Effects of tourism and eco-innovation on environmental quality in selected ASEAN countries

Zhao Wei^{1,2} · Huang Lihua^{2,3}

Received: 31 July 2021 / Accepted: 11 November 2021 / Published online: 13 January 2022
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2021

Abstract

Environmental issues have gained the attention of regulators and researchers worldwide. This present study empirically examines the validation of the environmental Kuznets curve (EKC) in the selected ASEAN economies for the period 1995–2018 in the presence of eco-innovations and tourism. This study assesses the short-run and long-run relationship between carbon dioxide emission, tourism, eco-innovations, and economic growth in ASEAN countries. To fulfil the objectives of the study, Westerlund and Edgerton (Oxf Bull Econ Stat 70:665–704, 2008) and Banerjee and Carrion-i-Silvestre (J Time Ser Anal 38:610–636, 2017) co-integration analysis have been applied to estimate the co-integration among variables because cross-sectional dependence (CSD) and slope heterogeneity was present. The short-run and the long-run empirical estimation have been done through cross-sectional auto distributive lag model. The findings provide evidence that an inverted U-shape nexus exists between carbon (CO₂) emissions and economic growth in the ASEAN countries, a validation of EKC. Eco-innovations and tourism are found to be the factors that mitigate CO₂ emissions. AMG and CCEMG results also confirm the robustness of short-run and long-run results. The findings of the study suggest that governments in ASEAN countries should promote tourism and eco-innovations (i.e., research and development) to mitigate CO₂ emission, which poses serious threats to environmental sustainability. Also, tourism and eco-innovations are the drivers of economic growth, and growth reconciles with environmental sustainability in the selected ASEAN countries. This study provides guidelines to the policymakers while formulating the regulations related to environmental degradation.

Keywords Environmental Kuznets curve · Tourism · Eco-innovation · Environmental quality · ASEAN

JEL classification Q53 · Q55 · Z32

Introduction

The global economic development trajectory in the current era has ramifications for our planet. Environmental deregulation, unrestricted use of resources, and rising inequality are the contemporary issues. In the absence of significant worldwide climate actions, the average global temperature can

climb by 2 °C, which results in more catastrophic disasters (droughts, floods, low agricultural productivity, rapid melting of ice caps and glaciers, etc.) and irreparable impacts on ecosystems (Mong0 et al. 2021).

Many believe that anthropogenic emissions of hazardous gases (such as CO₂) are the primary cause of the rise in global temperatures, which are hurting human and natural ecosystems. According to a recent report, greenhouse emissions resulting from human activities, such as bush burning and other deforestation activities, gas flaring, tourism, etc., account for over 95% of global warming (Mong0 et al. 2021). Tourism, a fast-growing sector and a significant part of the global economy, is inextricably related to the environment and climate (Ben Jebli and Hadhri 2018). Many tourism activities, e.g., transportation and accommodation, adversely affect the environment (Ehsanullah et al., 2021; Wang and Wu 2021; Li et al. 2021c). Remarkably, despite

Responsible Editor: Eyup Dogan

✉ Huang Lihua
huanglihua@fzfu.edu.cn

¹ Fuzhou Institute of Technology, Fuzhou 350506, Fujian, China

² Krirk University, Bangkok 10220, Thailand

³ Fuzhou University of International Studies and Trade, Fuzhou 350202, Fujian, China

the fact that tourism contributes to global economic growth (EG), it relies on energy supplied from fossil fuels, which pollutes the environment by emitting CO₂ (Li and Lv 2021; Sharif et al. 2017). Tourism contributes to 8% of greenhouse gas emissions globally¹ (Hsu et al. 2021; Lee et al. 2021). When tourism is not poorly planned, it can put a huge strain on the environment with disastrous long-term economic effects (Wang and Wang 2018). Though the transportation activities and wastes in tourism activities could enhance the amount of GHG emission into the atmosphere and adversely affect the environmental quality, the investment in the tourism infrastructure like accommodation, roads, canals, or parks is a helpful tool to add value to the environment and make it work worth living (Mamirkulova et al. 2020).

There are several reasons for adverse tourism effects on the environment. They may occur in any area if the number of tourists/visitors exceeds the capacity of the ecosystem. Soil erosion, more emission of greenhouse gases, habitat loss, exploitation of natural resources, wastes, and pollution are all possible outcomes (Lee et al. 2020). Furthermore, many tourism-related activities necessitate a substantial amount of electricity produced by fossil fuels, e.g., coal, oil, or natural gases. Due to insufficient logistics infrastructure, specific logistics services are generated during traveling and logistics infrastructure related to transportation that causes major environmental problems. All of this contributes to CO₂ emissions (Huang et al. 2020; Huang et al., 2021; Wang and Wu 2021).

Environmental economists argued about 3 decades back that the solution to environmental problems is the EG (Chien et al. 2021a; Nawaz et al. 2021b; Liu et al. 2021b). Grossman and Krueger, following Kuznets, discovered Kuznets curve between environmental deterioration and EG, which they called the environmental Kuznets curve (EKC). It shows that increased EG causes environmental deterioration, but after reaching a certain level, increased economic growth reduces environmental deterioration. Stated differently, EKC claims that environmental degradation and the level of income have an inverted U-shape relationship. The studies estimating the validity of the Kuznets Curve considered that GDP indicates EG (Nawaz et al. 2021a; Shair et al. 2021). However, GDP indicates EG as it is unable to depict the true relationship between growth in different economic sectors and environmental deterioration. Since different economic sectors vary in terms of their effects on the growth and environment, it is vital to test the EKC hypothesis in every sector (Chien et al., 2021b; W. Li et al. 2021a).

With the increased incidence of climate change, policy-makers have shifted their focus to promote a green economy that encourages growth while reducing the dangers of

environmental deterioration (Li et al. 2021b; Ozigbu 2019; Sun et al. 2020). Experts and researchers agree that it is vital to shift to a green economy, and it would not be possible without novel innovations. In recent decades, experts and economists have come to a remarkable agreement on the importance of eco-innovations or green technologies as an effective tool to achieve environmental sustainability, energy efficiency improvement, reducing negative impacts of resource use, and reducing the environmental dangers (Mongo et al. 2021; Xiang et al., 2021; Zhuang et al. 2021; Arain et al. 2020; Zhang et al. 2019; Raza et al. 2017). Eco-innovation² refers to new techniques, processes, behaviors, and products that significantly lead to a reduction in the harmful environmental impacts of economic activities. The development and implementation of innovative strategies through knowledge sharing and creativity significantly contribute to the sustainable performance (social, environmental, and economic performance) of the business enterprises (Abbas et al. 2019a).

Once the threshold level in the EKC hypothesis exceeds, technological growth or innovations play the essential role in lowering environmental pollution connected with increased income (Andreoni and Levinson 2001). That is, even if more economic activities necessitate greater energy consumption, smart energy policies can minimize pollution by reducing the need for energy (Fernández et al. 2018). Endogenous growth models also explain the impact of innovations on the interaction between environment and EG (Chien et al. 2021c; Fernández et al. 2018). These models imply that, as technology advancement or innovations increase, the rate at which environmental deteriorating sources are replaced by environmentally favorable sources also increases. More environmentally friendly resources are used, which have a positive environmental impact (Gormus and Aydin 2020; Mohsin et al. 2021). In the period when the spread of COVID-19 has become one of the major causes of environmental deterioration, innovation in human resource management could be helpful to overcome environmental pollution (Azizi et al. 2021).

The environmental challenge is still critical both in advanced and developing countries in spite of the level of income attained (Baloch et al. 2021). The amount of CO₂ emission in the six selected ASEAN countries like Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam is increasing as time passes, especially during the prevalence of COVID-19. The increased amount of CO₂ emission is adversely affecting the environmental quality, natural resources, the health of living beings, and the sustainable business performance in these countries. This needs the attention of researchers and academics to find the elements which could be helpful in reducing CO₂ emission

¹ Major contributors are China, the USA, and Germany.

² The Fussler and James in 1996 first developed the concept of eco-innovations.

and sustaining the environmental quality. Considering this need, the current study is about to be conducted. The main objective of the study is to elaborate on the influences of four significant factors like tourism, eco-innovation, GDP, and GDP² on CO₂ emission and environmental quality. This study is an excellent contribution to the literature because of the collective analysis of the impacts of tourism, eco-innovation, and EG on CO₂ emission and environmental quality. This study deals with the influences of both GDP and GDP² on environmental quality, which saves a significant position for the study in the literary world. Moreover, though the past studies have dealt with the ways how tourism, eco-innovation, GDP, and GDP² influence the CO₂ emission and environmental quality in Asian countries, hardly a study found which have dealt with this issue in these countries simultaneously, that is why the analysis of the interrelationship among the tourism, eco-innovation, GDP, and GDP² on CO₂ emission and environmental quality in the six ASEAN countries Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam is a great contribution to the literature.

The core objective of the article, therefore, is to empirically investigate the validation of the EKC in 6 ASEAN economies (Indonesia, Vietnam, Malaysia, the Philippines, Singapore, and Thailand). The study also examines the impact of tourism and eco-innovations on CO₂ emissions. The remaining part of the study is structured as follows: The “Literature review” section provides the review of the existing literature. The methodology applied for the analysis and data sources is discussed in the “Econometric model and econometric techniques” section. The empirical findings of the study are presented in the “Results” section. Conclusions and policy implications are discussed in the “Conclusion and policy recommendations” section, followed by references.

Literature review

The ecology of a country is extremely important to society and the economy. The health of all living beings is influenced by the quality of the country’s environment. It is a country with a good quality environment, such as clean air, soil, and water, which gives healthy natural resources and healthy living beings. People who are healthy can communicate with one another pleasantly and go about their daily tasks with vigor (Atalan 2020). Because natural resources are employed in various economic activities, and the economy requires a healthy workforce to carry out economic activities smoothly and efficiently, a healthy environment ensures a smooth and progressing economy. However, there are a number of pollutants that have an impact on environmental quality. Carbon dioxide (CO₂) emissions into the atmosphere are one of these pollutants that are increasing due to a variety of circumstances. CO₂ in the atmosphere

comes from two main sources. Natural resources and human resources are the two types of resources (Geng et al. 2018). Similarly, there are factors such as tourism, eco-innovation, and economic growth (EG), which have diverse impacts on CO₂ emission and, thus, on the environmental quality. In the past, there has been made long research and debate on the influences of tourism, eco-innovation, and EG on CO₂ emission and environmental quality in different manners. Our study cites many of such research studies to elaborate its subject.

Depending on the variables studied, extensive literature is available on the factors that determine environmental degradation/sustainability or quality. Due to concerns about sustainable growth, the association between EG and environmental deterioration has received much attention in the existing literature under the EKC hypothesis framework. Several articles have estimated the validation of the EKC hypothesis in different countries. For instance Omotor (2017) and Xueying et al. (2021) used two environmental quality indicators of CO₂ and sulfur dioxide (SO₂) emission to investigate the nexus between environmental deterioration and per capita income in ECOWAS countries. For both CO₂ and SO₂, the results from the random and fixed effect models indicated the validation of the EKC in the ECOWAS area. Between 1960 and 2010, Jula et al. (2015) analyzed the association between carbon emission and EG in Romania using per capita GDP. The empirical findings provided the evidence for the validation of an inverted U-shape curve and supported the EKC theory in Romania (Jula et al. 2015). In the similar line, Alege and Ogundipe (2015) analyzed the nexus between environmental sustainability and economic growth in Nigeria for the 1970 to 2011 period. The study used a fractional co-integration analysis approach and a cubic equation model, which contain CO₂ emission as a measurement for environmental quality, while GDP, openness to trade, institutional quality, and population density were the explanatory variables of the study. The results did not prove the existence of the EKC in Nigeria. However, the result showed that weak institutions, trade liberalization, and high population density lead to environmental deterioration. The study of Roca et al. (2001) examined the existence of EKC in Spain. For this purpose, different environmental pollutants related with per capita income were used, and income was found to be helpful in mitigating the pollutants from the environment, but it could not be the sufficient condition to solve the environmental issues.

However, the environmental impacts of tourism and eco-innovations under the EKC hypothesis are under-researched, especially in ASEAN countries. For instance, Lee et al. 2021 analyzed how tourism impacts the environment in China for the 2002 to 2018 periods. Applying the nonlinear ARDL model, the study evidenced that there was the considerable negative effect of tourism on the environment and there exist long-term

nexus between tourism activities and the environment in China. It was also found that the environment responded to tourism asymmetrically, such that the negative impact of increased tourism was lesser than the favorable impact of decreased tourism on the environment. It was concluded that tourism was a significant factor in the environmental performance of China (Chien et al. 2021d; Lee et al. 2021; Sadiq et al. 2021a). Wang and Wu (2021) examined how tourism growth affected the environment in the top five countries of the world (France, Spain, the USA, Italy, and China) for the period 1995–2018. Applying the ARDL test with the structural break, it was evidenced that tourism and economic growth positively affected carbon dioxide emissions in China, the USA, and France. The past research was conducted by Hussain et al. (2021) to investigate the influences of tourism and related factors on environmental quality with the predictor of CO₂ emission, especially during the prevalence of COVID-19. This study posits that the development of rural areas like the slums' crumbled infrastructure, which are developed by the tourism industries, is effective to cope with the pollutants. Thus, the development of tourism helps overcome environmental pollution. Similarly, Koçak et al. (2020) also evidenced the increasing effect of tourist arrivals, but the decreasing impact of tourist receipts on CO₂ emission while analyzing the world's top ten tourist destinations (Koçak et al. 2020; Li and Lv 2021). Li and Lv (2021), in an attempt to examine how tourism impacts CO₂ emission for a panel of 95 countries, found that tourism affected CO₂ emission positively. It was also found in the study that taking spatial dependence into consideration, the positive impact of tourism expansion on CO₂ emission came primarily through the spillover effects instead of the direct influence (S. Li and Lv 2021; Sadiq et al. 2021b). Zaman et al. (2016) estimated how international expenditures of tourism transportation affected carbon dioxide emission in the emerging economies from 1995 to 2013. The findings confirmed that increasing transportation expenditures for tourism affected carbon emissions in an increasing way (Othman et al. 2020; Zaman et al. 2016). The study of Aman et al. (2019) was conducted to test the benefits of tourism development to a country. This study elaborates how sustainable tourism development, like improved tourism infrastructure, innovation, and expansion of tourism services, brings improvement in behaviors, environmental quality, quality of life, and cultural development with the help of the smart PLS-SEM technique.

It has also been recognized that innovative technologies can play an effective role in the mitigation of CO₂ emissions (Ahmad et al. 2021b; Liu et al. 2021a, 2021b). The eco-innovation in the technologies through an effective entrepreneurial business network enhances sustainable business performance as the green innovation in the technology reduces the negative impacts of business processes on environmental, natural resources, and the health of human resources (Abbas et al. 2019b). A large number of empirical studies examining the innovation-environment nexus are available in the

existing literature. For example, Gormus and Aydin (2020) used the EKC hypothesis to estimate the nexus between EG, consumption of renewable energy, ecological footprint, and innovation for the top 10 innovative countries.³ Panel co-integration tests showed that innovations in R&D caused a reduction in environmental pollution. In the long term, all variables in EKC moved together, but EKC was found to be valid only for Israel out of all countries included in the sample (Gormus and Aydin 2020). Fethi and Rahuma (2019) investigated the role eco-innovations played in the mitigation of carbon dioxide emissions (CO₂) under the EKC, and the results of the DSUR Co-integration test and DH causality test revealed that eco-innovations (R&D) had a negative long-run effect CO₂. The findings proved the validity of the EKC and the Porter hypothesis⁴ for the countries under consideration (Fethi and Rahuma 2019). In the same vein, for developing economies, Fernández et al. (2018) analyzed the effect of innovation activities on CO₂, and it was found that there was a negative nexus between innovations and CO₂ emission by applying the ordinary least squares technique (OLS) (Crisóstoli and Fronti 2020; Fernández et al. 2018).

In contrast, higher expenditures on research and development led to environmental degradation (Shaari et al. 2016). Santra (2017) validates the existence of a positive nexus between carbon dioxide emissions and innovations in BRICS nations (Delbianco and Dabús 2020; Santra 2017). Ali et al. (2016) examined the nexus between innovations, financial development, use of energy, and growth in Malaysia, but their findings failed to support the positive contribution of innovation in mitigating CO₂ (Ali et al. 2016; Chien et al. 2021f; Hassan and Meyer 2021). Garrone and Grilli (2010) found that green R&D played an insignificant role in reducing CO₂ emission among 13 advanced countries (Garrone and Grilli 2010; Sgammini and Muzindutsi 2020). The innovation in tourism activities helps with the environmental impacts of COVID-19 (Abbas et al. 2021a).

The reviewed empirical literature evidenced that earlier studies about the validation of EKC and the effect of tourism and eco-innovations on CO₂ emission have been conducted in different countries. But, a lack of articles exists that investigated the validation of EKC in terms of tourism and eco-innovations, specifically for a sample of ASEAN economies. Therefore, this study bridges this gap by investigating the validation of EKC in the presence of tourism and eco-innovations by using panel data of six ASEAN countries. In addition, the present study has used economic growth along

³ Denmark, Finland, Germany, Israel, Korea, the Netherlands, Sweden, Switzerland, the UK, and the USA.

⁴ Portal Hypotheses: Strict environmental regulations can induce efficiency and encourage innovations that help improve commercial competitiveness.

with tourism and innovation to examine carbon emission that is also one of the first attempts.

Econometric model and econometric techniques

Comprehensive data for six ASEAN countries for the period 1995 to 2018 has been used to explore the validation of EKC in the presence of tourism and eco-innovations. The CO₂ emission has been used as a proxy of environmental sustainability, which is the dependent variable of the study. Tourism, eco-innovations, GDP, and GDP squares are the independent variables. Several other studies also implemented the above-mentioned variables as the determinants of environmental deterioration. Data is extracted from various secondary sources. We proceed to the model specification after taking these variables into consideration.

Theoretical model, data, and measurements

Grossman and Krueger's (1991) pioneering investigations attracted attention to the EKC hypothesis. According to the environmental Kuznets curve hypothesis, a relationship exists between EG and environmental deterioration. The quadratic function of income level is used in the standard EKC model. The standard EKC estimates the relationship between income level and the environment by using any of the four environmental variables, e.g., carbon dioxide per capita emission, nitrous oxide emission, annual mean temperature, and annual mean rainfall. Environmental pollution is assumed to be a constant function of income level and square income level in the model specification (Dlalisa and Govender 2020; Mosala and Chinomona 2020; Ozigbu 2019).

Following studies have been investigated the environmental quality with variance aspects such as Apergis and Payne (2009); Porter and Van der Linde (1995); Soytaş et al. (2007); De Vita et al. (2015); and Fethi and Rahuma (2019). This study has added the eco-innovations and tourism in the models used by the above-mentioned studies and modified the theoretical framework of environmental Kuznets curve for estimating the effect of eco-innovations and tourism on the emission of CO₂. This study has taken the GDP, GDP², eco-innovation (EIN), and tourism (TOR) as the independent variables, while CO₂ has been used as the dependent variable.

The model in its econometric form is given as follows:

$$CO2_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 EIN_{it} + \beta_4 TOR_{it} + u_{it}$$

where i is the cross-section and t is time.

CO₂ measures CO₂ per capita, GDP is EG, GDP² is the squared economic growth, EIN is the eco-innovation, TOR is tourism, and u_{it} is the error disturbance term.

Description of the variables

Variables	Measurement	Data source
CO ₂ emission (dependent variable)	Carbon dioxide emission (metric tons per capita)	OECD
Eco-innovations	Number of patents related to technology	OECD
Tourism	International tourism, number of arrivals	World Development Indicators (WDI)
Economic growth	Gross domestic product and gross domestic product square	World Development Indicators (WDI)

Econometric methodology

Cross-sectional dependence (CSD) and slope heterogeneity are the major issues that may arise in panel data analysis (Chien et al. 2021e; Dogan & Seker 2016). Therefore, it is necessary to check the above-mentioned issues before deciding on the appropriate econometric technique. The following steps can be used to summarize the panel data estimate procedure: CSD test, unit root tests, co-integration test, regression analysis, and robustness analysis. In the presence of the above-mentioned problems, appropriate techniques are “second-generation” econometric estimation techniques for heterogeneous panels (Chien et al. 2021d; Le & Ozturk 2020).

Six important steps are carried out for the empirical estimation of this study. First, the CSD test is applied. Second, the slope heterogeneity test proposed by Pesaran and Yamagata's (2008) is applied. Third, the existence of CSD necessitates the use of CIPS and the MCIPS test for panel unit root and Bai and Carrion-I-Silvestre (2009) to find the stationarity of all variables. Fourth, the Banerjee and Carrion-i-Silvestre (2017) and Westerlund panel co-integration tests are applied in order to confirm the co-integration among the variables. Fifth, to estimate short-run and long-run impacts, cross-sectional augmented autoregressive distributed lag (CS-ARDL) model is estimated. Finally, to estimate the independent variables' parameters, the AMG and CCEMG (Pesaran 2006) estimations are applied in the study.

Cross-sectional dependence test

Pesaran et al. (2004) proposed the CSD test that has a null hypothesis of zero or null dependence across cross-sectional entities of the panel. This test can be applied to a large number of panel data models such as heterogeneous dynamic panels having stationarity or unit root with structural breaks, having a small-time period and comparatively large cross-section (Pesaran et al., 2004).

$$y_{it} = \alpha_i + \beta_i x_{it} + u_{it},$$

where I is the cross-sectional identities, t is the time period, and X_{it} is a $(k \times 1)$ vector of the regressors. The α_i (intercept) and β_i (the slope coefficient) can differ across the cross-section members (Dobnik 2011; Wang et al. 2021). The test statistic is given as

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) \rightarrow N(0, 1)$$

where ρ_{it} represents the evaluation of the residual pairwise correlation of OLS and $\hat{\mu}_{it}$ is related to the given equation:

$$\hat{\rho}_{ij} = \hat{\rho}_{ij} \frac{\sum_{t=1}^T \hat{\mu}_{ij} \hat{\mu}_{ij}}{(\sum_{t=1}^T \hat{\mu}_{it}^2)^{1/2} (\sum_{t=1}^T \hat{\mu}_{jt}^2)^{1/2}}$$

Slope homogeneity test

Suppose CSD test shows that the problem of cross-sectional dependence among the regressors, it shows that each country exhibits similarity in terms of economic development movements. Therefore, it is important to control cross-sectional heterogeneity. Otherwise, the estimation results would be biased.

In this study, homogeneity tests established by Pesaran and Yamagata (2008) are also applied. The statistics of the test, proposed by Swamy is given as follows: $\hat{\Delta} = \sqrt{Z} \left(\frac{Z^{-1} \tilde{S} - k}{\sqrt{2k}} \right)$

where S is the Swamy statistics, following the assumption of normally distributed errors, and the delta statistics are calculated as follows:

$$\hat{\Delta}_{adj} = \sqrt{Z} \left[\frac{Z^{-1} \tilde{S} - E(\tilde{Z}_{it})}{\sqrt{\text{var}(\tilde{Z}_{it})}} \right] F(\tilde{Z}_{it} = k, \text{var}(\tilde{Z}_{it}))$$

$$= 2K(T - k - 1)T + 1$$

H_0 (null hypothesis) is homogeneity, and H_1 (alternative hypothesis) is slope heterogeneity for both statistics (Gormus and Aydin 2020; Local Buden of Disease 2021).

Panel unit root tests

Pesaran cross-sectional augmented (CIPS) test is used to estimate the stationarity because of the presence of CSD and slope heterogeneity. The equation for the CIPS test is given as follows:

$$\Delta Y_{it} = \varphi_i Y_{it-1} + \varphi_i \bar{Y}_{T-1} + \sum_{l=0}^p \varphi_{il} \bar{Y}_{t-1} + \sum_{l=0}^p \varphi_{il} \bar{Y}_{i,t-1} + \varepsilon_{it}$$

where Y_{t-1} and ΔY_{t-1} denote the average of lagged and 1st difference added for cross-sectional units (Su et al. 2021). The CIPS statistic is given as follows:

$$\widehat{CIPS} = \frac{1}{N} \sum_{i=1}^n CADF_i$$

Bai and Carrion-i-Silvestre (2009)

Bai and Carrion-i-Silvestre (2009), through the common factor model which was proposed by Bai and Ng (2004), proposed a unit root test for a panel data model that pooled modified Sargan and Bhargava (1983) (MSB) tests by considering multiple structural breaks and CSD. They allow for structural breaks for different countries at different dates in the slope, level, or in both and can have varying magnitudes of shift. Moreover, for a series, the number of breaks can be different, and they can also be different at level and slope within each series. An iterative estimation procedure is developed to treat the heterogeneous breaks.

The following model provides the basis for Bai and Carrion-i-Silvestre (2009) procedure.

$$X_{it} = D_{it} + F'_{it} + e_{it}$$

$$(1 - L)F_t = C(L)\mu_t$$

$$(1 - \rho_i L)_{eit=H-i(L) \in it}$$

where i = index (1 to N) denotes members of the panel and t (1 to T) represents the time.

$C(L) = \sum_{j=0}^{\infty} C_j L^j$ and $H_1(L) = \sum_{j=0}^{\infty} H_{ij} L^j$ represents the lag, and ρ_i shows the autoregressive parameter. The deterministic part of the model is represented by component D_i . F_t is a $(r \times 1)$ that represents the vector of common factors, and e_{it} represents the disturbance term. F_t need not be integrated into order one despite the operator $(1 - L)$ in the above equation. Bai and Carrion-i-Silvestre proposed the two models with to the deterministic component D_{it} . These two models are given below.

$$D_{it} = \sum_{j=1}^{li} \theta_{ij} D U_{ij,t}$$

$$D_{it} = \mu_i + \beta_{it} + \sum_{j=1}^{li} \theta_{ij} DU_{ijt} + \sum_{k=1}^{mi} \gamma_{ijk} DT_{ikt}$$

where li and mi represent the breaks at structures that affect the mean and the trend of a data series, respectively, and they need not be equal necessarily. The binary variables are $DU_{ijt} = 1$ if t is greater than T_{ijt} and 0 otherwise, and $DU_{ijt} = (t - T_{ibk})$ if t is greater than T_{ibk} and 0 otherwise. T_{ijk} and T_{ibk} show the j_{th} and k_{th} dates of the breaks in trend and level for the i_{th} individual with $j = 1$ to li and $k = 1$ to mi .

To enhance the statistical power, Bai and Carrion-i-Silvestre (2009) pool test statistics for the individual MSB. Cross-sectional independent panel members are required for this purpose, and this condition cannot be fulfilled in this framework. As the e_{it} is not dependent across the units of the panel, it is suitable to apply a combination of individual MSB. Two approaches for the individual MSB are provided. The first approach uses the mean of individual statistics:

$$z = \sqrt{N} \overline{MSB}(\lambda) - \bar{\kappa} / \bar{E} \rightarrow N(0, 1)$$

$MSB(\lambda) = N^{-1} \sum_{i=1}^N MSBi(\lambda)$, $\bar{\kappa} = N^{-1} \sum_{i=1}^N \kappa_i$ and $\bar{E} = N^{-1} \sum_{i=1}^N E_i$. Where κ_i and E_i represents the variance and mean of the individual modified MSBi (λ) statistic, respectively.

Bai and Carrion-i-Silvestre (2009) proposed a second approach on the basis of simplified test statistics that do not vary due to mean and trend breaks:

$$z = \sqrt{N} \overline{MSB}(\lambda) - \kappa^* / \bar{E}^* \rightarrow N(0, 1)$$

The second approach that pools the individual (t_e) p -values is also considered by Bai and Carrion-i-Silvestre (2009) to yield satisfactory results.

$$P = -2 \sum_{i=1}^N \ln p_i \rightarrow Y_{2N}^2$$

$$P_m = -2 \sum_{i=1}^N \ln p_i = \frac{2N}{\sqrt{4N}} \rightarrow N(0, 1)$$

where p_i , i (1 to N) represent the individual p value. Bai and Carrion-i-Silvestre (2009) represent the corresponding P and P_m as P^* and P^*m , respectively (Dobnik, 2011).

Westerlund panel co-integration tests (2007)

Co-integration tests are used to estimate long-run relationships between the variables. Normal co-integration tests like Johansen or Kao provide spurious/biased results in the presence of CSD. As a result, “Westerlund panel co-integration tests” (Westerlund 2007) is used to estimate the long-run co-integration of the regressors. The equation is given as:

$$\Delta X_{it} = \delta_i d_i + \epsilon_i \left(X_{it-1} \alpha_i Y_{it-1} \right) + \sum_{j=1}^p \phi_{ij} X_{it-j} + \sum_{j=0}^p \phi_{ij} Y_{it-j} + \mu_{it}$$

ϵ_i represents the speed of correction towards equilibrium.

The following equations give 4 formulas proposed by Westerlund (2007), including group mean statistics and panel statistics:

$$D_t = \frac{1}{N} \sum_{i=1}^N \epsilon_i / S_e(\hat{\epsilon}_i)$$

$$D_0 = \frac{1}{N} \sum_{i=1}^N \frac{T_{\epsilon_i}}{\epsilon_{i(1)}}$$

$$P_r = \frac{\epsilon_i}{Se(\hat{\epsilon}_i)}$$

$$P_\alpha = T\hat{\epsilon}$$

The least-squares estimates of ϵ_i and T are used to calculate the statistics. Furthermore, the D_t , D_0 statistics estimate the existence of co-integration in the cross-sectional unit, whereas the P_r and P_α represent whether co-integration is present in the whole panel or not (Le and Ozturk 2020).

Banerjee and Carrion-i-Silvestre (2017)

The co-integration test, developed by Banerjee and Carrion-i-Silvestre (2017) is also applied in this study which states that CSD is related with common factors calculated by each variable's averages in cross-section. The co-integration test is used for panels having different combinations of time and cross-section, and it permits structural break in the panel model (Bello & John-Langba 2020; Le and Ozturk 2020; Paulson et al. 2021).

Cross-sectional augmented autoregressive distributed lags

Because of its robustness against cross-sectional dependency and multiple orders of stationarity, the CS-ARDL approach is shown to be appropriate for our investigation. This study tested the short run and long run results by using (CS-ARDL) test. The cross-section averages are used to remove the cross-sectional dependency. The general equation of CS-ARDL is given as follows:

$$\Delta Y_{it} = \phi_i + \sum_{l=1}^p \phi_{il} \Delta Y_{it-l} + \sum_{l=0}^p \phi_{il} EXV_{st,l-1} + \sum_{l=0}^1 \phi_{il} \overline{CSA_{i,t-l}} + \epsilon_{it}$$

CSA represents averages of cross-section, which is further represented by $\overline{CSA_t} = \left(\overline{\Delta Y_t EXV_{st}} \right)$. Explanatory variables are denoted by EXV 's (C.-W. Su et al., 2021).

Common correlated effect mean group (CCEMG) and augmented mean group (AMG)

AMG and CCEMG estimation were developed by Pesaran (2006). The CCEMG estimation includes the mean of dependent and independent variables with the unobservable common effects ft , which verifies robustness even in the presence of slope homogeneity and CSD.

$$Y_{it} = \alpha_i + \beta_i X_{it} + \gamma_i \bar{Y}_{it} + \delta \bar{X}_{it} + c_i f_i + \epsilon_{it}$$

where Y_{it} and X_{it} represent the variables; β_i denotes the slope of a specific country; ft is the unobservable common factor; α_i and ϵ_{it} represents the intercept as well as the error term.

AMG estimator, introduced by Eberhardt and Teal (2010) and Eberhardt and Bond (2009), is also applied in this study besides CCEMG. The AMG method deals with ft mentioned in the equation below. To illustrate the AMG estimator, we consider the first differenced ordinary least square equation:

$$\Delta Y_{it} = \alpha_i + \beta_i \Delta X_{it} + \sum_{t=1}^T \phi_t D_t + \phi_i f_i + \epsilon_{it}$$

where Δ shows difference operator and ϕ shows the coefficients of the time dummy D . Next, by giving a unit coefficient to every group member and by taking the average of the group-specific parameters across the panel, the regression model for a specific group is estimated as follows:

$$AMG = \frac{1}{N} \sum_{i=1}^N \tilde{\beta}_i$$

Results

Cross-sectional dependence tests (CSD test)

As a preliminary step of the analysis, the CSD test to estimate the presence of cross-sectional dependence among the variables is applied. All the variables are first tested for interdependence across the countries under examination as, according to Pesaran (2006), when cross-sectional dependence is neglected; panel data studies show significant bias and size distortions. The results of the CD test are given in Table 1.

The highly significant p -values of each variable decisively reject the null hypothesis and show that CSD exists among the variables. Thus, any change in any variable such as eco-innovations or tourism in one country has its consequences in other countries too.

Table 1 Cross-sectional dependence analysis results

Variable	Test statistics (p -values)
CO2	23.012*** (0.000)
TOR	17.107*** (0.000)
EIN	34.001*** (0.000)
GDP	22.061*** (0.000)

Slope heterogeneity tests

In the second step, the slope heterogeneity test is applied. This method is based on the Δ and the adjusted Δ . These outcomes are posted in Table 2.

Results of slope heterogeneity analysis reveal that the null hypothesis of slope homogeneity cannot be accepted, and therefore, it is confirmed that heterogeneity exists across ASEAN countries.

Unit root tests

After the slope homogeneity test, it is necessary to determine whether the series is unit root or stationary. For this purpose, the CIPS test is applied. The cross-sectional IPS (CIPS) statistic is computed by the mean of individual CADF data for each country in the panel. The null hypothesis of CIPS states that the series is integrated of order 1, i.e., it has a unit root (Koçak et al. 2020).

Note: The level of significance is determined by 1, 5, and 10% indicated through ***, **, and *, respectively. For Bai and Carrion-i-Silvestre (2009) test, 1, 5, and 10% critical values (CV) for Z and Pm statistics are 2.326, 1.645, and 1.282, while the critical values (CV) for P are 56.06, 48.60, and 44.90, separately.

The results of the “second generation” unit root test (CIPS) and M-CIPS reveal that the null hypothesis of the test cannot be rejected, and all the variables under consideration have a unit root. Moreover, the results are given in Table 3, which confirms the existence of non-stationarity in constructs at 1% level of significance. Moreover, the null hypothesis of a unit root is accepted for all tests in the model without any break, with a break in the mean, and a break in the trend.

Table 2 Results of the slope heterogeneity analysis

Dependent variable: CO2	
Statistics	Test value (p -value)
Delta tilde	67.025*** (0.000)
Delta tilde Adjusted	46.057*** (0.000)

Table 3 Unit root test Pesaran

Variables	Level I(0)		First difference I(1)		
	CIPS	M-CIPS		CIPS	M-CIPS
CO2	−3.031***	−4.101**		−	−
TOR	−5.010***	−6.030**		−	−
EIN	−3.030***	−4.011**		−	−
GDP	−4.015***	−5.105**		−	−
Bai and Carrion-i-Silvestre (2009)					
	Z	P _m	P	Z	P _m
CO2	0.310	0.301	22.010	−4.041***	5.101***
TOR	0.521	0.428	19.100	−3.010***	4.021***
EIN	0.269	0.201	20.101	−5.065***	6.001***
GDP	0.417	0.347	18.231	−3.210***	4.023***

Panel co-integration analysis

The long-run parameters are computed after the co-integration relationship has been determined. Because of the presence of slope heterogeneity and CSD, this study performs Westerlund and Edgerton co-integration analysis. Moreover, Banerjee and Carrion-i-Silvestre (2017) co-integration analyses are also employed.

Westerlund and Edgerton (2008) panel co-integration analysis.

Table 4 reports Westerlund and Edgerton (2008) co-integration test results. Both $Z\phi(N)$ and $Z\tau(N)$ confirm that there exists a long-run association between CO2 emissions, tourism, eco-innovations, and economic growth, allowing for breaks both I slope and in level. The null hypothesis of no co-integration cannot be accepted because the test statistics are statistically highly significant.

Banerjee and Carrion-i-Silvestre (2017) co-integration analysis

In order to detect the long-run nexus, Banerjee and Carrion-i-Silvestre (2017) co-integration tests are employed, and the results are given in Table 5, which shows that long-run stable relationship exists among the variables.

Table 4 Westerlund and Edgerton (2008) panel co-integration analysis results

Test	No break	Mean shift	Regime shift
Dependent variable: CO2 emission			
$Z\phi(N)$	−3.151***	−3.015***	−4.124***
p_{value}	0.000	0.000	0.000
$Z\tau(N)$	−4.010***	−3.101***	−5.205***
p_{value}	0.000	0.000	0.000

Table 5 Banerjee and Carrion-i-Silvestre (2017) co-integration analysis results

Countries	No deterministic specification	With constant	With trend
Full sample	−4.012***	−3.013***	−5.121***
Indonesia	−5.101***	−4.101***	−6.023***
Malaysia	−7.031***	−6.035***	−8.202***
Philippines	−3.101***	−3.003***	−4.001***
Singapore	−5.801***	−4.139***	−6.170***
Thailand	−6.721***	−5.251***	−7.357***
Vietnam	−3.301***	−3.010***	−4.512***

Cross-sectional augmented autoregressive distributed lag model (CS-ARDL)

Because of its robustness against cross-sectional dependency and multiple orders of stationarity, the CS-ARDL approach is appropriate for our investigation. The short-run results are posted in Table 6. The short-run results show that tourism, eco-innovation, GDP, and GDP² are highly significant at 1% level of significance.

CS-ARDL (short-run results)

It is found that the speed of adjustment (ECT) is a highly significant and negative coefficient. ECT coefficient (0.223) shows that model will meet to long-run equilibrium path along with a 22.3% adjustment speed. The findings are consistent with Naradda Gamage et al. (2017); Ben Jebli, and Hadhri (2018); and Lee and Brahmasrene (2013). Tourism has a negative impact on CO2 emission, a finding contrary to theoretical considerations and previous findings. Coefficient shows that 1% increase in tourist arrival may cause CO2 emission to decline by 0.059%. The reason may be that tourism, in particular, by enabling the use of energy-efficient

Table 6 Short-run CS-ARDL results

Variables	Coefficients	<i>t</i> -statistics	<i>p</i> -values
Dependent variable: CO2 emission			
TOR	−0.059***	−8.005	0.000
EIN	−0.071***	−5.487	0.000
GDP	0.062***	−4.668	0.000
GDP ²	−0.022***	−3.442	0.000
ECT(−1)	−0.223***	−11.088	0.000

technologies and transportation, can assist control and reduce CO2 emissions, and tourism can also be used to raise environmental consciousness (Adewumi, 2020; J. W. Lee & Brahmasrene 2013; Paramati et al. 2017; Paulson et al. 2021). Moreover, tourism, being one of the major subsectors of the service sector, is also cleaner than the agriculture and manufacturing sectors. As a result, it may be helpful in reducing CO2 emissions (Koçak et al., 2020; Vermeulen et al. 2020).

Similarly, the coefficient of the second main variable, i.e., eco-innovations, is negative and highly significant, which confirms the fact that environment-friendly innovations decline environment deteriorations for each percent increase in patent filings in technology, CO2 emission declines by 0.071%. The finding is very useful in the current time as the world is facing serious environmental challenges currently. It supports the fact that cleaner technologies can reduce environmental dangers and helpful to lessen pollution and overexploitation of resources as eco-innovative processes generate more energy-efficient activities and products and consume lesser resource. Therefore, eco-innovations have beneficial effects on the environment (Fernández et al., 2018). Moreover, a one-time increase in activities leading to innovation stimulates businesses to have more investment in innovation, which in turn increases the use of environmentally friendly technology in the manufacturing process. Stated differently, firms with awareness, rich knowledge, and skills are more likely to develop and search for new technologies to minimize environmental condemnation (Ahmad et al. 2021a). The findings of the study are in line with the findings of Du et al. (2019), estimating a panel of seventy-one countries. The results are also consistent with Braungardt et al. (2016) findings from a group of twenty-seven European Union countries and with the findings of (Mongo et al. 2021).

Last, both GDP and GDP² confirm that the EKC hypothesis, which states that inverted U nexus between economic growth and CO2 emissions, exists in the selected 6-ASEAN countries. The findings reveal that a 1% rise in GDP increases CO2 emissions by 0.06%, while the negative coefficient of the squared term appears to support the decoupling of CO2 emission and gross domestic product at higher levels of income in the ASEAN economies. Previous studies also confirmed the validation of EKC using data of different countries, for example,

Table 7 Long-run CS-ARDL results

Variables	Coefficients	<i>t</i> -statistics	<i>p</i> -values
Dependent variable: CO2			
TOR	−0.264***	6.217	0.000
EIN	−0.158***	−3.101	0.000
GDP	0.357***	5.422	0.000
GDP ²	−0.069**	−2.541	0.035
CSD statistics	-	0.081	0.409

Bekhet et al. (2020) for Malaysia; Gormus and Aydin (2020) for Israel; and Fethi and Rahuma (2019) for the top twenty oil (refined oil) exporting countries. All these studies support our finding of the validity of EKC in ASEAN countries.

CS-ARDL (long-run results)

The long-run estimates of CS-ARDL analysis are given in Table 7

In the long run, all variables have the same sign as in the short run. Both tourism and eco-innovations are found to have a significant contribution towards CO2 reduction. The negative effect of tourism on CO2 emission is due to an increase in foreign exchange earnings which may be used to import advanced technologies, including eco-friendly technologies that advance environment-friendly economic growth, thereby reducing CO2 emission or preserving the environment. The validation of EKC is confirmed in the long run also as the coefficient of GDP is positive and the coefficient of GDP square is negative and significant. The reason for the positive impact of GDP or income growth on CO2 emission is that in the early stages of EG, there is greater use of natural resources and pollutant emission, which causes environmental degradation. But later, as income increases, environmental cleaning activities/fewer polluting activities take place in an economy. Technological progress occurs with economic growth as it is affordable to spend more on research and development by a wealthy nation. So, newer and cleaner technology replaces the dirty and obsolete technologies (Kennedy et al. 2020; Kiliç & Balan 2018). That is why economic growth after reaching the threshold helps in environmental sustainability. Therefore, these estimates verify EKC hypothesis validation in the ASEAN countries. The studies supporting our long-run estimates include Bekhet et al. (2020), Ahmad et al. (2021a) and Ozigbu (2019) studies.

Augmented mean group and common correlated effect mean group

Finally, a robust econometric approach of AMG and CCEMG is applied in the study, and results are posted in Table 8.

Table 8 AMG and CCEMG results (robustness check)

Dependent variable CO2	(CCEMG)					
	(AMG)					
	Coefficients	<i>t</i> -statistics	<i>p</i> -values	Coefficients	<i>t</i> -statistics	<i>p</i> -values
TOR	−0.375***	−4.124	0.000	−0.179***	−3.011	0.000
EIN	−0.081***	−3.013	0.000	−0.328***	−4.021	0.000
GDP	0.162***	5.065	0.000	0.210***	3.013	0.000
GDP ²	−0.303***	−3.011	0.000	−0.342***	−5.105	0.000
Wald test	-	82.53	0.000	-	34.051	0.000

The results of the robustness check support our findings provided in Table 8. Outcomes of AMG and CCEMG suggest that GDP will increase CO2 emission, but tourism, eco-innovations, and square of GDP will help decline environmental degradation. These results also validate the EKC existence in selected ASEAN economies in the presence of tourism and eco-innovations.

Discussion

The study results have indicated that tourism has a positive impact on environmental quality. The results imply that tourism development enables the government or environmental regulators to overcome the CO2 emission, which could adversely affect the environmental quality. These results are in line with the previous study of Abbas et al. (2021b), which indicates that during COVID-19, the contagious disease, tourism development in the form of eco-friendly improvement in tourism infrastructure assists in reducing CO2 emission. The study findings have revealed that eco-innovation has a positive impact on environmental quality. This means that with the implementation of the economic strategies which can bring green innovation in the economic processes, CO2 emission can be reduced, and environmental quality can be enhanced. These results are approved by the past study of Abbas et al. (2021c), which states that eco-friendly innovation in the communication network like eco-friendly technology and digital media sources are helpful in reducing CO2 emission even in the period of COVID-19.

It has also been indicated by the study results that EG has a negative impact on environmental quality. The increase in the economic activities to a limited extent causes the enhanced energy consumption and the use of technology which increases the amount of CO2 emission and reduces the environmental quality. These results are supported by the previous study of Su et al. (2021). This study elaborates the effects of EG on the environmental quality and mental health of living beings during the COVID-19 pandemic. According to the results of this study, the countries where there is more productivity and transportation are suffering from

the unpleasant atmosphere and bad environmental quality. The results of the current study have also indicated that EG² has a positive influence on environmental quality. The large increment in the economic activities reduces the emission of CO2 and is helpful in enhancing the environmental quality. These results are approved by the past study of Abbasi et al. (2021), which shows that the highly increased economic development encourages energy efficiency or the use of renewable energy resources for commercial purposes. Thus, it is possible to reduce CO2 emission and improve environmental quality.

Conclusion and policy recommendations

Despite extensive research on CO2 emissions and their primary contributors, little evidence was provided on the effects of eco-innovation and tourism on CO2 emission. Theoretically and empirically, the study bridged a gap existing in the literature by providing an integration of tourism and eco-innovation within the EKC model. The main purpose was to empirically analyze the validation of the EKC hypothesis in six ASEAN economies (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) over the period 1995 to 2018 by using carbon dioxide emission per capita as a measurement for environmental degradation and a measure of ambient air quality. The econometric model was based on the Grossman and Krueger (1991) model expanded to accommodate the role of tourism and eco-innovations on the EKC. In this regard, after applying preliminary tests of CSD and slope heterogeneity, the stationarity of the variables was checked by applying CIPS and M-CIPS. After confirming the cross-sectional dependence and heterogeneity among the variables, Westerlund and Edgerton (2008) and Banerjee and Carrion-i-Silvestre (2017) co-integration analysis has been applied, which show that co-integration exists among the variables. In order to estimate the long-run and short-run results, cross-sectional auto distributive lag model was applied, and the results were confirmed by robust techniques of AMG and CCEMG. The results revealed that there exists a significantly negative nexus between eco-innovations and

CO₂ emissions in the selected ASEAN countries. In the same vein, tourism (tourist arrivals) was also found to have a negative impact on CO₂ emissions. Moreover, the results also provided evidence of the EKC and therefore supported the EKC hypothesis in the selected ASEAN countries.

On the basis of the preceding conclusions, a number of policies were proposed for carbon emissions reduction. It is critical for governments to encourage businesses to pursue innovations and innovative activities on their own. Increased public R&D initiatives are also required. The findings of the study indicate that economic development in these countries will not jeopardize environmental quality. This suggests that these countries should increase their real income in order to improve their environmental standards. The Green Energy Policy Initiative is a positive step forward. The policy concept has huge environmental sustainability potential. However, the implications of this study may not apply to other environmental quality indicators such as sulfur and nitrogen oxides, as well as some natural resource extraction. As a result, comprehensive environmental policies are required for long-term growth.

Furthermore, increasing the number of tourist arrivals can be an excellent approach to stimulate EG and, as a result, reduce CO₂ emissions. It is suggested that policymakers should make strong efforts to attract international tourists and promote the international representation of the country at a number of tourism exhibitions or through the media. It will lead to both economic and environmental benefits.

Limitations of the study and future research

Despite the value of our findings, there are several caveats to be aware of. First, our findings for ASEAN countries are not generalizable as the “one size fits all” EKC forecast is in contrast to the evidence of diverse experiences of individual countries, as determined by List and Gallet (1999). Therefore, replicating our research on EKC validation in other underdeveloped economies (such as Pakistan, India, Brazil, Turkey) would be a promising area for future research, which are also facing the dual condition of protection of the environment and tourism led growth simultaneously. There is significant scope to empirically investigate these issues in other popular tourist destinations. Second, despite the fact that the environmental measure we used (i.e., CO₂ emissions) is identified as one of the primary pollutants, we accept that the results of an EKC estimation can be different for the type of pollutant evaluated. It means that various contaminants in the air and water can differently react in relation to economic growth. As a result, considering various indicators of environmental pollution or other types of environmental deterioration as a result of tourism expansion gives another possible extension. In addition, not only tourism and eco-innovations but also the other economic sectors

can also be taken into consideration if they are contributed to mitigate CO₂ emission and help improve environment stability. Because of the limits of data availability, the data of this study spans 1995 to 2018. Future research can cover a longer period with a wider scope.

Author contribution Zhao Wei: conceptualization, data curation, writing—original draft, and visualization. Huang Lihua: writing—review and editing and software, visualization, supervision, methodology, and data curation.

Data availability The data that support the findings of this study are attached.

Declarations

Ethics approval and consent to participate The authors declare that they have no known competing financial interests or personal relationships that seem to affect the work reported in this article. We declare that we have no human participants, human data, or human tissues.

Consent for publication Not applicable.

Competing interest The authors declare no competing interests.

References

- Abbas J, Hussain I, Hussain S, Akram S, Shaheen I, Niu B (2019a) The impact of knowledge sharing and innovation on sustainable performance in Islamic banks: a mediation analysis through a SEM approach. *Sustainability* 11(15):4049. <https://doi.org/10.3390/su11154049>
- Abbas J, Mubeen R, Iorember PT, Raza S, Mamirkulova G (2021a) Exploring the impact of COVID-19 on tourism: transformational potential and implications for a sustainable recovery of the travel and leisure industry. *Curr Res Behav Sci* 2:100033. <https://doi.org/10.1016/j.crbeha.2021.100033>
- Abbas J, Raza S, Nurunnabi M, Minai MS, Bano S (2019b) The impact of entrepreneurial business networks on firms' performance through a mediating role of dynamic capabilities. *Sustainability* 11(11):3006. <https://doi.org/10.3390/su11113006>
- Abbas J, Wang D, Mubeen R, Maqsood A (2021b) Global health crisis, smart lockdown, and the COVID-19 spillover impacts: a global perspective implications from Southeast Asia. *Front Psych* 12:1099. <https://doi.org/10.3389/fpsy.2021.643783>
- Abbas J, Wang D, Su Z, Ziapour A (2021) The role of social media in the advent of COVID-19 pandemic: crisis management, mental health challenges and implications. *Risk Manag Healthc Policy* 14:1917. <https://doi.org/10.2147/RMHP.S284313>
- Abbasi K, Adedoyin FF, Abbas J, Hussain K (2021) The impact of energy depletion and renewable energy on CO₂ emissions in Thailand: fresh evidence from the novel dynamic ARDL simulation. *Renewable Energy*. <https://doi.org/10.1016/j.renene.2021.08.078>
- Adewumi SA (2020) Challenges and prospects of rural entrepreneurship: a discourse analysis of selected local government areas of Osun state, Nigeria. *Int J Bus Manag Stud* 12(2):544–560
- Ahmad M, Jiang P, Murshed M, Shehzad K, Akram R, Cui L, Khan Z (2021) Modelling the dynamic linkages between eco-innovation, urbanization, economic growth and ecological footprints for G7

- countries: does financial globalization matter? *Sustainable Cities and Society* 70:102881
- Ahmad M, Khan Z, Rahman ZU, Khattak SI, Khan ZU (2021b) Can innovation shocks determine CO₂ emissions (CO₂e) in the OECD economies? A new perspective. *Econ Innov New Technol* 30(1):89–109
- Alege PO, Ogundipe AA (2015) Environmental quality and economic growth in Nigeria: a fractional cointegration analysis. *Int J Dev Sustain* 2(2)
- Ali W, Abdullah A, Azam M (2016) The dynamic linkage between technological innovation and carbon dioxide emissions in Malaysia: an autoregressive distributed lagged bound approach. *Int J Energy Econ Policy* 6(3):389–400
- Aman J, Abbas J, Mahmood S, Nurunnabi M, Bano S (2019) The influence of Islamic religiosity on the perceived socio-cultural impact of sustainable tourism development in Pakistan: a structural equation modeling approach. *Sustainability* 11(11):3039. <https://doi.org/10.3390/su11113039>
- Andreoni J, Levinson A (2001) The simple analytics of the environmental Kuznets curve. *J Public Econ* 80(2):269–286
- Apergis N, Payne JE (2009) CO₂ emissions, energy usage, and output in Central America. *Energy Policy* 37(8):3282–3286
- Araim H, Han L, Sharif A, Meo MS (2020) Investigating the effect of inbound tourism on FDI: the importance of quantile estimations. *Tour Econ* 26(4):682–703
- Atalan A (2020) Is the lockdown important to prevent the COVID-19 pandemic? Effects on psychology, environment and economy-perspective. *Annals of Medicine and Surgery* 56:38–42. <https://doi.org/10.1016/j.amsu.2020.06.010>
- Azizi MR, Atlasi R, Ziapour A, Abbas J, Naemi R (2021) Innovative human resource management strategies during the COVID-19 pandemic: a systematic narrative review approach. *Heliyon* e07233. <https://doi.org/10.1016/j.heliyon.2021.e07233>
- Bai J, Carrion-i-Silvestre JL (2009) Structural changes, common stochastic trends, and unit roots in panel data. *Rev Econ Stud* 76(2):471–501
- Bai J, Ng S (2004) A PANIC attack on unit roots and cointegration. *Econometrica* 72(4):1127–1177
- Baloch ZA, Tan Q, Kamran HW, Nawaz MA, Albashar G, Hameed J (2021) A multi-perspective assessment approach of renewable energy production: policy perspective analysis. *Environ Dev Sustain* 1–29. <https://doi.org/10.1007/s10668-021-01524-8>
- Banerjee A, Carrion-i-Silvestre JL (2017) Testing for panel cointegration using common correlated effects estimators. *J Time Ser Anal* 38(4):610–636
- Bekhet HA, Othman NS, Yasmin T (2020) Interaction between environmental Kuznet curve and urban environment transition hypotheses in Malaysia. *International Journal of Energy Economics and Policy* 10(1):384
- Bello PO, John-Langba J (2020) University students and police legitimacy: the South African Police Service before the loudspeaker. *International Journal of Business and Management Studies* 12(2):306–320
- Ben Jebli M, Hadhri W (2018) The dynamic causal links between CO₂ emissions from transport, real GDP, energy use and international tourism. *Int J Sust Dev World* 25(6):568–577
- Braungardt S, Elstrand R, Eichhammer W (2016) The environmental impact of eco-innovations: the case of EU residential electricity use. *Environ Econ Policy Stud* 18(2):213–228
- Chien F, Kamran HW, Nawaz MA, Thach NN, Long PD, Baloch ZA (2021a) Assessing the prioritization of barriers toward green innovation: small and medium enterprises Nexus. *Environ Dev Sustain*. <https://doi.org/10.1007/s10668-021-01513-x>
- Chien F, Ananzeh M, Mirza F, Bakar A, Vu HM, Ngo TQ (2021b) The effects of green growth, environmental-related tax, and eco-innovation towards carbon neutrality target in the US economy. *J Environ Manage*. <https://doi.org/10.1016/j.jenvman.2021.113633>
- Chien F, Pantamee AA, Hussain MS, Chupradit S, Nawaz MA, Mohsin M (2021c) Nexus between financial innovation and bankruptcy: evidence from information, communication and technology (ict) sector. *The Singapore Economic Review*, 1–22.
- Chien F, Sadiq M, Kamran HW, Nawaz MA, Hussain MS, Raza M (2021d) Co-movement of energy prices and stock market return: environmental wavelet nexus of COVID-19 pandemic from the USA, Europe, and China. *Environmental Science and Pollution Research*, 1–15. <https://doi.org/10.1007/s11356-021-12938-2>
- Chien F, Sadiq M, Nawaz MA, Hussain MS, Tran TD, Le Thanh T (2021e) A step toward reducing air pollution in top Asian economies: the role of green energy, eco-innovation, and environmental taxes. *J Environ Manage* 297. <https://doi.org/10.1016/j.jenvman.2021.113420>
- Chien F, Zhang Y, Sadiq M, Hsu CC (2021f) Financing for energy efficiency solutions to mitigate opportunity cost of coal consumption: an empirical analysis of Chinese industries. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-021-15701-9>
- Cristófoli ME, Fronti JG (2020) Stress test bancarios: Selección de indicadores claves para la estabilidad financiera. *Cuadernos De Economía* 43(121):63–78
- Delbianco F, Dabús C (2020) Is there Convergence in Emerging Countries? Evidence from Latin America. *Cuadernos de Economía* 43(121):79–90. <https://doi.org/10.32826/cude.v43i121.87>
- Dlalis SF, Govender DW (2020) Challenges of acceptance and usage of a learning management system amongst academics. *International Journal of Ebusiness and Egovernment Studies* 12(1):63–78. <https://doi.org/10.34111/ijebe.202012105>
- De Vita G, Katircioglu S, Altinay L, Fethi S, Mercan M (2015) Revisiting the environmental Kuznets curve hypothesis in a tourism development context. *Environ Sci Pollut Res* 22(21):16652–16663
- Dobnik F (2011) Energy consumption and economic growth revisited: structural breaks and cross-section dependence. Available at SSRN 1981869
- Dogan E, Seker F (2016) An investigation on the determinants of carbon emissions for OECD countries: empirical evidence from panel models robust to heterogeneity and cross-sectional dependence. *Environ Sci Pollut Res* 23(14):14646–14655
- Du K, Li P, Yan Z (2019) Do green technology innovations contribute to carbon dioxide emission reduction? Empirical evidence from patent data. *Technol Forecast Soc Chang* 146:297–303
- Eberhardt M, Bond S (2009) Cross-section dependence in nonstationary panel models: a novel estimator
- Eberhardt M, Teal F (2010) Productivity Analysis in Global Manufacturing Production
- Ehsanullah S, Tran QH, Sadiq M, Bashir S, Mohsin M, Iram R (2021) How energy insecurity leads to energy poverty? Do environmental consideration and climate change concerns matters. *Environmental Science and Pollution Research*. <https://doi.org/10.1007/s11356-021-14415-2>
- Fernández YF, López MF, Blanco BO (2018) Innovation for sustainability: the impact of R&D spending on CO₂ emissions. *J Clean Prod* 172:3459–3467
- Fethi S, Rahuma A (2019) The role of eco-innovation on CO₂ emission reduction in an extended version of the environmental Kuznets curve: evidence from the top 20 refined oil exporting countries. *Environ Sci Pollut Res* 26(29):30145–30153
- Garrone P, Grilli L (2010) Is there a relationship between public expenditures in energy R&D and carbon emissions per GDP? An Empirical Investigation. *Energy Policy* 38(10):5600–5613
- Geng Z, Kong X, Chen W, Su H, Liu Y, Cai F ... Zeng J (2018) Oxygen vacancies in ZnO nanosheets enhance CO₂ electrochemical

- reduction to CO. *Angew Chem* 130(21):6162–6167 <https://doi.org/10.1002/ange.201711255>
- Gormus S, Aydin M (2020) Revisiting the environmental Kuznets curve hypothesis using innovation: new evidence from the top 10 innovative economies. *Environ Sci Pollut Res* 27:27904–27913
- Grossman GM, Krueger AB (1991) Environmental impacts of a North American free trade agreement: National Bureau of economic research Cambridge. Mass, USA
- Hassan A, Meyer D (2021) Financial development–income inequality nexus in South Africa: a nonlinear analysis. *International Journal of Economics and Finance Studies* 12(2):335–351. <https://doi.org/10.34109/ijefs.202012206>
- Hsu CC, Quang-Thanh N, Chien F, Li L, Mohsin M (2021) Evaluating green innovation and performance of financial development: mediating concerns of environmental regulation. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-021-14499-w>
- Huang SZ, Chau KY, Chien F, Shen H (2020) The impact of startups' dual learning on their green innovation capability: the effects of business executives' environmental awareness and environmental regulations. *Sustainability* 12(16):1–17
- Huang SZ, Sadiq M, Chien F (2021) The impact of natural resource rent, financial development, and urbanization on carbon emission. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-021-16818-7>
- Hussain T, Abbas J, Wei Z, Ahmad S, Xuehao B, Gaoli Z (2021) Impact of urban village disamenity on neighboring residential properties: empirical evidence from Nanjing through hedonic pricing model appraisal. *Journal of Urban Planning and Development* 147(1):04020055. [https://doi.org/10.1061/\(asce\)up.1943-5444.0000645](https://doi.org/10.1061/(asce)up.1943-5444.0000645)
- Jula D, Dumitrescu C-I, Lie I-R, Dobrescu R-M (2015) Environmental Kuznets curve. Evidence from Romania. *Theoretical & Applied Economics* 22(1)
- Kennedy PL, Schmitz A, DeLong KL (2020) Biotechnology and demand concerns: the case of genetically modified US sugar beets. *AgBioforum* 22(1):49–60
- Kiliç C, Balan F (2018) Is there an environmental Kuznets inverted-U shaped curve? *Panoeconomicus* 65(1):79–94
- Koçak E, Ulucak R, Ulucak ZŞ (2020) The impact of tourism developments on CO2 emissions: an advanced panel data estimation. *Tourism Management Perspectives*. <https://doi.org/10.1016/j.tmp.2019.100611>
- Le HP, Ozturk I (2020) The impacts of globalization, financial development, government expenditures, and institutional quality on CO 2 emissions in the presence of environmental Kuznets curve. *Environ Sci Pollut Res* 27(18):22680–22697
- Lee C-C, Chen M-P, Peng Y-T (2020) Tourism development and happiness: International evidence. *Tourism Economics* 1354816620921574
- Lee C-C, Olasehinde-Williams GO, Ibikunle JA (2021) An asymmetric examination of the environmental effect of tourism in China. *Tourism Economics* 13548166211021173
- Lee JW, Brahmasrene T (2013) Investigating the influence of tourism on economic growth and carbon emissions: Evidence from panel analysis of the European Union. *Tour Manage* 38:69–76
- Li S, Lv Z (2021) Do spatial spillovers matter? Estimating the impact of tourism development on CO 2 emissions. *Environ Sci Pollut Res* 1–18
- Li W, Chien F, Hsu C-C, Zhang Y, Nawaz MA, Iqbal S, Mohsin M (2021a) Nexus between energy poverty and energy efficiency: estimating the long-run dynamics. *Resources Policy* 72. <https://doi.org/10.1016/j.resourpol.2021.102063>
- Li W, Chien F, Kamran HW, Aldeehani TM, Sadiq M, Nguyen VC, Taghizadeh-Hesary F (2021) The nexus between COVID-19 fear and stock market volatility. *Economic Research-Ekonomska Istraživanja*. <https://doi.org/10.1080/1331677X.2021.1914125>
- Li J, Wang D, Duan K, Mubeen R (2021c) Tourists' health risk threats amid COVID-19 era: role of technology innovation, transformation, and recovery implications for sustainable tourism. *Front Psychol* 12:769175. <https://doi.org/10.3389/fpsyg.2021.769175>
- List JA, Gallet CA (1999) The environmental Kuznets curve: does one size fit all? *Ecol Econ* 31(3):409–423
- Liu Z, Tang YM, Chau KY, Chien F, Iqbal W, Sadiq M (2021a) Incorporating strategic petroleum reserve and welfare losses: a way forward for the policy development of crude oil resources in South Asia. *Resour Policy*. <https://doi.org/10.1016/j.resourpol.2021.102309>
- Liu F, Wang D, Duan K, Mubeen R (2021b) Social media efficacy in crisis management: effectiveness of non-pharmaceutical interventions to manage the COVID-19 challenges. *Front Psychiatry* 12(1099):626134. <https://doi.org/10.3389/fpsyg.2021.626134>
- Burden L, of Disease, H. I. V. C. (2021) Mapping subnational HIV mortality in six Latin American countries with incomplete vital registration systems. *BMC Med* 19(1):4. <https://doi.org/10.1186/s12916-020-01876-4>
- Mamirkulova G, Mi J, Abbas J, Mahmood S, Mubeen R, Ziapour A (2020) New silk road infrastructure opportunities in developing tourism environment for residents better quality of life. *Global Ecology and Conservation* 24:e01194. <https://doi.org/10.1016/j.gecco.2020.e01194>
- Mohsin M, Kamran HW, Nawaz MA, Hussain MS, Dahri AS (2021) Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies. *J Environ Manage* 284. <https://doi.org/10.1016/j.jenvman.2021.111999>
- Mongo M, Belaid F, Ramdani B (2021) The effects of environmental innovations on CO2 emissions: empirical evidence from Europe. *Environ Sci Policy* 118:1–9
- Mosala K, Chinomona E (2020) Motorists attitudes towards implementation of E-tolls in Gauteng Province, South Africa. *International Journal Of Ebusiness And Egovernment Studies* 12(1):48–62. <https://doi.org/10.34111/ijebeg.202012104>
- Naradda Gamage SK, Hewa Kurupuge R, Haq IU (2017) Energy consumption, tourism development, and environmental degradation in Sri Lanka. *Energy Sources Part B* 12(10):910–916
- Nawaz MA, Hussain MS, Kamran HW, Ehsanullah S, Maheen R, Shair F (2021a) Trilemma association of energy consumption, carbon emission, and economic growth of BRICS and OECD regions: quantile regression estimation. *Environ Sci Pollut Res* 28(13):16014–16028
- Nawaz MA, Seshadri U, Kumar P, Aqdas R, Patwary AK, Riaz M (2021b) Nexus between green finance and climate change mitigation in N-11 and BRICS countries: empirical estimation through difference in differences (DID) approach. *Environ Sci Pollut Res* 28(6):6504–6519. <https://doi.org/10.1007/s11356-020-10920-y>
- Omotor DG (2017) Economic growth and emissions: testing the environmental kuznets curve hypothesis for ECOWAS countries. *West African Journal of Monetary and Economic Integration* 17(2):25–56
- Othman Z, Nordin MFF, Sadiq M (2020) GST fraud prevention to ensure business sustainability: a Malaysian case study. *Journal of Asian Business and Economic Studies* 27(3):245–265
- Ozigbu J (2019) Evaluating the validity of environmental Kuznets curve hypothesis: empirical evidence from Nigerian Economy. *Journal of Humanities and Social Science* 24(10):16–24
- Paramati SR, Alam MS, Chen C-F (2017) The effects of tourism on economic growth and CO2 emissions: a comparison between developed and developing economies. *J Travel Res* 56(6):712–724
- Paulson KR, Kamath AM, Alam T, Bienhoff K, Abady GG, ... Kassebaum NJ (2021) Global, regional, and national progress towards sustainable development goal 3.2 for neonatal and child health:

- all-cause and cause-specific mortality findings from the Global Burden of Disease Study 2019. *The Lancet*, 398. [https://doi.org/10.1016/s0140-6736\(21\)01207-1](https://doi.org/10.1016/s0140-6736(21)01207-1)
- Pesaran MH (2006) Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica* 74(4):967–1012
- Pesaran MH, Schuermann T, Weiner SM (2004) Modeling regional interdependencies using a global error-correcting macroeconomic model. *Journal of Business & Economic Statistics* 22(2):129–162
- Pesaran MH, Yamagata T (2008) Testing slope homogeneity in large panels. *Journal of Econometrics* 142(1):50–93
- Porter M, Van der Linde C (1995) Green and competitive: ending the stalemate. *The Dynamics of the Eco-Efficient Economy: Environmental Regulation and Competitive Advantage* 33:120–134
- Raza SA, Sharif A, Wong WK, Karim MZA (2017) Tourism development and environmental degradation in the United States: evidence from wavelet-based analysis. *Curr Issue Tour* 20(16):1768–1790
- Roca J, Padilla E, Farré M, Galletto V (2001) Economic growth and atmospheric pollution in Spain: discussing the environmental Kuznets curve hypothesis. *Ecol Econ* 39(1):85–99
- Sadiq M, Hsu CC, Zhang Y, Chien FS (2021a) COVID-19 fear and volatility index movements: empirical insights from ASEAN stock markets. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-021-15064-1>
- Sadiq M, Nonthapot S, Mohamad S, Keong OC, Ehsanullah S, Iqbal N (2021) Does green finance matters for sustainable entrepreneurship and environmental corporate social responsibility during Covid-19? *China Finance Review International*. <https://doi.org/10.1108/CFRI-02-2021-0038>
- Santra S (2017) The effect of technological innovation on production-based energy and CO2 emission productivity: evidence from BRICS countries. *Afr J Sci Technol Innov Dev* 9(5):503–512
- Sargan, J. D., & Bhargava, A. (1983). Testing residuals from least squares regression for being generated by the Gaussian random walk. *Econometrica: Journal of the Econometric Society*, 153–174.
- Sgammini M, Muzindutsi PF (2020) Effect of exchange rate movements on the performance of investment portfolios in South Africa. *International Journal of Economics and Finance Studies* 12(2):469–486. <https://doi.org/10.34109/ijefs.202012214>
- Shaari MS, Abdullah DNC, Alias NS, Adnan NSM (2016) Positive and negative effects of research and development. *International Journal of Energy Economics and Policy* 6(4)
- Shair F, Shaorong S, Kamran HW, Hussain MS, Nawaz MA (2021) Assessing the efficiency and total factor productivity growth of the banking industry: do environmental concerns matters? *Environ Sci Pollut Res* 28(16):20822–20838
- Sharif A, Afshan S, Nisha N (2017) Impact of tourism on CO2 emission: evidence from Pakistan. *Asia Pacific Journal of Tourism Research* 22(4):408–421
- Soytas U, Sari R, Ewing BT (2007) Energy consumption, income, and carbon emissions in the United States. *Ecol Econ* 62(3–4):482–489
- Su, C.-W., Umar, M., & Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote renewable energy consumption? Analyzing the role of political risk. *Science of The Total Environment*, 751, 142220.
- Su Z, McDonnell D, Wen J, Kozak M, Abbas J, Šegalo S ... Cai Y (2021) Mental health consequences of COVID-19 media coverage: the need for effective crisis communication practices. *Globalization and health* 17(1), 1–8. <https://doi.org/10.1186/s12992-020-00654-4>
- Sun H, Awan RU, Nawaz MA, Mohsin M, Rasheed AK, Iqbal N (2020) Assessing the socio-economic viability of solar commercialization and electrification in south Asian countries. *Environ Dev Sustain* 1–23. <https://doi.org/10.1007/s10668-020-01038-9>
- Vermeulen H, Gouse M, Delpont M, Louw M, Miller T (2020) Consumer acceptance of sugar derived from genetically modified sugarcane in South Africa. *AgBioforum* 22(1):1–12
- Wang C, Wang D, Duan K, Mubeen R (2021) Global financial crisis, smart lockdown strategies, and the COVID-19 spillover impacts: a global perspective implications from Southeast Asia. *Front Psychiatry* 12:1–14. <https://doi.org/10.3389/fpsy.2021.643783>
- Wang C-M, Wu T-P (2021) Does tourism promote or reduce environmental pollution? Evidence from major tourist arrival countries. *Environment, Development and Sustainability* 1–22
- Wang M-C, Wang C-S (2018) Tourism, the environment, and energy policies. *Tour Econ* 24(7):821–838
- Westerlund J (2007) Testing for error correction in panel data. *Oxford Bull Econ Stat* 69(6):709–748
- Westerlund J, Edgerton DL (2008) A simple test for cointegration in dependent panels with structural breaks. *Oxford Bull Econ Stat* 70(5):665–704
- Xiang H, Ch P, Nawaz MA, Chupradit S, Fatima A, Sadiq M (2021) Integration and economic viability of fueling the future with green hydrogen: an integration of its determinants from renewable economics. *Int J Hydrogen Energy*. <https://doi.org/10.1016/j.ijhydene.2021.09.067>
- Xueying W, Sadiq M, Chien F, Ngo TQ, Nguyen AT (2021) Testing role of green financing on climate change mitigation: evidences from G7 and E7 countries. <https://doi.org/10.1007/s11356-021-15023-w>
- Zaman K, Shahbaz M, Loganathan N, Raza SA (2016) Tourism development, energy consumption and environmental Kuznets curve: trivariate analysis in the panel of developed and developing countries. *Tour Manage* 54:275–283
- Zhang Y, Khan SAR, Kumar A, Golpira H, Sharif A (2019) Is tourism really affected by logistical operations and environmental degradation? An empirical study from the perspective of Thailand. *J Clean Prod* 227:158–166
- Zhuang Y, Yang S, Chupradit S, Nawaz MA, Xiong R, Koksai C (2021) A nexus between macroeconomic dynamics and trade openness: moderating role of institutional quality. *Bus Process Manag J*. <https://doi.org/10.1108/BPMJ-12-2020-0594>

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