Environment, Development and Sustainability (2024) 26:9481–9499
https://doi.org/10.1007/s10668-023-03104-4

Does tourism have an impact on carbon emissions in Asia? An application of fresh panel methodology

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Received: 22 April 2022 / Accepted: 2 March 2023 / Published online: 16 March 2023

Abstract

This research investigates the effects of tourism, GDP per capita, renewable energy, energy intensity, urbanization, and population on the environment in 40 Asian countries. Data from 1995 to 2019 are used in this analysis. Slope heterogeneity (SH), cross-sectional dependency (CSD), and the combination of level and first differenced stationary are all addressed using a new cross-sectionally autoregressive distributed lag (CS-ARDL) model in this work. Using Westerlund's cointegration method, these variables can be connected throughout time. To validate the findings, both augmented mean groups (AMG) and Common correlated effect mean groups (CCEMG) were utilized. The study results indicate that tourism helps slow the degradation of the natural environment. CO_2 emissions increase as a result of variables such as population growth, energy use, and economic development. Only tourism and renewable energy can help cut CO_2 emissions. As a consequence, CS-ARDL results are supported by results from AMG and CCEMG tests. Policymakers may be encouraged countries to adopt renewable energy and foster the expansion of the sustainable tourism industry.

Keywords CO_2 emissions · Economic development · Environment · GDP · Renewable energy · Tourism

1 Introduction

In the whole world context, tourism plays a significant role in both the commercial and social spheres. Nearly 10.3% of the world's gross domestic product (GDP) and 330 million jobs were directly or indirectly supported by the travel and tourism industry in 2019.

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(WTTC, 2020). The number of international tourists in Asia has mounted by 65% from 2010 to 2018 (ADB, 2019). Asia-Pacific is the fastest-growing region with a 5.5% growth in tourism in 2019 (WTTC, 2020). Besides the tourism industry, the real value of international trade is also growing noteworthy (Ahmedov, 2020; Dogan et al., 2017; Jeyacheya & Hampton, 2020; Voumik et al. 2022a). The total value of merchandise trade was 45.8% of the world GDP in 2018, which was 38.8% in 2000 (World Bank, 2022). Urbanization is also growing with the growth of the world population (UNWTO, 2018; Wu et al., 2020). However, urbanization has stimulated the growth of tourism over the investment and consumption effect (Wu et al., 2020). Simultaneously, carbon dioxide (CO_2) emissions increased as the population and economic activities grew (Katircioglu, 2014; Mehmood et al., 2021). Asia-Pacific region produced around 16,753 million metric tons of CO_2 in 2020, which was more than the collective emissions of the rest of the world regions (Tiseo, 2021). Almost 60% of the CO_2 emissions in the Asia–Pacific and globally 31% were produced by China alone.

Many studies have been conducted in the past two decades that have demonstrated that economic development is aided by elements such as tourism, trade openness, urbanization, population, and electricity consumption in countries regardless of their income level (low, middle, and high) and in developed and developing countries (Aslan, 2015; Majumder et al., 2023; Saleh & Yusuf, 2022; Santana-Gallego et al., 2011; Xu et al., 2022; Voumik & Sultana, 2022; Voumik & Ridwan, 2023). Globalization and tourism significantly influence global economic activities. The tourism and travel sector is acknowledged as a driver of economic development (Adedoyin & Bekun, 2020), which is connected to rising greenhouse gas emissions, especially CO_2, and is considered a significant contributor to climate change (Gossling et al., 2013; Selvanathan et al., 2021). However, tourism has been linked to rapid economic expansion, which has prompted extensive urbanization, trade, and energy use (Adedoyin & Bekun, 2020) and contributed to CO_2 emissions. To overcome the critical situation, effective planning in the tourism sector may contribute significantly to GDP (Nosheen et al., 2021).

The prospect of an environmental disaster exists in the course of the activity that will lead to the growth of the economy, and achieving zero pollution is not feasible (Mardones, 2019; Patel & Sukla, 2015). The arrival of travelers in a region tends to enhance GDP development but is also projected to degrade environmental quality (Tsui et al., 2018). While tourism seems to influence the economy, legislators and scholars have pointed out that GDP per capita is a poor substitution for sustainable development and social welfare since it is also linked to carbon emissions (Fleurbaey, 2009). As a result of tourism, CO_2 emissions from transportation rise while more visitors are arriving (Le & Nguyen, 2021). GDP per capita and tourism can contribute to environmental degradation (Kaiser & Vendrik, 2019; Shi et al., 2020; Voumik et al., 2022b).

While emissions related to tourism are presently contributing to changes in the environment and climate, tourism growth will continue to upsurge carbon emissions and provide considerable problems for ecological and tourism sustainability (Selvanathan et al., 2021). After that, a mutual understanding of tourism, trade, urbanization, GDP, CO_2, and population has played a substantial role in retaining and developing sustainable tourism in Asian Countries. Asia is one of the most important global parts because it encompasses 29.4% of the Earth's land area and has approximately 4.69 billion people in 2021, which means nearly 60% population of the world live in this region. In terms of economic contribution, this area contributes 39% of the global GDP. The significance of tourism and environmental degradation issues is growing simultaneously in Asian countries. However, Gossling et al. (2013) and Selvanathan et al. (2021) have mentioned the lack of studies on the nexus between tourism, trade, urbanization, GDP, CO_2, and population.

According to the BP Statistical Review (2021), global CO_2 emissions raised by 1.4% per year from 2009 to 2019. In 2018, the world saw a relatively more significant increase in global CO_2 emissions of 2%. As a result, policymakers continue to prioritize reducing CO_2 emissions, and they strive to do so by combining key factors such as tourism development, renewable energy, energy consumption, urbanization, GDP, and population. Research on CO_2 emissions is still significant in promoting sustainable economic development. Generally, each nation may make an effort to lower CO_2 emissions to enhance environmental quality, regardless of its degree of development. However, the economic pattern and geographic location of each region are different which needs a separate policy to deal with CO_2 emissions. Abbas et al., (2020) studied the link between tourism, economic growth, and CO_2 emissions for countries in Europe between 1988 and 2009. According to scientific evidence, tourism in the study region contributes to increased CO_2 emissions and economic development. Mohsin et al., (2021) studied Malaysia and found the long-term ratio of CO_2 emissions; additionally, the information showed a one-way causal connection between tourism and CO_2 emission. In the same way, Abbas et al., (2020) have demonstrated a unilateral association between tourism, GDP, and CO_2. This study employed GMM for data analysis from 1995 and 2013 in Asia–Pacific nations. In this regard, this present study explores the impact of tourism, renewable energy, urbanization, GDP, energy use, and population on carbon emissions in Asian countries. Asia is one of the most important world regions regarding social, economic, and environmental aspects. This region is the home of some super economic power countries like China, Japan, India, South Korea, and Indonesia. The Asia–Pacific region has become a popular tourism destination for travelers. In the Asia–Pacific region, both domestic and international tourist numbers and spending have grown significantly over the last decade. Thus, the link between tourism growth and carbon emissions is vital for this region (Tiseo, 2022). For that reason, 40 Asian countries were selected to conduct the study. As a result, the research makes an effort to make the following contribution to the current literature.

To our understanding, this is the first study to examine the relationship between tourism, renewable energy, energy consumption, GDP per capita, and population growth in Asia as a whole and its effect on CO2 emissions. The CSD is also examined in this research. The study used a unit root test and cointegration test of the second generation. Before developing any kind of policy, it is necessary to have a solid understanding of which aspect of the economy is primarily responsible for producing CO2 emissions. To begin, this study utilizes panel data from 40 Asian countries between 1995 and 2019 to draw conclusions. Secondly, Because of possible endogeneity, SH, CSD, and mixed-order unit root, this study uses a fresh CS-ARDL technique to make sure it does not influence. Finally, the use of AMG and CCEMG to make the model more stable and wide-ranging. This paper is structured as follows: Sect. 2 presents the relevant literature and emphasizes the relationship between tourism and CO_2 emissions and the other variables. Section 3 covers the data, methodology, and model of the paper. Section 4 interprets the results and findings of the study. Section 5 presents the concluding remarks, policy recommendations, and future direction for research.

2 Literature review

Tourism's link to GDP, urbanization, environmental deterioration, and power consumption has been well-researched (Adedoyin & Bekun, 2020; Shakouri et al., 2017; Shi et al., 2020). Using the panel cointegration and aggregated mean group methods developed by Sherafatian-Jahromi et al., (2017), we determined that CO_2 emissions in the five most visited cities in Southeast Asia were either linear or nonlinear. This result has important implications because it shows that tourism has a long-term effect on CO_2 emissions because the two are cointegrated. Economic development and tourism expansion were found to have a significant impact on CO_2 emissions, which Shakouri et al., (2017) analyzed using panel data from a number of Asia–Pacific countries from 1995 to 2013. The EKC theory was assessed by testing the long-term connections between GDP growth, tourism, energy intensity, and CO_2 emissions. The cumulative effect of tourist visits on CO_2 emissions is substantial and positive over the long run. Tourism, CO_2 emissions, energy use, and economic growth were all examined by Ravinthirakumaran and Ravinthirakumaran (2022) in the APEC area from 1995 to 2017. This was accomplished by combining strategies for estimating heterogeneous panel data with CSD. According to the data, the variables are stable at their initial differences, indicating CSD. Tourism and economic development have one-way causation to CO_2 emissions, according to the panel non-causality test.

From 1982 to 2018, a study examined how energy use, immigrant labor, and tourist arrivals impacted CO2 emissions in Malaysia which was studied by Rahman et al. (2022). The researchers used an ARDL technique, and the data revealed that natural gas and electricity use had a negligible impact on CO_2 emissions. The research found that increases in both tourism and energy use contributed positively to CO2 emissions, while increases in the number of foreign workers and overall population contributed only slightly. Adeleye et al., (2022) investigated the moderating role of per capita income on the relationship between CO2 emissions and tourism development in South Asia. The research employs a battery of analytical approaches to examine the discourse based on imbalanced panel data from South Asian nations from 1995 to 2019. The findings reveal, among other things, that (1) when it comes to the state of the economy, the amount of CO_2 emissions is a crucial factor, (2) there are considerable regional differences in the effects of pollution on tourism in South Asia, (3) tourism is strongly correlated with an increase in the economy, (4) South Asia's tourism expansion has a wide range of effects, and (5) with an increase in population, we can lessen the devastation caused by carbon emissions. In each nation, the results are different. In particular, CO_2 emissions negatively affect the tourism industry in Bangladesh, India, and Sri Lanka, while Nepal and Pakistan have shown a positive association. Economic growth encourages tourism and helps mitigate the disastrous effects of greenhouse gas emissions in Bangladesh, Bhutan, and Sri Lanka, while it discourages tourism and increases the shocking effects of greenhouse gas emissions in Nepal and Pakistan.

The association between tourism and CO_2 emissions has been discovered in literary works. Le and Nguyen (2021) used a large panel of 95 nations comprised of three subsamples of countries categorized by income level for the period 1998 to 2014, and conducted their research using a big panel of 95 countries and found that transport emissions are increased by tourism, but the number of tourists raises CO_2 emissions per capita. Over the past two decades, Wang and Wu (2021) investigated the environmental impact of tourism expansion in the top five most popular tourist arrival countries. Also, they examined the long-term link between tourism and environmental sustainability. The cointegration test revealed this to be the case. According to FMOLS and DOLS models developed by

Wei and Ullah (2022), tourism and digitalization increase environmental quality. It was found that under FMOLS and DOLS models, the quality of the environment is enriched by tourism and digitization. As the three previous strands of literature were brought together, a fourth strand arose that focused on the economic growth, tourism, commerce, urbanization, population, and pollutant emissions nexus. However, nothing is identified about multivariate disparities generated by various income levels. Using panel models, they experimentally investigated tourism growth, economic development, CO_2 emissions, and the use of primary energy at different periods of development are all intertwined in a complex web. CO_2 emissions and additional variables are intertwined across all countries.

Every 1% increase in inbound tourist expenditure leads to an increase of 0.084% of CO_2 in low-income countries, whereas middle-income and high-income countries climb by 0.072% and 0.069%. The impact of tourism on CO_2 emissions is more significant when the income is lower, and the stronger Granger causality occurs when the income is higher (Shi et al., 2020). Economic development, international commerce, tourist spending, and CO_2 emissions in Greece from 1970 to 2014 were examined by Işik et al., (2017). With the use of unit root tests and ARDL models, this was accomplished. Greek economic development, tourist spending, international commerce, and CO_2 emissions are all linked in the long run according to data from the VECM model. Economic expansion, economic development, international commerce, and tourist spending all increased Greece's CO_2 emissions. The magnitude of the tourism-environment degradation correlation is 0.132, indicating that tourism is critical to worsening the environment in Asian countries. Environmental deterioration is directly and profoundly affected by energy usage, urbanization, commerce, and financial growth. Using empirical evidence, researchers may conclude that environmental deterioration in the Asian area has been exacerbated by tourism, unrestricted trade, and urbanization (Nosheen et al., 2021). The study results reveal that economic development, energy use, and tourism all have negative environmental consequences (Cetin et al., 2018; Gulistan et al., 2020). From 1980 to 2017, Pakistan's CO_2 emissions resulted from foreign visitors, structural change, energy consumption, international commerce, and economic growth. The ARDL model was used in the research, showing that, apart from structural changes and trade, CO_2 emissions, and their drivers had a substantial positive long-run connection.

Looking at our area of interest, the association between tourism and carbon emission, as well as population, energy use, renewable energy, and economic growth, has been disregarded in most recent empirical research conducted in Asian nations. A cursory assessment of the available research also shows that the influence of tourism on environmental degradation in Asia has been investigated in connection to GDP, trade, and energy consumption (Nosheen et al., 2021). By addressing a vacuum in the empirical literature that had previously existed, this work contributes to current research in a significant way. In summary, many scholars have examined the impact of influencing factors such as population, energy use, GDP growth, and renewable energy on CO_2 emissions. However, very few research works have concentrated on the association between tourism and CO_2 emission in the Asian region. However, the existing tourism and pollution in the Asian region did not properly apply the CSD test, second-generation unit root, cointegration test, and novel CS-ARDL. This paper also applied the STIRPAT method in the Asian region. Hence, this present research effort is to test the effect of tourism, income, and energy consumption on CO_2 emissions to fill this gap.

Table 1 Variables list

Variables name	Log format	Indicator name
CO_2	LCO_2	Total CO_2 emissions
POP	LPOP	Population, total
GDPpc	LGDPpc	GDP per capita (constant 2015 US$)
TA	LTA	International tourism, number of arrivals
REN	LREN	Consumption of renewable energy
ENER	LENER	Energy intensity level
URBA	LURBA	Urban land area (sq. km)

Table 2 Summary statistics

Log of variables	*N*	Mean	SD	Min	Max
LCO_2	846	8.862	3.410	2.303	16.19
LPOP	1.025	15.12	3.168	9.141	21.07
LGDP	946	8.376	1.370	5.519	11.53
LTA	843	13.55	2.649	6.908	18.91
LREN	862	2.450	1.932	−4.605	4.538
LENER	758	1.467	0.595	−1.050	2.913
LURBA	1.025	3.757	0.599	2.471	4.605

3 Data and methodology

3.1 Data

This study selected 40 Asian countries and collected data from 1995 to 2019 for all the variables. The effects of tourism, population, economic expansion, renewable energy, and energy use on environmental degradation will be explored. Data were collected from the World Development Indicator, World Bank. Because of COVID-19, the researchers excluded data from 2020 and 2021. The STIRPAT model was used in this study. As it is commonly understood, this is a stochastic regression of environmental impacts (STIR) used to estimate the effects of the population (P), affluence (A), and technology (T). This model served as the basis for our variable selections, and we determined which variables are most important at the present moment to learn more about the environmental problems that are currently plaguing Asia.

Table 1 contains the definitions of the variables, as well as information on their anticipated signs and data sources. For the sake of our empirical research, the data have been changed to a logarithmic format since the log conversion ensures that the data are compatible with normality. Similarly, if the original data follow or approximate a log-normal distribution, the log-converted data will follow or approximate a normal or near-normal distribution. Specifically, the log transformation is used to eliminate or decrease skewness, and the results are provided as follows:

Table 2 contains an in-depth explanation of each variable, as well as statistics that summarize the data. It displays the total number of variables and observations as well as their means, standard deviations, minimum and maximum numbers. The mean of LPOP is considerably greater than the mean of the other variables that were considered.

3.2 STIRPAT model

A significant model that is frequently used for environment impact-related problem-solving is the Stochastic Impacts by Regression (STIRPAT) model. The researchers developed a model based on a well-known theory to accomplish the study's objective of examining the effects of tourism, renewable energy, income, population, urbanization, and energy intensity on the environment.

In the STIRPAT model, the technical term is very important. By making more effective use of energy appliances, these technologies have a positive effect on the environment and lower the overall level of pollution in the nations in which they are implemented. There are many ways in which a rise in GDP could be detrimental to the environment. Growth in GDP, for instance, encourages individuals to buy more consumables, such as homes, air conditioners, refrigerators, electronics, vehicles, and cosmetics, which in turn increase pollution. The increased demand for fossil fuels and overall increased consumption caused by a growing population is a major contributor to greenhouse gas emissions.

Conversely, renewable energy can lessen environmental damage because it is the most eco-friendly choice. This is because it does not contribute to pollution or the loss of natural resources. In contrast to fossil fuels, renewable energy sources have an infinite supply. However, unplanned urbanization exacerbates environmental degradation by increasing deforestation and forest land fragmentation. On the other hand, urbanization which is both planned and sustainable can slow the rate of environmental degradation.

This environment model of STIRPAT was used to predict the study's findings (Ehrlich & Holdren, 1971). Eqs (1, 2, 3 and 4) aid in the investigation of the various factors that contribute to the pollution of the environment. Several countries, including China, Pakistan, Bangladesh, South Korea, and India, have adopted the STIRPAT concept. Many areas, such as the BRICS, SAARC, G7, ASEAN, MINT, and OECD countries, have endorsed this approach as a viable option (Amin & Dogan, 2021; Hashmi & Alam, 2019; Paramati et al., 2017). An analysis of Asian countries' CO_2 emissions and technological progress was carried out using the STIRPAT model, which was used in this study. Environmental changes, including energy usage, population, renewable energy suing, urbanization, and economic progress, are widely studied by using this approach.

To control the population and economic level in Asia, it is assumed that LTA, LREN, LENER, and LURBA are related.

$$\mathrm{I} = \mathrm{BP}^{\mathrm{a}}\mathrm{A}^{\mathrm{b}}\mathrm{T}^{\mathrm{b}}\mathrm{u} \tag{1}$$

Or,

$$\mathrm{CO}_{2i,t} = f(\mathrm{Population},\ \mathrm{Affluence},\ \mathrm{Technological\ development}) \tag{2}$$

The research applied the extended STIRPAT model to achieve our goal. We propose the following model in light of the STIRPAT theoretical framework, which is based on population, wealth, and technology:

The extended form of the STIRPAT model is-

$$\mathrm{CO}_{2\mathrm{it}} = \beta_0 + \beta_1\mathrm{POP}_{\mathrm{it}} + \beta_2\mathrm{GDPpc}_{\mathrm{it}} + \beta_3\mathrm{TA}_{\mathrm{it}} + \beta_4\mathrm{REN}_{\mathrm{it}} + \beta_5\mathrm{ENER}_{\mathrm{it}} + \beta_6\mathrm{URBA}_{\mathrm{it}} + \varepsilon_{\mathrm{it}} \tag{3}$$

Here,

CO_2 = Total CO_2, TA = Total tourist arrivals, GDPpc = GDP per capita, TO = Trade openness, POP = Total population, ENER = Energy intensity, and URBA = Urban Area. Based on the extended STIRPAT model, the above important indicators are brought into the model. Now the logarithmic transformation of Eq. (3) is:

$$\mathrm{LCO}_{2\mathrm{it}} = \beta_0 + \beta_1\mathrm{LPOP}_{\mathrm{it}} + \beta_2\mathrm{LGDPpc}_{\mathrm{it}} + \beta_3\mathrm{LTA}_{\mathrm{it}} + \beta_4\mathrm{LREN}_{\mathrm{it}} + \beta_5\mathrm{LENER}_{\mathrm{it}} + \beta_6\mathrm{LURBA}_{\mathrm{it}} + \varepsilon_{\mathrm{it}} \tag{4}$$

The values of all variables are converted to natural logarithms, and the natural logarithm is denoted by the letter L. In Eq. (4), the exogenous variables that are taken into account each have a slope coefficient ranging from β_2 to β_6 and an intercept of β_0. Additionally, the letters "*i*" and "*t*" in the subscript stand for the countries and years of the model, respectively.

4 Results and discussion

4.1 Slope homogeneity (SH) test

In panel data econometrics, the issue of SH is critical. Pesaran and Yamagata's (2008) stated that SH test is used to verify that the slopes are homogeneous. The dispersion of the weighted slope of each individual is used in this assessment. The following equations provide the test statistics:

$$\breve{\Delta} = \sqrt{N}\left(\frac{N^{-1}S\% - k}{\sqrt{2k}}\right) \text{ and } \breve{\Delta}_{\mathrm{adj}} = \sqrt{N}\left(\frac{N^{-1}S\% - k}{\sqrt{\frac{2k(T-k-1)}{T+1}}}\right) \tag{5}$$

The findings of the slope homogeneity test conducted by Pesaran and Yamagata (2008) are shown in Table 3. It demonstrates that the model has an issue with heterogeneity. There is a wide variation in the slope of the model's coefficients between countries, which suggests that the model is not homogeneous. By imposing a homogeneity restriction on the variable of interest, it is possible that panel causality analysis can lead to incorrect results.

4.2 Cross-sectional dependence (CSD) test

In the research carried out by Pesaran (2015), a method known as a test for cross-sectional dependency in large panel data econometrics was utilized to investigate the possibility of cross-sectional dependence. It is required to first check for the presence of SH and CSD

Table 3 Slope heterogeneity (SH) test

SH Tests	Δ Statistic	*P*-value
$\breve{\Delta}$ test	8.447[a]	0.000
$\breve{\Delta}_{adj}$ test	7.127[a]	0.000

Here, H_0: the slope coefficients are homogeneous. **a** denotes less than 1% level before using appropriate panel data econometric unit root tests. The CSD test equation, in its most general form, is presented here.

$$\mathrm{CSD} = \sqrt{\frac{2T}{N(N-1)N}\left(\sum_{i=1}^{N-1}\sum_{K=i+1}^{N}\widehat{\mathrm{Corr}}_{i,t}\right)} \quad (6)$$

Here N is the number of countries and T is the number of years.

The results of the CSD test for weak CSD are presented in Table 4 and were conducted by Pesaran (2015). This demonstrates that there is a CSD present in the panel data. When working with panel data, we need to adopt a methodology that takes into consideration the possibility of SH as well as CSD. We are going to use the second-generation CIPS unit root test that was developed by Pesaran (2007), as well as Westerlund (2007) developed the second-generation cointegration methods.

4.3 Unit root test

After ascertaining whether or not the panel dataset has a potential CSD problem, the cross-sectionally augmented IPS (CIPS) test developed by Pesaran (2007) is applied. This test takes into consideration CSD. Traditional unit root tests, such as ADF, IPS, PP, and KPSS, have a limited capacity to account for CSD and SH, and as a result, they will produce spurious results. To acquire an estimate for the CIPS, we need to take a cross-sectional average of it, which can be seen in the following example:

$$\mathrm{CIPS} = \frac{1}{N}\sum_{i=1}^{N} t_i(N, T) \quad (7)$$

CIPS's growing prominence in the literature can be attributed to its ability to deal with CSD and SH. According to the test, a cointegration test must be conducted prior to the parameter estimate if the variable is stable at 1st difference. Both the null and alternative hypotheses emphasize non-stationarity, but the null hypothesis emphasizes it more than the option.

The panel unit root test is used in panel data analysis to determine whether or not the dependent and independent variables are stationary. This can be determined by comparing the results of the two tests. The process denoted by H_0 is a non-stationary one that

Table 4 Outcomes of CSD test

Variable	Test statistics (p-value)
LCO_2	7.22^a (0.00)
LPOP	18.91^a (0.00)
LGDPpc	18.41^a (0.00)
LTA	12.03^a (0.00)
LREN	2.30^b (0.02)
LENER	-3.20^a (0.00)
LURBA	7.54^a (0.00)

b and **a** explain the level of significance at 5% and 1%, respectively, whereas the values in parenthesis contain p-values

Table 5 Unit root test

Variable	CIPS test	
	Level	1st differenced
L CO_2	−1.957	−3.211[a]
LPOP	−2.340[b]	
LGDPpc	−2.549[b]	
LTA	−1.058	−4.258[a]
LREN	−4.369[a]	
LENER	−1.171	−6.190[a]
LURBA	−3.551[a]	

c, **b**, and **a** explain the level of significance at 10%, 5%, and 1%, respectively, whereas the values in parenthesis contain *P*-values

Table 6 Cointegration tests

Variable	Westerlund test for cointegration		
	Value	*Z*-value	*P*-value
Gt	−3.45	2.014	0.00
Ga	−6.25	2.147	0.14
Pt	−4.27	2.617	0.00
Pa	−3.27	3.007	1.00

has a unit root. While this is going on, H_1 is a stationary process that does not have a unit root. I(1) is the point at which all variables become stationary. Table 5 displays the findings of the CIPS panel unit root test. I(0) demonstrates that some variables are stationary at the level, while others are stationary in the first difference or I(1). The paper utilizes the CS-ARDL and Westerlund (2007) cointegration methods because of the mixed integration of variables.

4.4 Cointegration approach

Similar to panel unit root tests, the majority of the prior EKC research relied on panel cointegration tests that did not account for CSD. Westerlund (2007) developed a measure that is sensitive to the effects of CSD. The term "second-generation panel cointegration test" is used to describe this type of analysis. Cointegration can be determined by testing for mistake correction among panel members or across the whole panel, and this test is what we’ll be looking at here. This will be useful in testing for the existence of cointegration. After fixing the CSD problem in the dataset, the authors of the study looked for long-term stability in the model variables using the cointegration test created by Westurland (2007). In order to obtain two-group mean statistics and two-panel statistics, the test creates a new sample via the procedure of bootstrapping. Use these numbers to see how the two teams stack up against one another.

After checking if the variables are stationary, the next step is to see if they are also cointegrated across longer periods. To accomplish this goal, we used the cointegration tests outlined by Westerlund (2007), the outcomes of which are shown in Table 6. Using the Gt and Pt statistics shown in Table 5, we can see that the null hypothesis proposed by Westerlund (2007) is not supported by the data when the level of significance is set to 1%. Based on the *P*-values, we can draw this conclusion. This allows us to claim that our long-term variables are integrated.

4.5 CS-ARDL test

Westerlund's (2007) Panel Cointegration test, when conducted after the presence of CSD and heterogeneity, verified the existence of a long-run relationship. A recently created method called the CS-ARDL with the AMG and CCEMG will be used for this analysis. The CS-ARDL test, developed by Chudik et al., (2016), is used in this investigation. The procedure is used in both the lengthy and the quick assessments. The MG, PMG, GMM, and AMG all are inferior to the efficacy and consistency of this test (Atasoy, 2017). Several problems are addressed by this approach, including endogeneity, SH, CSD, non-stationarity (mixed-order integration), and unobserved shared components. This is because ignoring commonly occurring components will lead to inaccurate estimation findings. The model equation is written as follows:

$$\text{LCO 2} = \alpha_{it} + \sum_{j=1}^{P} \beta_{it}\, \text{LCO2}_{i,t-j} + \sum_{j=0}^{P} \gamma_{it} X_{t-j} + \sum_{j=0}^{3} \delta \overline{Y}_{t-j} + \varepsilon_{it} \tag{8}$$

where $\overline{Y}_t = \left(\Delta\overline{\text{LCO2}}_t, \overline{X}_t^{\prime}\right)^{\prime}$ and $X_{it} = \left(L\ \text{POP}_{it}\ L\ \text{GDP}\ pc_{it} L\ \text{TA}_{it} L\ \text{REN}_{it}\ L\ \text{URBA}_{it}\ L\ \text{ENER}_{it}\right)^{\prime}$.

A summary of the results for the CS-ARDL can be found in Table 6. Findings from this study suggest a strong correlation between income and CO_2 emissions, as evidenced by a positive coefficient of 1.1499, which shows that a 1% increase in GDP results in CO_2 emissions increasing by 1.149% in Asian nations. Also, GDP is a measure of a country's economic health that considers various factors. Consumption accounts for the bulk of GDP, and increased consumption is linked to an increase in carbon emissions (Dogan et al., 2019; Soylu et al., 2021; Tufail et al., 2021; Voumik et al., 2023b). It is also probable that when Asian countries' incomes rise, they will consume more, increasing CO_2 (He et al., 2021). The findings of Hasanov et al., (2021) for the BRICS nations, and Khan et al., (2021) for oil-exporting states demonstrated a positive relationship between CO_2 emissions and GDP, which is supported by this result. CO_2 emissions are favorably influenced by population growth, as demonstrated by the positive coefficient of 2.45, which shows that a 1% rise in population results in a 2.45% increase in Asian CO_2 emissions. On the other side, the negative coefficient of 0.3062 shows that a 1% increase in tourist arrivals corresponds to a 0.306% drop in CO_2 emissions in Asian countries. Theoretically, a rise in the number of tourists that Asian countries receive should result in an increased emphasis on ecotourism, green tourism, and sustainable tourism. To draw in more tourists from abroad, countries are increasing their investments in the development of natural reserves, forests, and parks. Additionally, research has shown that an increase of 1% in the usage of renewable energy leads to a decline of 0.3634% in CO2 emissions, demonstrating that the use of renewable energy reduces CO_2 emissions. By displacing fossil fuels, lowering CO2 emissions, cutting energy use, and making energy storage possible, renewable energy sources can significantly cut down on the world's CO_2 emissions. Reduce your carbon imprint and lessen the effects of climate change by switching to renewable energy (Voumik et al., 2022c). There is some rise in CO_2 emissions due to energy use, although it is negligible on a global scale. Consequently, the data show that an increase in urbanization of 1% in Asian countries raises CO_2 emissions by 0.014% over time.

Perhaps, these findings can be attributed to the countries' inability to adopt ecologically appropriate urbanization plans. The findings are almost similar to earlier studies on urbanization (Ali et al., 2019; Hanif, 2018). The results of the short-run CS-ARDL test are also included in Table 7. Data show that both population and GDP growth in Asian countries contribute to CO_2 emissions. Renewable energy use and tourism negatively influence CO_2 emissions, although there is little evidence that the two have a significant relationship. ECM's speed of adjustment is 0.872, indicating that the CS-ARDL model's adjustment toward equilibrium is 87%. Because the majority of Asian countries are developing nations that are still expanding, certainly in terms of economic expansion, which has a positive influence on CO2 emissions, the majority of the long-run coefficients are more significant than the short-run coefficients. This is because economic expansion has a positive impact on CO2 emissions. This is because the majority of countries in Asia are still in their emerging nation stages of development.

4.6 AMG and CCEMG test

This research estimates the long-run relationship based on two different estimators. Both of these estimators assume that each cross section has a heterogeneous slope and that they can account for CSD. The purpose of this is to assess the robustness of the estimate. The first estimate is called the AMG, and it was developed by Eberhardt and Teal (2011) as a proxy for the CCEMG. Eberhardt and Bond (2009) used Monte Carlo simulations to conduct additional research and testing on this estimator. The CCEMG estimator, which was proposed by Pesaran (2006), is the second one that has been utilized in this work. To account for the CSD and consider the cointegration, this estimator uses a framework based on shared factors. In either scenario, the correlations of the panel will be taken into consideration, which will make them more resistant to CSD issues. In addition to the CSD

Table 7 Outcomes of CS-ARDL

Variables	Long run results		Short run results	
	Coefficients	Std. Err	Coefficients	Std. Err
LPOP	2.4545***	3.022	1.8995**	2.2026
LGDP	6912**	1320	−5971	1509
LTA	−456***	7214	−324***	6201
LREN	−3624**	1319	−2805***	0900
LENER	1.4414	8219	1.2877	7960
LURBA	01,425**	07,669	0086	07,242
ECM	−0.872			

Table 8 Outcomes of AMG and CCEMG models

Variables	(1) AMG	(2) CCEMG
LPOP	0.188**	5.748**
	(1.067)	(2.462)
LGDP	0.177*	0.477***
	(0.148)	(0.165)
LTA	−0.0146***	−0.0105**
	(0.00302)	(0.00581)
LREN	−0.0352***	−0.0110***
	(0.0576)	(0.0416)
LENER	1.019	0.539
	(0.112)	(0.100)
LURBA	−2.439*	−5.187**
	(1.548)	(2.050)
Constant	11.78	78.59
	(19.03)	(90.69)
Observations	1,025	1,025
Number of ids	41	41

***$p<0.01$, **$p<0.05$, *$p<0.1$

estimator, the other two allow for heterogeneous slope coefficients, which leads to findings specific to each country.

In the present study, the AMG and CCEMG tests are used as a robustness check in Table 8, which allows for an evaluation of the CS-level ARDL's consistency. Based on the findings, it appears that both rising economic activity and growth and development positively influence CO_2 emissions. Achieving this result is in line with the CS-ARDL goals. In addition, the CS-ARDL outcomes are met by using renewable energy and tourism to reduce CO_2 emissions. Finally, energy intensity and CO_2 emissions are linked, but the relationship is insignificant. This result likewise supports the CS-ARDL long-term repercussions. The only discrepancy between the CS-ARDL model and these results is the sign of the urbanization coefficients.

5 Conclusion

The present study finds out relationships among international tourist arrivals, energy, urbanization, GDP, and population affect the environment in 40 Asian countries. This study is extremely important because Asia is one of the most popular tourist destinations, and the importance of the region in terms of political, social, and economical factors is growing all the time. This study showed that CO_2 emissions rise due to factors such as population, income, energy intensity, and urbanization. Environmental pollution is significantly influenced by population density, economic growth, and trade openness (Jiaqi et al., 2022). Nosheen et al., (2021) showed similar results as explained the long-run association between GDP, energy intensity, trade, urbanization, and environmental degradation. The findings were obtained using the CS-ARDL model also to check robustness the paper uses AMG and CCEMG estimators.

Furthermore, the fact that tourism minimizes CO_2 emissions in Asian nations supports the theory that countries are concerned about their natural environment, natural sanctuary, and wildlife reservation to attract tourists, which leads to lower levels of CO_2 emission. Similarly, Brahmasrene and Lee (2016) found that tourism is inversely related to carbon emissions in the ASEAN region. However, their study considers only Southeast Asian countries for the analysis. Energy consumption, industrialization, urbanization, and economic development have a direct and noteworthy influence on environmental deterioration. This suggests that environmental deterioration has been exacerbated in the Asian area as a consequence of energy intensity, population, income, and urbanization, according to findings. The findings of this study, which contradict the findings of the study carried out by Nosheen et al., (2021), show that the only things that can cut CO_2 emissions are the use of renewable energy and tourism. The major goal of this study is to contribute to the literature on tourism's impact on carbon emissions by analyzing the impact of tourism on CO2 emissions in a representative sample of 40 Asian countries. The study found that tourism in Asia helps down the rate of environmental degradation there. Therefore these results are dissimilar to Dogan and Aslan (2017) and Nosheen et al., (2021). For the years 2000–2020, this research empirically focused on the long equilibrium link and causation between tourism development and CO_2 emissions in Asia–Pacific nations via energy consumption and an increase in real income. As a result of long-term tourist visits, the quantity of CO_2 released into the atmosphere decreases.

5.1 Policy recommendation and future research

This finding is noteworthy for policymakers, researchers, and governments in Asian countries. This study is more significant for the countries largely dependent on the tourism industry. Subsequently, the research findings are important for achieving sustainability in tourism. Tourism-related services like transportation, accommodation, food consumption, and entertainment are the major contributor in the CO_2 emission. Sustainable tourism always addresses the issues like social inclusion, economic development and environmental protection of the present and future generations. To reduce environmental degradation in the Asian region, the tourism sector must undergo substantial adjustments in light of the contributions it makes to local employment, economic activity, and regional growth. As a consequence of the result, governments across Asia should develop environmental protection regulations and encourage the use of environmentally friendly technology within the tourism industry; subsequently, the economy may suffer in the long run if certain actions are taken. Countries in Asia should actively pursue sustainable tourism strategies. Sustainable tourism policy seeks to balance the interests of all parties involved by minimizing costs to the ecosystem and local communities while maximizing gains for the tourism industry as a whole.

Some of the goals of this policy are to safeguard the environment, keep historical sites open to the public, and encourage all parties involved in the tourism industry to act in a socially and environmentally responsible manner. The adoption of sustainable practices by the tourism industry is a major goal of sustainable tourism policy, which also emphasizes the importance of local community participation. Destinations can ensure that the benefits of tourism are felt by locals and visitors alike by adopting a policy that promotes sustainability. Since such methods reduce CO_2 emissions as a byproduct of economic growth, authorities are urged to regulate them to boost GDP. In addition, throughout the previous decade, both the consumption of energy and population have contributed positively and significantly to the expansion of the economy; nevertheless, the former has had a significantly greater influence on the economy. The government must put forth significant effort to devise a plan that would help develop infrastructure and promote tourism growth in Asian countries, as shown by the research conducted by Azam and Abdullah (2021). More resources should be allocated toward building up green economic sectors if we are to achieve sustainable growth in the years to come. To reduce carbon emissions, renewable energy sources must be utilized (Voumik et al., 2023a). To reduce CO_2 emissions from transportation, policymakers and tourism operators can encourage the use of low-carbon transportation methods such as electric cars and bicycles. The creation of eco-lodges and hotels that employ water and waste management systems, use renewable energy sources, and are built sustainably can aid in lowering carbon emissions.

Governments can help tourism businesses that invest in renewable energy like solar or wind power by giving them tax breaks and subsidies. The upfront costs of renewable energy systems can be reduced with the assistance of these incentives, making them more accessible to tourism companies. By spreading information about renewable energy and its many advantages, the tourism industry can inspire businesses to implement more environmentally friendly energy policies. Workshops, training sessions, and public initiatives are all great options for this. Businesses in the tourism industry that implement sustainable practices, such as using renewable energy, can earn recognition through certification programs like green globe. Since tourism relies so heavily on natural resources, it is imperative that the industry transition to green energy and products. Incorporating green energy into your daily routine will aid in protecting the planet and cutting down on carbon emissions. To promote the use of green energy, the government can give tax holidays. Additionally, the government can initiate green certification to recognize the green practicing business. To secure the social and economic well-being of present and future generations, sustainable development necessitates environmental and natural resource protection. Investing in renewable energy technologies will help Asian economies reduce environmental deterioration and minimize coal and oil's dominance in their energy usage. There are several possible policy measures, such as adopting renewable or environmentally friendly energy sources, energy-saving measures, controlling population growth, structural transformation of the industrial sector, and investment in sustainable tourism to reduce CO_2 emissions from Asian regions' economic growth.

5.2 Limitations of the study

The limitations of this study draw attention to potential research avenues that should be pursued in the future. However, even though institutional quality, research and development, and technological innovation are likely to play a part in the pollution haven and halo hypothesis, the model does not account for either of these characteristics. These problems, along with others like them, might be the subject of research in the future. Academics in the future who want to emphasize the actual policy implications of the results may find it useful to have a language that describes the interaction that occurs between the quality of the institutions and the natural resources.

Funding There is no funding for this research.

Data availability Dataset is available from the corresponding author on request.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest in this study.

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