Investigating the Relationship among Tourism, Economic Growth and CO_2 Emissions for G20 Countries

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Abstract: Tourism, an important economic activity for any nation, contributes significantly to GDP, particularly fast tourism, which means mass travelling and short-duration trips. As tourism expands, it necessitates the expansion of infrastructure, which requires energy consumption at a higher level leading to a rise in carbon footprints and environmental degradation. These difficulties hinder long-term livelihoods by increasing access to energy market volatility and insecurity as well as global supply chain interruptions, thereby impeding progress in achieving a Net Zero goal by 2050 in G20 countries, which currently account for 80% of global carbon emissions. Hence, understanding the connection between economic sectors and CO_2 emissions becomes important. The study analyses the long-term relationship among tourism, population growth, economic growth, renewable energy and CO_2 emissions by using Dynamic Ordinary Least Square (DOLS) in panel data analysis for G20 countries from 1990 to 2021, covering key global scenarios such as global financial crisis of 2008 and covid-19, to take the cross-sectional dependence into consideration. Further, the study concludes that tourism positively influences the economy's growth and promotes carbon emissions. Thus, it provides insight into maintaining economic growth and environmental sustainability by shifting towards renewable energy. Finally, the study suggests fostering low carbon emission development in G20 nations.

Keywords: Tourism, Sustainability, Environmental Degradation, Renewable Energy, Carbon Emissions, Panel Data, Economic Growth, DOLS technique, G20

1. Introduction

Tourism has long been believed to be a pivotal engine of economic growth, especially in countries rich in cultural legacy, developed infrastructural and natural beauty. The tourism industry growth is remarkable along with the demand of tourism in the last few decades [1]. Tourism accounted for 10.4% of all jobs globally and 10.5% of world Gross Domestic Product roughly US$1091 trillion [2]. Moreover, in the gap of three years, when transit was restricted due to covid -19, the contribution of tourism in world GDP has dropped to 9.1%. The recovery following 2021 led to spending of visitors reaching US$1091trillion in 2024 [3]. Clearly reflecting that tourism emerged as an important factor in the economic growth for both advanced and emerging economies [4], [5]. Also, it has been determined that tourism is a vial pillar of economic recovery [6]. Countries with a higher focus on tourism are found to recover earlier than the economies where

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tourism is not that significant. G20 countries depict about 66.7% of total population and contribute around 85% of GDP worldwide. In 2022, G20 economies welcomed about three-fourth of international tourists and, in 2019, before covid-19, direct GDP through tourism reached about 3.7% of G20 economies [7]. Concurrently accounting for 80% of carbon emissions.

Tourism and environmental quality is found to be an important link for the use of energy [8]. Despite the great significance of tourism in the growth of an economy, tourism has adverse impact on the environment. Increasing tourism requires the use of more energy and natural resources. All tourist activities are dependent upon energy generated from fossil fuels contributing CO_2 emission [9]. As a result of growth in population and depletion of natural resources, carbon emissions increased which ultimately contributes to environmental degradation. By contrast, tourism-driven economies invest more in eco-friendly, disruptive solutions to decrease carbon emissions [10]. Use of transportation medium can contribute to greenhouse gas emissions. Travelling in the air by aircraft and cars is responsible for the highest CO_2 emissions per passenger, which is followed by trains and buses. Due to this development in tourism, a dynamic change has been seen in this industry. The development in the tourism sector is a key input in environmental pollution. Thus, to provide a clean environment and a higher standard of living, sustainable tourism is necessary [11]. Economic growth paves the way for industrial activities and energy usage, but at a higher level of income, investments and focus on cleaner energy can reduce carbon emission hypothesized by the Environmental Kuznets Curve (EKC) [12].

As Climate change and CO_2 emissions contributing to global warming are emerging issues by considering population and tourism as key drivers of economic growth. While adoption of clean or renewable energy in tourism goes hand in hand to support sustainable development of an economy. Therefore, it is important to comprehend the sustainable development situation in the G20 nations.

This paper studies the interplay between tourism and carbon emissions by taking along economic growth and population as the key contributors to climate change. An attempt has been made to determine the existence of long run relationship among these. Thereby, the study aims to provide insights to balance economic development and environmental sustainability along with tourism at an international level.

2. Review of related literature

In this section, the study will discuss the works of scholars that have been already done as literature. There is enough literature that focuses on the main causes - energy use, tourism and economic expansion which influence CO_2 emissions. Researchers study the nexus through the varied econometric techniques and time frames. This section investigates the linkages among the factors influence carbon emissions based on time series data using economic techniques, considering various countries all over the globe. The literature will provide insight into clusters of countries and country specific studies.

2.1 Tourism and CO_2 emissions

All tourist activities are dependent upon energy generated from fossil fuels contributing to CO_2 emissions. A panel study provided robust results for Mediterranean counties from 1995 to 2014 explores the connection among economic growth, tourism and CO_2 emissions and found the presence of cross dependence and heterogeneity across the countries [13]. Thereby, concludes that 1% growth in tourism receipts resulted in rise by 0.09% and 0.145 in emissions using "Common Correlated Effect Mean Group(CCEMG)" and "Augmented Mean Group(AMG)" respectively and recommended that policy makers should focus upon policies for the conservation of environment and low carbon emission economy [9]. But from the long run estimates for EU nations from 1990 to 2013 revealed that a 1% rise in investment in tourism reduces CO_2 emissions by the amount of 0.033% [14]. An investigation on BRICS to understand the relation between tourism and carbon emission used DOLS approach from the period 1995 to 2020 and find out how these factors, use of energy and tourism impact CO_2 emissions by revealing the estimation that 1% rise in tourism results in 0.008% increment in carbon emission, further suggested long-term relationship among foreign direct investment (FDI), tourist arrival, economic growth and CO_2 emissions [15]. Similarly, for the same time frame of 1995 to 2020, but employing different techniques (ARDL) in BRICS showed a converse pattern for relationship between tourism and CO_2 emissions, where emissions may decrease by 0.39% due to 1% increase in tourism. Hence, promoting eco-friendly tourism and sustainable technological innovation in these countries can protect the environment [16], [14].

Various attempts are made to study OECD countries where most of the studies indicate that growing income promotes the deployment of low-emission technological solutions in tourism, thereby positively influence the environment [17], confirms that EKC hypothesis is consistent for these countries [18]. Further reflecting through the study for the period 1995-2010 which used EKC to show the interplay among GDP, energy, trade, tourism and CO_2 emissions concluded that 0.03% rise through a 1% increase in tourist arrivals, that is a proxy for tourism. The results suggest a relatively smaller yet positive linkage between tourism and emissions and recommend OECD members to further improve energy efficiency and promote trade activities [19].

As this section highlights the linkages of tourism particularly, it would be interesting to investigate the pattern for these variables in the top ten tourist destinations. Using EKC, hypothesis, impact of tourism on the climate has been studied from 1972 to 2021 in the top ten tourist destinations. Through CS-ARDL, short-run estimates were not significant but long run estimates suggested that a 1% rise in tourism may led to 0.221% decrease in CO_2 emissions [20] In the same manner, to see the ramifications of tourism development on carbon emissions in the leading tourist destination globally, considering the time frame of 1995-2014, revealed increasing effect of tourist inflows on CO_2 emissions and argues that rising tourists expands infrastructure services, such as hotels, transport energy use etc. and therefore responsible for rising emissions but strange is that the study found no significant impact between tourist receipts and environmental quality [21].

In emerging economies, tourism significantly affects the environment, such as [22] studies South Asian countries and examines the influence of economic growth, energy use, tourism on environmental changes for such a long time from 1995-2017. The paper argued that the elasticity of emissions for tourism growth is 0.165, indicates that tourism through arrival of tourists badly impacts the environment due to unsustainable practices of tourists, therefore, suggests fostering adoption of renewable energy to reduce carbon emissions.

Chinese provinces exhibit a long run relation between arrivals of tourist and CO_2 emissions from 2010 to 2017 using panel data model revealed that a 1% rise on emissions resulted in 0.17% decline in inbound tourism but 0.41% rise in domestic tourists, demonstrated two different trends in international and domestic tourism [23]. The study on Bangladesh finds significant relation among FDI, GDP, tourism and carbon emissions and showed that tourism has no detrimental effect on planet's carbon balance but observes an inverted U-shaped association between CO_2 emissions and economic development can be seen [24]. Emerging economies such as Pakistan reported short and long run positive and negative disturbances of tourism and economic growth affecting CO_2 emissions. Moreover, the study confirms unidirectional causality between economic growth & CO_2 emissions and bidirectional causality tourism & economic growth in Pakistan [25]. The interplay among urbanization, economic growth with the use of energy, tourism and CO_2 emissions in Singapore using DOLS technique found that a 1% increment in tourists activity is related with 0.45% rise in CO_2 emissions [26].

Tourism activities which are exacerbated using higher energy increase these emissions as well and therefore suggest implementing technologies related to clean energy and thereby promoting eco- tourism.

2.2 Growth of population, Economic Growth and CO_2 Emissions

BRICS nations collectively make up almost half of the population worldwide, contribute 24% in global GDP and a considerable portion of GHGs emissions, they offer a special framework for examining environmental pressure [15]. A study on BRICS finds that 1% increase in GDP, technology advancement and consumption of natural resources would rise CO_2 emissions by 1.8%, 0.15% and 0.10% respectively [16]. Hence suggested varied solutions like less carbon emitting transportation, sustainable tourism etc. Similarly, the investigation among economic growth, FDI, tourism and carbon emissions for the period 1995-2020 in BRICS using DOLS approach indicates that long term relationship among economic growth, FDI, tourist arrival and CO_2 emissions. Particularly for economic growth of countries, the estimate revealed a 0.10% upsurge in CO_2 emissions due to a 1% rise in GDP of these countries [15]. In low-income countries, different models using panel regression showed varied estimates for the association among CO_2 emissions, population, economic growth [27]. The population that is growing by 1% exhibits an increase in CO_2 emissions of 1.395% in fixed effects model, 0.911% in random effect model, 0.628% in S-GMM and 1.395% in D-GMMM. GDP also showed positive and significant coefficients in all models except fixed effects, where it showed no statistically significant relationship [28]. Evidence from European countries from 1975 to 1999 indicates that a 2.73% increase in emissions is caused when population is raised by 1% [29].

Historical studies have produced conflicting results regarding the connection between population, economic expansion and CO_2 emissions, especially in emerging or developing economies.

Using the technique of ARDL, the impact of income and population growth on CO_2 emission was studied for four countries covering Brazil, Indonesia, China, and India between1970 to 2012 [30], [31]. The finding implies that when income rises over the time, the emissions declines for all selected countries and a positive and significant relationship has been showed by population growth and CO_2 emissions for all countries except Brazil. By employing similar technique of ARDL and DOLS approach, the economic growth of Malaysia showed contradictory results while studying the linkages between growth and emissions for two different time periods. Historical perspective from 1970 to 1980 on Malaysia economic growth and environment suggested that rise in GDP results in reduction of carbon emissions whereas for the years 1980-2009, it showed a direct relationship between GDP and emissions, furthermore, indicated that population was not the key contributor to emissions in Malaysia [32]. Similar attempt is made by [33] for the country Malaysia from 1970 – 2014, revealed that both long-run and short-run, the economic growth of this country drastically enhances CO_2 emissions. For example, a 1% increase in GDP leads to 2.7% and a 2.9% rise in emissions. Additionally, the evidence of EKC is supported by this study. A similar trend has been depicted in its study for the year 1980-2009 [32]. The study conducted for Vietnam employed ARDL and VEMC model to investigate how energy use and economic growth effects climate change and triggers the environmental degradation. As per estimates, 0.89% CO_2 emissions may rise by 1.11% in sho0rt run and 0.89% in long run due to 1% rise in GDP [34]. For the development of an economy, it cannot be advisable to stagnate the growth of a country, rather emissions can be reduced by using clean energy sources and hence sustain the environment along with the growth of a country. In Turkey, researchers studied how use of clean energy, tourism, and growth affects carbon emissions dynamically and found that carbon emissions can be increased by 0.39% due to a rise in 1% of economic growth in Turkey [35]. A study covered a long period from 1990 to 2018 to exhibit the linkage between carbon emissions and growth for Peru using DOLS approach [36]. The inference depicts that a positive association exists between growth of Peru and its CO_2 emissions [37]. It further indicates that CO_2 emissions can be raised by 0.59% due to 1% increment in economic growth in Peru, hence provides suggestions to adopt cleaner energies to tackle the deterioration of environment.

2.3 Renewable Energy and CO_2 Emissions

Studies from low-income countries show that growing tourism, rising GDP and use of renewable energy are advantageous in validating EKC. The study from 26 low- income countries used GMM techniques for 2001 to 2020 and found that a 1% rise in consumption of renewable energy lowers emissions by 0.6985% [28]. Using different economic techniques such as “Fully Modified Ordinary Least Squares (FMOLS)”, “DOLS” and “fixed effects” for the time frame from 1995-2014 [38] observes the linkage between CO_2 emissions and renewable energy in EU-28 countries and provide inferences that consumption of renewable energy or clean energy is crucial to reach sustainable growth and additionally found out that renewable energy may allow the improvement in quality of environment.

Several researchers studied the relevance of renewable energy in curbing emissions in many countries all over the world for different time frames until 2010 such as [36] used DOLS approach for Peru from 1990 to 2018 and exhibits that 1% growth in renewable energy consumption is related to 0.52% reduction in $C0_2$ emissions. For the same period, [39]recommends decreasing emissions in China and switching from non-renewable sources of energy to renewable sources of energy through ARDL model. Similarly, using ARDL for the period 1990 to 2020 in Philippines [10] provides insights for low carbon economies and promoting renewable energy use and the study found that increment of 1% of renewable energy results in reduction of carbon emissions by 1.5%. Dynamic effects of various economic indicators along with role of renewable energy are shown for Turkey using time frame from 1990 to 2020 and econometric techniques of DOLS respectively. The results provide insights that emissions can be declined by 0.43% if renewable energy consumption is increased by 1% [35].

However, many studies covered variables related to renewable energy, tourism, growth, and carbon emissions [40], most of them are restricted to EU, OECD or South Asia etc. But do not provide insights for global level. Furthermore, previous studies cover shorter time periods and lack focus on major worldwide disruptions like covid-19. Some researchers studied the role of renewable energy validity of EKC hypothesis, few have explored collectively in the context of G20 countries where CO_2 emissions hold 80% contribution. This study fills these gaps by employing panel data analysis using DOLS technique to explore the linkages among tourism, growth of economy and CO_2 emissions considering the role of population and renewable energy from the period 1990 to 2021. The study offers insights to policymakers on how to balance sustainable growth and sustainable environment in the major economies of the world.

3. Research Methodology

3.1 Data and variables

The data related to variables - GDP, total population, tourists' arrivals, renewable energy and CO_2 emissions is collected from secondary sources for the period from 1990 to 2021. To examine the dynamic influence of economic growth, population, tourism and renewable energy on CO_2 emissions in G20 countries, the study employed DOLS technique for major analysis. The dependent variables are CO_2 emissions and GDP, total population, tourists' arrivals, and renewable energy consumption are taken as explanatory variables. Various transformations have been employed to ensure linearization of variables. Sometimes, the model has heteroskedasticity and variables are not normally distributed, log transformation are significant to make the residual more homogeneous and to normalize the data for applying many statistical methods. Here, renewable energy is converted into square root first and after that converted into log form. To make the remaining variables regularly distributed, they are all transformed into log form. Below the Table 1., the variables, their descriptions, unit of measurement and data sources are presented.

Table 1. Description of variables

Variables	Description	Log form	Unit of measurement	Source
CO_2	CO_2 emissions	LCO_2	Total CO_2 per capita	EDGAR
GDP	Economic Growth	LGDP	GDP (constant US$)	WDI
POP	Total Population	LPOP	Total no. of population	WDI
TA	International Tourism	LTA	No. of Tourists' arrivals	WDI
RNE	Renewable Energy Consumption	LSRNE	Renewable Energy use (% of Total Final Energy Consumption)	WDI

The above table describes the variables selected for the study and includes measurement units and sources of data as well. The data for CO_2 emissions is sourced from 'Emissions Database for Global Atmospheric Research (EDGAR)' and GDP, total population and renewable energy consumption are sourced through 'World Development Indicator (WDI)'. Data for the number of tourists' arrivals has been collected from 'WDI', which is available from 1995 to 2020 on WDI, but the study covers the period from 1990 to 2021, so data for remaining years has been collected from some country-specific sources such as 'UK Office for National Statistics', 'Govt. of Canada', 'European Commission', 'Japan Bureau of Statistics', 'China National Bureau of Statistics', 'Travel and Tourism (India)', 'Bandan Pusat Statistiks (Indonesia)', 'Trading Economics', United Nations World Trade Organization (UNWTO)' etc.

3.2 Model Specification

This section provides the equations for dependent and independent variables. The first equation describes the functional form of variables; the second equation describes the econometric model. Lastly, the third equation shows the log transformed model.

$$CO_{2it} = f\,(GDP_{it}, POP_{it}, TA_{it}, RNE_{it}) \tag{1}$$

Where CO_2, GDP, POP, TA and RNE are carbon emissions, Gross Domestics Product, international tourists' arrivals and renewable energy consumption respectively at time 't'. Cross sections are expressed by 'i' here.

The econometric model for this study is depicted as :

$$CO_{2it} = \beta 0 + \beta 1\ GDP_{it} + \beta 2\ POP_{it} + \beta 3\ TA_{it} + \beta 4\ SRNE_{it} + \mathcal{E}_{it} \tag{2}$$

Where ‘β0’ is the intercept, ‘β1’, ‘β2’, ‘β3’, ‘β4’ are the coefficients and is the error term. the variable renewable energy was not normally distributed. Hence, it was first converted into square root form and taken as its log form.

Additionally, the equation (2) can be written in the log form as:

$$LCO_{2it} = \beta 0 + \beta 1\ LGDP_{it} + \beta 2\ LPOP_{it} + \beta 3\ LTA_{it} + \beta 4\ LSRNE_{it} + \mathcal{E}_{it} \qquad (3)$$

4. Empirical results

4.1 Statistical summary

Table 2. Descriptive analysis

Variables	Mean	Standard Deviation	Minimum	Maximum
CO_2 emissions	0.8158842	0.3469851	-0.1611509	1.322839
GDP	12.1737	0.4730188	11.25372	13.32052
Total population	8.020165	0.4996995	7.02697	9.150512
Tourists’ arrivals	7.270967	0.6601123	5.390691	8.986267
Renewable energy consumption	0.4774844	0.2354068	0	0.89

Source: Author’s Calculation

Table 2. represents the statistics summary of the variables where mean value and standard deviation are shown. The descriptive analysis showed different values for selected variables, with CO_2 emissions have mean of 0.81 and a standard deviation of 0.34, and population and GDP exhibited higher values, which reflect economic and demographic variations.

4.2 Cross- sectional dependence analysis

In the first stage of panel data, a cross- sectional dependence test is conducted to analyze dependence among the selected variables. Generally, it is expected that panel models are cross- sectionally independent when N, the no. of cross sections are large, but in this study T, time dimension > N. Pesaran and Friedman’s test of cross section independence are applied to check cross-dependence. For the Pesaran test, we get a value of 0.0584, which is slightly greater than 0.05; therefore, the hypothesis given by Pesaran is accepted, and hence exists a cross-sectional dependence between the variables. Friedman’s test also gives similar results with a result value of 0.0031, where the hypothesis is opposite the former; hence, we have found cross-sectional dependence among the variables in the model.

Table 3. Results of Cross-sectional dependence test

Pesaran test = 1.893, Pr = 0.0584

Friedman test = 40.167, Pr = 0.0031

Source: Author's Calculation

4.3 Correlation

Table 4. Correlation Analysis Results

Variables	CO_2 emissions	GDP	Total population	Tourists' arrivals	Renewable energy consumption
CO_2 emissions	1				
GDP	0.2926	1			
Total population	-0.493	0.5043	1		
Tourists' arrivals	0.2534	0.6487	0.2845	1	
Renewable energy consumption	-0.6663	-0.0249	0.4649	-0.009	1

Source: Author's Calculation

In the Correlation analysis, the results exhibited a positive association between the independent variables (GDP and Tourists' arrivals) and dependent variable CO_2 emissions, whereas population growth and renewable energy consumption are negatively correlated to CO_2 emissions. As some countries may reflect decoupling phenomenon where efficient and clean energy supports economic and population growth without any rise in emissions.

4.4 Analysis of panel regression

Table 5. Regression Analysis Results

	Coefficients	Standard error	t-statistic	P>t	95% level of confidence interval
LGDP	0.406046	0.0233017	17.43	0	0.3602883, 0.451804
LPOP	-0.4327669	0.0200502	-21.58	0	-0.4721396, -0.39339
LTA	0.0359408	0.0143483	2.5	0.012	0.0077649, 0.064117
LSRNE	-0.5339233	0.0366872	-14.55	0	-0.6059662, -0.46188

Source: Author's Calculation

The panel regression analysis revealed that GDP and tourism are significantly and positively associated with CO_2 emissions. They both contribute to CO_2 emissions, which implies that the growth of an economy and tourism activities lead to the deterioration of the environment. Population growth negatively impacts CO_2 emissions, possibly due to use of clean energies and focusing on sustainable activities such as Smart cities development, renewable energy-based technology and public awareness towards sustainability can reduce the emissions despite of higher population.

4.5 Diagnostic Tests

Table 6. Results of Diagnostics Tests

Estimation Techniques/ Tests	Coefficients	P-values	Findings
Variance Inflating Factor (VIF)	Mean VIF = 1.87	…………..	No Multicollinearity
Woolridge test	F = 197.044	0.0000	First-order Autocorrelation is present
Breusch-Pagan/ Cook-Weisberg test	Chi^2 (1) = 0.16	0.6863	No Heteroskedasticity
Histograms	………..	…………..	Normally distributed variables after transformations

Source: Author's Calculation

In econometrics, diagnostics tests are carried out to check the consistency and credibility of the model. These are helpful in enhancing the robustness of the econometric model and ensure that interpretations derived from the model can be considered reliable for policy recommendations. As the model has presence of auto correlations, it may lead to biased results which may skew the estimated statistically significant coefficients. In general, autocorrelation exists when the variables are cross-sectionally dependent as in this case. Various methods can be used while facing first order autocorrelation in the model, such as Durbin- Watson d- statistics test, Newly-West standard errors or Dynamic panel models. In this study, "Dynamic Ordinary Least Square (DOLS)" method to address autocorrelation is applied. No multicollinearity and heteroskedasticity confirm the reliability and validity of the model.

4.6 Panel Unit Root Analysis

The model has cross-sectional dependence suggests for applying the second-generation unit root test. CADF and CIPS are used to check the stationarity of the variables. The variables showed stationarity at different levels. The variables CO_2 emissions, tourists' arrivals, and renewable energy consumption were found to be stationary at first difference. GDP is found to be level stationery. The variable, total population is found to be stationary at third difference.

Table 7. Results of panel unit root analysis

Variables	CADF				CIPS		
	L(0)	L(1)	L(2)	L(3)	L(0)	L(1)	L(2)
CO_2 emissions	-1.656	-2.446*	………	………	-1.664	-4.524*	………
GDP	-2.303*	…….	………	………	-2.345*	………	………
Total population	-1.274	-1.626	-1.994	-3.177*	-1.415	-1.954	-3.543*
Tourists' arrivals	-2.001	-2.678*	………	………	-2.450*	………	………
Renewable energy consumption	-0.266	-2.289*	………	………	-0.520	-4.832*	………

Note: *represents that value is significant. CADF: "Cross sectionally Augmented Dickey Fuller". CIPS: "Cross sectionally Augmented IPS". Source: Author's Calculation.

4.7 Endogeneity test

Endogeneity refers to the association between dependent and unexplained variables. As endogeneity leads to biased results, it is important to remove endogeneity or find a solution to correct it. So that results can be inferred unbiased. By applying 2 SLS (two stages least squares), which is usually used to check the endogeneity in the model, the results showed that variables are exogeneous by accepting the null hypothesis with P-values as described in the Table 8 below.

Table 8. Results of endogeneity test

Durbin (score), Chi^2 (2) = 2.36994 (P = 0.3058)
Wu-Hauman F(2,613) = 1.17608 (P = 0.3092)

Source: Author's Calculation

Thus, it ensures that the model is free of endogeneity. The study can apply DOLS model now to find cointegration between dependent variables and regressors, as there is no endogeneity.

4.8 DOLS (Dynamic Ordinary Least Square) technique

Table 9. Results of DOLS

Variables	Coefficient	t-statistic
GDP	0.354128*	21.76202
Total population	-0.448936*	-21.87056

Tourists' arrivals	0.047676	3.310527
Renewable energy consumption	-0.505694	-13.05292

Note: R^2 = 0.70, *represents that value is significant. The variable CO_2 emissions is dependent. Author's Calculation

The results from DOLS model indicate a significant relationship between independent and dependent variables. The positive coefficient (0.354) indicates that 1% rise in GDP cause a 0.354% rise in CO_2 emissions. A negative coefficient of population growth signifies that when the population increases, it reduces CO_2 emissions, probably sue to the efficient use of resources. Similar findings for population growth and CO_2 emissions were found by [12] and [33] using ARDL approach both, and [32] using DOLS approach. This may be supported as population growth is associated with urbanization and investment in energy efficient technology in G20 nations. Tourism depicts a significantly positive relation with the dependent variable (CO_2 emissions) with a coefficient of (0.047) signifies 1% growth in tourism is reflected by 0.0475 increase in CO_2 emissions. Renewable energy coefficient (-0.505) is negative, indicating a 1% upsurge in use of renewable energy reduces the carbon emissions by 0.505%. Thus, through using cleaner energy carbon emissions can be lowered significantly. Additionally, the value of R^2 is 0.70. Therefore, it suggests focusing on consumption of renewable energy to protect the environment and foster higher economic growth.

4.9 Panel Cointegration Analysis

Panel cointegration is important as it assists in identifying the long-term association between the variables and provides statistical efficiency. Here, cointegration analysis is conducted through the Kao test as major. The P- values are 0.000 for the test, so, it rejects the null hypothesis (H_0: no cointegration exists between variables) at the 1%, 5%, and 10% levels of significance [41]. Hence, supports long-term association between dependent variable and explanatory variables.

Kao test

Table10. Results of Kao test

	Statistics	P-value
Modified Dickey-Fuller	-32.1609	0
Dickey-Fuller	-21.6331	0
Augmented Dickey-Fuller	-13.0063	0
Unadjusted modified Dickey-Fuller	-37.8869	0
Unadjusted Dickey-Fuller	-21.9175	0

Source: Author's Calculation

For more specifications, Pedroni and Westerlund tests are conducted.

Pedroni test

Table11. Results of Pedroni test

	Statistics	P-value

Modified Phillips-Perron	-4.4727	0
Phillips-Perron	-18.3722	0
Augmented Dickey-Fuller	-17.68	0

Source: Author's Calculation

Westerlund test

Table 12. Results of Westerlund test

Statistic	P-value
3.2473	0.0006

Source: Author's Calculation

Pedroni and Westerlund's test also confirm that a long-term cointegration exists between the dependent and independent variables, as they both reject the null hypothesis (H_0).

The findings of the study indicates that the selected variables have a significant relationship. A long-term linkage can be indicated between carbon emissions and their drivers, which are GDP, tourism and population growth. Therefore, consumption of higher clean energy sources by the countries reduces CO_2 emissions, highlighting how renewable energy sources can resolve environmental degradation.

5. Conclusion and policy Implications

In nutshell, through the empirical analysis the study reveals that when an economy grows, it includes carbon emissions. Tourism, being the key driver of economic growth, also pressurize to use natural resources, especially in the energy sector. With international tourists' arrivals, carbon emissions have risen due to energy consumption in transportation and other tourist-related activities. promoting sustainable tourism and shifting towards renewable energy can mitigate environmental harm and support economic growth. The efficient use of resources and consumption of clean energy by the population of the country supports the conclusion that population increase and carbon emissions have a negative association. Furthermore, the consumption of renewable energy also highlighted a significant negative relation, which suggest carbon emissions can be declined by utilizing clean sources of energy. The study highlights the significance of policymaking in preserving the environment and sustaining economic growth together.

Although, the current study utilized all the potentials to give focus on several variables namely, tourism arrivals, GDP, population growth, CO_2 emissions and renewable energy. Despite of these variables, some more relevant variables such as industrialization, urbanization, FDI and technological innovations may be included. Furthermore, in the given study tourism is proxied by the number of tourists' arrivals while more proxies such as number of tourists' departures, tourism revenue etc. may be considered as well. Further studies may focus on more clusters and groups to study the dynamics of the economy and climate change by incorporating more indicators related to the environment and, hence, can assess the impacts of tourism on climate change [42].

G20 nation focuses on the adoption of renewable energy and aims to triple global renewable energy capacity by 2030. Countries should also promote environmentally friendly and sustainable tourism to safeguard long-term sustainable development while addressing challenges related to carbon emissions and environmental degradation. Also, the study explores the diverse interplay among tourism, economy, population, and carbon emissions, suggesting to use renewable energy sources and developing stronger sustainable practices and policies to achieve global environmental goals. Policymakers may seek sustainable growth while addressing CO_2 emissions and environmental degradation. The government may provide subsidies on clean energy sources such as smart grids and solar systems. For tourism, to utilize renewable energy public-private partnership could be more effective where owners of hotels and stays may employ solar panels for heating water for the tourists, furthermore use of wind turbines and motion sensor lights would be a great addition. This can be done on the ground level with the support from the tourists as well. Tourists may prefer home stays, walking and trekking, using public transport to save energy, in Bhutan, "High Value Low Volume tourism" [43] approach is used to save their environment along with maintaining their tourism and economic growth. Similarly, Costa Rica has attained a leading position in eco-tourism globally, through their continuous conservation efforts and innovative sustainable practices [44]. G20 countries may also adopt similar strategies to sustain the economy and environment together.

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