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# Tourism green growth through technological innovation

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**ABSTRACT**

The work seeks to assess the effect of technological innovation on the green growth of tourism across five continental regions using the STochastic estimation of Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model. Employing panel Granger causality tests, panel vector autoregression, impulse response functions, and forecast error variance decomposition, the research reveals the bidirectional causal relationship between green growth and technological innovation, emphasizing the importance of technological innovation for tourism. The study utilizes panel data from 126 countries spanning from 2010 to 2021 and employs a range of econometric techniques. These methods allow for a thorough examination of the causal relationships, short and long term impacts, and the relative importance of different variables on tourism related green growth. The findings further highlight the contribution of green growth to developing a sustainable economy and emphasize the significance of sustainable tourism as a significant factor in green growth policies. The study expands the application of STIRPAT to the green growth and tourism relationship and provides practical implications for stakeholders.

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## Introduction

Tourism is one of the world's largest economic sectors, exerting a substantial influence on the environment, society, and culture (United Nations World Tourism Organization [UNWTO], 2024). Tourist receipts reached USD 1.4 trillion, generating 27 million jobs in 2023. The global economic contribution of tourism is USD 3.3 trillion (3% of global GDP) and it is significant for economic development in many countries and the regions (World Travel & Tourism Council, 2024). However, it is also recognized that tourism can harm long-term economic growth due to its greenhouse gas (GHG) emissions and the loss of natural capital (Hall, 2015; Razzaq et al., 2023a). Moreover, the tourism industry accounts for roughly 8–10% of global GHG emissions, substantially

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contributing to climate change and its devastating consequences (Tourism Panel on Climate Change, 2023).

In response to these challenges, green growth has arisen as a viable approach to advancing sustainable tourism development while mitigating environmental impacts and reducing energy and carbon emissions (Pan et al., 2018). It is a strategy to achieve sustainability that emphasizes the importance of protecting the environment and producing greater efficiency in using natural resources through technological innovation while simultaneously achieving sustainable economic development (Fabozzi et al., 2022). Although there is criticism that the concept does not adequately address increased consumption and the rebound effects of efficiency improvements (Hall, 2015, 2022), green growth is supported by various international organizations that have identified the approach as a viable pathway to achieve sustainable development through inclusive growth driven by innovation and efficiency (DeLacey et al., 2014; Hickel & Kallis, 2020; Reddy & Wilkes, 2015; World Bank, 2012).

The application of the green growth approach to the tourism industry aims to minimize environmental impact and reduce energy and carbon emissions through ecological-human-cultural integration (Pan et al., 2018). More sustainable forms of tourism, including eco-tourism, rural tourism, agrotourism, and cultural tourism, have been identified as key contributors to green tourism growth (Reddy & Wilkes, 2015; Pan et al., 2018; Panzer-Krause, 2019; Wartini et al., 2022). Furthermore, sustainable tourism is essential in advancing environmentally sympathetic regional economic and community development (Reddy & Wilkes, 2015).

Efficient technological and socio-economic innovation is regarded as essential for green growth (Hall, 2022; Pan et al., 2018; Panzer-Krause, 2019). Studies have examined tourism related green growth using green growth indices or comprehensive green growth indices encompassing factors of both green and economic growth (Shang et al., 2023; Zhang et al., 2022; Zhao et al., 2021). Yet, a substantial deficiency in research exists of research examining the role and relationship of innovative technologies (e.g. intelligent automation, robots, artificial intelligence (AI)) as a factor in tourism green growth, and research that examines tourism related green growth on a regional basis, using frameworks like UNWTO's continental regions, remains limited. Overall, studies analyzing the association between green growth and tourism demand in the short and long-term are scarce (Reddy & Wilkes, 2015).

To fill this research gap, this study examines how technology affects tourism green growth over the short and long-term across five continental regions, focusing on applying innovative technologies such as intelligent automation, robotics, and AI (Majid et al., 2023; Pan et al., 2018; Panzer-Krause, 2019). To achieve this objective, this work utilizes the STochastic estimation of Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model, which examines the causal association between the green growth index, population, economy, technology, and tourism through the lens of green growth theory. Therefore, directly addressing the shortage of studies investigating the association between technologies and green tourism growth across different regions and time horizons (Reddy & Wilkes, 2015).

The study expands the application of the STIRPAT model to tourism and provides insights into the complex interactions between technology, economy, tourism, as well as green growth. The research also offers practical implications for stakeholders, including governments, businesses, and communities, by highlighting the crucial role of innovative technologies and tourism practices in achieving green growth.

## Literature review

### *Green growth*

The notion of green growth is an explicit response to the longstanding problem of there being biophysical, societal, and consumptive limits to economic growth (Ehrlich & Holdren, 1971; Hall, 2011, 2015; Meadows et al., 1972). The term "green growth" was first used by a Yale University research team when they published the Emerging Market Indicator in *The Economist* in January, 2000 (Lee, 2011). It became central to the landmark 2012 Rio + 20 UN Conference on Sustainable Development and has subsequently significantly influenced thinking on sustainability (Hickel & Kallis, 2020; Reddy & Wilkes, 2015). The UN Economic and Social Commission for Asia and the Pacific (UNESCAP, 2006) defined green growth as promoting economic development aimed at alleviating poverty without exacerbating environmental resource constraints and the climate crisis. The Organization for Economic Co-operation and Development (OECD) (2009) explained green growth as a process that fosters investment and innovation to support sustained growth while creating new economic opportunities. The World Bank (2012) suggested that green growth is inclusive, with it being regarded by them as the only clear pathway to sustainable development. The United Nations Environment Program (2013) regarded green growth as central to the idea of a green economy (Allan & Meckling, 2023), which is defined as an economy that significantly alleviates environmental risks and ecological scarcity while enhancing human well-being and social and economic equity.

Green growth seeks to convert resource constraints and the climate crisis into opportunities for economic development by reducing resource consumption and GHG in various industries and enhancing economic growth and welfare, e.g. by pursuing carbon efficient opportunities such as circular economic practices (Barua, 2022). Innovative technologies become central to green growth by providing increased efficiency in the use of resources and a reduction in throughputs, thereby promoting economic development without further damaging the environment (Fabozzi et al., 2022; Kuo et al., 2022; Nosheen et al., 2021).

Theories of green growth are grounded in several fields including complexity theory (Fabozzi et al., 2022), economics (Fernandes et al., 2021; Smulders et al., 2014), applied philosophy and critical social theory (Sandberg et al., 2019), and ecological modernization (Guo et al., 2017). In these approaches, the environment plays a fundamental natural capital and services role, which is closely related to traditional elements (labor, material capital, technology, human capital) of economic growth (Jacobs, 2012).

Huang and Zhao (2022) and Xu (2022) analyzed the complex interactions among natural resource consumption, green trade, and green growth and how sustainable use of natural resources and environmental protection can facilitate economic growth. In an approach that reflects "balanced" approaches to sustainability, Sun et al. (2020) argued that inclusive green growth harmonizes the three systems of economy, environment, and society. They highlighted that aligning resources with socio-economic development goals is a crucial challenge for inclusive green growth and emphasized the importance of innovative technologies among them. Similarly, Hickel and Kallis (2020) proposed that since countries cannot separate economic development from natural resource use, continuous economic expansion should be achieved through technological innovation that does not further run down natural capital.

### *Green growth and technological innovation*

Technological innovation presents opportunities in addressing pollution and improving environmental quality while mitigating economic risks (Cao et al., 2021). Several studies argue that technological innovation can maximize resource efficiency and environmental impact while achieving sustainable economic growth (Fabozzi et al., 2022; Hickel & Kallis, 2020; Nosheen et al., 2021; Sun et al., 2020), with green technology related to energy conservation, pollution prevention, waste recycling, green product design, and environmental management being a fundamental to achieve green growth (Capasso et al., 2019; Herman, 2023).

Innovative technologies are being applied in tourism in response to some of the problems it contributes to Majid et al. (2023). Tourism accounts for 8–10% of carbon emissions, tourism development has led to water shortages, waste pollution, and loss of biodiversity and habitat (Law et al., 2017). The World Health Organization (2023) estimates that climate change could lead to 250,000 deaths annually between 2030 and 2050, with health damage costs estimated at USD 2–4 billion per year; this means that in proportional terms (Hall, 2010), the emissions of the tourism industry are therefore potentially being responsible for 20,000 deaths per year (8% of GHG emissions), and extra health costs of USD 1.6–3.2 billion. Economic contributions that are not usually considered in tourism (Hall, 2008, 2010; Tourism Panel on Climate Change, 2023). Therefore, green growth may provide a valuable perspective on how technological innovation can help balance the preservation of natural capital with economic development.

### *Green growth and tourism*

To enable tourism to contribute to green growth, establishing networks between government and tourism enterprises and actively invest in innovative technologies such as renewable energy, green transportation, green architecture, green infrastructure, green agriculture, and intelligent technology is regarded as critical (Marsiglio, 2015; Pan et al., 2018; Panzer-Krause, 2019), while still providing for increases in tourist arrivals and receipts (Razzaq et al., 2023b; Shang et al., 2023; Zhang et al., 2022). For example, Gunduz Songur et al. (2023) argued that the hotel industry needs to reduce its carbon footprint by adopting green technologies and promoting technological innovation. However, analysis is required to better understand if green growth strategies through innovative technologies are possible in tourism (Panzer-Krause, 2019).

The STIRPAT model, which considers technological innovation, including green products, research and development expenditures, environmentally related patents, innovative technological infrastructure, green trade, and technological innovation index, which includes industry indicators, is a key tool for understanding tourism industry related economic and environmental linkages (Ahmad & Jabeen, 2023; Algieri et al., 2022). Razzaq et al. (2023b) reported that based on the STIRPAT model, environmental patented technologies stimulate economic growth as well as $CO_2$ mitigation in tourism development and argued that research on the tourism industry through an expanded STIRPAT model be continued.

The green growth index considers enhancing natural capital, sustainable economic growth, social development, poverty eradication, resource efficiency, and climate change adaptation as part of its metrics (GGGI, 2020). Several studies have examined tourism's green growth using the index and the goals that green growth should aim for (Shang et al., 2023; Zhang et al., 2022; Zhao et al., 2021). Shang et al. (2023) explored how tourism and energy resources influence green growth across income levels using panel data. Zhao et al. (2021) measured spatiotemporal patterns and spillover effects and suggested solutions to further develop the tourism industry on a regional basis, accounting for the specific characteristics of each region. Zhang et al. (2022) identified a framework for inclusive green growth in tourism, drawing on theories of spatial production and quality improvement. However, although their importance is recognized, there is a considerable gap in research examining the role and interconnections of innovative technologies as a driver of green growth in tourism (Reddy & Wilkes, 2015). Figure 1 indicates the concept of green growth in tourism.

Studies have been conducted at the national income level (Shang et al., 2023) and for specific countries (Zhang et al., 2022), but not at an aggregate region level, such as those used for UNWTO statistics, while studies analyzing the relationship between green growth and tourism over both the short and long-term are also limited. This study aims to analyze tourism's green growth by subdividing countries according to the five continental regions defined by the UNWTO, using the Global Innovation Index to confirm the degree of innovation in each country and region, and examining all patents, including green technologies. Such an approach provides a basis of comparison between the results of green growth analysis and UNWTO statistical and policy reporting.


**Figure 1.** Concept of green growth in tourism.

### *Stochastic estimation of impacts by regression on population, affluence, and technology*

The STIRPAT model is a widely used framework for analysing major factors affecting the environment, and can quantitatively assess the interactions between the key factors of population, affluence and technology. The framework of the STIRPAT model has the flexibility and scalability to examine environmental quality through a range of variables including technological innovation, green growth, R&D, patents, green trade, and tourism (Chekouri et al., 2020). These features have made it an important tool for understanding the interactions between the environment and various industries, including tourism (Ahmad & Jabeen, 2023; Algieri et al., 2022; Razzaq et al., 2023b).

Several studies of tourism have used the STIRPAT model. Solarin et al. (2024) examined the impact of population, GDP, and tourism market diversification index on ecological footprint and suggest that tourism market diversification promotes destination competitiveness and sustainability but increases pollution. However, they argued that the use of technology in tourism enables eco-friendly tourism products to reduce pollution. Arbulu et al. (2017) examined the impact of tourist arrivals in Mallorca, and reported that tourism directly affected environmental pollution. Arbulu et al. (2024) also used the STIRPAT model to attempt to understand the complex relationship between tourism development and environmental quality and found that tourism development has a direct impact on waste generation but that technology reduces waste over time. Therefore, based on previous research, this study will use the STIRPAT model to examine the relationship between population, affluence, technology, tourism, and the environment.

## Method

### *Theoretical formwork*

The STIRPAT model assesses the influence of population, economic activity, and technological factors on the environment. It develops the IPAT equation by Ehrlich and Holdren (1971) which emphasized that population affects the environment and presented the equation $I = P \times F$.

They then proposed the IPAT model. Equation (1), as an extended model that includes affluence and technology that can affect consumption and the environment.

$$\mathrm{I{=}P \times A \times T} \tag{1}$$

However, the IPAT model is constrained in its explanation of the relationship between environmental impacts (I), population (P), affluence (A), and technology (T) because it assumes that the remaining variables are fixed (Hall, 2010). Dietz and Rosa (1994) included a stochastic element by adding an error term to solve this limitation. The STIRPAT model is shown in Equation (2). Using natural logarithms on both sides of Equation (2) has the advantage of being able to offer ease of analysis due to its linear form and the concentration of each element affecting the environment (Koçak & Ulucak, 2019). Therefore, the study expands the STIRPAT model by inputting various variables that can affect the environment based on Equation (2).

$$I_i = a \times P_i^b \times A_i^c \times T_i^d \times e_i \tag{2}$$

Applying the logarithm to both sides of Equation (2) provides a linear form that is easy to analyze (York et al., 2003). This is useful for interpreting non-linear relationships between variables, manifested as an elasticity coefficient, which clearly shows the impact of a change in the independent variable on the dependent variable (Koçak & Ulucak, 2019). In addition, log transformation can contribute to stabilizing the distribution of data and reducing the impact of outliers. This is expressed in Equation (3).

$$\mathrm{lnI}_{it} = \mathrm{ln}\alpha_i + \beta\mathrm{lnP}_{it} + \gamma\mathrm{lnA}_{it} + \delta\mathrm{lnT}_{it} + \mathrm{e}_{it} \tag{3}$$

In this study, I includes green growth index, P includes population, A includes GDP per capita, T includes patent applications and global innovation index, and TO includes tourism receipts, tourist arrivals, and tourism expenditures. This study examines the effect of four potential factors that can affect impact through Equation (4) based on Ahmad and Jabeen (2023).

$$\mathrm{lnI}_{it} = \alpha_i + \dagger\mathrm{lnP}_{it} + \sum_{j=1}^{2}\gamma_j lnA_{j,it} + \sum_{k=1}^{3}\delta_k lnT_{k,it} + \sum_{z=1}^{3}\mu_z lnTO_{z,it} + \mathrm{e}_{it} \tag{4}$$

I, P, A, T, and TO are standardized vectors as follows:

$$I_{it} = (\text{Green Growth Index}_{it})$$

$$P_{it} = (Population_{it})$$

$$A_{it} = (GDP_{it})$$

$$T_{it} = (patent_{it}, GII_{it})$$

$$TO_{it} = (TR_{it}, TA_{it}, TE_{it})$$

Previous studies mainly either use only a single indicator, such as total emissions or waste, as the main indicator of green growth (Arbulu et al, 2024; Xu & Reed, 2019), or by controlling for production-based $CO_2$, demand-based $CO_2$, non-energy material productivity, environmental adjusted multifactor productivity growth, and mean population exposure to PM2.5 (Trinh et al., 2023). However, this study uses a green growth index that encompasses environmental, economic, and social factors to mitigate the bias that may arise from relying on a single green growth indicator and to provide a more multifaceted measure of green growth (De Pascale & Romagno, 2024).

Population and GDP per capita are used as variables for population (P) and affluence (A) based on previous studies (Shahbaz et al., 2016; Wang & Taghvaee, 2023; Xing et al., 2023). Patent application, used as a measurement variable for technology (T), is a proxy for innovative technology and an output of R&D, which can improve energy consumption efficiency (Huang et al., 2021; Xing et al., 2023). This study uses patent application as a measure of innovation in promoting green growth.

Typically, the STIRPAT model has analysed the impact of technology using variables such as green products, R&D expenditure, patents, and innovative technologies (Ahmad & Jabeen, 2023; Algieri et al., 2022; Razzaq et al., 2023b). However, we use the Global Innovation Index because technology does not exist merely in the form of a specific product but is the result of complex support and cooperation, e.g. intellectual property rights and intangible assets (Nasir & Zhang, 2024). Therefore, this study uses the Global Innovation Index as a technical variable.

TO is tourism, an important factor directly impacting the environment (Ahmad & Ma, 2022; Solarin et al., 2024). In previous literature, three main indicators have generally been used to analyse the environmental impact of the tourism sector: Tourist arrivals (Ahmad & Ma, 2022; Arbulu et al., 2024), tourism receipts (Ahmad & Ma, 2022; Katircioglu, 2014), and tourism expenditures (Arbulu et al., 2017; Arbulu et al., 2024), which the UNWTO emphasises should all be considered for a comprehensive understanding of tourism (Solarin et al., 2024). Therefore, this study will use tourist arrivals, tourism receipts, and tourism expenditures as the main analytical variables to explore the impact of tourism on green growth.

This study uses 126 countries that are part of the Green Growth Index and are categorized by UNWTO and the International Organization for Standardization into five continental regions (Africa, Americas, East/South Asia-Pacific, Europe, and Middle East) (Supplementary 1). The availability of Green Growth Index data from 2010 provides the start of the study period and key variables, including tourism receipts, number of arrivals tourists, and tourism expenditures, provide data up to 2021 (Supplementary 2). The population, GDP per capita, tourism receipts, tourism arrivals, tourism expenditures, and patent applications were sourced from the World Bank. The World Intellectual Property Organization provide the global innovation index.

### *Empirical methodology*

This study uses four econometric models as panel Granger causality test, panel vector autoregression (PVAR) model, impulse response function (IRF), and foresting error variance decomposition (FEVD). The STIRPAT model analyzes the effects of population, economic activity, and technology on the environment and economy. However, it is limited in that it cannot fully explain the complex interactions between variables. Therefore, the panel Granger causality test confirms the causal relationship between the two variables and examines the complex interrelationships of variables through the PVAR model (Aslan et al., 2022; Xu & Reed, 2019). Additionally, the IRF visually illustrates how changes in one variable affect other variables, while FEVD evaluates the extent to which the variability of each variable is explained by other variables (Xu & Reed, 2019).

These econometric techniques go beyond simple correlation analysis and delve deeper into variables' dynamic relationships and temporal characteristics. While ordinary least squares are generally effective at estimating linear relationships between variables, they have limitations in accounting for the dynamic characteristics and temporal causality of time series data. Ordinary least squares can only evaluate the correlation between two variables, but it is not suitable to account for causal relationships or complex interactions. Therefore, this study adopts time series-oriented methodologies, such as the Granger causality test and PVAR model, to identify the critical variables and determinants of green growth in tourism.

*Granger causality test* The Granger causality test is a method proposed by Granger (1969) to analyze the causal relationship between two variables using an F-test based on time series data. The panel Granger causality test uses the Wald test if the panel data has the stationarity of the time series. The basic formula of the panel Granger causality test is:

$$y_{i,t} = c_i + \sum_{j=1}^{p} \alpha_{i,j} y_{i,t-j} + \sum_{j}^{p} \beta_{i,t-j} x_{i,t-j} + \epsilon_{i,t} \tag{5}$$

$$x_{i,t} = c_{2i} + \sum_{j=1}^{p} \gamma_{i,j} y_{i,t-j} + \sum_{j}^{p} \delta_{i,t-j} x_{i,t-j} + \epsilon_{2i,2t} \tag{6}$$

$x_{i,t}$ and $y_{i,t}$ represent the observations of two stable variables for the i unit at the time t. It is assumed that the panel data set allows for heterogeneity in the individual cross-sectional units, that the constant terms have different values across cross-sections, and that the coefficient for individual autoregressive can have different values across cross-sections and time series units. The Granger causality test estimates the effect of the past observations of the x variable on the current observations of y to determine whether a causal relationship exists in the direction of x to y. In order to interpret the results obtained, the null hypothesis ($H_0$) is called $\alpha_{i,J} = 0$ or $\delta_{i,J} = 0$.

$H_0 : \alpha_{i,J} = 0$ is rejected, $H_0 : \delta_{i,J} = 0$ is adopted, x Granger causality in y
$H_0 : \alpha_{i,J} = 0$ is adopted, $H_0 : \delta_{i,J} = 0$ is rejected, y Granger causality in x
All $H_0$ are rejected, x and y Granger causality each other
All $H_0$ is adopted, x and y are mutually independent

*Panel vector autoregression* The Granger causality test based on PVAR sets all coefficients of the regression equation to zero and performs the Wald test (Aslan et al., 2022). The PVAR model is relatively simple, as shown in Equation (7). However, it has the advantage of being more flexible than the univariate model in modeling the interdependent and autocorrelation among variables, including individual group heterogeneity.

$$Y_{i,t} = A_1 Y_{i,t-1} + A_2 Y_{i,t-2} + \ldots + A_p Y_{i,t-p} + u_i + \epsilon_{i,t} \tag{7}$$

$Y_{i,t}$ is the dependent variable, and $Y_{i,t-1}, Y_{i,t-2} \cdots Y_{i,t-p}$ are the lagged values of the dependent variable. $A_1, A_2, \ldots, A_{p-1}, A_p$ are the parameters for each lagged value, $u_i$ is the characteristics of panel entitles, and $\epsilon_{i,t}$ is the error-term. PVAR is a model that uses the lagged values of the dependent variable as independent variables, and there is a problem of endogeneity due to the correlation between the error term and the independent variable. To solve the problem of endogeneity between the dependent and independent variables, this study aims to conduct a panel Granger test based on the temporal precedence of causation through the PVAR model estimated by the generalized method of moments method.

*Impulse response function* The PVAR can analyze the effect of the simultaneous external shock of all variables on each variable (Abrigo & Love, 2016). IRF is a method of analyzing the response of a variable to a time-varying shock of another variable, and IRF is defined as a moving average function, as shown in Equation (8).

$$Y_t = \alpha + \beta_t + \delta_1\beta_{t-1} + \delta_2\beta_{t-2} + \ldots + \delta_n\beta_{t-n} \quad (8)$$

$Y_t$ is the dependent variable at time t, – is the constant term, and $\beta_t$ is the structural shock at time t. $\delta_1, \delta_2 \ldots \delta_n$ can be expressed as $\cdot_n = \frac{\partial y_{t+n}}{\partial t'_t}$, and $\beta_t$ which means structural shock, means the effect on the endogenous variable $Y_t$. In this way, IRF can examine the response of endogenous variables to structural shocks, and the extent to which this impact is over time.

*Foresting error variance decomposition* FEVD is an analysis used to examine how much structural shock affects endogenous variables and estimates the variance of forecast errors of the endogenous variable $Y_t$ for each forecast period, and evaluating the relative contribution by expressing the proportion of each structural shock in this variance as a percentage (Abrigo & Love, 2016). The contribution of the j-th structural shock to the forecast error variance at time n can be shown in Equation (9). $\omega_j$ refers to the vector in the j-th column of $\omega$.

$$\mathrm{Var}\left(\beta_{ij}\right) = \left(\sum_{i=1}^{n} \delta_{i-1}\omega_j\omega_j{}'\delta_{i-1}{}'\right) \quad (9)$$

## Results

### *Descriptive statistics and model fit*

Supplementary 3 provides descriptive statistics for variables selected from 2010–2021. This study required that all variables should be converted to logarithmic data based on the STIRPAT. Therefore, every variable was added one for equalization of the variance of variables and data stability. It shows wide variations among the variables. The mean green growth index, population, GDP per capita, patent applications, global innovation index, tourism receipts, tourist arrivals, and tourism expenditures are 56.22, 54.7 million persons, USD 17,152, 14,707, 32.06, USD 6.96 billion, 11.9 million persons, and USD 6.26 billion, respectively. The correlation coefficient between TR and TE is 0.917, suggesting the possibility of multicollinearity. In checking for multicollinearity: TR and TE were in the range of 6, patent, GDP, and pop were in the range of 2, TA and GII were in the range of 1, and the mean variance inflation factor value was 3.27. Therefore, it is not multicollinear.

Before analysing the data, a hierarchical regression of Model 1 (Equation (1)), Model 2 (Equation (3)), and Model 3 (Equation (4)) was undertaken to check the fit of the STIRAPT model (Supplementary 4). The R-squared shows a stepwise increase in explanatory power with 26.21% for Model 1, 28.38% for Model 2, and 29.79% for Model 3. In addition, the Akaike Information Criterion and Bayesian Information Criterion confirm that Model 3 has the best fit with the lowest values of −1144.5973 and −1102.0273, respectively. Overall, model 3 has the highest explanatory power and the lowest Akaike Information Criterion and Bayesian Information Criterion values, making it the most suitable model.

### *Panel unit toot and cointegration tests*

Supplementary 5 is the result of panel unit root test. When the results of the Augmented Dickey-Fuller analysis were not differentiated, tourism receipts, tourist arrivals, and tourism expenditures were found to have an unstable time series. At the time of the first difference, four variables were found to have a stable time series. The Phillips-Perron analysis showed that two variables, tourism receipts and tourist arrivals, had unstable time series when not differenced. However, all variables were found to have stable time series when retested by the first difference. Even when using differenced variables in panel data, cointegration exists if a long-term equilibrium relationship exists (Seghir et al., 2015). Therefore, it is necessary to verify the existence of a cointegration (long term co-movement) before estimating the coefficients, particularly when the panel data exhibits a unit root (Koçak et al., 2020).

Supplementary 6 is the panel cointegration test result. Modified Dickey-Fuller and Augmented Dickey-Fuller show that the model does not have a long term equilibrium relationship, while Dickey-Fuller indicates the existence of a long term equilibrium relationship. Therefore, this study will analyze tourism receipts and tourist arrivals using differential variables based on Phillips-Perron's unit root test.

## *Changes in the green growth index by continent*

Figure 2 presents the change in the Green Growth Index by continent from 2010 to 2021 before proceeding to the panel Granger causality test, PVAR model, IRF analysis, and FEVD. The analysis shows an overall upward trend in the Green Growth Index across all continents. However, there are still significant differences between continents, indicating differences in regional levels of tourism development and attention to green growth factors. Causality is explored further below.

## *Granger causality test*

Granger causality tests were analyzed based on PVAR and applied to the five continental regions. The results of the Granger causality test are shown in Table 1. This study reports the direction of Granger causality from independent variables to the green growth index and the direction from the green growth index. In the case of All, all independent variables show the direction for Granger causality with the green growth index. This index demonstrates Granger causality only with GDP per capita and the global innovation index. The independent variables and the green growth index have either bidirectional or unidirectional Granger causality. For Africa, all independent variables display Granger causality with the green growth index. In other words, this index was found to have Granger causality with all other variables except tourism expenditures. Excluding tourism expenditures, there is a bidirectional Granger causality. In the case

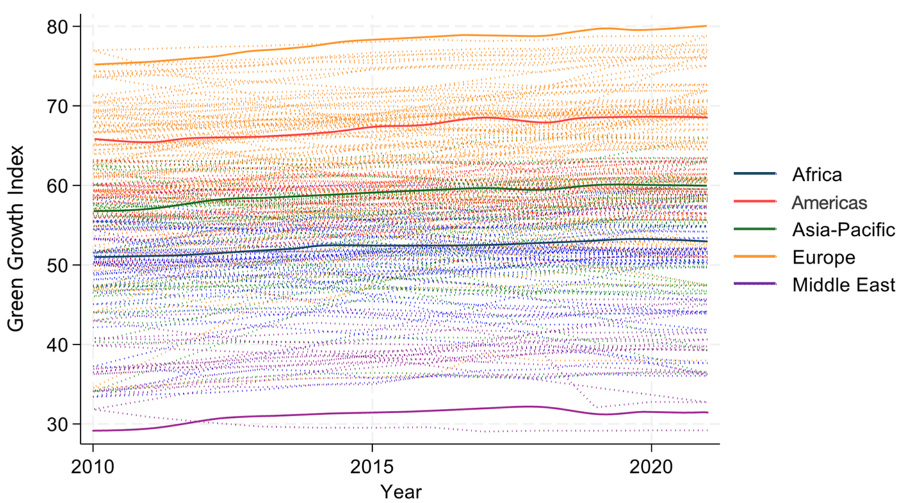


**Figure 2.** Changes in the Green Growth Index by Continent (2010–2021).

Table 1. Results of Granger causality test.

| Direction of Granger causality | | | All | Africa | Americas | East/South Asia and the Pacific | Europe | Middle East |
|---|---|---|---|---|---|---|---|---|
| POP | → | GGI | 35.202*** | 22.088*** | 2.769* | 47.431*** | 22.321*** | 0.042 |
| GDP | → | | 44.927*** | 3.424* | 16.826*** | 36.582*** | 25.279*** | 0.015 |
| Patent | → | | 49.939*** | 15.922*** | 1.154 | 0.293 | 17.953*** | 11.342*** |
| GII | → | | 18.359*** | 10.492*** | 28.997*** | 9.268*** | 4.471** | 2.091 |
| TA | → | | 67.667*** | 13.804*** | 3.243* | 45.305*** | 66.478*** | 8.736*** |
| TR | → | | 57.315*** | 15.151*** | 38.878*** | 11.895*** | 42.36*** | 2.835* |
| TE | → | | 55.629*** | 17.096*** | 39.761*** | 35.562*** | 40.503*** | 0.009 |
| GGI | → | POP | 0.015 | 8.243*** | 1.71 | 0.676 | 5.209** | 0.475 |
| | → | GDP | 13.721*** | 9.352*** | 1.738 | 4.561** | 1.205 | 0.166 |
| | → | Patent | 0.69 | 6.135** | 0.019 | 5.255** | 0.581 | 0.396 |
| | → | GII | 6.313** | 2.794* | 0.009 | 21.82*** | 0.313 | 0.298 |
| | → | TA | 0.676 | 4.245** | 0.024 | 6.895*** | 0.03 | 0.502 |
| | → | TR | 0.223 | 3.203* | 2.786* | 12.845*** | 0.117 | 0.239 |
| | → | TE | 0.29 | 0.752 | 0.533 | 2.92* | 0.177 | 0.185 |

*Note*: (1) All variables use log-term. (2) GGI: Green growth index, pop: Population, GDP: GDP per capita, Patent: patent application GII: Global Innovation Index, TR: tourism receipts, TA: Number of tourist arrivals, TE: Tourism expenditures, (3) Instruments: l(1/4). Robust standard errors, Z statistics in parentheses. The PVAR model estimated 2 lags according to the modified Bayesian information criterion (mBIC), (3) ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

of the Americas, all other variables, excluding patent applications, demonstrate Granger causality with the green growth index. The index itself shows Granger causality with tourism receipts. Except for tourism receipts, the other variables show a unidirectional causality. For East/South Asia-Pacific, all independent variables, except for patent applications, demonstrate Granger causality with the green growth index. This index displays Granger causality with all other independent variables excluding population. There is either unidirectional or bidirectional Granger causality between the green growth index and independent variables. In Europe, all independents demonstrate Granger causality with the green growth index. This index only demonstrates Granger's causality with population. There is a unidirectional Granger causality between the green growth index and independent variables except for population. The Middle East has the most limited set of relationships. Only three variables—patent applications, tourism arrivals, and tourism receipts—show Granger causality with the green growth index, which does not demonstrate Granger causality with any independent variables.

### *Impulse response function*

Figure 3 shows the results of the analysis of IRF. In all (A), all variables show a positive short term shock response to the green growth index. However, the shock response declines over time and eventually returns to the original level. In the case of result B, the green growth index exerts a negative influence on other variables except for GDP per capita. Then the impact of the shock gradually begins to recover to the original level.

For Africa (A), most independent variables show a short term positive shock response on the green growth index, which is followed by alternating negative shocks. The population consistently exerts a positive influence on the green growth index. In the result of B, the green growth index shows a positive shock impact response to tourism expenditure and tourism receipts in the short term, with the impact returning to its original level over time. Conversely, the green growth index has a negative shock from patent applications and population in the short term, but this effect reverts to its original level in the long term. The green growth index shows a short term positive response to shock in tourism receipts, global innovation index, and GDP per capita, but positive and negative shock responses are repeated in the long term.

According to result A for the Americas, all independent variables have marginally positive shock responses to the green growth index in the short term and then return to their original

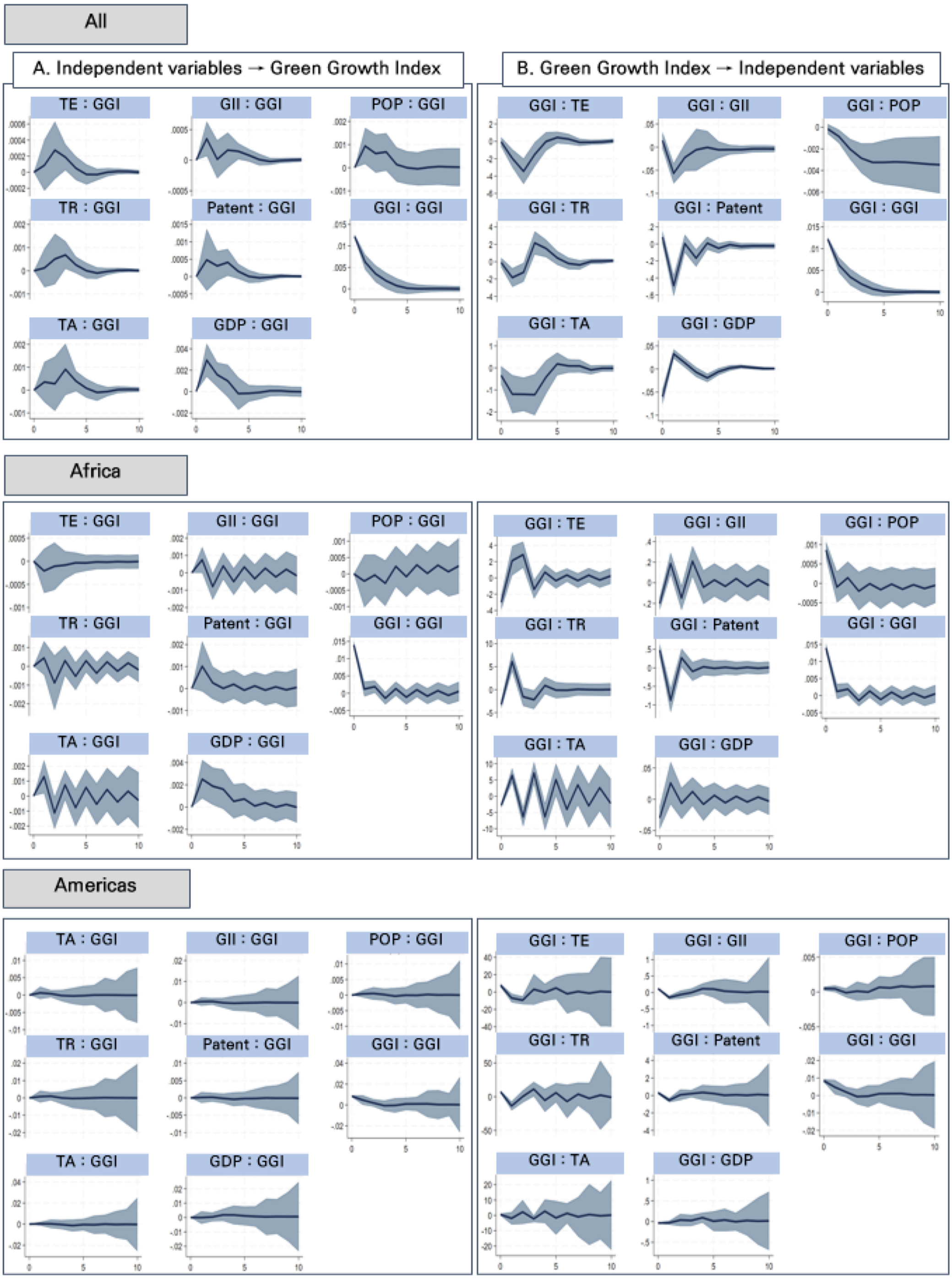


**Figure 3.** Result of impulse response function.

Note: GGI: Green growth index, pop: Population, GDP: GDP per capita, Patent: patent application, GII: Global Innovation Index, ET: Environmental revenue, TR: tourism receipts, TA: Number of tourist arrivals, TE: Tourism expenditures

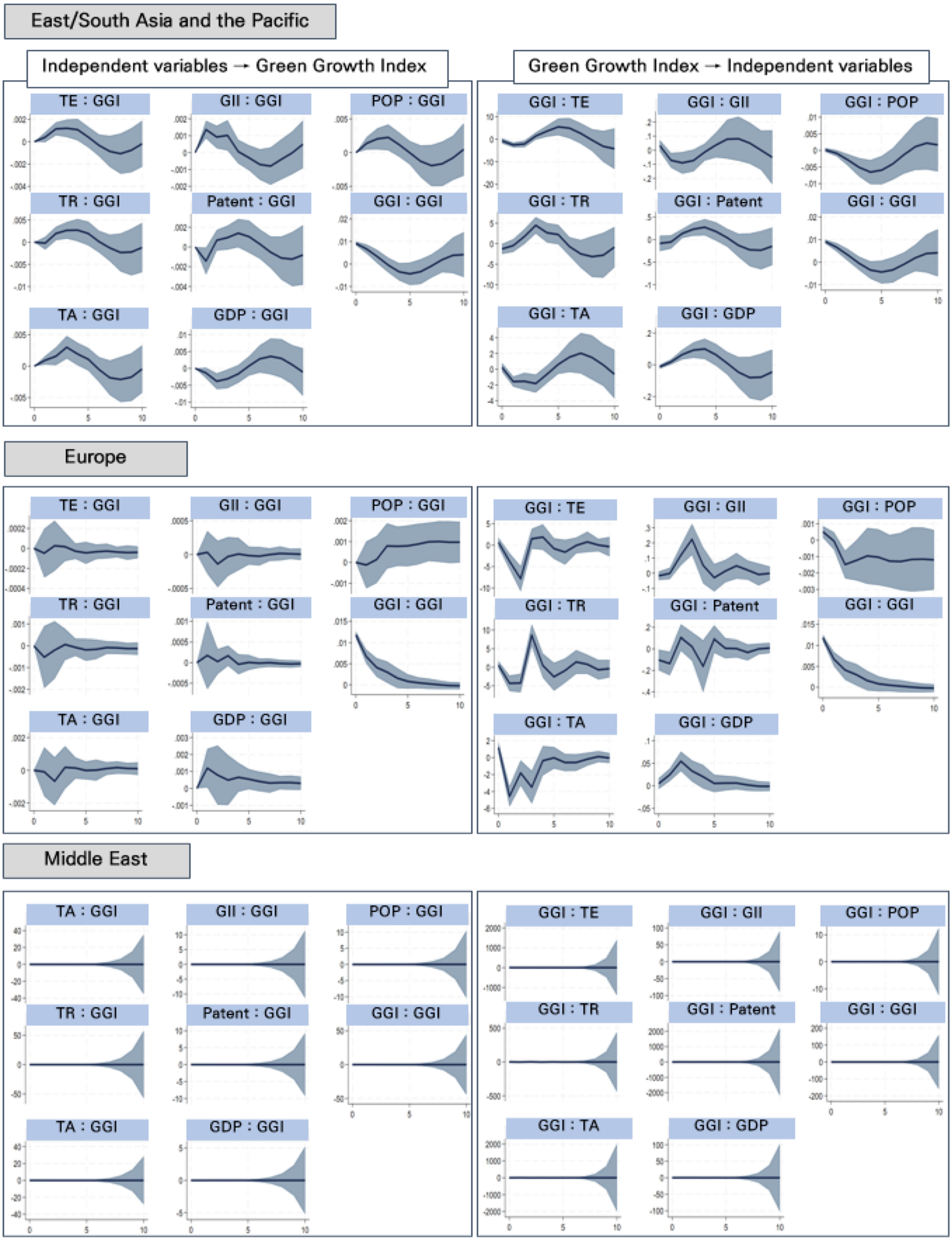


**Figure 3.** Continued.

levels. Looking at result B, the green growth index is negatively impacted by short term shocks to the tourism, technology, and population variables, with recovery occurring by the mid-term. The only positive shock response appears limited to GDP per capita, although this returns to its original level.

For the East/South Asia-Pacific (A), short term shocks positive responses to all tourism, technology, and population variables to the green growth but these shocks exert a negative influence over the long term. Conversely, GDP per capita negative effect on the green growth index in the short term, but gradually transitions a positive impact shock response over time. Looking at result B, the green growth index positively influences tourism expenditure, tourism receipts, patent applications, and GDP per capita in the short term, with a decreasing shock response over time. In contrast, the green growth index shows a positive long term shock response for tourism arrivals, global innovation index, and population but demonstrates a negative response in the long-term.

For Europe (A), all tourism variables and the global innovation index have a negative shock response in the short term but return to its original level in the mid-term. Patent applications and GDP per capita have a positive shock response in the short term and stabilize at its original level in the mid-term. Population is the only variable that shows a positive shock response to the green growth index across all periods. In result B, the green growth index exhibits a negative shock response on tourism variables and populations, while it shows a positive effect on all technology variables and GDP per capita.

For the Middle East (A), all independent variables display limited responses to the green growth index across all periods. Result B also shows that the green growth index has a minimal impact on the independent, but it is confirmed that there is more impact response than result A.

### *Forecast error variance decomposition*

Table 2 shows the results of FEVD. In the case of all, patent applications, population, and tourism expenditure were found to have high explanatory power at 9.14%, 7.59%, and 6.57% respectively. Population, GDP per capita, and global innovation index show that the explanatory power gradually increases over time. In Africa, except for population and GDP per capita, other variables have very high explanatory power for the green growth index every year, with tourism arrivals having the highest explanatory power (54.27%). Most variables show a steady increase in explanatory power compared to year one, while only the population shows a steady decrease. In the case of the Americas, except for population, the remaining variables have had high explanatory power for the green growth index over ten years and continued to increase explanatory power over time. Tourism expenditure explained 39.20% of the green growth index. For the East/South Asia-Pacific, GDP was found to have the highest explanatory power (38.16%), followed by

**Table 2.** Results of forecast error variance decomposition (A).

| | | (A) Independent variables → Green growth index | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Region | Period | POP | GDP | Patent | GII | TA | TR | TE |
| All | 1 | 0.03% | 3.64% | 0.36% | 0.20% | 0.23% | 0.01% | 0.00% |
| | 5 | 5.03% | 4.60% | 9.38% | 3.33% | 2.46% | 2.31% | 6.65% |
| | 10 | 7.59% | 4.63% | 9.14% | 3.41% | 2.44% | 2.24% | 6.57% |
| Africa | 1 | 21.31% | 3.87% | 10.69% | 13.55% | 18.01% | 18.68% | 14.99% |
| | 5 | 5.79% | 5.16% | 29.50% | 27.28% | 51.13% | 32.78% | 25.63% |
| | 10 | 3.32% | 5.44% | 29.50% | 27.79% | 54.27% | 32.76% | 25.88% |
| Americas | 1 | 5.83% | 10.87% | 8.02% | 25.59% | 1.26% | 31.26% | 29.09% |
| | 5 | 2.08% | 20.93% | 21.02% | 27.39% | 18.87% | 32.16% | 38.24% |
| | 10 | 6.42% | 21.55% | 22.25% | 31.20% | 21.18% | 32.74% | 39.20% |
| East/South Asia and the Pacific | 1 | 0.08% | 1.81% | 0.45% | 0.93% | 0.24% | 1.92% | 0.66% |
| | 5 | 27.72% | 37.38% | 6.18% | 12.03% | 16.76% | 7.61% | 10.60% |
| | 10 | 29.12% | 38.16% | 10.64% | 17.08% | 23.22% | 11.98% | 24.06% |
| Europe | 1 | 1.74% | 0.15% | 1.03% | 0.33% | 3.10% | 0.27% | 0.31% |
| | 5 | 6.35% | 20.97% | 3.47% | 20.68% | 34.71% | 15.30% | 20.40% |
| | 10 | 8.32% | 21.08% | 3.91% | 20.92% | 34.74% | 16.08% | 20.72% |
| Middle East | 1 | 0.87% | 1.93% | 0.69% | 0.01% | 1.45% | 4.31% | 18.80% |
| | 5 | 0.35% | 16.36% | 20.21% | 17.17% | 11.01% | 7.38% | 12.04% |
| | 10 | 0.29% | 13.08% | 16.34% | 13.71% | 10.14% | 6.95% | 11.32% |

*Note:* (1) All variables use log-term. (2) GGI: Green growth index, pop: Population, GDP: GDP per capita, Patent: patent application GII: Global Innovation Index, ET: Environmental revenue, TR: tourism receipts, TA: Number of tourist arrivals, TE: Tourism expenditures.

**Table 3.** Results of forecast error variance decomposition (B).

| | | (A) Green growth index → Independent variables | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Region | Period | POP | GDP | Patent | GII | TA | TR | TE |
| All | 1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | 5 | 0.79% | 5.51% | 0.23% | 0.08% | 0.54% | 0.36% | 0.05% |
| | 10 | 0.79% | 5.53% | 0.23% | 0.08% | 0.55% | 0.37% | 0.06% |
| Africa | 1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | 5 | 0.08% | 5.62% | 0.50% | 0.72% | 1.83% | 0.60% | 0.03% |
| | 10 | 0.15% | 5.78% | 0.50% | 0.87% | 2.24% | 0.75% | 0.03% |
| Americas | 1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | 5 | 0.53% | 5.89% | 0.21% | 0.57% | 2.05% | 1.44% | 0.59% |
| | 10 | 0.54% | 7.95% | 0.27% | 0.57% | 2.61% | 1.41% | 0.58% |
| East/South | 1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Asia and | 5 | 5.26% | 12.07% | 2.26% | 1.58% | 6.71% | 7.74% | 1.73% |
| the Pacific | 10 | 5.84% | 16.36% | 2.64% | 1.41% | 7.81% | 9.42% | 1.89% |
| Europe | 1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | 5 | 0.58% | 1.25% | 0.03% | 0.01% | 0.23% | 0.15% | 0.00% |
| | 10 | 2.50% | 1.57% | 0.03% | 0.01% | 0.25% | 0.18% | 0.00% |
| Middle East | 1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | 5 | 1.06% | 0.72% | 1.55% | 0.78% | 25.92% | 37.77% | 13.80% |
| | 10 | 8.80% | 0.55% | 1.74% | 0.81% | 25.37% | 36.83% | 13.29% |

*Note:* (1) All variables use log-term. (2) GGI: Green growth index, pop: Population, GDP: GDP per capita, Patent: patent application GII: Global Innovation Index, ET: Environmental revenue, TR: tourism receipts, TA: Number of tourist arrivals, TE: Tourism expenditures.

population and tourism expenditure in ten years. In addition, it can be seen that all variables have increased explanatory power over time. In Europe, all variables have increased explanatory power on the green growth index over time. Tourism arrivals have the highest explanatory power at 34.74%, while the patent application has the lowest explanatory power at 3.91%. In the Middle East, all variables show the highest explanatory power in the fifth year. Patent applications has had the highest explanatory power at 20.21%, and the population has the lowest at 0.35%. In the long term, the explanatory power of all variables decreases after the fifth year.

Table 3 shows the FEVD results of the green growth index for independent variables. In the case of All, Africa, and the Americas, it was found that the explanatory power was very low compared to A. Among them, the explanatory power of the green growth index for GDP per capita is over 5% in ten years, while other variables are very low. From this, the green growth index is more sensitive to each variable. In East/South Asia-Pacific, the explanatory power of green growth for GDP per capita is the highest at 16.36%, with tourism receipts (9.42%) and tourism expenditure (7.81%). The explanatory power of the green growth index for the remaining variables except the global innovation index, gradually increases over time. In Europe, all variables have a relatively low explanatory power. The green growth index explains within 3% of all variables in ten years. Among them, population has the highest explanatory power at 2.50%. In the case of the Middle East, it was found that the explanatory power is high compared to A. In particular, the explanatory power of the green growth index for every tourism variable is higher than others. Among them, tourism receipts have the highest explanatory power of 36.83% in ten years, while pollution is the lowest (0.55%).

## Conclusion and implications

### *Discussion*

The results of this study confirm the value of green growth approaches for sustainable tourism (DeLacey et al., 2014; Reddy & Wilkes, 2015). This study highlights the potential significance of technological efficiency oriented approaches to sustainability for encouraging more sustainable forms of international tourism while maintaining economic growth (Pan et al., 2018) and draws several conclusions.

First, the Granger causality test suggests that tourism (tourism receipt, tourism expenditure, and tourism arrivals) promotes green growth in the majority of the regions examined. Tourism is a double-edged sword, as destinations benefit from increased tourism receipts, which boosts economic growth but also leads to adverse environmental effects. Nevertheless, tourism can promote green growth in most continental regions because tourism spending directly benefits the local economy which can therefore economically support eco-friendly infrastructure and resource efficiency to enable green growth (Adedoyin et al., 2022; GGGI, 2020), such as encourage the adoption of renewable energy (Ansari, 2024). Furthermore, tourism arrivals can stimulate investment and community inclusion in nature conservation (Ansari, 2024). Tourism therefore aligns with the five key goals of green growth: natural resource protection, sustainable economic development, social progress, poverty alleviation, resource efficiency, and addressing and mitigating climate change (GGGI, 2020).

Second, the varying impact of tourism on green growth across continents can be attributed to a combination of technological innovation, economic conditions, and green policies. Europe and the USA showed less of a shock response to the Green Growth Index than other continents. Many European countries rank highly on the Climate Change Performance Index and have already implemented plans to meet more than 60% of their electricity needs with renewable energy. To achieve these plans, European countries aggressively invest in technology and implement policies (Burck et al., 2023). Europe already maintains high environmental standards and is highly developed economically, so it continues to strive for sustainable growth (Castañeda-García et al., 2023). In the Americas, the green growth index appears significantly influenced by the economic and innovation levels in the United States which ranks third in the Global Innovation Index. As suggested by the Environmental Kuznets Curve theory, environmental pollution increases, but as economic development reaches a certain threshold, investment in environmental protection tends to increase and reduce pollution (Chi, 2021; Gao & Zhang, 2021; Porto et al., 2023).

Third, this study highlights the potential significance of technological efficiency oriented approaches to sustainability for encouraging more sustainable forms of international tourism while maintaining economic growth (Pan et al., 2018). Innovative technologies (global innovation index and patent applications) are essential in driving green growth because they not only contribute to developing eco-friendly technologies and services but also potentially contribute to balanced economic development (Kuo et al., 2022; Sharif et al., 2023). Innovation can reduce the carbon emissions of tourism facilities through new technologies such as energy-efficient buildings, smart grid systems, solar panels, and wind energy, and reduce carbon footprints through use of eco-friendly transportation (Jahanger et al., 2023). Furthermore, smart technology can conserve water resources and improve waste management and resource recycling (Pereira-Doel et al., 2024).

Nevertheless, these findings come with important caveats. Although efficiency is integral to sustainable consumption in tourism, a fact acknowledged by even some of the harshest critics of green growth in tourism (Hall, 2015, 2022), it does not preclude the importance of encouraging sufficiency in tourism and recognizing that there are limits to growth in terms of environmental change, e.g. global heating; resource depletion, e.g. non-renewable resources; and societal acceptance, e.g. quality of life. Technological innovation and efficiency gains also have limits and not everything can be substituted, while if population and tourism growth continues at a rate greater than efficiency gains then, in the long-term, resource depletion is inevitable (Hall, 2015). Indeed, our findings reflect those of the original Brundtland report (World Commission on Environment and Development, 1987) that technological innovation helps delay reaching ultimate ecological limits but they do definitely exist. Further paradigmatic and system changes will arguably require a change in values, power, and their interplay with interests (Hall, 2011, 2022) which, although essential, is beyond the scope and space limits of the present paper.

### *Theoretical implications*

This research is significant for analyzing the green growth of tourism using the STIRPAT model. The core elements of green growth are maintaining natural capital and economic growth through technological innovation and greater efficiencies (Hickel & Kallis, 2020; Huang & Zhao, 2022; Xu, 2022). This study empirically found through the STIRPAT model that technological innovation—patent applications and global innovation index—is crucial in advancing green growth within tourism. This study has contributed to knowledge of green growth and tourism given the relative lack of previous research, and provides an important theoretical and empirical basis for exploring green growth in the future.

STIRPAT examines how population, economic activity, and technology influence the environment and economy, but there is a limit to explanations of the complex interactions between variables. This study used four analysis methods (Panel Granger causality test, PVAR, IRF, and FEVD) to verify the STIRPAT model, examining the model from multiple perspectives. Explaining complex interactions in various ways enables a deeper interpretation beyond simple correlations and enhances the reliability of decision-making. The study was able to capture both short and long-term changes in the green growth index. Thus, this study suggests that conducting various analyses within the STIRPAT model mitigates its limitations and contributes to its enhancement.

STIRPAT has previously been utilized to demonstrate the relationship between GHG emissions and renewable energy within the context of urbanization (Shahbaz et al., 2016; Xu et al., 2020), economic growth (Xing et al., 2023), and technology (Wang & Taghvaee, 2023). However, there are few papers in a tourism context. For sustainability and tourism, the relationship has been examined through the sustainable development index (Destek & Aydın, 2022), municipal solid waste (Arbulu et al., 2017), and wastewater emissions (Ahmad & Jabeen, 2023). However, there is little research examining tourism using the green growth index. Therefore, this study considerably expands previous research.

The green growth literature argued that innovative technology is central in achieving green growth (Barua, 2022; Koçak et al., 2020; Nosheen et al., 2021; Ulucak, 2020; Zhao et al., 2022). However, there is limited research analyzing the relationship between innovation and green growth in tourism, especially in analyzing this relationship through patent applications and the global innovation index. This study therefore establishes a theoretical framework connecting technological innovation with green growth and tourism and empirically verifies the link through the STIRPAT model. In addition, the study deepens the theoretical understanding of green growth and tourism through the Granger causality test, PVAR, IRF, and FEVD to analyze regional differences and short and long-term impacts. This study, therefore, reinforces the role of efficient approaches to tourism with respect to green growth (Hall, 2013).

This research examined 126 countries, categorized into Africa, the Americas, East/South Asia-Pacific, Europe and the Middle East, while previous studies focused on single regions (Razzaq et al., 2023a; Xu et al., 2020; Zhang et al., 2022; Zhao et al., 2021, 2022). This broadened the study's scope and uncovered characteristics associated with the UNWTO regions that are widely used to discuss the state of the global tourism industry in statistical and policy terms, allowing for a broader understanding of tourism's impacts and interrelationships.

In sum, this study establishes a novel theoretical framework connecting technological innovation and tourism green growth, empirically verifying this link *via* the STIRPAT model. Examining tourism green growth dynamically across regions and time horizons strengthens and extends green growth approaches and the emphasis on efficient resource use. Analyzing 126 countries across UNWTO regions uncovered broader tourism sustainability and economic linkages compared to prior single-region research, advancing global understanding. The findings provide new theoretical and empirical support for innovation's importance in promoting tourism green growth, meaningfully extending existing green growth and sustainable tourism research.

## Practical implications

The interaction between green growth and tourism identified in this research shows the value of green growth in tourism (Pan et al., 2018). Therefore, to achieve green growth in the tourism industry, it is essential to implement policies that actively promote more efficient forms of tourism (Reddy & Wilkes, 2015). Government and business need to develop policies that are specifically tailored to encourage technological innovation (DeLacey et al., 2014). These policies should focus on reducing emissions and boosting resource use efficiency to maintain or enhance natural capital over time. However, evidence to support such policies has been limited until the present research results.

In tourism, the results indicate that implementing the green growth index goals in policy terms may encourage the sustainable development of tourist destinations, providing for increases in tourism demand while meeting environmental indicators. Green governance, particularly regulations focused on greater resource efficiency, also encourages environmental sustainability in tourism. These interactions can benefit not only the tourism industry but also the broader economy, offering new sources of employment and income, while achieving long-term economic and environmental goals.

The results suggest that innovative technologies support green growth. This promotes new environmental technologies and enhances green technology and energy efficiency. Green technologies, including smart grid systems, renewable energy, and eco-friendly transportation and architecture, play a pivotal role in curbing emissions per unit of consumption in tourism (Hall, 2015; Jahanger et al., 2023; Lu et al., 2021). Furthermore, innovative technology tools like intelligent automation, artificial intelligence, chatbots, and real-time feedback technologies may also help foster eco-friendly behavior (Majid et al., 2023, 2024; Pereira-Doel et al., 2024). Importantly, the results suggest that it is possible to reduce the environmental footprint of tourism while supporting continued economic growth.

## Limitations and future research directions

This study examines green growth by allocating countries to continental regions, but limitations reflect the differences of each country. In particular, the weak IRF observed in the Americas and the Middle East. Future studies should focus on green growth by identifying economic groupings in finer detail as well as examining countries individually to identify more specific problems and explore solutions in a comparative context. This approach will enable a deeper comprehension of green growth and aid in the development of more tailored strategies for green growth and tourism.

## Disclosure statement

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