The Role of Green Technology Innovation on the Development of Sustainable Tourism: Does Renewable Energy Use Help Mitigate Environmental Pollution? A Panel Data Analysis

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Research Article

Keywords: Tourism development, Greenhouse Gasses Emission, Renewable energy, Energy

Posted Date: December 9th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-1077825/v1>

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Abstract

The tourism industry has been long blamed as the major driver to global warming due to it being the largest industry that uses more energy, most of which comes from sources that emits carbon-dioxide. However, despite all the blames on tourism for its negative effects on the environment, less work has been done to ascertain its impact on the environment. Unlike past studies that alludes that tourism development exacerbates the emission of carbon-dioxide hence global warming, the current research shows that in the OECD countries, tourism does not have any significant link with greenhouse gasses emissions. This is so because OECD nations have long started to shift from fossil fuel use, as sources of energy, to renewable energy use which doesn't exacerbates greenhouse gasses emissions. However, the current research concurs with the findings of past studies that renewable energy consumption significantly decreases greenhouse gases emissions. Using renewable energy sources of energy instead of fossil fuels should continue to be encouraged in all nations for the purpose of achieving low carbon in the future. The current study uses dynamic GMM model for 38 OECD countries from 2008 to 2019. Dynamic GMM model remains one of the best models since it corrects endogeneity problem in a model. GMM model overcomes autocorrelation, heteroskedasticity and normality problems, hence the robustness and reliability of results obtained. Gross Domestic Product and population size negatively affect greenhouse gasses emissions while inflation rate is observed to have a significant strong positive link with greenhouse gasses emissions.

Introduction

Tourism industry is one of the world industries that is largely blamed for causing greenhouse gases emissions which in turn causes global warming. The work of Tian, Belaid and Ahmad (2021) and Yue, Liao, Zhang, Shao and Gao (2021) alludes that the tourism industry had been long blamed for providing a strong impact on environmental degradation. However, it is shocking that despite all these accusations of the effects of tourism industry on environmental degradation, very few researches have been undertaken to examine the nexus between the two (see, for instance, Yue, et al., 2021; Tian, et al., 2021). Tourism industry is believed to negatively affect the environment because it uses more energy to undertake its activities. Yue, et al. (2021) also provides that the papers available, on the implications of tourism industry on the emissions of greenhouse gasses, provides contradictory results. For example, Zhang and Liu (2019) postulates that in the case of North and South East Asia (NSEA 10) countries tourism strongly causes environmental degradation, while Tian, et al. (2021) alludes that increase in Tourism development in the long-run tends to reduce emissions.

Therefore, there is still a gap in the literature study that needs to be covered by undertaking more researches in various nations and also by employing various methods for robust results. Due to this reason, the current research is aimed at covering the gap existing in the literature study by providing an alternative study on the impact of tourism development on greenhouse gases emissions. The current study differs from past researches in that it examines the impact of tourism development on greenhouse gases emissions in the Organization of Economic and Corporation Development (OECD) member countries which has not been examined before, to the best of our knowledge. The paper also employs dynamic Generalized Method of Moments (GMM) model which gives robust results in the existence of endogeneity in the specified model.

The research study also examines the Impact of renewable energy use on greenhouse gasses emissions. Renewable energy has to this point been applauded as the best alternative source energy that helps mitigate global warming effects since the sources of energy are friendly to the environment (Chaoqun, 2011; Salim & Rafiq, 2012; Becker & Fischer, 2013; Zhang & Liu, 2019; Shahbaz, et al. (2020), (for review see also, Deka, Cavusoglu & Dube, 2021; Deka & Dube, 2021). Of great importance is the Environmental Kuznets Curve (EKC) that was founded through a series of studies by Seldon and Sang (1994); Shafik (1994); Grossman and Kruger (1995) Stern, Common and Babbier (1996) after the work of Kuznets (1955) who adventured the existence of an inverted U-shaped association between income inequality and the growth of a nation's economy. The EKC proposition also argues that the inverted U-shaped curve association also exists between the growth of a nation's economy and environmental impacts. According to the study by Filippidis, Tzouvanas and Chatziantoniou (2021) the use of renewable sources and GDP growth rate exhibits a U-shaped curve, thus the EKC holds (see also, Ma, Ahmad & Oei, 2021; Dietz, Rosa & York, 2012). All these findings clearly point out that renewable sources of energy reduce environmental degradation and at the same time promoting economic growth.

As opposed to the many claims that tourism development exacerbates the emissions of greenhouse gasses, the current results in this research provides that in the OECD nations, tourism development does not have a significant impact on the emissions of greenhouse gasses. The reason behind the insignificant relationship between the two is due to the change by countries from using fossil fuel sources of energy to using renewable energy sources in the tourism industry. Thus, instead of using fossil fuel energy in the tourism industry, renewable energy has begun to be used. The results of the study also clarify the significance of renewable energy in curbing greenhouse emissions, since a negative significant effect has been ascertained.

Literature Review

Environmental Kuznets Curve (EKC)

Kuznets (1955) examined the association between income inequality and economic growth and came to a conclusion that the two exhibited for an inverted U-shaped relationship. According to the postulations by Kuznets (1955), as an economy grow from low GDP per capita to a higher one, income inequality tends to increase up until the turning point is reached. Further increases in economic growth beyond the turning point causes a decrease in income inequality in a nation. Almost forty years after the work of Kuznets (1955) other researchers such as, Seldon and Sang (1994); Shafik (1994); Grossman and Kruger (1995) Stern, Common and Babbier (1996) postulated that Kuznets' proposition is also applicable on environmental impacts, hence the EKC proposition was born. The EKC proposition, thus alludes that an increase in the economic growth of a nation will first encourages environmental degradation as nations uses sources of energy and engage on activities that harm the environment up until the turning point is reached where environmental stress is relieved such that any further increases in economic growth tends to reduce environmental degradation. Dietz, et al. (2012) argues that the turning point is achieved due to the shift of nations from fossil fuel energy use to renewable energy among many other factors, hence explains the reason behind EKC shape.

The argument by Dietz, et al. (2012) can be used to come up with proper policies in the tourism industry. Since the tourism industry heavily relies on energy to undertake its activities, if the industry uses fossil fuel

them an improvement in the tourism industry will come along with more degradation of the environment, which is the upward sloping part of the EKC curve. However, when nations realize the harm of non-renewable sources of energy and resort to using renewable energy then an improvement in the tourism industry will bring about less stress on the environment, which is the downward sloping part of the EKC curve. Tourism industry is good for the nations since it contributes a greater percentage on the countries' GDP and if it's growth damages the environment then a trade-off situation exists between the two. Thus, nations are encouraged to go for renewable energy which is environment friendly, see also Dietz, et al. (2012).

Impact of tourism development on the environment

It is generally agreed that tourism industry plays a very crucial role in causing environmental degradation in the world. This is so because the industry uses a lot of energy to carry out its activities. Most of this energy is obtained from non-renewable renewable sources that pollutes the air, thereby causing ozone thinning and hence global warming. The studies by Chaoqun (2011); Yue, et al. (2021); Tian, et al. (2021); Zhang and Liu (2019) among many others concurs that tourism development significantly impact the environment. The tourism industry is very crucial for the growth of the world's economy as it contributes a greater percentage of GDP. At the same time environmental degradation is not good for the world and the future generation. As a result, we agree with Dietz, et al. (2012) that this poses for a trade-off situation between both tourism development and environmental stress, since factors that improves tourism and hence GDP has the tendency of negatively affecting the environment. Therefore, nations should strive to come up with measures that promotes tourism development without harming the environment.

Empirical studies have so far brought mixed results on the nexus between the carbon-dioxide emissions and tourism development. Tian, et al. (2021) in their study observed that in the long-run increases in tourism development tended to reduce emissions of carbon-dioxide, indicating that tourism does not negatively affect the environment, rather it helps reduce pollution in the G20 countries. These findings are due to the reason that the G20 nations have started to shift from fossil fuel use to renewable energy use, hence the tourism industry which relies more on energy is having its activities handled through the use of renewable energy. However, these results contradict with the findings of Yue, et al. (2021) who postulates that tourism is a major driver of greenhouse gasses emissions. Thus, nations are encouraged to shift from using non-renewable energy and use those energy sources that are renewable as these sources will help mitigate environmental degradation.

Renewable energy and the environment

On the nexus between the use of renewable energy and greenhouse gasses emissions various studies has been done throughout the world (see for instance, Azam, et al. 2021; Mohsin, et al. 2021; Liu, et al. 2021; Xiaosan, et al. 2021; Hdom, 2019; Zhang, et al. 2021; Saldi & Omri, 2020; Wang, et al. 2021; Bhat, 2018; Attiaoui, 2017; Kahia, et al. 2019; Toumi & Toumi, 2019; Khan, et al. 2020) and different results were found. Some researchers observed that consumption of renewable energy provides a negative and significant effect on greenhouse gasses emissions which means that if more of renewable energy sources of energy are used in economic activities of nations the effects of greenhouse gasses emissions will be lowered (Khan, et al. 2020; Kahia, et al. 2019; Bhat, 2018; Zhang, et al. 2021; Wang, et al. 2021; Hdom, 2019; Xiaosan, et al. 2021).

These findings provide overwhelming evidence that if nations seek to curb the effects of greenhouse gases, then renewable energy is the way to go.

However, other few studies, for instance Mohsin, et al., (2021); Liu, et al., (2021) Zhang, et al., (2021), obtained a positive effect of renewable energy on greenhouse gasses emissions. These are some of the few studies that provides evidence that contradict with the wide literature studies and this anomaly might have raised due to models employed that might not be robust. Attiaoui, et al., (2017), and Toumi and Toumi, (2019) argues that the association between the two is neutral, while Saldi and Omri, (2020) alludes that no association exists between the two. Therefore, considering the overwhelming evidence provided by many studies that were carried out, as mentioned in the paragraph above, we ascertain that renewable energy use is capable of reducing greenhouse gasses emissions and should be used as a substitute to non-renewable sources.

Nexus between renewable energy and economic development

Recent studies on the nexus between use of renewable energy and the growth of the economy have shown that, renewable energy consumption provides a positive effect of economic growth (Wang & Wang, 2020; Smolovic et al., 2020; Rahman, 2020; Shahbaz, et al. 2020; Ivanovski, et al., 2021; Dogan, et al., 2021; Chen, et al., 2020). Thus, if world economies adopt the use of renewable sources, Gross Domestic Product will also be improved, on top of curbing greenhouse effect (see, Deka, Cavusoglu & Dube, 2021; Deka & Dube, 2021). Non-renewable energy has also been ascertained to have a significant positive effect on GDP despite it providing harm to the environment, Ivanovski, et al., (2021); Rahman, (2020), and this has left governments and policy makers facing a trade-off between the two. Both economic development and safe environment are of paramount importance to nations. Therefore, since renewable energy can be used in place of fossil fuel and can also improve GDP, then it is the way to go.

Various other researches have also ascertained renewable energy effect on employment. For example, Ge and Zhi, (2016) postulates that green economy positively affect employment, both in developing and developed nations. The association of renewable energy consumption and rate of foreign exchange as well as inflation has been ascertained and renewable energy use has been observed that it impacts both inflation and rate of foreign exchange negatively, showing that renewable energy use encourages appreciation of the foreign exchange value and stabilizes rate of inflation (Deka & Dube, 2021; Deka, Cavusoglu & Dube, 2021). Therefore, in order for nations to achieve a clean environment in the future together with high economic growth, stable inflation rate and strong exchange value, renewable energy use should be encouraged.

Research Design And Method

Sample and Data

To achieve the aim of this research study our sample data is of 38 Organization of Economic and Corporation Development (OECD) countries. Having used 38 countries in this research, this implies that our research makes use of panel data for the variables employed. The period of study is from 2008 to 2019 and yearly data is used. Therefore, since the data used is panel, then each variable is going to consist of 456

observations (12×38) and this data is large enough to produce reliable results that are not biased. Moreover, secondary data is used and is retrieved from OECD website.

Variables

In this current research seven variables from 38 OECD member countries are used for the purpose of achieving research study's aim. The seven variables employed are Greenhouse gasses emissions (GHG), Tourism development (TOR), Renewable energy (RE), Population size (POP), Inflation (INF), Gross Domestic Product (GDP) and Foreign Direct Investment (FDI).

Dependent variable

Greenhouse gasses emissions (GHG) of 38 OECD nations for the period 2008 to 2019 is expressed as the dependent variable in this research. Greenhouse gasses according to www.data.oecd.org refers to a combination of seven gasses that impacts global climate change. These gasses include: methane (CH₄), carbon-dioxide (CO₂), chlorofluorocarbons (CFCs), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), nitrogen trifluoride (NF₃), and Sulphur hexafluoride (SF₆) (www.data.oecd.org). The measurement of Greenhouse gasses emissions is thousand tones, tones per capita, while carbon-dioxide is measured in millions tones and tones per capita (www.data.oecd.org).

Independent variables

Three variables are expressed as explanatory variables in this study and these variables are: Tourism development, renewable energy and population size. The three variables have been chosen to be specified as explanatory variables of greenhouse gasses emissions because they are known to directly impact it. Tourism development indicator in this research is represented by Tourism receipts and spending. According to www.data.oecd.org, tourism receipts and spending constitutes of travel debits and credits and is the value of money spent by tourists on their visits outside of their own country. It is measured in United States (US) dollars. The tourism industry has been blamed as the major driver to greenhouse gasses emissions, Yue, et al., (2021); Tian, et al., (2021) and hence can be modeled to explain greenhouse gasses emissions. Renewable energy, according to www.data.oecd.org are those sources of energy that contributes to total primary energy supply, which are environmentally friendly and can be used over and over again. These sources of energy include: hydro, wave, geothermal, tide, solar and wind energy sources among many others. It is measured in thousand tones or as total primary energy supply's percentage. Renewable energy sources of energy have been promoted to be used as alternatives to fossil fuels that emits greenhouse gasses and hence can contribute in explaining greenhouse gasses emissions. Moreover, population size is the number of people that are present in, or people that are temporarily out of the country, including aliens who have permanently settled in the country (www.data.oecd.org). As the population size grows this means that more energy is required, since people use energy in their day-to-day activities and some of this energy is obtained from fossil fuels which emits greenhouse gases.

Control variables

To control for the model and to avoid missing out other explanatory variables, gross domestic product (GDP), inflation rate and foreign direct investment (FDI) are specified as control variables. GDP is the total value of

goods and services that are produced within the borders of a country irregardless of the citizenship status of the people involved in the production of those products. Thus, GDP include all products and services that might have been produced by local and foreign firms, as long as those products are produced within the boundaries of a country and not outside. Inflation is the rate at which prices of goods and services of a country changes over time, say in one year and in this research consumer price index (CPI) is taken to represent the rate of inflation (www.data.oecd.org). FDI flows is the value of cross border transactions that are related to direct investment and these take the form of equity, intercompany debt and earnings reinvestment transactions (www.data.oecd.org). It is measured in US dollars and as GDP share.

Method

As has been mentioned earlier on, this paper examines the impact of tourism development and renewable energy use of greenhouse gasses emissions therefore we follow the model below, as expressed in the form of a linear function:

$$\text{GHG} = f(\text{TOR, RE, POP, INF, GDP, FDI}) \quad (1)$$

Where, GHG represents greenhouse gasses emissions, TOR represents tourism development, RE represents renewable energy use, POP represents population size, INF represents rate of inflation, GDP represents gross domestic product and FDI represents foreign direct investment.

Due to the nature of our data sample size and time period of the study the best method to be used for robust results is dynamic Generalized Method of Moments (GMM) model. This is so because the number of countries included in our panel data (38) are more than the time period (12) under study. Therefore, when the number of countries or subjects under study is larger than the time period GMM model is the most suitable method to use. Anderson and Hsiao (1982); Holtz-Eakin, Newey and Rosen (1988); Arellano and Bond (1991); Arellano and Bover (1995); and Blundell and Bond (1998) in their series studies pioneered Dynamic GMM model. There are basically two types of GMM models, that is, first-difference GMM (GMM-DIF), by Anderson and Hsiao (1982); Holtz-Eakin, et al. (1988); and Arellano and Bond (1991), and Systems GMM model, by Arellano and Bover (1995); and Blundell and Bond (1998). The difference between the two is that first-difference GMM corrects endogeneity problem on the model through differencing the regressors and removing fixed effects, Arellano and Bond (1991), while systems GMM uses orthogonal deviations that subtracts variables' average of all future observations available (Arellano & Bover, 1995; Blundell & Bond, 1998). Systems GMM is generally preferred over first-difference GMM because it minimizes data loss and works well in both balanced and unbalanced panel data. First-difference GMM, in unbalanced data sets magnifies the gap because it subtracts previous data from contemporaneous one.

Generally speaking, GMM model is preferred over Ordinary Least Square methods because it overcomes the problems of heteroskedasticity, autocorrelation and normality problems (Fraj, Hamdaoui & Maktouf, 2018). Heteroskedasticity, autocorrelation and normality problems are very serious problems in time series data modelling since their presence will result in biased results being obtained. Therefore, any model that overcomes these problems is preferred. In addition to that, GMM model corrects endogeneity problem (see, Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998). Endogeneity emanates from various and different channels and is a situation where by one or more explanatory variables correlates with the error

term and these channels include but not limited to omitted variable(s) on the right-hand side of the regression, measurement errors of explanatory variables and simultaneity, where both the explained and the explanatory variable simultaneously affect each other.

In this research study we apply both systems and first-difference GMM for comparison purposes. The J-statistic and Arellano and Bond test of serial correlation are also employed as diagnostic tests. Before running dynamic GMM model in this study we start by checking the descriptive statistics of the variables, check unit root of the variables by employing Augmented Dickey Fuller (ADF) test, by Dickey and Fuller (1979) and Phillips Peron (PP) test, by Phillips and Perron (1988). Unit root test will help ascertain the integration order of the variables. Pedroni test of cointegration will also be used to check if the variables have a long run relationship. The equation below is the statistical representation of the GMM model employed:

$$GHG_t = \beta_0 + \beta_1 TOR_t + \beta_2 RE_t + \beta_3 POP_t + \beta_4 INF_t + \beta_5 GDP_t + \beta_6 FDI_t + et(2)$$

The statistical representation in equation 2 above represents the GMM model specified in this study. In the equation 2 above, GHG is the dependent variable while TOR, RE, POP, INF, GDP and FDI are explanatory variables. β_0 to β_6 are the Coefficient parameters of the models and et is the error term.

Results And Design

Descriptive statistics results

In Table 1 presented below in this research study, the results of the descriptive statistics of the indicators under study are presented. Greenhouse gasses emissions of all the 38 OECD countries for the period of 12 years has a mean value of 7.64, Maximum value of 21.76, minimum value of 1.27 and standard deviation of 3.94. Moreover, the mean, maximum, minimum and standard deviation values of tourism spending are 21495.56; 237726; 0; 35147.96 respectively. In the case of renewable energy use, the average, maximum, minimum and standard deviation values are 18.57; 12.48; 90.14; 0 and 16.98 respectively. Population size in the OECD countries is observed to have Mean, maximum, minimum and standard deviation values of 34.67; 328.33; 0.32 and 56.68 respectively. In addition, inflation rate is observed to have a mean value of 2.21%; Maximum value of 16.33%; minimum value of -4.48%; and standard deviation of 2.42%. The gross domestic product of the 38 OECD nations for the period under study shows that its average value is 38974.64; while it's maximum, minimum and standard deviation values are 120670.5; 10324.88 and 16969.43 respectively. Lastly foreign direct investment has a mean value of 27545.82 maximum value of 415271, minimum value of -151368.1 and standard deviation of 59263.18. The total number of observations for each and every variable is 456, see Table 1. The results of sum of each variable and Median value are also provided in Table 1.

Table 1
Results of descriptive statistics

	GHG	TOR	RE	POP	INF	GDP	FDI
Mean	7.461604	21495.56	18.56897	34.67290	2.206102	38974.64	27545.82
Median	6.870000	10887.50	12.48338	10.51072	1.776872	37684.20	7233.000
Maximum	21.76000	237726.0	90.13875	328.3300	16.33246	120670.5	415271.0
Minimum	1.270000	0.000000	0.000000	0.317404	-4.478103	10324.88	-151368.1
Std. Dev.	3.940370	35147.96	16.98201	56.67817	2.416702	16960.43	59263.18
Sum	3395.030	9780481.	8448.879	15776.17	1003.777	17733459	12533347
Observations	456	456	456	456	456	456	456

PP and ADF results unit root test

This research uses ADF and PP unit root test for checking the integration order of the variables under study and the results are given in Table 2 below. ADF and PP unit root test methods have been identified as the best and most reliable methods, see Granger (1986). Greenhouse gasses emissions in Table 2 below is not stationary at level and stationary at first difference as per ADF unit root results. Both ADF and PP test of unit root agrees that greenhouse gasses emissions is integrated of order 1. Tourism spending according to PP test is stationary at first difference at 1% significant level, hence it is integrated of order 1 and ADF test also confirm the same results at 1% significant level. Renewable energy use as per the findings in Table 1 is not stationary at level and stationary at first difference as per ADF test results, while PP test also confirms that at first difference it is indeed stationary. Moreover, Population size, as per PP test results, is not stationary at level but stationary at first difference at 1% significant level. The ADF test results also confirms that indeed at first difference it is stationary. Inflation rate according to both ADF and PP test results is stationary at both level and first difference at 1% significant level. The log of GDP (lnGDP) is not stationary at level and stationary at first difference as per both ADF and PP test. FDI at 1% significant level is not stationary at level but stationary at first difference as per ADF test, while PP test also confirms that indeed it is stationary at first difference, see Table 2 below.

Table 2
ADF and PP unit root results

	ADF		PP	
	level	1stD	level	1stD
GHG	88.73	141.74***	153.86***	338.43***
TOR	105.6**	113.13***	61.90	113.19***
RE	63.19	124.57***	168.32***	368.16***
POP	111.6***	141.52***	50.45	126.67***
INF	114.1***	202.2***	181.39***	323.64***
lnGDP	6.844	368.93***	8.975	426.44***
FDI	100.43**	145.99***	265.46***	429.73***
Note: *** significant at 1%				
** significant at 5%				
* significant at 10%				

Pedroni cointegration test

Coi

Integration test is one crucial test in economic modelling that needs to be checked in order to ascertain the long-run relationship between variables, Granger (1986); Engle and Granger (1987). According to Table 3 below in this research, Pedroni cointegration test is used. The results of Group ADF t-Statistic, Group PP t-Statistic, Panel PP t-Statistic and Weighted Statistic, Panel ADF t-Statistic and Weighted Statistic are significant at 1% level of significant showing that the null hypothesis of no cointegration should be rejected and accept that the variables are cointegrated. Group rho-Statistic, Panel v-Statistic and Panel rho-Statistic results show that null hypothesis of no cointegration should be accepted. However, this is overcome by the overwhelming evidence from Group PP-Statistic and ADF Statistic, and Panel PP-statistic and ADF-statistic which shows that the variables are cointegrated. Therefore, there is a long-run equilibrium relationship between greenhouse gasses emissions, tourism development, renewable energy, population size, inflation rate, GDP and FDI of the OECD countries.

Table 3
Pedroni results of cointegration

	t-Statistic	Weighted Statistic
Panel v-Statistic	-5.2744	-6.3097
Panel rho-Statistic	7.4942	7.2732
Panel PP-Statistic	-12.982***	-12.624***
Panel ADF-Statistic	-7.2490***	-2.8644***
Group rho-Statistic	10.2506	
Group PP-Statistic	-18.2575***	
Group ADF-Statistic	-3.5639***	
Note: *** significant at 1%		
** significant at 5%		
* significant at 10%		

Panel GMM Results and discussion

In this research study we give the findings of dynamic panel GMM model in Table 4 below. Both systems GMM and first-difference GMM model's findings are presented. The dependent variable in this model is greenhouse gasses emissions while the other variables are explanatory variables. The first difference of greenhouse gasses emissions is employed as an explanatory variable to cater for endogeneity problems that might exist. The second difference of greenhouse gasses emissions is also automatically employed as the model's instrument. Systems and first-difference GMM provides that one lag value of greenhouse gasses emissions significantly affects current value of greenhouse gasses emissions negatively. This shows that if greenhouse gasses emissions was high in the past it will drop in the future. This is a good sign since nations are working towards a low carbon environment in the future. The results of systems and first-difference GMM indicates that there is no significant association between Tourism receipts and spending in the OECD nations with greenhouse gasses emissions. This shows that tourism development does not significantly impact the emissions of greenhouse gasses. These findings oppose the postulations of Zhang and Liu (2019); Yue, et al. (2021) who alludes that tourism development positively affect carbon-dioxide emissions. The Coefficient value of systems GMM is positive in this research, see Table 4, indicating that a rise in tourism development should increase greenhouse gasses emissions, however it is not significant. The difference in the findings with past studies maybe due to the fact that the studies are done in different countries with different policies. OECD member nations have already started shifting to renewable energy use hence the reason behind no significant impact of tourism industry on greenhouse gasses emissions.

Renewable energy consumption provides for a very significant negative impact on greenhouse house gasses emissions. The results for both systems and first-difference GMM are significant at 1% level. Therefore, there is a strong negative link between renewable energy use and greenhouse gasses emissions. This shows that

renewable energy use is the major driver towards reducing greenhouse gasses emissions, Yue, et al. (2021); Tian, et al. (2021); Chaoqun (2011) and countries must be encouraged to adopt green technology to achieve low carbon in future (Salim & Rafiq, 2012; Becker & Fischer, 2013; Deka, Cavusoglu & Dube, 2021; Deka & Dube, 2021). The results of systems GMM in Table 4 below gives that population size of the OECD nations negatively affect greenhouse gasses emissions showing that an increase in population size significantly reduce greenhouse gasses emissions at 10% significant level. The Coefficient of first-difference GMM is negative but not significant. The findings on the nexus between population size and greenhouse gasses emissions differs from past studies such as Yue, et al. (2021) who observed that population positively affect carbon-dioxide emissions. The difference may be due to different population sizes and policies on population growth, for example some countries have adopted the one child policy which has seen population decreasing in some parts of Europe, together with the adoption of renewable energy use which does not emit greenhouse gasses.

Inflation rate is observed to provide a significant positive influence on greenhouse gasses emissions. This shows that high rate of inflation tends to influence an increase in the emission of greenhouse gasses. Therefore, if Inflation rate is stabilized together with using renewable energy sources, then a low carbon future accompanied with low rates of inflation will be achieved (Deka & Dube, 2021; Deka, Cavusoglu & Dube, 2021). In addition, Gross Domestic Product is observed to have a significant negative link with greenhouse gasses emissions. An increase in GDP of the OECD nations has the effect of reducing carbon-dioxide emissions. These findings are favorable in that no trade-off situation is faced by policy makers as nations seek to improve GDP and at the same time reduce greenhouse gasses emissions. All credit goes to green technology use as most of these OECD nations have resorted to using renewable energy and hence enjoying its fruits. FDI is found to have no significant impact on greenhouse gasses emissions. The Coefficient is negative indicating that an increase in FDI should reduce greenhouse gasses emissions, however its impact is not significant.

Table 4
Results of Panel GMM model

	GMM-SYS		GMM-DIF	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
GHG(-1)	-0.2855	-6.0202***	-0.2803	-6.2461***
TOR	1.6107	0.0267	-3.7306	-0.5211
RE	-0.1914	-13.875***	-0.1737	-13.424***
POP	-0.0974	-1.8742*	-0.1245	-1.5839
INF	0.1485	7.8762***	0.1449	11.936***
lnGDP	-2.8936	-6.8497***	-2.7529	-5.5463***
FDI	-1.0207	-0.1171	-6.7908	-0.1277
J-statistic		33.8002		33.7359
AR(1)				0.0447
Note: *** significant at 1%				
** significant at 5%				
* Significant at 10%				

Greenhouse gasses emissions (GHG) is the dependent variable.

The second lag of greenhouse gasses emissions (GHG(-2)) is the model's instrument.

The J-statistic results that is used for diagnostic testing of GMM model to see if the model is correctly specified gives that its value is less than the critical value and its p-value is greater than 10% significant level, showing that we should accept the null hypothesis that the model is specified correctly. Arellano and Bond test of serial correlation is also employed for first-difference GMM and its value is less than the critical value, while it's p-value is greater than 10% significant level. Therefore, we accept the null hypothesis, that there is no serial correlation problem in the model. Thus, the findings provided in this model are robust, reliable and valid.

Conclusion

The current study is undertaken for the purpose of covering the gap existing in the literature study on the association between Tourism development and environmental degradation. The tourism industry has been long blamed as the major driver to global warming since it is one among other industries that uses more energy (Chaoqun, 2011), most of which comes from sources that emits carbon-dioxide. Unlike past studies that alludes that tourism development exacerbates the emission of carbon-dioxide hence global warming (Tian, et al. 2021; Yue, et al. 2021), the current research shows that in the OECD countries, tourism does not

have any significant link with greenhouse gasses emissions. This is because OECD nations have long started the shift from fossil fuel use as sources of energy to renewable energy use which doesn't exacerbates greenhouse gasses emissions. However, the current research concurs with the findings of past studies that the consumption of renewable energy significantly reduces greenhouse gases emissions (Hdom, 2019; Mohsin, et al., 2021; Xiaosan, et al., 2021; Bhat; 2018; Kahia, et al., 2019; Khan; et al., 2019). Renewable energy use should continue to be encouraged in all world nations for the purpose of achieving low carbon in the future (Salim & Rafiq, 2012; Becker & Fischer, 2013; Deka & Dube, 2021). The current study uses dynamic GMM model for 38 OECD countries from 2008 to 2019. Dynamic GMM model remains one of the best models since it corrects for endogeneity problem in a model, Arellano and Bover (1995); Arellano and Bond (1991); and Blundell and Bond (1998). GMM model also overcomes autocorrelation, heteroskedasticity and normality problems (Fraj, et al., 2018), hence the robustness and reliability of results obtained. Gross Domestic Product and population size negatively affect greenhouse gasses emissions while inflation rate is observed to have a significant strong link with greenhouse gasses emissions. The results of Pedroni cointegration test show that the indicators under study have a significant long run relationship because they are cointegrated, Granger (1986).

The limitations of the study are that it might have omitted other crucial explanatory variables that might provide significant impact on greenhouse gasses emissions, such as urbanization, and fossil fuels use among many others. However, the results are robust because dynamic GMM model corrects for endogeneity problem that might arise due to omission of some regressors. Moreover, the findings of this research can be generalized to other developed nations with the similar conditions to those of the OECD. Therefore, there is need for more work to be done to examine on how tourism development, population size, renewable energy use and other regressors, affect greenhouse gasses emissions in developing nations such as African countries.

Declarations

Funding

No funding was received from any organization.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The data used in this paper is secondary data and were retrieved from the Organization for Economic Co-operation and Development (OECD) website www.oecd.org

Ethical Approval

Not Applicable

Consent to Participate

Not Applicable

Consent to Publish

The authors guarantee that this manuscript has not been previously published in other journals and is not under consideration by other journals. The authors also guarantee that this manuscript is original and is their own work.

Authors Contributions

AD: Conceptualization, Methodology. **CB:** Writing - original draft, Software. **HK:** Data curation, Writing – review. **HO:** Editing, Supervision. **AO:** Visualization, Investigation.

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