



The role of tourism and renewable energy in testing the environmental Kuznets curve in the BRICS countries: fresh evidence from methods of moments quantile regression

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Abstract

BRICS are among the rising nations which drive economic growth by excessive utilization of resources and resulting in environment degradation. Although there is bulk of research on environmental Kuznets curve (EKC), very limited studies explored the scope in context of tourism in BRICS countries. So this research is conducted to explore the association of tourism, renewable energy, and economic growth with carbon emissions by using annual data of BRICS countries from the year 1995 to 2018. By using the recent approach of method of moments quantile regression (MMQR), the finding shows that tourism has stronger significant negative effects from 10th to 40th quantile while the effects are insignificant at remaining quantiles. Furthermore, an inverted U-shape EKC curve is also apparent at all quantiles excluding 10th and 20th quantiles. For renewable energy, the results are found negatively significant across all quantiles (10th–90th) which claim that CO₂ emission can be reduced by opting renewable sources. Hence, the empirical results of the current study provide insights for policymakers to consume renewable energy sources for the sustainable economic growth and solution of environmental problems.

Keywords Tourism · Renewable energy · EKC · MMQR · BRICS

Introduction

In the twenty-first century, one of the top most issues faced by government and policymakers is global warming which has become a crucial issue globally (Rogelj et al. 2018; Destek and Sarkodie 2019; Khattak et al. 2020). The earth surface has amplified its average temperature 0.5 °C by taking 100 years more from 0.19 to 0.31 °C spanning the period 1880–1994, but surprisingly, it increased up to 0.9 °C in 2017 by using

only 20 years. The main reason behind such rapid rise of temperature is emission of greenhouse gases especially carbon dioxide (CO₂) emissions which occurs due to overutilization of fossil fuels in the form of gas, coal, and oil and acts as an energy source for economic activities (Gokmenoglu and Taspinar 2018; Sarkodie 2018; Rafindadi and Usman 2019). In 2014, Intergovernmental Panel report on Climate Change (IPCC Panel 2014) has identified that economic development and taming the living standard of people led to almost 76.6%

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of CO₂ emission in developing countries which is about 3/4 of the emission of greenhouse gases and is considered as the main culprit of polluting the world (Huaman and Jun 2014).

In recent years, the debate on energy consumption, economic growth, and environment quality has been stated by many experts; i.e., the expansion of economic activities are based on higher energy consumption (Sultan et al. 2018) and these higher energy consumption adversely exert pressure on environment (World Bank 2016; Koçak and Şarkgüneşi 2018). However, currently, the emissions have been lessened by increasingly consumption of renewable energy sources (Belaïd and Youssef 2017; Ben Jebli and Ben Youssef 2017). According to Bilgili et al. (2016), Bhattacharya et al. (2017), Dong et al. (2017), and Goh and Ang (2018), renewable energy is ideal for cleaner energy utilization in replacement of fossil fuels and hence leads to less CO₂ emissions.

At present, there are numerous studies that have been exploring the interactions between energy consumption, economic growth, and environment. But the association between energy utilization and environment quality with particular sectors of the economy remained unexplored which deserves attention, and tourism is among those segments. Both developed and developing countries have been experiencing the continuous growth in tourism sector over the last few decades. More importantly in developing countries, tourism sector acts a source of income by establishing enterprises and creating job opportunities followed by improvement in the infrastructure and contribution to the balance of payments. According to UNWTO (2017), the share of international tourism to world GDP accounts 10% and encompasses 7% of the world's export and 30% of the service exports in the former 5 years.

Besides increasing the national income, the tourism sector is also accountable for an increase in demand of energy either through fossil fuel consumption or through electricity in all tourism allied activities from transport (75%) to lodging (20%) or other sectors (5%) (see Dawson et al. 2010; Dubois et al. 2011; Gössling 2013; Saenz-de-Miera and Rosselló 2014; Tsai et al. 2014). Depending on the source of energy use, i.e., renewable or non-renewable energy use, the tourism sector may either reduce or enhance the pollution in the environment. Lin (2010) reflected that the modes of transportation preferred by visitors directly stimulate CO₂ emissions. The lightening and air conditioning in hotels also additionally accountable for overconsumption of energy either directly or indirectly and in both ways pose serious threats to sustainable development of environment (Ozturk et al. 2016). These undesirable effects boost developed and especially developing countries to take necessary measures to decline tourism-induced adverse impacts. Although tourism and environment are much related, only few studies explored its possible environmental effects in developing countries (de Vita et al. 2015; Dogan and Turkekul 2016).

Moreover, according to Future Markets' Insights (2020), the five progressively flourishing economies such as Brazil, Russia, India, China, and South Africa (BRICS) (Azevedo et al. 2018; Danish et al. 2019) not only show positive economic outlook but also hold greater potential for the development of tourism and offer more attractive choices for tourist destinations, both inbound and outbound tourism (Tradings 2020). Furthermore, the BRICS nations are expected to surge up in global gross national product (GNP) to 37.7% by the year 2030, which is more than Europe (15.3%) and USA (15%) (World Bank 2017). Though the rising economic prosperity of BRICS nations not only steers the development of tourism, the expansion of this sector also affects environment (Dong et al. 2017). So the harmful impacts of rapidly increase of tourism industry on the environment cannot be ignored (Tabatchnaiatamirisa et al. 1997; Gssling 2002), and if the situation persist, the unrestricted use of the resources for tourism would not only lead to the global warming but also are at menace of being depleted and remained unsecured for the upcoming generations. The statistics documented by British Petroleum (BP) in 2013 elaborated that emissions of CO₂ by BRICS members increased up to 14,110 million tonnes (Mt) which was twice larger than the emissions in 2000. Since 2009, every year, the members of BRICS emit almost 40% of carbon globally (BP Energy Economics. 2018). The drastic emissions of carbon have led BRICS members towards enormous environmental hazards (Shahbaz et al. 2016; Azevedo et al. 2018).

In developing countries especially in BRICS countries, the link among tourism and the environment is vital to examine, but it has not gained much consideration specifically under environment Kuznets curve (Kuznets 1955) framework. Recently, BRICS as emergent regions have been undergoing fast development in CO₂ emissions, GDP, energy consumption, and tourism. However, the linkages among these variables are slightly known in the region. So to enhance the scarce literature on this subject, the present study augments the notion of EKC through the enclosure of tourism along with renewable energy. This study is expected to propose more consistent and valid empirical results in the fields coping with environment so the contribution of this empirical study lies in threefolds. (1) The present study attempts to analyze the role of tourism, renewable energy consumption, and economic growth on CO₂ emissions for panel of BRICS economies (2) to investigate the existence of environmental Kuznets curve (EKC) across the entire carbon emissions distribution. (3) Moreover, choosing the appropriate econometric approach is vital for the validity of the findings, so the third contribution is that numerous studies which used panel data have estimated regression quantiles under conditional mean. But this study not only estimating the conditional means but additionally regulating the distributional heterogeneity and unveiling the explanatory parameters' latent effects across the conditional

distribution of dependent variable, so to get more robust and appropriate results of heterogeneous panel, a fresh approach named as methods of moments of quantile regression (MMQR) is employed (Machado and Silva 2019).

As compared with other models, the evaluation of the EKC hypothesis under conditional distribution of emissions at different quantiles offers many benefits: (1) the conditional quantiles' estimates stemming from the explained parameter are extra vigorous to outliers as compared with the conditional mean estimates that are more inclined to the misleading outliers' results (Koenker 2004); (2) the full distributional impact on emissions are failed to be portrayed by the conditional mean estimates so the quantile regression in panel regression has more intuitive appeal as it stratifies the independent variables' distributional effects over the dependent variable into various quantile ranges which makes simpler to categorize the heterogeneous cross-sectional groups with their heterogeneous effects. These aspects make MMQR the prime and correct approach in better understanding the relationship among tourism, renewable energy, and CO₂ emissions across heterogeneous quantiles and to yield more consistent and robust empirical results.

The structure of remaining study is as follows such as the “[Review of literature](#)” section delivers the literature review. Data and the methodology are presented in the “[Data and the methodology](#)” section. Subsequently, the “[Estimation results and discussion](#)” section includes estimation results and discussions. And lastly, on the basis of empirical results, the “[Conclusion and policy recommendations](#)” section delivers conclusions and policy recommendations.

Review of literature

In recent years, the literature of EKC is continually expanding and receiving attention of the emergent scholars in academic fields (Sarkodie and Strezov 2018; Sinha and Shahbaz 2018; Bekun et al. 2019; Rafindadi and Usman 2019; Aziz et al. 2020). The literature review section is accompanied by the streams of the studies dealing with tourism and renewable energy. These streams not only highlighted the EKC hypothesis tested before but also elucidated different approaches used by earlier researchers.

In the existing literature, many studies have evidenced the favorable impacts of tourism on environment such as Kongbuamai et al. (2020) in the ASEAN countries studied the effects of tourism, energy consumption, natural resources, and economic growth on ecological footprint over the years 1995 to 2016. The results not only showed an upturned U-shaped EKC but also evidenced negative relationship between the variables and suggested that the environmental quality in ASEAN countries can be improved by efficiently utilization of natural resources in tourism sector. Similarly, Danish

(2018) also validated EKC hypothesis in BRICS region from the year 1995 to 2014 and proved that the tourism sector negatively influences the environmental pollution. Likewise, Ben Jebli et al. (2019) scrutinized the causal associations of tourism, renewable energy, trade, GDP, and foreign direct investment with carbon emissions in 22 countries of central and South-America between the periods 1995–2010. The outcomes highlighted that tourism, renewable energy, and FDI are supportive for minimizing the emissions of CO₂. Other studies exploring the same phenomenon with same results include Lee and Brahmairene (2013), Katircioglu (2014), Ozturk et al. (2016), and Raza and Shah (2017).

Though the potential favorable impacts of tourism on CO₂ have been studied in the previous years, their adverse effects on the environment cannot be ignored, and in this regard, many recent studies have been conducted. The sector of tourism is one of the major sectors contributing to environment degradation as it relies on higher consumption of energy for its activities. Among recent articles, Gulistan et al. (2020) in 112 countries, Balsalobre-Lorente et al. (2020) in OECD countries, and Anser et al. (2020) in a panel of Group of Seven countries examined the association and documented that tourism induces environmental deterioration. Mikayilov et al. (2019) also explored the tourism and ecological footprint links in Azerbaijan over the periods between 1996 and 2014 by using time-varying coefficient cointegration (TVC) approach and also conventional cointegration approach. Their long-run results between tourism and ecological footprint invalidated the EKC hypothesis. Likewise, Shaheen et al. (2019) in their study endorsed the granger causality, i.e., the link between tourism and energy demand to CO₂ emissions and international tourism departure. Dogan and Aslan (2017) and Zhang and Liu (2019) in their work also proved the same results; i.e., the growth in energy consumption causes CO₂ emissions but in context of tourism, their results were not the similar. Zhang and Liu (2019) found that tourism may cause environmental degradation in 10 Northeast and Southeast Asian countries but Dogan et al. (2017) in panel of European Union found that tourism development supports in alleviating CO₂ emissions. The findings endorsed that the policymakers should emphasize on environmental protection and cleaner technologies. Some other studies in different countries such Durbarray (2015) in Mauritius, de Vita et al. (2015) in case of Turkey, León et al. (2014) in developed and less developed countries, Dogan et al. (2017) in case of Organization for Economic Cooperation and Development (OECD) countries, Mohammed (2015) in case of 48 top international tourism destinations, Katircioglu (2014) in Turkey, Katircioğlu (2014) in Singapore, and Sharif et al. (2017) in Pakistan also found the same consequences and revealed that tourism aggravates both energy consumption and CO₂ emissions. The fresh study of Fethi and Senyuçel (2020) also corresponded with the

previous literature and found that tourism development and CO₂ emissions are positively associated in 50 tourist destination countries.

In continuance to above plethora, some studies found mixed results such as Paramati et al. (2017a) in Eastern and Western European Union (EU) countries found that the effects are positive in case of Eastern EU, while in case of Western EU countries, effects are negative. Azam et al. (2018) also found that tourism and environmental pollution are positively significant in Malaysia while in Thailand and Singapore, the results are negative. Sghaier et al. (2019) reported the positive results for Tunisia but for Egypt, established an uptumed U-shaped negative relationship between tourism and environment. Paramati et al. (2017b) in another study exposed that tourism on environment affects differently both in developed and developing countries. It recovers environment rapidly in developed countries as compared with developing countries.

Moreover, our study also encompasses the stream of the researches dealing with renewable energy; there exists a number of studies which explored the interaction between economic variables and environment but not remained limited to environment and also encompassed other variables such as non-renewable energy, GDP, and trade (see Ocal and Aslan 2013; Al-Mulali et al. 2015; Jebli and Youssef 2015; Dogan and Turkekul 2016; Inglesi-Lotz 2016; Bhattacharya et al. 2017; Ito 2017; Riti et al. 2017; Gozgor 2018; Sarkodie and Adams 2018). Under the framework of EKC, several earlier studies exposed that the main cause of emissions of CO₂ is energy utilization (Pao and Tsai 2010) which is one of the key drivers of environment deterioration (Anatasia 2015; Heidari et al. 2015; Kasman and Duman 2015; Cetin et al. 2018; Koçak and Şarkgüneşi 2018). But renewable energy (e.g., wind, solar, and biomass) has been emerged as an alternative source to recover environment, and in this regard, various scholars have evidenced and endorsed the EKC such as Marrero (2010), Sulaiman et al. (2013), and Farhani and Shahbaz (2014). Their studies proved that continuously use of renewable energy regenerates the ecosystem. Similarly, Khattak et al. (2020) in their study found that consumption of renewable energy alleviated CO₂ emissions in panel of BRICS countries excluding South Africa, and EKC was also validated excluding India and South Africa. Nathaniel et al. (2020b) in CIVETS countries (Colombia, Indonesia, Vietnam, Egypt, Turkey, and South Africa) found that renewable energy recovers quality of environment. Naz et al. (2019) in Pakistan though invalidated the EKC hypothesis and proved pollution haven hypothesis among the renewable energy, foreign direct investment, economic growth, and CO₂ but the moderation and mediation effect of income and FDI with renewable energy concluded that renewable energy may support to endorse pollution halo hypothesis. The same outcome was proved by Elshimy and El-Aasar (2019) in Arab

world, Nathaniel and Theonu (2019) in Africa, Asongu et al. (2019) in sub Saharan Africa, Nathaniel et al. (2020a) in Middle East and North African countries (MENA), Zoundi (2017) in 25 African countries, Ito (2017) in developing economies, Cherni and Jouini (2017) in Tunisia, Dogan and Turkekul (2016) in the USA, Waheed et al. (2018) and Aziz et al. (2020) in Pakistan, and Cheng et al. (2019a) in BRICS countries. All these studies ascertained that consumption of renewable energy is likely to boost environment quality. Apart from those conferred above, some studies found mixed results; in case of China, Chen et al. (2019) besides invalidation of Kuznets curve hypothesis found that the impact of renewable energy and carbon emission is diverse across different regions of China over the period 1995–2012. Similarly, Charfeddine and Kahia (2019) also found marginal impact of renewable energy and financial development on CO₂ emissions for Middle East and North Africa over 1980 to 2015.

Additionally, the major criticism that exists in the previous related studies is methodology selection. The countries in a panel dataset are more probably subjected to heterogeneity and cross-sectional dependence, so the use of econometric methods that take into account the cross-sectional dependence and heterogeneity has tendency to give unbiased and more precise results. But in context of environment pollution of the BRICS countries, the earlier researchers have used several techniques such as OLS and FMOLS was used by Azevedo et al. (2018) and Hu et al. (2018), autoregressive distributed lag model by Gozgor (2018) and Sarkodie and Adams (2018), vector error correction model by Piaggio et al. (2017), fixed-effect panel regression by Nassani et al. (2017), and vector auto-regression by Li and Su (2017). Besides, some other studies also employed conditional mean method but this method has shortcoming that it only offers mean estimates for the whole panel and fails to deliver the complete picture of panel data's individual and distributional heterogeneity (Koenker 2004; Sarkodie and Strezov 2019) which may coxed to ambiguous results of regression analysis (Zhu et al. 2016; Cheng et al. 2018). To overcome the abovementioned shortcomings, the current study is attempting to evaluate the role of tourism, renewable energy utilization, economic growth, and tourism on CO₂ emissions for BRICS panel by employing method of moments quantile regression established by Machado and Silva (2019). Using this technique in BRICS countries will enrich the body of literature and will set new avenues for other researchers to explore the distributional heterogeneity in other regions.

Data and methodology

Based on the existing literature, our goal is to explore the role of tourism, renewable energy utilization, economic growth, and tourism on CO₂ emissions for BRICS panel.

Additionally, the current study is also endeavoring to test the EKC hypothesis among desired variables. To accomplish the motive of the study, we have included variables such as carbon dioxide (CO₂) emissions measured in metric tons and economic growth (GDP) measured in constant US\$. Similarly, renewable energy (RE) consumption is measured in percentage of energy consumption and tourism (TOR) measured in arrivals numbers. The data of GDP, TOR, and RE for the period of 1995 to 2018 is assembled from the World Development Indicators (WDI) databank, and CO₂ data is gathered from British Petroleum. We thus computed the following model:

$$CO_2 = \alpha_0 + GDP + GDP^2 + TOR + RE \tag{1}$$

Descriptive statistics

Table 1 portrays the descriptive specifics for the sample of BRICS region. The outcome reveals that the maximum value and the minimum value of CO₂ for BRICS countries are about 12.78 and 0.841, respectively. On the basis of the mean values, the GDP of all countries is approximately 3.315 and its standard deviation is about 0.039. Moreover, BRICS countries have renewable energy utilization with mean value of 26.47 and the standard deviation is about 17.30 with largest value of 54.48412 and the smallest value of 3.227. Finally on the basis of the mean value of tourism, the results show mean value of 16,958 which varies from 60,740 to 19,910 with standard deviation of 16,524. From Table 1, it can also be seen that the positive skewness has been exhibited by the variables; i.e., CO₂, TOR, and RE are positively skewed and have thinner tails than the normal distribution. The deviation of variables from the normal distribution can be confirmed by the Jarque-Bera statistics. The non-existence of normality except GDP let researchers to opt quantile estimations (Sharif

and Afshan 2018; Troster et al. 2018; Mishra et al. 2019; Sharif et al. 2019a, b).

Panel estimation techniques

For analysis of comparison, we employed the fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and the ordinary least squares (FE-OLS) fixed effects. The technique of FE-OLS is improved with standard errors of Driscoll and Kraay, which are robust to common forms of cross-sectional dependence and autocorrelation up to a definite lag. In order to estimate the dynamic cointegrated panel models, the main reason is heterogeneity issue as spotted by Pedroni (2004) with differences of mean amid cross-sections and variations in cross-sectional adjustment to the cointegrating equilibrium. The FMOLS (Pedroni 2004) amends these issues accordingly by including intercepts of individual-specific and allows properties of heterogeneous serial correlation of the error processes across individual members within the panel. Kao and Chiang (1999) extended the DOLS estimator to panel settings on the basis of the findings of Monte Carlo simulations, and DOLS was found to be unbiased in finite samples in comparison with OLS and FMOLS estimators. The endogeneity can also be addressed through the amplification of lead and lagged difference which suppress the feedback of endogeneity in DOLS estimator. Due to the limitations of previous estimation methods, a panel quantile regression technique was employed to examine the distributional and heterogeneous effect across quantiles (Sarkodie and Strezov 2019).

Due to the limitations in earlier estimation techniques, a panel quantile regression technique was employed across quantiles to observe the distributional and heterogeneous effects (Sarkodie and Strezov 2019). In 1978, Koenker and Bassett introduced the panel quantile regression method. The quantile regressions are generally applied to assess the conditional mean or various dependent variables' quantiles subjected to the values of explanatory parameters in contrast to least squares regression, which produce estimations of the conditional mean of the explained parameter subjected to definite standards of the explanatory parameters. In estimates, the quantile regression is more robust for data having outliers. Moreover in circumstances where the association between two variables' conditional means is insubstantial, it is the appropriate approach to use (Binder and Coad 2011).

However, we employed the method initiated by Machado and Silva (2019) named as method of moments quantile regression (MMQR) with fixed effects in this study. Though the quantile regression is robust to outliers, but within panel, it fails to consider the potential unobserved heterogeneity across individuals. This method certainly identifies the conditional heterogeneous covariance effects of CO₂ determinants by permitting the individual effect to influence the complete

Table 1 Summary statistics

| Variables | CO2 | LGDP | REN | TOR |
|-------------|----------|----------|----------|------------|
| Mean | 5.592449 | 3.315970 | 26.47671 | 16,958,226 |
| Median | 4.280584 | 3.317114 | 19.12144 | 8,904,000 |
| Maximum | 12.78498 | 3.409221 | 54.48412 | 60,740,000 |
| Minimum | 0.841937 | 3.237595 | 3.227796 | 1,991,000 |
| Std. Dev. | 4.054430 | 0.039982 | 17.30104 | 16,524,459 |
| Skewness | 0.270065 | 0.193855 | 0.094440 | 1.326592 |
| Kurtosis | 1.429390 | 2.619903 | 1.515449 | 3.670745 |
| Jarque-Bera | 11.49399 | 1.473963 | 9.798103 | 35.88613 |
| Probability | 0.003192 | 0.478556 | 0.007454 | 0.000000 |

Source: Author estimation

distribution rather than only altering means like Canay (2011) and Koenker (2004). This method is perfectly applicable in cases where the panel data is rooted with individual effects and when the explanatory variables have endogenous properties. It is quite an intuitive method because of yielding non-crossing estimates in quantile regression. The conditional quantile estimates $Q_y(\tau|X)$ of the location-scale variant model are expressed by the following equation:

$$Y_{it} = \alpha_i + X'_{it}\beta + (\delta_i + Z'_{it}\gamma)U_{it} \tag{2}$$

where the probability, $P\{\delta_i + Z'_{it}\gamma > 0\} = 1 \cdot (\alpha, \beta', \delta, \gamma)'$, and parameters are to be estimated. The individual i fixed effects are designated by (α_i, δ_i) , $i = 1, \dots, n$, and k -vector of known elements of X is denoted by Z which are differentiable conversions with component l given by:

$$Z_l = Z_l(X), l = 1, \dots, k \tag{3}$$

X_{it} is independently and identically distributed for any fixed i and also across time t . U_{it} is also independently and identically distributed across individuals i through time t and are orthogonal to X_{it} and are standardized to accomplish the moment conditions (Machado and Silva 2019), which amid other things do not infer stringent exogenous behavior. Equation (1) denotes the following:

$$Q_y(\tau|X_{it}) = (\alpha_i + \delta_i q(\tau)) + X'_{it}\beta + Z'_{it}\gamma q(\tau) \tag{4}$$

From Eq. (3), vector of independent variables are represented by X'_{it} ; i.e., GDP per capita is taken in natural log form (LGDP), the same with renewable energy (LRE), and tourism (LTOR) in this study. The quantile distribution of explained variable Y_{it} (i.e., natural log of CO2 emissions per capita) is represented by $Q_y(\tau|X_{it})$ which is conditional on the location of explanatory variable and $X'_{it} \cdot -\alpha_i(\tau) \equiv \alpha_i + \delta_i q(\tau)$ is the scalar coefficient which represents the fixed effect of quantile τ for individual i . In contrast to the common least square fixed effects, the individual effect does not show intercept shift. These parameters are time-invariant whose impacts of heterogenous are permissible to vary along the conditional distribution of the quantiles of endogenous variable Y . $q(\tau)$ represents the τ -th sample quantile which is assessed by resolving the resulting optimization issue:

$$\min_q \sum_i \sum_t \rho_\tau \left(R_{it} - (\delta_i + Z'_{it}\gamma)q \right) \tag{5}$$

where $\rho_\tau(A) = (\tau - 1)AI\{A \leq 0\} + TAI\{A > 0\}$ signifies the check function.

Estimation results and discussion

Unit root and cross-sectional dependence tests

To determine the variables' time series properties before computing unknown parameters, some compulsory initial tests are required to be taken. So, one of the important steps in this regard is to check the unit root, so in this regard, the findings of variables with and without trend are portrayed in Table 2. It is apparent from the unit root test that entire variables do not exhibit the problem of unit root at first difference. The results are highly significant at first difference both with trend and without trend.

It is more likely that countries in a panel dataset are more subjected to cross-sectional dependence, but the performance of old tests of unit root is not satisfactory as they do not encompass the cross-sectional dependence properties in the data series. And if the cross-sectional dependence occurring as a result of unobserved common factors is ignored, it diminishes the efficiency of panel data and leads to biased results (Phillips and Sul 2003). So to fix this issue and get robust coefficient estimates, second-order test of cross-dependence (CD) and cross-sectional augmented IPS (CIPS) are employed (Pesaran 2007), which remained unnoticed by test of first generation such as Levin, Lin and Chu, Im, Pesaran, and Shin (Raza and Shah 2017). The CD test results highly reject the null hypothesis for entire variables and reveal the presence of cross-sectional dependence in BRICS panel at 1% significance level (see Table 3). Furthermore, for CIPS unit root test, the results reflect the stationarity behavior of all variables at first difference which further certifies the existence of cointegration among variables in long run.

Panel cointegration test

We employed the cointegration test for panel data given by Pedroni (2004) and the bootstrapped cointegration test given

Table 2 Stationary analysis results

| Variables | Im, Pesaran, and Shin | | | |
|-----------|-----------------------|--------|-----------|-----------|
| | I(0) C | C&T | I(1) C | C&T |
| TOR | 0.382 | 0.401 | -5.483*** | -5.328*** |
| REN | -0.422 | -0.513 | -7.038*** | -7.228*** |
| GDP | 1.437 | 1.032 | -5.118*** | -4.833*** |
| CO2 | 0.968 | 1.046 | -5.499*** | -5.938*** |

The significance level at 1%, 5%, and 10% are represented by ***, **, and *, respectively

Source: Author estimation

Table 3 Unit root tests of cross-sectional dependence and CIPS

| Variables | CD results | p value | CIPS results | |
|-----------|------------|---------|--------------|-----------|
| | | | I(0) | I(1) |
| TOR | 18.483 | 0.000 | -0.473 | -1.733** |
| REN | 15.813 | 0.000 | -0.119 | -5.684*** |
| GDP | 29.162 | 0.000 | -0.684 | -3.996*** |
| CO2 | 34.048 | 0.000 | -0.335 | -5.443*** |

The significance level at 1%, 5%, and 10% are represented by ***, **, and *, respectively

Source: Author estimation

by Westerluns (2007) to avoid the spurious long-run liaison amidst parameters. Getting inspired by the methodology of Engle and Granger 2-step, Pedroni (2004) proposed panel cointegration framework of testing. According to the panel cointegration results, the hypothesis of no cointegration is rejected at 1% significance level because three tests such as panel v-statistics, panel PP-statistics, and panel ADF-statistics and two tests such as group PP and group ADF-statistics support this rejection. Since we have enough evidence, i.e., five results out of seven disclose that the variables in CO2 emission model move together in the long-run equilibrium (Table 4).

The cointegration null hypothesis with four additional tests is also performed under (Westerluns 2007) bootstrap technique which is regarded as second-generation cointegration test. This technique can provide us robust critical values by reducing the distortionary effects of cross-sectional dependence. The robust support for cointegration provided by this technique is displayed in Table 5. The result not only supports the null hypothesis rejection but also supports the long-run cointegration of desired variables in the model.

Table 4 Pedroni panel cointegration (Engle-Granger based) results

| Estimates | Stats. | Prob. |
|---|--------|-------|
| CO2 = f(GDP + GDP ² + TOR + RE) | | |
| Panel v-statistics | 2.431 | 0.008 |
| Panel rho-statistics | 0.657 | 0.745 |
| Panel PP-statistics | -3.475 | 0.000 |
| Panel ADF-statistics | -3.283 | 0.000 |
| Alternative hypothesis: individual AR coefficient | | |
| Group rho-statistic | 1.192 | 0.883 |
| Group PP-statistic | -3.872 | 0.000 |
| Group ADF-statistic | -4.058 | 0.000 |

Null hypothesis of no cointegration (Pedroni panel cointegration, 1999)

Source: Author estimation

Table 5 Westerlund (2007) bootstrap panel cointegration results

| Statistics | Value | Z value | p value | Robust p value |
|------------|---------|---------|---------|----------------|
| Gt | -5.432 | -4.688 | 0.000 | 0.000 |
| Ga | -23.831 | -19.483 | 0.000 | 0.000 |
| Pt | -28.481 | -16.321 | 0.000 | 0.000 |
| Pa | -32.615 | -31.889 | 0.000 | 0.000 |

The Westerlund 2007 panel cointegration null hypothesis is of no cointegration. The replication number is 500. Based on normal distribution, the p values are for a one-sided test. Based on 500 bootstrap replications, the robust p value are for a one-sided test

Source: Authors' estimation

Results of panel estimation

The estimation outcomes of FMOLS, DOLS, and FE-OLS are revealed in Table 6. The variables' coefficient is regarded as long-run elasticities as they are taken in natural log. The outcome shows that the coefficient estimates are quite closer in terms of statistical significance which is obtained from all three specifications, i.e., FMOLS, DOLS, and FE-OLS. Across all three specifications, the results of GDP2, TOR, and RE are more robust and significant having a negative effect on CO2 emissions. In case of GDP, the positive significant results are expected and correspond well with the previous studies which observed that an upsurge in the GDP multiplies the energy use and consequently lead to unfavorable CO2 emissions. It also infers that the BRICS region over the past few decades is among the most leading economies in the world which need more energy to keep pace with the economic development and thus discharges the toxic pollutants in the early phases of development. Moreover, the production of goods also necessitates the use of more fossil fuels and lead to more worsening of environment. This outcome is parallel with the recent findings of Udemba et al. (2019) in China who also found the positive liaison between GDP and CO2.

The quadratic function of income (GDP2) and CO2 ranges negatively from -19 to -22%. The positive coefficient of GDP and the negative coefficient of GDP2 are explicated by EKC hypothesis that infers that after reaching a certain economic development threshold, the additional upsurges in lead to lower emissions of CO2. The result in Table 6 shows the highly significant results for the EKC hypothesis, i.e., the upturned U-shape relationship between the economic growth and environment in the FE-OLS and DOLS at 1% level of significance and in FMOLS; the outcomes are significant at 5% significance level. The credibility of EKC imparts to the fact that the economic growth appeared in the BRICS countries is posing an ever increasingly challenge to the USA as their GDP in 2017 stroked up to 18 trillion U.S. dollars the

Table 6 Results of panel estimation for BRICS countries

| Variables | FMOLS | | | DOLS | | | FE-OLS | | |
|-----------|--------|---------|-------|--------|---------|-------|--------|---------|-------|
| | Coef. | t-stats | Prob. | Coef. | t-stats | Prob. | Coef. | t-stats | Prob. |
| LGDP | 0.785 | 9.493 | 0.000 | 0.462 | 16.594 | 0.000 | 0.842 | 6.483 | 0.000 |
| LGDP2 | -0.286 | -2.168 | 0.027 | -0.196 | -3.699 | 0.000 | -0.226 | -4.692 | 0.000 |
| LTOR | -0.387 | -11.594 | 0.000 | -0.331 | -7.593 | 0.000 | -0.316 | -8.493 | 0.000 |
| LRE | -0.236 | -5.694 | 0.000 | -0.264 | -5.794 | 0.000 | -0.218 | -7.002 | 0.000 |

Source: Author estimation

same as the USA in the same year (Plecher 2019) so it may help BRICS countries to opt environment clean technologies. Moreover, it exposes the balancing trend between the economic growth and the environmental quality as when the economy grows; the consumption of energy increases but when energy consumption shifts efficiently to the more conventional renewable energy sources, it reduces the carbon (CO₂) emission the same way as we have found in our results between GDP2 and CO₂. Sarkodie and Strezov (2019) in their work also found the same results between economic growth and pollution in developing countries. The other study conducted by Usman et al. (2019) in India; i.e., topmost emitter of carbon also established the EKC hypothesis. The same results were also reported by Rafindadi and Usman et al. (2019) in Africa, the leading GHGs and CO₂ emitter country, and also endorsed the EKC in the region. In Indonesia, Udemba et al. (2019) suggested that the higher and better economic growth of the country leads to lesser emissions. Thus, the more economic growth let countries to minimize their reliance on traditional fossil fuels and speedily reach to cleaner environment turning points.

Remarkably, the increase in the tourist arrival numbers by 1% is expected to decrease the emissions of CO₂ by ~33% in DOLS estimator and 31% in FE-OLS estimator. According to these results, it seems that the sector of tourism in the sample countries is not a major concern for pollution. It may also be elucidated by the fact that tourism sector has minimized their reliance on fossil fuels in their activities. The empirical outcomes on the other hand also show that sector of tourism has tendency to lessen environment pollution at a maximum rate. The maximum number of visitors helps countries to increase their revenues and invest on environmental friendly transportation. These results are consistent with those of Lee and Brahmastre (2013), Katircioglu (2014), Raza and Shah (2017), Danish (2018), Ben Jebli et al. (2019), and Kongbuamai et al. (2020) but opposite to the studies of Gulistan et al. (2020) in 122 countries, Anser et al. (2020) in Group of Seven countries, Fethi and Senyuçel (2020) in 50 tourist destinations, and Balsalobre-Lorente et al. (2020) in OECD countries.

Moving ahead to the environmental impact of renewable energy sources, the renewable energies are viewed as one of

the most feasible and sustainable solutions to mend the environmental status quo of our planet and alleviate and decrease the emissions without influencing the economic growth of countries. In our study, the RE energy is also negatively significant by 21% in FE-OLS estimator and 26% in DOLS in effect the level of carbon emissions. These verdicts infer that the energy consumption structured by the strength and intensity of renewable energy impacts CO₂ emissions, which is also reflected in the studies of Belaid and Youssef (2017) and Inglesi-Lotz and Dogan (2018) who revealed that renewable energy is significantly supportive to alleviate CO₂. There is bulk of studies in the economic literature related to renewable energy's impact on carbon emissions. Our results are aligned with the plethora of empirical evidences supporting that carbon emissions can be mitigated by switching to renewable energy sources drawn from clean sources (see Dogan and Eyup; Bölük and Mert 2015; Attiaoui et al. 2017; Bekhet and Othman 2018; Waheed et al. 2018; Sharif et al. 2019b; Aziz et al. 2020). For BRICS panel, Dong et al. (2018) also indicated that the consumption of renewable energy markedly reduces CO₂ emissions. But for South Africa, Khattak et al. (2020) showed insignificant results and also invalidated EKC hypothesis in all BRICS economies. Our results are slightly opposite to Chen et al. (2019) and Charfeddine and Kahia (2019) who also found marginal impacts of renewable energy on CO₂.

Results of panel quantile estimations (MMQR)

The effect of income in the form of GDP is positively significant and heterogenous for CO₂ across all quantiles at 1% significance level, and the impact of GDP on CO₂ across quantiles is increasingly upsurging while moving from lower to higher quantiles and reveals that rise in GDP by 1% stimulates CO₂ by 0.537–0.859%. At the uppermost quantile, the income had the highest coefficient and it deduces that carbon emission is at their lowermost level at quantiles where income effects on emissions are lowest. Contrary, at quantiles where emissions of carbon are highest, the income effects are also highest on emissions. It implies that more economic development leads to more carbon emissions by relying on fossil fuels for goods

production. Based on these outcomes, it is unveiled that in the BRICS countries, GDP is a main cause of CO₂ emissions over the specified period. The recent study of Cheng et al. (2019b) and Ummalla et al. (2019) in their studies also proved that coefficients of economic growth are positively and highly significantly with CO₂ emissions across the quantiles.

The economic development supported by effective regulatory framework is well-thought-out as a cure to recover environment. In case of GDP₂, its heterogeneous impact on CO₂ emission is present along the quantiles in the conditional distribution of carbon emissions. The impact of GDP₂ on CO₂ is negative but non-significant at the level of first two quantiles (i.e., 10th and 20th) while the coefficients are negatively significant from 3rd to 9th quantiles which reveals that a 1% increase in GDP₂ reduces CO₂ emissions by 0.129–0.296% in BRICS countries. At the higher quantiles, the impact of GDP₂ on CO₂ is higher and EKC being certified from 3rd to 9th quantiles. From these results, it can be assumed that nations inferior to the extreme lowest quantile progress are prioritized above the environmental quality. As well, nations being at smaller stages of development by virtue of their level of emissions may find it additional thought-provoking. The results are in aligned with the studies of Ike et al. (2020) who found an inverted U-shape relationship between economic growth and CO₂ emissions only at median in oil-producing countries and thus validating the environmental Kuznets curve hypothesis. It also implies that increased income promotes awareness about clean technology that may influence the turning points and amends the environment in a sustainable manner. So, it is advisable that BRICS countries should try to continue and outstretched their economic activities successfully and productively to stay beyond the threshold of income level for environmental improvements.

The panel quantile estimation in Table 7 shows the major findings; i.e., the TOR effect on emissions at lower quantile levels (i.e., 10th, 20th, 30th, and 40th quartiles) is negative and significant, while their effects turn insignificant from medium to highest quantiles (i.e., 5th–9th quantiles). These empirical findings demonstrate that tourism plays a substantial role in alleviating CO₂ emissions. The significant effects at lower quantiles are subjected to fact that countries may consume cleaner source of

energy. But from the medium to the upper extreme quantile, the insignificant results posited that larger number of visitors may augment the demand of energy, and countries are desperately bound to rely on non-renewable energy sources to meet their energy requirement for their tourism activities. In these circumstances, the non-renewable use of energy may not help countries to mitigate their emissions level. The findings of de Vita et al. (2015) and Katircioglu (2014) in case of Turkey, (Dogan et al. 2017) in OECD countries, and (Jebli and Youssef 2015) case of Tunisia also exhibit the same output.

In context of renewable energy, the results showed highly significant and negative effects on carbon emissions at all quantiles (i.e., 1st to 9th quantiles). This is an expected result that can be attributed by relying on renewable energy sources in substitution to fossil fuels in BRICS panel and is aligned with the study of Cheng et al. (2019b). It suggests that renewable energy retards CO₂ emission in the BRICS countries. This outcome is also in congruence with other studies such as Jebli and Youssef (2015), Jebli et al. (2016), Karasoy and Akçay (2019), and Asongu et al. (2019). The outcome further spots interesting results that at the lowest quantile, the renewable energy estimate holds highest coefficient and then decreases from the lowermost to uppermost quantile which means emissions of carbon are at their minimum levels at quantiles where effects of renewable energy on emissions are maximum. Contrary, at quantiles where emissions are highest, the effects of renewable energy on emissions are lowest. This infers that although there is advancement in the growth of renewable energy, the renewable energy share in total energy use is still inadequate in these regions.

Comparison of results of panel estimation models

Looking further at the graphical representation of the all panel estimation models such as DOLS, FMOLS, and FE-OLS and MMQR in Fig. 1, it is clearly shown that the coefficient of MMQR for all variables is diverse across all quantiles as compared with DOLS, FMOLS, and FE-OLS, which provides clear picture of the advantage of using MMQR approach. Unlike other estimators, the coefficient of GDP in case of

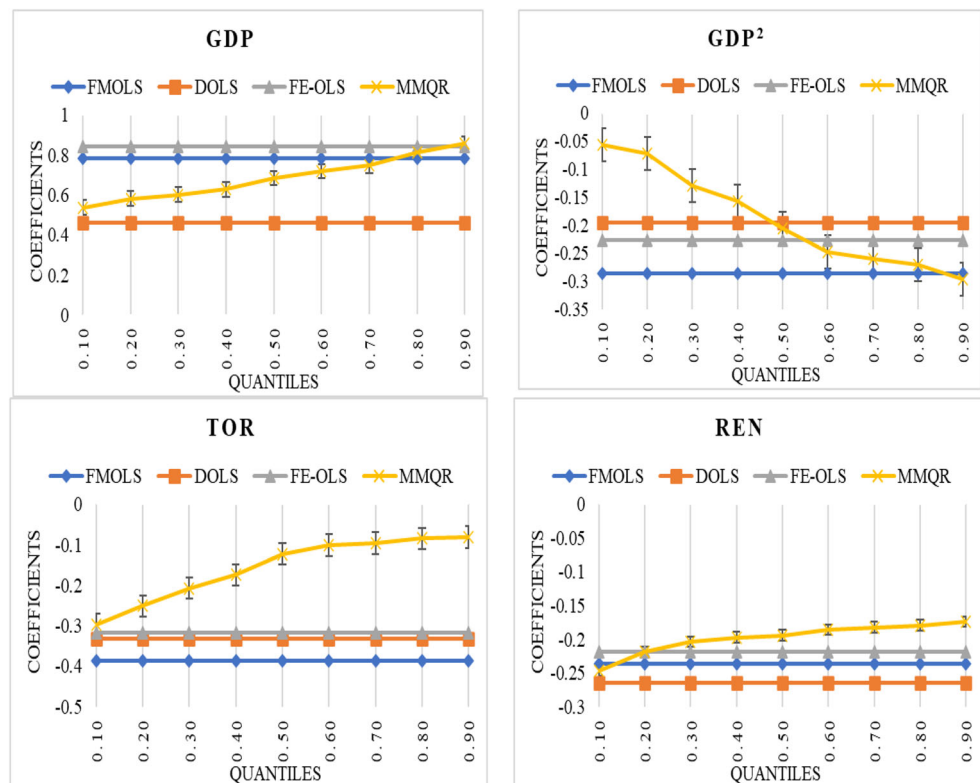
Table 7 Results of panel quantile estimations (MMQR)

| Variables | Location | Scale | Quantiles | | | | | | | | |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | | | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 |
| LGDP | 0.485*** | 0.284*** | 0.537*** | 0.583*** | 0.602*** | 0.629*** | 0.684*** | 0.719*** | 0.748*** | 0.815*** | 0.859*** |
| LGDP2 | -0.139** | -0.106* | -0.056 | -0.072 | -0.129** | -0.157** | -0.206*** | -0.247*** | -0.259*** | -0.271*** | -0.296*** |
| LTOR | -0.285*** | -0.133* | -0.296*** | -0.251*** | -0.207** | -0.174* | -0.122 | -0.101 | -0.096 | -0.084 | -0.081 |
| LRE | -0.357*** | -0.219*** | -0.247*** | -0.219*** | -0.203*** | -0.197*** | -0.194*** | -0.186*** | -0.182*** | -0.179*** | -0.174*** |

***, **, and * represent significant level at 1%, 5%, and 10%, respectively

Source: Author estimation

Fig. 1 Graphical representation of coefficient estimates for all variables across all quantiles, obtained from all 4 estimators



MMQR increases while moving from lower to higher quantile, indicating that GDP simply causes more emissions and that this relationship is highly quantile dependent. As expected, the results of GDP² not only sanction the EKC curve but also show dwindling of CO₂ emission while moving from lowest to higher quantiles and infers that the economic growth are inclined to adaption of eco-friendly technologies. The results in context of tourism provide interesting results which depict that in case of DOLS, FMOLS, and FE-OLS, the results remained consistent throughout the quantiles but in MMQR, the results show that CO₂ emission can be declined at lower half quantile but from medium to the upper half quantile, the tourism sector not helps countries to mitigate CO₂ emissions. In addition, the interpretation of the coefficient of renewable energy in all panel estimators is close enough but in case of MMQR, the results additionally shows that although renewable energy improves environment by reducing CO₂ emission but while moving from low to higher quantiles, the coefficient is not increasing which is explained by the fact that the share of renewable energy in total energy mix in emerging economies is not rising with the rise of economic growth.

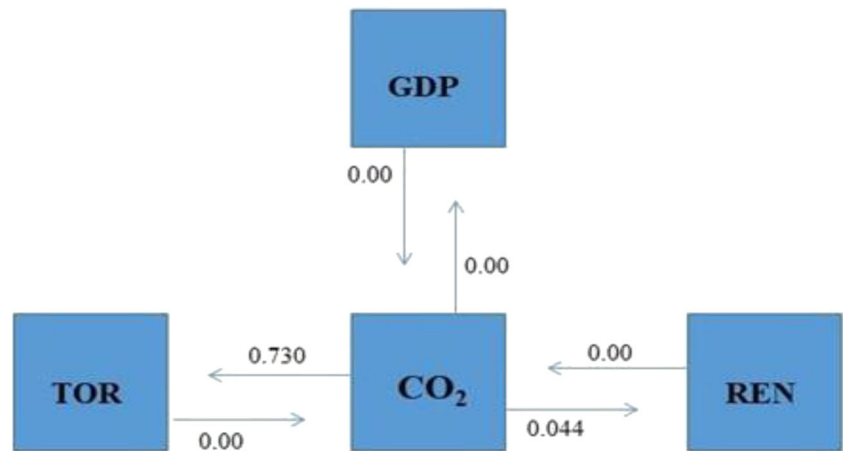
Comparing the results of all estimations, it is clear that the MMQR is an ideal and best suited approach to explore the clear and inclusive illustration of the association of variables. It performs better at judging both the coefficient and the significance of variables' effects.

Heterogeneous panel causality test

A framework that supports the models' heterogeneity by investigating the short-run bivariate causal relationship among the concerned variables such as GDP, GDP², TOR, RE, and CO₂ across the cross-sections is required. In this regard, Dumitrescu (2012) introduced the heterogeneous causality technique based on panel data which is useful and allows entire coefficients to remain diverse within the cross-sections. Moreover, the precondition of this test is that whole variables are required to be stationary. A visual inspection finding associated to causality test of panel is presented in Fig. 2. The results indicate that the bi-directional feedback is present between economic growth and CO₂ and between renewable energy and CO₂ which indicate that both variables, i.e., economic growth and renewable energy, cause carbon emissions and carbon emissions also affect both variables in return.

The results are aligned with previous studies of Lu (2017) and Danish et al. (2017) who also ascertained that renewable energy consumption and CO₂ emissions hold bi-directional causality. Dogan and Aslan (2017) in their study about association between CO₂, GDP, energy consumption, and tourism in the EU and candidate countries also delivered the same results. By using the Emirmahmutoglu-Kose Granger causality test of panel data, the outcome spotted that causality from tourism to carbon emissions is one way, while the real income

Fig. 2 Heterogeneous causality test based on BRICS panel



and CO2 emissions and CO2 emissions and energy consumption are two-way causality.

Conclusion and policy recommendations

Over the last few years, there is growing concern about climate change and global warming among the environmental specialists and policymaker, which are predominantly caused by burning of conventional fossil fuels for accomplishing the target of high economic growth, industrialization, and urbanization. But in context of tourism, only a handful of studies analyzed the tourism and CO2 relationship even though there is likelihood that tourism sector in BRICS countries can affect the environment. So, in this paper by assuming the above notion, we attempted to explore the association between tourism, renewable energy, and economic growth on CO2 in BRICS region for the period 1995–2018 under EKC framework by using the fresh approach of MMQR (2019). The MMQR approach is the first addition in the existing literature exploring nexus between tourism and CO2 emissions.

The empirical analysis confirmed that all variables are stationary at I (1) and possess long-run non-spurious association in both unit root and cointegration techniques of panel data. The positive coefficient of GDP and the negative coefficient for GDP2 also endorsed EKC hypothesis and stated that that BRICS region after reaching a certain economic development threshold has potential to reduce CO2 emissions. Though the estimation of FMOLS and DOLS evidenced that the tourism and renewable energy are substantial factors in recovering the environment quality like the previous study of Ben Jebli et al. (2019), the application of MMQR (2019) approach explicitly unveiled that although the TOR is negatively significant at the extreme lowest quantiles at 1% level of significance but later becomes non-significant from the 5th median quantile to extreme highest quantiles. This implies that although tourism lessens environment degradation at their initial and intermediate

phases of development but put forth adverse impacts on environment at upper extreme quantiles.

It is noteworthy to mention that more tourism and recreational facilities can pose a serious threat to ecosystem as BRICS countries are relying on fossil fuels and moreover the increase tourism sector puts severe impact on environment by the depletion of natural resources and physical degradation. In case of renewable energy, the results are expected and possess negative significance at all quintiles (from 1st to 10th), but interestingly, the renewable energy estimate holds highest coefficient at lowest quantiles and then decreases when move to uppermost quantile (as mentioned in the “[Estimation results and discussion](#)” section) which entails that the share of renewable energy in total energy use is less. Likewise, the causality results also indicated a bi-directional causal relationship between growth and CO2 emissions as well as renewable energy and CO2 suggesting that BRICS countries should work effectively and establish energy policies in alliance to the reduction of CO2 in a sustainable manner.

Observing the findings of the current study, it is pertinent to take pragmatic steps necessary to strengthen the environmental regulations in BRICS countries. Thus, it is on this premise that the following few substantial policy implications are asserted on the basis of the empirical results upshot from the current research which is enlightened in the subsequent passages: For the emergent BRICS economies, the maintenance of economic growth without costing environment degeneration is one of the big challenges to achieve, and if the situation endures, the increased pollution activating by economic growth will stance a great threat to global environment. So there is a need to enhance regulatory policies that triggers the use of non-renewable energy and increase the energy efficiency and share of renewable sources in energy mix. According to Asdrubali et al. (2015), the development of renewable energy in BRICS region is very essential to limit emission of CO2 as the renewable energies are considered as less unpolluted as compared with conventional coal-based energies. Furthermore, to maintain the momentum in the tourism sector,

there is a need to develop green tourism, favorable to ecosystem.

All sectors allied with tourism industries need to play mutual role in designing and implementing necessary measures to boost green environment. As the coefficient on tourism is quite high in the start and then becomes insignificant, more actions should be introduced such as environment-friendly transport in replacement of motorized, and more projects on the development of environmentally friendly technologies, especially those in relation with tourism sector, should be sponsored by the BRICS governments. In developing countries, there is a need to control emissions as these countries account more than half of global emissions and still expanding their activities so policies in favor of sustainable environment is needed in these countries.

As a direction for future research, the impact of international tourism on environmental degradation needs to be taken into account the BRICS countries individually; i.e., other researcher can query the current theme for each case of country in BRICS panel or can query other regions as well. The study of each country of BRICS panel in this way may help to gain deeper insights of the relationship. Moreover, another limitation is the use of CO₂ as a proxy measure of environment pollution but according to the study of Ozturk et al. (2016), CO₂ only spots the little share of the total environment damage. So the other researchers can use ecological footprints to explore more about the current topic as ecological print encompasses the anthropogenic pressure on the environment Hauke (2008), so it is more applicable and broader measure to explore the environmental degradation extent.

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