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Dynamic effects of tourism CO_2 emission intensity and economic growth under the framework of SDG 13

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Abstract. *The relationship between carbon emission intensity and economic growth in the tourism sector is of significant importance for formulating sustainable development policies. This study examines the impact of CO_2 emission intensity in the tourism sector on economic growth within the framework of the UN Sustainable Development Goal (SDG) 13: Climate Action. Tourism CO_2 emission intensity represents the ratio of carbon emissions generated by tourism activities to economic output and serves as a key indicator of the sector's environmental efficiency. A systematic analysis of existing empirical and comparative studies reveals that, while tourism development supports economic growth, the structure of energy consumption and the effectiveness of environmental policies directly influence emission intensity. The use of renewable energy, the development of green transportation, the promotion of eco-innovations, and the implementation of low-carbon tourism strategies contribute to reducing emissions and strengthening long-term economic sustainability. The study emphasizes that integrating climate policy, green investments, and sustainable tourism management is essential for achieving the targets of SDG 13.*

Keywords: *tourism, CO_2 emission intensity, economic growth, SDG 13, sustainable tourism, climate change*

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DİM 13 çərçivəsində turizmin CO_2 emissiya intensivliyi və iqtisadi artımın dinamik təsirləri

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Xülasə. *Turizm sektorunda karbon emissiyalarının intensivliyi ilə iqtisadi artım arasındakı əlaqə dayanıqlı inkişaf siyasətinin formalaşdırılması baxımından mühüm əhəmiyyət daşıyır. Bu tədqiqat BMT-nin 13-cü Dayanıqlı İnkişaf Məqsədi — "İqlim dəyişikliyinə qarşı mübarizə" çərçivəsində turizm sektorunda CO_2 emissiyalarının intensivliyinin iqtisadi artıma təsirini araşdırır.*

Turizmdə CO_2 emissiyalarının intensivliyi turizm fəaliyyətləri nəticəsində yaranan karbon emissiyalarının iqtisadi məhsulun həcminə nisbətini ifadə edir və sektorun ekoloji səmərəliliyinin əsas göstəricilərindən biri hesab olunur. Mövcud empirik və müqayisəli tədqiqatların sistemli təhlili göstərir ki, turizmin inkişafı iqtisadi artımı dəstəkləsə də, enerji istehlakının strukturu və ekoloji siyasətin səmərəliliyi emissiyaların intensivliyinə birbaşa təsir göstərir. Bərpa olunan enerjidən istifadə, yaşıl nəqliyyatın inkişafı, ekoloji innovasiyaların təşviqi və aşağı karbonlu turizm strategiyalarının tətbiqi emissiyaların azaldılmasına və uzunmüddətli iqtisadi dayanıqlılığın möhkəmləndirilməsinə töhfə verir. Tədqiqatda vurğulanır ki, iqlim siyasətinin, yaşıl investisiyaların və dayanıqlı turizm idarəçiliyinin inteqrasiyası 13-cü Dayanıqlı İnkişaf Məqsədinin hədəflərinə nail olmaq üçün zəruridir.

Açar sözlər: *turizm, CO_2 emissiyalarının intensivliyi, iqtisadi artım, DİM 13, dayanıqlı turizm, iqlim dəyişikliyi*

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1. Introduction

Tourism is a key driver of economic growth, employment, and regional development, yet it also contributes significantly to carbon emissions. This study examines the dynamic impact of CO_2 emission intensity in tourism on economic growth within the context of sustainable development. Emission intensity is assessed as a strategic indicator that determines the efficiency and competitiveness of the tourism sector. The study also analyzes the role of green energy, eco-innovation, and sustainable tourism management in achieving the goals of SDG 13.

2. Literature review

The relationship between the tourism sector's contribution to economic growth and the rise in carbon emissions is a significant topic of research within the context of sustainable development. Under SDG 13, the primary objective is to strike a balance between the economic benefits of tourism and the reduction of emissions. Existing studies indicate that tourism drives up CO_2 emissions through transportation, accommodation, energy consumption, and service infrastructure (Lee & Brahmasrene, 2013; Paramati et al., 2017). Khan et al. (2020), Nosheen et al. (2021), and Lenzen et al. (2018) have highlighted the importance of energy efficiency, renewable energy, and the carbon footprint of tourism. Recent research focuses on green energy, emission intensity, and carbon transfer. Nevertheless, studies examining the complex relationship between the CO_2 emission intensity of tourism, economic growth, and SDG 13 remain limited.

3. Data and Methodology

The methodological framework of the study is based on examining the relationship between CO_2 emission intensity in the tourism sector and economic growth within the context of SDG 13. An econometric analysis using panel data was conducted based on international statistical information. Tourism revenues, energy consumption, renewable energy usage, and economic openness were

considered as control variables. Fixed and random effects models, panel cointegration, and dynamic panel approaches were employed. Furthermore, international documents regarding climate policy, green tourism, and carbon emission reduction were evaluated through comparative and qualitative analysis. The use of country case studies and the comparison of various data sources enhanced the reliability of the findings.

4. Results and Discussion

Research shows that tourism development boosts GDP, employment, foreign currency earnings, and regional development; however, increased energy consumption in transport, accommodation, and infrastructure drives up CO_2 emissions. Renewable energy, energy-efficient buildings, smart systems, electric transport, and digital technologies can reduce both emissions and costs. Carbon taxes, green investments, and environmental standards promote low-carbon tourism, strengthening the sector's competitiveness by balancing economic growth with sustainability.

Table 1
Dynamic effects of tourism CO_2 emission intensity, economic growth, and SDG 13 indicators

Factor Group	Impact	Economy	Ecology	SDG 13
Revenue & Infrastructure	±	GDP / Growth ↑	Energy / Build ↑	Risk
CO_2 Intensity	-	Efficiency ↓	Carbon footprint ↑	Direct (-)
Green Transition (Energy, Investment, Transport)	+	Costs ↓ / Competitiveness ↑	Emissions ↓ / Eco-efficiency ↑	+++
Policy & Certification	- / +	Resource efficiency	Standards ↑ / Emissions ↓	+++
Sustainable Management	+	Stability	Eco-balance	Strategic

Source. Prepared by the author based on a summary of the literature (Conefrey & Hanrahan, 2025; Gazeloğlu & Erkılıç, 2025; Khan et al., 2020; Nosheen et al., 2021; Paramati et al., 2017; Shereni, 2024; Shi et al., 2024; Zhao et al., 2024; Lenzen et al., 2018 and other sources).

Tourism development boosts GDP, employment, and growth, but it can also increase energy consumption and carbon emissions. Green competitiveness supports sustainable development through renewable energy, efficiency, low-carbon transport, and innovation. Artificial intelligence enhances resource efficiency, reduces emissions, and strengthens climate adaptation.

In a simple way, we can express green competitiveness as follows:

$$G = k1\ P / (E + R + C)$$

Where k1 is a constant coefficient and indicates the overall efficiency of the system. This formula shows that as productivity increases and energy, resource, and carbon emissions decrease, green competitiveness increases.

To include the impact of AI, let us assume that AI application increases productivity and simultaneously reduces resource, energy, and emissions use. We can model this as follows:

$$P = P0\ (1 + a\ A)$$

$$E = E0\ (1 - b\ A)$$

$$R = R0\ (1 - c\ A)$$

$$C = C0\ (1 - d\ A)$$

Here P0, E0, R0, C0 are the initial levels, and a, b, c, d are positive coefficients indicating the effect of AI.

Substituting these expressions into the formula for G:

$$G = k1\ [P0\ (1 + aA)] / [E0(1 - bA) + R0(1 - cA) + C0(1 - dA)]$$

This model shows that as A increases (i.e., as AI is applied more), productivity increases, while the denominator decreases, and as a result, G increases.

We can write the sustainable development indicator in a broader form. Let D consist of environmental, economic, and social components:

$$D = k2\ (G + S + Q)$$

Where S is the social benefit (e.g., quality of jobs for local people) and Q is the quality of service. We can model the impact of AI on these indicators in the same way:

$$S = S0\ (1 + m\ A)$$

$$Q = Q0\ (1 + n\ A)\ \text{Thus:}$$

$$D = k2\ [G + S0(1 + mA) + Q0(1 + nA)]$$

The implication of this model is that AI increases the overall level of sustainable development by improving not only technical efficiency, but also social and qualitative aspects.

For a simpler interpretation, we can also write the total effect in a combined form:

$$D = k3\ (1 + t\ A)$$

Here, t represents the overall positive impact of artificial intelligence. When $t > 0$, the application of artificial intelligence enhances sustainable development. In tourism, AI boosts productivity, reduces resource and energy consumption, minimizes carbon emissions, and strengthens green competitiveness. The 3D model illustrates the relationship between green competitiveness and sustainable development as the intensity of AI application increases. In the model, the X-axis represents AI intensity, the Y-axis represents resource efficiency, and the Z-axis represents the overall sustainable development indicator.

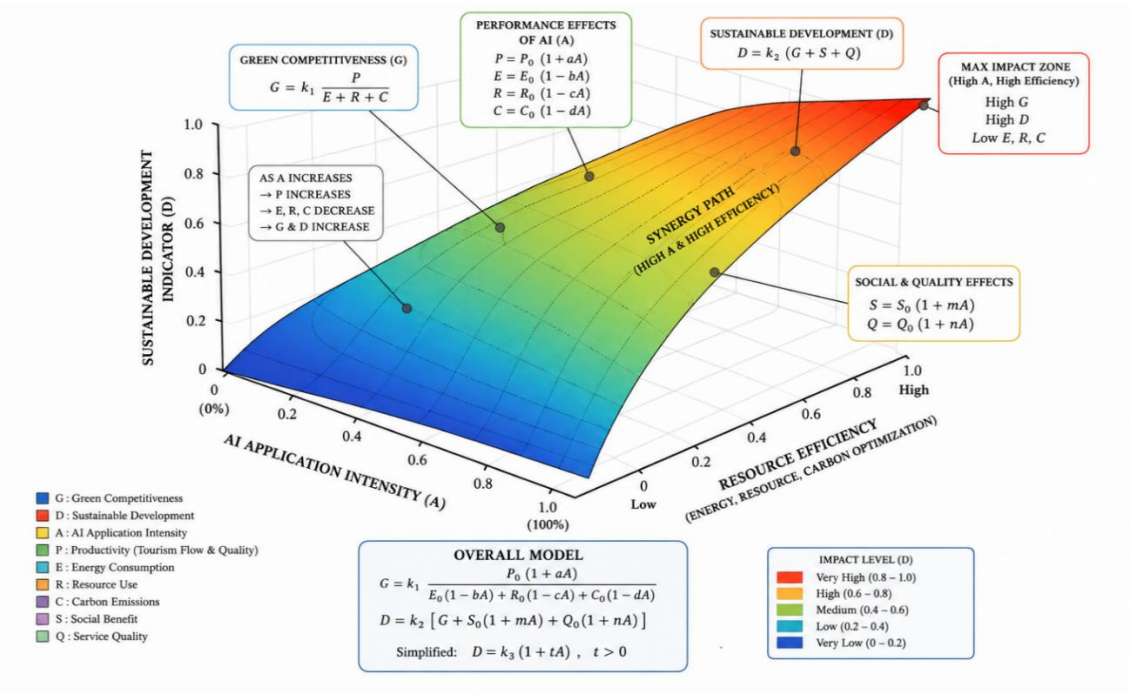


Chart 1

Three-dimensional conceptual model of the dynamic effects of AI-supported tourism mechanisms on green competitiveness and sustainable development

Source. Compiled by the author.

Chart 1 illustrates the impact of artificial intelligence on green competitiveness and sustainable development in the tourism sector. The X-axis represents the intensity of AI application; the Y-axis represents resource efficiency—encompassing energy use, resource utilization, and carbon emissions; and the Z-axis represents sustainable development. Increased AI adoption enhances efficiency, reduces emissions, and strengthens green competitiveness within the framework of SDG 13.

5. Conclusion

The relationship between CO_2 emission intensity in the tourism sector and economic growth highlights the importance of SDG 13. While tourism supports economic growth, it also drives up energy consumption and carbon emissions. Reducing carbon intensity can foster development through green energy, low-carbon transport, and eco-innovations. Artificial intelligence enhances resource efficiency, productivity, and emission reductions. A 3D model illustrates how AI balances economic efficiency with environmental responsibility. Green digitalization, financing, and carbon monitoring promote sustainable tourism.

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