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Impact of tourism on economic growth and CO_2 emissions in the EU: A dynamic panel threshold analysis

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Abstract

Purpose – The development of tourism provides significant support for economic growth, and also generates environmental effects that are generally not positive. Accordingly, this paper aims to explore the dynamic effects of tourism development in 27 European Union countries on economic growth and carbon dioxide (CO_2) emissions. The objective is to empirically examine the correctness of the tourism-led growth hypothesis (TLGH) and the Environmental Kuznets Curve (EKC). **Methodology** – The study applies a dynamic panel threshold regression to investigate whether the effects of tourism on economic growth and CO_2 emissions change after reaching a certain level of development (threshold). **Findings** – The research results support the validity of both the TLGH and EKC hypotheses. An increase in tourism development (measured by international tourists' receipts) stimulates economic growth. Additionally, tourism contributes to a lower marginal increase in CO_2 emissions if international tourists' receipts per capita exceed the threshold of $1,768 or if a country's GDP per capita surpasses $17,570. **Implications** – This paper contributes to the theoretical literature of the nexus between tourism, economic growth, and environmental effects by applying an advanced econometric methodology. Empirical research findings show that after reaching a specific development threshold, tourism fosters economic growth while reducing negative environmental impacts.

Keywords: tourism development, economic growth, CO_2 emissions, dynamic panel threshold regression, Environmental Kuznets Curve
JEL classification: Z32, O44, Q56, C23

Uticaj turizma na ekonomski rast i emisiju CO_2 u EU: Dinamička panel analiza sa pragom

Sažetak

Svrha – Razvoj turizma predstavlja značajnu podršku ekonomskom rastu, ali proizvodi i ekološke efekte koji, po pravilu, nisu pozitivni. Shodno tome, svrha ovog rada je da istraži dinamičke efekte razvijenosti turizma u 27 zemalja Evropske unije na ekonomski rast i emisiju ugljen dioksida (CO_2). Cilj je da se empirijski ispitaju hipoteza o rastu vođenom turizmom (HRVT) i validnost Ekološke Kuznetsove krive (EKK). **Metodologija** – U radu se

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primenjuje dinamička panel regresija sa pragom kako bi se utvrdilo da li se uticaj turizma na privredni rast i emisiju CO_2 menja nakon dostizanja određenog nivoa razvijenosti (praga). **Rezultati** – Rezultati istraživanja potvrđuju validnost HRVT i EKK hipoteza. Povećanje razvijenosti turizma (mereno vrednošću prihoda od stranih turista) podstiče privredni rast. Turizam doprinosti manjoj dodatnoj emisiji CO_2 ukoliko prihod od stranih turista po glavi stanovnika premaši prag od 1.768 USD, odnosno, ukoliko GDP per capita zemlje premaši 17.570 USD. **Implikacije** – Ovaj rad doprinosi teorijskoj analizi odnosa turizma, ekonomskog rasta i ekoloških efekata primenjujući naprednu ekonometrijsku metodologiju. Nalazi empirijskog istraživanja ukazuju da, nakon dostizanja određenog praga razvijenosti, turizam podstiče privredni rast, pritom ublažavajući negativne ekološke efekte.

Ključne reči: razvijenost turizma, ekonomski rast, emisija CO_2, dinamička panel regresija sa pragom, Ekološka Kuznetsova kriva
JEL klasifikacija: Z32, O44, Q56, C23

1. Introduction

Tourism is among the most rapidly expanding sectors in the 21st century. The tourism industry plays a crucial role in the global economy, contributing substantially to gross domestic product (GDP), directly and indirectly employing a substantial portion of the global workforce, and holding a notable share in total exports (OECD, 2024). The significance of tourism in global economic development is highlighted by the travel and tourism sector's contribution of 7.6% to global GDP in 2022, marking a 22% increase compared to 2021. The sector's contribution to global employment is also substantial. In the same year, this sector created 295 million jobs (9% of total employment), representing a 7.9% increase compared to 2021 (World Travel & Tourism Council, 2023). Several less-developed countries have enhanced their involvement in the global economy through tourism development. Considering this, many countries, regardless of their level of development, rely on tourism to improve their economic conditions.

Tourism boosts national revenue, encourages investment, creates employment opportunities, contributes to infrastructure development, enables economies of scale for local businesses, facilitates the spread of knowledge, skills, and advanced technologies, and is closely linked to other industries (Brida et al., 2016). This largely demonstrates that tourism has become essential for economies to minimise socio-economic disparities by improving the socio-economic status of individuals. The concept that tourism supports economic expansion is referred to as the tourism-led growth hypothesis (TLGH) (Balaguer & Cantavella-Jorda, 2002). This hypothesis originates from the export-led growth theory, which argues that economic growth is driven not only by increases in labour and capital but also by the expansion of exports (Brida et al., 2016).

However, despite its positive effects on growth and development, the tourism sector can also have negative environmental impacts, primarily due to the increased use of fossil fuels in most tourism activities. The expansion of this sector has resulted in higher fossil energy consumption and significant greenhouse gas emissions, especially carbon dioxide (CO_2) (Jebli et al., 2019). Conversely, the tourism industry is significantly susceptible to climate-related factors, especially extreme weather events, which can lead to security concerns, water scarcity, increased insurance expenses, and diminished destination appeal, ultimately limiting economic prospects for nations (Rigas & Kounetas, 2024).

The environmental impact of tourism development is often empirically investigated through the examination of the Environmental Kuznets Curve (EKC) hypothesis (Lee & Brahmasrene, 2013; Paramati et al., 2017). In the context of tourism and CO_2 emissions, this

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relationship suggests a non-linear, inverted U-shaped connection between tourism development and environmental degradation. At the initial stages of tourism development, CO_2 emissions rise due to reliance on fossil fuels and the lack of sustainable practices. As tourism progresses, emissions peak as revenues grow, but environmental awareness and regulations are not yet sufficiently strong. However, after reaching a turning point, further development in tourism reduces CO_2 emissions thanks to increased investments in green technologies, sustainable infrastructure, and stricter environmental policies (Onofrei et al., 2022; Shahnazi & Shabani, 2021).

Given the above, this paper aims to investigate the impact of international tourism on economic growth and CO_2 emissions in the 27 European Union (EU) countries. In other words, the paper tests the correctness of the TLGH on one hand and the legitimacy of the EKC hypothesis on the other. In line with the stated research objective, this paper aims to theoretically and empirically analyse whether and how the level of tourism development affects economic growth and the environment in EU economies.

This research advances the empirical literature by exploring the dynamic interplay between tourism development, economic growth, and CO_2 emissions. Despite the substantial growth of the tourism sector in EU nations, only few studies have investigated the dynamic link between tourism and economic growth, as well as tourism and CO_2 emissions. Additionally, the contribution of this paper lies in the application of a robust econometric methodology, specifically the dynamic panel threshold regression, which, to the best of our knowledge, has not been previously used to analyse the relationships between tourism, economic growth, and CO_2 emissions. The methodology developed by Kremer et al. (2013) for estimating the dynamic panel threshold model allows for the estimation of the threshold value and two different regimes – below and above the threshold – in which the explanatory variable (tourism development) may have different impacts on the dependent variable (economic growth or CO_2 emissions). In other words, this approach enables the detection of non-linear linkages, which is crucial for drawing valid conclusions and formulating effective economic policy measures.

The following research hypotheses are tested in the paper:

H1: An increase in the development of international tourism, measured by the value of international tourists' receipts, positively affects economic growth.

H2: The impact of tourism on increasing CO_2 emissions is lower in countries with higher levels of international tourism development, measured by the value of international tourists' receipts.

H3: In countries with higher levels of economic development, international tourism has a relatively smaller impact on increasing CO_2 emissions.

The first hypothesis is directly linked to the TLGH. If the research confirms H1, it can be concluded that this hypothesis is also valid. The second hypothesis is indirectly related to the EKC, as it predicts that a higher level of tourism development leads to a lower impact of tourism activities on CO_2 emissions. The third hypothesis complements the previous one and is directly linked to the EKC. Specifically, if the research confirms this hypothesis, it can be concluded that in more economically developed countries, the environmental effect of tourism, measured by CO2 emissions, is less harmful.

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2. Literature review

Tourism is becoming an increasingly significant part of the economy and a source of revenue in the modern context of globalisation and open markets. Thus, the link between tourism and economic growth is a crucial consideration for policymakers when formulating effective tourism strategies to support sustainable economic development. Academic and applied research lacks agreement on whether tourism propels economic activity or economic growth stimulates tourism expansion, as evolving economic or tourism conditions may reshape the intensity and trajectory of their interplay across periods (Antonakakis et. al., 2015).

Chatziantoniou et al. (2013) identified four types of tourism and economic growth linkages: a unidirectional causality where tourism drives economic growth (Işık et al., 2022; Rivera, 2017; Stančić et al., 2022; Tung, 2021; Xia et al., 2021), a unidirectional causality from economic growth to tourism (Aratuo & Etienne, 2019; Tang, 2011), a bidirectional tourism-economic growth relationship (Antonakakis et al., 2015; Mitra, 2019; Roudi et al., 2019), and a case where there is no relationship between the observed variables (Aliyev & Ahmadova, 2020; Gričar et al., 2021; Kyophilavong et al., 2018).

Numerous studies have explored the tourism-growth connection while considering additional factors such as political stability, trade openness, CO_2 emissions, gross capital investments, and foreign direct investments (Ahmad et al., 2020; Alam & Paramati, 2017; Amin et al., 2019; Azam & Abdullah, 2022; Balsalobre-Lorente & Leitão, 2020; Jambor & Leitão, 2017; Jebli et al., 2019; Mitra, 2019; Shaheen et al., 2019). Jebli et al. (2015) investigated the relationship between economic growth, tourism, and renewable energy in Tunisia from 1990 to 2010. The results indicated a causality from tourism to income per capita and a bidirectional causality between renewable energy and economic growth. Jebli et al. (2019) examined the causal links among renewable energy consumption, tourist arrivals, economic growth, CO_2 emissions and other variables in 22 countries in South and Central America for the period 1995–2010. The authors found that, in the short term, there is a unidirectional causality from economic growth to renewable energy and tourism. However, in the long term, bidirectional causality is observed between renewable energy, tourism, and CO_2 emissions. Jambor and Leitão (2017) analysed the relationship between tourist arrivals and economic growth in Central and Eastern European countries for the period 1995–2014. Their results confirmed that economic growth is positively affected by international tourist arrivals, trade openness, and foreign direct investments. Conversely, a negative correlation between economic growth and CO_2 emissions was found, indicating that economic growth does not necessarily undermine environmental sustainability. Alam and Paramati (2017), using data from the ten countries with the highest contribution of tourism to their GDP, showed that income per capita and trade openness stimulate tourism development. Additionally, they concluded that income per capita positively affects CO_2 emissions, whereas these emissions are negatively correlated with tourist arrivals and trade openness.

Lee and Brahmasrene (2013) analyzed the TLGH for EU economies and found that this hypothesis is valid in the long term. Amin et al. (2019) demonstrated that for South Asian countries, there was a causality from international tourist arrivals to economic growth and from energy consumption to both tourism and economic growth. Balsalobre-Lorente and Leitão (2020) studied the impact of tourist arrivals, renewable energy sources, trade openness, and CO_2 emissions on economic growth in the EU-28 countries from 1995 to 2014. They confirmed that tourism and other variables positively influence economic growth, supporting the TLGH for these countries. Shaheen et al. (2019) investigated the links among tourism, energy, the environment, and economic growth, concluding that tourism contributes to CO_2 emissions and that economic growth is linked to climate change. Ahmad et al. (2020) analyzed the impact of tourism, gross capital formation, and energy

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consumption on GDP in selected South Asian countries from 1995 to 2016. They demonstrated that tourism positively affects GDP in the selected countries, confirming TLGH. Additionally, the results confirmed the positive impact of energy consumption and gross investments on GDP. Azam and Abdullah (2022) found that in nine leading Asian tourist countries, including Indonesia, tourism and energy consumption positively affect economic growth.

The dynamics of economic growth - CO_2 emissions linkage also attract significant attention from researchers. This relationship can be viewed from two perspectives: first, a unidirectional causality from emissions to economic growth (Iqbal et al., 2023; Madaleno & Nogueira, 2023; Rigas & Kounetas, 2024) and second, causality from economic growth to CO_2 emissions (Ali et al., 2017; Mensah et al., 2018; Onofrei et al., 2022; Raihan & Tuspekova, 2022; Su et al., 2021; Thi et al., 2023; Ullah et al., 2023).

Shahnazi and Shabani (2021) suggest that this relationship can take six different forms. First, as an inverted U-shape, known as the EKC, which implies that CO_2 emissions increase with economic growth up to a certain point, after which further growth leads to a decrease in emissions. This viewpoint is explained by the fact that, in the early stages of development, countries depend on inexpensive hydrocarbon fuels. As the standard of living improves, these countries turn to adopting renewable energy sources that help reduce CO_2 emissions. Other possible forms include a U-shape, an N-shape, and an inverted N-shape relationship, as well as cases where GDP either reduces CO_2 emissions or where increased economic activity leads to higher CO_2 emissions.

Given the existing research on the relationship between tourism, economic dynamics, and environmental effects, it is evident that empirical findings are mixed. Accordingly, this paper aims to fill the research gap by analysing EU countries and applying advanced econometric methodology based on the dynamic panel threshold regression approach developed by Kremer et al. (2013). In examining the relationships among these variables, a limited number of studies employ threshold methodology in empirical analyses, resulting in less valid statistical inferences regarding the threshold point beyond which this relationship changes. This is particularly important when testing the TLGH and the EKC hypotheses. The econometric method by Kremer et al. (2013) successfully deals with the problem of potential endogeneity of regressors and takes the tourism development variable as both the explanatory variable and the threshold variable.

3. Materials and methods

3.1. Data and descriptive statistics

This study investigates the effect of tourism development on economic growth and CO_2 emissions in 27 EU economies from 1995 to 2020. The starting year is determined by data availability for all EU economies. To obtain more accurate estimates regarding long-term relationships among variables, the time-span concludes in 2020. Specifically, we aim to exclude the severe negative impacts of the COVID-19 pandemic on tourism activity and economic growth dynamics.

Economic growth is measured as a difference between the current period's Gross Domestic Product per capita ($GDPpc$) and that of the previous period. The level of tourism development is quantified using international tourist receipts per capita ($TRpc$) in constant USD, reflecting spending by inbound international visitors, such as payments to domestic transportation providers for cross-border travel. CO_2 emissions are defined as total annual carbon dioxide emissions from the agriculture, energy, waste, and industrial sectors,

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excluding Land Use, Land-Use Change, and Forestry (LULUCF), and are standardized to carbon dioxide equivalent, measured in tons per capita.

The estimation model also includes several control variables. Trade openness (TO) is defined as the sum of exports and imports of goods and services, expressed as a percentage of GDP. The inflation rate (INF) is represented by the consumer price index, which tracks the annual percentage change in the cost of a typical basket of goods and services for the average consumer. Gross fixed capital formation per capita ($GFCpc$) is measured in constant 2015 USD and includes fixed investments. Industry (IND) includes the value added (% of GDP) from mining, manufacturing, construction, electricity, water, and gas. Services (SER) refer to the value added, as a percentage of GDP, in sectors such as wholesale and retail trade (including hotels and restaurants), transport, and various services. Population (POP) counts all residents (midyear estimates) regardless of legal status or citizenship.

Data is sourced from the World Bank national accounts data (for GDP per capita, total output, gross fixed capital formation, industry, and services), the Emissions Database for Global Atmospheric Research (EDGAR) (for CO_2 emissions), the World Tourism Organization's Yearbook of Tourism Statistics (for international tourists' receipts), the International Monetary Fund (for inflation), and the United Nations Population Division - World Population Prospects (for population). As recommended by Paramati et al. (2017), all variables are converted into their natural logarithmic form to address issues related to the distributional properties of the data series. This transformation allows each estimated coefficient to be interpreted as an elasticity.

Table 1 reports the descriptive statistics for the abovementioned variables. The panel of EU economies is characterised by relatively stable economic and environmental indicators, as most variables show low or moderate variability.

Table 1: Descriptive statistics

Variable	**Mean**	**Maximum**	**Minimum**	**Std. Dev.**	**Observations**
$lnGDPpc$	9.984	11.629	8.172	0.729	702
$lnCO2pc$	2.009	3.259	1.098	0.407	702
$lnTRpc$	6.601	9.292	2.611	1.049	702
$lnTO$	4.603	5.946	3.587	0.451	702
$lnINF$	0.806	6.964	-3.906	1.078	702
$lnGFCpc$	8.405	10.576	4.751	0.781	702
$lnIND$	3.155	3.694	2.299	0.252	702
$lnSER$	4.114	4.383	3.685	0.109	702
$lnPOP$	15.795	18.236	12.841	1.362	702

Source: Authors' research

The scatter plot diagrams (Figures 1 and 2, left panels) visually present the link between tourism development and economic growth, as well as its association with CO_2 emissions, respectively. Both economic growth and CO_2 emissions are positively linked with tourism development. To illustrate the nonlinearity between these variables, LOWESS smoothing is applied (right panels in Figures 1 and 2). LOWESS is a non-parametric technique that does not presume any relationship between the variables (Al Shammre et al., 2023). The LOWESS curves indicate that the correlation between tourism development and growth is nonlinear. The same holds for the relationship between tourism development and CO_2 emissions, highlighting the presence of threshold effects. Therefore, the preliminary data analysis suggests employing the threshold regression approach.

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3.2. Econometric method

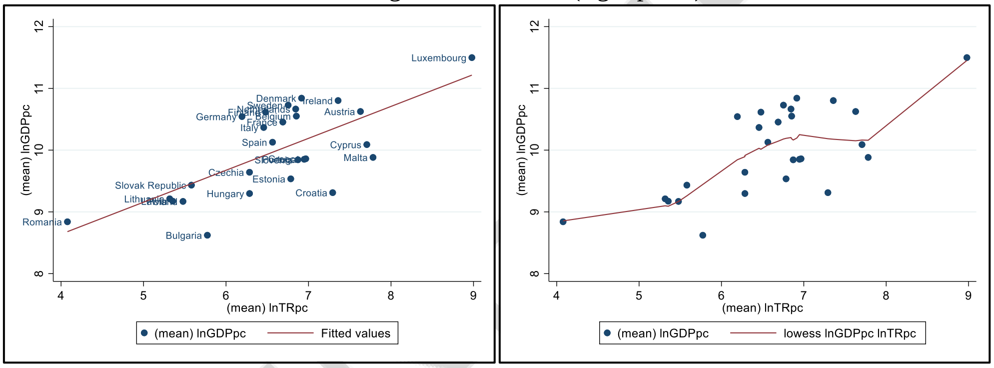
To examine the nexus between tourism development and economic growth and tourism development and CO_2 emissions, the following two models are employed:

$$GDPpc_{it} = \alpha_i + \beta TRpc_{it} + \delta_1 TO_{it} + \delta_2 INF_{it} + \delta_3 GFCpc_{it} + \delta_4 IND_{it} + \delta_5 SER_{it} + \delta_6 POP_{it} + \theta_t + \varepsilon_{it} \quad (1)$$

$$CO2pc_{it} = \alpha_i + \beta TRpc_{it} + \delta_1 TO_{it} + \delta_2 GFCpc_{it} + \delta_3 IND_{it} + \delta_4 SER_{it} + \delta_5 POP_{it} + \delta_6 GDPpc_{it} + \theta_t + \varepsilon_{it} \quad (2)$$

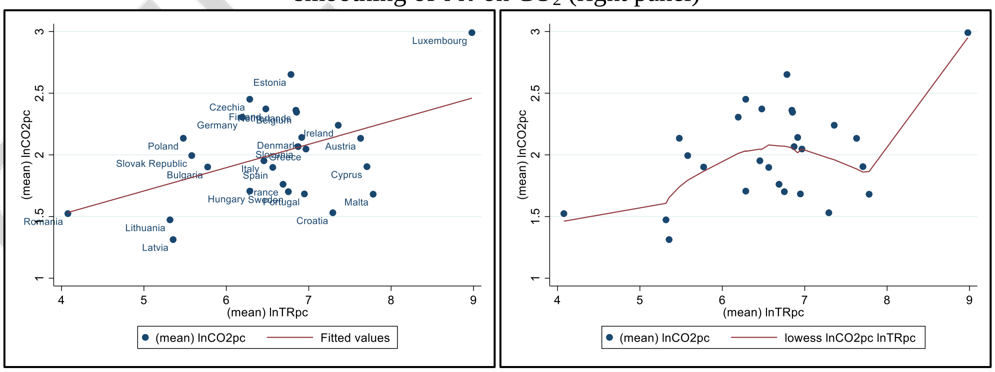
where $GDPpc$ represents the GDP per capita growth rate, $CO2pc_{it}$ stands for CO_2 emissions in tons per capita, i denotes the country (i = 1, …, N), t represents the time (t = 1, …, T), α_i denotes an unobservable country-specific effect, θ_t is the time-specific effect, β and δ_1 - δ_6 are the coefficients of the explanatory variable and the control variables (TO, INF, GFC, IND, SER, and POP), respectively, and ε is an error term.

Figure 1: The scatter plot for the mean values of TR and GDP (left panel) and LOWESS smoothing of TR on GDP (right panel)



Source: Authors' research

Figure 2: The scatter plot for the mean values of TR and CO_2 (left panel) and LOWESS smoothing of TR on CO_2 (right panel)



Source: Authors' research

As the data presented in Figures 1 and 2 suggest the non-linear (threshold) effects in the impact of tourism development on economic growth (CO_2 emissions), the dynamic panel threshold regression model proposed by Kremer et al. (2013) is applied. This method is founded on the General Method of Moments (GMM) approach. It builds on the static threshold model introduced by Hansen (1999) and the cross-sectional threshold framework proposed by Caner and Hansen (2004), utilizing Generalized Method of Moments (GMM) estimators to address endogeneity within a dynamic context. In such a way, it successfully copes with the potential endogeneity of regressors. It also allows the explanatory variable (tourism development in this study) to be a threshold variable simultaneously. Furthermore, this approach utilizes the forward orthogonal deviations conversion, ensuring that the original threshold model applied to static panels in Hansen (1999) remains appropriate in a dynamic setting (Kremer et al., 2013). As Kremer et al. (2013) suggested, the instrument variables should include the lagged dependent variable, the exogenous variable, and the other covariates. Accordingly, models 1 and 2 can be transformed as follows:

$$GDPpc_{it} = \alpha_i + \beta_0 GDPpc_{it-1} + \beta_1 TRpc_{it}\, I(TRpc_{it} \leq \gamma) + \beta_2 TRpc_{it}\, I(TRpc_{it} > \gamma) + \delta_1 TO_{it} + \delta_2 INF_{it} + \delta_3 GFCpc_{it} + \delta_4 IND_{it} + \delta_5 SER_{it} + \delta_6 POP_{it} + \theta_t + \varepsilon_{it} \quad (3)$$

$$CO2pc_{it} = \alpha_i + \beta_0 CO2pc_{it-1} + \beta_1 TRpc_{it}\, I(TRpc_{it} \leq \gamma) + \beta_2 TRpc_{it}\, I(TRpc_{it} > \gamma) + \delta_1 TO_{it} + \delta_2 GFCpc_{it} + \delta_3 IND_{it} + \delta_4 SER_{it} + \delta_5 POP_{it} + \delta_6 GDPpc_{it} + \theta_t + \varepsilon_{it} \quad (4)$$

where γ denotes the tourism development threshold value that is estimated, I represents the indicator variable with the value of 1 if the condition in the parenthesis is fulfilled and 0 otherwise, β_1 and β_2 represent the coefficients of the tourism development effect on economic growth (CO_2 emissions in Equation 4) below and above the threshold value of tourism development, respectively, whereas δ_1 - δ_6 are the coefficients of the covariates.

To empirically test the EKC (i.e. the assumption that a higher level of economic development, measured by GDP per capita, results in a lower impact on the environment measured by CO_2 emissions), the model from Equation 4 is modified by using GDP per capita growth as a threshold variable:

$$CO2pc_{it} = \alpha_i + \beta_0 CO2pc_{it-1} + \beta_1 TRpc_{it}\, I(GDPpc_{it} \leq \gamma) + \beta_2 TRpc_{it}\, I(GDPpc_{it} > \gamma) + \delta_1 TO_{it} + \delta_2 GFCpc_{it} + \delta_3 IND_{it} + \delta_4 SER_{it} + \delta_5 POP_{it} + \theta_t + \varepsilon_{it} \quad (5)$$

In further analysis, the model from Equation (5) is called Model 2a. By estimating this model, it is addressed whether a higher level of economic development (above the threshold) leads to lower emissions compared to the economic development below the threshold.

Utilising this method generates estimates that asymptotically align with a normal distribution. Consequently, the standard Wald test can be employed to assess the existence of a threshold. Therefore, the nonlinearity test using the $supW = supW_n(\gamma)$ statistic is performed, where the null hypothesis is $\beta - \delta = 0$, and $W_n(\gamma)$ represents the standard Wald statistic for each fixed value of γ.

To examine the dynamic bivariate panel causality among dependent, explanatory, and control variables, the study utilizes the heterogeneous panel causality model proposed by Dumitrescu and Hurlin (2012). This approach evaluates the null hypothesis of uniform non-causality against the alternative hypothesis of non-uniform (heterogeneous) causality across units. For each cross-sectional unit, Wald statistics are calculated separately to assess Granger non-causality. The overall panel test statistic is then determined by averaging these individual Wald statistics across cross-sections. This model effectively accounts for heterogeneity, performs well with small panel datasets, and manages cross-sectional dependence. These strengths make it a suitable choice for causality analysis in this research.

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4. Results and discussion

Prior to econometric estimation, the presence of cross-sectional dependence should be examined. Table 2 reports the results of the cross-section dependence test developed by Pesaran (2021). The results indicate a firm rejection of the null hypothesis of no cross-section dependence at the 1% significance level. Therefore, the second-generation panel unit root test is employed. The results of the Cross-section Im-Pesaran-Shin (CIPS) test proposed by Pesaran (2007) are presented in the right panel of Table 2. All variables are integrated of order $I(1)$ since they are nonstationary at levels and stationary at the first differences. This indicates that implementing the dynamic panel regression model proposed by Kremer et al. (2013) is justified. Specifically, this approach relies on first-differenced GMM estimates.

Though visually represented in Figures 1 and 2, the non-linearity and threshold effects should be confirmed more formally. To achieve this, the slope homogeneity test by Pesaran and Yamagata (2008) is used. If a threshold effect exists, the slope coefficients will differ before and after the threshold. The results from Table 3 demonstrate that the delta statistic achieves statistical significance, thereby rejecting the null hypothesis that slope coefficients are homogenous. This suggests a non-linear relationship in both Model 1 and Model 2. Model 2a is not tested for slope homogeneity because it contains the same variables as Model 2.

Table 2: The results of cross-section dependence and CIPS unit root tests

Variable	**Cross-section dependence test statistic**	**CIPS unit root test results**	
		Level	**First difference**
$lnGDPpc$	79.822^{***}	-0.314	-3.091^{***}
$lnCO2pc$	47.299^{***}	-2.011	-4.136^{***}
$lnTRpc$	63.722^{***}	-2.313	-3.908^{***}
$lnTO$	71.287^{***}	-1.816	-3.565^{***}
$lnINF$	46.612^{***}	-1.643	-4.649^{***}
$lnGFCpc$	51.459^{***}	-2.525	-4.264^{***}
$lnIND$	49.324^{***}	-2.166	-4.075^{***}
$lnSER$	61.844^{***}	-2.335	-3.958^{***}
$lnPOP$	5.799^{***}	-1.249	-2.438^{***}

Note: Pesaran CD test statistic values are presented. Deterministic components: constant and trend. ***, **, and * signify statistical significance at 1%, 5% and 10%, respectively
Source: Authors' research

Table 3: Slope homogeneity test results

Indicator	**Model 1**		**Model 2**	
	Coefficient	**Probability**	**Coefficient**	**Probability**
Delta	14.863	0.000	16.810	0.000
Adj. delta	18.947	0.000	21.428	0.000

Note: The test is performed using *xthst* command in Stata. H_0: Slope coefficients are homogenous
Source: Authors' research

Table 4 reports the estimates of the dynamic panel threshold regression model. For Model 1, the threshold value of the international tourists' receipts is 6.856. Given that the natural logarithm of this variable is included, the antilog value should be calculated. Specifically, it

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is \$949.6 per capita as a threshold value. Below this threshold, a one percentage point (p.p.) increase in tourists' receipts leads to a 0.019 p.p. increase in economic growth. On the other hand, above the threshold, a one p.p. rise in tourists' receipts produces a 0.017 p.p. increase in growth. This suggests relatively minor differences between the effects of tourism development on growth. However, supWald statistics is statistically significant, confirming the presence of non-linearity. The positive effects of tourism development on economic growth support the TLGH. As for the covariates' coefficients, they mainly show expected signs and magnitudes. Increased trade openness and gross fixed capital lead to higher economic growth, as suggested by several studies (Alam & Paramati, 2017; Jambor & Leitão, 2017; Jebli et al., 2019). In contrast, an increase in the share of industry and services in GDP, along with a rising population, adversely affects economic growth per capita, confirming, for instance, the findings of Paramati et al. (2017) for developed economies.

Table 4: Estimation results from the dynamic panel threshold regression

Variables	Model estimates		
	Model 1	**Model 2**	**Model 2a**
Threshold variable	$TRpc$	$TRpc$	$GDPpc$
Threshold estimate (γ)	6.856***	7.478***	9.774***
95% Conf. Interval	[6.7, 6.9]	[6.6, 7.8]	[9.6, 9.8]
	Impact of $TRpc$ on $GDPpc$	Impact of $TRpc$ on $CO2pc$	Impact of $TRpc$ on $CO2pc$
$\hat{\beta}_1$	0.019***	0.041***	0.029**
$\hat{\beta}_2$	0.017***	0.037***	0.025**
Impact of covariates			
$GDPpc_{t-1}$	0.661***	-	-
$CO2_{t-1}$	-	0.782***	0.852***
TO	0.139***	-0.191***	0.011
INF	-0.001*	-	-
$GFCpc$	0.159***	-0.054*	-0.057**
IND	-0.109**	0.064	0.423***
SER	-2.221***	-0.479***	0.266**
POP	-0.145***	-0.249***	-0.136
$GDPpc$	-	0.139***	-
$Const.$	4.855***	5.824***	-1.902**
Observations	675	675	675
Number of instruments	480	480	301
SupWald Statistic (p-value)	1357.93 (0.000)	1044.99 (0.000)	167.50 (0.000)

Note: ***, **, and * signify statistical significance at 1%, 5%, and 10%, respectively. The results are estimated using the *xtendothresdpd* command in Stata, proposed by Diallo (2020).
Source: Authors' research

Model 2 represents the impact of tourism development on CO_2 emissions. The estimated threshold is 7.478, which corresponds to the antilog value of \$1,768 per capita. Below this value, a one p.p. increase in the tourists' receipts leads to a 0.041 p.p. increase in CO_2 emissions. When the tourists' receipts are above the threshold value, its growth for one p.p. leads to a 0.037 p.p. rise in CO_2 emissions. In other words, the higher the tourism development level, the lower the impact of tourism on CO_2 emissions. The control variables' coefficients are mainly negative. This suggests that an increase in trade openness, the share

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of industry and services in GDP, population, and the share of fixed investments in GDP leads to a reduction in CO_2 emissions. Finally, it appears that the estimation results of Model 2a support the EKC hypothesis. Namely, when the level of economic development (measured by GDP per capita growth) is below the threshold of 9.774, a one p.p. increase in tourists' receipts leads to a 0.029 p.p. rise in CO_2 emissions. However, when the $GDPpc$ is above the threshold, the increase in CO_2 emissions is lower (0.025 p.p.). The antilog value of the threshold is $17,570. To put it differently, in countries with GDP per capita higher than this value, tourism produces lower CO_2 emissions, which is aligned with the postulates of the EKC. The covariates exhibit the expected impact on the dependent variable.

The causality between variables is tested employing Dumitrescu and Hurlin (2012) heterogenous panel causality test (Table 5). The bidirectional causality is confirmed between tourists' receipts and CO_2 emissions, which is aligned with similar studies (Ahmad et al., 2020; Paramati et al., 2017; Shaheen et al., 2019). This suggests that the two variables influence each other in the short term. A similar hold when it comes to the relationship between CO_2 emissions and other variables. However, the unidirectional causality from GDP per capita (and the share of services in GDP) to CO_2 emissions is identified. This implies that the emissions are driven by economic activity and not *vice versa*. On the other hand, there is unidirectional causality from tourism development to economic growth, which is in line with the TLGH. This relationship is documented in several studies (Işık et al., 2022; Stančić et al., 2022; Tung, 2021; Xia et al., 2021). As for other variables, the bidirectional causality with economic growth is identified. The exception is the unidirectional causality from trade openness to economic growth.

Table 5: The results of heterogenous panel causality test (Dumitrescu-Hurlin)

Null Hypothesis	**Zbar-Statistic**	**Null Hypothesis**	**Zbar-Statistic**
TR $\nrightarrow$ GDP	1.754^{*}	TR $\nrightarrow$ CO_2	9.528^{***}
GDP $\nrightarrow$ TR	-0.086	CO_2 $\nrightarrow$ TR	4.594^{***}
TO $\nrightarrow$ GDP	2.769^{***}	TO $\nrightarrow$ CO_2	3.120^{***}
GDP $\nrightarrow$ TO	0.259	CO_2 $\nrightarrow$ TO	1.757^{*}
INF $\nrightarrow$ GDP	9.663^{***}	GDP $\nrightarrow$ CO_2	7.563^{***}
GDP $\nrightarrow$ INF	2.532^{**}	CO_2 $\nrightarrow$ GDP	0.882
GFC $\nrightarrow$ GDP	3.993^{***}	GFC $\nrightarrow$ CO_2	4.997^{***}
GDP $\nrightarrow$ GFC	13.952^{***}	CO_2 $\nrightarrow$ GFC	2.436^{**}
IND $\nrightarrow$ GDP	6.238^{***}	IND $\nrightarrow$ CO_2	4.308^{***}
GDP $\nrightarrow$ IND	10.074^{***}	CO_2 $\nrightarrow$ IND	3.014^{***}
SER $\nrightarrow$ GDP	3.266^{***}	SER $\nrightarrow$ CO_2	3.715^{***}
SER $\nrightarrow$ GFC	13.022^{***}	CO_2 $\nrightarrow$ SER	-0.008
POP $\nrightarrow$ GDP	3.159^{***}	POP $\nrightarrow$ CO_2	9.580^{***}
GDP $\nrightarrow$ POP	15.329^{***}	CO_2 $\nrightarrow$ POP	7.486^{***}

Note: Sign "$\nrightarrow$" means "does not homogeneously cause".
***, **, and * signify statistical significance at 1%, 5% and 10%, respectively.
Source: Authors' research

One can conclude that the research hypotheses in this paper – H1 (tourism development positively affects economic growth), H2 (higher tourism development reduces the marginal increase in CO_2 emissions), and H3 (higher economic development diminishes tourism's environmental impact) – are empirically confirmed. The dynamic panel threshold analysis reveals that tourism stimulates economic growth across EU countries, supporting the TLGH. Simultaneously, the EKC hypothesis holds: when international tourism receipts exceed

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$1,768 per capita or GDP per capita surpasses $17,570, the marginal rise in CO_2 emissions from tourism decreases. This indicates that advanced economies leverage sustainable practices, green technologies, and stricter regulations to decouple tourism growth from environmental harm. Economically, these findings underscore the dual role of tourism as a growth driver and a sector where environmental sustainability can be achieved through targeted policies, particularly in high-income nations. The results advocate for policies that promote tourism while incentivizing green infrastructure and emission-reducing innovations to align economic and environmental goals.

The findings of this study align with several previous studies supporting the TLGH and EKC hypotheses (Işık et al. 2022; Rivera, 2017; Stančić et al. 2022). For instance, Balsalobre-Lorente and Leitão (2020) also confirm that international tourism positively affects growth in EU countries, with the impact being more pronounced in nations with higher economic development levels. Similarly, Lee and Brahmasrene (2013) identify a long-term relationship between tourism, economic growth and CO_2 emissions, reinforcing the conclusion that tourism is a key factor of economic expansion while exhibiting a nonlinear relationship with environmental degradation. In contrast, some studies challenge the TLGH, particularly in less developed economies. Kyophilavong et al. (2018) found no significant causal relationship between tourism and economic growth in Laos, suggesting that other macroeconomic factors may play a more substantial role in driving economic performance.

Regarding the tourism environmental effect, the study's findings support the EKC hypothesis, consistent with research by Jebli et al. (2019), who demonstrated that tourism-led CO_2 emissions initially rise but they decline after a certain income threshold is surpassed. However, Shaheen et al. (2019) present differing results, arguing that the tourism industry consistently increases CO_2 emissions without a clear turning point, especially in countries with weaker environmental regulations. The variation in findings across studies suggests that the effectiveness of sustainable tourism policies and green investments may significantly influence the environmental outcomes of tourism development.

5. Conclusion

This study provides empirical insights into the dynamic relationship between tourism development, economic growth, and CO_2 emissions within the EU using a dynamic panel threshold regression approach. The research confirms the validity of both the TLGH and the EKC hypotheses. The findings demonstrate that an increase in tourism development, measured by international tourists' receipts, positively impacts economic growth. Simultaneously, the environmental impact of tourism is found to be nonlinear, with higher levels of economic and tourism development contributing to a lower marginal increase in CO_2 emissions. The results suggest that tourism can be a sustainable driver of economic growth when managed effectively, ensuring that environmental impacts are mitigated through policy interventions and technological advancements.

A key contribution of this study is the identification of threshold effects in the relationship between tourism development and economic growth, as well as between tourism development and CO_2 emissions. The empirical results indicate that when international tourists' receipts per capita exceed $1,768 or when GDP per capita surpasses $17,570, the negative environmental impact of tourism declines. These findings imply that countries with higher levels of economic development can implement sustainable tourism strategies, invest in green infrastructure, and enforce stricter environmental policies to counterbalance the adverse effects of tourism.

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Despite its contributions, this research is not without limitations. Firstly, the study concentrates solely on EU countries, which restricts the ability to generalise the findings to other regions with differing economic structures and environmental policies. Future studies should explore similar relationships in developing economies where tourism may have a more pronounced impact on both growth and emissions due to weaker regulatory frameworks. Secondly, while the study controls for key economic and environmental variables, it does not explicitly account for the role of renewable energy adoption and technological innovations in mitigating tourism-induced CO_2 emissions. Incorporating these factors in future research could provide a more comprehensive understanding of sustainable tourism development. Another limitation relates to the dataset used in the analysis. The study covers the period from 1995 to 2020, which excludes the potential long-term impacts of the COVID-19 pandemic on tourism, economic recovery, and environmental sustainability. Given the significant disruptions in the tourism sector caused by the pandemic, future research should investigate how the post-pandemic economic landscape has altered the dynamics between these variables. Moreover, expanding the scope to include more granular data on tourism activities, such as domestic tourism, different modes of travel, and the carbon intensity of tourism-related industries, could offer deeper insights into policy implications. Future research should also explore the effectiveness of specific policy interventions in enhancing the sustainability of tourism-led growth. Comparative studies between EU and non-EU countries could help identify best practices that can be replicated globally.

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Conflict of interest

The authors declare no conflict of interest.

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