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GENERAL & APPLIED ECONOMICS | REVIEW ARTICLE

International tourism, exchange rate, and renewable energy: Do they boost or burden efforts towards a low carbon economy in selected African countries?

Kwame Adjei-Mantey¹, Frank Adusah-Poku² and Paul Adjei Kwakwa^{3*}

Abstract: Africa continues to suffer from the effects of climate change in many ways. Records show that the continent's carbon dioxide (CO₂) emissions have seen tremendous upward adjustments over the past decades. While international tourism and renewable energy have been touted as sources of reducing CO₂ emissions, the empirical evidence has been mixed, and it is also unclear how exchange rates moderate the effect of tourism on CO₂ emissions. With the recent pace of tourism and renewable energy development, as well as exchange rate fluctuations in Africa, the study assesses the impact of international tourism, exchange rate, and renewable energy on CO₂ emissions of seven most visited countries in Africa. Carbon dioxide emission was modelled within the Environmental Kuznets Curve (EKC) hypothesis. Regression analyses were performed using the quantile regression and fully modified OLS. Regression analysis from the fully modified OLS method shows that the EKC hypothesis holds for the selected countries; renewable energy and international tourism reduce carbon dioxide emissions; and exchange rate interacts with international tourism to reduce carbon dioxide emissions. The quantile regression shows variations in the impacts across the various quantiles. Countries in this study can rely on economic expansion, international tourism, and renewable energy to curb carbon dioxide emissions. It is recommended, among other things, that there should be the development of additional tourism locations and renewable energy adoption be scaled up as a means of reducing heavy polluting energy sources to reduce emissions emanating from the energy sector.

Subjects: Environmental Economics; Economics; Finance; Business, Management and Accounting

Keywords: international tourism; renewable energy; exchange rate; carbon dioxide emissions; sustainable development; climate change

JEL classification: Q20; Q53; Q54; Q55; Q56



1. Introduction

The pace of global carbon dioxide emissions continues to raise concerns for many in the field of environmental management, climate change, and development economics. This stems from the fact that carbon dioxide emissions, which form a greater portion of the greenhouse gasses responsible for climate change, have exceeded the pre-industrial emission level by more than 50% (NOAA, 2022). The consensus then is to limit the level of carbon dioxide emissions in order to prevent average temperature rising beyond 1.5°C. The sources of global carbon dioxide emissions are such that countries like the United States of America, China, India, Japan, and Russia are the leading contributing countries while Africa is the least contributor (Climate Policy Watcher, 2023). That notwithstanding, the African continent is the worst affected by the effect of climate change (African Development Bank, 2023), and moreover, the level of carbon emissions from the continent has increased by more than nine times from 5.24 billion tonnes in 1971 to 49.13 billion tonnes in 2021 (Our World in Data, 2023).

Over the past three decades, researchers have devoted attention to exploring the drivers of carbon dioxide emissions to help shape policy formulation in taming carbon dioxide emissions. Empirical studies have concentrated on analyzing the effects of socio-economic variables including income (Alhassan et al., 2022; Bjelle et al., 2021; Ehigiamusoe & Dogan, 2022; Kwakwa, 2020), population (Guo et al., 2016; Rehman et al., 2021; T. Yang & Wang, 2020; Aboagye, 2017), trade openness (Wang & Zhang, 2021), urbanization (Abbasi et al., 2020; Behera & Dash, 2017; Kwakwa & Alhassan, 2018) and industrialization (Asumadu-Sarkodie & Owusu, 2017; Kwakwa & Adusah-Poku, 2020; Zhang & Chen, 2021).

Two variables that have gained the attention of researchers in the environment literature in recent times are tourism and energy. The reason is that since the energy crisis in the 1970s, energy has emerged as an essential input for economic growth. Of course, energy drives economic activities in every country. However, because energy usage through appliances and heavy equipment is associated with carbon dioxide emissions, an increased energy consumption tends to create environmental problems through emissions. Indeed, records show that carbon dioxide emissions from energy use and industrialization formed about 89% of all greenhouse gasses from the energy sector in 2021 (IEA, 2021). This stems from the fact that energy from fossil fuel dominates energy usage globally. Empirically, Kwakwa and Adu (2015) found that total energy usage increased carbon dioxide emissions. In another study, Abokyi et al. (2019) found that fossil fuel positively affects carbon dioxide emissions. In addition, electricity usage (Rahaman et al., 2022) and energy intensity (Namahoro et al., 2021) have been reported to increase carbon dioxide emissions. Since energy is an essential input for economic activities, it is impossible to completely abandon energy usage despite its association with carbon dioxide emissions and the consequent effect on the health of the environment (Mitić et al., 2023; Ongan et al., 2023). Accordingly, the quest to develop and adopt renewable energy for economic activities has been trumpeted by many in recent years. The reason is that renewable energy is cleaner than fossil-based fuels. They emit less carbon dioxide and are thus, environmentally friendlier. In addition, they are efficient for production, and hence more output can be attained from consuming relatively lower amount of renewable energy (Gyamfi et al., 2022; Kwakwa, 2020). In this light, investment into renewable sources of energy has seen significant increment over the years. In 2020, global expenses in renewable energy stood at about 45% of the spending in the power sector (IEA, 2021) which saw a further 8% increase in 2022 from 2021 (IEA, 2022). This figure is disproportionately spread across the developed countries and few developing countries, especially China (World Economic Forum, 2022). Africa's development of renewable energy has taken a slower pace compared to other regions of the world (World Bank, 2023). It is estimated that biomass serves as the primary energy source for about 900 million people in Africa (IRENA, 2021). As of 2019, renewable energy formed only about 22% of Africa's total installed capacity (IRENA, 2021). This has led some to investigate how renewable energy affects gross domestic product (Zafar et al., 2019; Ivanovski et al., 2021; Saidi & Omri, 2020). Others have also looked at how it affects carbon dioxide emissions (Bölük & Mert, 2015; Karasoy & Akçay, 2019; Adedoyin et al., 2021; Bekun et al., 2023).

Another variable that has been noted as an avenue to promote economic growth and development is tourism, especially international tourism. Earlier studies have sought to identify how countries can promote their tourism to boost their GDP (Nissan et al., 2011; Fayissa et al., 2009). In more recent times, researchers have argued there is a need to pay attention to tourism if the fight against climate change (carbon emission) can be won (Agyeman et al., 2022; El Menyari, 2021; Ehigiamusoe et al., 2023; Lee and Brahmasrene, 2016). The reason is that tourism, especially international tourism can reduce carbon dioxide emissions through proper environmental management from tourism proceeds as well as the conservation of natural resources (Sunlu, 2003). Although it is argued that the tourism sector is more environmentally friendly than agriculture and industrialization (Azam et al., 2018), tourism can increase carbon dioxide emission because of the energy needed for transportation, feeding, accommodation, and other infrastructural development (Balsalobre-Lorente & Leitão, 2020). As part of the efforts to attain low carbon economy on the continent, many African countries have subscribed to the United Nation's goals. This is very necessary for the continent since it is the continent that is affected the most by the negative effects of climate change and global warming. Member countries have set out their nationally determined contributions to reduce emissions. Despite these, carbon dioxide emissions on the continent have seen an upward trajectory (World Bank, 2023). This development in Africa then presents itself as a research-worthy issue.

Furthermore, the development of the tourism sector of African countries has gained attention (UNWTO, 2017). As contained in the pillars of the African Sustainable and Responsible Tourism Charter, the continent is geared, among others, towards attracting 134 million tourists by 2030. A key pillar of the charter is to have a diversified tourism sector that integrates green activities and a sustainable economy (UNWTO, 2017). However, the effect of tourism development on the increasing trend of carbon dioxide emissions in the region has not received equal attention in the empirical literature (Agyeman et al., 2022; El Menyari, 2021; Ehigiamusoe et al., 2023; Lee and Brahmasrene, 2016). From another point of view, countries on the African continent have suffered from exchange rate depreciation (Elbadawi et al., 2012; Ofori-Abebrese et al., 2017; Sibanda et al., 2013). Exchange rates can affect carbon dioxide emissions through their effect on the trade structure of a country. A strong currency renders a country's export less attractive, reduce export, and can reduce carbon dioxide emissions whereas a weak currency can achieve the opposite (Zhang & Zhang, 2018). Despite this, empirical studies on the effect of exchange rate on carbon emissions in Africa is scarce.

From the above, the study seeks to examine the effect of tourism, renewable energy, and exchange rate on carbon dioxide emissions in Africa. While this may not be the first study of its kind, it is significant in the sense that previous studies have revealed a mixture of results that do not offer consensus to guide policymaking. The previous studies have not focused on leading renewable energy consumption or tourism destination countries in Africa. Records reveal Egypt, Tunisia, Kenya, South Africa, Zimbabwe, Ivory Coast, and Morocco as leaders in renewable energy development (Chandler, 2022; Kamer, 2023) and international tourism destination on the continent (Hotel Management Network, 2022; World of wanderlust, 2022). Moreover, they are among the countries with high levels of carbon emissions in the region (World Bank, 2023). Paying attention to these leading countries is significant since their tourism activities or renewable energy consumption may be crucial in aiding or hampering the attempt to achieve the low carbon goal. However, there have not been much investigations focusing on them. The outcome of the study using these countries will offer guidelines for other countries on the continent towards building low carbon economies. For instance, if renewable energy lowers carbon emissions then it becomes imperative for other countries to boost their renewable energy consumption and pay attention to the various types they are championing.

Previous studies have assumed that the relationship between carbon dioxide emission and its explanatory variables is linear. However, it may not be so since the effect of an explanatory variable may differ along the distribution (Koenker & Bassett, 1978). Thus, in terms of

methodology, the study employs the quantile regression method to account for such weakness in the previous studies especially for tourism in the case of Africa. Also, an interaction term effect between international tourism and exchange rate is analyzed. Since exchange rate appreciation has the tendency to increase international tourism, it is anticipated that the effect of tourism in these African countries may be hampered or induced by exchange rate which is quite high generally in African countries.

From the above, the study seeks to find answers to the following questions:

- (a) What are the effects of tourism, renewable energy, and exchange rate on carbon dioxide emissions of selected African countries?
- (b) How does the exchange rate moderate the effect of tourism on carbon emission of selected African countries?
- (c) Do tourism, renewable energy, and exchange rate have heterogeneous effects on carbon dioxide emission of selected African countries?

Answers to these questions offer at least three key contributions to the literature. First of all, the paper presents evidence from leading tourism and renewable energy consuming countries in Africa. Secondly, heterogeneous analysis of the effects of renewable energy, tourism, and exchange rate on carbon emission is performed for selected African countries. Thirdly, the moderating role of exchange rate in the international tourism-carbon emission nexus is examined.

The remaining parts of the paper proceed as follows: literature review in section 2; methodology in section 3; discussion of findings in section 4; and conclusion with recommendations in section 5.

2. Literature review

2.1. Impact of tourism on carbon dioxide emissions

According to the United Nations World Tourism Organization (UNWTO, 2020), tourism is projected to increase substantially across the world with the economic impact of tourism outweighing that of sectors like oil exports and the automobile industry. This role of tourism in reducing CO₂ emissions toward a sustainable environment has been explored by many empirical studies (Dogru et al., 2020, Kocak et al., 2020; Voumik et al., 2023a). These studies have arrived at varying conclusions depending on the context and scope as well as the methodology employed for the analysis. For instance, studies including Balsalobre-Lorente and Leitão (2020); Voumik et al. (2023a); in their examination of the interaction of tourism with CO₂ emissions have concluded that there is a negative relationship between tourism and CO₂ emissions. On the contrary, other studies like Koçak et al. (2020), Muhammed et al. (2021), Ibrahim and Mohammed (2023), Thi et al. (2023) also concluded with a positive relationship between the two variables. For the negative effect of tourism, those studies argue that the receipts from tourism improves incomes of the countries which pushes them to the stage where environmental quality is prioritized thus, investing in carbon dioxide reduction technologies. This assertion is also confirmed in a study by Deng et al. (2022) who used the panel threshold method to examine the asymmetric effect of financial development along FDI and globalization on pollution. The study found that financial development increases pollution before a threshold point and reduces it after the threshold. The receipt aspect of tourism therefore follows the EKC hypothesis, hence suggesting a non-linear association. On the other hand, the general justification for the studies with positive relationship is that because of the increased demand for transportation, food consumption, accommodation, and so on resulting from tourism and the intensity of travel services, CO₂ emissions are increased.

Balsalobre-Lorente and Leitão (2020) used the panel fully modified ordinary least squares (FMOLS), panel dynamic ordinary least squares (DOLS), and generalized method of moments (GMM) system to examine the relationship between tourism and CO₂ emission along with other

variables in both old and new EU member countries. Though the findings of the study indicated tourism contributes to reduction of CO₂ emissions, the choice of the countries to include in the study was based on the contribution of CO₂ emissions instead of tourism attraction; the latter forming the basis for selection of countries for our study. Thus, the countries in the study of Balsalobre-Lorente and Leitão (2020) may include countries that do not attract tourists and hence tourism has no or marginal impact on their CO₂ emissions. In another study Koçak et al. (2020), using the continuously updated fully modified (CUP-FM) and continuously updated bias-corrected estimators, found that tourism arrivals increase the amount of CO₂ emissions. On the other hand, tourism receipts were also found to reduce CO₂ emissions in the world's most visited countries. Disaggregating tourism into receipt (income generated) and arrivals (energy and resources used) is robust in examining the effect of tourism on CO₂ emissions. However, regardless of the recognition that tourism impacts on CO₂ emission through various channels, the study failed to account for the indirect effect of tourism through, for example, interacting tourism with other variables. Another study that attempted to account for the direct and indirect impacts is the study by Jiaqi et al. (2022). The authors employed spatial econometric models to examine a panel data of the top 70 most visited tourist sites in the world from 2000 to 2017. The study found that the negative and indirect effects of tourism on CO₂ emissions were significantly higher than the positive direct effects of tourism. This implies that overall, tourism worsens climate change by increasing the emission of CO₂ which is the main source of global warming and climate change. The employment of spatial models and selections of countries across the globe which may be scattered is likely to affect the result of such study. Thus, countries with heterogeneous characteristics or varying tourism patterns within their borders may require more detailed sub-regional analysis as witnessed in this study, rather than a global analysis..

2.2. Impact of exchange rate on carbon dioxide emissions

According to the World Trade Organization (2022), approximately 20–30% of total CO₂ emissions are associated with international trade. When a country's exchange rate appreciates or depreciates, it affects the volume of both imports and exports. For example, a depreciation of country's currency makes goods and services produced in the country cheaper for other countries. This increases the volume of the country's export with a corresponding increase in CO₂ emissions at the expense of imports. The dynamics of exchange rate on environmental pollution supports the pollution haven hypothesis which posits that firms will relocate to developing countries that are characterized by less stringent environmental regulations. This will consequently lead to increased emissions of the haven.

Using the non-linear auto-regressive distributive lag (NARDL) method of estimation, Shah et al. (2022) found that exchange rate depreciation is one of the main factors contributing to energy consumption and CO₂ emissions in both the short and long run in Pakistan. The study suggested that devaluation of a country's currency has economic cost in the form of high energy consumption increasing CO₂ emissions. A similar single country study by Zhang and Zhang (2018) also found that exchange rate appreciation has a negative relationship with CO₂ emissions in China. In another study, Smaili and Gam (2023) revealed that the effect of exchange rate on CO₂ emissions differs between developed and developing countries. While the exchange rate contributes to the reduction in CO₂ emissions in the long term for developing countries, the effect is positive for developed countries. In developing countries, higher exchange rate will affect prices of fossil fuel forcing local firms to switch to renewable energy sources that are not imported. As established by Shah et al. (2022), energy consumption is one factor that contributes to CO₂ emissions and shift from more carbon intensive (non-renewable) energy sources to renewables will lead to a reduction in CO₂ emissions.

2.3. Impact of renewable energy on carbon dioxide emissions

Energy has become a basic necessity on which humans thrive. Recently, the demand for energy has increased exponentially due to the rise in population coupled with the development of the global economy (Xu et al., 2019). One of the main causes of global CO₂ emissions was discovered

to be the high levels of non-renewable energy consumption because fossil fuel usage accounts for 80% of global energy consumption (Chen et al., 2022; Shah et al., 2022). Despite the fact that non-renewable energy sources, particularly fossil fuels, are crucial for most developing nations' economic growth, its effect on the environment's carrying capacity is worrying (Murshed et al., 2021). This has triggered many studies to ascertain whether renewable energy consumption is any better in terms of its effects on the natural environment.

An empirical study by Saidi and Omri (2020) on the effectiveness of renewable energy in mitigating CO₂ emissions revealed, among other things, that renewable energy is effective in reducing CO₂ emissions. Another study by Akram et al. (2020) conducted in Africa revealed that using renewable energy and promoting energy efficiency is a sure means to reduce CO₂ emissions on the continent. Similarly, Hao (2022) and Raihan et al. (2022) also found that renewable energy consumption contributes significantly to CO₂ emissions reduction. Rafei et al. (2022) used the panel vector autoregressive (PVAR) method of estimation to examine the role of economic complexity by focusing on institutional quality in mitigating environmental pollution. By grouping the countries into weak, medium, and high, in terms of their level of institutional and regulatory compliance, and using data for the period 1995 to 2017 for the analysis, the study found renewable energy to contribute to environmental sustainability through ecological footprints. In a related study, Usman et al. (2022) found in their study that measures aimed at promoting environmental sustainability, such as environmental innovation and environmental expenditure, reduce non-renewable energy consumption but promote renewable energy consumption. However, the opposite is found for environmental investment. Applying the Dumitrescu and Hurlin's tests for causality further revealed a unidirectional causality running from the two energy sources to environmental investment and expenditure. The implication drawn from Rafei et al. (2022) and Usman et al. (2022) is that, despite the negative effect of renewable energy on CO₂ emissions as established by the above listed studies, it requires active regulation measures to revise the conventional economic growth models in favour of green growth that prioritize renewable energy and other sustainable technologies.

On the contrary, Chen et al. (2022) find in their study using data from 95 countries that the reduction in CO₂ emissions resulting from the use of renewable energy is true only for developed countries that are characterized by strong institutions. However, in Voumik et al. (2023b), the effect of renewable energy on CO₂ emission is influenced by the shock in the economy. Thus, the study revealed that the effect is negative when there is a negative shock and positive when there is a positive shock using a time series data from Maldives. The authors recognized that renewable energy is a crucial means to reduce greenhouse gas emissions, despite the cost associated with the transition to renewable energy technology. The energy intensity of renewable technology is significant in the fight against pollution and climate change. Again, in a panel study of OECD countries by Dogru et al. (2020) renewable energy was found to contribute to the reduction of CO₂ emissions in the majority of the countries, but for some big economies in the sample such as Denmark, Germany, the Netherlands, Norway, Japan, Switzerland, and the Republic of Korea, renewable energy is found to have no effect on CO₂ emission. The literature suggests that renewable energy sources have played a role in meeting energy demands and contributed to a reduction in carbon dioxide emissions. However, the contribution of these sources is influenced by environmental constraints, technological advancements, economic challenges, and social factors. Notwithstanding, phasing out fossil fuels in favor of renewable energy is necessary to establish a sustainable socioeconomic system.

In summary, there is vast documentation on the effects of tourism, exchange rate, and renewable energy on the amount of CO₂ emissions across the world (Ali et al., 2021; Balsalobre-Lorente & Leitão, 2020; Sarpong et al., 2020). However, the results have been reported to be mixed, and the analysis is not common on the African continent. Furthermore, there is little documentation on how tourism affects CO₂ emissions considering the most visited tourist sites in Africa while the moderating role of exchange rate on the tourism-carbon emission relationship is scarce. Hence,

this study aims to fill the research gap in scope by focusing on seven leading tourism destinations in Africa and also explore the non-linear relationship and the interactive effect of exchange rate and tourism. This will enable policymakers to implement the right mix of interventions that will improve tourism on the African continent while reducing the amount of CO₂ emissions.

3. Methodology

3.1. Theoretical framework/underpinning

Theoretically, the relationship between international tourism, exchange rate, and renewable energy and CO₂ emissions is complex and dynamic. This relationship can be explained by how each of the factors influences CO₂ emissions. As countries develop economically and become more prosperous, they tend to experience an increase in international tourism. This can be attributed to rising incomes, increased mobility, and greater leisure spending. The growth in international tourism may contribute to higher CO₂ emissions due to increased transportation activity, energy consumption in hotels and infrastructure, and waste generation associated with tourism. However, as per capita income continues to rise, countries may prioritize environmental sustainability measures by investing in greener infrastructure, adopting sustainable tourism practices, and promoting eco-friendly transportation alternatives. At this stage, CO₂ emissions associated with tourism may decline. Again, exchange rates play a crucial role in economic development and can influence the environmental impacts of tourism. A weaker domestic currency can make a country's tourism destinations more affordable for international visitors, leading to an increase in tourism activity and associated CO₂ emissions. This is because a weaker currency stimulates economic growth, resulting in increased energy consumption and transportation activity. However, as countries progress along the income spectrum, they may implement policies to mitigate environmental impacts, such as carbon pricing or investment in renewable energy. This may be influenced by exchange rate effects on energy prices, making renewable energy more competitive and accessible. As a result, countries may experience a decline in CO₂ emissions despite continued tourism growth. Renewable energy also plays a vital role in mitigating CO₂ emissions and other environmental impacts of economic activities. As countries advance economically, they may invest in renewable energy infrastructure and transition away from fossil fuels. In the context of international tourism, countries with a strong renewable energy sector can provide cleaner energy sources for tourist facilities, transportation, and activities. This can lead to a reduction in CO₂ emissions associated with tourism, contributing to a decline in overall environmental degradation.

Following the above argument, it is clear that the Environmental Kuznets Curve (EKC) model can be employed as a theoretical framework underpinning the relationship between these variables, i.e., CO₂ emissions, international tourism, exchange rates, and renewable energy. The EKC model suggests that there is an inverted U-shaped relationship between per capita income (a proxy for economic development) and environmental degradation. In the context of this study, as countries progress economically, the environmental impacts of tourism may initially increase but can subsequently decline as environmental consciousness grows. Exchange rates can influence tourism activity and associated CO₂ emissions, while renewable energy can play a crucial role in decoupling economic growth from environmental degradation.

3.2. Empirical model

Our empirical model is based on the environmental Kuznets curve (EKC) framework which depicts a non-linear relationship between economic growth and environmental pollution. Thus, the EKC in its basic form shows the effect of increasing income on environmental quality. It argues that at lower levels of income, economic growth or increases in income worsens the quality of the environment through increased emissions. Beyond a certain threshold of income, however, increases in income lead to reduced emissions and therefore an increase in the quality of the environment, giving rise to an inverted U-shaped relationship between the two variables (Stern, 2004).

The EKC model is specified as:

$$LCO_{it} = \beta_0 + \beta_1 LY_{it} + \beta_2 LY_{it}^2 + \varepsilon_{it} \quad (1)$$

Where LCO is the log of carbon dioxide emissions, LY is the log of income, LY^2 is the log of income squared, i represent country, t represents time and ε is the independent and identically distributed error term. The betas are the parameters to be estimated.

To estimate equation one may yield unsatisfactory results due to omission of some important variables that may affect carbon emissions. Thus, modelling carbon emission as a function of income and its squared term would only lead to omission bias effect. As a result, other important variables that can drive carbon emission are to be added to the model. On the basis of prior studies and this paper's objective, Equation (1) is augmented to include other significant predictors of carbon dioxide emissions such as tourism, renewable energy consumption, and exchange rate. Hence Equation (1) is augmented to reflect the effect of tourism, renewable energy consumption, and exchange rate on carbon dioxide emissions, expressed in Equation (2).

$$LCO_{it} = \beta_0 + \beta_1 LY_{it} + \beta_2 LY_{it}^2 + \beta_3 LTOUR_{it} + \beta_4 LREN_{it} + \beta_5 EXR_{it} + \varepsilon_{it} \quad (2)$$

Where $LTOUR$ is the log of international tourism receipts (as a percentage of total exports), $LREN$ is the log of renewable energy consumption and EXR is the official exchange rate.

To ascertain how exchange rate with international tourism interacts to influence carbon dioxide emissions equation 2 is modified by including an interaction term of tourism and exchange rate ($LTOUR \times EXR$):

$$LCO_{it} = \beta_0 + \beta_1 LY_{it} + \beta_2 LY_{it}^2 + \beta_3 LTOUR_{it} + \beta_4 LREN_{it} + \beta_5 EXR_{it} + \beta_6 LTOUR_{it} * EXR_{it} + \varepsilon_{it} \quad (3)$$

From Equation 3 a positive coefficient of tourism (β_3) and a positive coefficient for the interaction term (β_6) is an indication that tourism increases carbon emission and it is reinforced by exchange rate. If a negative coefficient of tourism (β_3) and a negative coefficient for the interaction term (β_6) are recorded, it is an indication that tourism reduces carbon emission and it is reinforced by exchange rate. However, a positive coefficient of tourism (β_3) and a negative coefficient for the interaction term (β_6) is an indication that tourism increases carbon emission but the said effect is reduced by exchange rate. The opposite is true.

3.3. Source of data and data description

All the variables used in this study are sourced from the World Development Indicators of the World Bank (2022) database (<https://databank.worldbank.org/source/world-development-indicators#>). The seven leading tourism destination countries used in this study are Egypt, Tunisia, Kenya, South Africa, Zimbabwe, Ivory Coast, and Morocco. Our data are a panel data spanning the period 1995–2021. The choice of the period is informed by data availability for all seven countries.

Carbon dioxide emission is measured as per capita carbon dioxide emissions; income is measured by GDP per capita, tourism is measured as international tourism receipts (as a percentage of total exports), renewable energy is renewable energy consumption (as a percentage of total energy consumption) and EXR is the official exchange rate. Also, i represent country, t represents time and ε is the independent and identically distributed error term. The descriptive statistics of the variables and the correlation coefficients are shown in Table 1. In Table 2, the variance inflation factor is shown which depicts that multicollinearity is not an issue of concern in this study.

Table 1. Descriptive statistic and correlation results

Statistic	LCO	LTOUR	LREN	EXR	LY
Mean	0.363400	2.632066	2.960945	74.62364	7.885821
Median	0.590297	2.887463	2.661657	8.574708	7.895824
Maximum	2.148572	3.570642	4.421848	592.6056	8.745899
Minimum	-1.669721	0.086797	1.629241	0.945750	7.032171
Std. Dev.	1.136580	0.823123	0.916370	158.5333	0.506656
Correlation	LCO	LTOUR	LREN	EXR	LY
LCO	1.000000				
LTOUR	0.174232	1.000000			
LREN	-0.830280	-0.429686	1.000000		
EXR	-0.543644	-0.831689	0.617231	1.000000	
LY	0.958147	-0.007422	-0.747544	-0.377860	1.000000

Table 2. Variance inflation factor

	Coefficient	Uncentered
Variable	Variance	VIF
LREN	0.007702	2.603691
EXR	3.78E-07	1.519678
LY	0.009064	2.993072
LTOUR	0.001525	1.364462

3.4. Estimation technique

We begin the estimations by ascertaining whether our data from these seven countries are cross-sectionally independent. This has been the assumption for most first-generation panel unit root tests. However, due to the possible impact of an event on the macroeconomic indicators of all these countries at the same time which is likely to cause dependence among the countries in our dataset, it is imperative to test for cross-sectional dependence. We rely on four different tests, namely the Breusch Pagan LM test, the Pesaran scaled LM test, the Bias-corrected scaled LM, and the Pesaran cross-sectional dependence tests to achieve this objective.

After confirming that the data exhibit some dependence among our study countries, we use the cross-sectional Im-Pesaran-Shin (CIPS) to examine the stationarity properties of the data. The study chooses CIPS ahead of the traditional panel unit root tests such as the first general tests of Im-Pesaran-Shin (IPS), the Levin-Lin-Chu test (LLC), the Hadri LM test, and the ADF-Fisher test because it accounts for the presence of cross-sectional dependence. For comparison, the results of IPS and LLC are reported alongside those of the CIPS. We later proceed to test for the presence of a long-run relationship among our variables of interest using the Pedroni cointegration test. Due to the small cross-section of our dataset (seven countries), we estimate our model in Equation (2) using the Fully Modified Ordinary Least Square (FMOLS) method. This method was developed by Phillips and Hansen (1990) and is at its best in the presence of serial correlation and endogeneity in the independent variables. The FMOLS is also used to estimate models with variables integrated of order 1 and endogenous independent variables.

Furthermore, to ascertain the effect of tourism, renewable energy, and exchange rate on carbon dioxide emissions along a wide range of quantiles, the quantile regression analysis is performed. As noted in some studies, the quantile regression technique accounts for heterogeneity and non-Gaussian distributions. In addition, unlike the OLS estimators, quantile regression estimators provide robust results when the data contain outliers and are also skewed. The estimators

accommodate unobserved heterogeneity which facilitates the assessment of differences in the dependent variable among low, medium, and high changes (Koenker & Bassett, 1978; Kwakwa, 2021).

4. Results and discussion

This section reports the findings from the empirical analysis and discusses them. The estimation of the main results and examination of the relationships between variables is preceded by standard tests examining the properties of the data. First, we examine the cross-sectional dependence (CD) properties of the data. CD occurs within panel datasets when shocks from one cross-section of the panel yield spillover effects on another cross-section. It is important to observe the CD properties of the data in order to employ estimation techniques that account for its presence to avoid spurious results (Pesaran, 2007). Tables 3 and 4 present the results from CD tests. The results show that a null hypothesis of cross-sectional independence is rejected in favor of cross-sectional dependence. Thus, the data exhibit cross-sectional dependence.

Next, we examine the stationarity properties of the data to avoid arriving at spurious findings from the use of non-stationary data. Having noted the presence of CD in the data, we apply the Cross-sectional Im-Pesaran-Shin (CIPS) unit root test which is able to account effectively for the presence of CD in datasets in addition to the IPS test which is not robust in the presence of cross-sectional dependence to verify the stationarity condition of the series. The results reported in Table 5 show that all the variables are integrated of order 1.

Following the establishment of stationarity at first difference, we proceed to test for cointegration, which is a test of the long-run relationship among the variables. The results of the cointegration tests are shown in Table 6. The Pedroni cointegration test is employed, which has no weaknesses with regard to our datasets. In respect of the within-group dimension, the null hypothesis of no cointegrating relationship is rejected in favor of the alternative hypothesis of a cointegrating relationship in two of four test statistics while with respect to the between-group dimension, the null hypothesis of no cointegrating relationship is rejected in favor of the alternative of a cointegrating relationship in two of three test statistics. Altogether, there is evidence of cointegration among the variables and thus the study proceeds to estimate a regression to investigate the factors influencing CO₂ per capita among the seven countries.

Table 3. Results for residual cross-section dependence test

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	134.9742	15	.0000
Pesaran scaled LM	21.90420		.0000
Pesaran CD	8.082254		.0000

Table 4. Results for series cross-section dependence test

Series	Test			
	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
LY	276.94***	39.49***	39.35***	10.74***
LTOUR	115.96***	14.64***	14.50***	5.39***
LREN	195.97***	26.99***	26.85***	5.826***
LCO	249.91***	35.32***	35.17***	6.62***
EXR	187.67***	25.71***	25.58***	8.60**

*** $p < 0.01$; ** $p < 0.05$.

Table 5. Unit root test results

Series	LLC test		IPS test		CIPS test		Conclusion
	At levels	First difference	At levels	First difference	At levels	First difference	
EXR	82.473	382.853	-8.710***	-	-0.678	-3.94**	I(1)
LTOU	2.400	2.821	1.185	-3.504***	-1.13	-5.73***	I(1)
LY	-1.709**	-	0.886	-2.662***	-1.06	-2.53***	I(1)
LCO	1.554	-3.637***	-0.139	-4.903***	-1.07	-4.71***	I(1)
LREN	0.801	-4.092***	1.468	5.382***	-1.645	-4.17***	I(1)

*** and ** denote 1% and 5% levels of significance respectively.

Tables 7 and 8 show the results from the FMOLS regression which estimate the long-run elasticities of the variables with log of CO₂ per capita as the dependent variable. From Table 7, it is observed that income and the square of income have a positive and negative significant effect, respectively, on carbon emissions. This implies the existence of the Environmental Kuznets Curve (EKC) hypothesis in the case of these countries and confirms previous findings by (Apergis & Ozturk, 2015; Chien et al., 2021; Jahanger et al., 2022; Kwakwa et al., 2022). Initially, economic growth or increase in incomes are associated with increased emissions and thus, a worsening of environmental quality. Over time and beyond a certain threshold of income, however, further increases in income lead to a reduction in emissions due to a higher demand for a cleaner environment (Kwakwa et al., 2021) and consequently, higher environmental quality. Furthermore, factors such as better institutional quality (Ali et al., 2019; Rafei et al., 2022) to regulate the environment, which is often observed in countries when incomes are high, help to reduce emissions compared to what pertains at lower levels of income. The results suggest that recent economic expansions in the countries have been channeled to improve the quality of the environment via lower carbon emissions. It therefore indicates that their economic growth agenda has not ignored a cleaner environment agenda. This further points to the potential positive effect that increased incomes can yield to the environment should policy actions focus on enhancing environmental quality as incomes increase.

From Table 7 renewable energy is found to be negatively and statistically significantly related to CO₂ per capita. A 1% increase in renewable energy reduces emissions per capita by 0.22%. This is expected, as renewable sources of producing energy are cleaner, less polluting, or non-polluting in some cases. Thus, the continued use of renewable sources of energy as opposed to non-renewable traditional sources or increasing the share of energy sourced from renewables has a downward effect on carbon emissions in the selected countries and agrees with the findings of Adjei-Mantey and Adams (2023), Byaro et al. (2022) and Inglesi-Lotz and Dogan (2018). This is a call for emerging economies to invest in renewable energy and progressively increase the share of renewables in its energy mix to limit the deterioration of the environment. Policies to increase the share of energy sourced from renewables should be encouraged including incentives for large industrial entities to adopt renewables for their activities while promoting households to switch to renewable energy sources to the extent possible.

The study observed that tourism has a mildly significant but negative effect on carbon emissions. A 1% increase in international tourism receipts as a proportion of exports reduces CO₂ emissions per capita by 0.06%. This confirms the findings of Le and Nguyen (2021), Jiaqi et al. (2022) and Koçak et al. (2020) on the CO₂ emission reduction potential of tourism. It has been argued that tourism encourages better environmental regulation in destination cities (Tong et al., 2022). Destination countries are motivated to improve environmental regulation as heavy polluted cities will be less attractive to tourists which contributes to the negative relationship observed between tourism and

Table 6. Pedroni cointegration results

	Statistic	Prob		Weighted Statistic Prob.
Alternative hypothesis: common AR coefficients. (Within-dimension)				
Panel v-Statistic	-1.376054	0.9156	-1.364334	0.9138
Panel rho-Statistic	1.265905	0.8972	1.337016	0.9094
Panel PP-Statistic	-2.638782	0.0042	-2.648824	0.0040
Panel ADF-Statistic	-2.910401	0.0018	-2.893052	0.0019
Alternative hypothesis: individual AR coefficients. (Between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	1.934248	0.9735		
Group PP-Statistic	-3.114957	0.0009		
Group ADF-Statistic	-1.914883	0.0278		

Table 7. FMOLS regression results

Variable	Coefficient	Std error
LY	7.743***	1.076740
LY ²	-0.445***	0.069319
LREN	-0.216***	0.072195
LTOUR	-0.056*	0.029911
EXR	0.0002	0.000484
Adj-R ²	0.98	

*** $p < 1\%$ and * $p < 10\%$.

CO₂ emissions. Tourism has also been found to open up economies and to induce Foreign Direct Investment (FDI) inflows to support not only the tourism economy but also other sectors in the receiving economies (Yang et al., 2021). These FDI inflows may come with better, more efficient technology which reduces carbon emissions, while some inflows are strategically designed to support green projects thus contributing to tourism's negative effect on carbon emissions. In effect the results inform that the seven leading tourism destinations in Africa have benefited from the financial gains from international tourism. Also, the authorities might have been conscious of the effect that environmental degradation may have on their tourism fortunes. As such, they have ensured to improve the quality of the environment in the midst of international tourism development. Policy making could take advantage of the potential positive impacts of tourism on the environmental quality to channel FDI into green tourism projects that can attract international tourists.

Next, we proceed to examine the potential moderating role of exchange rates on tourism's effect on carbon dioxide emissions. The results are displayed in Table 8. Income, the square of income, and renewable energy all maintain their signs and significance on CO₂ emissions per capita. In addition, we find that exchange rates further reinforce the repressing effect of tourism on carbon emissions. The interaction term of tourism and exchange rate gives a significant negative effect. A 1% increase in exchange rates reduces CO₂ emissions per capita by 0.001% for every 1% increase in tourism receipts as a percentage of exports. Changes in the exchange rate affect carbon emissions primarily through exports and imports. It can be argued that an increase in the exchange rate makes it cheaper for tourists to visit and spend in the local economies and this supports why increases in the exchange rate reduce carbon emissions through tourism given the already established mechanism between tourism and CO₂ emissions.

Table 8. FMOLS regression (with interaction) results

Variable	Coefficient	Std error
LY	7.406***	1.008997
LY ²	−0.419***	0.065047
LREN	−0.187***	0.067929
LTOUR	0.020	0.035988
EXR	0.002***	0.000646
LTOUR x EXR	−0.0005***	0.000134
Adj-R ²	0.98	

***p<1%.

4.1. Quantile assessment outcomes

Further analysis was carried out using quantile regressions to examine a wide range of quantiles of the response variable, in this case, CO₂ emissions per capita. The findings from the quantile regression are presented in Table 9.

The results show that income and the square of income have a significantly positive and negative effect, respectively, on the 70th, 80th, and 90th quantiles. In other words, the presence of the EKC hypothesis is actually observed in the higher quantiles. This diverges slightly from the findings of Chien et al. (2021) who found income and its square to be significant across all quantiles in BRICS countries. However, the findings agree with Chien et al. (2021) on the fact that the turnaround points of the EKC shrink toward the higher quantiles suggesting that efforts are being made to transform the trajectory and composition of growth in favour of greater sustainability among the selected countries in this study.

Renewable energy has a negative effect across all quantiles. However, its significance is observed from the 10th to 50th quantiles and the 90th quantile in this study. The implication is that renewable energy consumption has significant reducing effect on emissions only at lower to medium emission quantiles and the highest quantiles, while the effect is not statistically significant at other emission quantiles. In other words, among the countries with lower emissions, and those with the highest level of emissions, increasing renewable energy use can have significant effects on carbon emissions and agrees with the findings of Syed et al. (2022), Altinoz and Dogan (2021) and Byaro et al. (2022).

The results show a checkered negative impact of tourism across the quantiles. The upper and lower quantiles show a significant reducing effect of tourism on CO₂ emissions, while those in the medium emission quantiles do not show significant effect. This implies that for countries that are within the upper emission quantiles and the lower quantiles, increasing tourism receipts leads to significant reductions in CO₂ per capita. For such countries, therefore, easing up inbound travel restrictions and promoting tourism would be beneficial for the environmental quality of those countries. Indeed, studies such as Tong et al. (2022) and Jiaqi et al. (2022) have observed that tourism's effect on CO₂ could be both direct and indirect and thus the overall effect depends on these two. While effects are not disaggregated in this study into direct and indirect effects, it is nonetheless plausible for these to play out in the respective quantiles leading to the observed effects of tourism across the different quantiles. The quantile regressions show a negative and significant effect of exchange rates across all quantiles and support the findings of Zhang and Zhang (2018). This may be that a rise in the exchange rate reduces the consumption behavior of individuals from energy-intensive goods to less energy-dependent goods.

Table 9. Quantile regression results

	Coefficient (Std. error)								
Variable	10th quantile	20th quantile	30th quantile	40th quantile	50 th quantile	60th quantile	70th quantile	80th quantile	90th quantile
LY	8.722 (7.698)	5.287 (9.824)	0.894 (2.519)	1.957 (2.981)	2.447 (3.113)	5.526 (3.337)	8.911*** (2.404)	10.082*** (2.361)	9.719***
LY ²	-0.461 (0.503)	-0.234 (0.642)	0.053 (0.154)	-0.012 (0.181)	-0.043 (0.189)	-0.233 (0.203)	-0.444*** (0.147)	-0.520*** (0.145)	-0.510*** (0.163)
LREN	-0.169*** (0.048)	-0.174*** (0.059)	-0.193** (0.092)	-0.209* (0.110)	-0.203* (0.11)	-0.128 (0.121)	-0.062 (0.095)	-0.025 (0.1116)	-0.234* (0.139)
LTOUR	-0.126*** (0.045)	-0.040 (0.057)	-0.125** (0.059)	-0.087 (0.068)	-0.087 (0.071)	-0.105 (0.073)	-0.179*** (0.064)	-0.187** (0.072)	-0.209*** (0.065)
EXR	-0.001*** (0.0004)	-0.001** (0.0005)	-0.001*** (0.0004)	-0.001*** (0.0004)	-0.001*** (0.0005)	-0.002*** (0.0005)	-0.002*** (0.0004)	-0.002*** (0.0004)	-0.002*** (0.0004)
C	-38.934 (29.272)	-26.212 (37.325)	-9.155 (10.399)	-13.379 (12.388)	-15.315 (12.920)	-27.842** (13.827)	-41.241*** (9.965)	-45.672*** (9.770)	-42.647*** (10.876)
Adj-R ²	0.82	0.83	0.83	0.81	0.80	0.78	0.78	0.79	0.78

***p<1%; **p<5% and *p<10%.

In summary, we find that international tourism has a repressing impact on carbon emissions and must thus be encouraged. Furthermore, our results confirm the existence of the EKC hypothesis among the seven countries as found by several other studies, while renewable energy adoption was also found to be crucial to reducing CO₂ emissions, particularly for countries at the lower and upper ends of the emission quantiles.

5. Conclusion and recommendations

The study examined the role of tourism, exchange rate, and renewable energy on carbon dioxide emissions in seven leading tourism destinations in Africa with data from 1995 to 2021. In analyzing the data, the Fully Modified Ordinary Least Squares (FMOLS) regression as well as a quantile regression approach to identify the diverse range of quantiles of carbon emissions over which the explanatory variables are relevant were employed. The countries are Egypt, Tunisia, Kenya, South Africa, Zimbabwe, Ivory Coast, and Morocco. The results showed that tourism has a negative and statistically significant effect on CO₂ emissions per capita, while the effect is reinforced by increasing exchange rates. Furthermore, renewable energy was found to also reduce carbon emissions, while the EKC hypothesis was found to exist for the panel of countries in the study. That is, emissions increase at lower levels of income and tend to reduce at higher income levels.

Following the findings of this study, we recommend that international tourism is promoted in our countries of study and by extension other emerging economies. This can be further enhanced by relaxing entry restrictions into the countries under observation and indeed other African countries to motivate more inbound travel by tourists to boost tourism receipts. Relaxing entry procedures and making it easier for inbound tourists potentially increase tourism and subsequently contribute to reductions in carbon emissions. Easing restrictions might include easing visa acquisition procedures such as offering limited time visas on arrival to potential tourists to encourage tourist visits to these countries. In addition to these, multiple tourism destinations within these countries should be developed to give tourists variety of places to visit once a decision to travel to these countries has been made. This makes it generally more attractive for a favorable tourism decision to be made. Development of these additional tourism locations should be done emission-free, which in itself could be an added incentive for tourists to visit especially since the global goal of environmental sustainability is becoming popular around the world by the day.

Furthermore, renewable energy adoption should be scaled up in these countries as a means of reducing heavy polluting energy sources to reduce emissions emanating from the energy sector. This way, carbon emissions will reduce to the benefit of the environment and future generations. Fortunately, many countries in Africa have sufficient renewable resources including solar and wind which could be harnessed effectively to increase the share of renewables in the total energy mix. Since a key component of international tourism is within-country transport as tourists would have to move from one place to another, it may be critical to develop transportation systems that rely on renewable or clean energy in order for tourists to use while visiting. For example, the use of electric tour buses rather than fossil fuel powered tour buses should be the policy so that potential emissions from transport during tourist visits could be reduced. This will further deepen the negative effect of tourism on carbon emissions. Policies to stabilize the exchange rate are recommended to achieve many macroeconomic outcomes. The carbon dioxide emission reducing effect following an appreciation of the exchange leads to the suggestion that authorities can capitalize on such appreciation of the exchange rate and draw citizens' attention to the need to engage in pro-environmental behavior so as to help reduce carbon dioxide emissions.

The limitations of the study include data limitations that made it impossible to consider more countries within Africa, especially given the continent's huge tourism resources and potential. Additionally, the study considers international tourism only and does not focus on local tourism which is also an important component of tourism receipts and potentially has implications for carbon

emissions as well. Thus, including local tourism in a future study might increase the generalization of the findings. Where data is available, the effects of various forms of tourism such as sports tourism, cultural tourism, and educational tourism among others can be assessed. A sectoral analysis regarding the effect of renewable energy would offer further insights for policymaking.

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