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Modelling Sustainable Non-Renewable and Renewable Energy Based on the EKC Hypothesis for Africa's Ten Most Popular Tourist Destinations

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Abstract: The main purpose of this study was to examine how tourism, GDP, renewable energy, and fossil fuels cause environmental damage. This study examined ten African countries between 1997 and 2021 to test the environmental Kuznets curve (EKC) theory. Egypt, South Africa, Kenya, Morocco, Tanzania, Tunisia, Mauritius, Ghana, Uganda, and Nigeria are the ten African countries with the most tourists. In this paper, the augmented mean group (AMG), mean group (MG), and common correlated effects mean group (CCEMG) models were used to deal with slope heterogeneity (SH), cross-sectional dependence (CSD), and a mix of first-differenced and level stationary variables. Though the inverted U-shaped exists, the findings are significant only for MG. The impact of renewable energy is favorable for the environment and significant for the AMG estimator. Inversely, impact of tourist arrivals and fossil fuels are detrimental for environment and significant. Based on the findings for each country, the tourism-based EKC theory only works for Kenya, Egypt, and Tanzania. The research found that using more renewable energy minimizes CO_2 emissions more effectively in almost all countries except Morocco and Ghana. Ghana, Kenya, and Uganda's CO_2 emissions increase when more tourists come from other countries. For the sake of both tourism and the environment, the government must reconsider its tourism policies and implement ones that include renewable energy. The findings of this study assist in the transition to clean energy, aiding in sustainable tourism growth. As a result, selected countries should develop a new tourism plan that focuses on renewable energy sources and protects the environment.

Keywords: carbon emission; environment; EKC; quantile regression; CCEMG; renewable energy; tourist arrivals; tourism in Africa

1. Introduction

The importance of tourism has increased in both developed and developing nations as proof of its favorable effects on economic growth has emerged in recent decades. Tourism has significantly impacted the economies of numerous nations as it generates income, taxes, foreign currency, and jobs. According to Lee and Brida [1,2], tourism can stimulate the development of new infrastructure and human resources, boost the efficiency of other economic sectors via either direct or indirect spillover effects, generate employment possibilities, and benefit hotels through economies of scale. Additionally, there is proof that micro-economies that rely heavily on tourism flourish [3]. The tourism industry has a substantial impact on the growth of economies and the creation of new jobs all over the world [4]. Visitors from other countries spent $1.8 trillion globally in 2019. This represents 6.8% of all goods and services traded globally. However, mobility constraints caused a reduction in the tourism and travel industry's contribution to global GDP from 10.3 percentage points in 2019 to 5.3 percentage points in 2020. The new figure is 6.1% higher than before.

According to the WTTC [5], the tourism sector in Sub-Saharan Africa could generate 3.8 million direct and indirect jobs over the next decade. Even though tourism is firmly established in many developed economies, Africa is only beginning to realize its full potential. The tourism industry in Africa is booming, with 67 million tourists visiting annually. Nonetheless, Africa remains far behind the rest of the world. Only 5% of all tourists visited Africa in 2018 [6]. Tourism has not been fully recognized as an essential source of economic and development power that could strengthen and expand the economies of African nations attempting to maintain and increase their impressive growth rates over the past few years. Africa only accounts for 1% of the $1.7 trillion tourism revenue [7]. Therefore, Sub-Saharan Africa has a great deal of tourism development potential.

According to UNWTO [8], all ten African countries with the highest number of tourist arrivals show an upward trend from 1997 until 2009. Ghana, Nigeria, and Uganda are the top three in tourist arrival, while Egypt is the least visited country. There was a sharp and temporary decline in tourist arrival for all countries between 2010 and 2011, possibly due to the global economic slowdown that took place between 2008 and 2010. However, the number of tourist arrivals has begun on track, proving that Africa has become a preferred destination by foreign tourists over other regions. Since the 1950s, the number of international tourists has increased by four to five per cent annually. Sub-Saharan Africa overtook Asia and the Pacific as the world's second-fastest growing tourist destination in 2020, with an increase in visitor numbers of 8% between 2019 and 2020 despite the pandemic [8]. Transportation and lodging for tourists rely on facilities, including airports, ports, roadways, railheads, and communications networks. More and more sightseers are opting to explore by car. There will be severe consequences for the environment as a result of this. Fossil fuels are integral to the tourism industry since travelers rely on them to transport them to and from their locations, power their hotels, and run the many other activities that make up a vacation.

Empirical and theoretical evidence links higher energy use to faster economic expansion. As a result, growing energy consumption is expected to boost economic growth. However, this could lead to even greater carbon emissions and the accelerated depletion of Earth's natural resources. For decades, carbon emissions' contribution to climate change and global warming have been at the forefront of political and media discourse around the world. Both the environment and humanity are in danger from climate change and global warming [9–15]. They must be slowed or stopped if they are to be mitigated [16]. Many hours have been spent investigating the significant contributors to carbon emissions. Some research did not support a correlation between energy use and carbon output, but it was still there. According to empirical research, carbon emissions rise with non-renewable energy sources but fall when renewable energy is implemented [17]. However, there is a lack of research into how expanding access to renewable electricity sources affects national carbon footprints. Because there has been so little prior empirical research on the influence of tourism on carbon emissions, this study focuses on African countries. Concern has been voiced by regional officials, scientists, and thinkers regarding carbon emissions. Carbon dioxide emissions rose to 62.8% in 1980, peaked in 1993, and fell to 51.4% in 2014. From

1980 to 2001, energy and heat generation were the fastest-growing source of global carbon emissions (from 39.8% to 59.2%) before levelling off at 54.5% in 2014.

Weather plays a significant part in luring visitors and giving some vacation spots an edge, which is why the industry relies heavily on it. Tourism is widely recognized as an essential driver of economic expansion. There will be an increase from 3.1% in 2014 to 3.3% in 2025 in the substantial contributions of the travel and tourism industry to GDP. According to the UNWTO, changes in rainfall patterns, water availability, and temperature are affected by tourism. The United Nations Environment Program (UNEP) and the World Tourism Organization [8,18,19] both report that this affects the distribution of biodiversity. The area's sea, land, water, and natural settings have possibilities for developing the tourism business. Approximately five per cent of the world's carbon dioxide emissions come from tourism [8]. In recent years, governments worldwide have begun to see tourism as a tool for economic growth and social progress. However, it is still one of Africa's principal drivers [20].

According to Rusu [21], increasing the number of tourists means a greater need for locally produced goods. The "free" resources used in tourism, such as coasts, mountains, and natural beauty, are often located in the world's poorer nations. When properly dispersed, tourism can profoundly affect the global distribution of wealth. Unfortunately, tourism does have some negative repercussions that must be dealt with. While tourism improves the living conditions of the host community, developing nations, especially in Africa, have yet to unlock the best political will and technical skills to handle global warming and tourist policies. The role of various national governments is crucial when addressing the adaptation of sustainable practices to lessen the danger of climate change policies.

Travel and tourism are vulnerable to climate change, especially in developing countries. African Union [22] reported that tourism is a major source of global greenhouse gas (GHG) emissions. As a result, the African continent participates in international efforts to combat climate change, which helps to increase policy alternatives for sustainable development. Based on data from the 2015 Climate Change Vulnerability Index, Zimbabwe, Sierra Leone, Madagascar, Mozambique, the Democratic Republic of the Congo, and Malawi are some of the most at risk in Africa from climate change consequences [23]. In addition to those countries, others are on that list of rising markets. Saharan and Southern Africa have decreased precipitation, while the Central African Republic has increased precipitation. The effects of carbon emissions on the economy and the environment and the policies that can be put in place to mitigate these effects have been the subject of fierce debate among experts and policymakers for years. The growth of the tourism industry is predicted to increase real per capita income, which will encourage even more foreign travel.

Tourists from other countries boost an economy by spending money on local transportation, utilities, and other services. These touristy places have likely benefited from tourism and associated economic activities (economic growth), but they have also become more susceptible to global warming as a result of the increased carbon emissions caused by increased energy consumption and the use of automobiles that rely on fossil fuels and other energy pollutants. We hope to contribute to the literature on tourism-emissions links by determining if the variables under observation predict each other through experimentally analyzing the direction of causal interaction between the components of interest.

In essence, the study adds four major benefits to the field. First, the paper introduced tourism-induced EKC. For our purposes, the combination of rapid economic growth and a rise in the number of tourists provide excellent conditions for the emergence of tourism-induced EKC. Second, the study correlates tourism-induced EKC with significant factors such as income, renewable energy, and fossil fuel usage. The EKC has not yet been applied to a multivariate framework, and this study is the first to do so, focusing on the most visited tourist destinations across Africa. Furthermore, this study finds that the macroeconomic elements that contribute to environmental deterioration are, in this particular African tourist hotspot, more regional in scope. An extended EKC model has been used to analyze CO_2 emissions, energy consumption, trade, financial sector growth, population growth, and tourism development [24–29]. Third, no other researcher has looked at the comparative growth of tourism over long periods of time using the 10 most popular African tourist locations as they have in this work. Fourth, the slope heterogeneity and CSD issues are taken into account in the analysis. The top African tourist destinations are probably very connected to one another by trade, tourism, education, religion, and treaties.

The first part of the study gives context on the relationship between tourism and CO_2 emissions, as well as on the EKC literature in key African countries. The rest of the parts of this investigation are as follows. First, the methodology and research paradigm are laid out in Section 3. Our results from the field research are presented in Section 4. In Section 5, the findings are discussed. Section 6 shows the conclusion, limitations, and future research. Finally, the policy suggestions are presented in Section 7. Appendix A shows the statistical data of this study and Abbreviations shows the abbreviation table of this study.

2. Literature Review

2.1. Tourism and Macroeconomic Variables

Numerous studies have examined how tourism affects macroeconomic variables such as GDP growth, urbanization, energy usage, and carbon dioxide emissions [26,30–34]. CO_2 emissions in five of Southeast Asia's most visited cities were either linear or nonlinear using the panel cointegration test, and pooled mean group methodologies were established by Sherafatian-Jahromi et al. [35]. This study has significant consequences because tourism and CO_2 emissions are cointegrated throughout time. To investigate how GDP growth and tourism affected CO_2 emissions, Shakouri et al. [31] analyzed panel data from several Asia-Pacific nations. The EKC hypothesis was tested by examining how several variables (GDP expansion, tourism, fossil fuel consumption, and carbon dioxide emissions) were related. Eventually, both CO_2 emissions and the number of tourists will decrease. Between 1995 and 2017, Ravinthirakumaran and Ravinthirakumaran [36] examined the APEC region's tourist industry, power consumption, economic expansion, and carbon dioxide emissions. This result was obtained using methods for computing heterogeneous panels with cross-sectional dependence. Constant differences between the variables indicate cross-sectional reliance.

The Westerlund panel cointegration test demonstrates a long-term link between the variables. While growth in tourism and energy consumption helps soften the blow of a growing economy, they ultimately have a minor impact on the world's CO_2 emissions. Based on the panel non-causality test results, economic expansion and tourism only cause CO_2 emissions in one direction. Controversy surrounds the EKC hypothesis and the possible costs of creating a tourism business, but neither issue is ancient. This has been a significant issue of contention for quite some time when discussing the correlation between tourism and greenhouse gas emissions. Researchers have extended the original EKC framework to include new policy variables such as electricity [33], exports [37,38], demography [24], urban development, economic growth [39], and research and development (R&D) [40]. As part of their research into a tourism-induced environmental Kuznets curve (EKC) model for the United Arab Emirates (UAE) from 1984 to 2019, Majumdar and Paris [41] published an autoregressive distributed lag (ARDL) model to determine the marginal impact of tourist arrivals and related variables such as credit facilities to the private sector, urban growth, and power generation use on emissions of CO_2. Long-term coefficients validated the EKC hypothesis of an inverted U-shape for carbon dioxide emissions and per capita income, environmental damage due to tourist arrivals, and expansion of financial sector, despite the Pesaran limitations test finding a repetition of short-run estimates.

2.2. Tourism, Energy Mix and Environmental Kuznet Curve (EKC)

Ciarlantini et al. [42] developed five panels for each country, including data on GDP, energy consumption, and the proportion of hotel nights spent by locals and tourists alike, to examine the likelihood of a tourism-induced EKC. The pooled OLS estimator, however, showed that the idea of tourism-induced EKC is not supported by any of the individual nations' datasets. An examination of the data for Portugal, Italy, and Greece revealed an inverse relationship between economic expansion and pollution. The findings were cloudier in countries such as France and Spain. In addition, tourists from other countries contribute to pollution, whereas those from the United States have the opposite effect. Panel data were used from 1995–2017 and the EKC hypothesis considered by Usman et al. [43] to test the hypothesis that the 20 economies with the largest emissions of greenhouse gases also had the highest rates of economic growth, energy consumption, and tourism. The team found that the EKC theory did not exist. With data from seven different countries, Isik et al. [44] tested the validity of the EKC hypothesis. They also considered the impact of the countries' usage of renewable energy sources and income from overseas tourists on their overall CO_2 emissions. Unfortunately, the hypothesis that tourists were also responsible for EKC was valid only in France. Researchers in the United States, France, Italy, and the United Kingdom found that increasing the usage of renewable energy sources reduced carbon dioxide emissions. However, the increase in international tourists had a side benefit on Italy's carbon dioxide emissions. Using annual data from 1995–2018 for the BRICS countries, Aziz et al. [45] investigated the connection between carbon emissions, tourism, and renewable energy. Quantile regression allowed us to observe tourism's statistically significant negative effect between the 10th and 40th quantiles (MMQR). On the other hand, the differences become much smaller with higher quantiles. Additionally, an inverted U-shaped EKC curve was predicted to be evident outside the 10th and 20th quantiles. Alsayed and Malik [46] simulated annual data from 48 African countries from 1960 to 2014 to analyze the EKC for the World Bank's specified income categories for Africa's economic sectors. The researchers used panel data regression and found a positive relationship between CO_2 emissions and GDP in Africa. The research also shows that the EKC hypothesis of an inverted U-shaped curve across all African economic levels in high-income countries with a higher turning point is valid and this finding was supported by Papavasileiou and Tzouvanas [47].

In a study spanning from 1980 to 2013, Ozkan et al. [48] tested the environmental Kuznets curve (EKC) theory in 16 developing and 16 developed countries. They focused on how increased air travel and economic development contribute to greenhouse gas emissions. Using World Bank yearly panel data, they observed low levels of environmental consciousness in both categories during 1980–2000. The results of the experiments support the inverted U shape of the EKC by demonstrating a dramatic increase in environmental sensitivity between 2001 and 2013. However, the stated political aims and intentions of the Kyoto Protocol align with these observations. They ran the Johansen cointegration test to elucidate these results. Apart from Colombia and Turkey, they discovered a consistent long-term relationship between air travel, emissions, energy consumption, and GDP in every country.

Mitic et al. [49] collated data from an extensive survey of individuals and groups of nations to test the EKC's validity. The many periods, external circumstances, and theoretical and methodological perspectives were cited as reasons for the lack of consensus. Researchers double-checked that their findings were consistent with those of other studies. Bese [50] analyses the probability of EKC homogeneity in Ghana using the Johansen cointegration and VAR Granger causality and Wald test assumptions. The Johansen cointegration test was used to look at long-term correlations between GDP, CO_2, energy consumption, and the square of GDP; however, neither the EKC hypothesis nor causal linkages between GDP and energy consumption were verified for Ghana. This lends credence to the neutrality hypothesis. Xu [51] collated environmental and economic panel data from 31 provinces, municipalities, and autonomous areas to study pollution's impact on China's economy.

Evidence supports the EKC theory that wastewater has an "inverted U-shape" relationship to GDP expansion. The strategy asks China to improve exhaust gas treatment instead, despite the country's relatively advanced wastewater treatment technology, given its level of development. Gao et al. [34] could characterize the trajectories and personalities of the EKC's evolutionary growth. Numerical analysis revealed a positive inverted U-shaped correlation between industrial waste discharge and GDP per capita. On the other hand, the GDP per capita was negatively correlated with industrial dust emissions. We find it surprising that the lines connecting NO_2 levels to GDP per capita, PM levels to GDP per capita, and dust levels to GDP per capita diverge. It was speculated that a rise in the economy would not prevent global warming. That is why they advocated for tighter regulations on industrial pollution. Similarly, Nuroglu and Kunst [52] computed the EKC by surveying a group of nations, including Mexico, Turkey, Azerbaijan, Bulgaria, Iran, Romania, and Gabon. This study aimed to investigate the potential of the emerging economies that make up the cluster and authors found that traditional and environmentally friendly economics use inverted U-shaped Kuznets curves.

Reviewing the literature, history, policy conceptions, and conceptual and methodological criticism of EKC, Sinha and Bhatt [53] offered a complete overview. The authors approximated the EKC with secondary data for India. They applied Kuznets' original model to calculate the monetary value of the inverse relationship between carbon emissions (in metric tons per capita) and GDP. They argue that the government of India is not renting the EKC out enough because the GDP of India increased after 1990 while CO_2 emissions increased more slowly. Kurniawan and Managi [54] used data between 2002 and 2012 to determine the relationship between pollution and income in Tangerang City. They used a pooled data regression technique to develop a model of the environmental Kuznets curve (EKC). The fixed effects model (FEM) and random effects model (REM) with a quadratic intercept were used. The results guided the quadratic FEM model toward the EKC-suggested link between per capita income and environmental quality.

From 1971 to 2008, GDP growth, energy use, trade openness, and population density theorize about EKC in Pakistan [55]. Auto regressive distributed lag (ARDL) bounds testing was used for the cointegration investigation. Xu [51] constructed a two-state variable environmental growth model and utilized an external forcing function to test the existence of the EKC hypothesis and obtain the optimal development route for the relationship between pollution and economic growth. The EKC relationship is a predictive model that considers the interplay of selected variables. Bo's [56] EKC evaluation was based on theory and data. His ultimate choice was hazy. The income elasticity of environmental quality demand, size, technical and composition effects, international trade, foreign direct investment, and historical accidents contribute to EKC. When health improves, so do environmental indicators, as shown by the empirical research on EKC. He was discouraged by the contradictory findings and emphasized the need for appropriate indicators and data for drawing reliable scientific conclusions.

In 2000, scientists Echevarria and Ho [57] examined the environmental Kuznets curve (EKC). The correlation between pollution measures and GDP per capita is structured like an inverted U. The EKC was deconstructed by calculating a measure of pollution intensity, also known as pollution per manufacturing unit, and then regressing this measure against per capita income to look for the predicted inverse relationship. The estimated result supported this notion. However, a simple static model laid the micro-foundations for the pollution-income connection [54,58]. As Plassmann and Khanna [59] showed, the environmental Kuznets curve does not depend on the absolute values of the returns to scale in abatement and gross pollution but rather on the relative magnitudes of these two metrics. They also claimed that increasing the expenditure on pollution control would be fruitless unless the benefits outweighed the costs, sometimes known as the returns to scale of abatement. Spangenberg [60] proposed Environmental Space to evaluate environmental pressures brought on using all resources (including energy, materials, and land). The data show that no EKC exists in any of the analyzed countries.

This research helps to fill in gaps in our understanding in a number of ways. To begin, this research uses data from the top 10 African nations in terms of tourism to examine the connection between rising tourism and rising CO_2 emissions, along with other variables related to the environment. Secondly, the standard EKC procedure is replaced in this investigation with the tourism-induced EKC hypothesis. Thirdly, by coupling the econometric analysis, the study used a second-generation econometric technique rather than a first-generation tool, for the reasons given below. The nations of Africa have extensive linguistic, cultural, religious, and commercial ties to one another. Therefore, the CSD test is crucial in this setting. However, the slope heterogeneity (SH) test is particularly important since the GDP, population, commerce, tourism, and other macroeconomic indicators in the various Arabian nations are not uniform. Once CSD and SH have been verified, the second-generation unit root test and the cointegration test may be applied. Before developing any sort of strategy, it is crucial to know which economic sector is responsible for the bulk of CO_2 emissions. This study employs a novel AMG, MG, and CCEMG methods that are definite to preserve endogeneity, slope heterogeneity, cross-sectional dependency, and mixed-order unit root.

3. Methodology

3.1. Data

In Table 1, this research examines many variables, such as GDP, tourism, renewable energy, and fossil fuels, affected annual CO_2 emissions in ten of Africa's most visited countries between 1997 and 2021. Prior to estimation, all variables were transformed into logarithms to guarantee precision. The variables are in the following form: CO_2 is CO_2 emissions (metric tons per capita), GDP is GDP (constant 2015 US$), GDP square is the square value of total gross domestic product, tourism is total tourist arrivals, Renewable energy is renewable energy consumption (% of total final energy consumption) and fossil fuel is fossil fuel energy consumption (% of total) [61].

Table 1. Variables' names and details.

Variable Name	Log Form	Indicators' Name
CO_2 emission	LCO_2	CO2 emissions (metric tons per capita)
GDP	LGDP	GDP (constant 2015 US$)
GDP square	$LGDP^2$	Trade (% of GDP)
Tourism	LTA	Total tourist arrivals
Renewable energy	LREN	Renewable energy consumption (% of total final energy consumption)
Fossil fuel	LFOS	Fossil fuel energy consumption (% of total)

Data Source: WDI [61].

The statistics for all variables are shown in Appendix A. The greatest and lowest mean values are for $LGDP^2$ and LCO_2, respectively, as the standard deviation value of $LGDP^2$ is the highest possible value. In contrast, the value of LGDP is the lowest possible value.

3.2. Tourism-Induced EKC Model

The regression model presented below was used to assess the validity of the EKC model for the ten nations with the most tourist arrivals from 1997 to 2021. Recent studies have examined the impacts of tourism on climate change by adding the expansion of the tourism industry into the conventional EKC model [25,62–65]. The literature proposes utilizing Equation (1), based on EKC's analytical and functional framework, to analyze the long-term relationship between environmental deterioration and related variables.

$$CO_{2i,t} = f\left(GDP_{i,t}, GDP^2{}_{i,t}, TA_{i,t}, REN_{i,t}, FOS_{i,t}\right) \quad (1)$$

CO_2 stands for carbon dioxide emissions, while GDP stands for actual gross domestic product per person. GDP^2 is the square term of real GDP per capita, given that GDP is the input for the square component. TA represent number of total tourist arrivals REN represent the renewable energy consumption and FOS represent fossil fuel energy consumption. The following Equation (2) is the elaborate form of Equation (1)

$$CO_{2i,t} = \alpha_o + \alpha_1 GDP_{i,t} + \alpha_2 GDP_{i,t}^2 + \alpha_3 TA_{i,t} + \alpha_4 REN_{i,t} + \alpha_5 FOS_{i,t} + \varepsilon_{i,t} \quad (2)$$

To accommodate the parameters necessary for empirical analysis, Equation (2) is rewritten as follows in Equation (3), considering log.

$$LCO_{2i,t} = \alpha_o + \alpha_1 LGDP_{i,t} + \alpha_2 LGDP_{i,t}^2 + \alpha_3 LTA_{i,t} + \alpha_4 LREN_{i,t} + \alpha_5 LFOS_{i,t} + \varepsilon_{i,t} \quad (3)$$

We anticipate that α_1 and α_2 will have favorable (positive) and unfavorable (negative) signals. This means that an increase in real GDP per capita causes an initial surge in CO_2 emissions, followed by a gradual decline as the economy matures. Having this directionality based on time will prove the EKC theory true in a country. It is also anticipated that the signs of α_4 and α_5 will be (negative) and +(positive), respectively. In contrast, a negative value for α_3 suggests that leading African tourist destinations will reduce their carbon output even as they see a rise in visitor numbers.

3.3. Econometric Models

To analyze the data, the study used unit root and cointegration tests of the second generation, which take into account the CSD and SH issues. Long-term associations were determined using the AMG, MG, and CCEMG estimators. First-generation estimators such as GMM, quantile regression, OLS, and GLS will produce erroneous findings in the presence of slope heterogeneity and CSD problems in the data. Thus, AMG, MG, and CCEMG, estimators from the second generation are appropriate for this study.

Concerns about unobserved heterogeneity, hysteresis, cross-section dependency, and slope uniformity are raised by Salim et al. [66] as potential sources of inaccurate estimations. Nevertheless, the CCEMG estimator has numerous advantages over alternative approaches.

The mean-group (MG) and fixed and arbitrary models typically used as standard estimators might yield inaccurate results and inconsistent values. The second issue is that if N is more significant than T, the generalized moment (GMM) estimators based on instrumental variables may provide incorrect and deceptive estimations [67]. Ten x-sections (N) and 36 intervals (T) are available for analysis in the present research. When there is a cointegration relationship, CSD, or unit roots in the data, and when there is uniformity in the slopes of the observed data, the CCEMG estimators work very well. The CCEMG is widely acknowledged as a more effective method since it may produce group-specific predictions within the same regression results. In addition, Salim et al. [66] showed that CCEMG correctly predicts the effects of both domestic and foreign shocks. First suggested by Pesaran [68], this concept was refined and sophisticated again by Kapetanios et al. [69]. To accomplish the first goal of our study, we have implemented the CCEMG estimator created by Pesaran [68] and the AMG estimator proposed by Eberhardt and Bond [70] and Eberhardt and Teal [71]. Both estimation methods are resilient to CSD because they consider cross-panel correlation. As opposed to CSD, the two estimation methods allow for a range of slope coefficients, providing country-specific results.

CSD and heterogeneity tests are utilized in this research, including those developed by Westerlund and Edgerton [72] and Eberhardt and Teal [63]. Estimates from the AMG, MG, and CCEMG methods are among them. Results from the panel estimate that methods may be biased and unreliable if they ignore the CSD and data heterogeneity. Therefore, researchers should conduct a CSD diagnostic test before undertaking a panel data analysis. In the case of panel data, the CSD can be used (all of the units in the same section are correlated). When T is more significant than N, the Pesaran CSD test helps verify this (as in the author's research).

3.3.1. Cross-Sectional Dependence Test (CSD)

In this study, we analyzed panel data; hence, a check for CSD is essential. The CSD is caused by underlying socioeconomic institutions, bilateral and multilateral trade, and international treaties that cause other global problems. This test informs how future assessments will be conducted. Therefore, the CSD test created by Pesaran [68] was used here. In Equation (4), a formula for determining CSD is as follows:

$$CSD = \sqrt{\frac{2T}{N(N-1)N}\left(\sum_{i=1}^{N-1}\sum_{K=i+1}^{N} Co\hat{r}r_{i,t}\right)} \tag{4}$$

where T represents the cross-sections and N represents the times.

3.3.2. Slope Homogeneity (SH) Test

In addition, it is critically important to apply SH. Data were compared to see whether they have any commonalities. As a result, the Pesaran and Yamagata [73] test is applied. For the sake of completeness, the formula for SH shows in Equations (5a) and (5b):

$$\check{\Delta} = \sqrt{\boldsymbol{N}}\left(\frac{\boldsymbol{N^{-1}\check{S}-k}}{\sqrt{2\boldsymbol{k}}}\right) \tag{5a}$$

In Equation (5a) the statistic is asymptotically $\check{\Delta} \sim N(0,1)$. In (5a), For this purpose, we will define $\check{S}$ as the cross-sectional unit-specific estimate divided by the pooled estimate, with the weights based on their relative importance.

In Equation (5b), for normally distributed errors, we may express the mean-variance bias-adjusted $\check{\Delta}$ in the following form:

$$\check{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\check{S}-k}{\sqrt{\frac{2k(T-k-1)}{T+1}}}\right) \tag{5b}$$

3.3.3. Stationarity Test

Data can also be tested for a unit root using these techniques and the commonly used CSD and SH tests. This assessment reveals details on the level of amalgamation. This study made use of the cross-sectional Im-Pesaran-Shin (CIPS) exam, which is a cross-sectional analysis. After checking if the panel dataset contains a possible CSD issue, the CIPS test developed by Pesaran [68] was applied. Concerns about SH and CSD were factored into the evaluation. Due to their inability to adequately account for CSD and SH, conventional unit root tests such as the ADF, PP, and KPSS sometimes produce misleading results. For this reason, we have employed a CIPS unit root test (in Equation (6)) to confirm whether or not the variables under consideration are stationary in the presence of CSD and slope heterogeneity. As seen in the following example, the research calculated a cross-sectional average to achieve the CIPS value. Equation (6) shows CIPS unit root test.

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T) \tag{6}$$

3.3.4. Co-Integration Test

After confirming the absence of a unit root, we used the panel cointegration test established by Westerlund [74] to see if the series was genuinely integrated. This panel data analysis accurately captures the relevant CSD and SH, allowing for reliable conclusions. Equations (7)–(10) shows the equivalency formula for cointegration test:

$$\mathrm{G}_{\alpha} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{N}} \frac{\acute{\alpha}_{\mathrm{i}}}{\mathrm{SE}(\acute{\alpha}_{\mathrm{i}})} \tag{7}$$

$$G_t = \frac{1}{n}\sum_{i=1}^{N}\frac{T\acute{\alpha}_i}{\acute{\alpha}_i(1)} \quad (8)$$

$$P_t = \frac{\acute{\alpha}}{SE(\acute{\alpha})} \quad (9)$$

$$P_\alpha = T\acute{\alpha} \quad (10)$$

When the slope heterogeneity issue, CSD dilemma, and the mixed-order stationary condition are confirmed, the research makes use of methods that take into account these concerns. G_α and G_t are group mean statistics and P_t and P_α are cointegration statistics. The AMG, MG, and CCEMG estimators work well under these conditions.

4. Findings and Results Analysis

Table 2 displays the results of the CSD test performed to rule out the potential of false co-integration in the data. We reject the null hypothesis of no CSD for all parameters (LCO_2, LGDP, $LGDP^2$, LTA, LREN, and LFOS) at the 1% significance level. This test provides evidence that CSD is present in the dataset under consideration. Social and economic policies highly similar to one another cause this CSD.

Table 2. Results of CSD Analysis.

Variable	Test Statistics (*p*-Value)
LCO_2	18.26 [a] (0.00)
LGDP	31.46 [a] (0.00)
$LGDP^2$	31.41 [a] (0.00)
LTA	26.06 [a] (0.00)
LREN	24.23 [a] (0.00)
LFOS	8.55 [b] (0.00)

The values denote the p-values in parentheses. In contrast, [b] and [a] explain the 5% and 1% significance levels, respectively.

The findings of the SH test [73] are shown in Table 3. This test assumes that the slope values are uniform throughout. Therefore, a 1% significance level is shown in the results in Table 3.

Table 3. Results of Slope Heterogeneity Test.

Slope Homogeneity Tests	Statistic	*p*-Value
$\check{\Delta}$ test	5.846 [a]	0.000
$\check{\Delta}_{adj}$ test	7.478 [a]	0.000

The homogeneity of slope coefficients is the null hypothesis for the slope heterogeneity test. The letter "[a]" indicates a rate of less than 1%.

Table 4 displays the outcomes of the unit root analysis. The findings indicate no movement in any variables after the initial difference. All parameters, including LCO_2, LGDP, $LGDP^2$, LTA, LREN, and LFOS, are integrated at I(0) and I(1).

Table 4. Second Generation Unit Root Test.

Variable	CIPS Test	
	At Level	1st Differences
LCO_2	−1.957	−3.211 [a]
LGDP	−2.340 [b]	−4.351 [a]
$LGDP^2$	−2.549 [b]	−3.689 [a]
LTA	−1.058	−4.258 [a]
LREN	−1.171	−6.190 [a]
LFOS	−3.05 a	−7.365 [a]

Note: [b], and [a] explain the significance levels at 5%, and 1%, respectively, whereas the values in parenthesis contain *p*-values.

After checking for stationarity, the next step is to see if the variables are cointegrated over the long run. Once it was determined that the variables were not stationary, the next step was to perform the transformation. To this end, we ran cointegration tests based on Westerlund's [74] work, and the results are summarized in Table 5. When the significance level is set to 1%, Table 5 shows that the data provided by G_a and G_t statistics do not support the null hypothesis proposed by Westerlund [74]. This conclusion is based on the *p*-values. Because of this, we can confidently say that our long-run variables have been integrated. We employed AMG, MG, and CCEMG estimators to examine the impacts of income, tourism, renewable energy, and fossil fuel, even though the data suffer from SH, CSD, and a combination of I(0) and I(1) unit roots. Additionally, it is essential to check whether the EKC hypothesis is true or false in the top African tourist destinations.

Table 5. Cointegration Test Result.

Variable	**Westerlund Test for Cointegration**		
	Value	**Z-Value**	***p*-Value**
Gt	−2.89	−0.576	0.090
Ga	−5.897	3.206	0.020
Pt	−5.109	1.784	0.420
Pa	−4.192	2.364	0.220

The output in Table 6 shows, in aggregate, the schedules of the AMG, MG and CCEMG test results. The estimated result is consistent with the presence of the EKC hypothesis, as the coefficients of GDP and its squared components are stated to be positive and negative signs, respectively. Although the MG test findings were not statistically significant, the AMG and CCEMG test results were, thus requiring us to confirm the EKC hypothesis. The theoretical significance of such an outcome ignites that, for the sampled countries, CO_2 emissions insets with the increase in GDP for the first periods (imparted by the positive sign of the coefficient of the LGDP term). Intuitively, with the lapse of time, as GDP ascents evermore, CO_2 emission will wane (marked by the negative sign of the coefficient of GDP^2). This will happen, in reality, only if the government initiates environment-friendly policies that suppress pollution activities. The tourist arrival (LTA) coefficient is found to be significantly positive in AMG and MG estimation and positive but insignificant in CCEMG methodology. Such an outcome extols the upsurge of tourists to increase CO_2 emissions further. The coefficient of renewable energy usage (LREN) is negative in all three tests. This result implies that the more the sampled countries shift to renewable energy usage, the lesser the CO_2 emission will be. Fossil fuel use is harmful for the environment and increases CO_2 emission to a greater extent. Such an inference is backed up by the variable's significantly positive coefficient, which is corroborated by all three estimations. However, we are not the only ones who have considered such an outcome.

Table 6. The AMG, MG, and CCEMG Test Results.

Variables	AMG	MG	CCEMG
LGDP	4.755	2.175 *	6.749
	(4.602)	(5.994)	(10.64)
$LGDP^2$	−0.269	−0.124 **	−0.416
	(0.310)	(0.433)	(0.705)
LTA	0.0816 **	0.0915 ***	0.0636
	(0.0401)	(0.0336)	(0.0407)
LREN	−0.786 *	−0.862	−0.647
	(0.404)	(0.525)	(0.401)
LFOS	0.742 ***	0.876 ***	0.693 ***
	(0.182)	(0.215)	(0.156)
Constant	−26.01	−13.99	−62.61
	(17.86)	(22.52)	(87.23)
Observations	192	192	192
Number of IDs		10	

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7 drafts out the EKC hypothesis on a national basis using the AMG estimate. A quick look at the data suggests that the EKC hypothesis is accepted in Egypt, Kenya, and Tanzania. In other words, as their GDPs rise steadily over time, these nations' CO_2 emissions initially rise but gradually decrease. As mentioned, the significant positive and negative signs of the coefficients provide conclusive evidence for such conclusions. Although the expected signs of the coefficients were preserved in Mauritius, Morocco, and South Africa, the EKC hypothesis could not be true because the coefficients were supposed to be small. Uganda's example remained significant, although the positive indicators of the coefficients fell short of expectations. In addition, Ghana, Nigeria, and Tunisia deviated from the EKC hypothesis since their coefficients were neither statistically significant nor of the expected indications. In the cases of Egypt, Morocco, and Tanzania, long-term tourist arrivals are predicted to be highly favorable and consequential. This result confirms our suspicions that these countries' excessive emission directly results from the influx of tourists.

Table 7. The Result of the Country-level EKC Hypothesis by the AMG Estimation.

	Constant	LGDP	LGDP2	LTA	LREN	LFOS
Egypt	−28.394	6.996 ***	−0.414 *	0.0610 **	−0.6262	0.0054* *
	[22.597]	[5.612]	[0.3497]	[0.0296]	[0.1354]	[0.059]
Ghana	24.320	−7.705	0.544	−0.0012 **	−0.9084	0.0457
	[52.203]	[14.94]	[0.946]	[0.0082]	[0.5064]	[0.0338]
Kenya	−59.69	16.427 **	−1.022 *	−0.0854 ***	−1.368	0.0886 ***
	[97.716]	[27.25]	[1.973]	[0.1047]	[0.4734]	[0.0406]
Mauritius	−92.69	22.96	−1.171	−0.0048	−0.3788 *	0.0106
	[14.075]	[3.204]	[0.1754]	[0.028]	[0.0571]	[0.0635]
Morocco	−23.313	5.415	−0.375 **	0.0091 ***	0.0209 ***	0.0184
	[20.20]	[5.756]	[0.3647]	[0.284]	[0.0581]	[0.066]
Nigeria	66.5693	−15.071 ***	1.253	−0.00175	−1.604 **	0.1048 **
	[20.858]	[5.617]	[0.3731]	[0.0501]	[0.7518]	[0.2171]
South Africa	−211.961	48.209	−2.731	−0.0142	0.0162	0.0322
	[128.73]	[29.511]	[1.717]	[0.0324]	[0.1367]	[0.0882]
Tanzania	−36.909	10.606 **	−0.609 ***	0.0324 **	−1.956 **	0.1548 ***
	[24.088]	[7.071]	[0.5318]	[0.1501]	[0.5139]	[0.0366]
Tunisia	−2.270	0.1269	0.0415	−0.0018	−0.2498 ***	0.0149
	[22.51]	[5.641]	[0.3543]	[0.0023]	[0.1206]	[0.0066]
Uganda	−12.41	2.133 ***	0.0317 ***	−0.73 **	−1.070	1.24 ***
	[20.82]	[6.573]	[0.5100]	[0.0712]	[0.295]	[0.265]

Standard errors are in the brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Conversely, the coefficient is negative in Ghana, Kenya, and Uganda. Consequently, we can assume that insurgency in the countries above will lead to emissions. It is a scary thought, but it is possible if the government will enact eco-friendly regulations that force people to reduce their contributions to pollution. Some countries, such as Mauritius, Nigeria, South Africa, and Tunisia, found a negative but not statistically significant coefficient. However, there is evidence that Mauritius, Nigeria, Tanzania, and Tunisia use much less renewable energy (LREN) than the global average. Theoretically, this would mean that these countries' emission levels would drop dramatically if they switched to using more renewable energy. Increased reliance on renewable energy sources is expected to spark a unidirectional shift in Morocco's emission levels. This substantial and favorable effect has been anticipated. The results were unfavorable but insignificant for Egypt, Ghana, Kenya, and Uganda. In contrast, they were neutral or slightly positive for South Africa. It has been observed that the use of fossil fuels (LFOS) has a net beneficial effect on emission levels across all African countries. However, the more fossil fuels these countries consume, the more pollution they will cause. Egypt, Kenya, Nigeria, Tanzania, and Uganda all show statistically significant results from the determined outcome. Furthermore, inconsequential outcomes were found in Ghana, Mauritius, Morocco, South Africa, and Tunisia.

5. Discussion

This study tested the most celebrated EKC hypothesis for ten of Africa's most popular tourist destinations. These nations provide significant empirical support for the EKC theory based on the MG results. However, the study's key findings demonstrated that the AMG and CCEMG test results were insignificant. The presence of EKC is very optimistic news for Africa because the environment will be sustainable in future. Past studies [21,34,41,45,46,48,51,75] provide evidence supporting the EKC hypothesis having similar consequences. The Tourist Arrival's coefficients are found to be significantly positive in AMG and MG estimation and positive but insignificant in CCEMG methodology. This result shows that increasing tourism will increase CO_2 emissions even more. The findings are similar in previous studies [76,77]. Tourism's impact on greenhouse gas emissions grows as the intensity of travel services grows alongside the demand for transportation. A further contributing factor to pollution is the rising number of tourists, which leads to a rise in consumption and shopping. The coefficient of renewable energy usage, which has been negative in all three tests, indicates that the more the sampled countries shift to renewable energy usage, the lower the CO_2 emissions. The findings are similar to these studies [78–80]. This is because renewable energy sources, including wind, nuclear, tidal, hydropower, geothermal, solar, and wave energy, produce the fewest greenhouse gas emissions. When fossil fuels are burnt, they release significant amounts of the greenhouse gas carbon dioxide. The findings are similar to these studies [9,40,81–84]. When fossil fuels such as coal, oil, and natural gas are burnt for energy, they create harmful pollutants and greenhouse gases. Climate change directly results from carbon emissions, which act as a blanket for atmospheric heat. Carbon dioxide emissions, a crucial factor in climate change, are primarily produced by the combustion of fossil fuels. Increasing atmospheric carbon dioxide and other greenhouse gases are to blame for the warming of the planet, which in turn affects weather patterns and causes sea levels to rise.

6. Conclusions, Limitations, and Future Research

The study quantified the link between the volume of CO_2 emissions and the number of international visitors to the most visited African cities. The primary goal of this article was to examine the connection between CO_2 emissions, fossil fuels, renewable energy, and tourism in the top African tourist countries from 1990 to 2021 and to develop a theoretical approach; the paper applied the tourism-induced EKC hypothesis. Tests for CSD have been run on the data and the results have been interpreted. The CSD test is very important when checking homogeneous cross-section data [85]. To further investigate whether or not the variables are stationary, a second-generation unit root test is conducted. In order to check for CSD problems and mixed-order stationarity, the AMG, MG, and CCEMG method is implemented. This study found that tourism and fossil fuel consumption contribute to rising emissions. In contrast, long-term economic growth and adopting renewable energy sources were found to have far more minor impacts. Results were found using the MG, AMG, and CCEMG estimators. As predicted, considerable positive and negative impacts were identified for using renewable energy and fossil fuels, though not universally so and certainly not for all countries. Concentration on renewable energy may be a reduction strategy of emissions instead of greater use of fossil fuels. Additionally, as seen in Table 7, research conducted on a country-by-country basis confirmed that the EKC hypothesis is accepted in Egypt, Kenya, and Tanzania. The empirical result shows that the rising number of tourists in Ghana, Kenya, and Uganda harms their emissions. One possible explanation is that these nations have adopted environmentally friendly tourism policies. Environmental management should be a great concern for the studied countries, where tree plantation in tourist places, coastal belts, and green urbanization significantly impact reducing emissions. There are some limitations of this research. The study relies on data availability and quality, which may be limited in some of Africa's tourist destinations. Moreover, the model is based on a simplified representation of the energy systems, tourism, and GDP of the ten tourist destinations in Africa and does not account for all the complexities of the real-world systems. The model makes certain assumptions about the behavior of energy consumption and production, which may not hold up in all cases. Future research can focus on collecting more detailed and accurate data on energy consumption, tourism, and other related variables in the ten tourist destinations to improve the model's accuracy. In the future, the model could also be extended to include more variables, such as globalization, health, financial development, safety, and infrastructure development, to better capture the dynamics of the energy systems in the tourist destinations.

7. Policy Implication

The positive and negative significant relationship between LTA, CO_2 emissions, and GDP has important policy implications. For instance, the significant positive relationship between tourist arrival and CO_2 emissions in the short run could imply ineffective policies to combat the factors driving polluting emissions. The significant positive relationship would imply that the economic activities of tourism sectors and their value chains have contributed harmful effects on the environment. Even though there is a positive relationship between tourism sectors and countries' GDP, some countries (Egypt, Kenya, and Tanzania) still show that the higher GDP emitted higher CO_2 emissions in the short run. One factor that could contribute to the higher CO_2 emissions in these countries is the increasing mobility demand services to support tourism services activities. Tourism contributes to CO_2 emissions by increasing demand for transportation, which is exacerbated by the intensity of travel services (i.e., airport transports, hotel transport, tourism agents' transport) which are highly reliant on fuel combustion mobility transport instead of energy-efficient transports. Furthermore, tourism development increases food consumption and shopping activities, contributing to carbon emissions.

Thus, policymakers need to pay attention to reducing transportation based on fuel combustion engines and shifting towards low-carbon transport modes by employing energy-efficient, hybrid, or EV transport modes in the tourism industries and their supply chain in order to meet the demand for faster reductions in greenhouse-gas emissions. This is especially true in Egypt, Morocco, and Tanzania. If African countries can confirm long-term tourist arrivals, the implications for carbon emissions are predicted to be highly favorable and consequential. This confirms our expectations that these countries' excessive emission directly results from the numerous inflows of tourists. Furthermore, in 2021, the International Energy Agency found that transportation accounted for 23% of worldwide energy-related CO_2 emissions. Although there has been a shift toward more fuel-efficient automobiles and the implementation of climate mitigation policies, growth in GHG emissions has remained due to rising demand. With its avoid-shift-improve (ASI) methodology, the Intergovernmental Panel on Climate Change (IPCC) has advocated for a holistic sustainability strategy for transportation. Avoiding unnecessary trips through creative spatial planning and demand management is the first step in this strategy for reducing emissions from passenger transportation. Next, passengers are encouraged to switch to more environmentally friendly modes of transportation such as walking, cycling, and public transportation. Finally, the energy and carbon efficiency of the selected mode of transportation is optimized. To minimize the negative impact of tourism on the environment, African countries should encourage ecotourism. African countries should promote local conservation efforts, preserve local culture and biodiversity, and Create conscientious about tourism.

On the other hand, the estimated results also show that there is a negative relationship between CO_2 emissions and the use of renewable energy in the sample countries, which could imply that the use of renewable energy sources, including solar, wind, hydro, biofuels and others, are at the center of the transition to a less carbon-intensive and more sustainable energy system for these countries. As a result, renewable capacity expansion in the next five years will be much faster than expected just a year ago. Based on the IEA [86], renewable energy sources are set to account for over 90% of global electricity capacity expansion over the forecast period. As a result, the renewable share (modern renewable) in final energy consumption has increased sharply, by 10.5% (in 2019 it was 11.55% compared to 6.55% in 1990). Thus, African countries should move to renewable energy from fossil fuels, eliminate fossil fuels subsidies, and price new fossil fuel technologies.

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Abbreviations

Abbreviation	**Definition**
GDP	Gross Domestic Products
CO2	Carbon dioxide emissions
EKC	Environmental Kuznets Curve
AMG	Augmented Mean Group
MG	Mean Group
CCEMG	Common Correlated Effects Mean Group
SH	Slope Heterogeneity
CSD	Cross-sectional Dependence

Appendix A. Summary Statistics of Variables

Table A1. Summary Statistics.

Variables	Mean	SD	Min	Max
LCO_2	−0.199	1.378	−2.971	2.149
LGDP	7.684	0.775	6.179	9.273
$LGDP^2$	59.64	11.92	38.18	85.98
LTA	14.64	1.176	12.07	16.53
LREN	3.413	1.005	1.629	4.558
LFOS	3.768	0.861	1.712	4.590

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