralized over time.

Overall, the discussion confirms that the ecological future of the European Union will largely depend on whether green adjustment mechanisms can progress faster than the environmental pressures generated by economic and urban expansion.

## 6. Conclusions

Cities have become central actors in the global response to climate change, as they concentrate both population growth and economic activity. With more than 56% of the world's population residing in urban areas, cities account for over 70% of global emissions, according to the United Nations. This dual role positions urban areas as both major contributors to environmental pressure and critical platforms for implementing sustainable solutions. In line with this global context, the empirical findings indicate that economic growth and urban expansion within the European Union remain key drivers of ecological degradation, as reflected in the rising ecological footprint. Tourism also represents a significant source of environmental pressure, accounting for approximately 8% of global emissions, with projections suggesting a substantial increase in emissions by 2030 compared to pre-pandemic levels. However, the ongoing recovery of tourism toward pre-COVID activity levels presents a critical window of opportunity to reshape the sector along more sustainable pathways.

The findings of this study provide empirical answers to the three research questions and allow for a broader evaluation of sustainable tourism transitions in the European Union. Concerning RQ1, which examined the short-run and long-run effects of tourism activity and urbanization on ecological footprint, the results confirm that both variables are statistically significant determinants of environmental sustainability, although their effects move in opposite directions. Urbanization emerged as a strong footprint-amplifying factor, indicating that continued spatial concentration of population, infrastructure expansion, and energy-intensive urban consumption generate persistent ecological pressure. Tourism activity, however, displayed a negative coefficient in both the short and long run, suggesting that tourism development in advanced European economies may increasingly operate through environmentally improved organizational practices, cleaner destination management, and stronger sustainability standards. Thus, RQ1 is confirmed by demonstrating that tourism and urbanization materially shape ecological footprint, but with fundamentally different environmental consequences.

With respect to RQ2, which asked whether renewable energy transitions can compensate for tourism- and urbanization-driven environmental pressures, the results indicate that such compensation is possible primarily over longer adjustment horizons. Although renewable energy consumption does not exhibit a statistically meaningful short-run corrective influence, its negative long-run coefficient confirms that the gradual substitution of conventional fossil-based systems contributes to reducing ecological demand over time. This means that renewable transition cannot instantly neutralize the environmental costs associated with growth and urban expansion, but it remains a crucial structural mechanism for long-term ecological stabilization. Accordingly, RQ2 is also empirically supported, with the qualification

that the environmental returns of renewable investment are cumulative rather than immediate.

The answer to RQ3 is particularly important from a methodological and policy standpoint. After explicitly accounting for cross-country interdependence through second-generation panel procedures and CS-ARDL estimation, tourism dynamics in the European Union appear to be footprint-mitigating rather than footprint-amplifying in the long run. This result suggests that once common shocks, interconnected markets, and shared sustainability governance are incorporated into the analysis, tourism no longer emerges solely as a source of additional environmental burden. Instead, within highly regulated and institutionally mature economies, tourism seems increasingly compatible with ecological stabilization, likely because the sector is more rapidly exposed to green certification, low-carbon destination management, sustainable mobility solutions, and environmentally conscious consumer demand. Therefore, the study provides evidence that the long-run environmental sign of tourism is context-dependent and conditioned by the regulatory and technological framework in which tourism expansion takes place.

Beyond resolving the research questions, the study contributes to the literature in several important respects. It broadens the tourism–environment debate by relying on ecological footprint as a consumption-based sustainability indicator rather than limiting the analysis to territorial emissions alone. In addition, by combining tourism intensity, urbanization, economic growth, and renewable energy within a cross-sectionally augmented dynamic panel framework, the paper demonstrates that environmental sustainability in advanced economies cannot be explained through isolated sectoral relationships, but through the interaction of multiple development forces under shared institutional interdependence. In this sense, the research offers a more integrated empirical perspective on the structural conditions under which tourism can coexist with climate-neutrality objectives.

Nevertheless, the analysis is subject to several limitations. The sample includes fourteen EU countries and therefore cannot entirely reflect destination-level differences in tourism specialization, urban governance quality, or national ecological policy implementation. A sample of 14 EU countries may restrict generalizability of the findings, and reliance on aggregate national data overlooks important regional and destination-level heterogeneity. Furthermore, ecological footprint remains a broad synthetic measure that does not isolate the separate environmental contributions of transport, accommodation, food supply chains, or imported tourism consumption. These issues open important directions for future research, particularly through destination-specific panel studies, nonlinear threshold modelling, and comparative assessments of alternative tourism structures within European urban systems.

The institutional implications of the results are substantial. Since urbanization remains the dominant long-run source of ecological pressure, EU sustainability

strategies must move toward stricter green urban planning, compact infrastructure, energy-efficient construction, and low-carbon public mobility. At the same time, the environmentally mitigating role of tourism suggests that tourism policy should continue to support eco-certification, sustainable destination governance, and green innovation instead of viewing tourism expansion exclusively as an ecological threat. Finally, the long-run significance of renewable energy confirms that clean energy investment must remain one of the central instruments for absorbing the environmental costs of affluence and urban concentration. The broader conclusion is that ecological stabilization in advanced European economies will depend not on limiting tourism or development itself, but on the institutional capacity to synchronize tourism governance, urban transition, and renewable energy policy within a coherent sustainability framework.

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## Turizam, urbani rast i ekološki otisak: Empirijski uvidi iz Europske unije

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### Sažetak

Turizam, urbani rast i ekološka održivost sve su više međusobno povezani u Europskoj uniji, gdje brza urbana ekspanzija i gospodarska aktivnost intenziviraju ekološke pritiske. Razumijevanje načina na koji turizam djeluje unutar tih dinamika postalo je središnje pitanje rasprave o održivom turizmu, budući da kreatori politika i ostali dionici nastoje uskladiti gospodarski razvoj sa zaštitom okoliša. Ovo istraživanje ispituje kratkoročne i dugoročne učinke turističke aktivnosti, urbanizacije, gospodarskog rasta i potrošnje obnovljive energije na ekološki otisak u 14 zemalja Europske unije u razdoblju od 1995. do 2024. godine. Primjenom CS-ARDL modela (cross-sectionally augmented autoregressive distributed lag), koji uzima u obzir međusektorsku ovisnost i heterogenost nagiba, analiza potvrđuje postojanje dugoročne kointegracijske veze među varijablama. Rezultati pokazuju da gospodarski rast i urbanizacija značajno povećavaju ekološki otisak, dok međunarodni turizam ima ublažavajući učinak na pritiske na okoliš. Obnovljiva energija pridonosi ekološkom poboljšanju u dugom roku, iako je njezin kratkoročni učinak ograničen. Empirijski rezultati naglašavaju potrebu za integriranim politikama koji objedinjuju održivi razvoj turizma, urbano planiranje i strategije obnovljive energije unutar Europske unije. Istraživanje ističe važnost koordiniranog djelovanja urbanista, kreatora energetske politike i dionika u turizmu kako bi se poticao gospodarski rast uz istodobno osiguravanje okolišne održivosti za buduće generacije.

**Glavne riječi:** održivi razvoj turizma, urbanizacija, procjena ekološkog otiska, okolišna održivost, usvajanje obnovljive energije, dinamika gospodarskog rasta, Europska unija

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