Revealing the nexus between tourism development and CO2 emissions in Asia: does asymmetry matter?

Kaixin Wangzhou1 · Julie Jie Wen1 · Zheng Wang2 · Huamin Wang3 · Chunbo Hao4 · Zubaria Andlib5

Received: 2 March 2022 / Accepted: 3 June 2022 / Published online: 15 June 2022
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2022

Abstract
Asia is one of the fastest-growing regions in international tourism, economic growth, and CO2 emissions around the globe. However, the relationships between tourism and CO2 emissions are little and unclearly identified. The purpose of the study is to explore the asymmetric nexus between tourism and CO2 emissions in a panel of five high emitters Asian countries covering the period of 1995–2019 by using panel-NARDL-AMG. The empirical results reveal that a positive shock in tourism arrivals increases CO2 emissions, while a negative shock also increases CO2 emissions in the long run. Moreover, a negative shock has a greater effect on CO2 emissions than a positive shock in Asia in the long run. Tourism receipts are expected to maintain the robustness of CO2 emissions in the long run in Asian economies. The authorities should develop and design green international tourism activities in the Asian economies.

Keywords Tourism developments · CO2 emissions · Asian economies

Introduction
An implausible amplification of economic happenings has been observed during the past few decades, and combined with the intensification of worldwide economic happenings, an intense upsurge in universal greenhouse gas emissions is observed (Aslam et al. 2021; Hussain et al. 2020). It is pragmatic that the immense increase in CO2 emissions, unexpected upsurge in temperature, and the climatic variations occur due to complicated phenomena ascending from complicated associations among environment, economic growth, and energy. Although energy contributes significantly to enhancing economic development, it also contributes chiefly to increasing environmental degradation (Belaid and Zrelli, 2019; Awan and Bilgili 2022). Environmental degradation and carbon emissions are associated with the upsurge in energy use due to increased economic accomplishments (Khattak et al. 2020; Awan et al. 2022). There is a need to control CO2 emissions for the achievement of economic sustainability; thus, this issue has emerged in the worldwide economy. Resultantly, it is vital to distinguish the major factors of CO2 emissions that enable all the economies to reach an agreement regarding policy measures that helps in combating the consequences of global warming (Yin et al. 2021; Li et al. 2022; Ngoc and Awan 2022).
Carbon emissions are the most commonly used indicator for measuring quality of environment, as it is estimated that the share of CO$_2$ emissions has reached up to 80% of total greenhouse gas emissions. All the factors that contribute significantly to increasing economic development also contribute significantly to environmental degradation due to increased production of CO$_2$ emissions. The considerable rise in tourism activities broadens the size of the worldwide economy, stimulates exports, and creates more jobs. Apart from job creation and wealth, growth in tourism activities creates sustainability-related risks around the globe. The use of unclean and non-renewable energy sources in this sector produces a negative influence on quality of environment (Gokmenoglu and Eren 2020). Because of Tugcu and Topcu (2018), tourism produces income at the cost of an increase in carbon emissions. UNWTO (2019) reported that the share of tourism in total pollution emissions was approximately 5% in 2016, and it is projected that this share will rise up to 5.3% by 2030. Due to the increasing contribution of tourism to environmental degradation, it has become fundamental for policymakers, environmentalists, and economists to examine the association between tourism and environmental quality.

The UNWTO (2019) claimed that the total number of tourists has reached to 1.4 billion in 2018 and it is projected that these numbers will be reached to 1.7 billion in 2030. Moreover, tourism-based economic accomplishments attract approximately US$ 1.7 trillion. Therefore, it is evident for economies to focus on the tourism industry in order to capture a larger share of tourism. But, the issue that most economies have to face is how to isolate the bad aspects of tourism from its goods, i.e., how to stimulate tourism in the economy without damaging quality of environment? In this perspective, it can be stated that tourism contributes significantly to understanding the association between environmental quality and economic development and attaining sustainable growth.

Theoretically, sustained economic development with good environmental quality is known as a standard of investigating the “sustainability of an economy” (Khattak et al. 2020). In the last few decades, the growing trends of tourism and its contribution to sustainable development such as environmental quality and economic growth have encouraged economists and environmentalists to incorporate tourism variable in the environment as well as production function. As far as the nexus between environment and tourism is concerned, literature provides two distinct propositions. In this context, the first study is done by Bach and Gobling (1996) who tried to disclose the association between environmental quality and tourism and reported that tourism tends to decay environmental quality due to a huge upsurge in carbon emissions. This finding is also in line with Goudie and Viles (2013). Furthermore, the literature found that tourism also contributes to wastage of natural resources and water that may exceed the soil erosion process and enlarge the extent of land, water, and air pollution (Latif et al. 2018; Chan et al. 2018). Moreover, as the ratio of tourism in the host country rises, it will enlarge the consumption of energy, due to a significant increase in hoteling, transportation, and other related activities, that ultimately contribute to raising pollution emissions (Nepal et al. 2019). In contrast, another proposition claims that tourism enhances the quality of environment by promoting effective usage of energy, encouraging technological innovations, and delivering other vital services. In this regard, it could be stated that tourism can contribute significantly to protecting environment if adopted sensibly (Imran et al. 2014; Dogan and Aslan 2017; Saint Akadiri et al. 2019).

A bulk of studies have investigated the tourism-based growth hypothesis and these studies conclude that tourism triggers economic development (Aslan et al. 2021). This economic growth comes at the cost of environmental, social, and economic deterioration (Azam et al. 2018; Kocoglu et al. 2022). Previous limited literature reveals that GDP per capita and tourist arrivals exhibit a non-linear association. Anoruo and Elike (2015) denote that the fundamental economic indicators such as GDP and prices exhibit asymmetric properties. The positive rise in economic growth from tourist arrivals offsets the losses when tourist arrivals fall. Kumar and Stauvermann (2016) explored the non-linear nexus between tourism and economic growth in the case of Sri Lanka. Eyuboglu and Euyuboglu (2020) denoted that the previous studies mostly employed a simple symmetric approach that lacks new econometric improvements such as NARDL. The drawback of the simple symmetric approach is that it assumes the impacts of a positive shock in the same manner as the impacts of a negative shock. In contrast, Granger and Yoon (2002) denote that the response to negative and positive shocks might be different. Most existing studies such as Chou (2013) and Dogru and Bulut (2018) consider symmetric estimations that are unable to report such non-linear results.

Sustainable tourism is a need of time and it needs the thoughtful attention of researchers and policymakers. Tourism is needed to attain economic growth but involved massive energy consumption, transportation, and other related activities that promote carbon emissions and environmental decay. Thus, it is very important to maintain a balance between tourism development and its connected influence on the environment. From the perspective of this background, the present study aims to explore the impact of tourism on environmental quality for emerging Asian economies. Asian countries selected for the analysis are China, India, Russia, Japan, and Saudi Arabia. These countries are the leading contributor to CO$_2$ emissions in Asia and are among the top 10 carbon emitters in the world. Furthermore, the tourism sector is also growing in the economies, which motivates us to analyze the tourism-CO$_2$ emissions in these economies. To the best of the author’s knowledge, this study is a pioneer in its kind. No doubt, tourism is a blessing for emerging economies due to its significant contribution in process of economic development, but it also
contributes to increasing carbon emissions in these economies. Thus, investigating the influences of tourism on carbon emissions for emerging economies is a very imperative issue. And, this is the first-ever study in which we will try to explore this nexus by assuming asymmetric changes in tourism. The asymmetric assumption implies that if an increase in tourism encourages CO2 emissions a decrease in tourism may exert a positive, negative, or even no impact on the CO2 emissions.

According to the world travel and tourism council (WTTC, 2019), tourism is one of the fastest-growing sectors of the world, which contributes to 10.4% of the global GDP, equal to US$ 9.2 trillion. On the other side, tourism-driven emissions are also on the rise, contributing to about 8% of the global CO2 emissions. Alongside the growing tourism industry, the Asian economies have also become the top contributors to global CO2 emissions (Usman et al. 2021; Wei et al. 2022). Some past studies have analyzed the relationship between tourism and CO2 emissions for a single country; however, none of them has exclusively focused on the selected Asian economies. Most of the macroeconomic series move asymmetrically due to exposure to external shocks, and tourism is no exception; hence, applying the asymmetric analysis is justified. Moreover, none of the empirics have focused on asymmetric analysis. To fill this lacuna in the literature, this study is the first effort to capture the tourism-environment nexus in the context of Asian economies.

The study contributes to the literature in the following ways. First, it is a pioneering work in the context of Asian economies that have tried to analyze the impact of tourism development on CO2 emissions. In 2017, the share of tourism was 5% of the total GDP of Asia. The countries we have selected for the analysis are among the top emitters of CO2 emissions. Therefore, it is pertinent to scrutinize the nexus between tourism and CO2 emissions in selected Asian economies. Second, this is the first effort to analyze the asymmetric impact of tourism sector development on CO2 emissions in selected Asian economies. Third, most past studies provide the long-run estimates only, whereas this analysis also provides both the short- and long-run estimates. Last but not least, the study also focuses on the causal relationship between the variables for policy suggestions, which is another contribution of the study.

where carbon dioxide (CO2) emissions are a function of tourism (Tourismit), gross domestic product (GDPit), population (POPit), energy intensity (EIit), and randomly distributed error term (εit). Equation (1) is a long-run model which is needed to be re-specified in the form of an error correction format (2) which can fulfill our objective of providing both short- and long-run estimates.

$$
\Delta \text{CO}_2, t = \beta_0 + \sum_{k=1}^{n} \beta_1 \Delta \text{CO}_2, t-1 + \sum_{k=0}^{n} \beta_2 \Delta \text{Tourism}, t-k 
+ \sum_{k=0}^{n} \beta_3 \Delta \text{GDP}, t-k + \sum_{k=0}^{n} \beta_4 \Delta \text{POP}, t-k 
+ \sum_{k=0}^{n} \beta_5 \Delta \text{EI}, t-k - \omega_1 \text{CO}_2, t-1 
+ \omega_2 \text{Tourism}, t-1 + \omega_3 \text{GDP}, t-1 + \omega_4 \text{POP}, t-1 + \omega_5 \text{EI}, t-1 + \epsilon_t
$$

(2)

Equation (2) represents the bounds testing approach to the cointegration and error correction model of Pesaran et al. (2001), commonly known as the ARDL model. Several other time series cointegration techniques were introduced by Engle and Granger (1987), Johansen (1988), and Johansen and Juselius (1990) but with few limitations. For instance, they all require that the series included in the model must be stationary at first difference or, in other words, the series must be I(0). However, the bounds testing approach by Pesaran et al. (2001) can deal with the variables of I(0) and I(1); therefore, we can include the mixture of I(0) and I(1) in the ARDL model. Another advantage of the ARDL model is its ability to simultaneously provide short- and long-run estimates (Usman et al. 2022). However, the long-run estimates are considered cointegrated or valid only if they are supported through a significant value of the bounds F-test (Bahmani-Oskooee et al. 2020). Moreover, the limited number of observations always remains a problem in the time series analysis. In contrast, the ARDL model can also deal with this problem and provide efficient and unbiased results with a small number of observations (Zhang et al. 2022). Last but not least, the ARDL provides efficient estimates in the presence of endogeneity and serial correlation due to the inclusion of the short-run dynamic process.

Next, we decompose the tourism variable into its positive and negative components by using the partial sum procedure of Shin et al. (2014).

$$
\text{Tourism}_{it} = \sum_{n=1}^{t} \Delta \text{Tourism}^+_{it} = \sum_{n=1}^{t} \max (\Delta \text{Tourism}^+_{it}, 0)
$$

(3)

$$
\text{Tourism}^-_{it} = \sum_{n=1}^{t} \Delta \text{Tourism}^-_{it} = \sum_{n=1}^{t} \min (\Delta \text{Tourism}^-_{it}, 0)
$$

(4)

The positive changes in the series are represented by Tourism+ in Equation (3), and the negative changes are

---

Model and methodology

Following the prior empirical studies (Koçak et al. 2020; Wei and Ullah 2022), we have established model (1) to scrutinize the relationship between international tourism and carbon emissions in Asian economies.

$$
\text{CO}_2, it = \beta_0 + \beta_1 \text{Tourism}, it + \beta_2 \text{GDP}, it + \beta_3 \text{POP}, it + \beta_4 \text{EI}, it + \epsilon_{it}
$$

(1)
represented by Tourism\(^{−}\) in Eq. (4). Then, we replace these partial sum variables in place of the original variable in Eq. (2).

\[
\Delta CO_2,t = \alpha_0 + \sum_{k=1}^{n} \beta_k \Delta CO_2,t-k + \sum_{k=0}^{n} \beta_k \Delta Tourism^{−},t-k \\
+ \sum_{k=0}^{n} \delta_k \Delta Tourism^{+},t-k + \sum_{k=0}^{n} \beta_k GDP,t-k \\
+ \sum_{k=0}^{n} \beta_k POP,t-k + \sum_{k=0}^{n} \beta_k EI,t-k + \omega_1 CO_2,t-1 \\
+ \omega_2 Tourism^{+},t-1 + \omega_3 Tourism^{−},t-1 + \omega_4 GDP,t-1 \\
+ \omega_5 POP,t-1 + \omega_6 EI,t-1 + \epsilon_t
\]  

(5)

After including partial sum variables into Eq. (2), the resulting Eq. (5) is known as the non-linear ARDL model. The NARDL model is an extended form of the ARDL model and can be handled with procedures and techniques used by the linear ARDL model. However, we need to perform short- and long-run WALD tests for the short- and long-run asymmetric impact of tourism on CO\(_2\) emissions. In the short-run asymmetric test, the combined effect of \(\Delta Tourism^{−}\) must be different from the combined effect of \(\Delta Tourism^{+}\). Similarly, the long-run asymmetric tests are confirmed if the estimate of \(\omega_2\) is significantly different from the estimate of \(\omega_3\).

**Data**

This study uses panel data of five Asian countries (China, India, Russia, Japan, and Saudi Arabia) from 1995 to 2019. The selection of Asian countries is based on high emitters and the availability of data on international tourism. We used two tourist arrivals and tourism receipts as independent variables, while we used tourism receipts in the model for robust analysis. We have included tourist arrival and tourist receipts as a proxy of tourism. For the sake of efficient finding, we converted all datasets into a natural logarithm except energy intensity. All datasets are obtained from WDI that compiled by World Bank. The mean of CO\(_2\), TA, TR, GDP, POP, and EI are 14.19 kt, 16.62, 23.14 US$, 8.69 US$, 19.27, and 7.07 MJ/$, respectively, while the standard deviation is 0.92 kt, 1.18, 1.23 US$, 1.47 US$, 1.50, and 2.66 MJ/$, respectively. The detailed data description of the variables and data are reported in Table 1.

**Results and discussion**

First of all, we need to test the stationarity of our dataset so that our results may not be considered spurious. For that purpose, we have used three panel unit root tests to verify that none of the variables in the model is I(2). These tests include Levin, Lin, and Chu (LLC), ADF–Fisher, and Im, Pesaran, and Shin (IPS). Table 2 presents the results of these unit root tests which confirm our chosen variables are either I(0) or I(1). Table 3 depicts the results of the linear and non-linear analysis as well as the basic and robust models. In the basic model, we have included tourist arrival as a proxy of tourism, while, in the robust model, we have used tourist receipts to represent the tourism. Moreover, the results of the cointegrations test and other diagnostics are also illustrated in the same table. The first and foremost thing we need to check

| Variables | Variable Definitions | Mean | Std. Dev. | Min | Max |
|-----------|----------------------|------|-----------|-----|-----|
| CO\(_2\) emissions | CO\(_2\) emissions (kt) | 14.19 | 0.92 | 12.24 | 16.15 |
| Tourist arrivals | International tourism, number of arrivals | 16.62 | 1.18 | 14.57 | 18.91 |
| Tourism receipts | International tourism, receipts (current US$) | 23.14 | 1.23 | 19.52 | 25.82 |
| GDP per capita | GDP per capita (current US$) | 8.69 | 1.47 | 5.92 | 10.79 |
| Population | Population, total | 19.27 | 1.50 | 16.74 | 21.06 |
| Energy intensity | Energy intensity level of primary energy (MJ$/2011 PPP GDP) | 7.07 | 2.66 | 3.74 | 14.39 |

**Table 2** Panel unit root testing

| Variables | Variable Definitions | LLC I(0) | I(1) | Decision | IPS I(0) | I(1) | Decision | ADF I(0) | I(1) | Decision |
|-----------|----------------------|----------|------|----------|----------|------|----------|----------|------|----------|
| CO\(_2\) | CO2 emissions (kt) | -0.526 | -2.862** | Decision | I(1) | -1.051 | -3.279*** | Decision | I(1) | -1.368 | -8.197*** | I(1) |
| TA | International tourism, number of arrivals | -0.863 | -3.701*** | Decision | I(1) | -1.448 | -3.304*** | Decision | I(1) | -1.128 | -8.236*** | I(1) |
| TR | International tourism, receipts (current US$) | -2.535* | -3.701*** | Decision | I(0) | -0.900 | -4.052*** | Decision | I(1) | -1.023 | -5.519*** | I(1) |
| GDP | GDP per capita (current US$) | -1.312 | -6.942*** | Decision | I(1) | -0.937 | -3.995*** | Decision | I(1) | 1.526 | -5.425*** | I(1) |
| POP | Population, total | -4.596*** | -3.810*** | Decision | I(0) | -3.810*** | -3.331*** | Decision | I(1) | -0.236 | -9.158*** | I(1) |

***p < 0.01; **p < 0.05; and *p < 0.1
is the estimate of ECM$_{t-1}$, if the estimated coefficient is negative and significant our long-run results are reliable. From Table 3, we gather that the estimates attached to ECM$_{t-1}$ are negative and significant in all the models confirming that all the long-run results are valid.

In the basic model, the CO$_2$ emissions in the Asian economies are positively and significantly affected by the tourists’ arrival in the long run. Hence, tourism hurts the environmental quality of Asian countries. With every single tourist coming in, the CO$_2$ emissions will rise by 0.051 kt. Tourism generates economic and social activities in the countries which leads to higher demand for energy. The demand for transportation, hoteling, accommodation, communications, and other related services will expand due to the rise in tourist arrivals as a result the energy demand will also rise which deteriorates the environmental quality due to the rise in CO$_2$ emissions (Katircioglu et al. 2014; Sharif et al. 2017). Moreover, at some tourist points, sports and cultural festivals are arranged for foreign tourists which enhances economic development and ultimately the energy

| Table 3 Panel ARDL and NARDL estimates |
|----------------------------------------|
|                                       |
| Basic analysis                        |
| ARDL | NARDL | ARDL | NARDL |
| Long run                              |
| TA   | 0.051*** 3.158 | 0.217*** 9.448 | −0.435*** 3.594 |
| TR   | 0.064* 1.752 | 0.075** 2.131 | −0.898*** 3.794 |
| Short run                             |
| D(TA) | −0.128 0.511 | −0.175 1.157 |    |
| D(TA_POS) | −0.300* 1.901 | −0.244 0.971 |    |
| D(TA_POS(−1)) | −0.546 1.161 |    |    |
| D(TA_NEG) | 0.529 0.953 |    |    |
| D(TR) | 0.009 0.076 | −0.038 0.451 |    |
| D(TR_POS) | −0.173** 2.226 | −0.218 1.191 |    |
| D(TR_POS(−1)) | −0.593 0.986 |    |    |
| D(GDP) | 0.039 0.529 | −0.301 0.873 | −0.247* 1.953 | −0.276* 1.875 |
| D(GDP(−1)) | −1.29 0.086 | 0.402 −0.166 | 1.515 −0.086 | 0.758 |
| D(POP) | −13.36 1.224 | −6.846* 1.901 | −5.427 1.384 | −6.918 1.405 |
| D(POP(−1)) | 5.389 1.345 | 5.128 1.096 | 6.843 0.733 | 7.601 0.384 |
| D(EI) | 0.021 0.387 | −0.061 0.518 | −0.028 0.363 | −0.024 0.240 |
| D(EI(−1)) | 0.077 0.874 | 0.063 0.425 | −0.024 0.636 | −0.021 0.322 |
| C | −2.836 3.354 | 1.925 0.681 | 2.291 2.038 | 5.094 2.442 |

Diagnostics

| ECM(−1) | −0.673*** 3.164 | −0.166 0.698 | −0.550** 2.506 | −0.683*** 2.717 |
| Log likelihood | 236.4 340.7 | 216 230.7 | 230.7 4.862*** 3.986*** |
| Wald-LR | 4.862*** 3.986*** |
| Wald-SR | 1.354 2.013 |

***p < 0.01; **p < 0.05; and *p < 0.1
consumption at that place. Tourism activities also create an income effect which increases the demand for domestic consumers, hence contributing to environmental degradation due to the rise in energy consumption (Nepal et al. 2019). Our finding complements the findings of Rico et al. (2019), Zhang and Liu (2019), and Qureshi et al. (2017).

This finding is backed by Fethi and Senyucel (2021), who reported similar findings for countries having top tourist destinations. This finding suggests that tourist destination economies use traditional methods of oil and fuel consumption in order to control CO₂ emissions and regain environmental sustainability. This finding is also in line with Li and Lv (2021), who denoted that a positive upsurge in tourism development intensifies CO₂ emissions. Their study also reported that the increasing effect of tourism development on carbon emissions mostly emerges from the spillover effect. Tourism development also stimulates the energy consumption attached to fossil fuel combustion and boosts infrastructure services, hence contributing to the intensification of CO₂ emissions. This finding is also supported by Razzaq et al. (2021), who disclose that tourism development intensifies CO₂ emissions irregularly across different stages of economic development. This finding is inconsistent with El Menyari (2021), who found that the tourism industry encourages the consumption of renewable energy sources revealing that the tourism industry tends to improve the environment.

The non-linear analysis in the basic model states that a positive shock in tourist arrivals augments the CO₂ emissions, whereas the negative shock in tourist arrivals also increases the CO₂ emissions. This is a sign of an asymmetry in the positive and negative effects of tourism on carbon emissions which is also confirmed from the significant estimate of the Wald-LR, illustrated in Table 3. Numerically, the CO₂ emissions rise by 0.217 kt with every tourist coming to the Asian countries. The implied reason for the impact of the positive shock on the CO₂ emissions is the same as already described in the context of the linear estimate of tourist arrivals. However, with every tourist, who is not visiting Asia, the carbon emissions rise by 0.435 kt. The implied reason could be the decline in the technology effect because of the decreased inflow of tourists in Asia. Due to negative shocks in the tourism industry, over time, the quality of transportation, energy, and communication infrastructure deteriorated which leads to an increase in the consumption of energy. Moreover, tourism encourages innovations because local firms in a destination country want to sell international quality and energy-efficient products to the tourists. Furthermore, the production methods of the firms become more energy-efficient and environmentally friendly because they do not want to spread the pollution which could lead to a fall in tourism in the country resulting in the fall of the nation’s wealth, in general, and tourism-related services in particular. Thus, tourism cannot only create an income effect in the economy but can also lead to a better environment if used prudently (Gössling and Hall 2006; Paramati et al. 2018).

This finding is supported by Chishti et al. (2020), who noted that tourism has asymmetric effects on pollution emissions in South Asia. A positive shock in tourism development is justified as tourism is the sub-category of the services sector and is a relatively cleaner source of income generation as compared with the industrial and agriculture sectors. A negative shock in tourism development infers a significant drop in tourist arrivals due to terrorist incidents and its negative impact on the local economy has significantly increased CO₂ emissions. The results imply that an increase in visitor arrivals will have a relatively small positive effect on the CO₂ emissions than the decline in visitor arrivals. Acheampong (2021) reported similar findings for Australia. The study argues that as the economy transforms from the services sector to the industrial set-up, CO₂ emissions start increasing.

In the linear base model, the long-run estimates attached to GDP and POP are significant and positive, while the estimate attached to EI is negative and significant. These findings imply that as the GDP per capita rises by one US dollar and population rises by one person the CO₂ emissions also raise by 0.049 and 1.449 kt respectively. However, a point rise in the ratio of energy intensity indicates the CO₂ emissions decrease by 0.008 kt. On the other side, in the non-linear base model, the estimates of GDP and POP are insignificant and the estimates of EI are positive and significant. The interpretation for these estimates is the same as already described in the linear model. The short-run estimates of linear and non-linear models, in the base model, appeared to be insignificant for most of the variables.

To further validate our findings, we have performed the analysis again by replacing the variable of tourist arrivals (TA) with the variable of tourism receipts (TR) and called it a robust model. The estimated coefficient of TR in the linear model is significant and positive and the size of the estimate is almost similar to the base model. As far as the asymmetric estimates of TR are concerned, the estimate attached to TR-POS is positive and significant and the estimate attached TR-NEG is negative and significant, implying that a positive, as well as negative shock in TR, increases the CO₂ emissions. Just like the base model, the asymmetric effects can be seen in the robust model and further validated from the significant estimate of Wald-LR in this model as well. However, if we compare the size of the estimate attached to TR-POS in the base and the robust models, it appears to be bigger in the former, whereas the estimate attached to TR-NEG is bigger in the robust model as compared to the base model. Similarly, the estimates of GDP and EI in the robust model appear to be significant and positive in both linear and
non-linear analyses, while the estimated coefficients of POP is insignificant in both the linear and non-linear analysis. Short-run estimates, just like the base model, come out as insignificant for most of the variables in the robust model. Hence, we can say that our findings do not alter much whichever proxy of tourism we use; particularly, the findings of the main variable almost remain the same. 

Last but not the least, we also provided the results of asymmetric causality in Table 4. However, from the results, we have found evidence of one-way causality only between the two variables, i.e., from TA-POS → CO2 and TA-POS → CO2 in the base and the robust models.

### Conclusion and implication

The relationship between tourism and carbon emissions is studied for selected Asian economies, from 1995 to 2019 by employing symmetric and asymmetric panel ARDL models. The long-run finding of the ARDL model indicates that tourist arrival has a positive impact on carbon emissions. The long-run findings of the NARDL model indicate that positive shocks in tourist arrival have a positive and significant impact on carbon emissions; however, the negative shocks in tourist arrival have a positive and significant impact on carbon emissions. The coefficient estimates of negative and positive shocks in tourist arrival indicate that a 1% upsurge in positive components of tourist arrival leads to increase carbon emissions by 0.217%; however, a 1% upsurge in negative components of tourist arrival leads to increase carbon emissions by 0.435% in the long run.

To check the robustness of the findings, the study has also used another variable, i.e., tourism receipts for investigating the linear and non-linear effect of tourism on carbon emissions. The long-run outcome of ARDL model indicates that tourism receipts exert a positive impact on carbon emissions. The long-run outcomes of the NARDL model indicate that tourism receipts exert a positive impact on carbon emissions.
demonstrate that positive shocks in tourism receipts exert a positive impact on carbon emissions; however, the negative shocks in tourism receipts exert a positive impact on carbon emissions. The coefficient estimates of positive and negative shocks in tourism receipts indicate that a 1% upsurge in positive components of tourism receipts results in rising carbon emissions by 0.075%; however, a 1% upsurge in negative components of tourism receipts results in increasing carbon emissions by 0.898% in the long run.

On the basis of our findings, we suggest that policymakers should consider both positive and negative shocks in the tourism industry because the effects of positive and negative shocks in the tourism industry are clearly asymmetric in nature. The selected Asian economies should draw attention to the development of the tourism industry. Furthermore, promoting sustainable tourism should be the goal of the policymakers that would not only raise the living standards of the local people but also helps to improve the environmental quality. Policymakers should improve the tourism industry to sustainable development by enforcing clean technology, clean energy, green transportation, resource-saving consumed mode, and smart green building. Furthermore, the introduction of green practices such as green transportation, energy, and management in the tourism sector can help consolidate the beneficial impact of the tourism industry on environmental quality in Asian economies. Policymakers and authorities should redesign Asian ecotourism policies. Thus, Asian economies could improve the tourism industry by lowering CO₂ emissions.

Our study can place a foundation for analysis on the nonlinear relationship between international tourism and CO₂ emissions. Our study covers several empirical research directions. The authors should extend the analysis to a regional level for Asian ecotourism policies. Future research may also include "ecotourism investments" in the analysis of tourism-related carbon dioxide emissions. A similar analysis conducts by researchers for other high-polluted economies. In the future, the authors should study the same model on each country separately or a different panel of economies.

Acknowledgements Hainan Medical University, Research on Health Tourism course construction under the background of construction of Hainan free trade port HYJW202102.

Author contribution This idea was given by Kaixin Wangzhou. Kaixin Wangzhou, Julie Jie Wen, Zheng Wang, Huamin Wang analyzed the data and wrote the complete paper, while Zubaria Andlib and Chunbo Hao read and approved the final version.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Not applicable.

Consent to participate I am free to contact any of the people involved in the research to seek further clarification and information.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

References

Acheampong AO (2021) Modeling tourism–environment relationship in Australia: does asymmetry matter? Singapore Econ Rev:1-31
Aslam B, Hu J, Majeed MT, Andlib Z, Ullah S (2021) Asymmetric macroeconomic determinants of CO2 emission in China and policy approaches. Environ Sci Pollut Res:1–14
Aslan A, Altinoz B, Oztosolak B (2021) The nexus between economic growth, tourism development, energy consumption, and CO2 emissions in Mediterranean countries. Environ Sci Pollut Res 28(3):3243–3252
Awan A, Bilgili F (2022) Energy poverty trends and determinants in Pakistan: Empirical evidence from three waves of HIES 1998–2019. Renew Sust Energ Rev 158
Awan A, Kocoglu M, Banday TP, Tarazkar MH (2022) Revisiting global energy efficiency and CO2 emission nexus: fresh evidence from the panel quantile regression model. Environ Sci Pollut Res:1–14
Azam M, Alam MM, Hafeez MH (2018) Effect of tourism on environmental pollution: further evidence from Malaysia, Singapore and Thailand. J Clean Prod 190:330–338
Bahmani-Oskooee M, Usman A, Ullah S (2020) Asymmetric impact of exchange rate volatility on commodity trade between Pakistan and China. Glob Bus Rev: 09721509209216287
Chan APC, Darko A, Olanipekun AO, Ameyaw EE (2018) Critical barriers to green building technologies adoption in developing countries: the case of Ghana. J Clean Prod 172:1067–1079
Chishti MZ, Ullah S, Ozturk I, Usman A (2020) Examining the asymmetric effects of globalization and tourism on pollution emissions in South Asia. Environ Sci Pollut Res 27(22):27721–27737
Chou MC (2013) Does tourism development promote economic growth in transition countries? A panel data analysis. Econ Model 33:226–232
Dogan E, Aslan A (2017) Exploring the relationship among CO2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: evidence from panel models robust to heterogeneity and cross-sectional dependence. Renew Sust Energ Rev 77:239–245
Dogru T, Bulut U (2018) Is tourism an engine for economic recovery? Theory and empirical evidence. Tour Manag 67:425–434
El Menyari Y (2021) The effects of international tourism, electricity consumption, and economic growth on CO2 emissions in North Africa. Environ Sci Pollut Res 28(32):44028–44038
Engle RF, Granger CW (1987) Co-integration and error correction: representation, estimation, and testing. Econometrica: J Econ Soc 55:251–276
Eyuboglu S, Eyuboglu K (2020) Tourism development and economic growth: an asymmetric panel causality test. Curr Issue Tour 23(6):659–665
Fethi S, Senyucel E (2021) The role of tourism development on CO2 emission reduction in an extended version of the environmental Kuznets curve: evidence from top 50 tourist destination countries. Environ Dev Sustain 23(2):1499–1524
Gokmenoglu KK, Eren BM (2020) The role of international tourism on energy consumption: empirical evidence from Turkey. Curr Issue Tour 23(9):1059–1065
Gössling S, Hall CM (2006) An introduction to tourism and global environmental change. Tourism Glob Environ Change:1-34
Hussain J, Khan A, Zhou K (2020) The impact of natural resource depletion on energy use and CO2 emission in Belt & Road Initiative countries: a cross-country analysis. Energy 199
Imran S, Alam K, Beaumont N (2014) Environmental orientations and environmental behaviour: perceptions of protected area tourism stakeholders. Tour Manag 40:290–299
Johansen S (1988) Statistical analysis of cointegration vectors. J Econ Dyn Control 12(2–3):231–254
Johansen S, Juselius K (1990) Maximum likelihood estimation and inference on cointegration—with appications to the demand for money. Oxf Bull Econ Stat 52(2):169–210
Katrıcıoglu ST, Feridun M, Kilinc C (2014) Estimating tourism-induced energy consumption and CO2 emissions: the case of Cyprus. Renew Sust Energ Rev 29:634–640
Khattak SI, Ahmad M, Khan ZU, Khan A (2020) Exploring the impact of innovation, renewable energy consumption, and income on CO2 emissions: new evidence from the BRICS economies. Environ Sci Pollut Res 1:16
Koçak E, Ulucak R, Ulucak ZŞ (2020) The impact of tourism developments on CO2 emissions: an advanced panel data estimation. Tour Manag Perspect 33
Kocoglu M, Awan A, Tunc A, Aslan A (2022) The nonlinear links between urbanization and CO2 in 15 emerging countries: evidence from unconditional quantile and threshold regression. Environ Sci Pollut Res 29(12):18177–18188
Kumar RR, Stauvermann PJ (2016) The linear and non-linear relationship between of tourism demand and output per worker: a study of Sri Lanka. Tour Manag Perspect 19:109–120
Latif MT, Othman M, Idris N, Juneng L, Abdullah AM, Hamzah WP et al (2018) Impact of regional haze towards air quality in Malaysia: a review. Atmos Environ 177:28–44
Li S, Lv Z (2021) Do spatial spillovers matter? Estimating the impact of tourism development on CO2 emissions. Environ Sci Pollut Res 28(25):32777–32794
Li X, Ozturk I, Ullah S, Andlib Z, Hafeez M (2022) Can top-pollutant economies shift some burden through insurance sector development for sustainable development? Econ Anal Policy 74:326–336
Naradda Gamage SK, Hewa Kuruppuge R, Haq IU (2017) Energy consumption, tourism development, and environmental degradation in Sri Lanka. Energy Sourc Part B: Econ Plann Policy 12(10):910–916
Nepal R, Al Irsyad MI, Nepal SK (2019) Tourist arrivals, energy consumption and pollutant emissions in a developing economy-imPLICATIONS for sustainable tourism. Tour Manag 72:145–154
Ngoc BH, Awan A (2022) Does financial development reinforce ecological footprint in Singapore? Evidence from ARDL and Bayesian analysis. Environ Sci Pollut Res 29(16):24219–24233
Paramati SR, Alam MS, Lau CKM (2018) The effect of tourism investment on tourism development and CO2 emissions: empirical evidence from the EU nations. J Sustain Tour 26(9):1587–1607
Qureshi MI, Hassan MA, Hishan SS, Rasli AM, Zaman K (2017) Dynamic linkages between sustainable tourism, energy, health and wealth: evidence from top 80 international tourist destination cities in 37 countries. J Clean Prod 158:143–155
Razzaq A, Fatima T, Murshed M (2021) Asymmetric effects of tourism development and green innovation on economic growth and carbon emissions in Top 10 GDP Countries. J Environ Plan Manag:1-30
Rico A, Martínez-Blanco J, Montlleó M, Rodríguez G, Tavares N, Arias A, Oliver-Solá J (2019) Carbon footprint of tourism in Barcelona. Tour Manag 70:491–504
Saint Akadiri S, Alola AA, Akadiri AC (2019) The role of globalization, real income, tourism in environmental sustainability target. Evidence from Turkey. Sci Total Environ 687:423–432
Shin Y, Yu B, Greenwood-Nimmo M (2014) Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In Festschrift in honor of Peter Schmidt (pp. 281-314). Springer, New York, NY
Usman A, Ozturk I, Naqvi SMMA, Ullah S, Javed MI (2022) Revealing the nexus between nuclear energy and ecological footprint in STIRPAT model of advanced economies: fresh evidence from novel CS-ARDL model. Prog Nucl Energy 148
Usman A, Ozturk I, Ullah S, Hassan A (2021) Does ICT have symmetric or asymmetric effects on CO2 emissions? Evidence from selected Asian economies. Technol Soc 67
Wei L, Ullah S (2022) International tourism, digital infrastructure, and CO2 emissions: fresh evidence from panel quantile regression approach. Environ Sci Pollut Res:1-8
Wei X, Ren H, Ullah S, Bozkurt C (2022) Does environmental entrepreneurship play a role in sustainable green development? Evidence from emerging Asian economies. Econ Res-Ekonomiska Istraživanja:1-13
Yin Y, Xiong X, Ullah S, Sohail S (2021) Examining the asymmetric socioeconomic determinants of CO2 emissions in China: challenges and policy implications. Environ Sci Pollut Res 28(40):57115–57125
Zhang D, Ozturk I, Ullah S (2022) Institutional factors-environmental quality nexus in BRICS: a strategic pillar of governmental performance. Econ Res-Ekonomiska Istraživanja:1–13
Zhang S, Liu X (2019) The roles of international tourism and renewable energy in environment: new evidence from Asian countries. Renew Energy 139:385–394

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.