Global Sustainability Research
https://doi.org/10.56556/gssr.v1i2.408
ISSN: 2833-986X

RESEARCH ARTICLE

Toward environmental sustainability: Nexus between tourism, economic growth, energy use and carbon emissions in Singapore

Asif Raihan[1*], Dewan Ahmed Muhtasim[2], Sadia Farhana[3], Md Ahsan Ul Hasan[2], Omar Faruk[2], Arindrajit Paul[2]

[1]Institute of Climate Change, Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia
[2]Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia
[3] School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian 16150, Kelantan, Malaysia

*Corresponding author: asifraihan666@gmail.com, ORCID ID: 0000-0001-9757-9730
Received: 09 December, 2022, Accepted: 25 December, 2022, Published: 27 December, 2022

Abstract
Singapore is a renowned tourist destination; however, the country's rapid economic growth has led to rising energy consumption and carbon emissions. This study aims to examine the factors that contribute to carbon dioxide (CO_2) emissions in Singapore, including tourism, economic growth, and energy use. The dynamic ordinary least squares (DOLS) approach was used to analyze time series data from 1990 to 2020. The results of the empirical study revealed that the tourist coefficient is positive and significant. A 0.50% increase in CO_2 emissions relates to a 1% increase in tourism activities over time, according to the findings. In addition, the result indicates that the economy's long-run growth coefficient is significantly negative. This shows that a 1% economic growth will reduce CO_2 emissions by 0.03% in the long run. Furthermore, a positive and statistically significant correlation for energy consumption suggests that a long-term increase of 1% in energy consumption is associated with an increase of 0.88% in CO_2 emissions. To promote the emergence of sustainable development and a low-carbon economy, this article proposed policy recommendations addressing the reduction of emissions and the promotion of ecologically responsible and sustainable tourism while boosting the utilization of renewable energy technologies.

Keywords: CO_2 emissions; Sustainability; Tourism; Low-carbon economy; Renewable energy

Introduction

Most greenhouse gases (GHGs) in the atmosphere are CO_2, and humans are responsible for most of these emissions. Human activities that contribute to climate change include using fossil fuels for energy and cutting down trees (Raihan et al., 2018; Jaafar et al., 2020; Raihan et al., 2021a; Raihan et al., 2021b; Isfat & Raihan, 2022). CO_2 emissions are expected to have devastating effects on the global climate system and every area of human existence. Due to atmospheric carbon dioxide sensitivity, the global climate system is quite sensitive. This is because climate change is expected to be one of humanity's biggest issues in the next decades (Raihan et al., 2019; Raihan et al., 2022a; Islam et al., 2022). Thus, reducing carbon dioxide emissions and enhancing the environment are two of the most critical global issues that must be tackled immediately to promote sustainable growth and mitigate climate change (Raihan & Said, 2022; Raihan & Tuspekova, 2022a). As a small, lowland city-state with one of the world's most open economies, Singapore is especially vulnerable to climate change's negative effects (Raihan & Tuspekova, 2022b). Singapore has ratified several international conventions to limit its carbon emissions and mitigate climate change. The Kyoto Protocol and Paris Agreement are examples of these conventions. As a result, understanding the main elements that affect CO_2 concentrations is crucial to improving Singapore's environment. Tourism, energy security, economic growth, and environmental sustainability are all crucial in Southeast Asian countries like Singapore. If modern growth methods cannot be separated from natural resources, the ecosystem will degrade (Raihan et al., 2022b).

Sustainable tourism is garnering global attention due to the direct, indirect, and induced economic effects of the tourist industry’s expansion. Singapore, one of Asia's most industrialized nations, relies heavily on tourism (Katirciolu, 2014). Singapore's economy also benefits from tourism. More than three times the country's population visited Singapore in 2019. However, the tourism industry's key players' decisions are affected by its fragility. According to the UNWTO, worldwide travel will peak in 2030. Because of this, global revenue is expected to reach $2 billion every year (Raihan et al., 2022c). Tourism boosts economies worldwide (Voumik et al., 2022a). However, tourism increases the need for energy to power transportation, accommodation, and support facilities, as well as food production and tourist site management, all of which can harm the environment (Raihan & Tuspekova, 2022c). The UNWTO estimates that tourism accounts for 5% of global emissions. Seventy-five percent of tourism emissions come from transportation, while twenty percent come from accommodations (Raihan & Tuspekova, 2022d). As a result, when economy and transportation activities are included, the country's energy usage illuminates the link between tourism growth and CO_2 emissions (Raihan & Tuspekova, 2022e). Tourism's importance in economic growth, particularly in Singapore, has been ignored in emission models due to the idea that tourism drives economic growth. Singapore has become one of the world's wealthiest nations due to its economy's rapid growth in recent decades. In 2019, Singapore's GDP per capita was USD 61174, ranking third worldwide (World Bank, 2022). However, whether unfettered economic growth harms the environment and generates enough cash to pay for environmental protection affects environmental development and sustainability plans. Environmental development and sustainability plans will be rescinded if unfettered economic growth harms the environment (Raihan et al., 2022d). Conversely, the environment could be improving due to the economy's ongoing replacement of polluting technologies with cleaner ones (Raihan & Tuspekova, 2022f). Because of this, assessing if Singapore's economic growth is linked to environmental sustainability is one of the most important things to undertake. Singapore's amazing economic growth is also linked to an increase in energy consumption and tourism. Due to its various energy resources, fast industrialization, and rising tourism Singapore's economy is one of the world's strongest. Singapore's growing energy needs can only be fulfilled by burning a range of fossil fuels (Mehmood, 2021). Singapore's rising dependence on fossil fuels for energy has increased CO_2 emissions and degraded the environment. Due to rising energy needs, As a result, there is widespread concern about rising emission intensity, especially in the energy sector. Thus, climate change has exacerbated Singapore's energy conservation debate. Because of this, it is more important than ever to understand how tourism, energy consumption, economic growth, and CO_2 emissions are linked.

However, despite the fact that the interplay between CO_2 emissions and their causes has recently been a prominent issue of discussion among researchers worldwide, only a small amount of research has been done in Singapore. To fill this research gap, the present study used econometric approaches to examine the dynamic effects of tourism, economic growth, and energy consumption on Singapore's CO_2 emissions. This study contributes to both the existing literature and Singapore's policymaking process. To be more explicit, the current study fills a research gap in the academic literature by conducting a comprehensive econometric analysis of CO_2 and its determinants in Singapore. The findings may give readers from diverse countries new ideas on environmental dynamics and sustainable management. Time series statistical features and long-term correlations among determinants are shown in this study. The study's findings would provide decision-makers with more complete and relevant statistics to establish successful policies in sustainable and environmentally friendly tourism, a green and low-carbon economy, and renewable energy development. These strategies may lessen climate change and carbon dioxide emissions. This research also aids in analyzing environmental laws and creating new ones. This will help Singapore prepare for global warming's effects. The guidance may also reinforce policies and action plans to mitigate climate change, ensuring long-term sustainable development and environmental quality.

The rest of the article is structured as follows. The Introduction is followed by the section Literature Review, where relevant research studies have been discussed. The third section is the Methodology section, followed by the Results and Discussion section. Subsequently, the last section presents the Conclusion, policy recommendations, limitations of the study, and future research directions.

Literature Review

The association between economic progress, energy usage, and pollution has been thoroughly documented in empirical investigations. A variety of research including numerous countries, factors, and methodologies were considered. Raihan et al. (2022e) revealed the positive effects of economic growth and energy use on CO_2 emissions In Bangladesh utilizing the DOLS, FMOLS, and CCR methods using the data over 1972-2018. Odugbesan and Adebayo (2020) found the positive impacts of economic growth and energy consumption on CO_2 emissions in Nigeria by utilizing the yearly data spanning from 1981 to 2016 employing ARDL, FMOLS, and DOLS techniques. Adebayo and Kalmaz (2021) used ARDL, FMOLS, and DOLS methods to uncover a positive interaction between economic growth and energy use on CO_2 emissions in Egypt by using the data from 1971 to 2014. By employing the ARDL approach, Nondo and Kahsai (2020) revealed the positive effects of economic growth and energy intensity on CO_2 emissions in South Africa from 1970 to 2016. Liu and Bae (2018) revealed the positive effects of economic growth and energy consumption on CO_2 emissions in China from 1970 to 2015 applying the ARDL method. By using time series data over 1985-2013 for 20 African countries, Raheem and Ogebe (2017) found that economic growth and energy use increases CO_2 emissions. By utilizing FMOLS and DOLS estimators using the data from 1971-2014, Vo et al. (2019) revealed that the level of CO_2 emissions is positively associated with economic growth and energy use in five ASEAN nations (Indonesia, Myanmar, Malaysia, the Philippines, and Thailand).

The influence of tourism on environmental degradation has been a frequent issue of controversy in recent years. Raihan and Tuspekova (2022c) revealed the positive effect of economic growth and tourism on CO_2 emissions in India by applying the DOLS, FMOLS, and CCR methods utilizing the data from 1990 to 2020. By utilizing the ARDL model for Pakistan using time series data from 1981 to 2017, Ali et al. (2020) found that economic growth, energy use, and tourism positively influence CO_2 emissions. Raihan and Tuspekova (2022d) revealed the positive effect of economic growth and tourism on CO_2 emissions in Turkey by applying the DOLS, FMOLS, and CCR methods utilizing the data from 1990 to 2020. By employing the DOLS, FMOLS, and CCR approaches using time series data covering 1990-2019, Raihan et al. (2022c) reported that economic growth and tourism increase CO_2 emissions in Argentina. Ng et al. (2015) found positive impacts of economic growth, energy use, and tourism on CO_2 emissions by employing the ARDL technique for Malaysia using the data over 1981-2011. By employing DOLS, FMOLS, and CCR techniques utilizing the data from 1990 to 2019 for Brazil, Raihan and Tuspekova (2022e) revealed that economic growth, energy use, and tourism have a positive impact on CO_2 emissions.

Furthermore, Ahmad et al. (2019) reported the positive effects of economic growth, energy use, and tourism on CO_2 emissions in Indonesia and the Philippines by applying the FMOLS technique utilizing the data over 1995-2014. Selvanathan et al. (2021) utilized the ARDL methodology to discover a positive effect of economic growth, energy use, and tourism on CO_2 emissions in South Asian countries using data over the period of 1990-2014. By applying DOLS, FMOLS, and CCR estimators using the yearly data spanning between 1990 and 2019, Raihan and Tuspekova (2022g) found that economic growth, energy use, and tourism influence CO_2 emissions positively in Mexico. In addition, Raihan and Tuspekova (2022h) used DOLS, FMOLS, and CCR methods to uncover a positive interaction between economic growth and energy use on CO_2 emissions in Kazakhstan by using the data from 1996 to 2020. By employing the DOLS technique using yearly data between 1995 and 2010, Dogan et al. (2017) reported that economic growth, energy use, and tourism trigger CO_2 emissions in OECD countries. By employing the DOLS, FMOLS, and CCR approaches using time series data covering 1990-2019, Raihan and Tuspekova (2022i) reported that economic growth and energy use increase CO_2 emissions in Nepal. In addition, Zaman et al. (2016) reported that economic growth and tourism positively influence CO_2 emissions in the panel of three diversified World regions including East Asia & Pacific, the European Union, and High-income OECD and Non-OECD countries. However, the review of empirical literature indicates that there is a scarcity of research on the relationship between CO_2 emissions and its determinants in the case of Singapore, although it has become a hot topic among current researchers worldwide. Therefore, the present study attempts to fill up the literature gap by investigating the dynamic impacts of economic growth, energy use, and tourism on CO_2 emissions in Singapore.

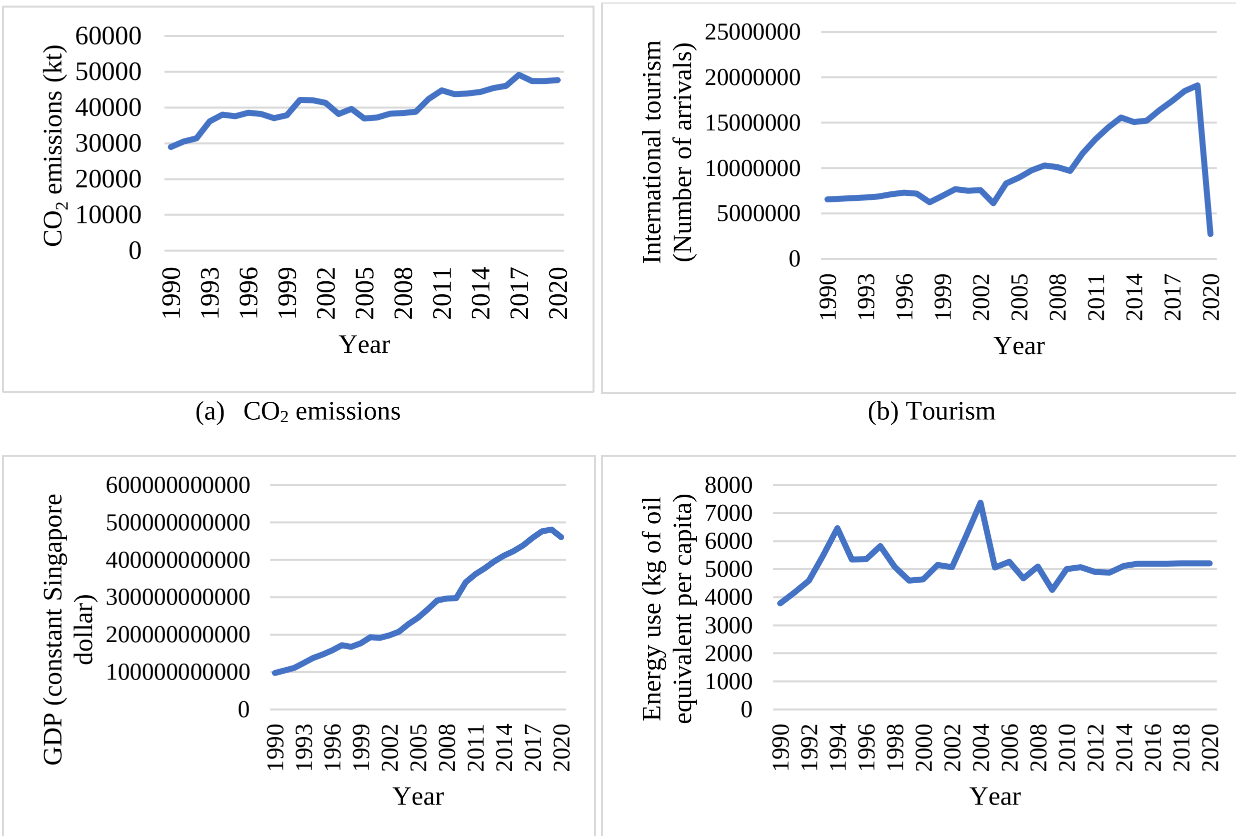
Methodology

Data

This study used the DOLS method of cointegration (Stock & Watson, 1993) because it may represent a continuous response variable as a function of one or more predictor components. It can be used to investigate experimental, economic, and environmental data and predict complex system behavior. Singapore is a popular tourist destination, and tourism increases energy demand, CO_2 emissions, and economic growth. Therefore, this study examined tourism, economic expansion, and energy consumption to determine how each of these factors affects CO_2 emissions. Time series data on Singapore from 1990 to 2020 were obtained from the World Development Indicator (WDI) dataset (World Bank, 2022). To assure a normal distribution, the variables are logarithmically converted for estimation. After logarithmically transforming the variables, organizing the features into a bell curve with more conventional proportions improves model fit. This lets us depict data more accurately. Table 1 lists variables, measuring units, logarithmic forms, and data sources. In addition, Figure 1 shows the study variables' annual trends.

Table 1. Logarithmic representations, units, and data sources of the variables

Variables	Description	Logarithmic forms	Units	Sources
C	CO_2 emissions	LC	Kilotons	WDI
T	International tourism	LT	Number of tourist arrivals	WDI
Y	Economic growth	LY	Constant Singapore dollar	WDI
E	Energy use	LE	Kg of oil equivalent per capita	WDI



(a) CO_2 emissions

(b) Tourism

(c) Economic growth

(d) Energy use

Figure 1. Singapore's yearly trends for the variables studied
Source: World Bank (2022)

Econometric strategies

In theory, tourism contributes to pollution and higher CO_2 emissions, which in turn are linked to rising energy use and a growing economy. This research aimed to estimate the impacts of tourism, economic growth, and energy consumption on CO_2 emissions by plugging relevant data into the following Equation (1) generated within the Marshallian demand function (Friedman, 1949) at time t:

$$C_t = f\,(T_t;\, Y_t;\, E_t) \tag{1}$$

Moreover, Equation (2) depicts the empirical model:

$$C_t = \tau_0 + \tau_1 T_t + \tau_2 Y_t + \tau_3 E_t \tag{2}$$

Further, it is possible to use Equation (2) as the econometric model in Equation (3):

$$C_t = \tau_0 + \tau_1 T_t + \tau_2 Y_t + \tau_3 E_t + \varepsilon_t \tag{3}$$

where τ_0 and ε_t stand for intercept and error term, respectively. In addition, τ_1, τ_2, and τ_3 denote the coefficients.
Furthermore, the logarithmic arrangement of Equation (3) can be expressed in Equation (4) as follows:

$$LC_t = \tau_0 + \tau_1 LT_t + \tau_2 LY_t + \tau_3 LE_t + \varepsilon_t \tag{4}$$

Figure 2 depicts a flow diagram of the analytical procedures employed in the study to investigate the nexus between tourism, economic growth, energy consumption, and CO_2 emissions in Singapore.

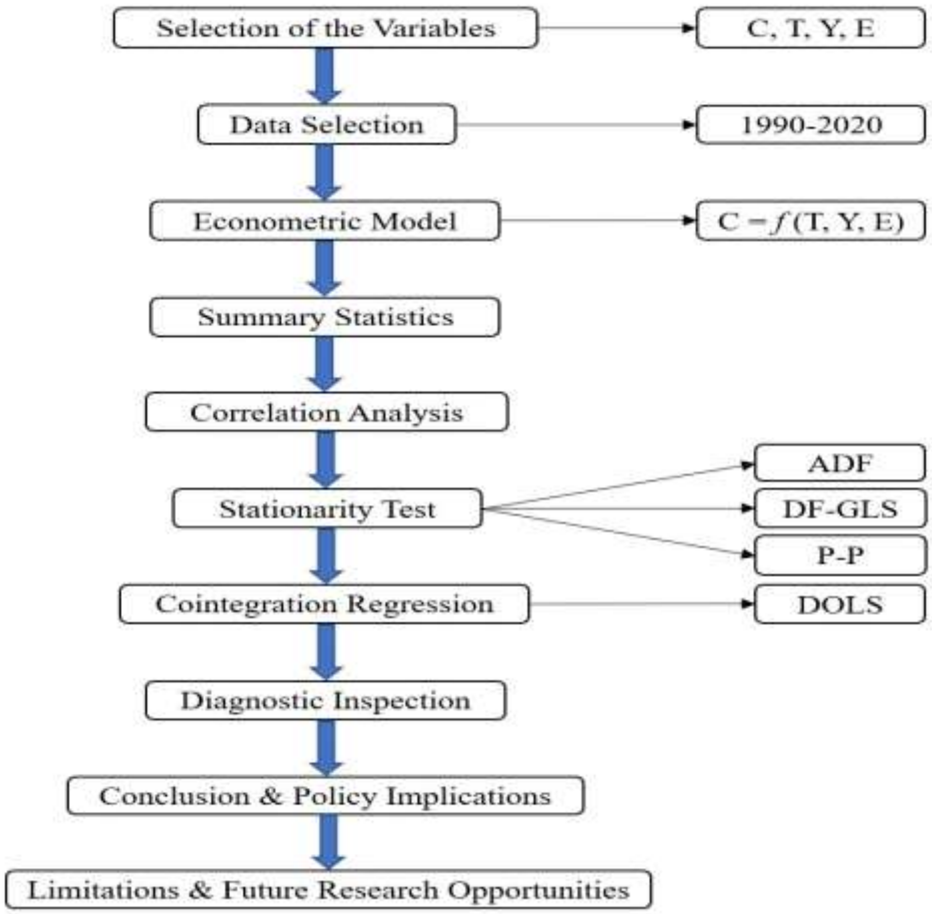


Figure 2. The flow chart of the analysis

Avoiding an incorrect regression requires testing the unit root (Raihan & Voumik, 2022a). First, differentiate the regression variables, then estimate the desired equation using stationary processes. This ensures the experiment's variables won't change (Raihan & Tuspekova, 2022h). In the empirical literature, the sequence of integration must be understood before determining cointegration. When defining the integration order of a series, several unit root tests are needed because their power depends on the sample size (Raihan & Tuspekova, 2022i). The current study used Dickey and Fuller's (1979) Augmented Dickey-Fuller (ADF) analysis, the DF-GLS test proposed by Elliott et al. (1996), and Phillips and Perron's (1998) P-P unit root test. These tests were aimed to find the autoregressive unit root (Raihan & Voumik, 2022b). In this study, the unit root test confirmed that no variable surpassed the order of integration and supported the DOLS methodology as an alternative to cointegration methods.

This study used DOLS to analyze time series data that includes initial difference term leads and lags. It also considers variables that explain outcomes. This is done to preserve endogeneity and compute standard deviations using a serial correlation-free covariance matrix of errors.

This ensures data accuracy. The DOLS method ensures that the predicted standard deviations were calculated correctly (Raihan and Tuspekova 2022j). The DOLS approach shows that the incorrect term has been orthogonalized by considering the words before and after each term. This can be achieved by comparing leading and trailing terms. The DOLS test can assess statistical significance as the DOLS estimator's standard deviations follow a normal asymptotic distribution (Raihan and Tuspekova 2022k). The DOLS method incorporates individual variables into the cointegrated framework in mixed-order integration. This can be done by estimating the dependent variable's value with respect to the explanatory components' levels, leads, and lags (Raihan et al., 2022e). The DOLS estimation's main strength is its cointegrated outline, which includes individual integration variables of a mixed order (Raihan et al., 2022f). In the DOLS technique of estimating, one of the I (1) components was regressed with the other variables, some of which were also I(1) variables with leads (p) and lags (-p) of the original difference, while others were I(0) variables with a constant term. This was done to determine which variable best described the relationship between the two sets of variables. Each aspect's value was carefully evaluated. These features were studied and contrasted before being grouped and summarized. By pooling explanatory component leads and lags, this estimate overcomes small sample bias, endogeneity, and autocorrelation (Begum et al., 2020). After determining that the variables under inquiry cointegrate, Equation (5) was used to estimate the DOLS long-run coefficient.

$$\Delta LC_t = \tau_0 + \tau_1 LC_{t-1} + \tau_2 LT_{t-1} + \tau_3 LY_{t-1} + \tau_4 LE_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LC_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LT_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LY_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LE_{t-i} + \varepsilon_t \quad (5)$$

where Δ is the first difference and q is the optimum lag length in the above Equation (5).

Results and Discussion

Skewness, kurtosis, probability, and Jarque-Bera normality tests are shown in Table 2. The kurtosis statistic was used to identify whether the series had light or heavy tails compared to the normal distribution. The empirical evidence shows that each series is platykurtic since every value is smaller than 3, the critical number. Skewness scores around zero suggest that all variables have met the normality premise. Low Jarque-Bera probabilities indicate normal parameters.

Table 2. Summary statistics of the variables

Variables	LC	LT	LY	LE
Mean	10.59614	16.04240	26.21635	8.539070
Median	10.56695	15.93525	26.22507	8.541262
Maximum	10.80243	16.76604	26.89910	8.905262
Minimum	10.27402	14.82420	25.30307	8.238199
Std. Dev.	0.129226	0.432733	0.497200	0.124795
Skewness	-0.584899	-0.224998	-0.201045	0.456229
Kurtosis	2.138226	2.290868	1.825116	2.865745
Jarque-Bera	1.792233	0.370839	1.991788	2.571713
Probability	0.408152	0.830756	0.369393	0.6061676
Sum	328.4804	497.3144	812.7069	264.7112

Table 3 shows the linearity of the variable connection. All parameters appear to be strongly correlated. This shows that when the first variable increases, so do the other variable. This inquiry used unit root tests to assess whether the variables were stationary based on correlation analysis.

Table 3. The results of the correlation analysis

	LC	LT	LY	LE
LC	1.000000	0.829646	0.882937	0.916525
LT	0.829646	1.000000	0.864545	0.927679
LY	0.882937	0.864545	1.000000	0.912535
LE	0.916525	0.927679	0.912535	1.000000

The autoregressive unit root was found using ADF, DF-GLS, and P-P techniques. Table 4 shows ADF, DF-GLS, and P-P unit root test results. Three unit root tests showed that variables were not stationary at the levels but became stationary at the first difference. Thus, the difference-oriented DOLS methodology is suitable for data analysis.

Table 4. The findings of unit root testing

Logarithmic form of the variables		LC	LT	LY	LE
ADF	Log levels	-2.3288	-1.8033	-2.4978	-2.0176
	Log first difference	-4.8421***	-2.7904**	-3.8153***	-5.9125***
DF-GLS	Log levels	-0.7277	-1.7846	-0.3732	-2.1862
	Log first difference	-4.7079***	-2.6944*	-3.9132***	-6.0523***
P-P	Log levels	-2.3158	-1.8033	-2.4979	-2.3458
	Log first difference	-4.8182***	-2.8369**	-3.7357***	-5.7726***

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 5 shows DOLS estimates. The long-run coefficient of LT, which is positive and statistically significant at the 1% level, shows that a 1% increase in tourism leads to a 0.50% increase in CO_2 emissions over time. This study found a strong correlation between Singapore's carbon dioxide emissions and tourist numbers. Tourism increases Singapore's air pollution, which worsens the environment. The study found that more visitors visiting Singapore increases energy usage and climate change. Since the research study's conclusions match those of other Singaporean studies, this discovery is not surprising. Zhang and Liu (2019) found that Singapore's carbon dioxide emissions increased with foreign tourists. In addition, research from other countries, such as Ng et al. (2015), Zaman et al. (2016), Dogan et al. (2017), Ahmad et al. (2019), Ali et al. (2020), Selvanathan et al. (2021), and Raihan et al. (2022c), supports the current study's conclusion that tourism and CO_2 emissions in Singapore are positively correlated. However, if tourism is not planned and controlled, it may harm the environment, which is vital to the tourism industry. Tsai et al. (2014) found that hotels with better service levels emit more CO_2 per guest. International tourism and travel spending increase carbon dioxide emissions in wealthy and developing nations (Zaman et al., 2016). Dogan et al. (2017) also revealed that tourism increases CO_2 emissions through various modes of transportation, touristic infrastructure development, and local government and commercial services. The travel and tourist business is a major contributor to the degrading environment. Tourism generates greenhouse gas emissions in transportation, energy, and heat production (Ng et al., 2015). Tourism harms the biophysical and sociocultural environment. Tourism releases smoke, sulfur dioxide, nitrogen oxides, and other hazardous pollutants into the atmosphere, deteriorating the environment. Tourist activities may damage the ecosystem, making the site less appealing. Waste mismanagement may turn a beautiful spot into the trash. Tourism also causes noise pollution from vehicles. The growth of the airline sector, hotel occupancy, and motorized boat use have all contributed to this issue (Raihan & Tuspekova, 2022b). Sustainable tourism is necessary to reduce tourism's negative impacts on society, the environment, the climate, and the economy.

Table 5. DOLS outcomes: dependent variable LCO2

Variables	Coefficient	Standard Error	t-Statistic	p-value
LT	0.498110***	0.314185	1.585401	0.0013
LY	-0.035536*	0.060398	-0.585401	0.0719
LE	0.880200***	0.329043	2.675034	0.0025
C	3.729782	1.843548	2.023155	0.1153
R^2	0.923172			
Adjusted R^2	0.902524			
Standard error of the estimate	0.057280			
Long run variance	0.007186			
Mean of the dependent variable	10.59614			
F-statistic	1129.36			
Prob (F-statistic)	0.000000			
Root mean square error (RMSE)	0.021297			
Mean Absolute Error (MAE)	0.018543			

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Singapore is used as a case study to see if economic production and environmental pollution are related. Despite LY's negative long-run coefficient, this discovery is statistically significant at 10%. This means that Singapore's CO_2 emissions will reduce by 0.03% for every 1% increase in economic development. This study found that economic growth did not harm the environment. The result shows that an expanding economy negatively impacts CO_2 emissions over time. The result showed that Singapore's ability to sustainably manage its environment increases with economic development. The study result is supported by Katirciolu (2014), Mehmood (2021), and Mansoor (2021)'s conclusions that Singapore's GDP and CO_2 emissions are inversely related. Studies from other countries also supported our findings. For example, Zaman et al. (2016), Ali et al. (2020), Ng et al. (2015), Ahmad et al. (2019), Selvanathan et al. (2021), Dogan et al. (2017), Raheem and Ogebe (2017), Liu and Bae (2018), Vo et al. (2019), Raihan et al. (2022e), Odugbesan and Adebayo (2020), Adebayo and Kalmaz (2021), Nondo and Kahsai (2020). Singapore's economy will rise which could improve air quality, as predicted by (Mehmood 2021). Even while economic expansion may improve human existence, it is crucial to determine if and how it may be made sustainable (Raihan et al 2022g). Development activities satisfy more societal demands as economic growth rises. These actions increase pollution, waste, and environmental damage (Raihan and

Tuspekova, 2022b). Thus, economic activities appear to protect and improve the environment rather than endanger it. However, not all economic growth is destructive to the environment or incompatible with environmental preservation. As income rises, people will be able to donate more to causes like environmental protection and pollution reduction. Tech-driven economic expansion boosts productivity and reduces pollution.

This research focuses on Singapore's high energy usage and environmental degradation. This study confirmed that fossil fuels constitute Singapore's main energy source, which increases CO_2 emissions over time. The anticipated long-run coefficient of LE is positive and statistically significant at the 1% level, indicating that a 1% increase in energy consumption in Singapore increases CO_2 emissions by 0.8%. As energy consumption rises, the environment will deteriorate. According to DOLS's extrapolations, greater tourism in Singapore boosts the economy but worsens the environment due to higher energy usage. This study's finding is consistent with Singapore's study by Katirciolu (2014). The positive association between energy use and CO_2 emissions supports previous studies that found many nations largely rely on coal, natural gas, and oil, which increases CO_2 emissions and environmental deterioration. For example, Dogan et al. (2017), Raihan et al. (2022a), Raheem and Ogebe (2017), Liu and Bae (2018), Vo et al. (2019), Raihan et al. (2022e), Odugbesan and Adebayo (2020), Adebayo and Kalmaz (2021), Nondo and Kahsai (2020), Ali et al. (2020), Ng et al. (2015), Ahmad et al. (2019), Selvanathan et al. (2021), and Raihan et al. (2022f). The present study’s result shows that Singapore's environmental quality is worsening as energy demand rises. Despite this, 86% of Singapore's primary energy comes from petroleum and other liquids, and 13% from natural gas. Thus, building a renewable energy infrastructure that can replace fossil fuels is the most important policy. Renewable energy sources are needed to ensure sustainable development and mitigate climate change's negative effects (Raihan et al 2022h). Renewable energy boosts the economy and lowers carbon emissions. It is eco-friendly and other benefits include increased energy availability and energy security (Voumik et al., 2022b).

As global environmental consciousness rises, Singapore must switch to renewable energy sources to enable the use of environmentally friendly energy sources and the creation of an eco-friendly ecosystem. Renewable energy accounts for less than 1% of Singapore's primary energy demand. Singapore needs a comprehensive renewable energy policy to transition to a low-carbon economy. However, the Singaporean government is investigating several ways to cut carbon emissions. The Singapore Carbon Pricing Act started operationally in 2019. This statute required carbon pricing. The Singapore Energy Market Authority (EMA) recently launched "4 Switches." This effort promotes clean power production. The Energy Management Agency (EMA) will research energy storage technologies for variable energy flows and potential technical solutions including carbon capture and storage. Regional electricity systems are another EMA focus. Singapore approved its "Green Plan" to mitigate climate change. The plan aims to add more than 321 acres of parkland, prohibit new diesel car and taxi registrations starting in 2025, establish 60,000 vehicle charging outlets nationwide by 2030, with two-thirds in public parking spaces and one-third on private property, and increase solar irradiation. Singapore launched a nationwide 111-acre floating solar panel farm in July 2021. The world's most powerful floating solar farm generates 60 megawatts of power. Singapore's five water treatment plants provide enough hydropower. The National Water Agency of Singapore expects the Sembcorp Industries-owned solar farm in Singapore to reduce carbon emissions by 32,000 metric tons.

It's crucial to note that the projected coefficients' signs are constant conceptually and practically. The current investigation uses many diagnostic methods to determine if the predicted model accurately represents reality. This study examines whether the calculated model matches reality. The revised regression model fits the data well, with an R^2 value of 0.92 and an adjusted R^2 of 0.90. These figures show that the independent factors might account for 90% of the dependent variable's change. The F-statistic supports the computed DOLS regression from both the dependent and independent variables. Given the F statistic's 0.0000 p-value, the model's variables' linear relationship is statistically significant. Third, the root mean square error and mean absolute error helped evaluate the model's predictions. The RMSE and MAE figures were near to 0 and did not indicate a negative value supporting the model’s fitness. To verify cointegration analysis, this study tested for normality, heteroscedasticity, and serial correlation. Table 6 summarizes the diagnostic test results. Residuals follow a normal distribution, according to four studies. The model also suggests no autocorrelation or heteroscedasticity. To determine model stability, the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of residuals (CUSUMQ) tests were applied. Figure 3 shows CUSUM and CUSUMQ statistics plots after applying a 5% significance threshold to the comparison. This figure shows confidence levels as red lines and residual values as blue lines.

Table 6. The outcomes of diagnostic tests

Diagnostic tests	Coefficient	p-value	Decision
Jarque-Bera test	0.735637	0.5300	Residuals are normally distributed
Breusch-Godfrey LM test	0.725496	0.6102	No serial correlation exits
Breusch-Pagan-Godfrey test	0.562482	0.7169	No heteroscedasticity exists

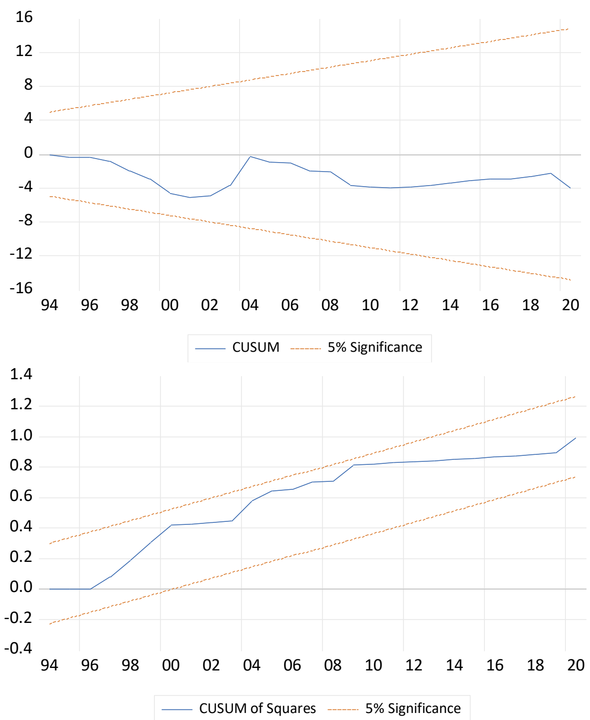


Figure 3. The plots of CUSUM and CUSUMQ

Conclusions and Policy Implications

This study examined the relationship between economic growth, tourism, energy consumption, and CO_2 emissions in Singapore using time series data from 1990 to 2020. The ADF, DF-GLS, and P-P unit root tests were utilized in order to determine the integration order of the series. The findings from the DOLS estimation revealed that tourism and energy use raise CO_2 emissions, which degrade Singapore's environment, but economic expansion decreases CO_2 emissions in the long run. This article proposes environmental policy concepts to ensure the long-term viability of the environment by implementing strict regulatory policy tools to stop environmental deterioration. The outcomes offer recommendations to governments seeking to achieve environmental sustainability while minimizing climate change's effects and adapting to them.

The analysis found that Singapore's government might help markets by creating a rigorous regulatory framework that produces long-term value for emission reduction and continuously supports innovative solutions that reduce carbon dependence. Singapore may continue to establish rules like a high carbon tax, carbon capture and storage, and emission trading schemes to minimize carbon dioxide emissions from fossil fuel combustion in industrial processes and power generation. Decoupling regionally involves changes in centralized nations' policies, conduct, and scientific and technological advancement. This will allow modernization based on technology that can meet growing demand while preserving natural capital. The government's main responsibility is funding research and development to reduce production's resource use and energy efficiency. For Singapore's stronger economic growth to reduce environmental challenges, the economy must convert to renewable energy. Legislators may help corporations create innovative technology and sustainable energy. Institutional alignment also promotes sustainable economic growth and the use of renewable and alternative energy in all economic activities. In addition, environmental regulations must be meticulously followed.

The study suggests using more renewable or clean energy sources to optimize Singapore's energy consumption structure performance. The latest study supported this notion. Conventional energy, which still dominates Singapore's energy use, is the main source of its high carbon dioxide emissions. Singapore may transition to renewable energy to decrease its environmental impact. Due to the limited area for renewable energy generation, practically all of Singapore's energy is imported. Singapore can meet all its renewable energy needs since solar energy is so abundant. Singapore has very strong sun radiation. Singapore may invest in innovation, research, and test beds to improve solar power system efficiency and explore creative ways to integrate them into urban areas. Singapore may examine regional power networks and create low-carbon solutions like low-carbon hydrogen utilization and carbon capture and storage to boost energy security and explore new energy supply possibilities. Singapore is constantly researching new energy sources to promote energy diversity and security. This would be part of nationwide efforts to provide reliable electricity availability. Singapore wants to continue research into nuclear energy and create the necessary capacities to understand nuclear science and technology, even though some technologies, like nuclear power, may become obsolete. Singapore can enhance its energy education programs. Tax incentives, economic subsidies, and government acquisitions can encourage greener energy consumption. There is a possibility that the government will enlist the assistance of the media in order to further its push for "low-carbon behaviors and consumption patterns" and its "green lifestyle notion."

The government of Singapore is able to put in place a system that will hold individuals, tourists, and other interested parties accountable for the damage they cause to the natural environment of the country's most popular tourist destinations. This will allow Singapore to continue to attract tourists to its most beautiful and unique areas. Not only would tourists have an overall more positive experience if all parties involved in the tourism industry were encouraged to embrace sustainability and environmental responsibility in their business practices, but they would also benefit from an increase in their level of education as a result of this. This is due to the fact that visitors would enjoy a more satisfying experience all around. In addition to educational pamphlets and booklets, it is likely that as many public service announcements incorporating easily digestible infographics should be delivered to the general population. People would be encouraged to appreciate the benefits of energy savings and environmental sustainability, as well as to engage in green behaviors while on vacation if these announcements were made, coupled with information on the efforts being made by the authorities and ongoing green development. In addition, the dissemination of this knowledge would motivate individuals to engage in environmentally responsible actions while they are at work. It is of the utmost importance that advancements in transportation technology, such as the employment of high-speed trains and airplanes that consume less fuel, be supported. Because of the rise in tourists, there is now a chance to cut carbon dioxide emissions by updating public transportation, investing in energy efficiency, and enhancing waste management. In order to safeguard the environment, the government might also decide to implement and strictly enforce environmental levies in regions that have a high visitor density and are important tourist destinations. Additionally, the government should make it less difficult for businesses in the tourism industry to adopt environmentally friendly and low-carbon technology in addition to alternative sources of energy for transportation, logistics, hotels, and other activities. This would result in a decrease in the total amount of carbon dioxide emissions and would also prevent excessive consumption of the earth's natural resources. There is a chance that Singapore would tighten the environmental regulations that it already has in place and shine a light on other nations whose tourism industries are contributing to the deterioration of the environment. The concept of "sustainable tourism" can be used to apply to a wide range of distinct sorts of tourism. Some examples of these types of tourism include cultural tourism, ecotourism, tourism that is centered on enjoyment and adventure, and educational tourism. It is vital that the governments in the Southeast Asian region collaborate and coordinate their efforts in order to put proactive measures in place to ensure that tourism is ecologically responsible.

However, despite providing a lot of factual data on Singapore, the analysis contains several shortcomings that need to be addressed in future research. Our study's major flaw was the unavailability of tourism data beyond the study period. This limited the prediction power of the econometric methodologies. Using econometric models or micro-disaggregated data, other nations can conduct more research. The study suggests studying the dynamic effects of socioeconomic and environmental variables on environmental pollution in developing nations with rapid economic growth to balance ecologically sustainable development with emission reduction. This will help to balance environmentally sustainable development and emission reduction. Future research could also consider other development aspects not examined in this study. For example, urbanization, industrialization, trade openness, financial sector development, direct foreign investments, institutional quality, globalization, technical innovation, and others. In order to compare country findings to panel forecasts, a future study may apply more complicated econometric methods. These comparisons with this study's findings may illuminate the relevant literature.

Acknowledgment: The authors declare no conflict of interest

Conflict of interest: The authors declare no conflict of interest

Funding: none

References

Adebayo, T. S., & Kalmaz, D. B. (2021). Determinants of CO_2 emissions: Empirical evidence from Egypt. *Environmental and Ecological Statistics*, *28*(2), 239-262. https://doi.org/10.1007/s10651-020-00482-0

Ahmad, F., Draz, M. U., Su, L., & Rauf, A. (2019). Taking the bad with the good: The nexus between tourism and environmental degradation in the lower middle-income Southeast Asian economies. *Journal of Cleaner Production*, *233*, 1240-1249. https://doi.org/10.1016/j.jclepro.2019.06.138

Ali, W., Sadiq, F., Kumail, T., Li, H., Zahid, M., & Sohag, K. (2020). A cointegration analysis of structural change, international tourism and energy consumption on CO_2 emission in Pakistan. *Current Issues in Tourism*, *23*(23), 3001-3015. https://doi.org/10.1080/13683500.2020.1804338

Begum, R. A., Raihan, A., & Said, M. N. M. (2020). Dynamic impacts of economic growth and forested area on carbon dioxide emissions in Malaysia. *Sustainability*, *12*(22), 9375. https://doi.org/10.3390/su12229375

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical* *association*, *74*(366a), 427-431. https://doi.org/10.1080/01621459.1979.10482531

Dogan, E., Seker, F., & Bulbul, S. (2017). Investigating the impacts of energy consumption, real GDP, tourism and trade on CO_2 emissions by accounting for cross-sectional dependence: a panel study of OECD countries. *Current Issues in Tourism*, *20*(16), 1701-1719. http://dx.doi.org/10.1080/13683500.2015.1119103

Elliott, G., Rothenberg, T. J., & James, H. (1996). Efficient tests for an autoregressive unit root. *Econometrica*, *64*(4), 813-836.

Friedman, M. (1949). The Marshallian demand curve. *Journal of Political Economy*, *57*(6), 463-495.

Isfat, M., & Raihan, A. (2022). Current Practices, Challenges, and Future Directions of Climate Change Adaptation in Bangladesh. *International Journal of Research Publication and Reviews, 3*(5), 3429-3437.

Islam, M. M., Chowdhury, M. A. M., Begum, R. A., Amir, A. A. (2022) A bibliometric analysis on the research trends of climate change effects on economic vulnerability. *Environmental Science and Pollution Research, 29,* 59300–59315. https://doi.org/10.1007/s11356-022-20028-0

Jaafar, W. S. W. M., Maulud, K. N. A., Kamarulzaman, A. M. M., Raihan, A., Sah, S. M., Ahmad, A., Saad, S. N. M., Azmi, A. T. M., Syukri, N. K. A. J., & Khan, W. R. (2020). The Influence of Forest Degradation on Land Surface Temperature – A Case Study of Perak and Kedah, Malaysia. *Forests, 11*(6), 670. https://doi.org/10.3390/f11060670

Katircioğlu, S. T. (2014). Testing the tourism-induced EKC hypothesis: The case of Singapore. *Economic Modelling*, *41*, 383-391. http://dx.doi.org/10.1016/j.econmod.2014.05.028

Liu, X., & Bae, J. (2018). Urbanization and industrialization impact of CO_2 emissions in China. *Journal of cleaner production, 172*,178-186. https://doi.org/10.1016/j.jclepro.2017.10.156

Mehmood, U. (2021). Globalization-driven CO_2 emissions in Singapore: an application of ARDL approach. *Environmental Science and Pollution Research*, *28*(9), 11317-11322. https://doi.org/10.1007/s11356-020-11368-w

Mehmood, U., & Mansoor, A. (2021). CO_2 emissions and the role of urbanization in East Asian and Pacific countries. *Environmental Science and Pollution Research, 28*(41), 58549-58557. https://doi.org/10.1007/s11356-021-14838-x

Ng, T. H., Lye, C. T., & Lim, Y. S. (2016). A decomposition analysis of CO_2 emissions: evidence from Malaysia's tourism industry. *International Journal of Sustainable Development & World Ecology*, *23*(3), 266-277. https://doi.org/10.1080/13504509.2015.1117534

Nondo, C., & Kahsai, M. S. (2020). The impact of energy intensity, urbanisation, industrialisation, and income on CO_2 emissions in South Africa: an ARDL bounds testing approach. *African Journal of Economic and Sustainable Development*, *7*(4), 307-330. https://doi.org/10.1504/AJESD.2020.106826

Odugbesan, J. A., & Adebayo, T. S. (2020). The symmetrical and asymmetrical effects of foreign direct investment and financial development on carbon emission: evidence from Nigeria. *SN Applied Sciences*, *2*(12), 1-15. https://doi.org/10.1007/s42452-020-03817-5

Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335-346.

Raihan, A., Begum, R. A., Said, M. N. M., & Abdullah, S. M. S. (2018). Climate change mitigation options in the forestry sector of Malaysia. *J. Kejuruter, 1*, 89-98. http://dx.doi.org/10.17576/jkukm-2018-si1(6)-11

Raihan, A., Begum, R. A., Mohd Said, M. N., & Abdullah, S. M. S. (2019). A review of emission reduction potential and cost savings through forest carbon sequestration. *Asian Journal of Water, Environment and Pollution*, *16*(3), 1-7. https://doi.org/10.3233/AJW190027

Raihan, A., Begum, R. A., & Said, M. N. M. (2021a). A meta-analysis of the economic value of forest carbon stock. *Geografia–Malaysian Journal of Society and Space*, *17*(4), 321-338. https://doi.org/10.17576/geo-2021-1704-22

Raihan, A., Begum, R. A., Mohd Said, M. N., & Pereira, J. J. (2021b). Assessment of carbon stock in forest biomass and emission reduction potential in Malaysia. *Forests*, *12*(10), 1294. https://doi.org/10.3390/f12101294

Raihan, A., Begum, R. A., Nizam, M., Said, M., & Pereira, J. J. (2022a). Dynamic impacts of energy use, agricultural land expansion, and deforestation on CO_2 emissions in Malaysia. *Environmental and Ecological Statistics*, *29*, 477-507. https://doi.org/10.1007/s10651-022-00532-9

Raihan, A., Begum, R. A., Said, M. N. M., & Pereira, J. J. (2022b). Relationship between economic growth, renewable energy use, technological innovation, and carbon emission toward achieving Malaysia's Paris agreement. *Environment Systems and Decisions*, 1-22. https://doi.org/10.1007/s10669-022-09848-0

Raihan, A., Farhana, S., Muhtasim, D. A., Hasan, M. A. U., Paul, A., Faruk, O. (2022h) The nexus between carbon emission, energy use, and health expenditure: empirical evidence from Bangladesh. *Carbon Research, 1*(1), 30. https://doi.org/10.1007/s44246-022-00030-4

Raihan, A., Muhtasim, D. A., Farhana, S., Hasan, M. A. U., Pavel, M. I., Faruk, O., ... & Mahmood, A. (2022e). Nexus between economic growth, energy use, urbanization, agricultural productivity, and carbon dioxide emissions: new insights from Bangladesh. *Energy Nexus*, *8*, 100144. https://doi.org/10.1016/j.nexus.2022.100144

Raihan, A., Muhtasim, D. A., Farhana, S., Pavel, M. I., Faruk, O., Rahman, M., & Mahmood, A. (2022f). Nexus between carbon emissions, economic growth, renewable energy use, urbanization, industrialization, technological innovation, and forest area towards achieving environmental sustainability in Bangladesh. *Energy and Climate Change*, *3*, 100080. https://doi.org/10.1016/j.egycc.2022.100080

Raihan, A., Muhtasim, D. A., Pavel, M. I., Faruk, O., & Rahman, M. (2022c). Dynamic Impacts of Economic Growth, Renewable Energy Use, Urbanization, and Tourism on Carbon Dioxide Emissions in Argentina. *Environmental Processes*, *9*, 38. https://doi.org/10.1007/s40710-022-00590-y

Raihan, A., Muhtasim, D. A., Pavel, M. I., Faruk, O., & Rahman, M. (2022d). An econometric analysis of the potential emission reduction components in Indonesia. *Cleaner Production Letters*, *3*, 100008. https://doi.org/10.1016/j.clpl.2022.100008

Raihan, A., Muhtasim, D. A., Khan, M. N. A., Pavel, M. I., & Faruk, O. (2022g). Nexus between carbon emissions, economic growth, renewable energy use, and technological innovation towards achieving environmental sustainability in Bangladesh. *Cleaner Energy Systems*, 3, 100032. https://doi.org/10.1016/j.cles.2022.100032

Raihan, A., & Said, M. N. M. (2022). Cost–benefit analysis of climate change mitigation measures in the forestry sector of Peninsular Malaysia. *Earth Systems and Environment*, *6*(2), 405-419. https://doi.org/10.1007/s41748-021-00241-6

Raihan, A., & Tuspekova, A. (2022a). The nexus between economic growth, renewable energy use, agricultural land expansion, and carbon emissions: New insights from Peru. *Energy Nexus*, *6*, 100067. https://doi.org/10.1016/j.nexus.2022.100067

Raihan, A., & Tuspekova, A. (2022b). The nexus between economic growth, energy use, urbanization, tourism, and carbon dioxide emissions: new insights from Singapore. *Sustainability Analytics and Modeling*, *2*, 100009. https://doi.org/10.1016/j.samod.2022.100009

Raihan, A., & Tuspekova, A. (2022c). Nexus between emission reduction factors and anthropogenic carbon emissions in India. *Anthropocene Science*, *1*(2), 295-310. https://doi.org/10.1007/s44177-022-00028-y

Raihan, A., & Tuspekova, A. (2022d). Dynamic impacts of economic growth, renewable energy use, urbanization, industrialization, tourism, agriculture, and forests on carbon emissions in Turkey. *Carbon Research*, *1*(1), 20. https://doi.org/10.1007/s44246-022-00019-z

Raihan, A., & Tuspekova, A. (2022e). Dynamic impacts of economic growth, energy use, urbanization, tourism, agricultural value-added, and forested area on carbon dioxide emissions in Brazil. *Journal of Environmental Studies and Sciences*, 1-21. https://doi.org/10.1007/s13412-022-00782-w

Raihan, A., & Tuspekova, A. (2022f). Role of economic growth, renewable energy, and technological innovation to achieve environmental sustainability in Kazakhstan. *Current Research in Environmental Sustainability*, *4*, 100165. https://doi.org/10.1016/j.crsust.2022.100165

Raihan, A., & Tuspekova, A. (2022g). Towards sustainability: dynamic nexus between carbon emission and its determining factors in Mexico. *Energy Nexus*, *8*, 100148. https://doi.org/10.1016/j.nexus.2022.100148

Raihan, A., & Tuspekova, A. (2022h). Dynamic impacts of economic growth, energy use, urbanization, agricultural productivity, and forested area on carbon emissions: New insights from Kazakhstan. *World Development Sustainability*, *1*, 100019. https://doi.org/10.1016/j.wds.2022.100019

Raihan, A., & Tuspekova, A. (2022i). Nexus between economic growth, energy use, agricultural productivity, and carbon dioxide emissions: new evidence from Nepal. *Energy Nexus*, *7*, 100113. https://doi.org/10.1016/j.nexus.2022.100113

Raihan, A., & Tuspekova, A. (2022j). Nexus between energy use, industrialization, forest area, and carbon dioxide emissions: New insights from Russia. *Journal of Environmental Science and Economics*, *1*(4), 1-11. https://doi.org/10.56556/jescae.v1i4.269

Raihan, A., & Tuspekova, A. (2022k). Toward a sustainable environment: nexus between economic growth, renewable energy use, forested area, and carbon emissions in Malaysia. *Resources, Conservation & Recycling Advances*, *15*, 200096. https://doi.org/10.1016/j.rcradv.2022.200096

Raihan. A., & Voumik, L.C. (2022a). Carbon emission dynamics in India due to financial development, renewable energy utilization, technological innovation, economic growth, and urbanization. *Journal of Environmental Science and Economics*, 1, 36-50. https://doi.org/10.56556/jescae.v1i4.412

Raihan. A., & Voumik, L.C. (2022b). Carbon emission reduction potential of renewable energy, remittance, and technological innovation: empirical evidence from China. *Journal of Technology Innovations and Energy*, 1(4), 25-36. https://doi.org/10.56556/jtie.v1i4.398

Raheem, I. D., & Ogebe, J. O. (2017). CO_2 emissions, urbanization and industrialization: evidence from a direct and indirect heterogeneous panel analysis. *Management of Environmental Quality, 28*(6), 851-867. https://doi.org/10.1108/MEQ-09-2015-0177

Selvanathan, E. A., Jayasinghe, M., & Selvanathan, S. (2021). Dynamic modelling of inter-relationship between tourism, energy consumption, CO_2 emissions and economic growth in South Asia. *International Journal of Tourism Research*, *23*(4), 597-610. https://doi.org/10.1002/jtr.2429

Stock, J. H., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica: journal of the Econometric Society*, *61*(4), 783-820.

Vo, A. T., Vo, D. H., & Le, Q. T. T. (2019). CO_2 emissions, energy consumption, and economic growth: New evidence in the ASEAN countries. *Journal of Risk and Financial Management*, *12*(3), 145. https://doi.org/10.3390/jrfm12030145

Voumik, L. C., Islam, M. J., Raihan, A. (2022b). Electricity production sources and CO_2 emission in OECD countries: static and dynamic panel analysis. *Global Sustainability Research*, *1*(2), 12-21. https://doi.org/10.56556/gssr.v1i2.327

Voumik, L. C., Nafi, S. M., Kuri, B. C., Raihan, A. (2022a). How Tourism Affects Women's Employment in Asian Countries: An Application of Generalized Method of Moments and Quantile Regression. *Journal of Social Sciences and Management Studies*, *1*(4), 57-72. https://doi.org/10.56556/jssms.v1i4.335

World Bank. (2022). World Development Indicators (WDI), Data series by The World Bank Group, The World Bank: Washington, DC, USA, 2022. Retrieved from https://databank.worldbank.org/source/world-development-indicators

Zaman, K., Shahbaz, M., Loganathan, N., & Raza, S. A. (2016). Tourism development, energy consumption and Environmental Kuznets Curve: Trivariate analysis in the panel of developed and developing countries. *Tourism Management*, *54*, 275-283. https://doi.org/10.1016/j.tourman.2015.12.001

Zhang, S., & Liu, X. (2019). The roles of international tourism and renewable energy in environment: new evidence from Asian countries. *Renewable energy*, *139*, 385-394. https://doi.org/10.1016/j.renene.2019.02.046