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Harnessing Renewable Energy to Advance Sustainable Tourism and Green Growth: A G20 Countries' Perspective

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This study aims to investigate the mediating and moderating roles of renewable energy (RENEW) between tourism and green growth (GG) in G20 countries. The empirical investigation finds that tourism promotes GG through RENEW. Furthermore, RENEW positively moderates the tourism-GG nexus. Policy recommendations suggest directing revenue earned from tourism toward integrating renewable energy infrastructure within the tourism sector to achieve GG and Sustainable Development Goals.

I. Introduction

The tourism sector has become one of the most vital economic industries globally, impacting world GDP, employment, and international trade (Rasool et al., 2021; You et al., 2021). However, the rapid expansion of tourism activities has raised considerable concerns about environmental sustainability, resource depletion, and climate change impacts. This creates an urgent need to understand how tourism development can be aligned with green growth objectives. The concept of green growth (GG) emphasizes economic progress while reducing resource depletion and ensuring environmental sustainability (OECD, 2011). One way to align tourism with GG principles is by integrating renewable energy (RENEW) into tourism infrastructure, such as solar-powered hotels, electric transportation, and eco-friendly accommodations, which can significantly lower the industry's ecological footprint (Becken & Simmons, 2002; Gossling & Hall, 2006). Recent empirical studies have documented significant relationships between RENEW and tourism development, with evidence suggesting bidirectional causality in the long run (Guo & Chai, 2025; Jebli et al., 2019).

The economic activities related to the tourism sector require energy consumption, and the current demand for energy is largely met by burning fossil fuels, which leads to carbon emissions and other forms of environmental degradation (Lu et al., 2019). However, an alternative to fossil fuels is renewable energy, which is cleaner and greener. Sarpong et al. (2020) showed that there is a unidirectional relationship between tourist arrivals and renewable energy consumption. This can be explained by the fact that

tourists, who are knowledgeable about environmental conservation, are drawn to destinations that prioritize sustainable energy sources. Furthermore, the arrival of international tourists can result in a greater influx of foreign finances, which can be allocated toward investments in renewable energy initiatives (Jebli et al., 2019).

Despite growing research interest in the relationships among tourism, renewable energy, and sustainability, several critical gaps remain in the literature. While studies have examined direct relationships between tourism, RENEW, and sustainability indicators, few have systematically investigated the mediating role of RENEW in the tourism-GG nexus for G20 countries. Although some research has explored moderation effects in environmental contexts, the specific moderating influence of RENEW on tourism's contribution to GG remains underexplored. Moreover, no comprehensive study has simultaneously examined both the mediating and moderating roles of renewable energy in tourism-green growth relationships, which has motivated the present research.

The theoretical foundation of the current research is based on the Tourism-Led Growth Hypothesis (TLGH), which suggests that tourism development serves as a catalyst for driving GDP, enhancing foreign trade, and creating long-term socio-economic benefits. Integrating TLGH with the green growth paradigm emphasizes that allocating tourism-generated profits to renewable energy and sustainable infrastructure can turn tourism's economic engine into a catalyst for environmental sustainability (Roy & Medhekar, 2025).

Therefore, it is essential to understand the relationship between tourism, renewable energy, and economic growth

to attain sustainable tourism and meet the demand for GG. Thus, the current study aims to investigate the mechanism, channel, and degree by which tourism fosters GG in G20 countries by examining the mediating and moderating roles of RENEW. The significance of studying the G20 is that it accounts for 85% of the world's total GDP, 75% of total trade, two-thirds of the world's population, and 70% of tourism, but releases 75% of CO₂ into the atmosphere (The Hindu, 2023). The novelty and contribution of this research lie in explaining how RENEW functions as both a transmission mechanism (mediator) and an amplifying factor (moderator) in the tourism–GG relationship by advancing the TLGH in the context of GG in G20 countries. The study's findings show strong evidence that renewable energy mediates the TOUR–GG path and positively moderates the favorable impact of tourism on green growth.

II. Data and Methodology

The data sample consists of 19 G20 countries from 2000 to 2019. The period following COVID-19 is not considered because it has significantly affected the tourism industry. In this context, adjusted net savings (ANS), including particulate emissions damage (as a percentage of GNI), is the dependent variable representing green growth (GG). ANS accounts for investment in human capital, deducts natural resource depletion and environmental damages, and adjusts for capital depreciation. A positive ANS reflects sustainable growth, while a negative ANS signals resource overuse and environmental degradation (Hania et al., 2025). Inbound tourism expenditure (TOUR) is the core independent variable, and the share of renewable energy production (RENEW) is the mediating variable. Additionally, this study uses research and development (R&D), exports (EXP), foreign direct investment (FDI), and financial development (FD) as control variables. This study uses the number of inbound tourist arrivals as a proxy for a robustness check to support the TOUR–GG relationship. Regarding data sources, TOUR is sourced from the World Tourism Organization database; ANS, RENEW, R&D, FDI, and EXP are obtained from World Development Indicators; and FD is from the International Monetary Fund.

To test whether RENEW mediates and moderates the relationship between tourism and green growth, the following models are used:

$$GG_{it} = \beta_{10} + \beta_{11}TOUR_{it} + \beta_{1n} \sum_{n=2}^t Controls_{it} + \varepsilon_{it} \quad (1)$$

$$GG_{it} = \beta_{20} + \beta_{21}RENEW_{it} + \beta_{2n} \sum_{n=2}^t Controls_{it} + \varepsilon_{it} \quad (2)$$

$$GG_{it} = \beta_{30} + \beta_{31}TOUR_{it} + \beta_{32}RENEW_{it} + \beta_{3n} \sum_{n=3}^t Controls_{it} + \varepsilon_{it} \quad (3)$$

$$GG_{it} = \beta_{40} + \beta_{41}TOUR_{it} + \beta_{42}RENEW_{it} + \beta_{43}(TOUR \times RENEW)_{it} + \beta_{4n} \sum_{n=4}^t Controls_{it} + \varepsilon_{it} \quad (4)$$

III. Results

The empirical analysis begins with several panel diagnostic tests presented in Table 1. The VIF results indicate that the mean VIF is less than 10, demonstrating no significant multicollinearity. The Wooldridge serial correlation test statistics and groupwise heteroscedasticity are significant at the 1% level, indicating the presence of serial correlation and heteroscedasticity in the data. Additionally, the coefficients of Pesaran and Friedman's cross-sectional dependence (CSD) tests are statistically significant, revealing a CSD problem. The CIPS unit-root test findings show that all variables are stationary and integrated at the first difference. The Westerlund cointegration results suggest a long-run association among the target variables.

Given the substantial cross-country differences, the fixed effects model is appropriate for addressing unobserved heterogeneity by controlling for country-specific characteristics within the G20 countries. Recognizing the issues of heteroscedasticity, serial correlation, and CSD, this study presents the results of the estimated models using the feasible generalized least squares (FGLS) method with country and year fixed effects, as it provides accurate estimates in the presence of these problems.

Table 2 displays the FGLS regression results. Column 1 shows that tourism has a positive and significant impact on ANS (0.908). Column 2 indicates that RENEW positively promotes ANS, with a coefficient of 0.300. This means renewable energy production directly and significantly affects GG. Furthermore, in column 3, RENEW continues to positively influence ANS (0.029) after controlling for TOUR. Since both TOUR and RENEW are positive and statistically significant, and the magnitude of their impacts in column 3 is reduced compared to column 1 and column 2, it can be concluded that RENEW mediates the TOUR–GG relationship. Finally, in column 4, the interaction coefficient of TOUR and RENEW is positive and statistically significant. This means the impact of tourism on ANS is amplified by RENEW. In other words, RENEW moderates the TOUR–GG relationship, and countries with stronger renewable production gain greater sustainability benefits from tourism.

Table 3 compares developing and developed countries. In developing countries, only RENEW independently promotes GG. Furthermore, there is neither mediation nor a significant moderation effect, reflecting lower integration of sustainable practices in the tourism sector due to weak institutions, lack of advanced technologies, and insufficient renewable integration. In contrast, in developed countries, both TOUR and RENEW independently promote green growth, and these effects are stronger. Moreover, both mediation and moderation processes are present. Tourism expansion raises energy demand, and with stricter environmental standards, greater financial resources, technological infrastructure, and eco-conscious consumers in developed countries, much of this demand is increasingly met by renewable sources. Thus, RENEW mediates the TOUR–GG relationship. Additionally, higher adoption of renewables strengthens the positive impact of tourism on GG by reducing tourism's ecological footprint and trans-

Table 1. Diagnostic and cointegration test results

Particulars	Test Name	Test Statistics	
Multicollinearity	Mean VIF	1.80	
Serial Correlation	Wooldridge test	100.492***	
Heteroscedasticity	Groupwise Heteroscedasticity	1551.12***	
CSD	Pesaran	2.987***	
	Friedman	38.687***	
Stationarity	CIPS Test		
	Variables	I(0)	I(1)
	ANS	-1.944	-3.871***
	TOUR	-1.878	-3.615***
	RENEW	-1.948	-4.727***
	FDI	-3.601***	-5.315***
	EXP	-1.414	-3.368***
	RD	-1.496	-3.717***
	FD	-2.851***	-5.130***
Cointegration	Westerlund	All panels are cointegrated	Some panels are cointegrated
		1.4975*	2.7157***

Note: ANS denotes adjusted net savings, a proxy for GG, which accounts for investment in human capital, deducts natural resource depletion and environmental damages, and adjusts for capital depreciation. TOUR refers to international tourism expenditure by tourists in other countries. RENEW represents the share of renewable energy as a percentage of total energy production. FDI indicates net direct equity investment in a country as a percentage of GDP. EXP denotes the value of exports of goods and services by a resident to a non-resident, expressed as a percentage of GDP. RD represents research and development expenditure measured as a percentage of GDP. FD indicates the level of financial development, measured by how developed financial markets and financial institutions are in terms of depth, access, and efficiency. Symbols denote statistical significance: *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

Table 2. FGLS regression results

Variables	(1)	(2)	(3)	(4)
	ANS	ANS	ANS	ANS
TOUR	0.908*** (0.122)		0.878*** (0.121)	0.773*** (0.168)
RENEW		0.0300*** (0.0076)	0.029*** (0.0083)	-0.0859 (0.0602)
TOUR×RENEW				0.0116** (0.0057)
FDI	0.0056 (0.105)	0.0036 (0.0976)	0.0504 (0.103)	0.135 (0.0992)
EXP	4.001*** (0.249)	3.825*** (0.219)	3.853*** (0.247)	3.684*** (0.284)
RD	1.636*** (0.243)	1.566*** (0.221)	1.731*** (0.238)	1.879*** (0.239)
FD	-9.167*** (0.895)	-9.067*** (0.929)	-8.909*** (0.861)	-10.10*** (0.991)
CONSTANT	-8.870*** (1.801)	-2.363 (1.621)	-9.148*** (1.720)	-6.812*** (2.076)
N	380			
Fixed Effects	Yes			

Note: Standard errors are reported in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively. Variables are defined in [Table 1](#).

lating tourism-driven economic activity into sustainable green growth.

To verify the consistency of the main findings, this study conducts robustness checks by substituting the main variables with alternative proxies. Specifically, inbound

tourism expenditure is replaced with inbound tourist arrivals obtained from the WTO. The robustness check in [Table 4](#) confirms that the main findings are not sensitive to variable measurement. Tourism expenditure continues to enhance GG, and RENEW maintains its mediating and

Table 3. Developed vs. developing country comparison

Variables	Developing				Developed			
	ANS	ANS	ANS	ANS	ANS	ANS	ANS	ANS
TOUR	1.097 (0.732)		1.229* (0.710)	2.386** (1.079)	0.907*** (0.122)		0.878*** (0.120)	0.773*** (0.167)
RENEW		0.088** (0.042)	0.065 (0.043)	0.438** (0.172)		0.030*** (0.007)	0.029*** (0.008)	-0.085 (0.060)
TOUR×RENEW				-0.037** (0.018)				0.011** (0.005)
N		200				180		
CONSTANT				Yes				
Controls				Yes				
Fixed Effects				Yes				

Note: Standard errors are reported in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively. Variables are defined in [Table 1](#).

Table 4. Robustness check

Variables	(1)	(2)	(3)	(4)
	ANS	ANS	ANS	ANS
INTOUR	2.057*** (0.137)		2.158*** (0.139)	2.022*** (0.157)
RENEW		0.0300*** (0.0076)	0.0490*** (0.0057)	0.0128 (0.0199)
INTOUR×RENEW				0.0067* (0.0035)
FDI	-0.0088 (0.106)	0.0036 (0.0976)	0.211* (0.116)	0.217* (0.120)
EXP	3.356*** (0.175)	3.825*** (0.219)	3.098*** (0.189)	3.020*** (0.214)
RD	1.497*** (0.140)	1.566*** (0.221)	1.614*** (0.159)	1.595*** (0.178)
FD	-10.97*** (0.581)	-9.067*** (0.929)	-10.80*** (0.598)	-10.59*** (0.625)
CONSTANT	-9.154*** (1.155)	-2.363 (1.621)	-10.70*** (1.156)	-9.778*** (1.201)
N			380	
Fixed Effects			Yes	

Note: Note: Standard errors are reported in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively. Here, INTOUR denotes the log of the number of inbound international tourist arrivals. Other variables are defined in [Table 1](#).

moderating role in the TOUR-GG relationship, though with some variation in magnitude. This confirms the validity and robustness of the main findings.

IV. Conclusion

To explore the mediating and moderating functions of renewable energy in relation to TOUR and GG, this study utilizes panel data from G20 countries spanning 2000 to 2019. Drawing on the tourism-led growth hypothesis, the findings reveal that tourism promotes green growth through renewable energy. Renewable energy also has a positive impact on green growth and mediates the

tourism–green growth relationship. Additionally, renewable energy positively moderates the beneficial impact of tourism on green growth.

The findings suggest several important policy implications. First, governments should prioritize and direct tourism-generated revenues toward renewable energy investments within the tourism sector, such as clean transport, eco-friendly accommodations, and energy-efficient infrastructure. Second, in developing countries, policies should aim to enhance renewable infrastructure, improve technology transfer, and build institutional capacity so that tourism and renewables can serve as complementary dri-

vers of sustainable growth. Third, developed countries should consider expanding their renewable capacity to offset the environmental costs of tourism. These policy insights contribute to the global discourse on achieving the Sustainable Development Goals (SDGs), particularly SDG 7

(Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action).

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References

- Becken, S., & Simmons, D. G. (2002). Understanding energy consumption patterns of tourist attractions and activities in New Zealand. *Tourism Management*, 23(4), 343–354. [https://doi.org/10.1016/S0261-5177\(01\)00091-7](https://doi.org/10.1016/S0261-5177(01)00091-7)
- Gossling, S., & Hall, C. M. (2006). *Tourism and Global Environmental Change: Ecological, Social, Economic and Political Interrelationships*. Taylor & Francis, Routledge. <https://doi.org/10.4324/9780203011911>
- Guo, Y., & Chai, Y. (2025). Toward green tourism: the role of renewable energy for sustainable development in developing nations. *Frontiers in Sustainable Tourism*, 4. <https://doi.org/10.3389/frsut.2025.1512922>
- Hania, A., Lee, C., & Yahya, F. (2025). Climate anxiety, economic policy uncertainty, and green growth. *Economic Change and Restructuring*, 58(1). <https://doi.org/10.1007/s10644-025-09854-7>
- Jebli, B. M., Youssef, B. S., & Apergis, N. (2019). The dynamic linkage between renewable energy, tourism, CO2 emissions, economic growth, foreign direct investment, and trade. *Latin American Economic Review*, 28(1), 1–19.
- Lu, Z., Gozgor, G., Lau, C. K. M., & Paramati, S. R. (2019). The dynamic impacts of renewable energy and tourism investments on international tourism: Evidence from the G20 countries. *Journal of Business Economics and Management*, 20(6), 1102–1120. <https://doi.org/10.3846/jbem.2019.10181>
- OECD. (2011). *Towards Green Growth: Monitoring Progress*. Sixth Meeting of the UN Committee of Experts on Environmental-Economic Accounting, New York. <https://doi.org/10.1787/9789264111356-en>
- Rasool, H., Maqbool, S., & Tarique, Md. (2021). The relationship between tourism and economic growth among BRICS countries: a panel cointegration analysis. *Future Business Journal* 2020, 7(1), 1–11. <https://doi.org/10.1186/s43093-020-00048-3>
- Roy, M., & Medhekar, A. (2025). Tourism-Led growth hypothesis: a global perspective bibliographic analysis. *Asia Pacific Journal of Tourism Research*, 1–32.
- Sarpong, S. Y., Bein, M. A., Gyamfi, B. A., & Sarkodie, S. A. (2020). The impact of tourism arrivals, tourism receipts and renewable energy consumption on quality of life: A panel study of Southern African region. *Heliyon*, 6(11). <https://doi.org/10.1016/j.heliyon.2020.e05351>
- The Hindu. (2023). *G-20: What are the emissions-related commitments of the countries? | Explained - The Hindu*. <https://www.thehindu.com/sci-tech/energy-and-environment/g-20-what-are-the-emissions-related-commitments-of-the-countries-explained/article67288727.ece>
- You, W., Zhang, Y., & Lee, C.-C. (2021). Climate Risk, Economic Stability, and Tourism: A Cross-Sectionally Dependent Heterogeneous Panel Causality Analysis. *Energy Research Letters*, 2(2). <https://doi.org/10.46557/001c.25723>