



Pathways to decarbonization in India: the role of environmentally friendly tourism development

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Abstract

The paradigm of sustainable tourism policy implications aims to prioritize the decoupling association between tourism development and environmental deterioration. The study revisits the dynamic associations among carbon dioxide emissions, economic growth, international tourism, education, renewable energy consumption, and gross capital formation for the case of India through the lens of the environmental Kuznets curve hypothesis framework. The long-run dynamics among the variables confirm the inverted U-shaped environmental Kuznets curve hypothesis for India. The regression findings affirm that higher international tourist arrivals, renewable energy use, and gross capital formation curb emissions in the long run. Besides, the coefficient of the interaction term between tourist arrivals and capital formation is evidenced to be positive implying capital formation has not been conducive in the pathway of sustainable tourism practices. On the other hand, the negative coefficient of the interaction term between education index and renewable energy consumption unveils the importance of educational advancement in the pathway of renewable energy penetration to thrive environmental sustainability. This study concludes with some policy suggestions to be incorporated within the existing ecological and energy approaches that may aid India in practicing the smooth functioning of low-carbon tourism models.

Keywords International tourism · Environmental sustainability · Renewable energy transition · Environmental Kuznets curve · Gross capital formation · Carbon dioxide emissions

Introduction

Tourism contributes to one-tenth of the global output, around one-third of world exports of services, and one in every ten jobs worldwide (UNWTO 2018). In spite of the fact that there are prevailing worries about tourism-induced economic expansion and adverse environmental outcomes, still tourism is hailed as a global powerhouse of income and employment development. Over the last two decades, the term “sustainable tourism” has attracted a lot of interest from researchers and policymakers (Nepal et al. 2019; Hughes et al. 2015; Saarinen 2006). However, there appears to be a significant gap between theory and practice in this domain. Consequent to the announcement of the year 2017 as *International Year for Sustainable Tourism for Development* by the United Nations, most of the nation’s worldwide are re-exploring the impacts of tourism and formulating policies to promote sustainable tourism practices which can contribute to the UN Sustainable Development Goals (SDG). Moreover, the 17 distinct SDG targets have reawakened a sense of urgency in the tourism industry to address issues

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such as poverty eradication (SDG-1), food security (SDG-2), and combating environmental degradation (SDG-13). The beauty of the idea of sustainable tourism lies in the fact that the five pillars of sustainable tourism (UNWTO 2018) are aligned with the 17 SDGs, which means a country if targets to achieve growth in sustainable tourism will automatically also progress in all 17 SDG's (refer Fig. 7 in Appendix). The natural landscape and the rich cultural heritage of India combined with the policy boost through the “Incredible India” campaign make it a viable candidate for achieving economic growth through sustainable tourism practices. Therefore, in this study, we have analyzed the current state and impact of tourism in India on environmental development while controlling for gross capital formation (GCF), renewable energy consumption (REC), and educational progress in the environmental Kuznets curve (EKC) framework.

Consequently, policy planning of fostering sustainable tourism practices is designed to not only advocate the social, cultural, and economic welfare of the nation but also to meet the ecological commitment through the pursuit of environmental well-being. The existing literature on the effect of tourism development on environmental well-being provides varied results. For instance, empirical investigations by Katicioglu et al. (2014), Paramati et al. (2017), and Nepal et al. (2019) confirmed the adversative upshot of tourism development on the environment. In contrast, other studies have concluded that the expansion pathway of the tourism sector may substantially be contributing to environmental well-being (Azam et al. 2018; Koçak et al. 2020). In addition, capital investment in the tourism sector can be viewed as one of the vital drivers to thrive sustainable tourism practices. While various studies in the literature consider this factor as a standalone component in the determination of environmental welfare (Akalpler and Hove 2019; Rahman and Ahmad 2019), none of the studies still date is found to examine the composite effect of capital formation in tourism development in the abatement of carbon emissions. Furthermore, while a plethora of studies investigates the EKC hypothesis in different geographical regions using aggregated/disaggregated REC levels (Bilgili et al. 2016; Dogan and Seker 2016), none of the studies has commented on the importance of educational advancement in renewable energy penetration in the context of climate change.

Against this literature gap, this study takes a unique slant to inspect the role of tourism development in the abatement of CO₂ emissions in India under the framework of EKC. In this paper, 30 years of yearly data spanning from 1990 to 2019 has been used. This study in a variety of ways adds to the current body of knowledge. To begin, traditional EKC literature has used energy consumption data on renewable and fossil fuels, aggregated or disaggregated levels. Supposedly, this is the first attempt in the existing vast body of literature that examines the composite effect of educational

prosperity in the expansion pathway of renewable energy on environmental welfare. Second, while various studies examine the role of tourism development in bringing environmental sustainability in the EKC framework, the composite impact of capital formation in tourism sector expansion is neglected. This study aims to address this interaction effect of tourism development and capital formation in the correction of environmental degradation. Third, while extant EKC literature in the context of India fails to offer any convincing confirmation regarding EKC shape, this paper aims to anticipate if any other alternate shape of EKC in India can be derived from the present analysis.

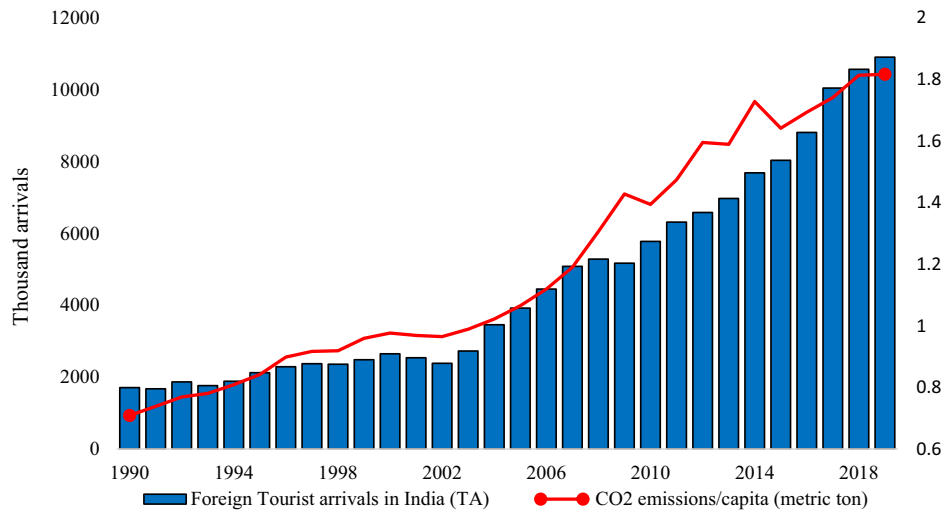
The rest of the paper is organized as follows: The “Macroeconomic trends in India” section introduces the important macroeconomic factors discussed in this paper. In the “Literature review” section, a concise review of the literature has been given. The theoretical underpinning is described in the “Theoretical framework model build-up” section. The “Data” section articulates the data description of the variables. The “Estimation strategy” section entails the definite econometric approach. The empirical outcomes are discussed in the “Results and discussions” section. Finally, the conclusion and policy implications are introduced in the “Conclusion and policy implications” section.

Macroeconomic trends in India

In the modern era, climate change mitigation has been receiving serious policy attention and has become the center of policy debate throughout the globe. Environmental deterioration through CO₂ emissions is a significant source of concern for the developing nations, as these countries are inclined to emphasize economic expansion over ecological improvement. As anticipated, India is no exception to the persistent worsening of the country's CO₂ emissions figures. Hence, the environmental deterioration related to CO₂ emissions and its connections with tourism development, economic growth, and REC has been discussed briefly in this segment.

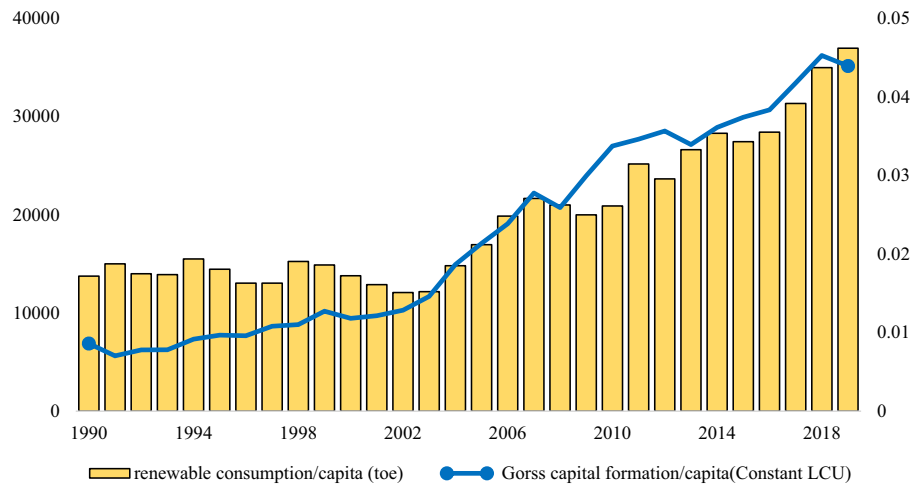
Over the century, India has always been marked as a preferred destination for domestic and foreign tourist's arrivals for religious, divine, and leisure activities (Kaul and Gupta 2009). The tourism sector in India is the 7th biggest economic sector in the world and is prophesied to be developed by 6.9% annually in the coming decade (Yes Bank 2017). In India, tourism is at the center of service excellence and presently contributing to approximately 9.6% of GDP. The tourism sector is crucial for the economic and financial development of a nation for its considerable contribution to driving economic growth with employment opportunities, forex earnings, and infrastructural development. With the mounting concern of global warming and climate change,

Fig. 1 Plot of annual foreign tourist arrival and per capita CO₂ emission. Notes: Foreign tourist arrivals and CO₂ emissions per capita are shown in the primary (left) and secondary (right) axes, respectively



Notes: Foreign tourist arrivals and CO₂ emissions per capita are shown in the primary (left) and secondary (right) axes, respectively

Fig. 2 Plot of renewable energy consumption and gross capital formation. Notes: Per capita renewable energy consumption and gross capital formation are shown in the primary (left) and secondary (right) axes, respectively



Notes: Per capita renewable energy consumption and gross capital formation are shown in the primary (left) and secondary (right) axes, respectively

the developing nations are in the rapid transit phase moving towards the service industries to be benefitted from the competitive advantage, while also fostering policy thrust to the sustainability dimensions to have minimal impact on environmental quality. With no exception, the Government of India has also undertaken various policy agendas in the tourism sector aimed at pursuing sustainable tourism practices in this sector. This is not only intended to benefit the local community by increasing the job opportunities and ensuring a steady source of income but also to satisfy the tourists with minimum expenses at the cost of lower environmental penalties (Hussain et al. 2015). Figures 1 and 2 depict that both foreign tourist arrivals and the CO₂ emissions of India exhibit an increasing trend. But with time, the

gap between these two data series is evidenced to be narrower. This reflects the reduction in the emission intensity from tourism activities over 1990–2019 and provides a clear indication of performing sustainable practices in this sector.

The association between economic growth and CO₂ emissions is much contextual in the ongoing debate on climate change (Balsobre-Lorente et al. 2021; Murshed et al. 2020; Razzaq et al. 2021). While India has experienced steady progress in per capita GDP by 2.7 times over 1990–2019, per capita CO₂ emissions have also increased by 1.6 times over the same timeline. So, GDP is demonstrated to grow much faster than CO₂ emissions in the concerned period of analysis. This can primarily be attributed to the unplanned and unregulated expansion of urbanization and industrialization

with special emphasis being placed on energy-intensive manufacturing value added of GDP to resuscitate the home-grown manufacturing as an initiative to the “Make in India” project (Bandyopadhyay and Rej 2021).

While the present policy thrust is aimed to support the monetary motor of the nation by revitalizing the energy-intensive domestic manufacturing, the Government of India is also committed at INDC to diminish the carbon emissions intensity of GDP by 30–35% by 2030 from 2005 level through upgrading the renewable energy capacity accumulation to 40% in the countrywide energy portfolio. Presently, installed capacity from all forms of renewable energy has reached 1,097,465 MW and per capita, REC has grown by 1.7 times over the year 1990–2019. Strategy push of growing the portion of renewables in the energy blend and advancement of accomplishing energy proficiency measures add to decrease of CO₂ emanations as well as help in a critical decrease of the significant air toxins liable for corruption of air quality like decrease of SO₂ by 25%, NO_x by 30%, and PM 2.5 by 20% (IEA 2020).

Literature review

Throughout the most recent couple of many years, worldwide consideration has focused to concentrate on the connection between CO₂ discharge and its determinants (Wang and Wang 2021; Wang and Su 2020). In the present study, we have decomposed the literature review into five essential parts. First, the literature related to the connections between tourism and environmental quality has been discussed. Second, the dynamic linkage between economic growth and CO₂ emissions has been discussed with special reference to the EKC hypothesis for India. Third, we have focused on the literature discussing the role of renewable energy in the correction of environmental pollution. Fourth, we have stressed the literature highlighting the impact of capital formation on CO₂ emissions. Finally, we have articulated the literature discussing the tourism-growth nexus.

Tourism and CO₂ emissions

Over the last few decades, environmental economists, policymakers, and academicians have centered the prodigious attention to study the socio-economic factors responsible for environmental deterioration. While a plethora of existing literature has explored the dynamic linkage between economic growth and the CO₂ emissions nexus, a limited number of studies are found to date to scrutinize the role of tourism on environmental quality. Katircioglu et al. (2014) reported that international tourism has a long-run positive association with CO₂ emissions for Cyprus over 1970–2009 while examining the long-run dynamics among energy consumption,

CO₂ emissions, and international tourism. León et al. (2014) examined the role of tourism in the abatement of CO₂ emissions for 14 developed and 31 underdeveloped countries utilizing nine years of data from 1998–2006 in the STIRPAT framework. This study evidenced that the detrimental impact of tourism is larger in developed countries. Paramati et al. (2017) concluded that successive growth in tourism in developing and developed economies correspond to the accelerated deterioration of environmental quality over 1995–2012. Sharif et al. (2017) investigated the CO₂ emissions-tourism-economic growth nexus in Pakistan over 1972–2013. This study evidenced a unidirectional short-run causality from tourist arrivals to CO₂ emissions and concluded that tourist activity in that nation is harmful to environmental quality.

Eyuboglu and Uzar (2020) examined the role of tourism on environmental well-being for Turkey over 1990–2014 and concluded that development in the tourism sector through more attraction of foreign tourists is positively associated with CO₂ emissions. Khan et al. (2020a, b) validated the tourism push emission hypothesis for 51 Belt and Road Initiative (BRI) countries over 1990–2016 while investigating the role of tourism and natural resources in the correction of CO₂ emissions in these nations. Nepal et al. (2019) confirmed that the development pathway of the tourism sector is profoundly connected with sped up weakening of environmental quality for the Nepalese economy over the period 1975–2014. Ehigiamusoe (2020) unveiled the beneficial effect of tourism on environmental well-being at the beginning phase of tourism growth but exacerbates the environmental quality with further expansion of tourism activity following a “U-shaped” relationship between tourism and environmental degradation for 31 African countries. Katircioglu (2014a, b) identified that tourism impacts negatively on climate change and confirmed the existence of an inverted U-shaped relationship for Singapore. Katircioglu (2014a, b) further identified that tourism development in Turkey has contributed to energy consumption and environmental degradation. Similar results have been identified by de Vita et al. (2015) for Turkey and Katircioglu et al. (2020) for Cyprus.

While various studies suggested that successive development in the tourism sector may substantially increase CO₂ emissions, Azam et al. (2018) evidenced the beneficial role of the tourism sector on environmental quality in Thailand and Singapore for 1990–2014 while exploring the long-run effect of tourism on environmental quality. Shakouri et al. (2017) revealed that progress in the tourism sector will be beneficial for environmental well-being while examining the impact of tourism development on CO₂ emissions for selected Asia-Pacific countries over 1995–2013. Koçak et al. (2020) examined the impact of tourism arrivals and tourism receipts on CO₂ emissions for 10 most visited countries using the annual data of 1995–2014 in the STIRPAT

framework. This study concluded that tourism receipts improve CO₂ emissions, while tourism arrivals exert a detrimental impact on environmental quality. Liu et al. (2019) divulged that tourist receipts are not associated with the deterioration of environmental quality while examining the dynamic linkage between CO₂ emissions, energy consumption, and international tourism in Pakistan over 1980–2016. (Katircioglu et al. 2018) study identified that tourism development and ecological footprint shows an inverted U-shaped relationship for the top 10 tourist destinations and exerts an improving effect on ecological footprint. Furthermore, Katircioglu et al. (2019) suggest that climate change positively influences foreign tourist flows to small island states such as Cyprus and Malta.

Economic growth and CO₂ emissions

Isolating economic growth from CO₂ emissions has become a global concern (Wang and Zhang 2020; Li et al. 2021). Over the last three decades, the nexus between environmental degradation and economic growth has been receiving overwhelming attention in the existing body of literature in which the nexus is strongly tied to studying the validity of the EKC hypothesis (Wang et al. 2022). It has been derived from a similar hypothesis coined by Noble winner economist Simon Kuznets (Kuznets 1955). The pattern of relationship between economic growth and CO₂ emissions following the EKC hypothesis has been evaluated empirically to various specifications in different geographic locations and time horizons by employing different econometric methodologies resulting in diverse outcomes. The vast body of EKC literature tests for the linear, quadratic as well as cubic connections between economic growth and CO₂ emissions. Several studies that have tested the quadratic association between pollution and economic growth and evidencing the existence of “inverted U”-shaped EKC hypothesis includes the empirical investigations by Katircioglu et al. (2014) for Singapore, Gökmenoğlu and Taspınar (2016) for Pakistan, Jiang et al. (2021) for China, Haseeb et al. (2018) for BRICS nations, Danish et al. (2017) for Pakistan, Ozatac et al. (2017) for Turkey, and Dong et al. (2017) for BRICS countries. Several studies that have aimed to investigate the cubic connections between economic growth and environmental degradation and have confirmed the existence of “N-shaped” EKC includes the empirical evidence by Koc and Bulus (2020) for South Korea, Churchill et al. (2018) for 20 OECD nations, Özokcu and Özdemir (2017) for 52 emerging economics, and Allard et al. (2018) for 74 countries. Some studies are evidencing the existence of “inverted N”-shaped EKC include the empirical investigations by Bekhet and Othman (2018) for Malaysia, Churchill et al. (2018) for Denmark, and Özokcu and Özdemir (2017) for 26 high-income OECD countries.

There is also limited literature available for India contributing to the understanding of the shape of the EKC and the existence of the EKC hypothesis. Jayanthakumaran et al. (2012) investigated the long-run dynamics between CO₂ emissions, economic growth, energy use, and trade for India and China over 1971–2007 by employing ARDL methodology. This study evidenced the existence of an inverted U-shaped EKC hypothesis for both India and China. Tiwari et al. (2013) evidenced the existence of an “inverted U”-shaped EKC hypothesis for India in both the short and long run while examining the long-run association between CO₂ emissions, economic growth, coal consumption, and trade openness over 1966–2009. Kanjilal and Ghosh (2013) confirmed the existence of an “inverted U”-shaped EKC hypothesis for India while examining the regime shift co-integration between CO₂ emissions, economic growth, energy use, and trade openness for the annual data of 1971–2008. The empirical investigation by Sinha and Shahbaz (2018) also has claimed the existence of “inverted U”-shaped EKC hypothesis for India over 1971–2015 while examining the co-integration relationship between CO₂ emissions, economic growth, renewable energy generation, electric power consumption, and international trade.

Danish et al. (2021) supported the existence of an inverted U-shaped EKC hypothesis for India over 1971–2018 while estimating the short and long-run dynamics between economic growth, CO₂ emissions, nuclear energy consumption, and population by employing the dynamic ARDL technique. While various studies have tested for the quadratic connections between economic growth and CO₂ emissions, very few studies are available for India aiming to investigate the cubic connections between the same. The empirical investigation by Pal and Mitra (2017) provided strong evidence of the existence of N-shaped EKC for India over 1971–2012 while examining the role of economic growth, energy import, trade, and electricity generated from coal on environmental degradation. Bandyopadhyay and Rej (2021) confirmed the existence of “inverted N”-shaped EKC for India over 1978–2019 while examining the role of nuclear energy, GDP polynomials, FDI polynomials, and trade openness on environmental quality.

REC and CO₂ emissions

Energy is believed to be a key influencer of both economic growth and CO₂ emissions (Manigandan et al. 2021; Alam et al. 2020; Pachiyappan et al. 2021). In recent years, a plethora of studies have investigated the beneficial role of REC in the correction of CO₂ emissions (Murshed 2022; Kuramovich et al. 2022). IEA (2019) reported that emissions from the global power sector have been evidenced a sharp decline by 170 million tonnes in the year 2019 which can primarily be attributed to the enhanced capacity addition and

acceptance of renewable energy in the global energy portfolio. Dogan and Seker (2016) investigated the role of renewable and non-REC in the correction of CO₂ emissions in the EKC framework over the data spanning from 1980–2012 for the European Union and confirmed the long-run negative association between REC and CO₂ emissions. Bilgili et al. (2016) examined the impact of REC on environmental well-being in the EKC framework over 1977–2010 for 17 OECD countries and concluded that adoption of renewable energy in energy portfolios aids in the reduction of CO₂ emissions. Bhattacharya et al. (2017) examined the role of institutions and REC on CO₂ emissions reduction for 85 developed and developing nations over 1991–2012. This study concluded that renewable energy deployment in these economies may prompt the accelerated reduction of CO₂ emissions.

Zoundi (2017) investigated the role of renewable energy and conventional fossil fuel energy consumption on CO₂ emission in the EKC framework over 1980–2012 for twenty-five selected African countries. This study concluded that the beneficial impact of REC has been outweighed by the fossil fuel energy consumption in these economies. Charfeddine and Kahia (2019) examined the role of REC and financial development on CO₂ emissions over 1980–2015 for twenty-four MENA countries and concluded that adoption of REC in these economies is found to have weak contributions towards the improvement of environmental quality. Paramati et al. (2017) found the beneficial effect of accelerated adoption of renewable energy on environmental quality while examining the role of stock market growth and renewable energy usage in the correction of CO₂ emissions for G-20 nations over 1991–2012. Danish et al. (2019) concluded that accelerated adoption of renewable energy may help in the reduction of CO₂ emissions for Brazil, China, India, and Russia while investigating the existence of the EKC hypothesis for the period 1990–2015. Murshed et al. (2021a, b) evidenced the beneficial role of REC in the abatement of carbon emissions for five selected South Asian nations over 1995–2015.

Capital formation and CO₂ emissions

In the contemporary era, the impact of capital formation on environmental quality has much been debated in the existing literature on climate change and environmental degradation mitigation. The existing body of literature evidences the mixed result regarding the impact of capital formation on CO₂ emissions. The literature encapsulates the helpful impact of capital formation on environmental well-being including the empirical findings by Akalpler and Hove (2019) for India, Abbas et al. (2020) for selected Asian and African countries of the Belt and Road Initiative project, and Khan et al. (2020a, b) for 122 countries. Also, numerous literature includes the adversative effect of capital formation

on environmental quality such as Bekun et al. (2019) for South Africa, Rahman and Ahmad (2019) for Pakistan, Zafar et al. (2019) for G-7 and N-11 countries, Paramati et al. (2017) for 26 developed nations, and 18 developing nations.

Tourism and economic growth

The role of tourism as a source of economic growth has been debated in extant literature for over a decade. Many studies have highlighted the positive impact of tourism on economic growth, better known as the tourism-led growth hypothesis. Belloumi (2010) for Tunisia, Katircioğlu (2011) for Singapore, Al-mulali et al. (2014) for middle eastern countries, Jalil et al. 2013 for Pakistan, Tang and Tan (2015) for Malaysia, Ertugrul and Mangir (2015) for Turkey among others found evidence in support of tourism-led growth hypothesis. However, Oh (2005) for Korea, Parrilla et al. (2007) for Spain, Lee (2012) for Singapore, Tang and Jang (2009) for the USA among others have proved the existence of growth-led tourism hypothesis. Additionally, some studies uphold the bidirectional or feedback effect (Apergis and Payne 2012; Dritsakis 2004; Katircioglu 2009a, 2009b), Kim et al. 2006; etc.), while others have identified insignificant relationship or neutrality hypotheses (Chou 2013; Katircioglu 2009a, b, c). Cárdenas-García et al. (2015) has highlighted that the relationship between tourism and economic growth happens in more developed countries, while Figini and Vici (2010) have highlighted that tourism does not accelerate economic growth in developing countries. For India, the literature on the tourism-led growth hypothesis is rather scant and the results are contradictory. While Ghosh (2011) identified that there is no long-run relationship between international tourist arrivals and economic growth, Tang et al. (2016) found the existence of a feedback relationship. Ohlan (2017) identified unidirectional Granger causality from inbound tourism to economic growth.

Theoretical framework model build-up

In this part, the theoretical structure of dynamic connections between CO₂ emissions with GDP, tourism, REC, and GCF has been discussed. The dynamic linkage between economic growth and environmental pollution is symbolized as the environmental Kuznets curve (EKC) hypothesis. The theoretical framework of EKC speculation, first proposed by Grossman and Krueger (1991), represents environmental degradation as a linear function of economic growth as long as a certain income level is attained. In the wake of arriving at a specific income level, the climate begins improving with the further expansion of economic activity, showing non-linear linkages between economic growth and CO₂ emissions that follow an “inverted U”-shaped curve (Dong et al. 2017;

Katircioğlu 2014a, b). Several studies highlighted the cubic association between economic growth and CO₂ emissions following an “N-shaped” curve, according to which emissions level increases until having reached the first turnaround point. The pollution level then begins to decrease as we approach the second turnaround point and again increases beyond the second turnaround point (Churchill et al. 2018; Pal and Mitra 2017).

In the continuous discussion on climate change in the theoretical literature, the role of tourism development in attaining environmentally friendly economic growth has received enormous attention in recent years. The dynamic connections between tourism development and environmental degradation are well known as the tourism push emission hypothesis, according to which the expansion pathway of the tourism sector is strongly associated with the accelerated deterioration of environmental quality through enhancing the usage of energy in tourism mobility, specifically in the transportation sector. Furthermore, the construction of new tourism facilities places a huge strain on restricted resources like land and water, as well as contributing to environmental degradation through soil erosion, the loss of natural habitat, and extinction of endangered species (Khan et al. 2020a, b; Eyuboglu and Uzar 2020). Tourism development can be beneficial for environmental well-being if policy thrust pushed to promote ecotourism practices (Azam et al. 2018).

In the line of attaining the SDG-7 of achieving the energy security objective through supplying modern, reliable, and clean energy to all and undertaking the objective of SDG-13 to combat climate change, understanding the theoretical framework behind the dynamic linkages between REC and environmental debasement is more logical in the EKC structure. Enhanced acceptance of renewable energy in global energy blend can be viewed as one of the prime contributors towards reduction of CO₂ emissions by enhancing the reduction of reliance on imported oil and improving energy security by diversifying the risk associated with the price volatility of imported fossil fuel (Charfeddine and Kahia 2019; Baloch et al., 2019). The successive improvement in education can be viewed as an essential determinant in the expansion pathway of renewable energy adoption. Education can help to formulate effective and efficient energy strategies that can promote energy education in the society which ensures more rational usage of energy, reduces energy expenditure, and enhances awareness about societal benefits of using renewable energy (Rej and Nag 2021b), all of which essentially lead to the reduction of environmental degradation.

A plethora of studies undertake capital formation as a control variable while investigating EKC. The extant literature that analyses the dynamic linkage between capital formation and environmental deterioration yields mixed outcomes. The capital formation may be associated with

the reduction of environmental pollution if infusion of capital is mostly be done in environment-friendly and energy conservative assets (Abbas et al. 2020; Akalpler and Hove 2019). The capital formation may aggravate the environmental deterioration if capital investment is channeled toward the acquisition of energy and resource-intensive assets like machinery and infrastructure and promoting the adoption of capital in outdated technology that reduces energy efficiency (Paramati et al. 2017; Rahman and Ahmad 2019). In light of the foregoing discussions, the estimation of EKC with the presence of international tourist arrivals, REC, and GCF can be specified as follows in Eq. (1):

$$C_t = f(GDP_t, GDP_t^2, TA_t, REC_t, GCF_t, EI_t \times REC_t, TA_t \times GCF_t) \quad (1)$$

In contrast with the linear model, the above specification is transformed to log-linear form since log-linear assessment can generate more reliable and productive appraisals (Alam and Paramati, 2016) and can be modified as follows:

$$\ln C_t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln GDP_t^2 + \alpha_3 \ln TA_t + \alpha_4 \ln REC_t + \alpha_5 \ln GCF_t + \alpha_6 (\ln EI_t \times \ln REC_t) + \alpha_7 (\ln TA_t \times \ln GCF_t) + \varepsilon_t \quad (2)$$

where C_t represents per capita CO₂ emission, GDP_t captures per capita real GDP, GDP_t^2 denotes square of per capita real GDP, TA_t indicates the foreign tourist arrivals, REC_t stands for per capita REC, GCF_t captures per capita GCF, $(EI_t \times REC_t)$ indicates the interaction term between EI and REC per capita, $(TA_t \times GCF_t)$ denotes the interaction term between foreign tourist arrivals and per capita GCF, and ε_t is the random error term. The shape of the EKC is dependent on the sign of different α parameters. The existence of the inverted U-shaped EKC hypothesis can be validated if the expected sign of α_1 is positive and statistically significant and the expected sign of α_2 is negative and statistically significant. The signs of α_3 and α_5 may be positive or negative. The expected sign of α_4 should be negative and statistically significant. The expected value of $\alpha_6 < 0$. The value of statistically significant $\alpha_3 < 0$ and $\alpha_7 > 0$ jointly suggests that capital formation has not been conducive to ecotourism development. On the other hand, a negative value of α_7 divulges that policy thrust on enhanced capital formation has mostly been done in the ecotourism sector to promote sustainable tourism practices.

Data

The current work exploits 30 years of annual time series information on CO₂ emissions, foreign tourist arrival in India including nations from Pakistan and Nepal, economic growth, REC, EI, GCF, and population from 1990 to 2019. We are not able to extend our analysis beyond the mentioned

period due to the non-availability of EI data before the year 1990. CO₂ emissions, REC, and GCF are converted in per capita form using population data. The factors considered in the present study incorporates CO₂ discharge per capita in metric tons, real GDP per capita as a proxy for economic well-being measured in constant 2010 US\$, foreign tourist arrival in India including nations from Pakistan and Nepal as a proxy for international tourism, REC per capita measured in tonnes of oil equivalent, and GCF per capita in constant LCU. The data of real GDP, GCF, and population are sourced from World Bank. The data of foreign tourist arrivals is taken from the Indiastat database. The data of EI and REC are taken from UNDP Human Development Reports and BP Statistical Review of World Energy respectively. CO₂ emissions data is taken from the World Bank and BP Statistical Review of World Energy. Table 1 summarizes

the exact specifications of the variables, whereas Table 2 presents descriptive data. Table 2 postulates that all the key variables in the present study are right-skewed and follow a normal distribution as evidenced from the Jarque–Bera normality test.

A slew of studies recommends that data series be normalized before being used in any econometric model (Alam and Paramati, 2016; León et al., 2014). Since the variables in our present study are measured in a different dimension, particularly educational progress is measured as an index while other variables are measured in different units, natural logarithmic transformation of all the variables could help to maintain uniform measurement across the variables, avoiding the problems of distributional properties and may induce stationarity in the series of variables.

Table 1 Variables specification

Variable	Definition	Source
CO ₂	Carbon dioxide emissions (metric tons per capita)	World Bank, BP Statistical Review of World Energy
GDP	Economic growth (real GDP per capita constant 2010 US\$)	World Bank
REC	Renewable energy consumption (Tonnes of oil equivalent per capita)	BP Statistical Review of World Energy
EI	Education Index: average of mean years of schooling index and expected years of schooling index	UNDP Human Development Reports
TA	Foreign tourist arrival in India including nations from Pakistan and Nepal	Indiastat: Socio-Economic Statistical Data
GCF	Gross capital formation (constant LCU per capita)	World Bank

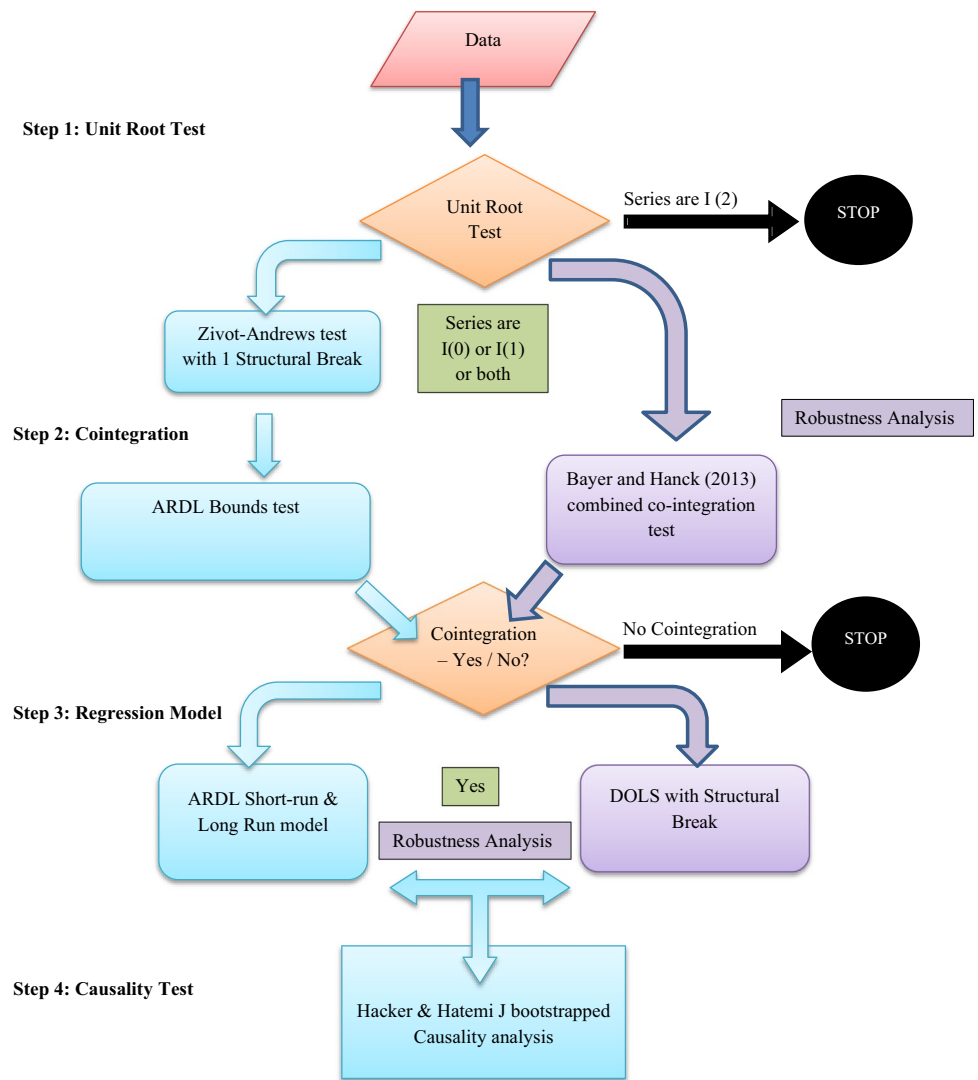
All the data are annual data spanning from 1990 to 2019.

Table 2 Descriptive statistics

Variables	CO ₂	GDP	REC	EI	TA	GCF
Mean	1.19	1139.52	0.025	0.431	4,660,422	17,957.5
Median	1.04	1009.42	0.020	0.424	3,688,044	15,993.7
Maximum	1.82	2152.27	0.046	0.558	10,895,305	36,179.6
Minimum	0.71	575.50	0.015	0.311	1,677,508	5630.1
Standard deviation	0.37	485.43	0.009	0.082	2,890,593	10,292.9
Skewness	0.41	0.66	0.869	0.178	0.788	0.32
Kurtosis	1.68	2.25	2.639	1.664	2.396	1.571
Jarque–Bera	3.01	2.89	3.935	2.389	3.559	3.065
Probability	0.22	0.23	0.139	0.303	0.169	0.216
Observations	30	30	30	30	30	30

CO₂ is carbon dioxide emissions per capita, GDP is gross domestic product per capita, REC is renewable energy consumption per capita, EI is education index, TA is foreign tourist arrival, and GCF is gross capital formation per capita.

Fig. 3 Flow diagram of the econometric model investigations



Estimation strategy

In this study, a four-stage econometric modeling strategy has been adopted. A flowchart depicted in Fig. 3 explains the method used in each step of the study.

Unit root analysis

The unit root test is done to examine the order of integration of the variables under study and to search for stationary properties. Different co-integration methods have different requirements for the order of integration of the series of variables, for example, the Johansen-Juselius co-integration approach requires that all the variables be integrated of order I(1) (Johansen and Juselius 1990; Rej and Nag 2018; Jian

et al. 2019). All the variables in the Autoregressive distributed lag model (ARDL) need to be integrated of I(1) or a mixture of both I(1)/I(0) but not to be integrated of I(2) (Pesaran et al. 2001; Odhiambo 2009).

The widely used DF-GLS and PP unit root tests are employed in both level and first difference to explore the degree of integration of the variables in our present study. However, due to the existence of a structural break in the time series, these tests can produce inefficient estimates. Therefore, following Yuping et al. (2021), the Zivot and Andrews’s (1992) (ZA) unit root test is utilized in this study to identify the existence of a structural break in the time series.

Co-integration test

The co-integration analysis is exploited to assess the long-run association among the variables employed in the model. In the present study, following Rehman et al. (2021), the long-run dynamics among the underlying variables are tested through Bayer–Hanck (2013) combined co-integration method and ARDL bounds test technique.

The findings from the traditional co-integration models are often biased because of insufficient sample size and other properties. Bayer and Hanck (2013) proposed the Bayer–Hanck joint test for non-co-integration, which overcomes the limitations of the traditional co-integration models while providing efficient estimations in the presence of inadequate sample size. Furthermore, this procedure integrates the results of various traditional co-integration models and sums up the outcomes utilizing a Fisher statistic dependent on the accompanying specification as follows:

$$EG - J = -2[\ln(P(EG)) + \ln(P(J))] \tag{3}$$

$$EG - J - B - BDM = -2[\ln(P(EG)) + \ln(P(J)) + \ln(P(BO)) + \ln(P(BDM))] \tag{4}$$

where EG-J denotes the probability values of joint test of Johansen (J) tests and Engle-Granger (EG) test, while EG-J-B-BDM denotes the probability values for the joint (Banerjee et al. 1998; Boswijk 1994; Engle and Granger 1987; Johansen 1988) tests.

The ARDL bounds test of the co-integration proposed by Pesaran et al. (2001) is employed in our present study to investigate the long-run relationship among the variables under consideration. The ARDL technique is favored over other existing co-integration techniques as it is best suited to smaller sample sizes, better accuracy, independent of the level of integration, and allows for investigation in different optimal lags compared to other conventional tests. Finally, following Murshed et al. (2021a, b), the ARDL technique can effectively address the potential endogeneity problems associated with some of the variables and offers unbiased estimates.

The ARDL model is shown in Eq. (5) as follows:

$$\begin{aligned} \Delta \ln C_t = & \phi_0 + \phi_1 \ln C_{t-1} + \phi_2 \ln GDP_{t-1} + \phi_3 \ln GDP_{t-1}^2 + \phi_4 \ln TA_{t-1} + \phi_5 \ln REC_{t-1} \\ & + \phi_6 \ln GCF_{t-1} + \phi_7 (\ln EI * \ln REC_{t-1}) + \phi_8 (\ln TA * \ln GCF_{t-1}) + \sum_{j=1}^{k_1} \beta_{1j} \Delta \ln C_{t-j} \\ & + \sum_{j=1}^{k_2} \beta_{2j} \Delta \ln GDP_{t-j} + \sum_{j=1}^{k_3} \beta_{3j} \Delta \ln GDP_{t-j}^2 + \sum_{j=1}^{k_4} \beta_{4j} \Delta \ln TA_{t-j} \\ & + \sum_{j=1}^{k_5} \beta_{5j} \Delta \ln REC_{t-j} + \sum_{j=1}^{k_6} \beta_{6j} \Delta \ln GCF_{t-j} + \sum_{j=1}^{k_7} \beta_{7j} \Delta (\ln EI * \ln REC_{t-j}) \\ & + \sum_{j=1}^{k_8} \beta_{8j} \Delta (\ln TA * \ln GCF_{t-j}) + \gamma_1 break_t + \epsilon_{1t} \end{aligned} \tag{5}$$

where Δ represents the first difference operator, ϕ_0 denotes the coefficient of the constant term, ϕ_1 – ϕ_8 are long-run

coefficients, β_{1j} – β_{8j} are short-run coefficients, k_1 to k_8 are the associated lag lengths, γ_1 is the coefficient of structural break dummy, and ϵ_{1t} is the error term.

The accompanying measures can be utilized to play out the ARDL bounds test: the initial step is to decide the optimal lag determination through Akaike Information Criteria (AIC). The *F* test is then used to examine the long-run relationship among the variables. The null hypothesis of no co-integration, $H_0: \phi_1 = \phi_2 = \phi_3 = \phi_4 = \phi_5 = \phi_6 = \phi_7 = \phi_8 = 0$ can be tested against the alternative hypothesis, $H_1: \phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq \phi_5 \neq \phi_6 \neq \phi_7 \neq \phi_8 \neq 0$. Two strands of critical *F* statistics figured by Pesaran et al. (2001) under the suppositions of stationary at the level for one set of critical values (lower bounds) and stationary at the first difference for another set of critical values (upper bounds). The speculation of the co-integration situation may be arrived if the calculated *F* statistics surpass the upper bounds critical value. No co-integration situation is also possible if the calculated *F* statistics fall underneath the lower critical bounds value. Finally, uncertain circumstances might also emerge if the estimated *F* statistics plunge between the upper and lower critical bounds.

The error correction term (ECT) and the short-run coefficients are estimated using Eq. (6):

$$\begin{aligned} \Delta \ln C_t = & \phi_0 + \sum_{i=1}^{k_1} \phi_{1i} \Delta \ln C_{t-i} + \sum_{i=0}^{k_2} \phi_{2i} \Delta \ln GDP_{t-i} + \sum_{i=0}^{k_3} \phi_{3i} \Delta \ln GDP_{t-i}^2 \\ & + \sum_{i=0}^{k_4} \phi_{4i} \Delta \ln TA_{t-i} + \sum_{i=0}^{k_5} \phi_{5i} \Delta \ln REC_{t-i} + \sum_{i=0}^{k_6} \phi_{6i} \Delta \ln GCF_{t-i} \\ & + \sum_{i=0}^{k_7} \phi_{7i} \Delta (\ln EI * \ln REC_{t-i}) + \sum_{i=0}^{k_8} \phi_{8i} \Delta (\ln TA * \ln GCF_{t-i}) \\ & + \gamma_1 break_t + \Psi_1 ECT_{t-1} + \mu_{1t} \end{aligned} \tag{6}$$

where Ψ_1 denotes the error correction term coefficient, the rate at which the error is rectified from one period to the next on the approach to long-run equilibrium.

The Hacker and Hatemi-J bootstrap causality analysis

The unit root and co-integration analysis assist in the assessment of the long-run relationship among the variables under consideration, but analysis of causal relationship analysis is also indispensable for further policy inferences. Toda and Yamamoto (1995) adapted the conventional Granger causality tests by estimating the modified Wald (MWALD) statistics, which allows for more flexibility in estimating a causal association without the need of pre-testing the stationarity properties. However, Hacker and Hatemi-J (2006) reported asymptotic MWALD statistics and showed the potential biases in analysis subject to the inadequate sample size, whereby

Table 3 Unit root test

Variable	Form	DF-GLS		PP		Order of integration
		Intercept	Trend + intercept	Intercept	Trend + intercept	
lnC	Level	0.853 (0.401)	− 1.859 (0.074)	− 0.409 (0.895)	− 1.941 (0.608)	I(1)
	First difference	− 5.762*** (0.000)	− 5.709*** (0.000)	− 5.644*** (0.000)	− 5.534*** (0.001)	
lnGDP	Level	− 0.538 (0.595)	− 2.016 (0.054)	3.209 (1.000)	− 3.081 (0.129)	I(1)
	First difference	− 2.811*** (0.009)	− 4.448*** (0.000)	− 5.186*** (0.000)	− 8.364*** (0.000)	
lnGDP ²	Level	− 0.521 (0.607)	− 1.592 (0.123)	4.277 (1.000)	− 2.545 (0.306)	I(1)
	First difference	− 2.702** (0.012)	− 4.448*** (0.000)	− 4.538*** (0.001)	− 7.413*** (0.000)	
lnTA	Level	− 0.511 (0.615)	− 1.887 (0.073)	0.631 (0.988)	− 2.344 (0.399)	I(1)
	First difference	− 2.181** (0.039)	− 2.815*** (0.010)	− 4.126*** (0.004)	− 3.994** (0.021)	
lnREC	Level	0.636 (0.529)	− 1.526 (0.138)	0.887 (0.994)	− 1.312 (0.865)	I(1)
	First difference	− 4.129*** (0.000)	− 4.533*** (0.000)	− 4.124*** (0.004)	− 5.427*** (0.001)	
lnGCF	Level	− 0.565 (0.578)	− 2.155** (0.039)	− 0.179 (0.931)	− 2.717 (0.238)	I(0)/I(1)
	First difference	− 2.501** (0.019)	-	− 6.488*** (0.000)	− 6.329*** (0.000)	
lnEI*lnREC	Level	0.341 (0.736)	− 2.465** (0.021)	− 0.166 (0.932)	− 1.729 (0.712)	I(0)/I(1)
	First difference	− 3.899*** (0.001)	-	− 3.954*** (0.005)	− 3.871** (0.027)	
lnTA*lnGCF	Level	− 0.201 (0.842)	− 2.206** (0.036)	0.303 (0.974)	− 2.828 (0.199)	I(0)/I(1)
	First difference	− 3.216*** (0.003)	-	− 5.472*** (0.000)	− 5.214*** (0.001)	

Probability value is given in parenthesis. *** denotes a 1% level of significance, ** denotes a 5% level of significance.

Table 4 Zivot and Andrews structural break test

Variable	Level		First difference	
	t-statistics	Time break	t-statistics	Time break
lnC	− 4.124***	2008	− 6.853***	2005
lnGDP	− 5.193***	2000	− 4.345*	2004
lnGDP ²	− 4.444***	2000	− 4.345*	2004
lnTA	− 3.469	1998	− 4.954***	2004
lnREC	− 4.054***	1999	− 5.361**	2004
lnGCF	− 5.625***	2004	− 7.831***	2003
lnEI*lnREC	− 3.735**	2005	− 6.311***	2003
lnTA*lnGCF	− 4.719***	2004	− 7.227***	2003

We have considered the break in the intercept. *** denotes a 1% level of significance, ** denotes a 5% level of significance, * denotes a 10% level of significance.

also recommended modification of MWALD statistics with bootstrapped distribution for reducing small sample size bias. Moreover, Hacker and Hatemi-J (2012) endorsed exhausting endogenized lag length dependent on a new data strand created by Hatemi-J (2008) known as the Hatemi-J criterion (HJC). The MWALD statistics are estimated from an order k VAR model, which can be specified as follows:

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \dots + \alpha_k Y_{t-k} + \vartheta_t \tag{7}$$

Table 5 Bound F test for co-integration

Estimated model	lnC = f(lnGDP, lnGDP ² , lnTA, lnREC, lnGCF, lnEI*lnREC, lnTA*lnGCF)	
Bound test F statistics	47.738***	
Optimal lag length	2, 2, 2, 2, 1, 1, 2	
Pesaran et al. (2001)		
Critical value	Lower bound I(0)	Upper bound I(1)
1%	2.96	4.26
2.5%	2.6	3.84
5%	2.32	3.5
10%	2.03	3.13

*** denotes a 1% level of significance, ** denotes a 5% level of significance, * denotes a 10% level of significance. The break dummy corresponding to the year 2008 has been included in the model.

where ϑ_t denotes the vector of error terms, evaluated randomly with replacement after bootstrapping. The Wald statistics are determined using Toda and Yamamoto (1995) procedure with bootstrapping M times, resulting in a bootstrapped Wald distribution for evaluating the causal relationship.

Table 6 Results for combined co-integration test by Bayer–Hanck (2013)

Estimated model: $\ln C = f(\ln GDP, \ln GDP^2, \ln TA, \ln REC, \ln GCF, \ln EI^* \ln REC, \ln TA^* \ln GCF)$					
Fisher type	Test statistics	CV@1%	CV@5%	CV@10%	Decision
EG-JOH	55.465***	15.00	10.18	8.13	Co-integrated
EG-J-BO-BDM	110.727***	28.99	19.45	15.59	Co-integrated

The break date dummy BD_{2008} of the dependent variable is included in the model. ***, **, and * indicate the results are significant at the 1, 5, and 10% levels, respectively.

Table 7 Long-run coefficient estimates

Variables	Coefficient	<i>t</i> -statistics	Prob
lnGDP	18.099***	6.635	0.001
lnGDP ²	−1.324***	−6.881	0.001
lnTA	−4.031***	−4.881	0.005
lnREC	−0.425**	−2.765	0.039
lnGCF	−9.367***	−6.409	0.001
lnEI*lnREC	−0.284**	−3.264	0.022
lnTA*lnGCF	0.562***	5.996	0.002
Shape of EKC	Inverted “U”-shaped		
Turnaround point	Year: 2004 (\$929.8)		

*** denotes a 1% level of significance, ** denotes a 5% level of significance, * denotes a 10% level of significance. The turnaround point has been calculated as per Shahbaz and Sinha (2019).

Results and discussions

Unit root test results

In this study, DF-GLS and PP unit root tests have been used to evaluate the stationary properties of the variables in both level and first difference forms. The unit root test results as shown in Table 3 revealed that all the variables are non-stationary in level except lnGCF, lnEI*lnREC, and lnTA*lnGCF, which are observed to be stationary in level with the assumptions of allowing deterministic trend and intercept at 5% level of significance. Furthermore, the null hypothesis of the unit root test (i.e., non-stationary) is rejected at a 5% level of significance as the variables are transformed to the first difference. So, the empirical results confirm that all the underlying variables are fractionally integrated of I(0)/I(1) that intends to employ the ARDL bounds test of co-integration in the way of investigating the long-run dynamics among the variables.

Various examinations propose that DF-GLS and PP unit root tests can give biased and inefficient evaluations under the presence of an underlying break in the time series data (Bandyopadhyay and Rej, 2021). In this way, the ZA test has been engaged to recognize the presence of an underlying break in the time series. The results of the ZA test

as tabulated in Table 4 highlight that all the variables are stationary at both level and first difference, except for lnTA which is stationary only in the first difference. The structural break of the dependent variable lnCO₂ is evident in the year 2008, which is aligned with the global financial crisis which resulted in economic recession throughout the World. In the succeeding examination of co-integration and regression modeling, the structural break date is included.

Co-integration test results

The results of the ARDL bounds test of co-integration, as presented in Table 5, indicate that the computed *F* statistics are much higher than Pesaran et al. (2001) upper bound critical values at 1% level, thereby refuting the speculation of no co-integration relationship among the underlying variables. This result strongly suggests the existence of long-run dynamics among the variables employed in the model for the period 1990–2019. It is noteworthy to mention that the dummy variable for the structural break date of 2008 estimated from the ZA test is also augmented in the model, thereby further validating the long-run relationship under the assumption of a structural break in the model.

The conventional co-integration tests are often found to provide biased estimates with the presence of an inadequate sample size. Consequently, it is worthwhile to validate the results of the ARDL bound test of co-integration by using second-generation co-integration models. The result for the Bayer–Hanck co-integration test is presented in Table 6. The Fisher statistics for EG-JOH and EG-J-BO-BDM tests are evidenced to be much greater than the critical values at a 1% level of significance, thereby confirming the existence of a long-run co-integrating relationship among the variables. The inclusion of the structural break date dummy in the model further validates the co-integration relationship in presence of structural breakpoint.

ARDL results

The long-run coefficient estimates from the ARDL model of Eq. (5) have been presented in Table 7 and reveal that the long-run coefficient accompanied with per capita GDP and its square term is demonstrated to be positive and negative individually and significant at a 1% level of significance.

Table 8 Short-run elasticity estimates

Variables	Coefficient	<i>t</i> -statistics	Prob
$\Delta(\ln\text{GDP}_t)$	18.35 ^{***}	11.47	0.000
$\Delta(\ln\text{GDP}_t)^2$	-1.35 ^{***}	-11.83	0.000
$\Delta(\ln\text{TA}_t)$	-2.06 ^{***}	-10.42	0.000
$\Delta(\ln\text{REC}_t)$	-0.19 ^{***}	-7.26	0.001
$\Delta(\ln\text{GCF}_t)$	-5.04 ^{***}	-14.85	0.000
$\Delta(\ln\text{EI}_t^* \ln\text{REC}_t)$	-0.08 ^{**}	-3.02	0.029
$\Delta(\ln\text{TA}_t^* \ln\text{GCF}_t)$	0.31 ^{***}	13.80	0.000
Constant	7.47 ^{***}	30.63	0.000
BD ₂₀₀₈	-0.15 ^{***}	-27.19	0.000
ECT (-1)	-1.07 ^{***}	-30.28	0.000
R^2	0.993		
Adjusted R^2	0.985		
<i>F</i> statistics [Prob.]	115.83 ^{***} [0.000]		
D/W statistics	2.22		

*** denotes a 1% level of significance, ** denotes a 5% level of significance, * denotes a 10% level of significance.

Table 9 Diagnostic tests for the ARDL model

Diagnostic test	Null hypothesis	Statistics	Decision
Jarque–Bera test	H ₀ : Normal distribution of error terms	χ^2 : 1.043 Prob: 0.594	Error terms are normally distributed
Breusch–Godfrey serial correlation LM test	H ₀ : No autocorrelation	<i>F</i> -stat: 1.025 Prob: 0.458	No serial correlation
Breusch–Pagan–Godfrey test	H ₀ : Homoskedasticity	<i>F</i> -stat: 1.886 Prob: 0.249	No heteroskedasticity
Ramsey RESET test	H ₀ : Model specification is correct	<i>F</i> -stat: 2.207 Prob: 0.212	Model is correctly specified

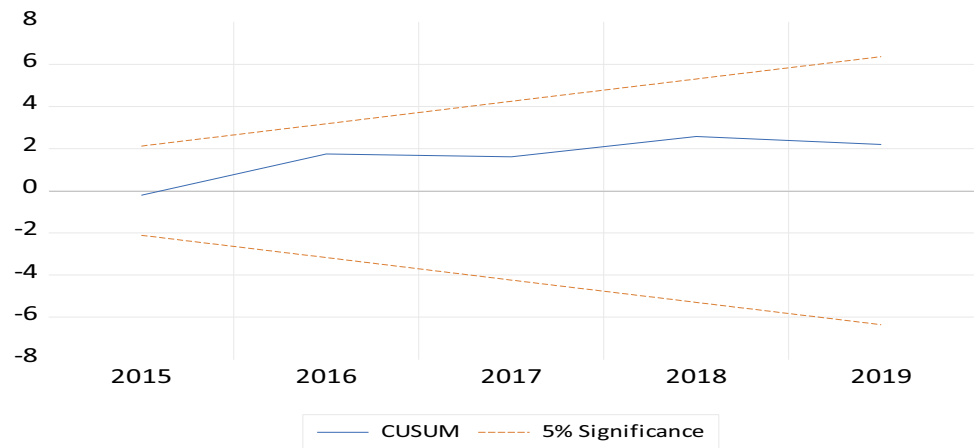
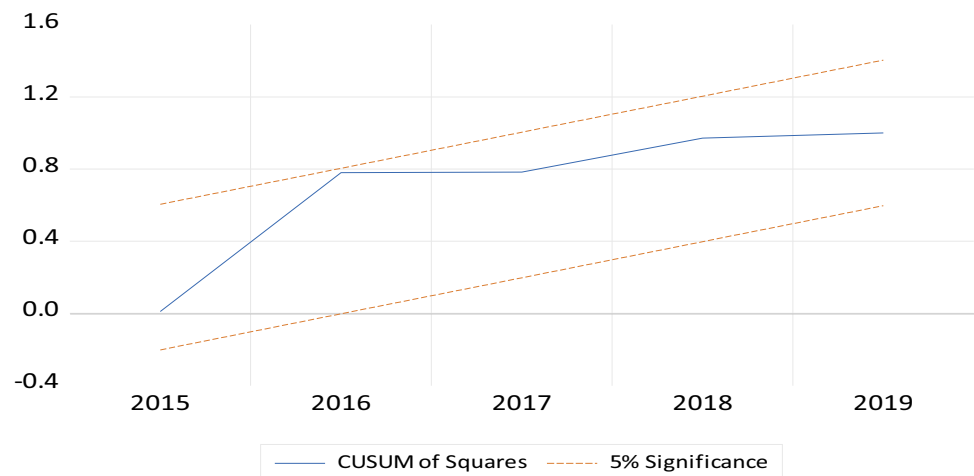
These empirical results provide a strong confirmation of the existence of the inverted U-shaped EKC hypothesis in India. Our findings are in accordance with the empirical proof of the presence of inverted U-shaped EKC hypothesis for India by (Danish et al., 2021; Jayanthakumaran et al., 2012; Rana & Sharma, 2019; Sinha & Shahbaz, 2018; Tiwari et al., 2013). The estimated turning point of the inverted U-shaped EKC is found to fall within the sample range. The turning point is estimated at \$929.8 corresponding to the year 2004. The turnaround point of the inverted U-shaped EKC indicates that India’s EKC hit a positive peak in 2004, and pollution levels began to decline with the development of economic activity after that year.

The empirical results tabulated in Table 7 highlight the beneficial effect of tourism development in the abatement of environmental degradation indicating a 1% increase of foreign tourist arrivals in India is associated with the 4% reduction of environmental pollution. The results are aligned with the empirical findings by (Azam et al., 2018) for Singapore and Thailand and (Shakouri et al., 2017) for Asia–Pacific

countries. Our findings suggest that the present policy thrust of India is encouraging more to promote sustainable tourism practices. India is always regarded as an enriched reservoir of landscape and a rich tapestry of cultural heritage with the future opportunity of generating revenue through the transformation of these resources as a preferred destination of tourist activities. The Government of India has undertaken various measures to safeguard its national heritage and promote nature-based tourism practices that may ensure a valuable source of income for the preservation of natural resources. GCF is found to have a long-run beneficial effect on environmental quality. Our findings are in line with the empirical outcomes by Akalpler & Hove (2019) for India. These findings further imply that the present policy thrust of India is encouraging more to invest in energy conservative assets and prompting to mandate strict energy efficiency measures that can bolster the nation’s economic engine while reducing energy intensity at a large. The interaction term between tourism and GCF is also found to be statistically significant and positive at a 1% significance level.

These findings suggest that capital formation has not been conducive to sustainable tourism development in the correction of environmental pollution. This result further implies, although India’s present policy planning favoring to promote sustainable tourism practices, India has not been able to generate sufficient capital investment which is essential in the expansion pathway of ecotourism development.

Table 7 postulates that at a 5% level of significance, the long-run coefficient of REC is determined to be significantly negative. The result suggests that a 1% increase of renewable energy capacity addition in the Indian energy mix corresponds to the 0.43% reduction of CO₂ emissions. The results are aligned with the findings by Sinha and Shahbaz (2018) for India, Danish et al. (2019) for BRICS nations, and Paramati et al. (2017) for G-20 nations. Our findings imply that accelerated capacity addition of renewable energy in the energy portfolio might assist India to achieve the INDC target of decreasing the CO₂ discharge intensity of GDP by 30–35% by 2030 from 2005 levels. The expansion

Fig. 4 Plot of the CUSUM test**Fig. 5** Plot of CUSUM of the square test

pathway of REC may also help India in the improvement of energy security while easing energy poverty, which could have helped the nation to grow the economic engine of the country. The interaction term between the EI and REC is evidenced to be negative and significant at a 5% level of significance. These findings unveil the importance of educational advancement in developing nations like India to thrive the ecological sustainability through enhancing the creation of mass awareness to promote renewable energy usage and rational usage of energy consumption to bring down the energy expenditure.

The short-run elasticity estimates of the variables have been reported in Table 8. Table 8 highlights the existence of the inverted U-shaped EKC hypothesis for India in the short run. Table 8 also divulges that the short-run marginal effect is quite lesser than the long-run marginal effect except for GDP and its square term. The dummy coefficient relating to the break year 2008 is observed to be negative and significant at a 1% level of significance. The possible clarification of the advantageous impact of the structural break in the neutralization of environmental pollution can be attributed to the global financial crisis in the year 2008

that negatively impact the economic growth and reduced the foreign-exchange reserves which are essential to import energy-intensive products. The gradual increase of attrition rate and the unemployment rate as a consequence of the financial crisis 2008 is also dipping the energy consumption level resulting in the massive reduction in emission level.

The adjustment coefficient in Table 8 is found as negative and significant at a 1% level of significance inferring the error is amended from one period to the next, resulting in a high rate of roughly 107% progress towards a long-run equilibrium pathway. The diagnostic test results, as presented in Table 9, confirm that the serial correlation, normality, heteroskedasticity, and specification test results qualify the ARDL estimation. The plots of CUSUM and CUSUMQ statistics in Figs. 4 and 5 are also evidenced to be well inside the critical limit suggesting that ARDL estimations have qualified the stability test.

Robustness checks

The robustness of the estimated ARDL model is further being verified with the dynamic OLS (DOLS) technique.

Table 10 Long-run coefficient estimates from DOLS

Variables	Coefficient	<i>t</i> -statistics	Prob
lnGDP	49.549**	5.504	0.032
lnGDP ²	− 3.477**	− 5.514	0.031
lnTA	− 15.956**	− 4.879	0.039
lnREC	− 1.072**	− 6.289	0.024
lnGCF	− 28.529**	− 5.326	0.034
lnEI*lnREC	− 0.473*	− 3.101	0.091
lnTA*lnGCF	1.821**	5.188	0.035
Shape of EKC	Inverted “U”-shaped		

*** denotes a 1% level of significance, ** denotes a 5% level of significance, * denotes a 10% level of significance. The break dummy corresponding to the year 2008 has been included in the model.

The results of the DOLS method are tabulated in Table 10 and postulates the existence of an inverted U-shaped EKC hypothesis for India. The results of the DOLS method as tabulated in Table 10 are also found to be consistent with the results of long-run coefficient estimates of the variables from ARDL estimations of Eq. (5), shown in Table 7.

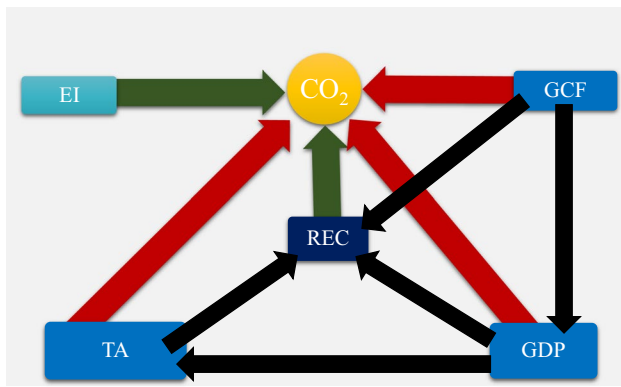
Hacker and Hatemi-J bootstrap causality test results

The causal relationship between the variables has been explored using Hacker and Hatemi-J’s (2012) bootstrapped causality test. The MWALD statistics for the causality test and the bootstrapped critical values at 1%, 5%, and 10% significance levels are reported in Table 11. The results of the causality test can be summarized as follows: (i) unidirectional causality from GCF to GDP essentially evidences the

Table 11 The Hacker and Hatemi-J (2012) bootstrap causality results

Causal relationship	MWALD statistics	CV @1%	CV @5%	CV @10%
lnGDP → lnCO ₂	4.117*	7.569	4.316	2.978
lnEI → lnCO ₂	6.037**	8.318	4.222	2.894
lnREC → lnCO ₂	6.220**	7.781	4.296	2.979
lnTA → lnCO ₂	14.599***	7.749	4.362	3.028
lnGCF → lnCO ₂	25.66***	13.01	7.613	5.664
lnCO ₂ → lnGDP	0.009	8.167	4.432	3.008
lnEI → lnGDP	4.616	10.906	6.779	4.96
lnREC → lnGDP	0.733	8.097	4.36	2.99
lnTA → lnGDP	0.699	12.191	7.163	5.288
lnGCF → lnGDP	0.189***	0.076	0.001	0.000
lnCO ₂ → lnEI	0.007	8.047	4.461	2.988
lnGDP → lnEI	3.68	12.627	7.606	5.653
lnREC → lnEI	0.057	7.604	4.225	2.978
lnTA → lnEI	4.475	12.805	7.529	5.544
lnGCF → lnEI	0.466	7.974	4.353	3.025
lnGDP → lnTA	14.522***	13.618	7.879	5.79
lnEI → lnTA	1.35	11.971	7.159	5.324
lnCO ₂ → lnTA	0.29	7.858	4.438	2.986
lnGCF → lnTA	2.351**	4.899	1.675	0.776
lnREC → lnTA	0.849	8.085	4.449	2.968
lnGDP → lnGCF	0.138	7.603	4.102	2.864
lnEI → lnGCF	1.744	7.503	4.211	2.936
lnTA → lnGCF	0.114	7.474	4.175	2.95
lnREC → lnGCF	0.002	8.082	4.274	2.959
lnCO ₂ → lnGCF	1.027	12.103	7.168	5.386
lnGDP → lnREC	8.531***	7.887	4.192	2.978
lnEI → lnREC	0.123	7.989	4.111	2.913
lnTA → lnREC	11.472***	8	4.204	2.86
lnGCF → lnREC	8.406***	7.812	4.297	2.911
lnCO ₂ → lnREC	0.536	8.24	4.469	3.109

***, **, and * indicate the test statistic value lies above the bootstrapped critical values at the 1%, 5%, and 10% level of significance. X → Y indicates the changes in X may cause changes in Y.



Note: Causality test. Note: $X \rightarrow Y$ indicates change in X may cause a change in Y .

Fig. 6 Short-run causal linkages summarized from Hacker and Hatemi-J bootstrapped. Note: causality test. Note: $X \rightarrow Y$ indicates a change in X may cause a change in Y

existence of capital investment-driven sustainable growth hypothesis in the short-run, (ii) unidirectional short-run causality from economic growth to CO_2 emissions highlights the inability to control CO_2 emissions without affecting the economic growth, (iii) existence of unidirectional causality from EI to CO_2 emissions unveils that educational prosperity and quality of life enhance the energy consumption level in the short run, which contributes to CO_2 emissions, (iv) unidirectional short-run causality from REC to CO_2 emissions implies that enhance the production of energy-intensive renewable technologies contributes to CO_2 emissions in the short run, and (v) unidirectional causality from GDP to tourist arrivals confirms the existence of the economic growth-driven sustainable tourism hypothesis in India. The causal network as depicted in Fig. 6 divulges that GDP, GCF, and tourist arrivals not only have a direct impact on CO_2 emissions but also have an indirect impact on the CO_2 emissions through the channel of REC.

Conclusion and policy implications

The tourism industry is usually viewed as a supportive industry of a nation that plays a significant role in enriching society at various stages of sustainable development. This paper has revisited the EKC hypothesis for India with special reference to the encouraging prospects of sustainable tourism practices, growth in REC, educational advancement, and eco-friendly capital investment initiatives.

Additionally, the interaction term between EI and REC, as well as, the interaction between foreign tourist arrivals and GCF has been added in the existing framework to unveil further interesting insights. The ARDL limits test of co-integration and Bayer and Hanck (2013) combined co-integration test is used in this work to confirm the long-run dynamic relationship between the underlying variables. The long-run and short-run impacts of economic growth, tourist arrival, REC, GCF, and the interaction terms on environmental degradation have been analyzed by employing the ARDL model. The strength of the ARDL results is confirmed with extreme conviction through the dynamic OLS technique. Finally, The Hacker and Hatemi-J (2012) bootstrap causality test was used to investigate the causal relationship between the underlying variables.

This study uncovers some novel insights about India's long-term economic growth strategies with a clear focus on sustainable tourism practices. The empirical findings strongly support the existence of the inverted U-shaped EKC hypothesis in India for both the long run and short run. Both the long-run and the short-run marginal impact of GDP and its square term on environmental degradation are found to be almost similar. The inverted U-shaped EKC's turnaround point indicates that India has reached the pinnacle in 2004 and pollution levels began to decline with the further expansion of economic activity afterward. These findings show that the current economic growth pattern is environmentally benign and affiliated with India's long-term sustainable policy strategy. Furthermore, the evidence of unidirectional causality from GDP to CO_2 emissions unveils the high degree of interdependency between these two policy variables.

Moreover, the unique insights of a negative association between tourism growth and environmental degradation further uphold India's current policy alignments in promoting sustainable tourism practices. These findings yield some policy recommendations for the expansion of the tourism sector with policy preference aligned to practicing all aspects of sustainability dimensions. Several strategies can be formulated that have aimed to continue the smooth functioning of low-carbon tourism models. On the one hand, the government should proactively involve in raising public awareness and spreading word of mouth about sustainable tourism activities. On the other hand, the government should prudently formulate the guidelines about efficient usage of natural resources in tourist places and alternate action plans of investing adequate capital

to pursue an advanced low-carbon tourism model in the tourist destinations where emissions are evidenced to be quite substantial. In such frequently visiting tourist destinations, the introduction of carbon taxes may subside the environmental consequences and aid to preserve the natural resources. However, the present study also evidences the deadlier effect of the interaction term between capital formation and tourism on environmental quality. This finding shows that capital formation has not aided in the development of sustainable tourism in the mentioned time spanned of analysis. Hence, there exists ample scope in the development of the required infrastructure in the expansionary pathway of converting landscapes and unexplored national heritage as a preferred destination of tourist attractions that may further boost environmental sustainability through nurturing ecotourism practices.

In addition, the empirical findings further provide evidence of *ceteris paribus*; augmentation of GCF has a long-term beneficial effect on environmental quality. This result implies that the present policy thrust dissuades capital formation in energy-intensive dirty and obsolete technology and encourages investment in environment-friendly green and energy-efficient technology. The evidence of unidirectional causality from GCF to GDP is the indication of the existence of capital investment-driven sustainable growth hypothesis which is an essential input to the infrastructural development of sustainable tourism practices, as evidenced by the unidirectional short-run causality from GDP to foreign tourist arrivals.

Furthermore, the long-run impact of REC on CO₂ emanation is demonstrated to be significantly negative succeeding renewable energy as a prospective source of energy to alleviate CO₂ effluence in the long-run sustainable energy pathway. Enhanced espousal of renewable energy in the national energy portfolio will not only aid India to achieve the future challenges in targeted emission reductions but also can contribute to the energy security of the nation. The government of India has undertaken various policy measures to promote renewables, including levying a lower goods and services tax (GST) for production of renewable energy devices, subsidizing on the tariff of renewable electricity consumption, and enacting the discriminatory subsidy on renewable tariff, i.e., tariff-based subsidy will be higher for rural poor and lower for industries. The expansion pathway of renewable energy is currently facing serious policy challenges in the form of high fixed cost and maintenance cost, low-reliability factors in terms of availability and load constraint, and massive land requirements

for setting up of the new renewable energy projects. For a densely populated country like India, such huge availability and acquisition of land is a major stumbling block in the expansionary pathway of renewable energy penetration. Hence, policy preference of promoting educational advancement has serious policy implications in the smooth transitioning pathway to renewable energy. The interaction term between EI and the REC is evident to have a constructive effect on environmental welfare which essentially highlights that increasing energy literacy rate and promoting mass awareness of enhancing usage of renewable energy in the economy can further aid India to achieve the strict targets of INDC commitment. Educational advancement may also aid in technology diffusion that may bring advanced technologies which can ensure better reliability factors in renewable technologies and aid in the reduction of life cycle land use requirement of renewable energy penetration.

Precisely, India is currently facing an inverted U-shaped EKC hypothesis, while presently going down through the second limb of inverted U. The current policy directives of the accelerated espousal of renewable energy in the national energy mix, effective strategies of promoting educational progress to bring technological innovation and creation of enhancing mass awareness about the societal benefit of adopting renewable energy, policy thrust towards implementation of sustainable tourism practices, and investment opportunities in energy-efficient and environmentally friendly technology may aid India avoiding the negative peak of EKC by enlarging the second arm of the inverted U and may contributing to more flatter view of EKC curve. At the same time, the disassociation between tourism growth and capital formation may accelerate the ascent to a negative peak of inverted U in the coming days which can be linked to the more prominent N-shaped trajectory in near future. The government of India should provide serious policy emphasis on supplying quantum of capital necessitated for the infrastructural development in ecotourism initiatives and raising capital fund through public–private partnership opportunities for developing the entire innovation chain of renewable technology growth path, to win the contest of climate change by nourishing the future targeted emission reduction plan in the international climate agreement.

The present study has limitations of being solely focused on a single country; future studies can focus on additional panel datasets involving further advanced econometric methodologies to unravel the dynamics at a broader scale. Another direction of future research could be to study the impact of the COVID-19 pandemic in the present econometric model setup.

Appendix

Fig.

Fig. 7 Sustainable Development Goals and 5 pillars of Sustainable Tourism (Source: Author's illustration based on information from UNWTO, 2018 report)



Source: Author's illustration based on information from UNWTO, 2018 report

Author contribution Soumen Rej: conceptualization, investigation, methodology, formal analysis, and visualization; Arunava Bandyopadhyay: conceptualization, investigation, methodology, formal analysis, and visualization; Muntasir Murshed: introduction, literature review, methodology, and analysis; Haider Mahmood: literature review and conclusion; Asif Razzaq: reviewed, editing and made suggestions to improve the quality of the manuscript.

Data availability The data sources are mentioned in the manuscript.

Declarations

Ethics approval and consent to participate Not applicable.

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